

Adventures in EcoDesign of Electronic Products

1993-2007

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Accountholder: De Stevels/Dronkers Stichting - CofC 17155904 Eindhoven, the Netherlands.

Adventures in EcoDesign of Electronic Products: 1993-2007

A personal vision

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Delft University of Technology, Delft, The Netherlands

Design for Sustainability Program publication nr. 17

ISBN/EAN: 978-90-5155-039-9

Coverdesign and layout by Duygu Keskin

Printed by PrintPartners Ipskamp, Enschede, The Netherlands

Distributed by DFS

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Acknowledgments

This book is dedicated to Annet Stevels-Ekering, my wife; active participant in all the adventures described in this book.

This book describes fifteen years of work in Industry and in Academia in the field of Applied Ecodesign. Most of it has been done at the Design for Sustainability Lab (DfS) of the Faculty of Industrial Design Engineering (IDE) of Delft University of Technology.

Many IDE students have contributed to it in some form or another through their M.Sc. projects.

Results of research done by Assistant Professor Arjen Jansen, and my former Ph.D. students Dr Ir Menno Nagel, Dr Ir Nicole van Nes and Dr Catherine Rose can be found in various chapters of the book.

Since they have been working a full period at the DfS, Prof.Dr Casper Boks, Dr Ir Jaco Huisman and the future Ph.Ds Oriol Pascual and Renee Wever have become real collaborators to this book.

Through its diversity and its indomitable spirit, the Design for Sustainability Lab is the ideal environment to generate all kinds of creative ideas.

The Environmental Competence Centre (ECC) of the Consumer Electronics Division of Royal Philips has been the origin and the stimulator of my Applied Ecodesign activities.

The cooperation agreement between ECC and DfS has been the real basis for all the activities described in this book.

Chapter 1: Introduction

1.1 Introduction to Adventures in EcoDesign of Electronic Products

This book is about my adventures in EcoDesign of Electronic Products during the years 1993-2007. In these fifteen years tremendous changes have taken place in the field. I have actively participated in these developments, both as a Senior Environmental Advisor at the Environmental Competence Center (ECC) of the Consumer Electronics Division of Royal Philips Electronics (1993-2004) and as (part-time) Professor in Applied EcoDesign in the Design for Sustainability (DfS)/Design Engineering group of the Faculty of Industrial Design Engineering at Delft University of Technology (1995-2007).

At the end of the eighties, the United Nations published a report with the title 'Our Common Future' (the so called Brundtland report). This report made mankind realize for the first time in history that apart from production processes, products themselves could have serious adverse environmental impacts. In 1993, design to improve environmental properties of products (EcoDesign) was still unknown territory. Apart from some activist ideas and general principles – there was little in place. A lot of work was needed to develop this field and several industry sectors - including the electronic products one - started to tackle the subject. Philips, in particular its Consumer Electronics Division, was one of the first movers in the field. As a result I got the assignment to develop EcoDesign (see highlights of the year, 1993).

In the beginning the activities had a narrow focus, primarily they involved a lowering of the environmental load over the life cycle of products. The notion that EcoDesign and the environment in general are of much wider significance and are in fact opportunities for more responsible (Ecoefficient) production and consumption, well known today, was still far away.

Today it is recognized that there are additional opportunities: applying environmental thinking to business and value chains (including suppliers, consumers) will add 'value' and will assist in overall quality performance. The main elements of this environmental thinking involve looking at what are often old problems from a fresh perspective such as:

- Functionality thinking ('what is really needed')
- Life cycle approach ('stakeholder benefits')
- Prevention ('do not allow bad things to happen')
- Do more with less ('take time to be creative')
- Paradigm shift ('thinking out of the box')

The activities of both Philips ECC and Delft's DfS group were in their initial stages pragmatic and empiric in character. It was a typical bottom-up approach: just do it and later on discover or try to discover whether there are general underlying principles. From that perspective the development of environmental thinking has been the result of a step-by-step discovery process.

During such a journey, without a detailed map, the traveler in EcoDesign needs to keep a few things in mind in order to be successful, or at least to be able to survive. I learned these lessons the hard way, through practice. They are as follows:

- Always ask yourself: why am I doing this, what do I (really) want to achieve?
- Always be positive: be convinced that it can be done, in spite of all the criticism and skepticism of others.
- Get facts: if you know where you stand, you better know where you want to go.
- Be ambitious but think in alternatives: what is relatively the best?
- Set priorities: invest time and effort in activities where you can significantly contribute.

This book describes my adventures in EcoDesign from the perspective of today. The core consists of a selection of conference contributions and publications that have been written during the period between 1993-2007. The selection has been made in such a way that it is a mix of more practical and more conceptual papers, with applications clearly dominating.

Quite a lot of these papers have been written jointly with my PhD students and post docs. and as such represent the activities of the 'Applied EcoDesign' group at Delft University. In many cases there has been cooperation with Philips ECC as well.

The papers clearly show a specific view on EcoDesign realities, which is not necessarily shared by all practitioners in the field. As will be explained later in this book, Applied EcoDesign has a strong scientific basis, but in the end there are subjective elements in it as well. As a result there are a large variety of opinions and approaches.

For me that is one of the attractions to working in this field. There is always a debate. There is always a challenge that requires creative new thinking.

Chapters in the book include:

- Design, EcoDesign and Functionality, Ecovalue
- EcoDesign for X (X = energy, materials, packaging/transport, chemical content, recycling)
- EcoDesign and Business
- Value Chains
- Ecodesign Tools
- Recycling of Consumer Electronic Products
- Organizing Take Back and Recycling
- Environmental Legislation
- Teaching EcoDesign
- China
- The Future

Apart from the chapters, there are six types of additional boxes which tell short stories relevant to my adventures in the EcoDesign. These are about:

- Personalities that have educated and inspired me most, regarding my profession.
- Highlights for each year between 1993-2007
- Cities in the world that have a special significance for me with regards to EcoDesign & Environment.
- Rituals and habits with particular reference to universities, showing their traditions, "pomp & theatre" and fun.
- Tidbits which are interesting and funny events that simultaneously provide some valuable learning.
- Some Facts and Figures related to my activities in the field.

On top of that some pictures are shown in the book. Either these refer to episodes in Adventures in EcoDesign or to locations which are important in my personal life.

The most terrible thing I have experienced in my whole academic and professional life is sitting or working in overheated (why not save energy and put it all on 19°C/67°F in winter?) and dry classrooms, offices and meeting rooms. Working as a professional in the field of EcoDesign does not make any difference in this respect. I always wanted to escape from this. I wanted to put on a jersey and coat and take my papers and to go outside and smell the fresh air and feel the wind blow while doing a piece of work. Traveling is bad. Being locked up in trains, airplanes, hotels and conferences is even worse; it is alienation of nature.

The Philips Parks at Philips in Eindhoven and the Botanical Garden at Delft University, are such escapes. I used them often. Even at home I have always kept a desk outside. Elsewhere I had to look for them. This is the reason why I have included in this book suggestion for visits to parks and suggestions for walks. Enjoying the sounds and silence of nature refreshes body and soul. It makes you ready for another adventure in EcoDesign.

Highlights of the year, 1993

How it all started

At the end of 1992 I had spent 26 years working for Philips. As a PhD student at Groningen University, being sponsored by Philips (1966-1969), it was obvious that I should start at the Natuurkundig Laboratorium (Nat.Lab.) of Philips Research (1969-1980). Very early on I generated two inventions for producing Cesium Iodide input screens for X-ray image intensifiers. They allowed for the substantial reduction of the X-ray dosage used when examining patients. This made the company a lot of money. Even if the output value of the rest of my career would have been zero, I would have been a very profitable employee overall.

After some ten years, I needed a new challenge, because research had become a bit dull. After short stints at audiotape and glass fiber cable production (which were adventures in themselves) I popped up at the Glass Division (see also Personalities, 13) where I evolved into a successful trouble shooter – I could even get the notorious '78 glass' (see also Personalities, 14) under control.

My next job was being a business manager of the Optics Business Unit. My first responsibility was to enact a drastic restructuring of the business. It was difficult but I managed to get into black figures. Subsequently, the dominating issue was how to deal with the unreliable yet major customer Philips Consumer Electronics. This was a hard fight as well. In the end the result was that through an 'internal take-over' I ended up on their payroll with the assignment to manage the Laser Optics group. It was a disastrous job, at least for me. Pretty soon I was replaced and became Laser Optics technology transfer manager in Asia (China, Korea, Taiwan, Malaysia, and Singapore). I loved working there and successful; moving to Asia became very likely. My wife Annet and I went looking for housing in Singapore and were considering how to tell the story to our aging parents. Two weeks later it was over; the Consumer Electronics business was in bad shape. Expansion activities in Asia were put on hold. I was to lose my job and be pushed into an outplacement program.

At that very moment environmental issues related to product manufacture and use emerged. Philips Consumer Electronics decided to set up a small department to address this new subject.

They wondered who to put on the job. Since there was the perception that environmental issues had something to do with chemistry, and since I was one of the few employees in the division having studied chemistry, they took me.

Reluctantly I went to work – there was no alternative!

There I sat with no vision, no 'call', no ambition, other than simply to survive. I had no knowledge, only the will to make something happen and a diversified track record that might be of some value. Most of all I had no idea what to expect...

1.2 Times have changed

The development of Applied EcoDesign during the years 1993-2007 is sketched out in the form of the table below. The numbers refers to the chapters of this book.

For each chapter it is indicated in which year the subject was addressed for the first time. In the last column the initial idea behind the activities has been indicated as well as the perception about it today.

It is concluded from this table that the subject of Applied EcoDesign has shown enormous growth, both in width and in depth. In 1993 nine 'subjects' were included in the field. In fifteen years time another 36 were added to bring the total up to 45. In the period between 1994-1997 fourteen new subjects were added, in 1998-2001 twelve more and in 2002-2007 still another 10.

The dynamics are further demonstrated by the fact that in each field there have often been quite radical changes in thinking. Generally speaking the focus has broadened from an initial focus on environmental issues exclusively to reflect a wider socio- economic perspective.

Table 1.1 Evolution of subjects and content in the Applied EcoDesign field

Chapter Number	Chapter title	Year when subject came up	What was the starting point, what is the approach today
1	Introduction		
1.1	Introduction to Adventures in EcoDesign of Electronics Products	1993	From the drive to do something about 'Eco' to societal and business value creation
1.2	Times have changed: the growth of Applied EcoDesign	1993	From a dogmatic secessionist approach to a flexible, integrated one
2	EcoDesign		
2.1	The dynamic development of EcoDesign, 2003-2007	1993	From design issues only to design/managerial/stakeholder issues and management of 'Eco' in a business context
2.2	Design, EcoDesign & Functionality. An extended paradigm for Applied EcoDesign	2002	From design rules to contributions to functionality through considering enablers, markets, value chains and system management
2.3	Ecovalue, a new method to link EcoDesign and Business	2002	From trying to deal with rebound effects to optimizing environmental load/price ratios
3	Design for X		
3.1	Design for Energy reduction	1993	From CO ₂ reduction to kWh reduction
3.2	EcoDesign and Material Application	1993	From dematerialization to optimizing functionality
3.3	EcoDesign and Packaging/Transport	1993	From reduction to optimizing functions like physical protection, promoting sales and a positive unpacking experience
3.4	EcoDesign and chemical content	1993	From elimination of substances to reduction of risk

Table 1.1 Evolution of subjects and content in the Applied EcoDesign field (continued)

4	EcoDesign and Business		
4.1	The first wave of EcoDesign	1995	From being environmentally right to getting it environmentally right
4.2	The integration of EcoDesign into processes	1997	From lowering environmental load to making money with 'green'
4.3	Product environmental care systems	1997	From checklists to comprehensive approaches
4.4	Managing Environment and Business today: planning and performance	1998	From measurement of 'green' design performance to 'green' business planning and business performance measurement
4.5	Product life time and Product life time Extension	1993	From lifetime extension to influencing the replacement behavior of consumers
4.6	Human powered products	1997	From battery elimination to convenience and fun
4.7	Sustainability	2001	From responding to outside drivers to well understood self interest
5	The Value Chain		
5.1	The concept of the Value Chain	1999	From issue identification to active chain management
5.2	Involvement of suppliers in green, EcoQuest	1995	From supplier requirements to supplier self reliance
5.3	Green Supply Chain Management	1998	From defensive to proactive
5.4	Green marketing and communication	1995	From 'Eco language' to placing 'Eco' in a benefit context
5.5	Communicating 'green' through Design	2002	From minimizing environmental load to making 'green' products attractive, while keeping the load low
6	EcoDesign Tools		
6.1	What is green?	1994	From emissions to resources and potential toxicity. From 'scientific green' to 'government green' and 'green' perceptions.
6.2	Life Cycle Analysis and Factor Methods	1996	From creativity to validation tools
6.3	Environmental Benchmarking	1996	From environmental performance measurements to improvement tools
6.4	Applications of Environmental Benchmark	1997	From 'green' products to 'green Flag-ships'

Table 1.1 Evolution of subjects and content in the Applied EcoDesign field (continued)

6.5	EcoDesign tools, new style	2002	From reducing load to balancing the three 'green' dimensions to create value
7	Recycling of Consumer Electronic Products		
7.1	Recycling, the years 1993-2000	1995	From treatment to integral management
7.2	Making reuse/recycling strategies for products	1997	From generic to product specific approaches
7.3	Disassembly	1994	From design to lasting advantages of disassembly analysis
7.4	Quotes for Environmentally Weighted Recyclability	2000	From a weight based to an environmental weight based approach
7.5	Ecoefficiency considerations and End-of-Life	1993	From environmental gain to environmental gain per Euro invested
7.6	Design and Ecoefficiency at End-of-Life	1993	From a single minded approach to one of 'the opportunities'
8	Organizing Take-Back and Recycling		
8.1	System Organization	2001	From a focus on product categories based on application to a focus on material composition
8.2	How to improve Performance of Take Back Systems	2003	From compliance with the law to better serving its environmental intent
8.3	The NVMP take-back and recycling system in the Netherlands	1999	From individual producer responsibility to carrying this responsibility out in a collective form
9	Legislation		
9.1	On the Effectiveness of Legislation	2002	From prescriptive and flawed legislation to flexible implementation
9.2	The European Directives	2001	From doing good for the environment to creating Ecovalue for money
9.3	The role of Governments	2006	From principles to Eco effective implementation rules
9.4	Will China show the way?	2006	From a developing country to a leader in recycling and EcoDesign?
10	Teaching of Applied EcoDesign		
10.1	The teaching modules for Applied EcoDesign	1997	From principle based to practice based
10.2	Teaching Applied EcoDesign in academia	2001	From isolation to integration into the curricula
11	China		

Table 1.1 Evolution of subjects and content in the Applied EcoDesign field (continued)

11.1	Introduction to Eco and China	2003	From western solutions to doing it the Chinese way
11.2	EcoDesign and China	2004	From being behind to moving in front
11.3	Electronics Recycling in China	2005	From low tech primitiveness to high tech sophistication
12	The Future		
12.1	The Future of Applied EcoDesign	1993	From internal focus on Design and Eco to external orientation on value chains and (Eco)value

Tidbits, I

Boonstra goes green

It is always a hell of a job to get environmental issues positioned on the company agenda. There are always other more pressing matters which take priority. Moreover, there is a general prejudice that environmental efforts will only cost money and the fear that you will be considered to be a 'soft' manager if you involve yourself with 'green'.

Philips turned out to be no exception in this respect, with the only advantage being that they started their efforts early. There was some good luck as well; activities like packaging reduction, weight reduction and simplifying product architectures (lower assembly times) were started under a 'green' banner and were successful. This improved the credibility of the Environmental Competence Centre because it directly resulted in money for the company.

What was happening in reality was challenging the over-specification which many Philips products used to have. Traditionally these are solid, sturdy and square, so reductions were easy to find. In this way substantial environmental improvements were achieved as well, so this was really a win-win situation.

The success made us more ambitious: let's make a real 'green' TV with drastically reduced energy consumption, lots of recycled material and no potentially toxic substances. Tribute to Bert Sondern: he was the driving force behind this project and he managed to make it work. Within one year it was in place: a real 'green' product with a technical performance equal to that of a standard TV.

There was a huge problem however, Bert was a loner and had not involved the internal value chain (see chapter 5.1) at all. Product managers said that the 'green' TV did not fit in the product line up, marketing managers said that the brochures for next year had already been printed. Production managers complained about the clamp constructions in the product, purchasing managers saw parts which they thought would be expensive and safety and reliability engineers were negative about tests which were still to be done.

As a result the 'green' TV has never been taken to the market, yet it was a huge success. It was a technical treasure trove out of which a lot of features were introduced, step-by-step, in future product generations.

The biggest success it achieved however, was when Bert managed to put the 'green' TV on the table of Cor Boonstra, the president and CEO of the company. Up until that moment Boonstra had been seen as a hard driving, relentlessly restructuring manager with little respect for the company's traditional values. Environment was not in his dictionary at all.

However, as a good salesman, Boonstra saw the opportunity of the 'green' TV: enhance the image of the company through such products and reach out to a group of customers not addressed so far by Philips.

After having seen the 'green' TV Boonstra mandated that from now on each business group should have at least one 'Green Flagship' product in their product portfolio.

The 'green' TV was dead, long live 'green' products!

Conferences

In the 1993-2007 period, I attended 68 conferences on environment. With few exceptions all of them were focused on electronics and environment. With all variety in their programs, venues, attendance and people, there has been one self imposed requirement to contribute at least one paper to all events. Quite a lot of these are reproduced in this book.

The most important conferences in the field come in a series. These include:

**the CARE/Electronics Goes Green Conference, organized biannually in Europe, alternating in Vienna and Berlin (I participated in 1996, 1998, 2000 and 2004)*

**the International Seminar on Environment and Electronics, organized annually in the USA in various cities (I participated ten times , in the 1995-2004 period)*

**the EcoDesign Conference, organized biannually in Tokyo /Japan (I participated in 1999, 2001, 2003)*

**the International Electronics Recycling Conference, organized annually in Europe (Davos, Basel, Hamburg). My participation has been in 2002, 2003, 2004 and 2005; the related World Recycling Congress in Shanghai (2005) has been visited as well.*

Participation in conferences is indispensable to do good research work, it is an opportunity to learn, it gives inspiration to think and is assisting in establishing scientific and social contacts. Apart from that there is feedback to your own work and the opportunity to set up further cooperation.

Most conferences have been visited with a delegation of Delft Ph.D and graduate students. For them the requirement to present a paper applied as well. The preconference walks were notorious, but the Gang dinners are still famous! (see Rituals and Habits, 5)

Chapter 2: EcoDesign

2.1 The Dynamic Development of EcoDesign, 1993 - 2007

The development of Applied EcoDesign from the early nineties until the present has been sketched out in the figure below:

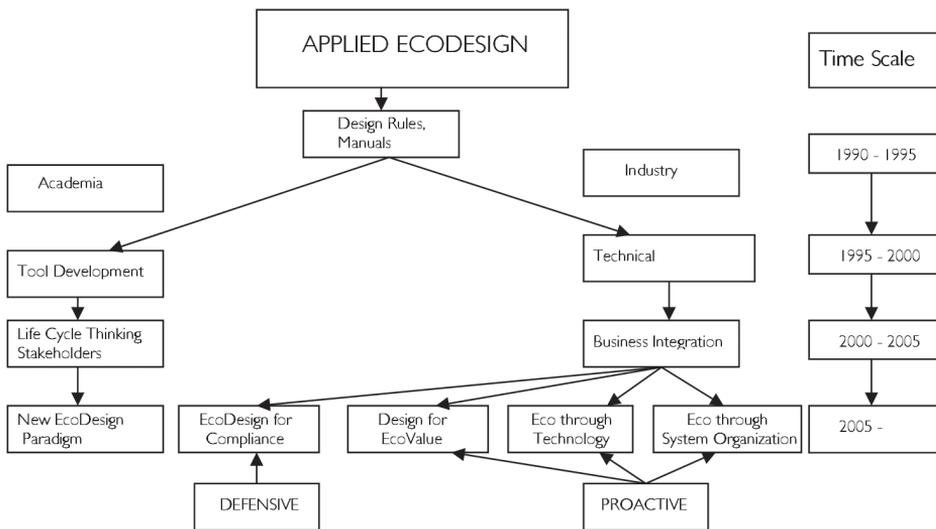


Figure 2.1 The development of Applied EcoDesign

In the first stage of Applied EcoDesign, in the early nineties, a lot of attention was paid to the development of appropriate design rules. These were brought together in manuals in which the background of the rules were explained. As a result there were highly recommended rules (mandatory in industry), recommended rules and optional rules. Checklists were used as the main tool to ensure comprehensiveness and completeness of the actions (see also chapter 4.1).

After 1995, the common paths of Applied EcoDesign in academia and industry started to separate. In academia a lot of attention was paid to the development of more sophisticated tools to support EcoDesign. In particular, various methods based of Life Cycle Analysis (see chapter 6.2) were proposed.

In industry a more practical and implementation oriented approach began to develop. Primarily this considered the technical aspects of EcoDesign rather the methodological ones. A real departure from the approach so far was the “reverse approach”. It starts with identifying improvements options in focal areas like

energy consumption, materials application, packaging and transport, chemical content and recyclability and integrating these into one life cycle perspective. Moreover, the options generated were prioritized according to their environmental merit but also according to their benefit for companies, consumers and society in general. This contrasted greatly with the traditional approach, which was primarily holistic. Departing from this picture has subsequently been attempted in order to break down the issues into improvement options which can then be transformed into action agendas through stakeholder discussions.

During this period industry also realized that apart from 'scientific green' there are also 'green' requirements mandated by governments as well as consumer opinions about 'green' that do not necessarily coincide with the scientific perspective (see chapter 6.1). However, in the real world, governments and customers are strong drivers for business.

It was also discovered that Applied EcoDesign could enable substantial cost reduction in many cases and was therefore beginning to be seen more and more as a tangible contributor to competitive advantage. This perception sped up the integration of Applied EcoDesign into business around the turn of the century. EcoDesign started to be consciously managed. Systematic procedures were developed to do this, the so-called Product Environmental Care Systems (see also chapter 4.3).

'Green' started to become integrated into Product Creation Processes (see chapter 4.2.1). An important tool to support the practical implementation of this 'integrated green' are the Environmental Benchmark methods (see chapter 6.3)

Also the subject of 'green' marketing and communication was addressed (see chapter 5.4). After the year 2000 a further widening of the scope of Applied EcoDesign took place through the introduction of procedures for 'green' business planning (roadmaps) and methods to measure environmental performance on a managerial level. These methods can be applied to individual products, to business units and even to the performance of executives in charge of 'green' (see chapter 4.4).

During this period academia was paying special attention to Life Cycle Thinking and stakeholder issues. A lot of papers were published about what practitioners of Applied EcoDesign in industry should do in this respect, however there was little connection to what happened in practice within companies. The gap between academia and industry, which appeared between 1995 and 2000, grew even wider.

After 2005, electronic companies started to make strategic choices with regards to 'green'. Generally current industrial activities in Applied EcoDesign can be described in four categories:

- EcoDesign for Legal Compliance (after 2005 several environmental laws for products came into effect, particularly in Europe and Japan, see chapter 9).
- 'Eco' through system organization. This includes, amongst other things, 'green' supply chain management (outsourcing of production, chemical content issues) and organization of recycling systems.
- 'Eco' through technology. The main focus for this activity is the reduction of energy consumption in the use phase (see chapter 3.1). Chief ways to do this are applying different physics in order to realize the required functionality (Liquid Crystal Displays instead of Cathode Ray Tubes; fluorescent instead of incandescent lamps) and miniaturization of Printed Wiring Boards (IC technology, assembly technology).
- Design for Ecovalue (see chapter 2.3). The main idea is to develop products where the ratio between price paid by the consumer and the environmental load over the life cycle of the product is more favorable. Ecovalue is in fact an environmental quality concept for products.

Among electronic companies the mix of activities, as described above, varies greatly. As a result, today companies can be classified on a scale ranging from defensive (compliance only) to proactive (see also the publication below: *"EcoDesign Operationalization and Company Performance in Electronics Industry"*).

Today pressure from the legal side is enormous, particularly in Europe. As a result recent developments show there is a tendency to focus more and more on compliance. On one hand this is justified, industry is by nature not a "natural talent in green", so a set of minimum requirements should be in place. On the other hand this makes it so that fewer and fewer resources are channeled toward proactive activities. In this way a chance for competitive advantage is being lost.

In academia today, Applied EcoDesign is in a kind of crisis. A large part of the academic output reflects the EcoDesign approaches and tools of the nineties. Times have changed in Applied EcoDesign (see chapter 1.1), but there are many who could not follow and have become fixated on old ideas.

This situation in academia and the developments in industry (too much orientation on defensive items) suggests, in my opinion, that it is necessary to come to an extended paradigm for Applied EcoDesign. This will enable more proactive efforts in Applied EcoDesign in industry and academia.

Such an extended paradigm is proposed in chapter 2.2. It is based on experiences in industry (see chapter 4,5 and 6). For academia it provides a new research agenda. Subjects to be addressed under the extended paradigm (which is in fact based on empirics rather than on proof) could include:

- 1) Relation of physics of functionality realization and "bandwidth" of EcoDesign.
- 2) Expression of 'green' through design, measurement of 'green' design performance.
- 3) Balancing Emissions, Resource aspects and potential toxicity ("risk") in environmental performance.
- 4) Target group products (customization).
- 5) Ecovalue issues.
- 6) Internal value chain management.
- 7) Dissolving lock ins in value chain management.
- 8) Are services really greener than products?
- 9) Environmental accounting.
- 10) 'Green' asset management.
- 11) Recycling and (or versus) control of toxic materials.
- 12) Durability, reuse and material recycling, "product transition".

EcoDesign Operationalization and Company Performance in Electronics Industry

Oriol Pascual; Ab Stevels

Abstract

Performance measurement is a fast evolving and diverse research field which often ranks high on the agenda of academics and practitioners from functions including management, accounting, marketing, and human resources. This paper reviews the state-of-the-art for business and environmental performance from both literature and field observations. As a result, two EcoDesign operationalization strategies are identified based on the use of performance measurements. The authors propose a performance index known as Ecovalue that not only aims to reduce the environmental load of products, but also their consumption.

Key words: product performance, EcoDesign, Ecovalue.

1. Introduction

Traditionally, the technical aspects of EcoDesign have been more widely explored by academia and practitioners with, until recently, little or only theoretical attention being paid to how to manage it in an industrial context. In Pascual's article [1], the misconnection between technical and managerial developments of EcoDesign research was empirically demonstrated. In addition, in [2] it was shown that electronics manufacturers generally have different strategies in terms of EcoDesign activities and ways to communicate them. Also, recent standards like ISO14001 in essence do not address EcoDesign, and non-descriptive technical reports like ISO14062 – that could be regarded as an attempt towards a model of reference for EcoDesign – are only slowly gaining a foothold in industry. From these arguments, it is clear that operational aspects of EcoDesign are not (yet) standardized, resulting in the lack of a recognized model or framework of authority or excellence.

A previous study carried out at Delft University of Technology [3] showed that organizations within the same industrial sector, and operating under similar regulatory and market conditions, operationalize EcoDesign applying two different approaches; i) continuous improvement oriented companies and ii) legislation oriented companies. Since the existence of two different EcoDesign strategies is now beyond discussion, it is now a relevant research question whether the depth of EcoDesign operationalization and level of EcoDesign performance depend strongly on the strategy followed by a particular company. It is therefore relevant to explore performance indicators in the electronics industry that provide priority setting and help develop an action plan.

2. Goal

At Delft University of Technology empirical research has been carried out addressing the following question: what is the influence of EcoDesign operationalization strategies in the economic and environmental performance of electronic companies? The goal of this paper is to demonstrate which operationalization strategy, from those previously defined, provides a better ground to manage EcoDesign operationalization efficiently.

3. Methodology

The results of this study are based on the previous work of the authors, including literature research and interviews with the electronics industry carried out beginning fall 2003. The scope comprises electronic and communication companies classified by the Global Fortune 500 list. First, a review of both business and environmental performance frameworks found in literature is presented. Then the outcome from some seventeen Global Fortune 500 companies from Asia, USA, and EU which participated in semi-structured interviews addressing both the operational and the strategic level of EcoDesign is exposed. The aim of this project was to collect specific information in two EcoDesign related areas; i) the internal value chain, addressing communication and dissemination of knowledge relevant to EcoDesign and ii) performance measurement (both environmental and economical).

Information has been collected from three organizational levels: corporate level, members of environmental support departments, and business units. Confidentiality was ensured for all companies included in the study, therefore names of those organizations that were visited are not disclosed here.

Performance indicators studied include, among others, results from the Dow Jones Sustainability Index, which can be related to product environmental performance.

Section 4 offers a review of performance literature both at the business and environmental level. Section 5 focuses on observations from field research and presents an overview of performance methods. Section 6 discusses the findings; and the last section offers conclusions and recommendations.

4. Performance improvement is based on measurements

Most companies share the vision of doing more, better and faster, with less. With that aim, companies are managing their improvement efforts based on facts and those facts are derived from measuring performance. Companies are using performance measurements to achieve desired performance levels. As Lebas and Euske [4] described, the foundations of performance are "doing today what will lead to measured value outcomes tomorrow." As a result, performance measures help companies to set priorities, develop action plans and provide feedback about progress.

Performance activities are usually organized in business performance measurement and control systems which are the formal, information-based routines and procedures managers use to maintain or alter patterns in organizational activities [5].

When it comes to improving business performance managers have no shortage of tools and techniques to choose from. At the company level for instance, performance measurement systems are integrated into the organization by means of performance frameworks covering financial and non-financial data. Some of the most well documented frameworks are reviewed here.

4.1 Business Performance Frameworks

Traditionally, business performance relies on economic results based on figures like profit, rate of return, or share price. However, by early 1990 non-financial performance gained importance when organizations started measuring cycle times, quality rates, customer satisfaction, etc. By the mid-nineties, non-financial performance became as relevant as financial performance due to the success of frameworks like the Balance Scorecard (BSC) of Kaplan and Norton [6], which suggested that managers need a multidimensional measurement system to guide their decisions, including leading and lagging indicators and measurements focusing on the outside and the inside of the company.

According to Kaplan and Norton [6] performance measurement should allow managers to answer the following four fundamental questions:

1. How do we look to our stakeholders (financial perspective)?
2. What must we excel at (internal business perspective)?
3. How do our customers see us (the customer perspective)?
4. How can we continue to improve and create value (innovation and learning perspective)?

BSC organizes its measurement system from four perspectives. The financial perspective includes traditional accounting measures. The customer perspective groups measures relating to the identification of target groups for the company's products in addition to marketing-focused measures of customer satisfaction, retention, etc. The internal business process draws heavily from the concept of the value chain. Finally, the learning and growth perspective includes all measures relating to employees and systems the company has in place to facilitate learning and knowledge diffusion [7].

Based on the same principle, other authors developed frameworks which encourage executives to pay attention to horizontal flows of materials and information within the organization. For instance, Brown [8] highlights the difference between input, process, output and outcome measures. Meanwhile the Performance Pyramid [9] ties together the hierarchical view of business performance measurement with the business process view. It also makes explicit the difference between measures that are of interest to external parties: customer satisfaction, quality and delivery, and measures that are primarily of interest within the organization [10].

A widely extended framework is the Excellence Model developed in 1992 by the European Foundation for Quality Management (EFQM). The EFQM Excellence Model is a holistic self-assessment tool that helps organizations to establish an appropriate management system by measuring where they are on the path to excellence. This model helps them understand the gaps and to create stimulating solutions. This non-prescriptive framework is based on nine criteria. Five of these criteria are 'Enablers' and four are 'Results'. The 'Enabler' criteria cover what an organization does. The 'Results' criteria cover what an organization achieves. 'Results' are caused by 'Enablers' and feedback from 'Results' help to improve 'Enablers'.

The theory underpinning the Business Excellence Model is that 'enablers' are the levers that management can pull to deliver future results.

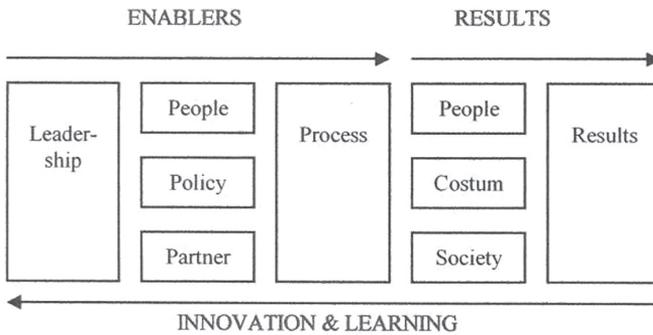


Figure 1 Business Excellence Model by EFQM

Some companies place the environment in the context of the Business Excellence Model, with the aim to make the environment part of total business performance. Nevertheless, environmental performance takes several forms in business contexts.

4.2 Environmental Performance

During the 1990s environmental management systems like ISO 14001 or EMAS gained momentum and therefore environmental performance monitoring did also. In this context, performance monitoring refers to the methods that organizations use to measure, analyze, and monitor their performance in key dimensions (in this case environmental performance and its relationships to overall business performance) [11].

Environmental performance systems can be organized at corporate, production and product level. At the corporate level, Illkinitch et al [12] identified four dimensions of corporate environmental performance from conceptual and empirical literature: 1) organizational systems; 2) stakeholder relations; 3) regulatory compliance; and 4) environmental impacts.

At the production level, ISO 14031 describes environmental performance evaluation as a regularly recurring process as well as placing general requirements for indicators. It also lists detailed examples for each evaluation area. The basis for environmental performance evaluation is the so-called operational system, which corresponds to an input-output analysis of material flows.

Environmental performance evaluation is defined as an “internal process and management tool designed to provide management with reliable and verifiable information on an ongoing basis to determine whether an organization’s environmental performance is meeting the criteria set by the management of the organization” [13].

4.3 EcoDesign Performance

Since companies are profit driven, and environmental aspects and EcoDesign are not as imperative as costs, examples exist where applied EcoDesign is aligned with existing cost management systems. The goal of these methods is to achieve a balance between product performance and economic implications as well as integrate EcoDesign with regular business practices.

According to the World Business Council for Sustainable Development (WBCSD), “Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth’s estimated carrying capacity.” In other words it says: creating more value with less Eco-costs (*doing more with less*). Ratios (weighting) dealing with environmental and economic aspects constitute the form of Ecoefficiency that is discussed in this paper. Examples of product Ecoefficiency methods follow:

- *Activity based LCA*: Activity-Based LCA tries to break the holistic view of “classic” LCA by combining LCA method with Activity-Based Costing as it handles costs, energy consumption and waste generation under the presence of uncertainty. The purpose of the method is to create an integrated economic and environmental assessment method that internalizes energy and waste issues. Examples of Activity-Based LCA application are given in reference [14].

- *Life Cycle Engineering*: Besides the environmental aspects of a product life cycle the approach of Life Cycle Engineering (LCE), developed and applied by IKP since 1989, offers the combined assessment of ecological, economic and technical aspects.

LCE allows a consistent modeling of process chain economics and a better inclusion of technical properties into the ecological life cycle model derived from LCA [14].

LCE defines the factory as a system boundary; the aim is to focus on those elements that can be influenced by the organization. The approach is based on Life Cycle Costing, Activity Based Costing theory, ISO 14040, Quality Function Deployment and Total Quality.

In a later version of LCE, social impacts of products have been included. Examples of LCE can be found in reference [15].

- *QWERTY (Quotes for Environmentally Weighted Recyclability)* was developed in order to quantify the environmental gain that can be realized per amount of money invested in the setting up of take back and recycling systems. The resulting eco-efficiency calculations are presented in two-dimensional graphs in which one axis displays economic costs and revenues, and the other displays environmental burden and gain.

The graphs illustrate the Eco-efficiency effects of changes in take-back system operation such as; applying new technologies, changing collection infrastructures, the consequences for the various stakeholders involved and how return behavior can influence system performance.

The examples for plastic, metal, precious metal and glass dominated products show that improvement avenues in design, technology, policies and take-back system operation are different for these four categories [16].

After reviewing performance measurement methods (financial and non-financial) the relevance of the subject to efficiently managing all sorts of aspects in a business becomes clear.

The next section shows the relationship between performance and EcoDesign operationalization from field observations.

5. Two sizes fits most

In a field research study carried out at Delft University of Technology, it was observed that electronic companies can be clustered into two groups mainly as a result of how environmental product performance data is used. A first set of companies fall into the group "legal oriented companies", meanwhile the other cluster is being named "continuous improvement oriented companies". A description of operationalization strategies follows:

5.1 Legal oriented companies

Within this category are organizations primarily focusing on legal compliance and the external image of the company, rather than reduction of product's environmental load. Since most companies in this category are component manufacturers or assemblers, and in a business to business (B2B) industry, it makes business sense to adopt such an approach.

Pragmatically, this is reflected by a qualitative approach which involves qualitative environmental performance measurement and goals. This approach does not mean that environmental improvements are not achieved in B2B operations. Most product related environmental improvements in B2B have their origins in autonomous technology evolution, rather than in planned intentionality. Sustainability reports in this category provide qualitative information about a company's activities in qualitative terms. Most are not verified by a third party. Focus is on social issues, rather than environmental and economic aspects.

5.2 Continuous improvement oriented companies

The process starts by planning (to design or revise business process to improve results), doing (implement the plan and measure its performance), checking (assess the measurements and report the results to decision makers), and finally acting (decide on changes needed to improve the process). The underlying managerial principle appears to reflect the Deming's cycle [17].

Organizations following this principle are aware of the environmental performance which translates into quantifiable reduction of their product's environmental load, as well as an estimation of rewards from their efforts and integration of environmental issues into regular business. Reporting done by companies in this category is characterized by in-detail environmental data related to production and products, which is very often verified by a third party. Importance is given to environmental issues, rather than financial and social ones.

Legal Compliance oriented companies

Continuous Improvement oriented companies

- Top management commitment
- Qualitative measurement environmental performance
- No rating of products
- Champion yes/no
- Not connected with regular business practices
- No environmental accounting
- No Eco-efficiency
- Top management commitment
- Public quantifiable goals
- Measurement environmental performance (quantitative)
- Rating products as 'green'
- No environmental champion (systematized approach)
- Connection with business practices
- Environmental accounting
- Eco-efficiency

Table 1 Strategies for introducing EcoDesign into business operations in the electronics sector

Legal Compliance oriented companies	Continuous Improvement oriented companies
- Top management commitment	- Top management commitment
- Qualitative measurement environmental performance	- Public quantifiable goals
- No rating of products	- Measurement environmental performance (quantitative)
- Champion yes/no	- Rating products as green
- No connected with regular business practices	- No environmental champion (systematized approach)
- No environmental accounting	- Connection with business practices
- No eco-efficiency	- Environmental accounting
	- Eco-efficiency

Within continuous oriented companies, the following clusters of environmental performance were found:

- *Simplified LCA*: The idea of commercial LCA tools not being useful in industrial contexts was widely spread amongst respondents. All companies interviewed for this study developed their own simplified tools, clarifying that commercial tools are not aligned with company needs and priorities, and full LCA analysis is too costly and time consuming.

- *Phase specific (EOL)*: Some organizations, focus on recyclability rates and disassembly. End-of-life issues are gaining relevance in the electronics industry due to the development of WEEE Directive.

- *Benchmarking*: allows organizations to realize how far they are from their competitors and define who is 'best in class' regarding environmental performance of products.

- *Checklists*: are used to assess toxicity performance of products. In the case of supplied components, in most cases, chemical analysis is done to ensure compliance with company and governmental regulations. Checklists do not usually measure environmental performance of products, but rather determine presence or absence of certain substances.

- *Ecoefficiency*: two Asian organizations were using an individually developed Ecoefficiency method based on two indexes: "energy use" and "resource use".

The "energy use" index relates to greenhouse gases.

Efficiency and resource efficiency are expressed by a "resource" index. The indexes indicate environmental performance of products with simple figures. The aim of the indexes is to compare environmental efficiency of new products with products developed in the past.

In both cases, the organizations were using aggregated figures (total amount of products produced) which rarely lead to priority setting or an action plan.

The following section discusses important observations and provides background information for upcoming research.

6. Discussion

In the previous section it is shown that at large electronic companies, EcoDesign operationalization strategies can be clustered in two groups. The aim of this paper was to investigate which operationalization strategy, from those previously defined, provides better grounds for managing EcoDesign operationalization efficiently. Authors observed continuous improvement strategies based on performance measurements, and the data gathered provides the ground for better control of activities and establishes the basis for alignment of EcoDesign activities with business activities. Florida [11]

Suggested, in a study of 11 plants from different industry sectors, and more than 100 personal interviews, that to obtain environmental gains explicit performance monitoring systems are required.

From the range of performance measurement methods presented in previous sections, a distinction can be made between "validation tools" and "action oriented methods." Validation tools are those proving current perfor-

mance status. Examples belonging to this category are LCA, resource and energy indexes (as described above), or the Business Excellence Model.

These performance methods show evidence of where the company stands regarding a specific aspect, without providing guidance for improvement. On the contrary, action oriented methods provide grounds for the development of specific and target oriented strategies. Action oriented methods include environmental benchmarking, and QWERTY/Eco-efficiency.

It is not the goal of this paper to determine if it pays to be 'green'. Several authors (Bonifant, Elington, Everett, Florida, Hart, Howes, Porter) have tried to answer that question without providing a clear answer; as Reinhardt declares, "it is not about if it pays to be 'green', but under which circumstances it makes sense to be 'green'" [18]. Furthermore, the views of these authors are summarized in table 2 developed by Kolk [19].

Table 2 Environmental and economic relations in business contexts

Complementary	Profitable; win-win
Compatible	Cost-neutral
Conflicting	Environment should prevail
Conflicting	Economy should prevail

Both academics and practitioners agree that you cannot manage what is not measured. Therefore, to set priorities and define a plan of action, a performance measurement system is needed. The system should be able to provide information about where the company stands in relation to EcoDesign.

Since EcoDesign operationalization activities are developed in companies it is important to realize that the main goal of a business is to create value for all actors involved. When defining EcoDesign performance, the concept of value creation plays a relevant role.

In industrial markets - often called B2B - calculating the economic value of a good or service is often fairly straightforward. In consumer business, which accounts for 2/3 of the USA economy, there is usually a difficult to quantify leap to be made between the product or service delivered and the value created. For consumers, value often resides in functionality of the product, cost of ownership and such intangibles as a product's look and feel (e.g. the colorful iMac, or an Armani design); emotional qualities (such as nostalgia), and associated status and prestige. It can be said that for Western societies, such intangibles are gaining ground.

From an EcoDesign perspective, value created through EcoDesign is about environmental performance of the product/service, functionality and economic related aspects. In that sense, it seems that traditional EcoDesign (project based) suffers from a degree of saturation and a strategic shift is observed amongst front-runner companies from an absolute reduction of environmental load to measuring performance based on consumption (products sold) and functionality. From supply side to demand side oriented strategies. Limitations exist with such performance methods. In one case the organization is using aggregated figures including all products sold, in the other case, economic implications are not included. As a result, it becomes difficult to set priorities, develop action plans, and integrate methods into regular business activities.

As a response to the situation described here, the authors would like to introduce in this paper the concept of Ecovalue, which also deals with the demand side, instead of exclusively attempting to reduce environmental load. Therefore, Ecovalue is defined as the ratio between a monetary amount (price) and the environmental load over the life cycle of the product/service concerned.

$$\text{Ecovalue} = \text{price}/\text{environmental load}$$

Figure 2 Ecovalue Formula

The idea behind the index is to place EcoDesign in the business context of design for functionality, making clear what amount it is paid per unit of environmental load. It is suggested that a focus on the demand side (how do consumers spend their money) rather than on the supply side (what environmental load is involved) will be helpful to move EcoDesign towards achieving better results. Ecovalue is an "action oriented method." The question that all actors in the value chain should ask is: for the money spent/invested, what is the environmental impact? This has consequences for policy-makers, companies, and consumers.

Based on facts, policy-makers can define taxation of consumption according to environmental performance of products. Consequently, products with low Ecovalue can be taxed accordingly, which goes to the root of the sustainability principle: consumption. Consumers would then have to decide what value they get for their money spent. This brings back the issue of immaterial value, which in this context gains relevance and may become the real source of differentiation amongst companies.

For companies and managers, by applying the Ecovalue concept it is possible to achieve higher integration of EcoDesign activities in the context of the business. This is done by integration of economic aspects that provide managers with grounds to make decisions based on facts which have consequences at the corporate/strategic level. Since companies are action oriented, Ecovalue helps to define strategies by offering priority setting and action plans.

Research is under development at Delft University of Technology regarding Ecovalue and its consequences for EcoDesign, policy makers, and consumers. Future publications will show empirical results using real product data to determine the potential of the concept.

7. Conclusions

This paper presented conclusions from a literature review and a field research study regarding operationalization and performance of EcoDesign within the electronics sector.

Two clusters of operationalization strategies have been presented; continuous oriented companies and legal oriented companies. From both strategies, continuous improvement oriented companies present better control and management of information and processes, as well as ensuring higher integration of EcoDesign within the rest of business activities.

Within performance measurements a distinction can be made between methods for validation (illustrate internally and externally how the organization is performing), and action oriented methods (show internally how the processes can be improved). Efficient EcoDesign management is based on facts and clear goals. Therefore, continuous improvement, action oriented performance methods and business integration by consideration of economic aspects when defining EcoDesign strategies are preferred. Finally, the concept of Ecovalue and its potential has been introduced. Further research in this area will follow.

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Personalities, I

Anthonie Jacob ('Ton') Bosman: order and logic

Ton Bosman was my first boss at Philips Research (the 'Nat. Lab.') in Eindhoven. He was a physicist with a strong empirical approach ('knowing by measuring'), but simultaneously he urged us to search for the physical ratio behind the results too. This approach is helpful particularly for young graduates. It helps build structure and logic in research work, it also stimulates one to dig deeper for underlying principles.

What I benefited most from during my life however, are Ton Bosman's lessons about communication of scientific results, both written and spoken.

After you finished writing a paper he checked its organization, whether the conclusions were supported by the facts, whether the data obtained were fully exploited, the logic behind its reasoning and the self explanatory nature of figures and tables. The accuracy of the chemistry (that is your job!), or any other science, was secondary. Applying such ideas about writing publications consequently results in a drastic improvement of the quality of the writing.

With regards to scientific presentations at conferences (or in the Lab itself) Ton Bosman's principle was: let the young researchers take the floor right from the start of their career. He even passed invitations for keynote lectures on to us. For instance, as a 29 year old I was a keynote speaker in Japan amongst 60 and 70 year old scientists. When I arrived at the conference, the Japanese thought that Philips had sent the wrong person.

Ton had only one condition: before anything is being presented, there must be a practice lecture first. There you stand trying to do your best but it is by far not good enough. You note that the slides are not well organized and contain too much information. You must determine where the highlights are, what your messages are, if you are missing interim conclusions, what the climax is, and if there is lack of intonation in what you say, etc. etc. All these remarks can be summarized into one sentence: offer your audience understandable key conclusions and messages and do not try to show how great a researcher you are –that is assumed from your inclusion in the program.

These were terrible afternoons, but you learn quickly because you definitely do not want to be corrected in this way again and again.

My graduate and PhD students know very well what the 'Bosman method' is!

The 'Bosman' Walk: Start at the Eindhoven High Tech Campus.

Walk through the campus in any way you like. Leave through the most southern exit. Pass under the freeway and go directly R (Dirk van Hornelaan) at its end go R (Ansbalduslaan), go L and second L (August Sniederslaan). Go straight ahead to the Azalealaan go R (Alsemlaan) and L. Turn L at the Burgemeester Mollaan and go back to the Campus.

2.2 Design, EcoDesign and Functionality, an extended paradigm

2.2.1 Design Processes

Apart from an increase in the number of fields which can be considered under the umbrella of Applied EcoDesign there is another general conclusion to be drawn from chapter 1.2: EcoDesign is integrated today into Design processes, into the Business and into Value Chain Management. It is nothing special, it is not separate anymore. 'Eco' is to be taken into account like other design aspects like physical and economic requirements (hard criteria) and aesthetics, 'usefulness', identity and meaning (soft criteria).

The extended paradigm for Applied EcoDesign is therefore primarily to be derived from design approaches, not from Eco-approaches.

In literature there are many definitions trying to answer the question, "What is design?" A PhD student at Stanford University (Søren Petersen) has listed more than ten such answers. The one I like most reads: "Design is about using technology to create forms and functions that serve people in an optimal way, while making good use of the power of the meanings and values conveyed by those forms." I like this definition because:

- Technology is seen as a (necessary) enabler
- Forms (immaterial, emotion) and function (physical) are considered to be equally important
- Intent is to serve people (not producers or self fulfilment of designers)
- Power of meanings and values (immaterial aspects, emotion) is highlighted clearly

Interpreting this definition leads to the conclusion that design creates 'functionality' in different forms:

1. Physical functionality (transport, music ...)
2. Economic functionality ('value for money' ...)
3. Immaterial functionality (easy, fun, convenience, health & safety ...)
4. Emotional functionality (nice design quality, 'green', recyclable ...)

When seen as a set of creative processes design can be seen as it is represented in figure 2.1. From this diagram it can be seen that the core of the Design Process is to make a synthesis of 'inputs' originating from five sources:

- The Functionality Analysis (what do users want)
- Input from the market (what do users prefer or what can they afford)
- Enablers from technology (what can be of help in realizing the function)
- Value Chain Analysis (what is the impact of 'trade')
- Product context (embedding in infrastructures)

The core of the process sketched in figure 2.2 is the horizontal axis consisting of Functionality Analysis, Synthesis to Product Designs and Design Results.

For the functionality analysis the chief question is: what has to be realized in terms of physical function (transport, music, etc) and for what price (or cost of ownership). However, particularly in wealthy societies there are two other functionality dimensions which play an increasingly important role:

Immaterial aspects: convenience, health & safety, fun ...

Emotional aspects: aesthetics, quality feel, cultural meaning, status, 'green' ...

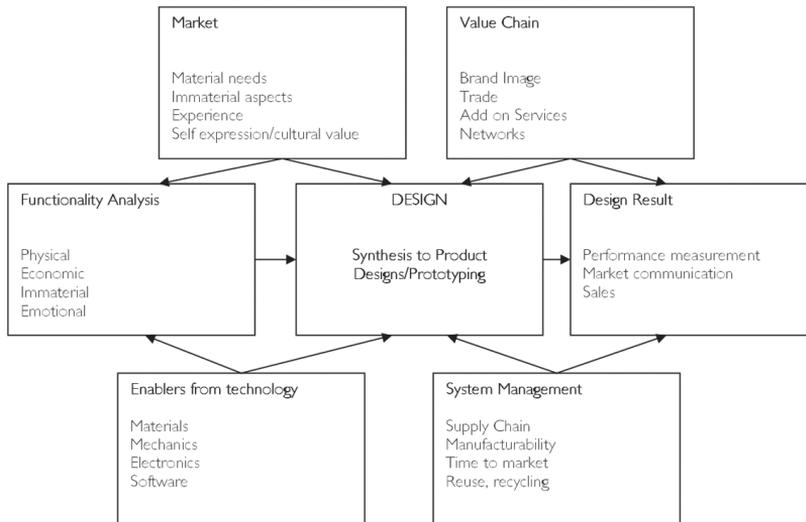


Figure 2.2 A sketch of the Design Processes

Next to price, these two dimensions demand that product differentiation be emphasized among products with identical physical functionality. This is because consumers have vastly diverging views on the importance of immaterial and emotional aspects when making purchasing decisions. This means that today a lot of products are bought on the basis of perceptions such as fashion and experience, rather than to fulfil primary (physical) needs. As a result there is no 'one size fits all' anymore. This even applies to 'emotionally cold' products like electronics. Cell phones and portable audio are typical examples of products where impulse and fashion come first; adequate physical functionality is taken for granted.

Whereas functionality analysis mainly refers to 'wishes and dreams', the market analysis is much more about the confrontation with real consumer behaviour in practice. The big question here is: how will they spend their money, what is their real priority when confronted with the huge number of products being offered. Realizing a variety of designs for one (identical) physical functionality is easier today. There are many enablers available from technology: a variety of materials and surface treatments, smarter (electro)mechanics and software.

Also the value chain needs to be considered. Today trade has a very powerful position, the producers have lost their dominance. As a designer knowing through what channels the product to be designed will be sold is therefore an important issue; each channel will have specific requirements, both for the product itself but also for packaging and transport. At the front end (suppliers, today producers are rather product assemblers rather than real manufacturers) and the back end (recycling of discarded products) there are issues to be considered by designers as well.

Another design dimension to be considered is product context. This includes issues such as manufacturability, networks and services.

Manufacturability can be an opportunity as well as a threat. The opportunity is that if the successful design is also 'designed for production', manufacturing can be ramped up very fast and high margins associated with the introduction of innovative products can be reaped. If this is warranted, trade will step in quickly as well. The flipside of this is that if the great designs are difficult to produce (complicated parts, difficult assembly process) something which could be a hit in the stores becomes a disaster in practice. When distribution is slow, trade will back-off; the impatient consumers of today will buy something else.

Connectivity is another item in the product context. It is a must that products can be easily plugged into systems and infrastructures. Ensuring convenience is a big source of competitiveness and income.

Finally, the possibility of selling add-ons and services is an opportunity as well. A modern business trend is to

sell hardware in order to develop new businesses for - often specifically linked to products - consumables. All these items demonstrate that **the role of the designer has dramatically changed**. In the early design phases he (or she) has become a design 'organizer', analyzing functionality, markets, enablers, value chains and product context in order to bring them together into one design specification. This is very much in contrast with the traditional perception about designers, which are supposed to sit behind a drawing board stare out of the window and be creative, very creative (only).

Once a design specification is in place, the detailed design can start. This phase continues to reflect traditional ideas. After prototyping, the Design Results need to be tested regarding their performance, so that appropriate market communication and sales activities can be started. Criteria for 'design quality' are the usual 'hard criteria' (conformity to physical and economic requirements). Increasingly soft criteria play a role varying from aesthetics to 'usefulness', fitness for purpose, integration with services, identity properties, cultural meaning and environmental friendliness.

In terms of the diagram shown on the previous page, performance measurement means a check is made to confirm that all elements mentioned are presented in a balanced way.

Rituals and habits, I

The Academic Blessing

Traditional Dutch ideas about universities suggest that a PhD supervisor ('the promotor') is the 'administer of science'. This means that the PhD candidate has to be educated in the true ways of doing research as well as being educated to develop well argued conclusions, even if these conflict with those of the promotor.

Nevertheless the supervisor is responsible, particularly after approval of the thesis. Criticism from members of the PhD committee are directed towards him or her rather than the candidate.

In order to do a really good job as supervisor a high level of involvement is required and simultaneously the 'promotor' must try to limit their role to that of a sparring partner. The 'promotor' hopes that the candidate deals well with their ideas and suggestions.

Once the dissertation has been approved for defense by the PhD committee members the real work is over. However, the real emotion is at the end of the defense: awarding the degree of Doctor to one of 'your' folks is touching and deeply emotional. Luckily, after the official promotion ritual here in Delft is the opportunity for a personal speech from the supervisor.

This habit of bestowing an Academic Blessing to the young doctor has almost vanished, but I have kept the tradition of saying (in Latin): vivat, crescat, floreat – may this doctorate be alive, grow and blossom. It is more than a tradition, it is heart and soul!

2.2.2 Integration of EcoDesign into the Design Processes

EcoDesign can be defined as an activity aimed at lowering the environmental load of products/functionalities over their life cycle.

For EcoDesign basically the same set of design processes as described in 3.1 above apply. It is nothing special; in fact it is (or should be) on equal footing with Mechanical Design, Electrical Design, Software Design, Design for Aesthetics, Design for Convenience, etc. All of these aspects have to be integrated into one final design concept.

It has been the tragedy of many EcoDesigners that they considered themselves to be involved exclusively in Environmentally Oriented Product Design. This wording claims a kind of priority for 'Eco' over the other design approaches and claims, a 'moral superiority' towards users too. Sometimes even the wording "responsible design" is used instead, suggesting that other forms of design are irresponsible.

If users do not accept these 'green' or responsible designs (for real or perceived reasons, like poorer physical functionality, higher price, less convenience or fun, lousy aesthetics, and poor quality), the conclusion of such designers is that the general public needs to be educated. In the case that this does not work out (and it will not), all kinds of things, which come down essentially to (wild) forms of dictatorship in the name of the environment, have been proposed. Engaged 'green' designers and consumers seem to be the antithesis: 'green' is 'green'; consumers are consumers ... and they will never meet.

The idea to link the self-interest of consumers with environmental issues (see chapter 5.4 of this book) and let money do part of the work instead of design (for instance tax consumption instead of income, see 9.3) is far outside the mindset of many traditional EcoDesigners. Excellent representatives of this community have been observed to go down the drain when trying to promote Eco in conventional companies. In such companies 'green' is on the map, but it is also clear that it is a small territory. Wanting to rule over the entire business in spite of that is the best recipe for self destruction.

In practice (Applied) EcoDesign is therefore subordinate to design for (overall) Functionality (see chapter 3.1). For commercial companies this means EcoDesign should contribute to value creation in the shop. This value is determined by the physical functionality and price/cost of ownership, but increasingly by immaterial and emotional functionality. Especially in wealthy societies this is applicable. A lot of products are bought on the basis of 'fashion', not on basis of functionality. This is the great opportunity: Applied EcoDesign is in an excellent position to contribute to enhancing the functionality (value) of products in the shop:

For price buyers: less materials, less packaging, simplification of product architecture and less energy in the use phase are both 'green' accomplishments and contribute to a lower cost of ownership.

For buyers interested in technology: products with smart functionality realization are innovative and generally speaking 'green'. They also have high innovative value.

For quality buyers: nice looking 'green' products score well in the category 'emotional functionality' and can command high prices.

Many consumers show a mix of the behaviours listed above. In the 'green' functionality analysis it is therefore important to identify specific target groups to which the product is catering. This helps to decide what enablers should be mobilized. The channels through which the product will be sold will have an impact on design for reduction of the environmental load in the production phase and on design for recycling. The product context will have an impact on the opportunities for the greening of production processes and the development of services to extend the life time of products.

Atlanta, GA and Minneapolis, MN: south and north

Atlanta, GA is a successful city. Its success radiates through the whole state of Georgia. Cotton and peanuts have disappeared and only survive in the very South Plains of the State, the Jimmy Carter country. Maybe they are still there only for show. High tech industries and service businesses have replaced the stereotypes about the southern USA that I learned at school fifty years ago.

The Georgia Institute of Technology was started to assist in rebuilding the South after the Civil War. Originally for white men only, it opened up in the fifties and sixties of last century. It is now a real example of diversity and inclusion. TECH has been steadily rising in the US university rankings and has climbed to a position just behind MIT, Stanford and Caltech. Their ambition is to make it to the top spot.

In September 2001, I was in Atlanta to prepare for a visiting professorship in 2002. In the same week, there was a conference in Minneapolis to be held by NEPSI (the National Product Stewardship Initiative). I got invited to give a presentation on the Dutch take back and recycling system (see chapter 8.3), so I traveled to the Twin City.

Next morning in the hotel there was something strange at breakfast. Nobody was there, so I decided to try out my brand new three band phone. I called Annet in the Netherlands. She said: "Where are you? A plane has just hit the Twin Towers". I rushed up to my room and switched on the TV, just in time to see the second plane hit the other Tower. It was devastating – I sat flabbergasted for more than an hour watching TV.

The meeting was cancelled, only some twenty people were there; the others did not show up because all air traffic had been stopped. The only thing we could do was to go for dinner that night. Almost nobody ate. Few of us said anything. All of us drank, a lot – it was a very sad and gloomy night.

While I was trapped in Minneapolis I spend my time writing a publication (see chapter 5.3.1), and roaming through the streets; occasionally checking on flights back to Atlanta. There were none; however, someone from the seminar group got a hold of a rental car and offered me a lift to Knoxville – close to Atlanta. We drove 1,000 miles in 1.5 days – how empty the Midwest is!

I was dropped off at the Philips factory in Knoxville, three minutes before twelve. All the employees stood outside in a circle around the flag, to silently commemorate the victims of September, 11. I joined the circle. Many of my friends over there were surprised to see me stepping out of a car and joining the circle – a stranger from a foreign planet. After the ceremony we talked – and they helped. The next day I caught the first flight to Atlanta. There I was waiting for my (scheduled) flight back to Amsterdam. On Friday night I heard that it had left Amsterdam, so the next day it would go back. Yes! I would be in time for a PhD defense and ceremony in Delft (see Rituals and Habits, 1), where I was the supervisor and promotor.

At the airport it was a mess, all the rescheduling had to be done for all the people who got stuck. Business class helped me survive; the plane left on time but half empty ... The paperwork and the new security measures had taken their toll.

In the Netherlands the Second World War is most important historical event, in France the First World War, in the UK both World Wars, in Germany there might be even three (the 1870 War included). In Atlanta it is (still) the Civil War, in Minneapolis it is the War on Terror, at least that is the association I will always have when I read or hear the name of that Twin City.

Atlanta City walk : Go by Matra (public transport) to station E2. Walk to Oakland Cemetery and back (southern direction), then walk north to the Martin Luther King Memorial Center. Walk east to downtown (Auburn Avenue). Go north on Peach Tree, all the way up to Georgia Tech (L via North Street). Go R (Chery Street), L (Bobby Dodd Way) and cross through the First Drive, go north, go L tot sixth street, R to MacMilland Street, R (Eighth street), Left in Memphis Street, end at the Students Pizza Bar.

Favorite Restaurant: Max Lagers American Grill & Brewery, Peach street.

Country walk: Georgia is generally too hot to walk. Make car trips to Athens, Stone Mountain, Providence Canyon, State Park and last but not least Helens (German Village).

2.2.3 Design for X

In a way similar to the way in which Applied EcoDesign is subordinate to Functionality Value, Design for X is subordinate to Applied EcoDesign in its totality. Instead of creating value in shop, now lifecycle impact minimization is the overriding principle.

Design for X can include:

- Design for energy reduction
- Design for reducing impacts of material use
- Design for reducing packaging and transport
- Design for reducing chemical content
- Design for recycling

Applying a specific Design for X approach means therefore that a life cycle check is needed: if there are gains achieved in department X_1 , it should be confirmed that this is not undone by bigger losses in department X_2 . In practice this life cycle priority is not always adhered to: there is still dogmatism surrounding the 'dematerialisation principle' and there are still European Directives in place (WEEE and RoHS, chapter 9.2.1) in which the life cycle perspective has been ignored.

In practice situations occur in which one domain X has to be sacrificed for another one. A well known example is energy saving lamps. Compared to incandescent lamps, production of energy saving lamps requires more material. However, the higher initial environmental load is earned back by lower energy use over the life cycle, both environmentally and economically.

Another example is the fact that material reduction generally results in a lower recyclability of products. Since recyclability of materials is never 100%, material reduction is preferred (see also chapter 7.5).

Balancing chemical content items with other domains of Design for X is more cumbersome; it means weighting toxic potential (risk) against environmental load (see also chapter 6.5).

Inside one domain X there can be several subordinated (potentially conflicting) domains as well. An example is Design for Recycling:

This can include:

- Design for achieving the highest level of reapplication of materials
- Design for maximizing the amount of resources saved
- Design to minimize landfill
- Design to get maximum control of potentially toxic substances.

A good example here is the recycling of plastics in products. Aiming for high levels of reapplication will result in lower yields and therefore in more leftovers. Maximizing the saving of resources could mean not achieving the maximum environmental gains possible. Minimizing landfill implies incineration which could give rise to higher emission levels. Controlling potentially toxic substances in plastics will not result in maximum resource savings.

No general rules can be given for how to tackle these kinds of issues. The best recommendation is to look at it from a product specific perspective and to try to reconcile technicalities with associated stakeholder perceptions (see chapter 6.1).

Beijing, in front of our apartment on the campus of Tsinghua University**2.2.4 An example of 'green' functionality analysis**

The example given below was triggered by a discussion with a consultant. He had accepted an assignment to promote PVC as a 'green' and cheap basic construction material for window frames. He established that the energy/kg to produce PVC is lower than its alternatives and it is cheap, and all the stories that chlorine is bad are based on emotions. He asked if Delft University would be so kind to provide some energy data so that the story could be communicated to the general public. Since this is only a small deal and since Delft is a public institution he presumed that it would be done for free.

This is a perfect demonstration of how the extended (look at functionality and value) Applied EcoDesign paradigm and the traditional one (look at kilograms and scientifically calculated environmental load) can collide. Over the phone I tried to explain to the man the use of a 'green' functionality analysis to support conclusions. This discussion initiated the development of a functionality aspects table for window frames made out of aluminium, wood and PVC.

Table 2.1 Value/cost perceptions of materials in a window frame application

*Functionality	Perceived value/cost of materials			Remarks
	Aluminium	Wood	PVC	
<i>*Physical Functionality</i>				
Ability to carry heavy windows	high	lower	lower	
Wear and tear degradation	high	medium	lower	
<i>*Economic Functionality</i>				
Price of Product	high	medium	low	
Cost/year	medium?	medium	medium?	life time depending
Maintenance cost	low	high	medium	f.e. cost of painting
End-of-life cost	low	medium	high	PVC: depending on type of adhesives
<i>*Immaterial Functionality</i>				
Convenience	NA	NA	NA	
Health and Safety	high	medium	low	Wood: depending on type of paint, PVC: perceived emissions of monomers
Cleaning	NA	NA	NA	Depends on cleaning agent
<i>*Emotional Functionality</i>				
Aesthetics	high	medium	low	Generally depends on how individuals see this
Quality perception	high	medium	low	
Environment "energy"	low	high	medium	Aluminium seen as energy intensive
Resources / Material	medium	high	low	PVC seen as resource intensive
Chemical content	high	medium	low	
Recyclability	high	medium	low	
Durability	high	medium	low	
Looking 'natural'	medium	high	low	

Please note that this table is about perceived value/cost by users. This does not necessarily represents what is scientifically true.

On the basis of this perceived value/cost analysis, it is concluded that aluminium has a high perceived value and high perceived initial cost, but low costs during later stages of the lifecycle. Regarding immaterial functionality the data does not allow conclusions; more user research needs to be done here. In the department 'emotional functionality' aluminium generally scores medium to high with energy needed for production as an exception. PVC is almost the opposite of aluminium: lower physical functionality, low initial cost, more unfavourable cost during the life cycle. Emotionally PVC scores consistently low. Wood is somewhere in between because it is seen as positive in the resource domain (renewable, 'natural') but with a strong negative point in the field of maintenance.

The conclusion is therefore that the best material choice is to be made on the basis of the type of customers to be addressed (price buyers, 'tech' buyers, quality buyers), the type of outlet (cash and carry store, home improvement store, speciality store), and the type of building (houses, offices, shopping malls).

After material choice, a number of Design for X approaches still apply. Experiences have shown that inside the domain of functionality value there is a lot of room for EcoDesign to manoeuvre (see also chapter 5.5).

Highlights of the year, 1994

What is 'green'?

The highlight of 1994 was addressing the question, "What is green?" As the Environmental Competence Centre, we had to formulate a program through which the company could 'green' its business. Before doing so, it was necessary to know what 'green' really stands for. From the outside world came conflicting answers.

Universities presented a 'scientific' perspective through the promotion of the newly developed Life Cycle Analysis (LCA) methods. The chief conclusion was that energy consumption for electronic products represents the dominant environmental impact.

Government 'green' turned out to be largely determined by geography. For instance, in a densely populated country (little landfill space) like the Netherlands with its location near the sea (water pollution), waste reduction, waste recycling and heavy-metal-control ranked high. In Switzerland (dying forests in the mountains) SO_2 and NO_x ranked as the number one impacts. In the USA it was toxic substances (clean up of dump sites).

Non governmental organizations like Greenpeace were focusing on substances perceived to be 'hazardous' like PVC and brominated flame retardant plastics. Such 'green' perceptions were supported by large sections of the general public.

In the table the priorities of the different stakeholders are summarized. The table also shows that particularly for consumers priorities change as a function of time.

Ranking of green issues (for electronic products)

	Consumer 2004	Consumer 1996	Consumer 1991	LCA	Dutch government
Energy consumption	1	1	4	1	3
Waste/Recycling	3	2	5	4	2
Materials use	2	3	1	3	6
Packaging	6	4	2	5	5
Sustainability	4	5	6	NA	1
Production processes	5	6	3	2	4

This diversity of opinions poses a dilemma for industry. Questions arise such as, what to do in practice, what is the real priority and what is the best balancing act?

The decision was taken to separate items related to materials ('basic' materials, packaging, chemical content, recycling) and energy. For the materials part the 'environmental weight' design tool was introduced (see chapter 6.2.2).

Energy was measured in watts, thus indirectly laying the basis for benchmarking (see chapter 24). The choice was not to go for a full LCA, the chief reason being that it does not address government and perceived 'green'.

2.3 Ecovalue, a method to link EcoDesign and Business

In this book, Ecovalue is being defined as the ratio between the cost of ownership of a product for the user (numerator) and the environmental load of the product over its life cycle (denominator). Ecovalue therefore combines the supply side (traditional EcoDesign, lowering of the environmental load over the life cycle) and the demand side (how do consumers spend their money) and breaks from traditional environmental approaches, which almost always focus exclusively on the supply side.

There have been several drivers for the Applied EcoDesign group at Delft University to deal intensively with Ecovalue.

1) It was realized very early on that traditional EcoDesign lowers the environmental load of products but simultaneously often results in lower cost of ownership. Less energy consumption, fewer materials, less packaging, more efficient transport and simplified product architecture all contribute towards that end. This means that with successful EcoDesign, there is an important 'rebound' effect: such products enable the purchase of more goods (which entails additional environmental loads).

2) Moving production overseas (system organization) generally results in equal or even higher environmental loads, but the products concerned get cheaper. This is a rebound effect as well.

3) Innovation (technology) can either lead to cheaper products (DVD players versus CD players) or to more expensive ones (LCD TV's versus CRT TV's). In this case there is a rebound as well, but it can have a negative result.

Considerations like the ones above lead to the conclusion that in 'green' products value has to be added in order to prevent the occurrence of big rebound effects. Adding value should aim at training consumers to be prepared to pay more for their products. It will be shown in chapter 5.4 that only a minority of consumers are prepared to pay more for 'green'. Therefore the value has to be sought elsewhere, that is in immaterial and emotional functionalities of the product (see chapter 2.2).

Ecovalue is clearly different from an Ecoefficiency approach for products, as for instance put into practice in Japan. In this case, the ratio between functionality level (measured by certain indices) and environmental load over the lifecycle is being considered. Ecoefficiency defined in this way is still a supply side and technically oriented indicator. Whether consumers are prepared to pay extra for more Ecoefficiency is not considered.

The first Ecovalue studies at Delft University consisted of 'general mapping' of Ecovalue figures. Energy turned out to have the lowest Ecovalue followed by materials and components. Products score better and services score the highest. This result gives interesting clues regarding how to move to more sustainable consumption. It was concluded for instance that a 32 inch high-end TV had a higher Ecovalue than a standard 20 inch TV. With food, meat is a protein source with a higher Ecovalue than beans. Both conclusions go against conventional environmental wisdom.

Electronic products have a lot of added value. Their Ecovalue is higher than the average for the complete product basket by the average consumer; most food products, and particularly gas, rank below the average.

In the last ten years however, the Ecovalue of most electronic products is showing a negative trend. The positive effects of better EcoDesign are reversed by lower prices.

This observation triggered a study on how electronic products can be developed with a higher Ecovalue. Some preliminary results are presented in the paper below: *"Maximizing Profitability With Ecovalue"*.

The general conclusion of this study is that higher Ecovalue can be obtained by better tailoring products to specific consumer groups, particularly for 'quality buyers' and 'high tech buyers'.

Maximizing Profitability With Ecovalue

Oriol Pascual; Ab Stevels

Abstract

'Green' product design is a widespread practice amongst the consumer electronics industry. However, it is perceived that the low-hanging fruit has already been picked and, at present, 'green' product design suffers some sort of status-quo. A major issue appears to be the gap between its environmental and managerial dimensions which jeopardize its potential for improved profitability (environmental and economic). Additionally, traditional 'green' product design approaches have neglected the demand side of the supply chain; how consumers spend money. In this paper, the authors argue that the market is a diverse place where functional and intangible product values have the potential to maximize environmental and economic profitability when taken into account in 'green' product design strategies. As a result, a new managerial framework aiming at value creation has been developed. Within value-based strategies, a new Ecoefficiency method called Ecovalue is used to set design priorities based in market segmentation and consumer purchasing power.

Key words: EcoDesign, Ecovalue, ecoefficiency, demand side, management, profitability.

1. Current status of EcoDesign

'Green' product design (or EcoDesign), the practice of reducing the overall environmental load of products during their lifecycle, is a widespread practice amongst the electronics industry. By 2004, seventy-five percent of the world's largest electronics companies claimed to practice some sort of EcoDesign related activities [1]. However, scholars and practitioners feel that while previous developments have lead to the successful picking of low-hanging fruits, the discipline currently suffers some sort of *status-quo* [2-8]. The rationale for this situation refers both to 'green' product design methodologies and tools, and to how these are managed within business contexts. Literature identifies a few main barriers to achieving further developments; a mismatch between 'scientific green' and 'government green' (what is needed and what it is defined by law) [9], an excessive focus on the supply side of the value chain [10], and reduction of environmental load as a unique and absolute perspective to decide design alternatives.

A comprehensive study carried out by Delft University of Technology amongst Global Fortune 500 companies from the electronics and communications sectors, reveals the difficulties for business managers to define environmental priorities in line with the company's overall strategic thinking [12] as well as to determine what the profitability of 'green' product design strategies is. Performance measurement systems, language used, and communication related issues seem to be some of the major drawbacks that have led to the current situation [11, 12].

In response to this, the Design for Sustainability program at Delft University of Technology asks the question: "how can 'green' product design contribute to maximizing environmental and economic business profitability?" Taking into account that sustainability is about production and consumption, and that currently most 'green' product design development pays attention to the supply side only (producers), the role of the demand side (consumers and the market) within 'green' product design is a relevant subject of research.

In this paper, the authors argue that the gap between environmental needs and business performance can be bridged by creating the right conditions within the internal and external value chain, and setting priorities in line with overall business goals. A newly proposed Ecoefficiency method represents the main focus of this paper: Ecovalue - a priority setting tool aligning environmental, customer and business value. Previous publications by the authors broadly cover the criteria used for the development of Ecovalue. Basically, those are:

- Sustainability is about production AND consumption.
- Markets are diverse places; profitability is maximized by product differentiation.
- Product value is a mix of functional and intangible value (i.e. status, design, feelings). Different market segments perceive it differently.
- Reduction of production costs has limited potential. Increasing the value of products has limitless potential.

Therefore, in this paper the authors focus their attention on the applicability of Ecovalue. Section two presents some background information regarding this Eco-efficiency method. Section three presents a step by step methodological approach to Ecovalue. Finally, the validity of Ecovalue is tested and its potential is demonstrated by presenting a case study using a set of four Philips televisions with different environmental loads and shelf prices.

2. Setting priorities with Ecovalue

Previously, a paradigm shift to the demand side has been proposed to address the current status-quo of 'green' product design and to provide new design directions. Additionally, it has been argued that such a shift could contribute to increased product value and business profitability (economic and environmental). Finally, the paradigm shift aims to align 'green' product design with traditional business management activities. Such a shift to the demand side largely depends on the criteria used to measure product performance. In light of this, the authors present a new Ecoefficiency approach that provides an innovative perspective on the field of 'green' product design, as it helps to measure product performance.

Ecovalue is defined as the rate between product price and product's environmental load, helping to define priorities when applying value-based strategies in 'green' product development. Ecovalue may become truly meaningful when it is used to define product performance, envisage a medium-long term strategy, set quantifiable goals, review developments and redefine targets.

Ecovalue aims to fulfill the need for decision making in 'green' product design based on known facts. Ecovalue acknowledges market diversity where consumers value different attributes in products. For this purpose, the criteria used to set priorities rely on market composition, consumption power, and a product's environmental load. Units used include retail price in monetary units and a product's environmental load, expressed in millipoints (mPt). Arguably, some may define retail price as an unstable unit for this purpose. Retail price is an economic unit at the demand side representing functional and intangible values, amongst others, of products. Additionally, retail price links value created with value captured and a customer's willingness pay. Ecovalue combines market economy principles and 'green' product design.

Ecovalue addresses the following questions; how much environmental load per monetary unit are consumers willing to spend? Can intangible value contribute to creating overall product value while keeping environmental load to a minimum? In this paper it is demonstrated that product differentiation also applies to 'green' product design. Ecovalue provides managers, policy makers and consumers the possibility to formulate informed decisions based on facts. For a given set of product scenarios, Ecovalue defines the ratio between monetary value for each unit of environmental load. Ecovalue is useful to:

- Identify environmental improvement directions for design, technology development, investment, recycle systems, and public policy making.
- Set priorities regarding scenario and strategy evaluation
- Create strong basis for stakeholder dialogue based on facts.

Summarizing, Ecovalue provides the necessary elements for the development of strategic action plans. Citing Itter & Lacker's "*you need to link measures to company strategy: what are the performance areas and drivers that make the greatest contribution to the company's financial outcomes?*" [13].

The upcoming section describes eight possible scenarios (environmental and economic trade-off) under an Ecovalue perspective. Four trade-offs options deliver a negative Ecovalue while the other four produce a positive one. Later, a detailed description of the above described Ecovalue methodology follows, using four television sets as a case study the potential of this ecoefficiency approach is described.

2.1. Ecovalue scenarios

Ecovalue is based on relative terms: taking a reference product as a baseline. Eight strategic options can be defined by increasing and/or decreasing a product's environmental load and overall product value. Table 1 describes the strategic options and implications for both business and the environment. From the available options, positive Ecovalue is highlighted in grey. Variations in relation to a baseline product are represented either by "+" (to express increase) or by "-" (to express decrease). A reduction of environmental load is represented in the table by an increase of a product's environmental performance, the opposite holds true. The resulting Ecovalue for a specific option is attained by the resulting addition.

Table 1 Improvement potential according to product value & environmental performance

Strategy Options	Price	Environmental Performance	Resulting Ecovalue Change	Target Group	Observations
1	++	+	+++	Experience buyers	Best Ecovalue option from a business perspective
2	++	-	+	Feature buyers	Positive Ecovalue option, however negative for the environment
3	+	++	+++	Experience buyers	Best Ecovalue option from environmental perspective
4	+	--	-	Feature buyers	Negative Ecovalue option, however positive from a business perspective
5	-	++	+	Price buyers	Positive Ecovalue option, however negative for business
6	-	--	---	Not applicable	Negative economic and environmental profitability
7	--	+	-	Price buyers	Negative Ecovalue option, positive for the environment
8	--	-	---	Not applicable	Negative economic and environmental profitability

Similarly, Ecovalue can be easily visualized (Figure 1) on a graph where the X axis represents environmental load, and the y axis represents product value (as shelf price). Products plotted at the left side of the discontinued line offer high Ecovalue (ratio price-environmental load). Products on the right side of the graph offer high environmental load at low price/costs (for consumer) and under value-based strategies, should be avoided. When deciding what design directions to take, managers should ask “for which target group is my product more attractive?”

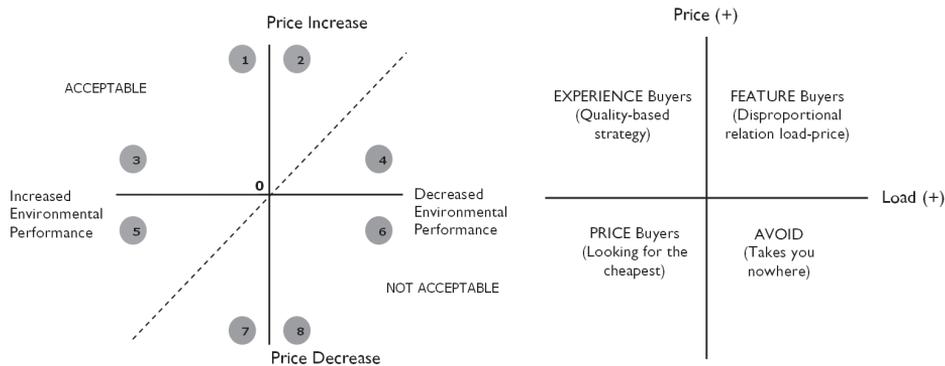


Figure 1 Visualization of Ecovalue

Experience buyers (strategy #1 & #3): Experience buyers willing to pay premium prices (Low environmental load at high cost). For this strategy, both Ecovalue and environmental load run parallel. Innovation strategies often fall under this category, you can command and control an increased price through technology, EcoDesign, system organization and legislation. This strategy requires using technology and intangibles to appeal to consumers. Consumers in this category are willing to pay a premium for products which deliver convenience and status. A shift from CRT to LCD would illustrate this option.

Price Buyers (strategy #5 & #7): Apply traditional EcoDesign strategies when you are forced to lower the price. This strategy leads to relatively low environmental load at low costs. 1/3 of EU citizens are price buyers who may

go for this option. Conditions suggest that production could be handled in China (if it is not already taking place there) when production efficiency is achieved. However, this still is an issue for consideration.

Feature buyers (strategy #2 & #4): Feature buyers, #2 => positive rebound effect, #4 => negative rebound effect. This strategy represents the real dilemma. For #2, if price can be increased disproportionately and the environmental load decreased, then the rebound effect applies. This holds true for feature buyers for whom purchases mean an economic increase anyway. The opposite holds for #4. For this option, it is relevant to carefully define strategies.

Avoid (strategy #6 & #8): Relatively high environmental load at low price. Value-based strategies ask for quality and “first in class” status. Strategies #6 & 8 deliver low economic and environmental profitability. Low ranking companies take this way.

Figure 1 and Table 1 show that the effects of planned actions can be demonstrated. Assuming that a company has to, or wants to, do ‘green’ product design (do good for the environment), Ecovalue would help to define what is the best strategy to apply from a profitability perspective (environmental and economic) in order to make decisions based on facts rather than assumptions. This framework can be used by multiple stakeholders.

The next section describes a step by step method to calculate Ecovalue. On this occasion, televisions are used as a case study to illustrate the process.

3. Ecovalue methodology & TV case

Theoretical principles behind the Ecovalue concept have been defined in previous sections. In this section we describe a five-step methodology which leads to the definition of an action plan where decisions are based on product profitability.

3.1. Define scope

Ecovalue is based on relative terms, helping to prioritize between different scenarios according to the value created per unit of environmental load. Therefore, at least two product/services must be selected for the study; one is used as a baseline (existing product) and the others represent design alternatives.

Dealing with product functionality (physical, economic, intangible): products in the scope of the study may include a mix of functionalities. Although for the ratio to provide meaningful results, it is suggested that a range of products be selected delivering a common physical functionality (i.e. image reception, audio, storage of data). Variables (scenarios) can then be selected according to technological and physical characteristics of products. Physical functionality is the basis, then alternative scenarios can be chosen according to target groups (experience, feature, and price buyers), enablers (science, technology, supply chain), and drivers (i.e. legislation, competitiveness). *Example:*

- Functionality: display image on screen
- Technological variables: CRT, LCD, Plasma
- Physical variables: screen size, material application, volume

To illustrate how Ecovalue works, we have chosen four products from the Philips family of displays as a case study. Two CRT televisions (one for the Chinese market, and one for the European market) and two LCD televisions (both for the European market).

3.2. Gather data

Ecovalue requires two sets of data: monetary units and environmental load.

Monetary units: consumer price as set by company catalogues or shelf price. All forms of monetary units (currency, GDP) are applicable. Use the same monetary unit for all products/services of the product set. When different prices are available, apply average. Take into account differences in retail and catalogue prices which can vary up to 50%. For justification of retail price as unit used here, you may like to review Pascual’s article [14].

Environmental load: environmental load of a product lifecycle is determined by physical units and/or Life Cycle Analysis (LCA) software like Ecoscan or SimaPro. For the development of this case, Ecoscan has been used which

provides results in millipoints (mPt). Physical units for volume, weight, energy, etc. can also be used as units for environmental load. Since Ecovalue works with relative terms, it is important to use a similar baseline.

Limitations: Ecoscan software was updated in 1999 which modified the value of units, making comparison between the previous version (eco-indicator 95) and the new version (eco-indicator 99) unworkable. It is suggested to use values from a single version of the software to ensure accuracy of results.

Regional differences are not taken into account in Ecoscan. Environmental conditions in China are different than in the EU, however this is not reflected in Ecoscan (e.g. energy in China 100% coal). This relates to both the production and usage phases. These limitations cannot be avoided, however Ecovalue aims at finding strategic directions, design venues, investment options, or determining the efficiency of legislation. Ecovalue is a managerial approach, therefore it does not need the accuracy required from science; the direction that the venue is pointing is more important.

3.3. Turn data into information

Apply the Ecovalue formula (Figure 2) to selected products/services provides the resulting numerical figure, known as "Ecovalue". Results are revealed on a graph (Figure 3) including all products/services from the defined scope.

Ecovalue = price/environmental load

Figure 2 Ecovalue formula

From the previous results, select the field of attention. Look at prioritization fields in more detail: where is it possible to make an improvement? Due to property issues, the authors cannot provide detailed information. Results are summarized in Table 2.

Table 2 Summary of Ecovalue results for CRT and LCD televisions

28" & 29" CRT TV '05	2005		2004	
	Philips 29pt7333 (China market)	Philips 28pw8620 (EU market)	Philips 23pf9946 (EU market)	Philips 32pf9956 (EU market)
Average price (€)	354,63	481,00	979,32	2155,92
<i>Env. Load (Eco'99 Pt)</i>				
Manufacturing	12298	8754	4738	4738
Accessories	179	101	411	411
Packaging	130	595	292	292
Usage	59702	46898	45464	45464
Disposal	-2577	-2179	-570	-570
Total	69732	54169	50335	50335
Eco Value (€/Pt)	5,09 €/Pt	8,88 €/Pt	19,46 €/Pt	42,61 €/Pt

3.4. Benchmark results

How can this information be interpreted? From an environmental perspective, high Ecovalue is positive for the environment since it means that every unit of environmental load represents high monetary value (functional value + marginal value = exchange value). Ecovalue is then represented graphically with the aim to visualize the trend amongst those products that were analyzed.

Since Ecovalue shows results on a relative basis those results vary depending on what the reference product is. On the following page, graphs represent how the set of TVs used for this study score in relation to their counterparts.

4. Interpretation of results & discussion

Results are visualized on a graph (Figure 3) where the X-axis represents environmental load, and the Y-axis represents product value (shelf price). Products plotted on the left side of the discontinued line offer high Ecovalue (ratio price-environmental load). Products at the right side of the graph offer high environmental load at low price/costs (for consumers) and under value-based strategies, should be avoided.

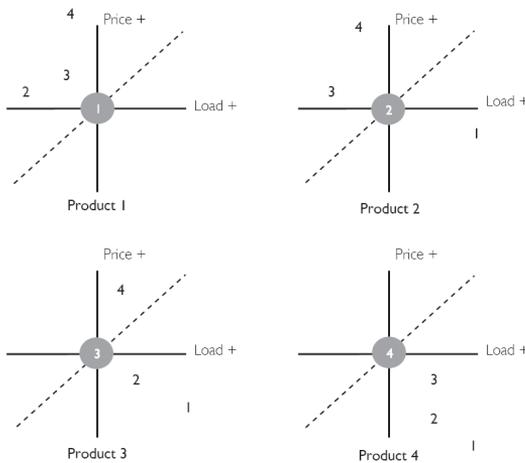


Figure 3 Scenarios for TV case study

A detailed review of results for the illustrated case follows.

1- Product #1 scores lowest of the four possibilities presented. High potential for improvement regarding environmental load and value seems to be present. If the idea is to keep a low cost display within your product portfolio, sell the product to the Chinese market where there is a high rate of price buyers. In this case, you can only create Ecovalue by reducing product environmental load.

2- Product #2 scores better than #1, however there is still room for improvement due to potential technology shift (from CRT to LCD). Conversely, in Western EU this product appeals to only 1/3 of the public (price buyers). It may be an interesting option to increase Ecovalue intangibles through design or sacrifice a minimum environmental load to appeal to more profitable market segments (upgrading). Also, with growing income per head in China, this is a candidate.

3- Product #3 scores better than #1 & #2, however a sacrifice its environmental load a little bit would allow for the improvement of the overall product value dramatically. It fits feature buyers: latest technology at reduced prices.

4- Product #4 is the best in class for this set of products, from an Ecovalue perspective. It targets experience-quality buyers, it can command a high price because of its large screen, technological advances, and because "it fits nicely in the house"

A company producing product #1, can do a lot for its customers and the business by applying traditional EcoDesign. If a company produces product #4, then it is best in class. Under Ecovalue principles, a producer of product #2 and #3, can find ways to improve product performance while improving business performance, by making decisions according to its target group and overall business strategy.

5. Conclusions

'Green' product design requires finding the balance between main players; production, consumption, and the environment. From a producer perspective, physics & chemistry, legislation and system organization are system boundaries. As suggested in the text, these aspects require different approaches and use of language. In this paper, the authors call for a paradigm shift within traditional 'green' product design approaches; from pure reduc-

tions of product environmental load, to the maximization of product economic and environmental profitability by understanding market reality. The rationale behind this is twofold; consumption is a major factor determining overall environmental load created. Additionally, it makes business sense to explore how 'green' product design contributes to creating value for customers and the rest of the value chain.

Currently, most efforts aiming to improve environmental performance focus on the supply side of the value chain, where the *low-hanging fruit* has been picked and little further improvement can be achieved with traditional 'green' product design approaches. Once cleaner production techniques have been applied and the limits of physics explored, how can sustainability move forward? Consumer purchasing decisions and the use of purchasing power ultimately determine the route towards a sustainable (or unsustainable) society. Here, the authors describe three main consumer groups: price buyers, feature buyers, and experience buyers. Each consumer group perceives product values differently, providing evidence that the market is a diverse place where product differentiation is also relevant for 'green' product design if profitability has to be maximized. Within this context, it is the combination of functional and intangible product values that define environmental and economic profitability. While some consumers look for basic functionality at a low price, others are willing to pay a premium for intangible values like design, exclusivity, or newness.

Within this context, the authors argue that 'green' product design can contribute to value creation by maximizing environmental and economic product profitability. From a business perspective, product profitability can be maximized by delivering tailor made solutions for each consumer group. Value-based strategies, a comprehensive managerial framework aiming to organize internally for value creation, have also been briefly described here.

Ecovalue, the rate between consumer value and environmental load, has been the main topic of this paper. Ecovalue is an Ecoefficiency method to set priorities driven by the environmental and economic profitability of products. The approach has been validated with a case study using four television sets, and has been proven to:

a. Improves data gathering

Product price is easily available, while for environmental load electronic companies usually are requested to apply for Type III labeling which asks for a life cycle analysis. It is already there. Simplified LCA also works. Alternatively, physical units can be also used.

b. Provides a common language

Engineers, designers & managers can understand and interpret Ecovalue results; high Ecovalue is preferred amongst a set of alternatives. By allocating results on a graph, results are easily visualized and decisions can be taken according to overall business strategy.

c. Leads to informed decision making

Ecovalue provides the basis for decision making based on facts. It addresses the question; for a specific target group, which design alternative (scenario) provides higher profitability?

d. Aligns environmental and business strategies

Finally, Value-based strategies and Ecovalue align 'green' product design with overall business strategy by addressing the ultimate goal of value creation.

Here we explained how Ecovalue works for EcoDesign in business, however it also applies to:

- Policy making
- System optimization
- Consumer decisions

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Tidbits, 2

The Cheapest Advice in my life

It was a boring conference. It was about implementation of environment within industrial corporations, but almost all speakers had an academic background and most of them gave the impression that they had never seen a factory from the inside.

In the afternoon, I decided to leave early and to go for a drink at the bar. There I met a participant who told me to have exactly the same feeling. She was new in the field and had been sent to the conference by her employer, a big footwear & apparel company in the USA. Her mission was to develop 'green' ideas, to be discussed at their first company environmental conference. We chatted about how to implement EcoDesign and suddenly she asked: "What advice would you give to a company starting in this field?" Based on the Philips experience the answer was easy: start with packaging & transport, which can be reduced by at least 10%. She did not believe me and was particularly suspicious about the 10% figure. How could a well seasoned company still reduce so much? During a meal we discussed this over and over again and finally we decided to make a bet. It was settled that she would pay for the drinks and the food and if the target was not reached she would be repaid her money.

For two years I did not hear anything, then I got a phone call. Some of the directors of the company were in Brussels and wanted to see me because the company had been able to realize the 10% reduction target.

During the lavish Belgian lunch the story came out: at the environmental conference two years ago there were a few suggestions provided. The suggestion from 'the weird professor from Holland' was considered to be a mission impossible at first. Later it was accepted for lack of good alternatives and the organization was able to deliver. The result was hundreds of thousands or may be even millions of dollars saved. Thank you very much!

It was the cheapest advice I ever gave, at least looking at how it had worked out.

Later, the company financially supported my visiting professorship at Stanford University, which was a great gesture.

This case shows that environmental considerations can have a much wider, managerial significance. The companies perceived their business as footwear and apparel. Packaging and transport (P&T) had been seen as a necessary evil and therefore received little attention (see also chapter 3.3). An environmental perspective looks at the total value chain and therefore treats P&T on an equal footing with other company activities. The result was that reducing the environmental load through P&T improvements also brought in money directly. Due to the fact that P&T is usually neglected it can be an easy score!

Just do it!

Facts and Figures, 2

Graduation students

In twelve years time, forty students have graduated under my supervision. Before starting at Delft University in 1995, I had another six students as company supervisor. Gender has been almost 50/50: 22 females and 24 males.

The average score for the graduation projects has been 7.8 out of 10. Chiara Mulas was my last graduate and she had the best score: 9.5. Eelco Smit, Merijn Neleman and Geert Jan Een hoorn followed with a 9.

Of the Delft University projects, most took place at Philips: twenty four. Nineteen of them had a strong focus on environment. The projects at other companies totalled 16 with 13 being strongly 'green'.

Six of the projects have been abroad. These are the most challenging; both for the student and for the supervising team.

Generally speaking, there appears to be a broad gap between what students get taught at the University and practice in industry. Many of the graduates have initially difficulties in adapting themselves to the new situation. Gradually however, intelligence, creativity and initiatives make up for the lack of practical experience. Near the end, most projects get a clear upswing as regards content and as a result the grading improves as well.

On average therefore, the value for the host company or institution is much higher than the out-of-pocket cost and the hours which have to be invested in a graduation project.

Get a Delft student on board: it is win-win !

Chapter 3: Design for X

3.1 Design for Energy Reduction

3.1.1 The relevance of energy reduction; its position in Design Processes

From the very beginning of EcoDesign activity I had an unpleasant feeling that too little attention was being paid to energy reduction compared to its share in the life cycle load of electronic products. For this reason some 850 conference papers on EcoDesign were checked regarding their contents. The outcome was compared with calculations on the life cycle load (on the basis of Ecoindicator 95) for a variety of electronic products like appliances, consumer electronics, IT and Telecom products. The results are given in Table 3.1.

Table 3.1 Comparing environmental load and the number of publications for the life cycle stages of electronic products.

EcoDesign Focal Area	Environmental load over the life cycle (%)		Percentage of papers addressing the issue (2000-2005)
	Average	Range	
Energy in the use phase	70	40-98	2.5
Materials and chemical content	35	20-60	30
Packaging and Transport	5	2-12	2.5
Recycling (100% return)	-10	-3 - -15	50
General Methodology	-	-	15

This table shows that on average approximately 70% of the total environmental load is due to energy consumption in the use phase. At the right-hand side of the figure the percentages of papers devoted to each subject at Applied EcoDesign conferences (Electronics goes Green, CARE, ISEE, EcoDesign Japan) are given. Here energy is represented in roughly 2.5% of the papers. Such a figure contrasts completely with the 70% figure mentioned above. This result suggests that Applied EcoDesign was in a period where EcoDesign considerations were still very strongly material/mechanical and compliance driven (recycling laws were the first product laws introduced). Today there is a slight improvement in favor of energy related papers, but these still amount to around 5% of the total.

In the table below life cycle impacts of some selected consumer electronic products are given.

Table 3.2 Life cycle impacts of some consumer electronic products (Ecoindicator 95, in mPt).

Life Cycle Stage	TV 28 inch	Audio system FW780	Portable phone DECT
Manufacturing	750	500	20
Usage	3000	1200	15
Packaging / transport	60	10	<1
Disposal	60	30	3
Total	3820	1714	38

The data in this table underpins the general picture of fig. 3.1, but also shows that some products have a substantially higher impact over the lifecycle than others. For a 28 inch TV the load is one hundred times that of a portable phone (calculations based on an average user scenario). Such considerations are important when setting priorities in EcoDesign actions, for instance when a company wants to comply with the European EuP Directive, see chapter 9.2.2.

As explained above, the lack of attention paid to energy reduction is not due to lack of reduction potential. Below a benchmark result (see chapter 6.3) is shown for the 'on' mode of Cathode Ray Tube based TVs with Philips products as a reference ('on' mode for 'Philips' is 100%).

Table 3.3 Example of energy reduction potential for TVs.

32"TV	+12%	up to	76%
29"TV	-1%	up to	42%
28"TV	+2%	up to	48%
25"TV	-5%	up to	55%
21"TV	+10%	up to	63%
14"TV	+20%	up to	100%

Reference Philips Product in category = 100%

The table shows that even for mature products like CRT TVs there is still substantial reduction potential among brands. Generally speaking the energy consumption of most brands is higher than for Philips – this is due to the longstanding cooperation between Philips Consumer Electronics and its IC suppliers (common roadmaps for development). Making such roadmaps with suppliers are therefore important enablers (see chapter 2.2). Science and technology can contribute as well: in particular miniaturization of electronics. Also money can be seen as an enabler:

- Smarter ICs reduce energy dissipation and make it so that on Printed Wiring Boards (PWBs) fewer additional components are required, therefore indirectly contributing to lower costs as well.
- Lower energy consumption results in less heat dissipation and lowers the need for cooling elements on PWBs.
- Less wiring means less heat dissipation and therefore less cost.

Consumers (the market), generally like energy reduction simply because they have to pay the electricity bills. However, care should be taken to apply this idea across the board and without further consideration (or explanation). Utility products (like fridges, washing machines) are seen by users as having to do a job

with the lowest energy possible. If there is a 'functionality problem' other sources (like for instance detergents in washing) have to provide solutions. Experiences with Ecolabeling of utility products have shown that, at least in the Netherlands and the UK, a substantial part of the buying public is prepared to pay a price premium (which will not be earned back in a reasonable period) for lowest energy products!

Fun products (TVs, Audio, DVD) are a different story. Low energy products are often associated with lower picture or music quality and therefore not accepted upfront. There is a lot to explain in such situations and a producer requires credibility to help ensure that energy reduction achievements are accepted in the market. Most people are not prepared to sacrifice; fun is superseding the environment, even if it costs a few tens of Euros per year extra.

The situation is even more delicate in the category 'power products' (vacuum cleaner, electrical tools). Here product performance is perceived to be related to power consumption, the more the better. However, studies at TU Darmstadt and TU Delft have shown for vacuum cleaners that performance is also strongly related to the geometry of tubes and suction heads and that identical performance can be obtained at half the power. A lot of consumers simply do not believe this – perception prevails.

Also value chain issues play a role in considering energy reduction. Situations occur where one party has to invest (usually the supplier or the producer), but the beneficiary is a different party (the consumer). Market pressure does not allow increasing prices (a little bit), so the investment is not earned back on a company basis (on a societal basis it is). Well-known examples are an on/off switches for electronics, lowering of the stand-by energy and the investment in transformers with a high efficiency. Although from a societal perspective there is, in these cases, very good environmental and economic payback, chain improvement does not happen. In my opinion this is a situation where the market does not deliver so that governmental action is demonstrated to be justified (see chapter 9).

Finally there is the issue of the designers themselves. Energy consumption is important; however most designers have more inclination to work on materials (and are not educated sufficiently in tackling electrical issues). Furthermore designing is 'nice', organizing enablers and managing the value chains is an opportunity that many designers are not aware of or possibly even afraid of ("this is not my job").

When operating the design processes (see fig. 2.3 in chapter 2.2) with regards to energy consumption, the language of communication deserves special attention. Currently there is a strong tendency – because of the Kyoto agreement targets - to talk about energy savings in terms of avoided tons of CO₂. The environmental reason for this is that on average in Europe (precise figures are dependant on the fuel mix used to generate energy in a certain region or country) the impact category CO₂ represents only some 20% of the total environmental load of producing electricity (this figure is based on calculations with Ecoindicator 95/99). Other impact categories, i.e. dust particles, comprise the remaining 80%. The table below shows that communicating in terms of less kWh instead of reduced CO₂ has many advantages as well:

Table 3.4 Communication about Energy Saving kWh or CO₂?

Issues	kWh	CO ₂
Understanding	Everybody understands	Vague/indirect notion
Metrics	In/dependant of country	Dependant on energy mix
Benefits	Money	Have a soft flavor
Image	Links with high tech	Links with alternative
Target setting	Transparent	Not transparent

From a consumer perspective the chief argument, regarding a preference for communicating in kWh, derived from this table is that the issue of energy saving is brought much closer to the average citizen and becomes tangible (money). Moreover, it becomes transparent to all stakeholders with regards to performance.

Johannes Cornelis ('Han') Brezet: inspiration and fun

Han is guilty. He was the guy who brought me to Delft, where he was, and continues to be, a full-time professor in Ecodesign and Design for Sustainability. He taught me that even when two people have huge differences of opinion about topics like engineering, science, society or politics, they can still be best friends and colleagues. Our debates started when he presented the Ecodesign handbook at Philips in 1994 (see Highlights of the year, 1995) and have continued in one form or another ever since.

We share a few things too; interest in nature, displeasure with university bureaucracy. We try to do things, irrespective of the circumstances, with a human touch. We stand firm when organizational reshuffling - so-called spearhead programming - and strategic planning threaten to drag our Design for Sustainability group down. This happens frequently. DFS is cross-functional; it does not fit into the traditional university mould. To deal with it you need a flexible approach and to renounce territorial thinking. Han particularly, had to fight hard for this. It leaves scars on your soul.

Most of all Han and I differ. Maybe this is best explained by stating that Han wants to put more environmentalism into engineering and physics and I want to put more physics and engineering into environmentalism. He is always optimistic, I am not. He is in favor of a loose approach to a wide variety of subjects. I want more focus and discipline. If the environmental problems cannot be solved in the rich societies, I see it as being a little arrogant to teach the third world about them. Han is a strong supporter of the Bottom of the Pyramid (BoP) idea, which is western companies developing products for the poorest populations in the world. I see this as charity with a hidden agenda, although companies do more good supporting BoP projects than advertising on billboards in soccer stadiums.

Left and right, pressure on the supply side or addressing the demand side, tax income or consumption, punish sympathizers of Mao Tse Toeng and the German Democratic Republic or not, Den Uyl or Wiegel (two Dutch politicians), Feyenoord or PSV (soccer clubs), Rotterdam or province, the list of issues which we have debated about is long. It has always been intriguing and in the end we have not agreed on much.

The discussions are always fun and done with an open mind, which often results in a creative resolution.

Once Han and I were out on a bird watching tour near the Zwanenwater in the North of Holland. It rained, there was not much to see, so we went back soon. Han's battery-operated car door opener fell into a pool. There we stood! With the help of our fingernails we unscrewed the device, rubbed the wires and the battery until they were dry, put it back together again and a miracle happened ... the door opened.

On our way back we concluded that a human powered car-door-opener would have done a much better job. Han favored it because the batteries are eliminated which is good for the environment. I liked it because the required function is better served by applying different physics.

Anyway, soon after a student had designed one!

The 'Brezet' Walk: go from Rotterdam Central Station by tram 7 or 9 to Kralingen. Get out at Oude Dijk/Oranjelaan. Walk into the Oranjelaan, proceed to Julianalaan, follow the Kralingse Plaslaan and go L into the Kralingsebos. Walk north around the Kralingse Plas, stay within the circumference of the Prinses Beatrixlaan (outer circular road). You will end at the Lange Pad. Go back to the starting point through the Kralingse Plaslaan or the adjacent footpath.

3.1.2 Technicalities of energy reduction

3.1.2.1 Energy analysis

Energy analysis is an important way to create an action agenda for energy reduction. Basically it is simple: measure a product from a previous generation or a product of a competitor with a comparable functionality. Measure the energy input and figure out how much of this input is contributing to the function or sub function and how much is dissipated. Such input/output analyses can be done on a product level, sub-assembly level (or Printed Wiring Board level) and component level.

Such measurements can form the basis for improvement actions in the field of design, but also for actions in the supply chain and for further investment in technology.

This is illustrated by an energy analysis on an electric oven (see also Tidbits, 10). This is an example where spectacular reductions were obtained for the old product. This was partly due to the fact that the oven design was outdated (from the eighties of last century), and partly a result of looking more creatively at the functionality to be realized. This example therefore also demonstrates that 'green' design is most important but eliminating 'non-green' design history' contributes a lot as well.

Table 3.5 Energy analysis of an electric oven.

Energy consumption of	Consumption per year kWh, Old Product	Consumption per year kWh, New Product	Action taken
Clock/timer	35	9	Design for clock/ timer with low power (supply chain action)
Pre heating elements	10	4	More effective pre heating cycles (technology, design)
Heating elements	42	34	Change geometry of heating elements (design)
Lamp	3	2	Replace lamp by low watt, better positioning (supply chain, design)
Losses	4	2	Better insulation (design)
Total	94	51	

The measurements in table 3.5 are based on a certain user scenario. The energy consumption of the clock/ timer turned out to be very high because it is running 365 days a year and because this clock was still an old-fashioned mechanical one.

Through a combination of selecting a new supplier and the design of an electronic device, energy consumption was reduced by a factor 2.5, while keeping preheating time constant.

The alternative could have been shortening the preheating time, but that would have given rise to more energy use in the heating phase itself.

Crucial to the real functionality (preparation of delicious food) is to have an even temperature distribution throughout the preparation of the meal being prepared.

Redesigning the geometry of the heating elements and adjusting the heating cycles to a 'flatter profile' turned out to dramatically increase food quality, as well as taste (increase of functionality), while still reducing energy necessary by some 20%. With this major issue, the functionality thinking of Applied EcoDesign was replacing the 'technical functionality thinking' of the producer organization. Its design paradigm had been: does the food get hot and does it get well done. The immaterial/emotional functionality (does the food prepared taste good?) had not been addressed in this approach.

Also the lighting in the oven was repositioned and replaced by a lamp using fewer watts.

Insulation was improved as well; contrary to expectations heat losses due to insufficient insulation were small. This 'prejudice' was not based on hard data. This once again emphasizes the importance of an energy analysis.

3.1.2.2 Cooperation with suppliers

In 3.1.2.1 some examples have already been shown where checks on energy consumption of purchased components and parts are helpful:

- Replacing a mechanical clock by an electronic one
- Replacing a lamp by a lower wattage one

To this other examples in the purchasing field can be added:

- Catalogue work: in the 'Green' TV project all traditional components (resistors, elco, etc) were checked for their energy use and replaced by ones with the same functionality but using less energy. On a Printed Wiring Board level this yielded a reduction of 15%.
- Efficiency of transformers in TVs. At the same level increases of 5% in efficiency could be obtained by changing supplier. If slightly more is paid, efficiency can be increased from 70% (quite usual in electronic devices) to over 90%. Due to energy savings there is a high environmental and economic pay-back, but there is often a value chain problem: the initiator (producer) is not rewarded by the beneficiary (the consumer).

Next to one-sided producer action, cooperation with suppliers - for instance in the form of common roadmaps for future energy reduction - can show spectacular results. An example is given below; it refers to cooperation between Philips Consumer Electronics and Philips Semiconductors in the period 1999-2002 (see also table 3.2).

Table 3.6 Results of producer-suppliers joint roadmaps for Integrated Circuit development (Philips Consumer Electronics/Philips Semiconductors, 1999-2002).

	Philips	Competitor 1	Competitor 2
<i>Audio System</i>			
Operational energy (W)	35	37	37
Standby energy (W)	2.1	4.6	4.6
<i>Portable radio</i>			
Operational energy on (W)	3.4	2.8	3.7
Operational energy off (W)	5.9	6.5	6.5
Standby energy (W)	1.8	2.0	2.1
<i>32 " TV</i>			
Operational energy (W)	132	150	157
Standby energy (W)	0.3	1.5	1.9

It is concluded from this table that through cooperation significant energy reductions have been obtained for Philips products.

3.1.2.3 The role of Design

Design can play an important role in energy reduction both through functionality analysis and by more 'design technical' contributions:

- Is the physical functionality specification met in a really minimalist way? (electronic companies with a long tradition tend to over specify in this respect).

- Is the economic functionality/price reduction addressed in a proper way (today there is overemphasis on this point, in Europe only 1/3 of the buying public are real price buyers, see chapter 2.2 and 2.3).
- Is the immaterial/emotional functionality sufficiently addressed (electronic companies are 'technical' and tend to pay inappropriate attention to this, see 3.2.1).

More technical design elements include:

- Apply different physics (LCD instead of CRT displays)
- Eliminate superfluous components due to design history (see for instance above)
- Minimize cabling and wiring between subassemblies by appropriate product architecture
- Introduce more power options (sleeping-mode etc.)
- Add on-off switches (a lot of electronic products today do not have them; in 'off-mode' there are still energy losses, for instance in the primary of a transformer)

3.1.2.4 Portable products, the battery issue

When considering energy issues, portable products deserve special attention. Batteries used in such products represent an important environmental load. The resource intensity of electricity generated from batteries is much higher than electricity from the net. However, functionality (allowing things to be portable, convenience) supersedes the environmental drawbacks. Simultaneously however, functionality can be the lever to consider replacement. Despite their convenience, all users hate batteries because they:

- Always run out at an unwanted/crucial moment (convenience)
- Are moisture sensitive (see Personalities, 2)
- Require a visit to the store to buy them
- Are relatively expensive
- Are bad for environment; effort needed for 'green' disposal

Design Strategies to migrate the negative sentiment of consumers will have therefore high (Eco)value (see chapter 2.3). These include:

- Lowering energy consumption of portable products
- Change to rechargeable batteries
- Human powered products (see chapter 4.6) or application of other 'alternative' power sources.

3.1.2.5 Ready Reckoners

In order to allow us to compare the environmental impact of electricity generation of electronic assemblies and of electronic components with those of materials see chapter 3.2.2. Below some environmental impact data are given:

Table 3.7 Environmental impact of electricity generation (mPt, Ecoindicator 95)

Eco-indicator 95 (millipoints)	
Electricity 230V oil	1.8 per kWh
Electricity 230V coal	1.2 per kWh
Electricity 230V browncoal	2.4 per kWh
Electricity 230V gas	0.06 per kWh
Electricity 230V nuclear	0.03 per kWh

This table clearly shows that depending on the fuel used, the environmental impact of electricity generation varies greatly. Due to the fact that the fuel mix used varies per country in Europe, the differences per country are substantial as well:

For selected electronic components some average figures are as follows:

Table 3.8 Environmental impact of selected electronic components (mPt, Ecoindicator 95)

Eco-indicator 95 (millipoints)				
Elcos	big d	> 22 mm	55	per kg
	small d	< 22 mm	80	per kg
Film condensators			0.2	per piece
Line Output Transformer (LOT)			50	per piece
Connectors			458	per kg
Trafos			68	per kg
Switches			38	per kg
Heat sinks			80	per kg
Shielding (tinned)			25	per kg
Wire bridges			6	per kg

Again there is a big variety in impact.

Finally some data is given for electronic assemblies.

Table 3.9 Environmental impact of some electronic assemblies (mPt, Ecoindicator 95)

Eco-indicator 95 (millipoints)				
Speakers	internal	15		per kg
	external	12		per kg
CRTs		15		per kg
PCBs	without components	300		per m ²
	including components	1300		per m ² (powerboard)
	including components	2200		per m ² (logic board)
Batteries		116		per kg

Looking at this table and comparing the figures with those presented in chapter 3.2.2, it can be concluded that compared to materials as such, processed materials like components and subassemblies have a much higher impact.

Stand up, people of Denmark

Stand up, people of Denmark! This is the famous slogan through which N.F.S. Grundtvig tried to rejuvenate Denmark in the 19th Century after its lost wars with Prussia and during the societal crises which followed those defeats.

The Danes did just that and nowadays their society is one of the happiest, most peaceful and environmentally friendly countries in Europe. Sometimes extremisms flares up, but this is always counterbalanced by the big centrist forces within Danish society .

Being a member of a PhD committee in Denmark is a pleasure. I have done it twice. Preparation is similar to what I experienced in Norway (see Rituals and Habits, 15). However, at a defense the old Grundtvigian spirit comes to life again.

'Attacks' by committee members are aggressive, the candidates defend themselves with passion. This true academic debate lasts a long time: 2 hours is the minimum. It is public; spectators including family can watch the proceedings. This ceremony is serious, executed as prescribed by the rules, but it has the character of a theater as well.

One candidate's parent commented, "I never imagined that my son was capable of doing so well in such proceedings. It is kind of fun and a great game too!"

Is it really a game? Or is it still serious? In Denmark, the committee still has to decide formally and to confirm their earlier 'yes' vote after the defense. This is not a precooked item. Again, there is a lot of intense debate, sometimes there is an initial 'no' by one of the committee members, just to provoke the exploration of all aspects of the candidates performance. In Denmark, a doctorate never comes easily!

Yes, there we are back again, in the class-room, the committee has decided, the result is positive!

Et hjertelig tillykke!

3.2 EcoDesign and Materials Application

3.2.1 The relevance of considering materials

When the environmental impact of materials application in electronic products (production of materials and their utilization) is considered, it ranks second after energy in the use phase (see fig. 3.1) with some 35% of the total load. Although in Applied EcoDesign a lot of attention was spent on material application, there is still substantial room for improvement. A comparative benchmark of product weight among different brands for consumer electronic products shows big differences, as will be clear from the table below.

Table 3.10 Benchmark of product weight of consumer electronic products (weight of the Philips reference product = 100%).

Product Category	Weight of competitors products		
TV	+3%	up to	+20%
Audio systems	-18%	up to	+47%
Portable Audio	-11%	up to	+25%
CRT monitor	+9%	up to	+20%
LCD monitor	-16%	up to	-4%
DVD	-16%	up to	+8%
VCR	-17%	up to	+10%

Reference Philips Product in category = 100%

It can be concluded from this table that although products with almost identical functionality were selected in each product category, differences are relatively big even for a mature product. The same holds when the variety in materials is being considered. Below data are presented for the ratio between plastic weight and total material weight.

Table 3.11 Ratio between plastic weight and total material weight of consumer electronics products (the ratio for the Philips reference product = 100%).

Product Category	Plastic weight / (Plastic + Metal weight)		
Audio Cat.1	-7%	up to	+3%
Audio Cat.2	-12%	up to	+5%
Audio Cat.3	-8%	up to	+10%
Audio Cat.4	-20%	up to	-3%
DVD	+2%	up to	+38%
VCR	-42%	up to	-18%

Reference Philips Product in category = 100%

For energy savings, considering the type of functionality of the product is highly relevant (see chapter 3.1.1). However, for reducing the environmental load of materials the characteristics of materials themselves are most important. The type of material used (metal, plastics, wood or glass), and the type of surface finish applied, is highly relevant for all 'non-physical' functionalities of the product. Particular emotional functionality (quality perception, nice design, feel good 'green') stands out in this respect. An example of this has already been given in chapter 2.1. Generally speaking, metals are perceived by consumers to have more 'quality' than plastics, whereas wood represents more 'natural' feelings. When designing for lower environmental load this is to be kept in mind. If such actions conflict with the functionality requirements of the targeted group of customers, great care should be taken.

A similar issue exists for recycled materials. These have a two-sided perception; on one hand they are perceived as having less quality, on the other hand they are seen as 'good for the environment' and contributing to lower prices.

In environmental benchmarking (see chapter 6.3) it has been observed that some brands in the consumer electronics business consistently spend more money on those materials and parts that prospective buyers can see and touch. Money is correspondingly saved on the interior parts, so the price of the whole product on the market is roughly the same. However, prices commanded through this design strategy are 5-10% higher than for comparable products of competitors.

This observation has been one of the leads for the Eco-value approach (see chapter 2.3).

At established companies in the electronics industry there is a clear resistance against business in pre-owned products. This is an approach in which high-end products are actively taken back (for instance by offering big discounts for customers buying new), and are subsequently remanufactured and resold again. Once, I was involved in a business plan for pre-owned high-end printers. Such companies consider their business turf to be new products only, even if there is excellent potential for 'second-hand'.

Such a situation exists for instance in the field of high-end printers. The business plan showed excellent prospects. It was a combination of adequate return discounts and balanced pricing of the pre-owned products. In this way the products could be well positioned with respect to 'new' products of the same company and cheaper products of the competition. The value proposal of the plan was further enhanced by the fact that through pre-owned products the installed base in the market would be increased. For printers this is relevant in view of the sales of branded ink cartridges.

The plan was rejected by the board of the company however on the basis of emotion: such business does not fit in our scope. The project went down the drain.

In the field of the enablers for 'greener' material application, forming technology deserves special attention. An example is using new technology through which less material is needed to realize the required physical functionality. Philips Consumer Electronics was one of the first companies to introduce the gas-assisted plastic molding technology for the housings of their products. Through this technology plastics parts with thinner walls could be manufactured. However, their strength could be kept at the same level by putting extra ribbons into the design. In total the result has been that the weight of the housings were reduced by some 20%.

It is to be realized that generally speaking the environmental load of forming materials is low compared to 'producing the kilograms'. This means that a strategy in which a more sophisticated technology is used which yields less waste, mostly is a 'green' one as well.

Savings like this one are mostly realized by suppliers, so for materials saving there is a close connection to supply chain issues (see also chapter 5.3). This also holds for the reverse supply chain – the application of recycled materials (plastics, glass). Here the big issue is to achieve the right economy of scale. Two examples demonstrate this:

*At Philips Consumer Electronics, it was shown in the early nineties that the use of recycled plastics in housings could contribute up to 50% of the total weight of such parts - at least when certain quality requirements were met. Plastic molders can operate well with recycled material but have to slightly adapt their temperature settings. Such changes involve losses in yield during the transition and therefore are to be done only once or twice, but not continuously. Therefore, in practice a constant flow of material with constant quality is required. In view of the efforts on introduction, application of recycled material with lower than 10% content is unattractive.

All these considerations demanded that Philips require that one supplier (= one source) be capable of supplying at least 500 tons/year with a quality guarantee. This turned out to be a huge problem in practice. Few recyclers have such amounts available for one customer. Moreover, the quality guarantee turned out to be a problem as well. Material supplied in summer turned out to be slightly different than in winter.

*For TV glass similar requirements hold. TV glass is not compatible with, for instance, bottle and window glass. It is a much more high-grade product, requiring very specific ingredients. Moreover, the screen glass and the funnel glass of a Cathode Ray Tube (CRT) have different (incompatible) compositions. Post consumer glass should therefore have the right composition (screen glass free of funnel glass and vice versa), should be absolutely metal free and should be milled into an appropriate grain size distribution – not too many coarse pieces (bad melting properties) and few fine particles (foam formation on melting).

Similar to the recycled plastics, application of recycled glass requires adaptations in the temperature profile of the glass tank, preferably to be done only once. On the basis of these requirements it can be calculated that for appropriate introduction of post consumer glass, some 5,000 tons of constant quality glass per year is needed. This makes it necessary to organize a pool of the glass cullet which is produced by the recyclers. Currently such a system is still under development.

For most designers working with materials is a part of their formal education and therefore a core skill. This is an advantage and a disadvantage at the same time because the environment and 'nice design' are partly at odds (why do 'Green Flagship' products look so lousy, see chapter 5.5). A careful balance between environmental and other design quality items, in immaterial and emotional quality, is of utmost importance.

This also applies for communication issues; on one hand material reduction and/or replacement by lower impact materials is easy to explain to the general public and to quantify, on the other hand this could be perceived as going for 'cheap' solutions.

Beijing, bottom up and top down

My wife Annet and I lived in Beijing for almost three months in the beginning of 2005 – I was a visiting professor at Tsinghua University. We lived on campus just north of the 4th ring road. Only ten years before this was at the uttermost outskirts of town, now space up to the 5th ring road has been filled with buildings. The 6th ring road is still under construction, but will be finished in a few years time from now. Parallel to this, buildings between the 5th and the 6th sprout up all over the place. Urban planning is clearly a top-down activity and its implementation takes place at a dazzling speed. Every time you come back to Beijing you see new things. Every time the traffic gets more and more congested too. Air pollution has increased now to breathtaking levels and only shortly after a rain shower can you find some fresh air.

Outer change is enormous and looks to be orchestrated, although not completely controlled. There are also these smaller 'bottom-up' changes. Look at what you can buy in the shops for the ordinary people (not the ones for tourists or the well to do, these are 'international' with international prices too), like the grocery shop and the fruit market at the Tsinghua campus. This is really 'local', no English is spoken there. A piece of paper to scribble numbers on is good enough, although there is little reason to bargain – prices are very low anyway. As sports it is OK. In mid-winter (it can be very cold in Beijing in February/March, northern winds bring the cold directly from Siberia) you can buy fresh strawberries, cherries, and all kinds of vegetables on campus, all grown 2,000 km to the south. People buy it, enjoy it, and are well acquainted with it. This must have been a big change in habits and a first class logistic achievement. An invisible hand seems to have organized it all. Ten years ago there was none of this, there was just cabbage outside every Hutong building. How was this change caused?

Is it just change in Beijing? Will there be anything left of the past? Yes, a lot is to stay. Chinese culture is well engrained in the minds of everybody; it is largely as it was. Self-confidence and pride have grown. China will do it in its own way and it will be successful. Progress is both top-down and bottom-up and it shows everywhere, day and night. Three months is not long enough to get fully immersed in these fascinating developments. It is definitely good enough to get a proper idea of it.

City walk: Beijing is too big a city to do it all by walking. Rent a bike instead (this can be done in every hotel). See the tourist highlights by bike. Avoid the big avenues, cycle through the back streets and Hutong areas. For a comprehensive all day tour through Beijing look at Lonely Planet guidebook, Beijing, p. 64 – 69.

Favorite restaurant: the small restaurant in the shopping center in the southern part of Tsinghua Campus (opposite the 4 story building). There is only one English menu-card, which is of no help – but the food is excellent.

Country walk: www.beijingshikers.com offers organized group walks every week in the countryside around Beijing. There is also a book 'Hiking around Beijing' which assists in do-it-yourself organization (rent a car with driver who brings you to the start of the walk and picks you up afterwards). Favorite walks: Great Spur (Xiang Shui Hu section of the Great Wall) - a day on the Great Wall without seeing anybody - and Silver Mountain/Silver Pagoda (Yin Shan Ta Lian/Yin Shan Ta Qun).

3.2.2 Technicalities of 'green' material application

3.2.2.1 Analysis of material application

A thorough analysis of material application (type of material, weight or weight/material mix of subassemblies) is an essential part of the environmental benchmark (chapter 6.3). A comparison with the material application of competitors forms the ideal basis for brainstorming and for detailed functionality analysis.

The results of such benchmarks still show traces of different design histories in various regions of the world, and even at individual companies:

- In terms of overall weight, Japanese electronic products generally have lower weight than European products, where American products are last in this respect. This reflects – even today – how resource issues have been dealt with in the past.
- Some companies excel in plastic application, others in metal application. In most cases this can be explained by whether there is (or has been) in-house production of parts or by the presence of long-term relationships in the supply chain.
- Some companies excel in design and production of Printed Wiring Boards with relatively low weight and surface area. This points to having easy access to advanced Integrated Circuits and exploiting this advantage properly.
- A few companies turn out to be masters in function integration and miniaturization, others are not.

These examples show that for a designer it is relevant to closely examine the 'context' of the principal for which the design work is being done.

This conclusion also holds for 'internal' design traditions. Some of the companies have for instance a tradition of 'over-specification' – produce sturdy products which make a solid impression to customers.

From an environmental perspective there is much to be gained from such considerations; from a cost reduction perspective as well.

It is also to be realized that many customers of electronic products also live in a world of thinking dominated by mechanics. 'Make products a bit solid, so that they live longer and do not fall apart easily' is still often heard in Quality Function Deployment processes. It is not well acknowledged today that more products ultimately fail on electronics than on mechanics. Checking on customer complaints and returned products is therefore a very relevant item for better material application.

3.2.2.2 Materials reduction

Going for material reduction is a design strategy, which is very relevant both for the environment and for economic aspects. The potential is still big after many years of EcoDesign (see chapter 3.1.1).

However, dematerialization must be weighed against the total life cycle perspective. Sometimes life cycle considerations lead to the opposite conclusion: use more material for instance ('materialization') in order to save a lot of energy. Well-known examples of this are fluorescent lamps (incandescent lamps require less material but are very energy inefficient) and human-powered radios.

Sometimes extra material has to be used to increase the Ecovalue of products (see chapter 2.3). For instance a 32-inch 100Hz TV has a (much) higher ecovalue than a 14-inch 50Hz TV. Conventional environmental wisdom tells consumers to go for the 14-inch TV, Ecovalue considerations suggest the opposite.

Small material 'sacrifices' also play a big role in communicating 'green' products more effectively (see chapter 5.5).

Saving materials through function integration yields less environmental gains than it is thought to bring. The famous (negative) example is in the integration of TV and VCR functions into one product, the TVCR. This product was popular for a short period at the end of last century. By integrating both functions in one housing between 5% and 10% of the total weight was saved. However, integration of the standby functions was not possible, on the contrary it became more complex during integration. The result was an overall increase of the energy consumption by some 20%. This reversed an overall environmental gain in the production phase into a loss on life cycle basis when comparing the TVCR with the original products on a stand-alone basis.

Functionality mixing of components and materials is often a phenomenon, which blocks material reduction. In Tidbits, 8, the example is given of an electromagnetic shield which was used as a mechanical support as well. With more modern electronics the shield was not needed anymore. Designing it out turned out to be difficult, however due to the other functions it had entered into design history. The lesson is that functionalities, particularly mechanical and electrical ones should be kept apart in a design.

3.2.2.3 Material Substitution

Environmental benchmarks (see chapter 6.3) also give a good idea about the so called 'practical design bandwidth', that is how much the composition of materials needed to realize a certain functionality can vary. In theory this bandwidth is indefinite, in practice it is not, (see also table 3.2). Due to the physical requirements associated with the functionality, there is limited 'choice' of basic materials but still plenty of room to maneuver. How these maneuvers work out environmentally can be estimated with the numbers given below. In the tables, data are presented for the environmental impact of materials and their processing. These data are given in millipoints (mPts), this is the standard unit for the Ecoindicator 95 calculation system. Table 3.12 below, shows the environmental impact of metals and precious metals.

Table 3.12 Eco indicators for metals and precious metals

Metal	Impact (mPt/kg)	
	Virgin material	100% recycled material
Iron	12	N.A
Steel	14	3
Stainless steel	98	N.A
Aluminium	53	1
Copper	76	28
Nickel	380	N.A
Lead	580	30
Zinc	640	N.A
Silver	1500	N.A
Palladium	375000	N.A
Platinum	560000	N.A
Gold	100000	N.A
Rhodium	1000000	N.A

It is concluded from this table that iron and steel have the lowest scores: stainless steel, aluminium and copper have impacts which are 4-7 times higher. Nickel, lead and zinc have high impact scores and precious metals have very high impact scores. Recycled metals have an impact which is 10% - 30% of that of virgin material. Table 3.13 shows Eco indicator figures for plastic materials:

Table 3.13 Eco-indicators for plastics

Plastic type	Impact (mPt/kg)	
	Virgin material	100% recycled material
HDPE, PP	4	
LDPE, PC, PET, PVC	5	
PVC in cables	15	
(HI) PS	4	
ABS	5	all 0.5-2.5
PA	13	
PE	4	
PUR	6	
Cast epoxy	11	

It is concluded that almost all plastics have impacts in 4-8 mPt/kg range, which is substantially lower than for metals. In the application, plastics are therefore the environmental materials of choice, if the physics of the required functionality allow it. It is also to be realized that when immaterial and emotional requirements are taken into account (see chapter 2.2 and also Tidbits 3) metals are often favoured. If the recycling phase is considered alongside the application phase metals have an even better position due to their better recyclability.

However, it is better from an environmental perspective if recycled plastics can be used in a product. The environmental impact of such material is very low.

In table 3.14 below, the environmental loads of various forms of material processing are listed.

Table 3.14 Eco indicators of material processing

Process	Impact (mPt/kg)
Pressing/deep drawing of steel	1.0
Aluminum extrusion	2.6
Cold rolling	0.3-0.5
Injection molding of plastics	1-2
Sawing/ cutting steel (m ²)	2-4
Sawing/ cutting aluminum (m ²)	0.5-1

From this table it is clear that for material processing the loads are substantially lower than the environmental load of producing materials. This leads to the conclusion that generally speaking reducing material amounts from an environmental perspective has priority over the reduction of the environmental load of material processing. Under certain circumstances, even some extra 'processing load' can be sacrificed to save more material. In table 3.15 the Eco indicators of material surface treatments are listed.

Table 3.15 Eco indicators of surface treatments

Process		Impact (mPt/m ²)
Zinc plating	thermal	17
	electrolytic	5
Chrome plating		61
Lacquer on plastic		11
Lacquer on steel		6
Nickel-plating		4-14

This table shows that the impact of treatments is generally high, also in comparison with the impacts of producing the underlying material itself. From an environmental perspective surface treatments are therefore not to be encouraged. Issues of longer life of the parts and products can counterbalance this conclusion. It is also to be realized that surface treatments can contribute to creating 'Ecovalue' through enhancing immaterial and emotional value. This is a very central issue, for instance some of Philips Consumer Electronics 'Green Flagship' products turned out to sell better if their outer appearance was improved (see chapter 5.5 and also Tidbits 6). In such situations a careful balancing of the different functionality types (physical, economic, immaterial and emotional) is required.

Pictures, 2

Brussels, Grote Markt - History looks upon us

3.3 EcoDesign and Packaging & Transport

3.3.1 The relevance of considering Packaging & Transport

For most electronic products the environmental impact of packaging and transport (P&T) is around 10% of the total lifecycle impact and therefore relatively low. This is only one of the reasons why, generally speaking, little attention has been focused on this area. It also relates to the fact that most electronic companies don't consider P&T a core part of their business and therefore do not actively manage costs in this field. Moreover, in practice, gaining an overview and insight into P&T chains requires an understanding of the many actors involved (production site, logistics to harbor followed by (overseas) transport, logistics to supply center, logistics to trade). Parts of the P&T chain are paid for by different parties as well, this makes integral cost and impact minimization a cumbersome task.

Nevertheless, there are many good reasons to have a close look at P&T. First, in this field there is a high correlation between environmental load and cost savings for a company. Because of this P&T reduction projects should not be subjected to the doubt and the prejudice typically applied to 'green' projects. It is even recommended that when starting in Applied EcoDesign a P&T project is one of the projects to be completed first. Success will be visible, raise awareness, and build credibility that 'green' can deliver business results.

A second reason is: in the last decade the P&T chain has dramatically changed. A lot of production is currently outsourced to low wage countries (more transport over longer distances). Volumes per account have increased dramatically and there is more 'sales out of the box', leading to new requirements. This means decisions taken about P&T in the past have to be reviewed anyway; 'green' can easily piggyback on such processes.

The traditional physical functionality of packaging and transport is to ensure that products arrive at their final destination complete and undamaged. This includes mechanical protection and keeping goods dry and clean. It includes accessories and easy handling as well.

Increasingly packaging also has a role in providing information (informing supply chain, attract consumer attention) and keeping integrity (prevent theft). Recently it has been discovered that packaging can contribute to emotional functionality as well, for instance for products sold frequently as a gift. In such a case packaging should also be 'nice' and should preferably have a surprise element (and should be easy to open).

Gift packaging, and to some extent sales packaging, have in terms of the market 'added Ecovalue' (see chapter 2.3). This type of packaging however does not necessarily represent the lowest environmental impact (see 3.2).

As pointed out in chapter 2.3, this can nevertheless be an attractive 'green' packaging strategy as long as higher prices can be obtained.

Science and technology have been looking intensively in the last years to reduce the environmental load of packaging materials. A lot of attention has been paid to replacing styrofoam buffers for instance with cardboard based buffers— which are cheaper as well. It has been shown that this is possible, for example by introducing molded fiber and so-called 'bee board' (honeycomb) material. Unfavorable cushion values and availability problems in the supply chain have prevented widespread introduction of this alternative.

In system management, the use of recycled material is an important issue. In principle cardboard boxes with up to 60% recycled material can be used to pack electronic products. By far this percentage has not been realized on a global scale. This means that there is a lot of potential here for the reduction of environmental load. Partly this is due to the producer's lack of awareness of this opportunity. Partly this is due to limited availability and high prices, particularly in Asia.

On the other hand the value chain, in particular trade, is pushing for more attractive packaging, which includes everything besides dull brownish and grayish boxes with high recycled content (as minimizing environmental load over the P&T cycle would require). Big retail chains have gained tremendous power in the last decade with respect to producers. This is an important issue to be taken into account.

In conclusion, it can be said that tailoring the real P&T functionality required for the needs of the upstream and downstream value chain is needed for designing the packaging & transport concepts, which are best from their Ecovalue point of view.

Highlights of the year, 1995

Delft University

After I had been working for some two years in the environmental field somebody from Delft University unexpectedly entered my office. It turned out to be Han Brezet (see Personalities, 2). From his bag he produced a big blue book called 'Milieugerichte Produktontwikkeling' (Environmental Product Development) and he said, "This is the book. If Philips applies the methods in this book it will do well in EcoDesign and the environment." I reacted cautiously. In business things are a bit more complicated than an enthusiastic university professor realizes. After some discussion, wherein I gave him the benefit of the doubt, I promised to study the book. It was a weird book. I had never seen anything like it. It had limited understanding of business realities, was full of environmental dogmatism, showed activist views on management and did not take into account that in business money is important.

The feedback meeting was held two weeks later. The only thing I could say was: for application inside Philips this book has no value. In this company the only thing that can be done with it is to throw it away. That was what I actually did and as a result the atmosphere became pretty tense. However, I had produced a document with a lot of suggestions how to do improve the book. Moreover, I offered that if the design manual was rewritten it could be tested at Philips.

Following that meeting there were many stormy discussions to come. Although sometimes emotional the atmosphere remained positive. 'Delft' realized that their ideas needed much more testing in practice. 'Philips' realized that their environmental activity was opportunistic and conceptually weak.

This created the basis for letting some students work on their graduation projects at the Environmental Competence Centre.

We also both joined the CARE network for recycling and discovered when we were working in tandem that we were far ahead of the rest of the crowd. At a CARE-meeting in Dresden, I managed to buy a box of cigars for Han Brezet. He replied by joking that he would make an effort to have me appointed part-time professor in Delft.

This turned out to be more serious than it initially seemed. Han made a plan for the cooperation of Philips CE and the Faculty of Industrial Design Engineering including exchange of data and experience, a jointly financed part-time chair and the sponsorship by Philips of PhD students.

To my surprise it took the management of Consumer Electronics only 30 seconds to say yes. At Delft University, it took more than a year, which is fast by their standards.

Anyway, as of December 1st 1995 I was officially appointed part-time professor in Design, in particular in the Environmental Design of Electronic Products.

3.3.2 Benchmarking of packaging, bulk packaging strategies

Below is a traditional benchmarking study of consumer electronics products packaging is presented. It is found that both for weight, volume and environmental impact improvements are still possible. Moreover, it is shown that when production is moved overseas volume reduction of packaging becomes much more important than the traditional strategy of reducing box weight. A variant of this design strategy is the introduction of so called multiple packaging as proposed in the following paper "Opportunities for Innovative Eco-efficient (Bulk) Packaging for Consumer Electronics Products".

Opportunities for Innovative Eco-efficient (Bulk) Packaging for Consumer Electronics Products

Casper Boks; Ab Stevels; Maarten ten Houten; Marjolijn Thijssen

Abstract

When solutions are based on and limited to traditional concepts and standard solutions, the theoretical improvement potential for packaging of consumer electronics is very limited, although practice shows that there is still considerable room for improvement. Recent trends imply however that changing from a weight based to a volume-based strategy is likely to be substantially more beneficial. And when taking an integral perspective, using detailed cost structures and environmental analysis of the complete distribution chain, it can be shown that economical as well as environmental benefits become clear once the paradigm of single set packaging is abandoned and multi- or bulk packaging solutions are created. In cooperation with Delft University of Technology, Philips Consumer Electronics has created several of such concepts that show an improvement potential of up to 40-60% in both environmental and economical costs.

1. Packaging in the electronics manufacturing industry

Packaging design has a peculiar position for original equipment manufacturers (OEMs). On the one hand, packaging serves important functions, such as protecting products against the harms of impacts, static loads, vibrations and climatic changes, the facilitation of handling products and it often has a sales function as well. On the other hand, OEMs are product creation focused, and therefore packaging does in some cases not receive the attention it should. Moreover, costs are incurred at various stages and at various manufacturing and distribution locations of one company. Also, packaging design, transportation and distribution management is often outsourced. Consequently, knowledge about the integral packaging and transportation costs can be very limited.

This situation of scattered information and decision-making is likely to lead to sub optimal solutions, both in terms of environmental and economical units. Even though single set packaging solutions may be close to optimal based on company wide specifications, this is no guarantee that over the whole transportation and distribution chain there is no room for improvement. Also the lack of knowledge about integral packaging and transportation costs will hamper the search for improvements in the overall packaging activities of a company.

One important reason for this lack of information is the fact that packaging design is often one of the last design activities in the product creation process. When only little time and budget is left for this stage, it happens that under severe time and budget constraints a 'low risk' packaging is designed based on traditional concepts and using standard solutions. This means that in most cases sub optimal solutions are reached, implying (probable) considerable improvement margins, again both from an economical and environmental perspective.

There are ample additional incentives for packaging reduction as well; these include ease of disposal for the customer, compliance with packaging reduction covenants, (legal) recycling obligations as well as a company's (environmentally conscious) image.

2. Packaging: an element of Environmental Benchmarking

At Philips Consumer Electronics, Environmental Benchmarking is the backbone of many of its environmental activities as well as of improvement studies for products and packaging concepts. These studies are an ongoing process embedded in business procedures, and are at times carried out in cooperation with Delft University of Technology's Design for Sustainability Program. In the environmental benchmarking process, five focal areas are identified to which improvement studies are targeted. These focal areas are energy, materials application, chemical content, recyclability, and packaging [1].

Considering the focal area of packaging, measurements are taken considering the weight and number of the packaging materials (cardboard, bags, buffers, foams, strips etc.) and documentation. In addition, weight and volume ratios for the packaging in relation to the product are determined. A packaging equation is calculated to incorporate a number of these measurements into a one-figure score -- giving a quick-to-interpret measure, although interpretation of all measurements is required to avoid any misinterpretation. Figure 1 provides an example of a packaging fact sheet as generated by the Environmental Benchmarking Method -- here similar products from four brands are compared.

PACKAGING

$$\text{Packaging formula} = \frac{\text{packaging weight}}{\text{product weight}} + \frac{\text{box volume}}{\text{product volume}} \cdot \text{number of materials}$$

Goal

To compare the differences in the packaging issues weight, volume and used materials between the VCRs.

Results

- **Brand B** is better (13%) than **Brand C**, but on par with **Brand A** and better than **Brand D** on packaging.
- **Brand C** uses "eggboard" as buffer material. While **Brand B** and **Brand D** uses EPS and **Brand A** has an incorporated buffer folded in the box.
- **Brand B** has a low packaging ratio score because of its size and weight, but still uses one more material than **Brand C**. This is due to the smaller product size and volume.

	Brand B	Brand C	Brand A	Brand D
Ratio weight packaging/product	0,23	0,36	0,37	0,33
Ratio volume packaging/product	2,86	3,13	3,15	2,89
Number of materials	3	2	3	3
Packaging Formula	1,97	2,27	2,33	2,82

Unit	Brand B	Brand C	Brand A	Brand D
Box (outside)	g	490	714	1114
Box (inside)	g	-	-	-
Buffer EPS	g	48	-	78
Buffer cardboard	g	-	143	-
PE bag (roll)	g	-	1	27
PE bag (foam)	g	26	14	17
DFU	g	113	347	468
Cardboard	g	-	56	67
Total	g	677	1275	1245

Volume box	dm ³	Brand B	Brand C	Brand A	Brand D
		20,83	29,64	40,80	32,49

VCR Benchmark

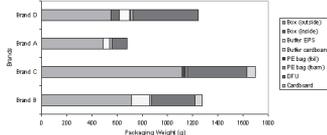


Figure 1 An example of a packaging fact sheet

2.1 Packaging - improvement studies

Recently a number of consecutive projects have been carried out, in cooperation with Delft students, to study the possibilities for reduction of costs and environmental load of packaging and transport in the total distribution chain [2,3]. Carrier products for these projects were typical consumer electronics such as VCR/DVD-like and CRT-based products. These projects are reported on in this paper. Additional information is taken from another study that recently took place in 2003 at Delft University of Technology, to study in detail the possibilities of combining superior mechanical properties of moulded pulp buffers as a packaging material for durable consumer goods, with superior environmental qualities. In these projects, stress was put on:

- The identification of cost drivers in the whole packaging, transportation and distribution chain;
- Investigating in detail what the costs were for each driver.
- Investigating the environmental impact during each stage of the packaging, transportation and distribution chain.

These analyses provided a detailed breakdown of costs structures that were very useful in analysing opportunities for improvement. What contributed to this was the fact that analyses were made for various types of transport, i.e. full truckloads, less-than-full truckloads, mixed-pallet and parcel distributions, etcetera. Thirdly, based on the above findings, concepts were designed for improving the complete packaging chain.

3. Key findings

The key findings of the mentioned projects can be summarised on three levels, addressing conventional strategies (section 3.1), volume strategies (section 3.2) and integral (bulk) strategies (3.3).

3.1 Weight reduction strategies

Using a conventional approach for packaging improvement using single set packaging, by now only little improvement can be realised. Such strategies are mostly based on (material) weight reduction. Especially given the current set of functional requirements and considering that packaging design is done for decades already, design based on traditional requirements is already close to optimal.

Nevertheless, the practical materialisation of such conventional strategies is often sub optimal. Benchmarking studies show that seldom, a single company consistently scores best on all aspects of packaging. This is true for

both single benchmark studies addressing products of similar functionality, price, generation etc. as well as for benchmark performance over longer periods of time. At the least this implies that there is almost always room for improvement, even using traditional material reduction strategies.

This gap between theoretical and practical results is likely to originate from factors other than technical ones; a further research at Delft University of Technology is planned to address this issue.

In order to generate improvements that focus on improvement studies within traditional strategies, for one of the projects described above, competing products from Philips and over ten of its competitors were analysed. Because of the fortunate presence of a large reservoir of benchmark data it was possible to generate sufficient data on three performance criteria: a volume index (box volume over product volume), a weight index (box weight over product weight), and an ecoindicator statistic (Ecoindicator mPt over product weight). Using these criteria, and by comparing Philips scores to best, average and worse case performance insightful conclusions were drawn relating to specific brand performance in consumer electronics packaging. From the data analysis, targets for packaging reduction based on the scores on the performance criteria of the best competitor could be derived. As in environmental benchmark reports, benchmarked products are of equal or similar price, generation and functionality, these should apply for individual brands. The targets are displayed in the Table 1.

Table 1 Index and statistic reduction targets

Product	Volume Index	Weight Index	Eco Indicator statistic
Audio mini system	11%	28%	15%
Portable CD player	0%	4%	24%
CDR	30%	13%	20%
Mainstream TV 21"	9%	15%	16%
Mainstream TV 28"	21%	34%	32%
Upmarket TV 32"	1%	29%	15%
VCR	2%	26%	4%
DVD	0%	0%	9%
Cellular phone	16%	5%	30%
CRT monitor	4%	0%	16%

3.2 Volume strategies

It was found that three main parameters of consumer electronics packaging influence cost and environmental load during the life-cycle. Volume is the most important driver, as 72% of the environmental load in the life-cycle is generated by transport. Volume influences costs for 38%. The other two important parameters are weight and material selection, the latter causing 28% of the total environmental load and 41% of the costs.

In the current situation where many production facilities of large original equipment manufacturers are moving to countries with lower wages, it is a given that average transport distances in the electronics industry are increasing substantially. There is also a trend that sales of consumer electronics products take place in large stores of outlet chains instead of from individual retailers, which means that these stores are increasingly buying in bulk. Both these situations imply that volume reduction strategies are most likely to be both feasible and lead to significant reductions in environmental impact as well as in packaging costs.

In an example worked out in detail at Delft University of Technology, it was found which strategies contribute to what extent to cost reduction. Assume that, based on detailed distribution cost data for a specific TV set, the maximum potential cost saving is 100%, by removing the packaging entirely. Although this is an utopical situation, volume based improvement strategies can partly achieve this cost saving by:

- Increasing the number of sets per truck (17% potential cost saving)
- Increasing the number of sets per square metre of warehouse floor (by reducing packaging dimensions, increasing stack height) (15%)

- Adapting packaging to Europallet or block pallet size (16%, 13%)
- Increasing the number of sets per Europallet or block pallet (9%)
- Increasing mixed pallet and parcel distribution efficiency by reducing single set volume (7%)

It was also found that by combining all improvement strategies for this particular TV set (using volume-based, but also other material reduction strategies), a 55% reduction of current distribution costs could (theoretically) be achieved, using only strategies that do not rule each other out.

Clearly, volume based strategies can be beneficial for single set packaging, but becomes increasingly interesting for multi set packaging, something which is discussed in the next section.

3.3 Integral (bulk) strategies

One of the principle teachings of ecodesign is the importance of taking a complete chain and life-cycle perspective in order to avoid suboptimisation. Applying such a perspective on packaging design, the potential of volume strategies become even more apparent.

In this light, multi- or bulk packaging concepts are candidate strategies for bringing this about. As a response to the trends identified in the previous section, in two projects done in a cooperation between Delft University of Technology and Philips Consumer Electronics, several of these concepts have been developed for Philips VCR/DVD shaped products (see for an example Figures 2-4, designed by Thijsse [2]) and for Philips television sets (Figure 5, designed by Keijzers [3]).



Figure 2 Inflatable packaging concept

Cost savings in these cases are generated mainly because of material cost reduction and optimisation of replenishment and storage costs. However, such solutions will imply changes in the supply chain -- the integral perspective brings about that in order to fully reap the benefits of bulk packaging strategies, some sacrifices will have to be made 'along the way'. Detailed analyses in the mentioned projects has shown that costs for extra activities include mainly those for repacking sets, including transport and storage costs of cushions to distribution centre warehouses, and the costs for repacking operations themselves. However, it was found that under the assumption that only 60% of the sets need repacking, the cost savings outweigh any extra repacking costs. The sets that do not need repacking are those bought by for example the previously mentioned large retail chains that buy products off the OEM in bulk. An additional advantage is that goods that are delivered in bulk can already be customized in the country of production.

Hence, especially for large distance shipping, bulk packaging can be a feasible and cost-saving operation. With increasing transport distances, transport efficiencies increase while other costs remain constant. This is especially important in the light of production facilities being shifted to for example Far East countries like China.

KEYWORDS

- Transportation of five products in multi-packaging from AC to retailer
- Sales packaging = inflatable handbags protected by secondary packaging
- Inflating of handbags at retailer
- Volume reduction of packaging by deflated air and packing multiple products
- Volume Index 1.5

ADVANTAGES:

- Cost reduction of 37%
- Reduction environmental load of 53%
- Easy to carry packaging for customer
- Re-usable packaging
- Less damage to final sales packaging

DISADVANTAGES:

- Inflation is required
- Fixed number of sets for retailer

Figure 3 Characteristics inflatable packaging concept

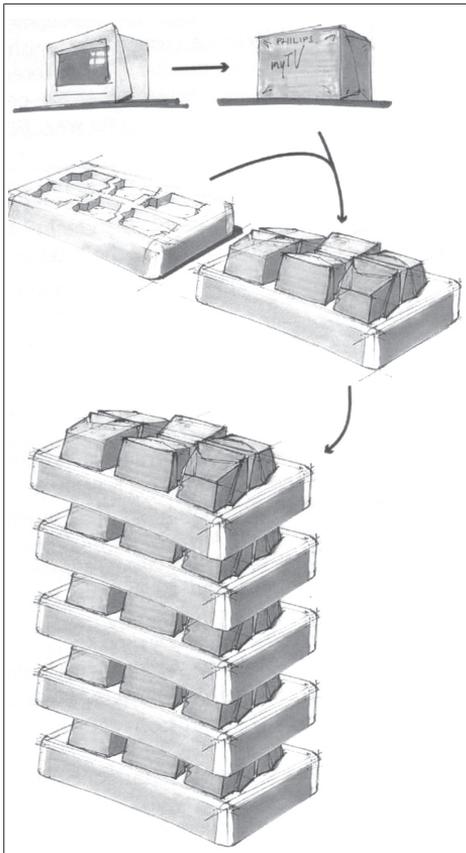
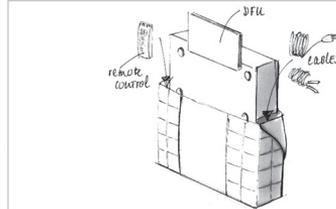
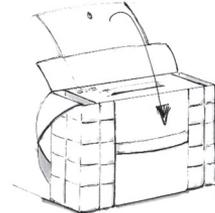


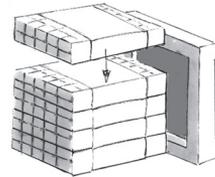
Figure 5 Design for bulk packaging of TV sets



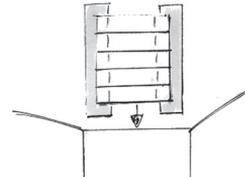
PACKING OF THE HANDBAG AT THE AC



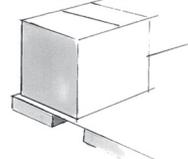
CLOSE THE DEFLATED HANDBAG



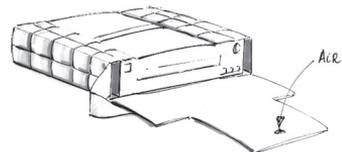
PLACE EPS BUFFERS ON THE SIDES



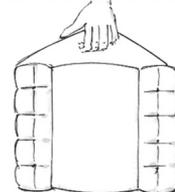
PACKAGE WITH 5 PRODUCTS IN BOX



BOX ON PALLET



INFLATING AT RETAILER



CARRYING HANDBAG BY CUSTOMER

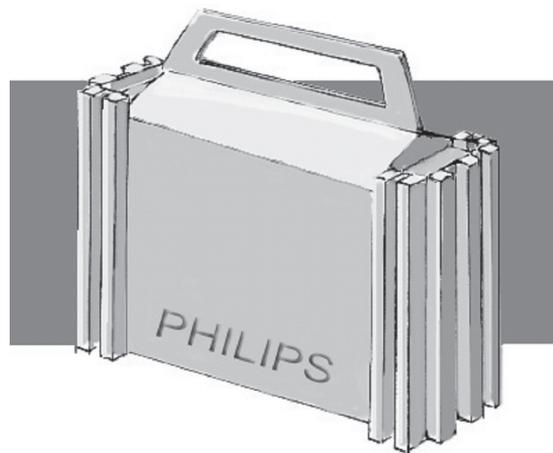
Figure 4 How the inflatable packaging concept works

4. Paper-based packaging good source for improvement

More recent work at Delft University of Technology has put emphasis on paper-based packaging. Packaging concepts based entirely on paper fibres constitute a good source for promising packaging concepts for consumer electronics. Such concepts have been around for a long time for other product categories or as a partial solution but are fairly new to the electronics industry. However, some OEMs state that they use moulded pulp wherever they can, whereas other manufacturers have found it difficult to overcome problems with fluctuations in the quality of the offered moulded pulp, which at this time prevents large-scale applications, especially for larger/heavier products. Hence, two projects are on the way at Delft University to optimise mechanical properties (such as increasing degrees-of-freedom in shaping) of moulded pulp applications for packaging whilst at the same time preserving or improving environmental characteristics.

From the side of the packaging industry, there is evidence that they could have problems with keeping up with the pace of the consumer electronics industry (ever changing demands, shifting production locations). This is partly due to the reason why for example Beeboard®, another fibre-based packaging material, has moved out of this business.

Research at Delft University of Technology has combined paper based packaging solutions with bulk packaging concepts which has resulted in for example a foldable carton handbag (Figure 6) for packing DVD/VCR shaped products, similar to the inflatable packaging concept shown in Figure 2.



KEYWORDS

- Transportation of five products in bulk packaging from AC to DC
- Sales packaging = foldable handbags protected by secondary packaging
- Unfolding the cushioning handbags when the products are separated from the bulk
- Volume reduction of packaging by foldable cushioning blocks
- Volume Index of 1.1 (bulk) and 1.7 (final sales packaging)

ADVANTAGES:

- Cost reduction of 23%
- Reduction environmental load of 53%
- Easy to carry packaging for customer
- Only cardboard used
- Unfolding the cushioning handbags when the products are separated from the bulk
 1. Picked from bulk at DC: pack accessories at DC
 2. Picked from bulk at wholesaler: less transported volume

DISADVANTAGES:

- Probably larger cushion thickness required
- Fragile handgrips

Figure 6 Concept and characteristics of a foldable carton handbag

5. Conclusions

The main conclusion derived from the above projects is that when using multi or bulk packaging, a substantial reduction of the transported volume can be realised, as well as a substantial reduction in the use of packaging materials. Also, a large package is heavier than the currently used single set packaging, resulting in lower drop heights thus requiring less packaging material. Since products can share cushioning materials and cardboard, the amount of packaging materials is reduced.

Additional benefits were found as well: the use of multi packaging concepts shows many advantages for volume reduction, thus lowering transport costs by increasing transport efficiency. These benefits are particularly relevant in large distance shipping, which is becoming more of an issue recently because of production outsourcing to for instance countries in the Far East.

Acknowledgements:

The authors wish to greatly acknowledge Dr. Hans van Wijngaarden (Philips CE), and Renee Wever, Thomas van der Schoor and Maarten Keijzers (ex-students Delft University of Technology) for their research contributions that have contributed to this paper.

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Personalities, 3

Martin Charter: against all odds

Martin Charter put his Ecodesign activity at University College of Arts & Design on the world map – against all odds. Starting as a relative outsider in the Ecodesign community and working in a country where there was little attention being paid to the field, he managed to move forward.

How can this be achieved?

Take the initiative, organize meetings and seminars, start a journal (Journal of Sustainable Product Development) and organize conferences (Towards Sustainable Product Development, now in its tenth edition). Beat the drums. Try many things. Build on successes. Hold on to the good things and let them develop and grow.

From Martin I learned to pay attention to small and medium sized enterprises (SME's). In such companies it is more difficult to move these efforts forward. Most likely EcoDesign concepts are communicated to them in an unnecessarily complicated or intellectual form. Martin has put a lot of effort into creating a better approach for SME's and has demonstrated that such companies can do a very good job. The secret is: keep it simple and stupid (KISS).

Unlike like Han Brezet (see Personalities, 2) Martin and I agree about a lot of things (universities, government) but it is more fun to disagree with him about things like the role of industry in 'Eco', the role of 'educating consumers about green', cricket or rugby, John Smith or Boddingtons, English and Dutch humor, for instance. It is great working and having fun with him.

The 'Charter' Walk: go from London Waterloo Station to Farnham. Take the bus in southern direction to Haslemere on Midhurst and get out at Frensham Great Pond. Make one of the signposted walks.

3.3.3 Container transport, packaging functions

The work in 3.3.2 triggered further work on the Ecoefficiency of container loading. In the paper below it is concluded that, due to the present characteristics of packaging (Styrofoam buffering) for consumer electronics, insufficient product weight is being transported in relation to packaging volume. Moreover, it was shown that the volume index (volume of packaging product/volume of product) was inconsistent for products with high volume. This shows that the packaging volume of such products is simply too high and therefore indicates reduction potential.

Almost all smaller products showed unusually high volume indices as well. This was ascribed to requirements from the sales perspective rather than from the transport perspective.

All of these observations lead to new P/T strategies, applicable dependent on the type of product concerned:

- Balance better shock resistance requirements and container load requirements.
- Align in detail the 'sales requirements' for smaller products (or 'gift' requirements) and optimise packaging (volume) accordingly.

The study on "Increasing the benefits of product-level benchmarking for strategic eco-efficient decision-making" presented below was carried out by Renee Wever, a talented Ph.D. student who came on board 'Applied EcoDesign' in 2004.

Increasing the benefits of product-level benchmarking for strategic eco-efficient decision-making

Renee Wever; Casper Boks; Thomas Marinelli; and Ab Stevels

Abstract

Purpose: Widely accepted classifications of benchmarking distinguish between different levels of benchmarking. Strategic-level benchmarking is considered to be of a higher sophistication than product-level benchmarking. Such strategic benchmarking would be based on process information instead of product information. The purpose of this paper is to research the possibility of obtaining strategic-level information based on an extensive amount of product-level benchmark data.

Methodology/Approach: The data used in this paper originate from the environmental benchmarking program of Philips Consumer Electronics (CE). Philips CE has successfully implemented benchmarking as an environmental improvement strategy for its products. Product-level competitive benchmarking is used to assess the environmental performance of Philips' products compared to its main economic rivals. Since the start of environmental benchmarking over 100 studies have been performed on products ranging from large CRT television sets to small Personal Audio products, thus generating a considerable pool of product-level benchmark data. This paper reports on an extensive synthesis of product-level benchmarking data concerning the packaging of these consumer electronics products.

Findings: It is shown how strategic-level information is obtained from a synthesis of these separate benchmarking studies. It is also shown how this synthesis yields useful strategic-level managerial information and practical design input. Finally, advantages of this approach as compared to classic strategic-level benchmarking are identified.

Research implications: The study has yielded empirical data indicating a limitation in current benchmarking classification.

Keywords: benchmarking, environment, sustainability, consumer electronics, packaging, cushioning

Introduction

Environmental benchmarking of products has been systematically done at Philips Consumer Electronics since the mid-1990s, when the so-called Environmental Benchmarking Method was developed in cooperation with Delft University of Technology (Boks and Stevels (2003)). Since the 1998 launch of the EcoVision corporate program within Philips, environmental benchmarking has also gradually been embedded in mainstream business activities. Today, environmental benchmarking serves mainly as a means to verify the presence of so-called Green Flagships in the Philips product line. These are Philips products that outperform their direct commercial competitors on five environmental focal areas, which are energy, weight, packaging and transportation, potentially toxic substances and recyclability.

The results of environmental benchmarking are integrated in the Business Excellence Model, which is used to evaluate business performance. This Business Excellence Model – initiated by the European Foundation for Quality Management (EFQM), and founded by amongst others British Telecom, Renault, Philips and KLM – is becoming an international standard of best practice performance [1]. Through self-assessment, or third party assessment, this model is a practical tool to help organisations identify where they are on the path to excellence, helping them understand the gaps, and initiate systematic continuous improvement programmes and then monitor the areas that they want to improve.

The integration of environmental benchmarking in this Business Excellence Model has created one of only few examples so far where a multinational has succeeded in structural integration of environmental performance criteria into mainstream business criteria (Pascual et al., 2003). As such, environmental benchmarking has been highly successful in generating environmental improvements for numerous products, but has also provided eye-openers for cost reductions and opportunities for innovation outside the environmental context. One of the first examples where environmental benchmarking has been successful this way has been reported on in Eenhoorn and Stevels (2000).

Since the start of benchmarking at Philips CE over 100 benchmark studies have been performed, solely on a product level. The standard procedure involves the identification by a business group of a candidate product for benchmarking analysis, which is then carried out by the Sustainability Center (SC), a competence center working with the business groups in integrating sustainability issues with main stream business. The Philips product is then benchmarked against its best commercial competitor and one or more other direct competitors. The environmental performance of these products is compared on five focal areas, namely energy, weight, packaging and transport, potentially toxic substances and recyclability. For each focal area standardized environmental indicators have been developed by which the products are judged. For further explanation on Philips' environmental benchmarking procedure see Boks and Stevels (2003).

Each benchmark study results in a report which concludes whether or not the Philips product under evaluation can be named a "green flagship". These reports are very useful for environmental improvement in product redesigns, yet so far they remain on a specific product level. In recent years it was acknowledged that it may well be possible to draw more general business performance conclusions by combining data from multiple product-level reports, which could support strategic decision making. Or as Boks and Stevels (2003) put it: "...whereas the individual benchmark reports have contributed to product improvements, cost reductions and general environmental awareness through the organization, it is believed that from combining data from individual benchmark reports additional data and pointers for improvement can be generated...".

A literature search proved to provide little further methodological or anecdotal assistance how such exploitation of multiple product-level data could be made beneficial on a process and strategic level, as will be further explained in the subsequent chapter. First experiments in this area for the Philips Consumer Electronics case were reported in Boks and Stevels (2002a, 2002b). In this paper, a more substantial case study is reported on, aiming to show how product-related benchmarking was used on a process and strategic level, and to propose an extension to existing classifications of benchmarking.

Paper Outline

This paper is organised as follows: the next chapter (Benchmarking Classification in Literature) provides a scientific context in which Philips' environmental benchmarking activities are explained, and provides a basis for showing how multiple product-level data can support more strategic forms of decision-making, as opposed to mere product improvement. This will be illustrated in the subsequent case study on environmental benchmarking of packaging of consumer electronics. Finally conclusions will be drawn from this case study, which will then be used to discuss the implications for scientific classifications of benchmarking.

Benchmarking classifications in literature

Several researchers and practitioners have proposed classification schemes for different types of benchmarking. The most common classification is a distinction into four groups, namely internal, competitive, functional and

generic. (Watson, 1993, p. 89; Bendell, et. al. 1993, p. 69. and Falnita 2001). Here, 'internal' refers to a comparative study of the performance of two or more parts of a company. Competitive studies compare performances of different companies that are direct competitors. Functional benchmarking studies compare performance on a certain functional activity, but between organizations that are generally not direct competitors.

Generic benchmarking is defined by Watson (p. 260) as 'an application of functional benchmarking that compares a particular business function at two or more organizations selected without regard to their industry'. As Watson explains (p. 91), this classification is based on the different sources of data and types of benchmarking partners. Firstly there is a split between internal and external benchmarking. External benchmarking can then be split into studies that are either competitive or non-competitive. Finally the non-competitive studies can be divided into functional and generic. In the Philips context, environmental benchmarking has evolved from looking for improvement in comparison to previous Philips models (= internal) towards an external competitive perspective.

Watson also discusses benchmarking as a developing science. Figure 1 shows the development of benchmarking over time, according to the art-transitioning-to-science model, as he calls it. The figure illustrates how the first generation of benchmarking practices occurred as product-oriented reverse engineering or competitive product analysis, by comparing product characteristics, functionality and performance. From there, subsequent generations of benchmarking have been mostly applicable to processes, focusing on how competition was managing development rather than surveying end results of product development. The fourth generation is called Strategic Benchmarking by Watson, and is defined as a systematic process for evaluating alternatives, implementing strategies, and improving performance by understanding and adapting successful strategies from external partners who participate in an ongoing business alliance. The fifth generation Watson sees as the emergence of a global application of benchmarking, thus dealing with the globalization of industries themselves.

A parallel with Philips' past and current environmental benchmarking practices can be drawn here as well, but only as far as second generation benchmarking. As stated, up to the mid-nineties, focus was mainly on benchmarking of Philips' own products with previous models, a fact finding mission looking for improvement potential, based on disassembly (reverse engineering), rather than a structured, well documented benchmarking approach. From the mid-nineties on, the method was structured and included analysis of competitor's products.

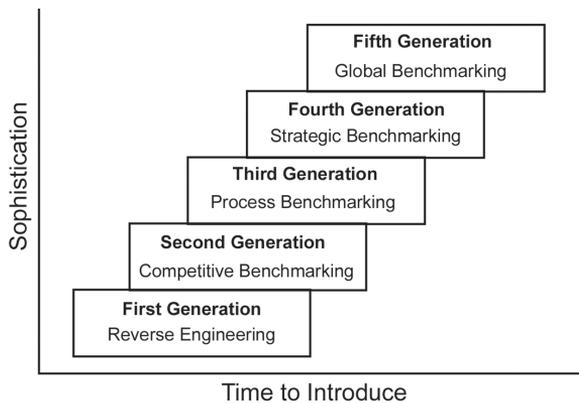


Figure 1 Benchmarking as a developing science (Watson, 1993, p. 6)

Following Watson, in order to develop more sophistication into its environmental benchmarking process, Philips would need to focus more on processes rather than keep focusing on products. It is the aim of this article to show that bringing more sophistication into environmental benchmarking is also possible by limiting yourself to product-level data. In the next chapter, a case study is reported on in which a multiple product-level data analysis approach was used to exploit existing (and growing) reservoirs of product-level benchmarking data.

In such a synthesis it will be relatively easy to identify best performance products or product groups. Yet, as stressed by Watson (1993, p. 17), a benchmark study is more than a search for the best-in-class performer. It

consists of two parts, namely measuring performance and identifying enablers. An enabler is the underlying solution, which causes the best-in-class to be that good, and that can be implemented in the own organization. So just comparing certain characteristics of a product and determining which product performs best is not benchmarking. Only if the underlying solution is sought and identified, the procedure can be truly considered benchmarking. This translates to the Philips case as the procedure in which a benchmark study is not only used to identify the best performing product in each focal area, but it is also attempted to identify what causes a product to perform better than its competitors, identifying enablers for Philips' own product designs. The challenge in a synthesis of product-level benchmark data lies in also lifting enablers from product-level to a strategic level.

Case study: environmental benchmarking of packaging

As mentioned in the introduction the environmental benchmark procedure was developed in cooperation between Philips and Delft University of Technology. This cooperation makes the environmental benchmark procedure an ideal source of data for further scientific exploration. In order to advance in terms of multiple environmental benchmark data analysis as proposed in the previous chapter, an extensive case study has been conducted. In principle this could have been done on each of the five focal areas mentioned in the introduction. Of these five focal areas, packaging was selected as very suitable for such a first case study, as the environmental indicators for packaging are relatively straightforward, as will be explained later on. Furthermore the packaging of nearly all products that are benchmarked have the same basic layout, namely a cardboard box with some kind of inner packaging. Finally, enablers identified in competitor products are not likely to be patent protected to such an extent that they cannot be used to improve one's own products. Patents that do exist tend to be owned by packaging suppliers and not by direct competitors. Hence such patents will generally speaking not block implementation. An example of such a patent protected packaging solution is Beeboard®, a honeycomb structured, paper-based board used as a cushioning material. In other focal areas patents may be a problem, as for instance within the focal area of energy. Here, a competitor has been found to produce a more energy efficient portable CD player thanks to a different driving system. This system could not be adopted as it was patent protected by that competitor. Combined with the fact that the transportation phase is gaining importance due to outsourcing of production to the Far East, this makes packaging a logical choice for this case study.

The environmental impact of packaging

To determine which performance indicators are most suitable for a synthesis it is useful to examine the environmental impact of packaging in more detail. In the last two decades packaging has received considerable environmental attention. The focus of this attention has, on the one hand, been strongly on the production stage, and on the other hand on the end-of-life phase of packaging. This focus is caused mainly by the EU packaging legislation, which resulted from the many legislative initiatives by member states in the early 1990s. With the introduction of the 'Directive on Packaging and Packaging Waste' (1994) the European Union set targets for recycling. The first article of the directive clearly reflects the focus on the production and end-of-life phase of the packaging:

... this Directive lays down measures aimed, as a first priority, at preventing the production of packaging waste and, as additional fundamental principles, at reusing packaging, at recycling and other forms of recovering packaging waste and, hence, at reducing the final disposal of such waste.

Although the directive does state that the entire life cycle should be taken into account, in all its other guidelines it focuses solely on material reduction and packaging recovery. Various research projects done within Philips, partly in cooperation with the Design for Sustainability group at Delft University of Technology, have shown however that the environmental impact from packaging of CE product is highest during transportation and distribution. Packaging, and in particular cushioning, adds volume to a product. This additional volume has to be transported as well. It has been shown that from both an economical and environmental perspective transportation is generally about twice as important as the bill of materials (BOM) of the packaging (e.g. Thijsse, 2001, Wever, 2003). This means that in most cases volume is a more relevant packaging characteristic than weight, although until now weight has been most commonly used as a criterion for assessing the environmental impact of packaging. Furthermore the strategy of material reduction and design for recycling has been followed for a decade now and all easy

improvements have been made. As will be shown below, a volume-reduction strategy still shows a major potential for improvement, not only environmentally, but economically as well.

Packaging data in Philips' environmental benchmarking procedure

Since Philips started benchmarking in the mid-1990s, the method has continuously been developed and adjusted to new insights. As a result, the amount and type of data collected and recorded concerning packaging has increased over time. Similarly, the way in which packaging performance was judged has also evolved over time. However, throughout the whole data collection process figures for the following volume related variables have always been measured:

- Packaging volume, defined as the volume of the rectangular cardboard box around a product;
- Product volume, defined as the volume calculated on basis of the maximum height, width and length of a product in the position in which it is to be transported, i.e. the smallest enclosing rectangular box shape;
- Volume index, defined as the ratio between the box volume and the product volume.

The relative score of the volume index has proven to be a very useful indicator for packaging benchmarking. Through its relative nature it is also highly suitable for a multiple product-level data analysis.

Synthesis of volume index

The data set used, is derived from benchmark reports written in the period 2002 – 2004. (Prior to that date only total packaging volume was recorded, and not the actual dimensions of the packaging. These dimensions are essential in a later stage of the synthesis. Hence data from 2001 and earlier was excluded). The data set consists of 96 products of which approximately one third are Philips products, the rest are competitor products. The data set contains a wide range of products, such as Baby Care products, DVD players and recorders, television sets and monitors (both traditional CRT and LCD screens) and Personal Audio players. Figure 2 shows the volume index of several benchmarked products against product volume itself. Less volume-efficient packages will have higher volume indices, thus producing data points higher in the graph.

Figure 2 shows data points to be distributed along the axes of the figure. For larger products the data points show a relatively constant volume index, while as product volume drops, the range for the volume index becomes increasingly larger, with some products showing a dramatic increase. These highly increased values will be discussed in the next paragraph on packaging functions. Firstly the focus will be on the constant volume index for larger products. One hypothesis that can be derived from Figure 2 is that there is apparently a minimum volume index.

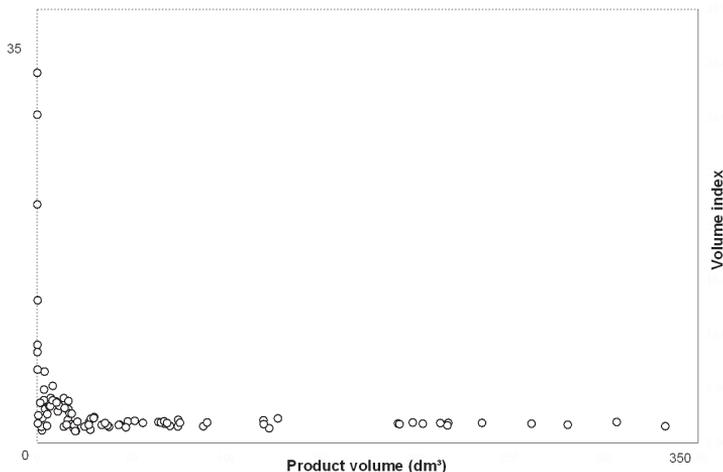


Figure 2 Volume index against product volume for 96 consumer electronics products.

Investigating this volume index further, Figure 3 shows packaging volume against product volume, for the same data set. As bigger products imply bigger boxes, a positive correlation is logical. Figure 3 shows that correlation appears to be linear.

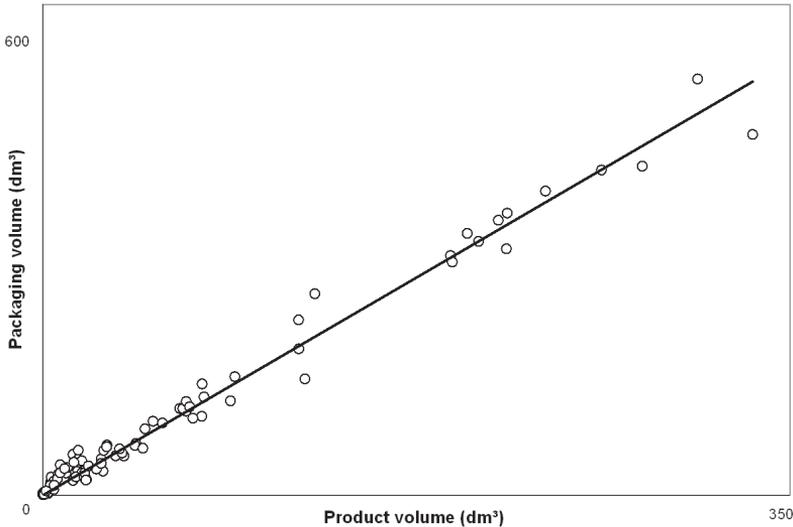


Figure 3 Packaging volume against product volume. The fitted line has been forced through the origin. It has a $R^2 = 0.9805$.

A trend line can be fitted through these data points. A linear least squares fit was made, which was forced through the origin, and had a $R^2=0.98$, suggesting a good fit. The fitted line can be interpreted as the average market performance (AMP) for consumer electronics products, under the assumption that the products analyzed provide an average representation of consumer electronics products. This data set can be analyzed for brands and product groups, and for identification of opportunities for information gathering that go beyond single products. Such opportunities include:

- If the data set is split into a single brand and its competitors, it can be analyzed whether this particular brand is performing better or worse than the average market performance. An example is shown in figure 4.
- One can analyze whether certain product groups are scoring consistently better or worse than others. An example of this is the product group of DVD players, which will be further discussed later on.
- Outliers that are identified using this procedure may not any longer be perceived as incidental bad scores but may receive more attention.
- A savings potential can be calculated which could be reached by bringing down those packaging volumes that are above the current AMP.

This last point of potential savings will also be further discussed. Before that, the highly increased volume indices of relatively small products will be analyzed in greater detail.

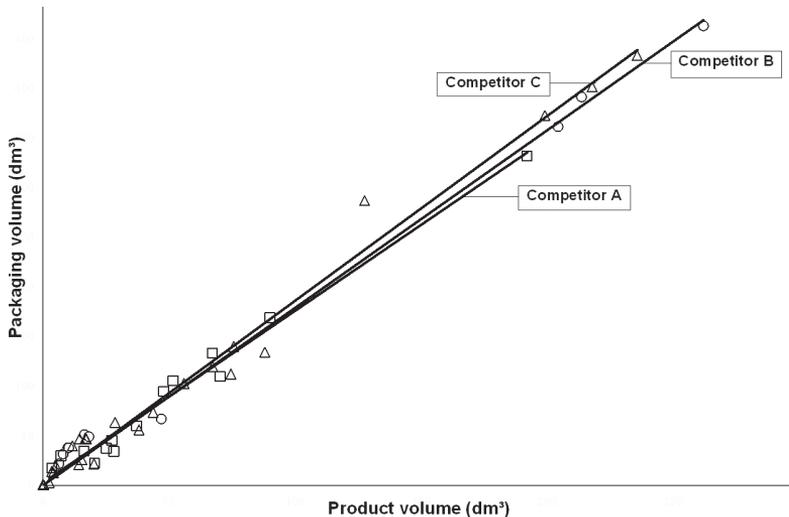


Figure 4 Packaging volume against product volume, split for three competitor brands.

Packaging functions

Figure 2 clearly provides basis for the hypothesis that there are two distinct groups of products within this data set. One group (A) has a constant volume index as described previously; an other group (B) has significantly higher volume indices, and contains only relatively small products. To test this hypothesis, a study was made of the type of products in each group and an analysis was made of the requirements the packaging for these products has to fulfill.

First, analysis shows that there are no product types that are in both groups. Group A consists of television sets (both with traditional CRT screens and LCD screens), monitors (again both CRT and LCD) and audio sets. Group B consists of universal remote controls and several personal audio players, such as MP3 players. Baby care products and DVD players are in the area where the two groups meet in figure 2; hence they can not be placed without further analysis.

With the larger products in group A the volume of the packaging is determined by the volume of the cushions, which in turn is determined by purely mechanical aspects. Given a certain fragility of the packed product and an expected roughness of the distribution chain a certain amount of protection is needed against shocks and vibrations. In practice, the roughness of the distribution chain is modeled in a test procedure, which typically consists of a series of drop tests which the product has to survive undamaged. Even though each company has its own internal standard for these drop tests, and even though fragility is a product specific characteristic, the outcome of the combination of these factors apparently does not differ very much across product types within the field of consumer electronics products. The cause of this consistency will be the basis for further research in the future.

The packaging design for the products in group B with higher volume indices is not determined by distribution considerations alone. Here, other functions of the packaging, such as attracting consumer attention, are far more influential in the design. A better understanding of these sales-related functions of the packaging is needed to explain these higher volume indices. Based on preliminary discussion with several packaging designers within Philips, a list of packaging functions was established. Nine different functions were thus identified, which may have to be fulfilled by a packaging of a consumer electronics product. Several products were then scored by product managers or packaging designers working in that particular field.

Specific functions

The functions identified are 1. mechanical protection, 2. keeping dry and clean, 3. containing accessories, 4. enabling handling, 5. informing the supply chain, 6. informing the consumer, 7. attracting attention from consumers, 8. preventing theft, 9. proving newness.

Mechanical protection has been explained above. Keeping dry and clean is also a type of protection. If products come with a lot of different accessories, such as remote controls, cables, batteries etc, these accessories have to be kept together by the packaging. Products may be too heavy for easy manual handling, in such cases their packaging facilitates mechanical handling.

Both the supply chain and the consumer require information. For the supply chain this is information on content and destination of the packaging and handling instruction, such as 'this side up'. For consumers this is information such as brand, color, product features etc.

Before a consumer can notice this information, his or her attention first has to be drawn by the packaging, through size and (graphic) design. Smaller, high value products are very theft sensitive. One of the ways of preventing theft is by making it difficult to conceal a product under clothing or in bags, which comes down to bigger boxes. Finally, with some products consumers require some proof of newness. Especially with products related to health care, such as electrical toothbrushes, this is important, but it also applies to products such as mobile phones.

Analysis

Table 1 gives the results of this analysis. Each product is scored on each of the functions using a scale from 0 to 4, with zero meaning 'not-relevant' and 1 to 4 meaning an increased influence on the final packaging appearance. As stated, scoring was done by product managers and/or packaging designers working in that particular field. Due to the practical reason of availability of those people the product types represented in table 1 are not an exact match for the product types in the data set of the environmental benchmarking, yet the similarity is considered to be sufficient to draw conclusions on.

Of the functions represented in Table 1, not all functions will actually result in a more voluminous packaging. The functions that may result in an increase of volume are: mechanical protection, containing accessories, handling, attracting attention and prevention of theft.

Table 1 Influence of potential packaging functions on the final appearance of the packaging for several types of consumer electronics products.

Product Type \ Packaging Functions	Mechanical Protection	Keeping dry and clean	Containing accessories	Handling	Informing supply chain	Informing consumer	Attract consumer attention	Prevent theft	Proof of newness
TV sets	4	4	2	3	2	1	1	0	0
DVD(R)	4	3	2	1	2	2	3	0	1
Audio sets	4	3	2	1	2	2	2	0	1
Personal audio	4	2	3	0	2	4	4	4	3
Mobile phones	1	3	4	0	3	3	3	3	4
Shavers	1	2	4	1	1	4	4	3	3
Light bulbs	4	3	0	2	2	3	2	1	1

Discussion

As said, the fit in Figure 3 can be perceived as the average market performance (AMP). There are both products performing better and products performing worse than the AMP. For the products from group A there is neither a product type scoring consistently better than AMP, nor a single brand that is consistently better than the AMP. Had a particular brand scored consistently better, this might have been caused by using different design criteria, based on a less hazardous transport system, or the acceptance of more transportation damage. As this is not the case, it can be concluded that the spread results from specific design choices that were made during the design of either the packed product or the packaging. Hence, from a point of view that is only concerned with efficient packaging, one can say that the AMP should always be attainable for each product. Hence a guideline for the design phase of the packaging can be developed. If a packaging concept scores above the AMP, the cause should be identified and a redesign considered, either of the product or the packaging.

Potential Savings

From a managerial point of view, just identifying bad scores is insufficient. A redesign will cost money and takes time to be implemented. It is therefore important to estimate the economical saving potential of a redesign. There is a relatively easy way in which the environmental benchmark analysis as done above can provide an indication for this potential, namely through the reduction in transportation costs. Here it is important to realize that the differences in figure 3 may be small, but the financial consequences of a relatively good or bad score are considerable. Bringing down the volume index to the AMP will result in smaller packaging, which in turn results in more products per shipment (= higher container load). Because of obvious discontinuities, not every reduction results in immediate increase of container loading, but in essence there is an inverse linear correlation. If one assumes that this correlation and the cost per shipment of the transportation mode used is known, one can calculate the savings per product. These data can then be combined with sales data or sales projection to set priorities for packaging redesigns. Within this study such a calculation was performed for transportation by standard ISO sea container (ISO container IAA as described in ISO 668 and ISO 1496) from Shanghai to Rotterdam Harbor. Cost for such a shipment is approximately €2500,- per container. Based on the internal volume of the sea containers (65m³) and the possible volume reduction it can be calculated how many more products would go into one shipment. The cost of the shipment can then be allocated over more products, which results in savings. For this study numerous products were identified with savings potentials between €0,50 and €1,00 per product. In a market with low profit margins, these are significant savings, and they are only the savings from costs for sea transport, not including savings on other parts of the transportation, nor material savings.

Design consequences

It has been shown from Figure 2 and Table 1 that there are two distinct groups of consumer electronics packaging, namely those where the dimensions of the packaging are a result of required mechanical protection (group A), and those where the dimensions are the result of sales-related packaging requirements, such as attracting consumer attention (group B). For both groups design solutions can be suggested that would make the packaging more environmentally friendly (and usually cheaper) without endangering the fulfillment of other packaging functions.

For group A, packaging designs with a volume index over the fitted line call for a redesign, either through making the product less fragile, or by increasing the volume efficiency of the packaging.

An example here is the product group of DVD players. From Table 1 it can be concluded that packaging volume of DVD players is mainly determined by mechanical requirements. Yet, DVD players as a group were found to perform worse than AMP (not only Philips, but competitors as well). This is a typical example of information only obtainable through multiple data analysis.

For group B, where sales-related functions call for increased packaging size, there are still ways of limiting the volume. If one is designing a packaging for maximum shelf space, to attract the attention of the consumer, this might call for a higher and wider package, but it would not necessarily require a considerable depth as well.

To illustrate this case, one of the benchmark studies on personal audio products is a good example. All products in this particular benchmark study had volume indices far above the volume index of group A. Yet there was

still a factor 2 difference between two of these products. The smaller packaging actually belonged to the commercially more successful product. Studying this product yielded understanding on how sales-related functions such as attracting consumer attention could be done without using a bigger box. This product used a simple but strong shape in combination with appealing graphics, combined with high production quality and an attention to detail rarely seen in packaging design for CE products. Thus the packaging gets a sort of jewel box feeling. This understanding cannot only be adapted to Philips' personal audio product, but to other Philips products within group B as well.

Other options for synthesis

Within this paper focus has been on the volume index as an indicator for the environmental performance of a packaging. As such it has been very useful, but it is not the only indicator that was used. To illustrate the possibilities for further synthesis these other indicators deserve to be mentioned:

- Weight index (weight of the packaging divided by the weight of the packed product). The weight index can be seen as an indicator for material efficiency. Here caution is advised as cushion materials can differ quite strongly in weight. Paper-based solutions are usually heavier than plastic foams.
- Container loading (number of packages that will go into one unit of load, for instance a truck or a sea container). This indicator is only meaningful in case of full truck loads and full container loads. In case of mixed containers the volume index is a more sensible indicator for transport efficiency. As an example, Figure 5 shows container loading performance of the products in the data set. Here the first indication of efficiency is the distance between a data point and the line above, that indicates the theoretical maximum container loading at that packaging volume. Yet, even a data point that is on this line may be improved, as it may still be possible to design a smaller box, resulting in a shift to the left of the graph, allowing more packages per container.

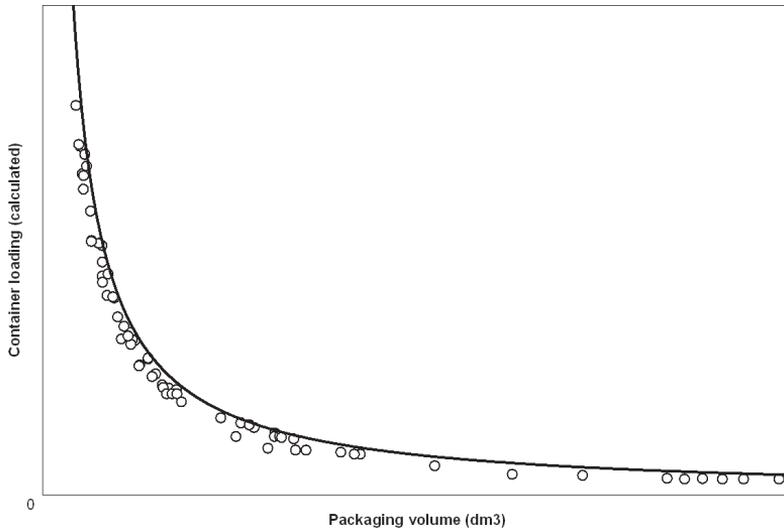


Figure 5 Container loading against packaging volume. The black line indicates the theoretical maximum, i.e. the internal container volume divided by the packaging volume.

Conclusions from case study

This case study has shown that valuable information can be obtained from multiple product-level benchmark data analysis. It has been shown that strategic information could be retrieved on product-group or even company level. In summary:

- Based on data from almost one hundred products it has been possible to identify a level of Average Market Performance, facilitating the identification of products with exceptionally good or bad performance on selected criteria;
- Although environmental benchmarking was done on a product level, it has created the insight that there are essentially two distinct groups of products within the Philips CE portfolio, namely A: products where the packaging fulfills distribution functions, and B: products where the packaging fulfills sales functions. The under-performance of the DVD player product group was only noted in reference to other products from group A. This dominance of certain packaging functions and the consequence of two distinct groups of products is something that will be studied in more depth in the future;
- It has been possible to connect findings from product-level benchmarking studies to product-specific, as well as general design aspects that span across product categories;
- It has been possible to project cost savings on basis of the above findings.

This success is partly due to the fact that the Philips benchmarking procedure is based on standardized relative scores, such as the volume index for packaging. These scores are applied to all products in the portfolio.

Based on this case study it seems likely that similar syntheses of benchmark data can be performed in other focal areas. An essential condition is that relative scores can be developed that allow comparison between product types. Examples can for example be found in recyclability scores and energy consumption data based on usage profiles.

Implications for scientific classifications of benchmarking

The previous chapters illustrate that the proposed extension to competitive benchmarking is likely to yield tangible benefits that extend beyond the benefits of competitive benchmarking. The reason that this form of benchmarking is not well aligned with the classifications of benchmarking discussed previously is in the fact that it uses product-level data to result in strategically useful information, rather than that it uses process information for that purpose.

In other words, Philips' environmental benchmarking procedures remain on a product level up to a relatively high level of sophistication. This is of course because of the high number of different but identically structured product-level benchmark studies that can act as a source for strategic information.

To what extent these findings call for an extension of existing theoretical insights such as Watson's model remains to be discussed. Multi-product (category) level benchmarking is not an activity easily prescribed – but rather an activity that needs to develop over time in a company, and can only flourish under certain conditions. Such conditions will likely include a highly competitive market, cooperation between business units, a visible team performing the analyses, in combination with consistence and continuity in operational aspects and management support.

Hence, one successful case where multi-product-level benchmarking has yielded strategic benefits does not necessarily call for generalization. But based on the assumption that other organizations would be able to attain similar benefits given the opportunity to adapt the (environmental) benchmarking process as described in this paper, there would be logic in giving strategic product-level benchmarking a more prominent place in theory. It is not the aim of this paper to discuss what type of benefits inherent to process-level benchmarking would be attainable through multi-product level as well, but some benefits of multi-product-level benchmarking over process-level benchmarking are likely to be:

- It is easy to make benchmarking a continuous process, due to the relative smallness of a single benchmark study. As this will result in benchmarking of consecutive models of a certain product it allows for trend research;
- It provides a level of detail otherwise unobtainable. Solutions that can be easily and directly implemented will be identified. Such low hanging fruits would probably be missed in the big picture of a process/ strategy benchmark;
- It is easier to distribute costs. Costs can be easily redirected to business units as costs per project are relatively limited;
- It is easier to select benchmarking partners. As the benchmarking is concerned with a product of a competitor

instead of their organization they do not have to actively participate, which might be difficult from a competitive or even anti-trust point of view.

Conclusions

From the case study it was concluded that benchmarking on a product level against direct commercial competitors has been a successful strategy for Philips CE. Lots of interesting improvement opportunities have been identified this way. The large amounts of product specific data thus collected are very suitable for performing a synthesis to a higher level of organization, thus generating insight in operational performance on division or even company level and providing performance indicators suitable for middle and higher management levels. Furthermore it can be concluded that performing environmental benchmarking on packaging does not only yield environmental improvement options. Most opportunities identified from an environmental perspective turn out to be economical improvements as well.

It is likely that benefits from this type of multi-product-level benchmarking activities can be attained in other contexts as well, and may partly replace elements of more complicated process-level benchmark activities. Research at Delft University of Technology in collaboration with Philips Consumer Electronics aims to continue to contribute to this understanding.

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[1] see: www.efqm.org

Credible as steel

It is a tough job to sell steel on an environmental basis. Its very nature means that the environmental impact per kilogram of plastics is lower. In many applications the better physical properties of steel often cannot compensate for that. Steel is slowly losing ground to other materials and even seems to be on the retreat in traditional fields like construction steel for building and cars. An attempt to exploit the superior recyclability of steel (see 7.4) went astray when applying the life cycle principle. This is obvious; physical and chemical properties of materials cannot be changed by law.

What to do to increase the environmental credibility of steel?

The key word seemed to be sustainability. Its concept has three pillars: not only environment but also social progress and economic development. If it could be shown that steel is scoring well in the last two departments, it could possibly overcome intrinsic disadvantages such as its higher environmental load per kilogram (or physically equivalent load).

Taco accepted this job for his graduation project. I involved myself strongly in the project because intuitively I have never liked 'one dimensional beauty contests'. The challenge turned out to be a nightmare: how can you measure contributions to 'social progress' and 'economic development'? Can some producers or production locations contribute more than others? Can the sustainability story behind the product be presented? Taco wrestled through a lot of literature and had a problem coming up with an interesting proposal. There seemed nevertheless to be potential in the concept, but the communication problem was there to stay. Even more pressing was the issue of measuring the sustainability performance; how to find a yardstick through which improvement can be measured and managed. There were lots more questions than answers!

The graduation project was at a point of near collapse, Taco felt very unhappy – he had put in long hours and a lot of creativity, but had yet to reach a satisfactory result.

Somewhere in his papers was the word 'functionality'. It was decided to move away from broader sustainability thinking and take 'functionality' and the 'Impact of Functionality Realization' as the core of the approach. Impact was split into direct impact (the traditional environmental impact) and indirect impact (changing – in particular adding – functionality through using a material like steel). The latter is relevant because environmental comparisons are usually made assuming constant functionality. The cornerstone of the credibility of steel is in the extra functionality it adds in many applications – in spite of higher environmental load as such.

For steel five areas were identified where it can provide this add-on functionality. These were:

- 1. Better preservation (of - for instance- food)*
- 2. Facilitates handling (less damage, loss on handling)*
- 3. Better information to consumers*
- 4. Facilitates consumption (easy, less leftovers)*
- 5. Quality consumption (better taste)*

For a given application these five elements have to be scored in a comparative way against the environmental impacts (resources, emissions, potential toxicity), economic impacts (costs, revenue) and societal impacts (health, physiological needs, etc.). For this purpose the so-called functionality-sustainability matrix has been developed.

In the end ... it worked! On a quantitative basis a quick analysis now can demonstrate where steel has chances and where it is on the defensive. Spend your creativity on the opportunities!

3.3.4 Sales packaging

After volume issues (3.3.3), sales functionalities of packaging of small products were studied in much more detail.

A representative product for this group is a shaver. The packaging is a typical mix of transport function (moving large quantities overseas), outspoken sales function (sold in big stores, a lot of competition, how to attract attention of potential buyers) and sometimes a gift function (the high end products are bought predominantly by women to give as a present to their partner). The following study "Multiple Environmental Benchmarking Data Analysis and its implications for design: a case study on packaging" gives an indication of the chief packaging issues to be addressed.

Multiple Environmental Benchmarking Data Analysis and its implications for design: a case study on packaging

Renee Wever; Casper Boks; Hein van Es and Ab Stevels

Abstract

For almost a decade Philips Consumer Electronics has been performing environmental benchmarking as a way of evaluating and improving the environmental performance of its products. This benchmarking is performed on product-only level and aims at five focal areas; energy, weight, packaging & transportation, potentially hazardous substances, and recyclability. It is believed that by combining the results from individual benchmark studies more general business performance conclusions may be drawn. In the past some preliminary studies have been done in this field. This paper reports on a more extensive study concerning the focal area of packaging & transportation. This analysis has yielded insights that could not have been obtained from product-level reports. It has been found that there are two distinct groups of products in the Philips CE portfolio, both asking for their own specific design and management approach. A second study is performed to determine what distinguishes these two groups. Finally, a case study on Philipsave packaging was performed to verify the findings.

Key words: benchmarking, consumer electronics products, eco-design, packaging, electric shavers.

1. Introduction

Environmental benchmarking of products has been systematically done at Philips Consumer Electronics (CE) since the mid-1990s, when the so-called Environmental Benchmarking Method was developed in cooperation with Delft University of Technology [1]. This environmental benchmarking method has been highly successful in generating environmental improvements for numerous products, but has also provided eye-openers for cost reductions and opportunities for innovation outside the environmental context.

As such, Philips CE considers benchmarking a more useful method for environmental improvement of its products than just performing Life Cycle Assessments (LCA). The main advantages of benchmarking are that it allows a focus on those environmental parameters that can be influenced by the CE company itself and that it is about striving to be better than your competitor, in stead of scoring on an absolute scale [1].

Since the start of benchmarking at Philips CE over 100 benchmark studies have been performed, solely on a product level. In recent years it was acknowledged that it may well be possible to draw more general business performance conclusions by combining data from multiple single product reports, which could support strategic decision making. Or as Boks and Stevels [1] put it: "...whereas the individual benchmark reports have contributed to product improvements, cost reductions and general environmental awareness through the organization, it is believed that from combining data from individual benchmark reports additional data and pointers for improvement can be generated...".

First experiments of this Multiple Environmental Benchmarking Data Analysis (MEBDA) were reported in Boks and Stevels [2,3]. In the present paper, a more substantial case study is reported on, aiming to show how product-related benchmarking was used on a process and strategic level.

2. Study I: MEBDA

The benchmarking at Philips CE is carried out by the Sustainability Center (SC), an environmental know-how center of the CE division that works with the business groups to combine the environmental perspective with the business perspective. The standard environmental benchmarking procedure involves the identification by a business group of a candidate product for analysis. The Philips product is then compared with its best commercial competitor and one or more other direct competitors. The environmental performance of these products is scored on five focal areas, namely energy, weight, packaging & transportation, potentially hazardous substances and recyclability. For each focal area standardized environmental indicators have been developed by which this scoring is done.

In principle a MEBDA can be performed on each of the five focal areas. In this case study the focal area of packaging & transportation was selected. Packaging is a suitable subject for a first project because nearly all products have a packaging with the same basic lay-out, namely a cardboard box and some form of cushioning.

This makes comparison across product groups easier. Within the benchmark procedure several data concerning packaging are recorded, among others these are number of different materials, their weight and dimensions of the outer packaging (height, width and depth). Combined with the data from the packed products (again weight and dimensions) these data present several options for multiple analysis. (Multiple) analysis of the performance of packaging has to be done by relative scores or indicators, as a 28" television set cannot be blamed for being packed in a larger and heavier package than a 15" set, as the product is simply bigger.

To determine which indicator is the most sensible to use in a MEBDA, the environmental impact of packaging needs to be discussed in more detail.

Various research projects done within Philips and the Design for Sustainability group at Delft University of Technology have shown that the environmental impact of transportation is about twice the impact of the bill of materials (BOM) of the packaging [e.g. 4,5]. This ratio applies to the economic cost as well; again transportation is about twice as expensive as the BOM.

Hence transport efficiency of CE products is important both from an economical and environmental point of view. This efficiency is determined by volume. All modes of transport have a maximum payload. Based on this maximum weight of the cargo and the volume of the cargo space, a maximum density can be calculated if the space is to be used completely. If such a calculation is made for standard 40' sea containers (as described in ISO 668 and ISO 1496) a breakeven density of about 400 grams per liter is found. Bare CE products may be over this value, but in general packed CE products have much lower densities. Figure 1 presents a plot of the products from the data set, and the breakeven densities of several modes of transport. As trucks come in many different designs there is a considerable spread in possible breakeven densities.

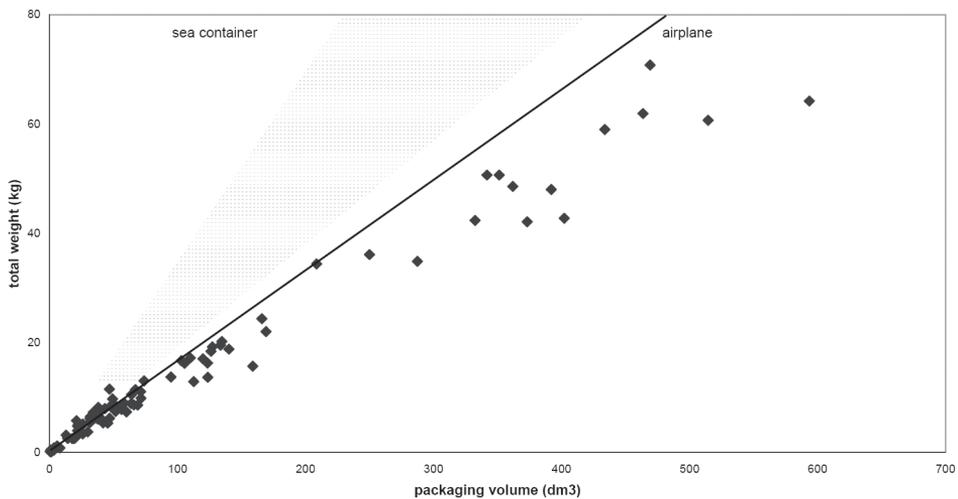


Figure 1 Densities for several CE products and breakeven densities for several modes of transport

From Figure 1 it can be concluded that in most cases volume is a more relevant packaging characteristic than weight, although until now weight has been most commonly used as a criterion for assessing the environmental impact of packaging. It should be noted that volume and weight are not two independent variables, as smaller boxes will on average also be lighter.

Several relative scores can be used for volume efficiency in packaging. Some of the options are:

- Volume index, i.e. the ratio between the volume of the box and the volume of the packed product (= product-box efficiency),

- Container efficiency, i.e. the percentage of volume of a full shipment that is occupied. This is a measure of the amount of air that is left around the stacked packages, due to incompatibility of the packaging dimensions and the internal dimensions of the transportation unit (= box-container efficiency),
- A combination of these, i.e. the percentage of the internal volume of a transportation unit that is actually occupied by product, if the maximum amount of packages has been stacked in it (= product-container efficiency).

It depends on the actual design of the distribution chain which is most appropriate. Whether volume index or container efficiency is more appropriate is determined by whether products are more likely to be shipped in mixed loads or in full container loads.

By calculating these values for all products in the data set it becomes possible to do trend research, and to compare the relative performance of products within and across product groups and between brands.

3. Results

Both the volume index and the effective use of container space will be studied in more detail. Figure 2 presents the volume index for the data set. Product volume is defined here as the maximum height, width and depth of the product, in the orientation in which it is transported. On the horizontal axis is the product volume; on the vertical axis is the volume index. The volume indices of the packages from the data set are mostly in the region of 1.5 to 2.0. Only a small group of products, which themselves have relatively low volumes, show distinctly higher volume indices.

Figure 3 shows the volume index in a different way, namely with the product volume on the horizontal axis and the corresponding packaging volume on the vertical axis. A linear least squares fit was made, which was forced through the origin, and had an $R^2=0.98$, suggesting a good fit. Figures 2 and 3 have demonstrated that interesting findings can be obtained through a MEBDA of the volume index, which is the product-box efficiency.

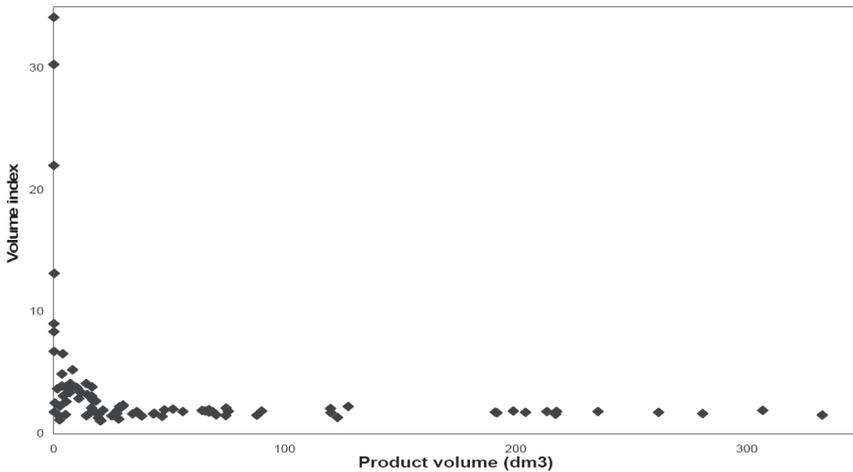


Figure 2 Volume index for the data set; defined as the ratio between pack volume and product volume.

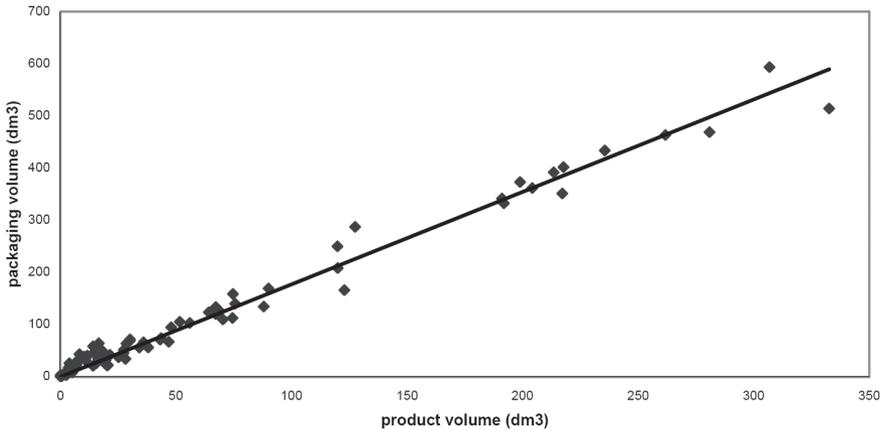


Figure 3 Volume index with a least squares fit, forced through the origin, ($R^2=0.98$).

The box-container efficiency will be studied next. Figure 4 shows the relative use of container volume. Here several assumptions were made, as no hard data on the distribution organization by competitors is available:

1. Packages are transported in standard 40' sea containers,
2. Packages are transported in full container loads, i.e. a sea container is filled with one type of product only,
3. Packages are stacked in by hand (hence not in separate units, like pallets or on slip sheets). This way a best-case scenario for volume efficiency is obtained, as the maximum number of products goes into one shipment.
4. Packages are only transported in an upright position.

Based on these assumptions the maximum number of packages that can be put in a container is calculated. The total volume of these packages is then compared to the volume of the container, resulting in a relative score. As Figure 4 shows, these scores range from near 100% to as low as 65%. This emphasizes again the importance of volume as compared to weight in impact minimization strategies.

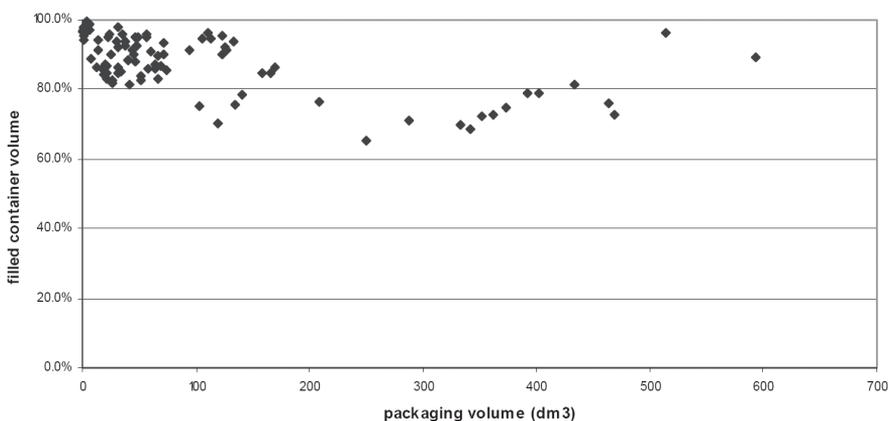
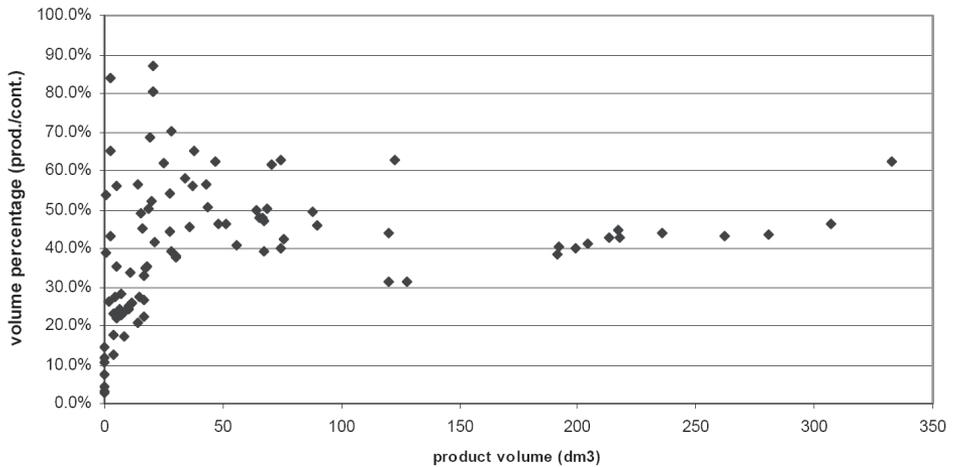


Figure 4 Relative use of container volume, with maximum cargo.

These two measures of volume efficiency (productbox efficiency and box-container efficiency) can be combined into one score. This score would represent the efficiency of packed products to the transportation unit. Figure 5

shows these scores for the products in the data set. On the horizontal axis is the volume of the packed products; on the vertical axis is the percentage of container volume occupied by the total number of products that fit in a fully loaded transport unit. We see that larger products tend to have a relative use of container volume of approximately 45%. With smaller products there is a much wider spread, some products score as high as 85%, others are below 10%.



Furthermore, where there appears to be a strict ratio between packaging volume and product volume for distribution dominated packages, no such ratio can be observed for sales-dominated packages.

Table 1 Influence of potential packaging functions on the final appearance of the packaging for several types of consumer electronics products.

Product Type \ Packaging Functions	Mechanical Protection	Keeping dry and clean	Containing accessories	Handling	Informing supply chain	Informing consumer	Attract consumer attention	Prevent theft	Proof of newness
TV sets	4	4	2	3	2	1	1	0	0
DVD(R)	4	3	2	1	2	2	3	0	1
Audio sets	4	3	2	1	2	2	2	0	1
Personal audio	4	2	3	0	2	4	4	4	3
Mobile phones	1	3	4	0	3	3	3	3	4
Shavers	1	2	4	1	1	4	4	3	3
Light bulbs	4	3	0	2	2	3	2	1	1

6. Discussion of both studies

The Multiple Environmental Benchmark Data Analysis, combined with the second study, has identified two distinct groups of products within the Philips CE portfolio. Each group asks for its own design approach for minimizing the package volume, and thereby the environmental impact. In the group of distributiondominated packages these options include:

- Reconsidering the test norms for distribution simulation,
- Reconsidering the acceptable damage rate during transport,
- Switching to more volume efficient cushioning materials,
- Using the fit in Figure 3 as a rule of thumb to indicate packages of unnecessary size.

With sales-dominated packages totally different design strategies apply. First, these products may be highly suitable candidates for bulk packaging. This would mean long-distance transport in minimal, multi-product cushions, and repacking into final consumer packages near the point of sale [6,7]. Second, one may attempt to design packages in such a way, that the sales related functions are fulfilled in another way than through increased volume.

7. Study III: Case of Electric shavers

To verify the findings from studies I and II, concerning two distinct groups of consumer electronic products, a case study was performed on electric shavers. A shaver is a logical choice as it was not in the data set of the first study, thus presenting new data which allows for checking the findings of study I. Furthermore, it was a subject in study II, where it was identified as belonging to the sales-dominated products.

In essence this third study is a limited MEBDA, as it is restricted to one product category. An analysis was made of several designs from recent years for electric shavers from the Philishave (sold as Norelco in North America) brand and competitor brands [8]. In total 18 products were included of which roughly half were by Philishave. With the exception of one earlier product all products were from the 2001-2005 period.

Following the same sequence as study I, Figure 6 shows the densities of the shavers in the study. This figure shows that several products would be weight limited if transported by some truck or by airplane. However, all products are volume-limited if transported by sea container, which is in fact the most important mode of long-distance transport for electric shavers.

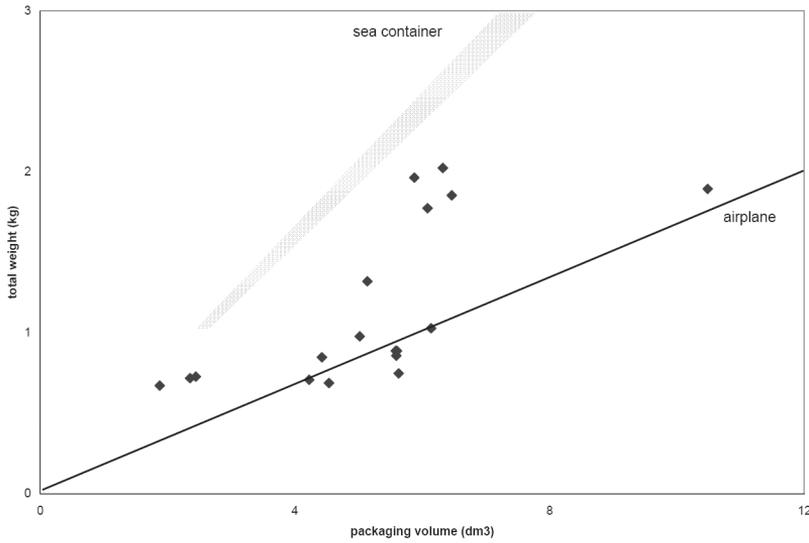


Figure 6 Densities for 18 electric shavers and breakeven densities for several modes of transport.

It was found that shavers have a volume index in the region of 1.5 to 7, so significantly higher than volume indices of the distribution-dominated packages. Special gift-boxes were even more voluminous. This complies with the conclusion from study II that shaver packaging design is dominated by sales-dominated functions. Subsequently, using EcoScan software, calculations were made to determine the ratio for Packaging-Transportation (P:T) for these designs. Here only the transportation from the factory in the North of the Netherlands, via Antwerp Harbor and Vancouver Harbor, to New York City was used. The results are shown in Figure 7.

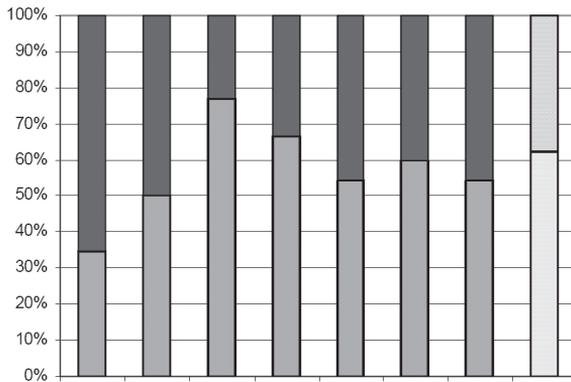


Figure 7 Ratio between impact of production & end-of-life of the packaging and transportation for seven shaver designs. The column on the right shows the average score.

It shows that on average the P:T score is 3:2. Hence the image from previous studies [4,5] is not confirmed entirely. This difference may have two causes. First packaging design for shavers is different from the products in the first study (Figures 1-5) as the basis is not a cardboard box, but a PET blister. Second, the final part of the distribution, from the distribution center to the retailer was not included.

An interesting finding is that the packaging of electric shavers shows a serious increase in environmental impact of the last decade. An analysis of the packages shows that this is directly related with the increase of importance of the sales related functions of the packaging. This increase is due to a changing market situation. Two distinct changes have taken place, or are taking place:

- Competition in the market for electric shavers has increased, as new brands have entered the market
- The retail situation is changing towards supermarket set-ups. Shops like Wal-Mart in the US and Mediamarkt and Carrefour in Europe are becoming increasingly important retailers in this market. These shops sell products in their box. There are few shop assistants to aid customers, hence the packaging becomes more important in selling the products.

These developments have resulted in a trend of subsequent packaging designs being more communicative, but also more expensive and more environmentally unfriendly.

In paragraph 6 strategies were presented for volume-efficient packaging design for distribution-dominated packages. For sales-dominated packages it is clear that volume efficiency is even more rewarding, yet harder to achieve. Future research at Delft University of Technology will aim at developing methods for assessing volume efficiency of sales-dominated packages and developing strategies for volume-efficient redesigns, without compromising their sales-related performance.

8. Discussion and conclusions on MEBDA

In this case study on packaging and transport, MEBDA has proven to be a method of uncovering valuable managerial information. This information is helpful in managing eco-design of packaging as it resulted in guidelines for acceptable and unacceptable packaging designs and also provides inside in the environmental performance of different business units within one company and between different brands.

Theory prescribes that such process-level or strategiclevel information be obtained through process benchmarking, which in this case would mean comparing the packaging development process of Philips with the packaging development process of a different company [9,10]. As the literature demonstrates, this would also yield valuable managerial information. However, MEBDA seems to have certain advantages compared to direct process benchmarking:

- It is easy to make benchmarking a continuous process, due to the relative smallness of a single benchmark study. As this will result in benchmarking of consecutive models of a certain product it allows for trend research;
- It provides a level of detail otherwise unobtainable. Solutions that can be easily and directly implemented will be identified. Such low hanging fruits would probably be missed in the big picture of a process/strategy benchmark;
- It is easier to distribute costs. Costs can be easily redirected to business units as costs per project are relatively limited;
- It is easier to select benchmarking partners. As the benchmarking is concerned with a product of a competitor instead of their organization they do not have to actively participate, which might be difficult from a competitive or even anti-trust point of view.

Even though packaging was a highly suitable candidate for MEBDA, other environmental focal areas show a potential for MEBDA as well. An essential condition is that relative scores can be developed that allow comparison between product types. Examples can for example be found in recyclability scores and energy consumption data based on usage profiles.

In essence this approach can also be adopted in any other case of product-only benchmarking. Next to the ability to develop suitable relative scores, the main condition is to develop a constant method of working to allow for comparison over time and across product types.

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Rituals and habits, 3

Diploma, gown, sash and bonnet

Finally, you are almost 'through' at the day of graduation. The presentation about the project has been given and questions have been answered. Everybody is sitting in the classroom waiting for the graduation committee to return for the diploma ceremony. They march in, the professor in front, clad in his gown with sash; the bonnet on his head.

Ladies and gentlemen, it is a pleasure to tell you that ... has passed the exam and got .. as a final mark ...

I ask the candidate to rise and to come to the front ...

'Empowered by the law on higher education and scientific research, I promote you ..., born in ... on ..., to Engineer in Industrial Design Engineering'. As proof I hand over to you the diploma signed by the Chairman of the Examination Committee and to which the Great Seal of the University has been attached.

This is followed by a more personal speech.

That is the way I do the graduation. Few of my colleagues do it like that. Graduation nowadays is not considered a real 'academic ceremony' anymore so gowns and other paraphernalia are not supposed to be worn. I do not agree; if there is one academic ceremony deserving full pomp it is graduation. This is in my opinion the heart of university activities!

The Dean was aware of what I was doing. In his official capacity he told me that he had to inform me that wearing the official outfit when handing over a diploma was not allowed by university rules. My response was: "I will continue until the moment I receive an official letter from you ordering me to stop doing it". The letter never came.

Once, during the diploma ceremony, the door was left ajar. The Dean passed by, saw the full ceremony happening, and positioned himself on the doorstep. I did not flinch and continued, but expected to be contacted by him later.

One hour later I met the Dean in the corridor. In passing-by he said: 'Ab it was great ...'.

3.4 Design and Chemical substances

3.4.1 Functionality and chemical substances

Chemical substances - many people including lawmakers say 'hazardous' substances - are difficult to include into life cycle assessments. This will be detailed in chapter 6.1. The reason is that they pose a risk to cause an environmental load, rather than a well defined emission that can be measured. However, if properly handled, this risk can be reduced, possibly to (almost) zero. An example of this is solder containing lead in electronics. As long as it is in the product in use, the toxic risk of lead does not materialize; there is no danger at all. However, if after use the discarded product is disposed of in a wet uncontrolled landfill the lead in the solder can contaminate groundwater. If this product was recycled properly the lead in the solder would have been recouped, so that it can be reused again.

As long as electronic products are not fully recycled (in particular collection rates of discarded products are relevant here, even in the best recycling systems existing today, collection is far from 100%) special attention needs to be paid to the chemical content of products. Although unbalanced in its present form, the European Directive on Restriction of Hazardous Substances is therefore justified (see chapter 9.2.1).

It also must be realized however that potentially toxic substances in electronics represent a clear physical and chemical functionality, both for materials and components. Flame-retardants in materials ensure safety, solders allow electrical joints, additives in plastics improve the properties of these materials and chromium and zinc layers are put in place to protect against corrosion.

Potentially toxic substances are also essential for achieving the proper functionalities of several components used in electronic products (electrolytes in condensators, 'dopes' in IC and solar cell materials).

Most potentially toxic substances involve substantial cost (for instance lead is relatively expensive, as well as bromine used in flame retardants). However, since they make products 'smaller, smarter, lighter, stronger', the physical and immaterial functionality value of such substances is very high.

On the contrary, the emotional value of potentially toxic substances is clearly negative in the perception of the general public. The only 'correct' concentration of such substances is zero. There is also a lack of trust about what producers and governments communicate about the control of potentially toxic substances. This is as a result of too many scandals in the past. This means that substances rank much higher on environmental priority lists than seems to be warranted on the basis of science. Since they cannot be properly rated against other environmental aspects like emissions and resources (see also chapter 6.1), substance control is to be considered as a separate environmental issue with high relevance in the functionality analysis.

Science and technology can in many cases deliver alternatives for existing potentially toxic substances in electronics. There is lead-free solder and technology which is ready to be applied in practice. There are alternatives for bromine and chlorine containing flame retardants and there are replacements for cadmium in chargeable batteries and in colorants for plastics. Spotting such opportunities is an important task for a designer in his/her role of a design organizer.

In some cases there are no alternatives; the Substances Directive of the EU therefore contains exemptions (see chapter 9.2.1). In cases where there is no escape, the only thing a designer can do is to limit the amount of the substance to the very physical or chemical minimum required. Eliminating 'overdose' is a strategy which is still much more effective than many EcoDesign practitioners think.

In minimizing chemical substances the supply chain management also plays an essential role. Almost all materials are purchased. Most components and subassemblies are manufactured by third parties and today entire products are sometimes assembled by subcontractors. It is therefore necessary to have a so called 'chemical content system' in place (see 3.4.2).

Also on the sales side substances play an important role. Legal requirements for products brought to the market are to be complied with. Violations of these requirements will be punished heavily, both monetarily (fines, products are not allowed to be put on the market anymore) and in terms of brand image. A well-known example in this field is the case of Sony. A couple of years ago, Playstations with what was determined to be excessively high cadmium content were not admitted to the market in the UK. The damage for the company has been enormous (tens of millions of Euros at least).

Potentially toxic substances rank high in the (environmental) evaluations of products by Consumer Unions. Such ratings have a high level of credibility with consumers because they are supported by clear facts.

Berlin, East and West

Post-war events have shaped my attitudes in life. The war in Korea, the suppression of the revolution in Hungary, the Suez and the Cuba crises, all happened in the period when I grew up. Of course there was also the political focal point Berlin. I remember little of the blockade of West Berlin in 1948, but a lot about the uprising there in 1953 and even more of the building of the Wall in 1961. It existed for 38 years, only a transient page in history; however, for me it is more than half of a lifetime.

Oddly enough I have only a limited association of Berlin with Nazism. That is my dominant feeling in Nuremberg. A visit to the Reichsparteitagsgelände (now a second hand car trading place) brings to life what you have seen in films only: the marching, the songs, the screaming of the leaders, the shouts of the crowds.

Back to Berlin: I was there for the first time in 1986. It was a rainy, cold November day. I was standing on a platform near the Reichstag where you could see East-Berlin: the front post of the Empire of Evil. At that moment my only thought was: this will last forever, Eastern Europe is lost, the Iron Curtain will never be lifted again. In school I learned that in the end democracy will always prevail, but at that location the opposite seemed to be true: systems with sufficient cynicism and contempt can stand for longer than a lifetime.

The Wende of 1989 was a complete surprise to me. I followed the events with intense attention. The real emotion came three years later when I was back in Berlin in 1993. I was in tears when I walked through the Brandenburger Tor for the first time. It is over I thought, a new period in history has started! Simultaneously, I realized how much had to be done to bridge the gaps, both the material and the immaterial ones.

For me Berlin has become the capital of Europe, the place where east and west come together – with a lot of pain and tension.

Berlin Dahlem is not Berlin Marzahn and Berlin Erkner is not Berlin Lichtenfelde. It will take one generation (or even more) to bring these planets together for real. Anyway there is hope and sufficient will to do it...and in the end it will be achieved!

East is east and west is west and they will meet!

Berlin promises that achieving the impossible will be possible. When working in the environmental field this has been an important source of strength!

City walk: Start at Bahnhof Zoologischer Garten, Hardenbergplatz, follow the footpath behind the Zoo, cross the Landwehrkanal and go R into the park, north of the Neuer See. Make a short excursion to the Siegessäule and get back to the park. Cross the whole Tiergartenpark in eastern direction and at its very end go to the Potsdamerplatz.

From here to the Pariser Platz and make a detour to the Reichstag. Go back to Unter den Linden, go L to Friedrichstrasse, go R Oranienburgerstrasse, R into Monbijoustrasse, R Am Kupfergraben and L to Scholl and Universitätsstrasse, Left to Unter den Linden and straight to the Alexanderplatz.

Favorite Restaurant: Hausbrauerei Spandau, near terminus of S5/S75.

Country walk: Go to S Bahnhof Potsdam. Take the bus to Werder and get out at the stop at Holländischer Mühle. Climb the stairs to the top of the Franzenberg, follow the path and go R to the Bahnhof Caputh/Geltow, take the ferry or use the railway bridge to cross the Havel river. Follow the path marked by red stripes. Go through Flottstelle village, go R 110m before the end of the village through the woods to Ferch, go right and follow the path along the Schielower See to Petzow and back to Holländischer Mühle.

3.4.2 The designer and chemical content

As is clear from 3.4.1, chemical content is pretty intangible but plays an important role in the functionality analysis. The immaterial and emotional functionalities are dominating in practice and this leads to a difficult balancing act:

- On one hand the basis for design should be rational and science based. On the other hand societal concerns are for real.
- On one hand changes of proven concepts will be resisted in industrial organizations. On the other hand in wealthy societies a lot of people buy on the basis of perceptions ('image') not on the basis of what is real (environmental performance).

For cases where decisions about the application of substances are not obvious, the following scheme can be given:

Table 3.16 Checklist to take decisions in chemical content

<u>Get facts</u>	<u>Look at the external world</u>	<u>Study Technicalities</u>
What type of substances are used?	Customers perception of the substances	Availability of alternatives
What is the form and what are the quantities?	Legislation or future legislation	Effect on physical functionality of a replacement
	What are competitors doing?	Feasibility of elimination
		Can the supply chain help?

In practice such a scheme has been extremely helpful in making timely design decisions about the introduction of lead free solder, elimination of bromine in flame-retardants and reduction of PVC type plastics. In order to facilitate the design decisions, an information system should be available upfront. This is described in the section below.

Pictures, 3

Berlin, the Brandenburger Tor, the music plays "hoch auf dem gelben Wagen"



3.4.3 Substances inventories

In order to facilitate chemical content decisions, many companies are now making substance inventories, in practice these are often called 'chemical content systems'.

Philips Consumer Electronics has been operating such a chemical content system since 1994. Other companies have followed. Especially in the early years cooperation with suppliers was seen as a problem. Some of them did not understand the issue; others gave incomplete or wrong answers to the substance questionnaires or did not want to give an answer at all. This situation has substantially improved but still two people work fulltime on it in order to fill the last gaps (98% of 25.000 code numbers have been covered) and to keep the system updated.

Basically the system gives 'environmental indicators' for the chemical composition of purchased articles (these can be materials, components, subassemblies or even complete subcontracted products).

The environmental indicators (E.I.) can have the following values:

Table 3.17 Environmental indicators of materials and components

<u>E.I.</u>	<u>Release status</u>	<u>Description</u>
9	Yes	Complete and reliable info; no relevant substances
6	Allowed	Contains environmentally relevant substances in concentrations above thresholds of EACAM list; but no banned substances
T	Temporarily	Contains no banned substances, other substances unknown
R	Rejected	Contains banned substances
Blank	Pending	No (complete) environmental information available

As can be seen from this table there is a distinction between three types of articles:

- the ones to be 'banned' from use because they contain substances posing an unacceptable environmental risk.
- the ones containing substances to be considered to be relevant for the environment, not to be banned from use yet (but preferably used in a limited fashion).
- the ones which can be used freely.

In the Philips system articles which contain the following substances are 'banned':

Table 3.18 List of substances to be banned

<ul style="list-style-type: none"> • Hexavalent chromium • Cadmium and compounds • Mercury and compounds • Asbestos (all types) • Chlorofluorocarbons (CFC's) • Polybrominated biphenyls (PBB's) and biphenyl ethers (PBBE's) • Chlorophenyls biphenyls (PCB's) terphenyls (PCT's) • Pentachlorophenol (PCP) • Polyvinylchloride and -blends (PVC), for packaging only • Lead and lead compounds (excl exemptions in the European RoHS Directive)

In the Philips Chemical content system not only banned substances have to be declared when occurring above a certain concentration threshold, but also environmentally relevant substances. The reason for this is that apart from legislated substances (the 'banned' ones) there are substances, which are candidates for future legislation. Their timely identification will allow proactive action. Substances which hamper recycling or have a negative reputation with customers are included on the list as well (or increase cost of recycling). In order to get a list, which is still manageable for suppliers, some 20 (groups of) substances, which are most relevant for the consumer electronics industry, have been selected from a broader list of candidates to be included. The threshold values have been set on the basis of the following considerations :

- perceived potential toxicity
- traceability / simplicity of chemical analysis
- other practical reasons

The relevant substances list reads as follows:

Table 3.19 List of environmentally relevant substances

Component information	Component (family)	Type number
	Supplier	Component weight
Compound	Threshold	Present in practice
Antimony and – compounds	10	
Arsenic and – compounds	5	
Beryllium and – compounds	10	
Cadmium and – compounds	5	
Chromium and – compounds	10	
Cobalt and – compounds	25	
Lead and – compounds	100	
Mercury and – compounds	2	
Metal carbonyls	10	
Organic Tin	10	
Selenium and – compounds	10	
Tellurium and – compounds	10	
Thallium and – compounds	10	

In order to get information the lists of banned substances and relevant substances are sent to the suppliers in one combined form. This is to prevent suppliers only filling out the banned substances form and refraining from considering the relevant substances. In the explanatory letter accompanying the list it is explained that the purpose of the list is to get information and to develop improvement plans on basis of this information, when necessary.

When an answer has been given, it is checked by the Environmental Competence Centre (currently Sustainability Centre) of Philips. When the answer is satisfactory, an Environmental Indicator (see above) is given and this indicator is put into the system.

Generally it takes from 2 up to more than 10 exchanges before the information is complete and the supplier has signed a certificate of the following form:

The information will be treated confidentially	
Supplier	:
Material (family)	:
Trade name	:
Return completed to	: Philips Div. Purchasing Eindhoven, The Netherlands
If valid tag	
* Supplier warrants that in the above indicated components as used by Philips Consumer Electronics BV and/or its affiliated companies no substances are present from the Philips Consumer Electronics List of Hazardous Substances or, if present, are below the listed concentration levels.	
* Suppliers confirms that the above indicates components as used by Philips Consumer Electronics BV and/or its affiliated companies contain the following materials from the Philips Consumer Electronics List of Hazardous Substances with concentrations above the listed levels (please indicate chemical(s) concerned, and concentration in ppm value on above mentioned list). Supplier warrants that no other substances are present in the supplied components or, if present are below the indicated concentration levels as mentioned in the above List, as submitted to the supplier.	
Name	: Supplier's Company Stamp
Function	:
Date	:

Box 3.1 Example of an environmental certificate to be given by a supplier

In spite of this 'guarantee' it turns out that (depending on product category) 2% -5% of the suppliers cheat. This means that in view of fines by authorities (the remediation cost in products already produced can be much higher) and damage to their image (and loss of business associated with that) strict control of the producer side remains necessary. Following article categories deserve special attention in this respect:

- Switches
- Cables and wiring
- Pigmented plastics
- PVB laminates
- Electromotors
- Springs
- Flame retardant plastics in e.g.
 - brackets
 - connectors
 - transformers
 - encasing
- Electrolytic capacitors

Box 3.2 Components and materials deserving special attention as regards chemical content.

The Philips Consumer Electronics experience with a chemical content program shows that it works out in a positive way both internally as well as externally.

The internal success shows that through the program banned substances can really be eliminated. Moreover many more components and materials used are fully released and correspondingly the amount of environmentally relevant substances present in the products has been reduced. Through the program, the transparency of component and material selection has been substantially increased. The chemical content program has been an important driver for the reduction of the amount of code numbers in the purchasing system as well as the reduction of administration costs as well.

The external success of the program is that legal compliance can be achieved proactively. This was for instance the case with the European Directive on the Restriction of Hazardous Substances (RoHS) where – with the exception of lead free soldering- all the substances to be banned had been eliminated before the directive came into force. Knowing precise details about chemical content allows ease of communication to the outside world; it is one of the reasons why the environmental image of Philips is very good.

A successful chemical content program works out in two ways: internally (box 3.3) and externally (box 3.4).

Internal successes
<ul style="list-style-type: none"> • Banned substances under control • Fully released C&M dramatically increased • Know what we are doing (transparency) • Chemical content has been a useful tool to reduce code numbers, achieve economy of scale/global purchasing

Box 3.3 Internal success of chemical content program

External successes
<ul style="list-style-type: none"> • Compliance so far done pro-actively • Easy communication quality (however, cannot score as a company, prefer to do it via associations) • Environmental image of Philips is very good

Box 3.4 External successes of chemical content program

Highlights of the year, 1996

Business Integration

Until 1996 the Environmental Competence Centre (ECC) of Philips Consumer Electronics followed the traditional Eco-approach. It was an activity separate from the mainstream business, operating with its own design manuals and working on separate projects.

At that stage it was a fruitful approach. Being a stand-alone unit it could develop without the interference of prejudice, lack of environmental awareness or disbelief about their ability to contribute to the bottom line. All of such perceptions were still present in abundance within the organization.

In 1996 this approach started to demonstrate its limits. Initial sympathy was waning, it remained quite voluntary. However, a lot of credibility had been built on the basis of the results of the initial projects.

The time was ready to become more anchored in the organization and in particular to be included into the Product Creation Process (PCP) and subsequently into contributing to the guidelines for the business processes. There are a lot of these processes, ranging from product planning to marketing.

In this way the environment has really been put on the business map; it has become an integral part. Simultaneously this raised a lot of questions; it's there and it's been recognized what needs to be done, but how can it be done?

This necessitated the ECC to make a variety of 'supporting documents' for all the environmental paragraphs in the guidelines. This includes explanatory papers for 'green' strategy making, road-mapping, benchmarking procedures, the 'green' brainstorm document, the Ecodesign-matrix and validation procedures (Eco-indicator calculations). Marketing and sales and 'green' communications were also addressed. It took us two years to put all of this in place. It was challenging. It was an enormous kick and we were rewarded. 'Green' became a normal part of the business. Yes, it is a small territory on the map, but it is one!

3.4.4 Enablers to eliminate or diminish the use of 'hazardous' substances

In this paragraph five of such enablers are listed. There are not meant to offer a principal solution for the issues raised in 3.4.2 and 3.4.3, but certainly will contribute to substantial improvement: "what is known better, is better managed".

The enablers include the following:

- Research to find 'hazardous-free' replacements for the current materials / components which are on banned or to be watched lists.

In order to get a holistic environmental perspective, a positive outcome in the field of potential toxicity should be checked against effects in the field of energy involved in manufacturing the alternative and as resource impacts for instance according to formula I of chapter 6.5.

Outcomes should also be positioned on a stakeholder 'priority list', which rates environmental improvements according to their ecoefficiency.

- A "just do it approach". Find your way through practical experiments (pilot projects). A lot of improvements options in the field of 'hazardous' ends up in end-less debate whether they really bring something substantial for the environment at acceptable costs. This is because environmental and cost data are not sufficiently available. Moreover, almost all environmental (calculations) tools have a subjective part (even LCA has). The result is that outcomes, which are inconsistent with 'beliefs' of stakeholders, spark new discussions about methodology and data accuracy. Pilot projects create a common basis, show the real world and take away prejudice and dogmatism about measures to be taken.

- Fighting design tradition, revisit decisions of the past

When developing new products, companies limit the change they make as much as possible. This has logic in view of time to market, limiting industrial risk and minimizing efforts to be done in the supply chain. The kinds of items are one of the reasons that EcoDesign is so successful; it issues perspective and therefore stimulates companies to review all kind of decisions taken in the past. When doing so, apart from the environmental dimension itself, 'automatically' also technological and supplier aspects are considered and it is discovered that also in these domains there are new developments, which contribute to improvement. It is the experience of the author that better using the latent opportunities of technology and of the supply chain is a very fruitful EcoDesign strategy. In the project described in 3.4.3 it turned out that for many components the amount of 'environmental relevant substances' varied greatly for the same type of functionality and simple exchanges with suppliers were sufficient to bring their amounts down. A study by Fraunhofer IZM (ISEE, Boston, 2003) came to the same conclusion.

Apart from a certain amount of conservatism, which even designers have, time pressure is an important factor that in product design the number of design alternatives considered is limited in practice. A continuously running program of environmental benchmarking on consumer electronic products at TU Delft and Philips Consumer Electronics shows that individual companies have their own design traditions and fail in practice to refresh them swiftly, even if competitors demonstrate there are better/ 'greener' solutions.

- Create a lever from a general cost perspective

Materials containing 'hazardous' substances are generally speaking more expensive than the same materials without such additions. In the case of flame retardants it pays to 'design for thermal management'. By avoiding hot spots in products, the amount of flame retardants plastics can be substantially reduced; this is an example where there is a clear cost lever to do this extra work. In the case of solder, cost is however more a durability than a material application issue, however indirectly it is – products with a shorter lifetime involve use of more substance per unit of time

Reduction of the amount of cable and wires (which usually contain a lot of 'relevant substances') is also in this category. The usual attitude of mechanical designers is that they are not responsible for this because it is 'electrical', where the electrical designers do not feel so because they see themselves rather as 'electronic'. Practice shows that assigning somebody to be responsible for all cabling/wiring in a product produces simultaneously reduction of 'hazardous' and of 'cost'.

- Create a lever from the perspective of end-of-life cost

Material fractions which contain 'hazardous' substances imply mostly higher end-of-life cost, particularly for plastics when incinerated, hazardous' containing plastics are in higher tariff classes. Mechanical recycling of such material is often not possible because the (hazardous) additives destroy the mechanical properties of the secondary material.

This makes that when 'materials' cost is considered on a life cycle basis, a cost driver is generated to eliminate hazardous substances. Due to the confusion about WEEE implementation (see chapter 8.2) it is currently impossible to estimate to what extent this can be a real driver in practice. Research in this field (making scenario's) is however to be encouraged.

Tidbits, 4

An Experiment after Christmas

The days between Christmas and December 31 are always a quiet period. During this period daylight is short, the weather is unpleasant (at least in the Netherlands) and the whole world seems to be asleep.

It was time to do an experiment in the home in which we lived as of 1977. The experiment was to count the number of lighting fixtures in place and check lighting needs in 20 years time and combine these with the actual usage pattern. It was a traditional eco-investigation: do needs and functionality (still) match in view of developments in technology, in this case the availability of a wider range of energy saving lamps.

The outcome was a surprise in two ways:

- *There are many more lighting fixtures in your home than you think there are*
- *The hours of use warrant a much more extended use of energy saving lamps in spite of their higher price.*

Altogether, there were many good reasons to plan for lots of replacements in the new year. When checking for the lamps I got seriously disappointed:

- *The choice of energy saving bulbs with low wattage (having the lumen equivalent of the incandescent bulbs to be replaced) was very limited.*
- *The color rendition of most of the energy saving bulbs was poor. Energy had been minimized but a little efficiency sacrifice in order to bring color rendition up to the level needed for living rooms had not been considered as yet.*
- *Some of the bulbs were too big to fit inside the lamp shades.*
- *Energy saving bulbs with small fittings were not available.*

These findings were in fact the perfect illustration that the concept of energy saving lamps had been exploited in a very technical fashion (minimize energy consumption) but had not yet been used to optimize the functionality/environmental load ratio (see chapter 2.3).

This was a very interesting and relevant conclusion and therefore I decided to include it in my presentation at the next Philips Global Environmental Conference.

My proposal was that Philips Lighting should make available to its customers a do-it-yourself checklist. Extensions of the product range and more application research (satisfying the real needs of the consumers) were to be considered as well. The Lighting people were not amused. They said, "We have done already so much". As a Consumer Electronics person you are not qualified to speak about such subjects.

In 2007 a lot has since been improved. Check out your lighting habits, find out where bulbs needs to be replaced. Hopefully, the assortment in the shops is now good enough to fulfill all your needs!

Chapter 4: EcoDesign and Business

4.1 The first wave of EcoDesign

4.1.1 Design Manuals

In 1993 I started Applied EcoDesign from square one with no knowledge, no know-how, just common sense. Like a paratrooper I was dropped over unknown territory. After surviving the landing, the first thing to do is to get some orientation before the accomplishment of the mission can be started.

Applied EcoDesign turned out to be an activity, a kind of profession at best. For sure it is not a scientific discipline; there were (and there are) no fixed rules or agreed ways of working. In 1993, there were only 'principles' which were interpreted in different ways and therefore could be called 'beliefs'. Moreover, there were (and again are) no standards to measure Applied EcoDesign performance in a business context. At the end of the century Life Cycle Analysis methods got widespread application, but this is basically a methodology and not real science. Moreover it gives a limited description of 'green', both from the environmental and the business perspective (see also chapter 6).

In spite of all this confusion, I had to offer something tangible to the Philips Consumer Electronics. Business is digital, either it is done or it is not done, there is no in between. There is no time for lengthy discussions with all kinds of nuances. Messages have to be presented in a simple form to large audiences of non-experts. Therefore the first version of an EcoDesign Manual was a very simple one. Its mission was: raise awareness, let people set the first steps and maybe most important, avoid the environmental stupidities of the past.

Experiences with this manual were reported by the end of 1994, in the following paper "*Towards sustainable development, the Philips Consumer Electronics experience*". It shows that the first successful steps for practical implementation had been set. Moreover, several tools to support Applied EcoDesign were in the process of development. What was clearly felt to be missing is the link with the business and in particular the incorporation of 'green' in the product strategy.

Towards sustainable development, the Philips Consumer Electronics experience

Ab Stevels

I. Introduction

Environmental issues have been addressed by the industry now for some 25 years. Process oriented environmental care has been put into operation and nowadays programmes to control emissions into the air, water and soil are implemented with increasing sophistication.

Environmentally oriented product development (EPD) has received attention only recently. In the last five years analysis of environmental impacts from the "cradle to grave" of products have begun. Particular reference is made to the use of resources (materials, energy) while issues regarding end-of-life and re-use in any form get substantial attention.

A basic consideration is that EPD should be sustainable, i.e. that production, use and the end-of-life of products should not hamper the well-being of future generations.

There are various types of environmentally oriented product development (EPD):

I. Operational EPD

This considers

- materials, including type, quantity of use, and hazardousness
- materials functionality
- energy consumption
- interconnection/disconnection, end-of-life aspects

II. Strategic EPD

This considers - alternative functionality

- logistics, distribution
- life time of product, repair
- re-use (in any form)

III. Managerial EPD

This considers - integration of EPD in business management

- integration of EPD in procedures for product definition, creation and release
- manuals and their implementation
- internal and external communication

The basis for EPD is Life Cycle Analysis which makes an inventory of environmental effects and classifies them. In this way Eco-profiles of the products concerned are generated. Philips Consumer Electronics has been engaged from the very beginning in the various forms of EPD. In the chapters below progress in the field is reported and outlook for the future is discussed.

2. The Environmental Design Manual

The basic instrument for moving towards sustainable product development is the Environmental Design manual. It essentially serves two purposes:

- to give general background and information on environmental issues relevant for the Consumer Electronics industry.
- to give a survey and consolidate environmental directives.

There are three types of directives

I Mandatory directives. Non-compliance with such directives is not acceptable, will stop further development and release procedures until remediation

II Directives. Non-compliance is only acceptable with good reasons, to be endorsed by management.

III Recommendations

Directives in all classes apply globally, i.e. irrespective of location of development and production sites. The status of directives (class I, II or III) depends on legislations/regulations and (pro-active) Philips policy.

Following aspects are considered in the environmental design manual:

1. Environmental policy and organization
2. Release status of components and materials
3. Power consumption
4. End-of-life
5. Packaging
6. Marking, labelling, customer information
7. Purchasing
8. Production operations
9. Environmental design evaluation

3. Implementation of the Environmental Design Manual

The design manual, as described above, has been written by environmental specialists in a small central group of the Product Division. The same people are in charge of the implementation and the development of supporting tools. Environmental managers in the Business Groups support this process and adapt it to their specific needs.

Kick-off efforts for the implementation of the manual are done through training courses on the spot. One or more products developed/manufactured at the location have been chosen as the carriers. This speeds up the actions of the first level of implementation, which aims at creating awareness and helping the organization to know where it stands with regards to the environmental aspects of their products.

For the second phase improvement actions are formulated on the basis of the issue list resulting from phase I. In the end full compliance with the manual (as regards all directives of class I, II and III) is to be reached.

Presently, the Environmental Design Manual has been introduced in most locations of Philips Consumer Electronics. This means:

- in various businesses (TV, audio, video recorders, car systems, monitors, business electronics)
- in various disciplines (predevelopment, development, purchasing, production, marketing & sales).
- in various cultural settings around the globe.

There are three critical success factors:

- Integration of the environmental manual in standard procedures and practices. We have from the very beginning chosen for integration rather than environmental issues as a special item: practice shows that we are right.
- How to set priorities. Introduction of a design manual also is a cultural process. It takes time, you cannot turn 'green' overnight. Having success with the first items selected is crucial for the follow-up.
- Insight into cost consequences. Most people think that environmental matters only cost money and cannot bring money. There is still a substantial job to be done to change this mindset.

These matters will be illustrated by various examples.

The process of implementing the manual has also shown that its systematic approach yields a lot of improvement options. A lot has already been gained; there still is a lot more to be gained before limits set by the required functionality of the products - i.e. by the physics, chemistry and electronics to achieve these - are reached.

4. Environmentally oriented product strategy

The environmental design manual, as described in the preceding chapters, chiefly deals with operational issues. Current products are addressed, the catchphrase is “do it better than you did before.”

Tools include:

- Chemical content data bank. Eliminate the legislated substances, bring down the amount of environmentally unfriendly materials.
- Design evaluation method. Score higher marks on an LCA oriented scale (above release threshold).
- Packaging assessment. Bring down packaging weight/product weight ratio. Score above release threshold.
- End-of-life cost. Keep end-of-life cost/cost price ratio below certain limit.

Such tools help the manual to operate better and better.

The Consumer Electronics industry still is at the very beginning in developing advanced environmentally oriented product strategies. This is a complicated process in which a large number of often unknown parameters have to be assessed, e.g.

- current products with alternative products for which still a lot of research and predevelopment is to be done.
- life time extension versus refurbishment concepts.
- logistics for sales and take-back.
- sale versus lease concepts.
- scientific (LCA based) 'green' versus customer perceived 'green'.
- chain management issues.

A common denominator in all these matters is the Life Cycle Analysis. Apart from its complexity and its subjective valuation of the Eco-profile results fail to connect properly with the approach in business terms.

An interesting concept therefore is the so-called Life Cycle Cost (or SEED = Support of Environmental Economic Decisions) concept. This methodology gives a description in monetary terms of all cost elements of a product (from “cradle to grave”) which refer to non-renewable resources in particular, with reference to material use and energy use.

Such a description allows easy comparison with other business data like cost price, investment, depreciation etc. Easy application will be found in making choice of materials a priority, setting of development programmes, design evaluation and assessing new concepts/alternatives.

A key issue is the extent to which LCC (SEED) correlates with LCA. In a market economy such a correlation is estimated to be (fairly) high, since e.g.

- scarce materials are expensive
- energy use has to be paid for
- waste has to be paid for.

Research and practical tests will be needed to develop such systems. Progress in these matters is urgently needed to make further breakthroughs towards sustainable development.

Jacqueline Marian ('Jacqueline') Cramer: radical and realistic

Jacqueline taught me that you should have ideals and be radical in pursuing them, but also that when necessary you should go back to reality and come to practical compromises and solutions.

In the early years in the Ecodesign world, such ideas did not exist. It was a dogmatic world with principles, design rules and strict paradigms, it was almost a religion or at least a set of 'Ecodebeliefs'. Jacqueline turned out to be determined but not absolute in her thinking. Soon after I met her for the first time she was hired by Philips Consumer Electronics to enhance 'green' operations, particularly in the product creation processes. She did it - her 'STRETCH' approach laid the basis for radical 'green' innovation in 1995-1997 (see also chapter 4.1). We discovered that the success of this approach depended on how well you manage the boundary conditions. It was the origin of ideas about business integration (see chapter 4), the Ecodesign matrix (see 4.2) and of social issues in sustainability as well.

I very much enjoyed the discussions I had with her. Again, we had different views on society and the world and a different perception of what companies should achieve. 'Amsterdam versus province'. What brought us together at the end of most debates was action, 'do something practical, stop intellectualizing the subject, do something sensible'.

Appointments with Jacqueline always seemed to involve a mix-up. Either the train was late, or there was misunderstanding about the time or the location.

The offices where she used to work at TNO in Apeldoorn were a maze. Gatekeepers there treated you like a criminal and did not point out where to go. I couldn't even find the front door of the building she was working in.

After some fifteen minutes I finally found a backdoor, bewildered I entered her room!

The 'Cramer' Walk: start from Arnhem Central Station, follow the Sonsbeeksingel, enter the Sonsbeekpark at the Daalseweg ahead of you. Keep at left in the park and walk as you like – best is to cross the Parkweg and to include 'Zijpendaal' in your itinerary (you can even walk from there to the Zoo).

4.1.2 Product planning

Apart from discussing the impact and conditions for the success of implementing EcoDesign Manuals, the following paper also flags up the need to put Eco-activities into a wider perspective, which is called Environmentally Oriented Product Strategy and later renamed Strategic 'Green' Product Planning. Outside help was needed to develop this type of planning in such a way that it fit into the operations of Philips Consumer Electronics (at that time still called Philips Sound & Vision) and maintained a clear 'green' focus. Outside help was needed to achieve it and this was provided by Professor Jacqueline Cramer (see also personalities, 4). She was hired for this job and the effect was a tremendous win-win. The Philips environmental activities gained in strategic strength and gathered momentum at the CE Executive Board level. Jacqueline's academic perspective was severely tested from a practical perspective and thus was strengthened.

The results of this cooperation were amazing:

- The four levels of EcoDesign, later well known globally by publications of Brezet et al., were identified for the first time.
- The concept of (radical) environmental brainstorming to be consolidated ('back to reality') in product concepts was generated and practiced in this period.
- Jacqueline Cramer's approach to 'green' product planning was explained in a page hand book called STRETCH (Selection of sTRategic EnvironmenTal Challenges)

A summary of these activities is given in the following publication "Strategic Environmental Product Planning within Philips Sound & Vision".

Strategic Environmental Product Planning within Philips Sound & Vision

J.M. Cramer and A.L.N. Stevels

Until now no structured methodology existed for attuning environmental considerations to the business strategy of companies. The Environmental Competence Centre of Philips Sound & Vision in The Netherlands has developed and tested a methodology for this purpose. This methodology, called Selection of Strategic Environmental Challenges (STRETCH), has proven to lead to promising results and should therefore be actively promoted. In this article, the authors show how the application of STRETCH provides the possibility of meeting three main objectives: First, focusing on the incorporation of environmental aspects into the company's business strategy can elicit innovations that may enhance the competitive position of the company by cost reduction and/or higher market shares. Second, the environmental opportunities and threats to be expected in the future can be anticipated in an earlier phase. Through this proactive approach a company can amid external criticism and take the lead in environmental priority setting. Third, by applying the STRETCH methodology even higher eco-efficiencies are expected to be reached than through incremental, step-by-step environmental improvements.

Achieving sustainable development presents an enormous challenge to society. It means that within just a few decades we must learn to deal much more efficiently with energy and raw materials. According to some estimates, within the next 50 years the burden on the environment will have to be reduced to an average of one-tenth of the current levels (this means an increase in eco-efficiency by a factor of ten) in the highly industrialized, Western countries. As a first step in this direction, Von Weizsacker, Lovins, and Lovins promote an increase in eco-efficiency by a factor of four (this means one-quarter of current levels). In order to reach this target, co-efficiency improvements will have to be made at four different levels:

1. Step-by-step improvement of the offering of present products (the most relative form);
2. Radical redesign based on existing concepts;
3. Product alternatives (other concepts or replacement of products by services); and
4. Design for the fully sustainable society (the most absolute form).

Initiatives have already been taken within the industry to increase the average eco-efficiency of products. Most of these efforts focus on step-by-step, cost-effective environmental improvements of existing working methods, products, and services within a time scale of one to three years. Various techniques and methodologies have been developed to analyze and assess the environmental merits of such product improvements related to level 1.

Incremental improvements provide significant progress in the early stages by capitalizing on "low-hanging fruit" (the easy improvements). After that first period, incremental changes become less profitable in terms of both economic and ecological efficiency. Then, more far-reaching environmental improvements begin to deliver a higher reduction in environmental impact at relatively lower costs. These latter improvements usually require more fundamental, strategic choices both in the techno-economic and cultural senses. However, focusing on such more far-reaching environmental improvements can elicit innovations that may enhance the competitive position of the company by cost reduction and/or higher market shares.

If one wishes to reach the target of a tenfold increase in the average eco-efficiency mentioned above, more far-reaching improvements related to levels 2, 3, and perhaps even 4, are therefore necessary. Contrary to incremental improvements, relatively little experience has been gained within the industry with the implementation of such product improvements. At Philips Sound & Vision more and more attention is being paid to these more far-reaching improvements under the heading of "strategic environmental product planning." Experience is being built up, especially in environmental product improvements at levels 2 and 3.

For the design for the fully sustainable society (level 4), no comprehensive concepts are available yet. Rather than concentrating on this most absolute form of sustainable development, Philips Sound & Vision has chosen to focus on those matters which can be realized now. The philosophy is: Let's first learn to walk, then start running and, after a lot of training, we will finally be able to win the marathon.

This article will report on the way that Philips Sound & Vision has set up its strategic environmental product planning and how involvement has been created across the organization. After an introduction to the history of the

environmental policy developed by Philips Sound & Vision, a methodology will be presented on how to cope with strategic environmental product planning. This methodology, developed at Philips Sound & Vision, will be illustrated using a number of practical examples. The article then reflects on how strategic environmental product planning can be structurally integrated within the business. In a concluding paragraph, the application of this strategic approach is evaluated in terms of the merits both for the environment and the business itself.

The Environmental Policy of Philips Sound & Vision

Philips Sound & Vision is part of the Philips Sound & Vision Business Electronics division. This division is one of the eight divisions of Philips Electronics. Philips Sound & Vision consists of three business groups: BG TV, BG Audio and BG IR3 (VCR). Every BG has its own environmental coordinator, and most industrial facilities have also appointed an environmental coordinator. The Environmental Competence Centre (ECC) was established in the early 1990s to coordinate environmental activities within the whole Sound & Vision/Business Electronics division. The Environmental Competence Centre cooperates closely with the Corporate Environmental & Energy Office (CEEEO) at corporate level. Philips's corporate environmental strategy is based on a series of initiatives at both corporate and product division (PD) level and aimed at ensuring that the company's environmental policy is properly implemented.

In 1991, the former CEO of Philips, Mr. Timmer, formulated eight environmental objectives to be achieved:

Corporate projects: Setting operational targets

- Implementation of certifiable environmental management systems (according to the BS 7750 and ISO 14001) by the year 2000.
- 25 percent reduction in energy consumption by the year 2000.
- 15 percent reduction in packaging materials by the year 2000.

Product division programs: aimed at improving products and the exchange of information

- EcoDesign, as an integral part of the product creation process.
- Communication strategy.
- External lobby.
- Internal network.
- Supplier requirements.

Besides the reduction of energy consumption and packaging materials, the implementation of the ISO 14001 standard and related items in the ISO 14000 series forms a major spearhead of the corporate environmental program. Philips is preparing all of its 250 plants in 60 countries for ISO 14000 certification by the year 2000 through a hands-on training program. The objective of this training program is to develop a list of what the factory is doing right, along with a list of what still has to be done for the plant to be certified. Philips Electronics's CEEEO coordinates these activities.

Ultimately, at PD level the eight environmental objectives have to be implemented. Every division, including Philips Sound & Vision, has built up experience in the environmental field since the 1970s. In the 1970s and 1980s, the emphasis in the environmental policy of Philips Sound & Vision was on incremental improvements, especially in its production processes. The major driving forces behind this were legislation and regulation, and the associated rules concerning licensing. Since the early 1990s, the focus has widened to encompass improvements in the consumer electronics products themselves. An initial driving force for this was the corporate environmental policy formulated by Mr. Timmer. Another reason was the growing public pressure to find socially responsible ways of disposing of used consumer electronics goods. Additional factors were the (professional) customers' requirements with respect to the use of certain chemical substances and the short-term cost-effectiveness of some environmental improvements (e.g., through material saving, application of recycled material).

In recent years, Philips Sound & Vision has initiated numerous activities to improve its products from an environmental perspective. A manual on environment-oriented product development ("eco-design") has been produced for designers. The manual includes mandatory environmental requirements for design, and voluntary guidelines

to stimulate creativity for eco-design. For instance, a major project is being carried out to reduce the number of environmentally harmful substances in consumer electronics products. One example of this is the decision to stop using flame retardants in the plastic housing of televisions (which, in contrast to other brands; has been the case with Philips televisions since 1987). In addition, the manual contains guidelines concerning the best ways of designing consumer electronics products so that they can be reprocessed in environmentally sound ways at end-of-life. Training programs and workshops are organized to transfer environmental expertise to those responsible for product development. All these activities have taught the organization that environmental improvements can lead to a win-win situation, in which business opportunities can also be created.

Based on this learning process, Philips Sound & Vision is now turning attention to more far-reaching and complex solutions, aimed at radical redesign based on existing concepts and at product alternatives (level 2 and 3 improvements). In that context, it has developed the concept of the "green television," which incorporates all the accumulated environmental know-how of the moment. This concept will be used as a measurement for future generations of the product.

After gaining some experience with the design of these more far-reaching environmental product improvements, the company recognized the need to structure the way that decisions about strategic environmental product planning were prepared. No guidelines or rules of thumb existed for determining how to select promising environmental opportunities. The question arose of how the company could systematically elaborate its strategic environmental opportunities and decide which ones to take on board. Until recently, this had not been a prominent issue at Philips Sound & Vision.

Thus, originally the business strategy to be followed by Philips Sound & Vision was relatively simple: a defensive strategy in order to meet existing environmental regulation and covenants, or a cost-reduction strategy aimed at improving the environmental performance in a way that realized short-term cost savings. However, the strategy became more complex as Philips Sound & Vision began to introduce more far-reaching environmental improvements. The growing interest in this latter type of product improvements went hand in hand with the adoption of a third strategy. This latter strategy aimed at a more competitive market position through increasing its market share and improving its public image. Identifying promising environmental opportunities and selecting those options turned out to be much more complicated in this case. It required clear strategic choices with regard to the environmental issues that it wants to boast in the market. Not only Philips Sound & Vision but also most other companies had little experience with such a strategy.

The STRETCH Methodology

To generate and select green opportunities a methodology called Selection of Strategic Environmental Challenges (STRETCH) has been designed and tested at Philips Sound & Vision. The basic questions that needed to be answered were: What opportunities or threats does the environmental issue present for a company such as Philips, particularly for Sound & Vision? What technological options are available for dealing as adequately as possible with environmental problems? And finally, the most crucial question: *Which environmental opportunities should be selected to enhance the business and improve the environmental performance of its products?*

In order to address these questions, data are needed on the key drivers that will determine the future business strategy in general. For instance, in the case of Philips Sound & Vision the collection of data consisted of information about economic factors (i.e., future market perspectives of the consumer electronics sector in general and of the company itself) and the technological innovations to be expected. Moreover, some information was needed about cultural trends and the possible set of environmental issues at stake in the future. On the basis of this information, a limited number of plausible scenarios can be formulated relating to possible future product market strategies. These scenarios are used to help prioritize, select, and finally implement the most promising environmental challenges to be adopted by the company.

The STRETCH methodology consists of the following five activities:

Step 1: the identification of the crucial driving forces that will influence the business strategy in general;

Step 2: the design of a limited number of plausible scenarios that I, leading to a list of potential product market strategies; the company can adopt on the basis of step

Step 3: the specification of potential environmental opportunities and threats for each scenario on the basis of a checklist of environmental design options;

Step 4: the selection of environmental challenges per product leading to a substantial improvement of its environmental performance (in the order of magnitude of a factor of 4);

Step 5: the implementation of the environmental challenges ultimately selected.

Step 1: Identification of crucial driving factors

The kind of data to be collected about the key drivers determining future business strategies in view of environmental issues largely depends on the industrial sector at stake. Within larger companies, a specific key group often works on strategy development and assists management in strategic decision making. These key people use various sources, techniques, and methods to acquire insight into the technological trends and the present and plausible future market position of the company in relation to its competitors. They are crucial sources of information and can provide relevant documents and oral information. Moreover, additional information and viewpoints should be collected through literature and interviews.

Information about future cultural trends can be acquired via specialized trend labs that systematically monitor changes in consumption patterns and cultural preferences. Key experts in assessing future societal trends can also be interviewed. For companies producing end products in particular, information about future cultural trends, together with focused marketing research per product, forms an important ingredient of their market strategy.

Step 2: Design of plausible scenarios

The information collected in step 1 is then to be interpreted in a time scale of one to five years (or beyond, depending on the particular strategy of the company). A useful instrument for doing this is the method of scenario analysis. Larger companies often analyze their future market perspectives with the help of sector scenarios. A scenario is not a prediction, but a systematic way of thinking effectively and creatively about the future. It is an instrument for designing views of plausible future situations in which decisions will work out. Sector scenarios generally consist of the following steps:

- Identify uncertainties in the sector (e.g., number of competitors, strategies of parties, new products, cost structures, demand level, and environmental pressure on society).
- Determine factors that cause these uncertainties (e.g., technological changes, users' needs, innovations, government policy, and competition).
- Formulate assumptions about the main causal factors.
- Compose a limited number of consistent scenarios.
- Describe the possible consequences of each scenario for the sector.
- Formulate the kinds of competitive advantages (e.g., operational risks, feasible profit margins, investment needs, and growth in turnover).
- Formulate possible consequences for competitive behavior (e.g., price and cost strategy, differentiation).

With the above procedure, companies can anticipate future threats and opportunities, taking into account their own weaknesses and strengths. Due to the many uncertainties involved in this process, the development of a limited number of plausible scenarios can help in selecting the ultimate business strategy. On the basis of these sector scenarios, companies are able to derive their own long-term strategic planning (including promising product market strategies).

Step 3: Specification of potential environmental opportunities

In this third phase, the crucial choice is made on the initial selection of promising environmental challenges. In order to make this selection, the product market strategies developed in step 2 should be related to potential environmental threats and opportunities.

The particular environmental issues which will be headline news in the coming five years, or even beyond that, cannot be predicted with great precision. The ECC of Philips Sound & Vision has therefore developed a general

checklist of environmental product design options that serves as a guideline for prioritization (see **Exhibit 1**). This checklist has been compiled on the basis of various sources.

This checklist of environmental design options can serve as a tool to assess the environmental challenges at stake when a company implements the product market strategies formulated in step 2. The central question to be answered is how to substantially improve the company's environmental performance and at the same time improve its competitive edge in the market.

To generate creative ideas brainstorming sessions can be a valuable instrument. These brainstorming sessions are preferably held first at PD level in order to gain a bird's eye view of promising environmental strategies at division level. To specify the most promising environmental design options at this level the support team should be organized from key persons from within the organization (for example, representatives of strategy development, product management, marketing, and the environmental department).

Exhibit 1. Checklist of Environmental Design Options

Minimization of production impact

- Minimization of waste, emissions, and energy use
- Respect for biodiversity

Minimization of product impact

- Reduction of toxic substances
- Minimization of materials consumption (e.g., through miniaturization, weight reduction, systems integration)
- Minimization of use of non-renewable resources
- Minimization of fossil energy consumption (e.g., through energy efficiency and durable energy use)

Efficient distribution and logistics

- Produce where you consume
- Direct distribution to consumer

Intensity of use

- Lease vs. sell
- Collective use

Durability of products

- Reuse
- Technical upgrading
- Longer lifetime
- Reparability
- Refurbishing
- Aging with quality

Recyclability of materials

- Reduction of materials diversity
 - Materials cascading
 - Design for disassembly
 - Selected, safe disposal
-

Step 4 Selection of environmental challenges per product

In step 4, the preliminary choices of the most promising environmental design options made at division level should be discussed with the various Business Groups (BGs) or Business Units (BUS). In the end, each BG or BU needs to select its own priorities and further elaborate the most promising environmental challenges.

In principle, there are two ways to proceed at BG/BU level. The quickest way is to review the environmental design options initially selected at division level and pick out those options that are most relevant for that particular BG/BU. Next, focused brainstorming sessions can be organized to elaborate each option in great detail, together with relevant specialists. The results of these sessions can be translated into R&D and/or concrete product development plans.

The second, more time-consuming way, is to organize an intensive brainstorming session per product. In this case, one does not take the initial selection at division level as a starting point for further elaboration but just as an initial input for the brainstorming session at product level. During such a brainstorming session, which usually takes about two days, all environmental design options are taken into account one after the other. The result will

be a well-underpinned list of creative options to enhance the business through specific environmental challenges. Depending on the product at stake, specific representatives from the organization can be asked to attend the brainstorming session. These can be marketing people, product managers, and technical people. However, other stakeholders, key suppliers, or customers can also be involved in specific issues. After the brainstorming session, the most promising ideas need to be further investigated in the form of projects with the help of specific experts from the company. Small experiments can also be set up to test the economic viability of specific strategies. In principle, the brainstorming sessions organized at BG/BU level should be prepared by collecting key data about the product and its market and technological perspectives and the environmental performance of the present product.

One of the first companies to try structuring brainstorming sessions aimed at eco-efficiency improvements by a factor of 4 is Dow. The way in which this company designed the brainstorming process has been an inspiring example in developing our own methodology at Philips Sound & Vision and is now being used at Philips also.

Step 5: Implementation of those environmental challenges ultimately selected

On the basis of the step 4 results, management should decide on the environmental challenges to be implemented in the organization. The management should select those opportunities that seem promising both from a marketing/economic and an environmental perspective. After this selection, each strategy requires its own implementation trajectory (at Philips called "roadmap"), depending on the kind of improvements to be made.

Application of the STRETCH Methodology within Philips Sound & Vision

The STRETCH methodology described above has proven to be of practical use at Philips Sound & Vision. After collecting and integrating available data (steps 1 and 2 of the methodology) the ECC of Philips Sound & Vision identified a number of promising environmental strategies (step 3). To prioritize these strategies, the ECC organized brainstorming sessions with representatives of various key persons at Philips, namely representatives of strategy development at the Sound & Vision division, representatives of Philips Corporate Design and environmental experts from the Sound & Vision division.

This group of people then formulated a number of criteria to guide the process of prioritization. These criteria were:

1. Environmental improvements should preferably provide a business opportunity or competitive advantage.
2. Projects should have clear environmental relevance.
3. Environmental improvements should preferably be quantifiable.
4. Environmental problems directly related to health and safety issues require more attention.
5. Implementation should not be hampered because of difficulties in cooperation with third parties or because of lack of expertise within the company.

With the help of the criteria mentioned above, the brainstorming group made an initial selection of promising projects. This led to the selection of nine projects for further investigation. These projects are related to the following technological options:

- minimization of raw materials, toxic substances and energy consumption;
- further increase in material recycling;
- optimizing the life of the product (e.g., by recycling the product or components, technical upgrading);
- improving the efficiency of distribution of the product;
- finding alternative ways of performing the present function of the product.

The environmental coordinators of each of the three main BGs within the Sound & Vision division were asked to select projects that were considered relevant for their BG. Each BG selected five projects. Together, the BGs covered all nine projects. Within the framework of each project, brainstorming sessions were organized with relevant persons from the particular BG, including product managers, marketing people, and technical experts. Although the general approach of the ten projects was similar, the elaboration of each topic was tailor-made to each BG

and each project. Let us illustrate this point on the basis of the following three examples:

- The reduction in the energy intensity of Consumer Electronics products;
- The reduction of the material intensity of Consumer Electronics products;
- The development of potential strategies to enhance the durability of products.

With respect to the item “reduction in the energy intensity,” an intensive brainstorming session was held in the BGs TV, Audio, and VCR in order to generate and select more far-reaching environmental improvements in the energy consumption during use and standby. As improvements could be made in various parts of the product (e.g., in the components or in the printed circuit board), experts from various backgrounds were present at these workshops. The options that these experts proposed are currently being elaborated in a technical, economic, and marketing sense.

Secondly, “the reduction of the material intensity of Consumer Electronics product” was also elaborated in a specific way. In order to generate options for the reduction of material intensity, close cooperation was established between Philips and one of its main suppliers of materials. Various brainstorming sessions were held to identify promising alternative materials that are lighter, but at the same time have the appropriate functionality for fulfilling the demands on the product. The results of these brainstorming sessions are currently being elaborated in R&D projects.

The project related to “the development of potential strategies to enhance the durability of products” was elaborated in a slightly different way. First, a summary of the potential options for optimizing the life of products was made on the basis of a literature survey. Next, the capability of Philips Sound & Vision in meeting these options as a way to achieve further optimization of the life of its products was assessed. At this stage, it was found important to gauge the view of the outside world on this matter. To this end, Philips Sound & Vision's ECC in The Netherlands organized a brainstorming session with external stakeholders that was attended by 15 representatives from environmental, consumer, and women's groups, from the Ministry of Housing, Physical Planning and the Environment, and the Ministry of Economic Affairs, from relevant research institutes and from Philips.

The participants at this session were asked which five (not more) activities they thought Philips Sound & Vision should give the highest priority in the context of the theme of “optimizing product life.”

The reactions of the participants suggested a clear prioritization. Particular attention was given to the following topics:

- Making more robust constructions.
- Designing modular constructions.
- Selling the use of products/leasing.

These results were presented in brainstorming sessions with the BGs Audio and VCR. Establishing which additional methods stand a good chance of success in the future of Philips Sound & Vision is currently part of further internal consultation and investigation. Initial results show that products usually break down due to thermal problems (too high temperature) or defective components or joints. Only after more information has been gathered on the various advantages and disadvantages of improving the durability of the products will Philips take concrete action.

The three examples clearly show that it usually takes a number of brainstorming sessions and specific R&D initiatives before a final assessment is made of the most promising environmental opportunities to be implemented. Through these sessions and specific projects, learning experiences are built up that are used to reduce the present uncertainties about environmental opportunities and market perspectives. When the company has learned more about these more far-reaching environmental improvements, it becomes easier to integrate these endeavors into the regular product development process.

The Structural Embedding of Strategic Environmental Product Planning

The selection of promising environmental challenges, as described above, is one of the two main pillars of strategic environmental product planning. The other pillar concerns the structural embedding of this endeavor within the

organization. In practice, this is an even harder job than identifying and selecting strategic options. It requires a strategic way of thinking about environmental issues within the organization, especially at senior management level. In fact, it requires environmental issues to become an integral part of the strategy development and marketing of new products. Achieving this involves a process of cultural and organizational change that takes time.

Within Philips Sound & Vision, integration of this kind is also a new phenomenon. In the past, major attention was focused on incremental environmental improvements that were usually made at the operational level. Now that more far-reaching environmental improvements are at stake, the time scale involved has been extended one year to one to five years (and even beyond that). As a result, these improvements require decisions at strategic company level.

The implementation of this strategic approach can be successful only if the environmental aspects are incorporated into the process of product planning as a structural component. Companies usually structure this whole process, from generating to ultimately realizing new products, in a more or less similar fashion. During all phases of this so-called "product creation process" environmental aspects can play a role. Roughly speaking, the following five phases can be distinguished:

1. Generation of first ideas of the new product.
2. Design of drafts of the new product.
3. Proposal of the new product concept.
4. Design and engineering of the new product concept.
5. Development, manufacturing, evaluation of the new product.

At Philips Sound & Vision the product creation process is divided into two main phases: first, the strategy & planning (including "know-how" planning) phase and, next, the product realization process (from concept start to commercial release).

In the first phase, a product/marketing strategy is formulated, and the architecture and standard design planning is derived from this strategy. In the second phase, various quality controls and validation procedures are carried out by implementing numerous go/no-go decisions. Each step in the product realization process must conform to a set of standards and release criteria before the next step can be made. In this second phase, major changes in the product design cannot be implemented. Such decisions need to have been made in the first phase.

In the context of the structural embedding of STRETCH three major actions should be undertaken. The first action at Philips Sound & Vision was the integration of environmental goals into an early phase of the product creation process. Although it may seem simple to do, it requires enormous effort to promote this integration within the existing organization.

First of all, the written procedures already in place should be evaluated with regard to environmental aspects. Where necessary, these procedures should be reformulated in order to incorporate the environmental items to be taken into account. This requires cooperation between the various people responsible for such procedures. At Philips Sound & Vision various interviews were held to explore the way in which environmental aspects can be incorporated into the written procedures. As this division was in the process of restructuring the procedures of the product creation process in the context of the so-called "SPEED" project, the environmental aspects were included in this procedure. This led to the incorporation of environmental aspects in all phases of the product creation process.

After having incorporated environmental aspects into the written procedures, the next step is to deploy the environmental responsibilities. This process, currently taking place, is the most difficult part of the integration process. It requires people at various levels within the organization to take environmental aspects into account. This often involves substantial cultural changes to the way people think and act. Changes of this kind take time. A second action to be undertaken is the incorporation of the above procedure into the environmental management systems-ISO 14001 and related items in the ISO 14000 series. Until recently, the environmental management system BS 7750 had a common primary focus on procedures to reduce the emissions of individual plants through process improvements. The integration of environmental issues into product design strategies has received limited attention.

With the current replacement of BS 7750 by the international standard on environmental management systems-

ISO 14001 and related items in the ISO 14000 series-this situation will change. More than the BS 7750, the ISO 14000 series stresses the importance of product-oriented objectives and auditing tools and product-oriented support tools (e.g., lifecycle assessment). Therefore, Philips expects that the implementation of the ISO 14000 series will provide a good framework for environmental product improvements. However, adoption of the standard will not in itself guarantee optimal environmental outcomes.

At Philips, the CEEO is presently elaborating the ISO 14001 standard in such a way that the standard is well suited to the Philips' context. Within the organization a specific quality system already exists, called Philips Quality Assessment (PQASO). Within this particular system of PQA 90 the ISO 14001 standard will be included.

A final action to be undertaken in the context of the structural embedding of STRETCH concerns the attuning of the selected environmental challenges to the general marketing strategy of the company. In order to bring about these challenges, a fundamental change is required in the company's marketing strategy on the environment. The company needs to adopt an aggressive strategic attitude. This is quite different from following a defensive strategy that is designed to comply with all the relevant environmental legislation and regulations. A direct cost-reduction strategy that focuses mainly on measures that provide short-term solutions is strongly supportive but not the heart of the matter. A company that wants to introduce more far-reaching environmental measures derived from STRETCH must make strategic choices as to how the company wants to strengthen its market position by means of a better green profile than its competitors.

Philips Sound & Vision as well as most other companies have hardly gained practical experience with such an aggressive strategy. Exceptions in this respect have been market entrants with market-shaping strategies. They profile themselves from the start as environmentally responsible companies. Good examples of the latter (outside the area of consumer electronics) are companies such as Ben and Jerry's ice cream and the Body Shop. Most companies that have already built up a particular image and tradition have more difficulty in adopting an aggressive environmental strategy. Such companies cannot just change their deeply rooted image, culture, and knowledge overnight for the sake of the environment.

The Sound & Vision ECC has recently started to set up the activities necessary to develop an adapted marketing strategy within the framework of STRETCH. This environmental strategy aims for:

- average to good performances right across the board in the environmental field;
- ensuring sufficient compliance with environmental regulations (in the fields of products and process);
- where possible, yielding money directly from environmental activities;
- outlining a specific marketing strategy, both internal and external, for those environmental items with which Sound & Vision wishes to project a positive image, and converting this strategy into a real marketing and PR strategy in conjunction with the marketers and press officers.

Conclusions

Until now, no structured methodology existed for attuning environmental considerations to the business strategy of companies. The Philips Sound & Vision Environmental Competence Centre has developed a methodology for this purpose. This methodology is called STRETCH (Selection of Strategic Environmental Challenges). The objective of STRETCH is to incorporate environmental considerations into the business strategy and select strategic environmental challenges in an early phase of business development.

The application of STRETCH provides the possibility of meeting three main objectives:

First, focusing on long-term environmental product design strategies can elicit innovations that may enhance the competitive position of the company. Through the integration of eco-efficiency goals into product innovation in general, a company does not aim to beat the competitors purely on environmental grounds, but on its innovative product strategy in general. In this way, economy and ecology can go hand in hand.

By taking environmental aspects into account at an early stage of product development, more far-reaching improvements can be made in future consumer electronics products compared with the current range of products. The first strategic environmental efforts, like those taken by Philips Sound & Vision, are still more the exception than the rule. This approach, however, could provide a way forward to substantial improvements in eco-efficiency.

Second, the environmental opportunities and threats to be expected in the future can be anticipated in an earlier

phase. Through this early warning system, an attempt can be made to diminish the negative consequences in an early stage and a response will not be required when it is actually too late. In this way actions are more proactive rather than defensive.

Thus, the company can even be one step ahead of all kinds of government demands and public pressure by redirecting product development in the context of sustainability in a more fundamental way. By proactively integrating environmental aspects into the earlier phases of the product creation process, external criticism can be avoided and the lead taken in environmental priority setting.

Third, as a result of more far-reaching environmental improvements even higher eco-efficiencies are expected to be reached than through incremental improvements. At this stage, the exact data on eco-efficiency gains to be realized within the nine strategic projects currently being carried out at Philips Sound & Vision cannot be provided; these will be collected during the execution of the projects.

On the basis of the STRETCH methodology, Philips Sound & Vision has prioritized nine projects for further investigation. Through the performance of these projects, learning experiences are built up that can reduce present uncertainties about the environmental opportunities and market perspectives. Once the company has learned more about the more far-reaching environmental improvements, it becomes easier to integrate these endeavors into the regular product creation process.

From initial experiences with the application of STRETCH within Philips Sound & Vision, we learned that environmental objectives can be attuned very well to the business strategy. We are convinced that the promotion of this method within the organization can lead to a win-win situation, in which business and environmental improvements can go hand in hand. Moreover, we learned that the implementation of environmental challenges is not only the task of product development departments but of the whole business.

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Rituals and habits, 4

Eh, eh, eh

One of the great things at Industrial Design Engineering is that the graduation is individual (see also *Rituals and Habits, 3*). Part of the exam is that the candidate has to give a presentation about his or her graduation project. It is an important part; if you have good results but you are not able to communicate them to the outside world, this is a serious problem later on in professional practice.

Forty-five minutes are allotted for the presentation. Finishing in less time is not encouraged, using more time could mean that you cannot express yourself in a clear and crisp manner. Rehearsing before can be done with friends and fellow students but not with mentors. At this stage of the graduation project their earlier help is now being judged.

A lot of prospective candidates make a good show of their presentation, some struggle. There is one thing which is very common amongst all the presentations: almost everyone says 'eh' with a frequency ranging from near to zero up to 3 times per minute. Experience shows, that the amount of eh's cannot be correlated with the strength of the presentation. What is relevant however is the frequency distribution. When candidates have not memorized (parts of) their speech or have difficulty in explaining an item, the 'eh' frequency goes up, sometimes upwards of 10 times/minute. Bursts of 'eh' or the absence of it are a powerful yardstick to make proper judgments on the quality of presentations.

Nice story, eh!

4.1.3 The unpredictable 'outcomes of going green'

Strategic Environmental Product Planning has been presented to the organization as 'Ecoefficiency', that is an activity serving both environment and economy. All business groups at that time (Audio, TV, Monitors and VCR (video cassette recorders)) took the idea on board and in 1996-1997 there was huge activity in the field: brainstorm sessions, idea generation, priority setting, implementation etc. It turned out that 'Eco' is a tremendous catalyst for generating a wealth of ideas. Several of these had little to do with 'Eco' itself, showing that looking to products from an environmental perspective generates a much wider catalogue of improvement opportunities. This experience led to the proposition that "Eco is a new perspective to look at often old problems, often yielding results which go far beyond Eco". It was true and it is still true and in my opinion this is the best reason to provide a budget for environmental departments (provided that they play this catalyst role properly).

How 'STRETCH' worked out is documented in the following paper "*The Unpredictable Process Of Implementing Eco-efficiency Strategies*" for the three business groups (at BG Video Cassette Recorders). Things took a different turn after the advent of Digital Video Disk Players. Ecodesign investment went into the new DVD players rather than into the older VCRs. Of all the strong results reported here, there was one shocking outcome of these activities: no matter how 'Eco' creative you are, almost irrespective of your environmental know how, external factors which have little to do with the environment ultimately determine to a large extent the results of an 'Eco' drive.

When this was realized, this led to an important paradigm shift: for 'Eco' success the first thing to do is to actively manage internal and external business processes. A new buzzword was born: INTEGRATION. This was a watershed also in a different way; it was the moment when most of the EcoDesign approaches used in academia and other research institutions and proactive industry started to diverge (see chapter 2.1).

The Unpredictable Process Of Implementing Eco-efficiency Strategies

Jacqueline Cramer and Ab Stevels

I. The promising potential of eco-efficiency

A growing number of companies are aware of the need to take the environment seriously. They realise that the environment should not be seen as a threat, but as a challenge for business. Some scientists even argue that we are on the eve of an 'industrial transformation' that can lead to a sustainable development for society. These predictions are perhaps too optimistic. But undoubtedly, companies are currently making tremendous strides towards sustainable development.

The most important sustainable development trend within industry is the increasing attention being paid to eco-efficiency (DeSimone & Popoff, 1997). This concept of eco-efficiency was introduced by the World Business Council for Sustainable Development, a group of prominent companies. They define the concept as follows: "Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity." (WBSD, 1995)

So eco-efficiency means not only *ecological* efficiency, but also *economic* efficiency. It makes a direct connection between ambitious environmental targets and enhanced market opportunities. A number of companies, including Philips Electronics, Akzo Nobel, and Dow are making efforts to put the eco-efficiency approach into practice (Fussler, 1996; Cramer and Stevels, 1997; Cramer, 2000). Their experiences teach us that this approach fundamentally differs from the environmental management approach that is pursued by most companies. First of all, it involves a chain-oriented approach requiring more communication and co-operation between partners in the product chain (for instance, between suppliers and customers). The eco-efficiency approach is also much more strategic in nature than the more operational environmental management approach currently in place in most companies. More eco-efficient products should also be economically attractive as well as serve long term goals. Consequently, the environment becomes part of a company's strategic planning and requires a greater involvement of management in environmental policy.

Experiences gained so far with the eco-efficiency approach have shown that it is perfectly possible to create win-win situations. Eco-efficiency improvements can lead to cost reduction, strengthen the market position of existing products, extend the product range and create new markets, avert criticism from external stakeholders, and increase the possibility of the company's survival in the long term.

There are many examples of companies that grasp these market opportunities. For instance, automobile manufacturers are investing in research and development on fuel efficiency and vehicle recycling in order to strengthen their competitiveness and improve their environmental image. Societal pressure to reduce the environmental burden of vehicles has forced the industry to develop such innovative solutions. As a result, they are offering competitive advantages for eco-efficiency improvements.

In other cases, the eco-efficiency approach has led to substantial cost reductions. For example, Philips Medical Systems has realised a tremendous reduction in material consumption for one of its medical instruments, the MRI. This redesigned instrument weighs 35 tonnes less, resulting in a transport cost reduction of 50 per cent. Moreover, the product is easier to dismantle and recycle than the original instrument.

Another example is the carpet producer Interface. A total of 40 factories have saved about USD 60 million by reusing and reducing waste. The Canadian electricity company Ontario Hydro was also able to save USD 37 million through energy-efficiency improvements alone (Cramer, 1999).

A last important example is Xerox, a major producer of photocopiers. The company set a goal of using as few natural resources as possible, which meant focusing on reusing and recycling waste materials. Old copiers are now being "remanufactured" and their spare parts reused. In 1995, this strategy led to a cost savings of USD 12 million in the recycling program and USD 50 million in the spare parts recycling program (Elkington, 1997, p. 314).

These examples illustrate the promising potential of eco-efficiency.

However, it is not possible to determine in advance what marketing and strategy opportunities will ultimately present themselves. This will only become evident during the change process, since this involves innovations whose outcome is often unpredictable. The identification of promising eco-efficiency improvements is, therefore, more of a search process than a well-defined development path. This point will be illustrated below on the basis of the experience gained by Philips Consumer Electronics in strategic environmental product planning.

2. Strategic environmental product planning within Philips Consumer Electronics

Since the early 1990's, the environmental policy of the Philips Consumer Electronics division (PCE) has evolved from a purely process orientation towards a focus on consumer electronics products themselves. An initial driving force for this was the corporate environmental policy formulated by the former CEO, Mr Timmer. Another reason was the growing public pressure to find socially responsible ways of disposing of used consumer electronics goods. Additional factors were the demands made by professionals and consumers regarding the use of certain chemical substances and the short term cost-effectiveness of some environmental improvements (i.e., through material reduction, application of recycled material).

Since 1990, PCE has introduced a number of measures to improve its consumer electronics' products incrementally. For instance, a major project was carried out to reduce the number of environmentally harmful substances. Based on this experience, PCE turned its attention in 1995 to farther reaching, strategic environmental improvements aimed at product alternatives and a radical redesign based on existing concepts. To structure this strategic approach, a methodology was developed, called STRETCH, an acronym for *Selection of Strategic Environmental Challenges* (Cramer and Stevels, 1997).

STRETCH represents a similar view to the one expressed by Hamel and Prahalad in their book *Competing for the Future* (1994). Instead of looking defensively for the right 'fit' among its own business operations and between them and external environmental demands, a company must make room in its business strategy for 'stretched' objectives (Cramer, 1999). Therefore, the basic idea behind the STRETCH approach is that the selection of promising eco-efficiency improvements over the whole lifecycle should be attuned closely to the Business Groups' (potential) business strategy and to the future demands of external stakeholders, including those of its suppliers and customers. In order to ensure that the STRETCH approach becomes an integral part of the general business planning, it has to be embedded structurally in the organisation and attuned to related activities (i.e. ISO 14001). The STRETCH approach was tested first at PCE and later at Akzo Nobel. It can be stated based on their learning experiences that the STRETCH approach consists of the following six steps:

Step 1: Survey the unit's (potential) product/market strategies and the most important driving forces determining business strategy in general.

Step 2: Monitor new developments and trends in the environmental debate and changes in influence exerted by external stakeholders.

Step 3: Identify potential eco-efficiency improvements that can be made in the product chain.

Step 4: In light of the previous steps, select eco-efficiency improvements leading to the development of promising market opportunities or preventing potential market threats, then formulate an action plan for short-term and long-term eco-efficiency improvements in the product chain.

Step 5: Embed the STRETCH approach in the organisation.

Step 6: Bring the results in line with related Business Group activities, i.e. ISO 14001 compliance, product stewardship, and product development.

The implementation of STRETCH started at PCE with the collection and integration of available data (steps 1, 2 and 3).

Subsequently, representatives of strategy development and environmental experts from the Consumer Electronics division and representatives of Philips Corporate Design made an initial selection of promising project themes.

Nine project themes related to the following technological options were selected for further investigation:

- Minimising raw materials, toxic substances and energy consumption;
- Increasing further material recycling;
- Optimising product life (e.g. by recycling product components and by upgrading technically);
- Improving product distribution efficiency;
- Finding alternative ways of performing the present function of the product (either by applying more eco-efficiency physical principles or looking at more service-oriented systems).

These themes were discussed with representatives of the three main Business Groups (BG) of the Philips Consumer Electronics division: TV, Audio and Monitors. Each BG had to select four to five themes for further investigation. Within the framework of each BG, brainstorming sessions were organised with relevant persons from the particular BG, including product managers, marketing personnel and technical experts.

The brainstorming technique used was the one developed by Dow (Fussler, 1996). It centres on brainstorming sessions for teams of experts from different backgrounds aimed at generating promising eco-efficiency strategies. During each brainstorming session, ideas are generated that will reduce the environmental burden of the new product substantially and lead at the same time to promising market opportunities.

Separate brainstorming sessions were held on the particular themes selected by each of the three main BG's. On the basis of each session's results, BG representatives formulated priorities for the development of new, more eco-efficient products. Most of these priorities could not be implemented immediately, but needed to be further studied both from a technical and a business perspective. As will be shown below, it took sometimes two to three years after the brainstorming sessions began before their results were visible in the regular product planning process. It was impossible to predict which of the ideas generated during these sessions was implemented in the end. It appeared that the pace and success of the implementation process related mainly to the following five factors:

1. The organisation's culture (i.e. internal factors, such as management interest, environmental skills, cross-functional linkages, personnel motivation);
2. The business conditions (i.e. profitability, market share);
3. The degree of environmental influence exerted by external stakeholders, (customers, authorities);
4. The available room to manoeuvre regarding product housing and functionality in relation to combined environmental and economic gain;
5. The degree to which the environment can be used to gain a competitive edge.

The relevance of the five factors mentioned above could be assessed by each BG at the introduction of the eco-efficiency approach. However, this information was insufficient to formulate firm conclusions about the success or failure of some of the promising eco-efficiency improvements selected during the brainstorming sessions. For each case considered, the road towards implementing eco-efficiency improvements turned out to be a special journey with its own specific characteristics. As will be shown in the PCE cases (i.e. Monitors, Audio and TV), the results were quite unpredictable both in terms of achievement and time.

3. Catalysts for eco-efficiency improvements at the start of the brainstorming sessions

In order to clarify the potential responsiveness to eco-efficiency improvements within the BG's Monitors, Audio and TV, the authors have presented below an overview of the main catalysts for eco-efficiency improvements at the start of "STRETCH" brainstorming sessions in 1996-1997:

Table 1 Catalysts for eco-efficiency at the start of STRETCH brainstorming sessions (1996-1997)

	Monitors	Audio	TV
1 <u>Internal factors (culture)</u>			
Management attention	Strong	Weak	Moderate
Environmental skills	Fair	Fair	Good
Cross-functional linkages	Good	To be improved	To be improved
Eco-efficiency activities already in place?	Limited program	Small program	Extensive program
Personnel motivation	Good	Good	Good
2 <u>Business conditions</u>			
Profitability	Good high	Marginal low	Moderate
Market share	Growing	Recovering	High
3 <u>External influences</u>			
Customer pressure	Strong	Absent	Moderate
Legislation	Weak	Absent	Strong
4 <u>Room for manoeuvre</u>			
Product functionality	Good prospects for win-win	Moderate scope for win-win	A lot of improvements already realised
Product alternatives	Alternative is different (LCD screen)	Different physical principle (wind up radio)	Physical principle (LCD screen)
5 <u>Competitive edge</u>			
Competitive environmental benchmarking done?	Yes	No	Yes
Is competition active?	Yes	No	Starting

It can be concluded from table 1 that the internal factors differ greatly in the three BG's. In the Monitors group, a member of the Management Team had made himself a 'defender of the environment' and was pushing hard for results, in particular for a combined customer and environmental benefit. Due to the high motivation of the employees involved, a good cross-functional linkage could be established and the existing backlog in environmental skills could be reduced. This led to an acceleration in eco-efficiency activities in a short period of time.

In 1996-1997, management's interest in eco-efficiency activities was weak in the Audio group. At that time major attention was being paid to the first results of a turnaround program. All efforts were being put into further implementation of the restructuring programs. The environment was 'alive' but had a low profile. However, after the business results had become healthier, effective product and program managers stepped in and achieved good results.

The TV group had already an extensive eco-efficiency program in place. As a result the group scored well in environmental benchmarking. However, this turned out to be more of a disadvantage than an advantage for further progress: apart from a strongly motivated environmental manager located in the development department, the TV group showed otherwise moderate interest, particularly the marketing department.

Furthermore, the three BG's' business situation was completely different in 1996. Monitors had developed a profitable business, enjoyed growing value and market share and had created a good investment position. On the other hand, Audio was still recovering from a slump in 1992-1995. Its restructuring process absorbed almost all the resources and attention of management. TV viewed the environment from a different perspective: due to the good environmental performance already in place this BG could differentiate itself in a market with stabilising volume and over-capacity.

As regards external influences, the Monitor group customers - the big computer companies - exerted strong, tangible pressure both for environmental improvement and lower retail prices; the main customers of Audio and TV are private households who only exert a diffuse pressure. An influential external pressure on TV was the European consumer test magazines that introduced an environmental section in their television evaluations. However, since Philips TV's scored well in these surveys, these tests did not engender further action.

In the field of legislation the debate about manufacturer responsibility and take-back obligations was very heated for TV, marginal for monitors ("the TV issue has not yet been solved, afterwards only it will be our turn") and non-existent for audio ("our products are much smaller and represent a low percentage of electronic waste").

Management's room to manoeuvre on this issue was determined to a large extent by the physical, chemical and electronic prerequisites for realising a certain functionality (pictures, sound, etc.). The environmental improvement potential is therefore dependent on the housing resulting from these factors. Products containing a cathode-ray tube (CRT) generally offer the best scope for eco-efficiency gains due to their relatively high energy consumption and weight. An important difference was that the TV group development department had already taken many initiatives and was even considering aiming to achieve an environmental breakthrough by initiating an environmentally friendly TV project.

Monitors was less advanced but as such the housing offered more potential. Liquid Crystal Display (LCD) screens are an alternative for CRTs and this technology will be environmentally friendlier at a later stage of development. Due to the fact that LCD screens are substantially easier to view, Monitors decided to push ahead with this technology. In TV application the prospect of such a 'flat screen' is attractive. However, for the time being brightness and contrast challenges combined with a high price are serious roadblocks to the introduction of the LCD screen as a consumer commodities on the mass market. Products were planned to be introduced slowly to the market and for high end (superior quality) products only.

For Audio, human-powered radio's were a viable alternative for portable products. In 1996, only the 'Bay Gen' human-powered radio was on the market but was seen by industry leaders as too heavy, unattractive and difficult to operate. The real message ("There are other ways to realise Audio functionality") which this product was sending to the market was not perceived as such by the Audio management. After a heated debate in the Environmental Team, the product manager involved decided not to follow up the human-power avenue for the time being.

Competitive benchmarking had been done in 1996-1997 for both TV and Monitors with completely opposite results. Most TVs scored well in environmental and efficiency performance tests against the competition. For Monitors, the competitive benchmarking results showed an urgent need for improvement. This was even more pressing when the competition started including environmental arguments in their sales pitches. (This was not the case for TV.) Audio started benchmarking two years after the eco-efficiency brainstorming sessions. At this time, a successful turnaround had been achieved and the eco-efficiency success of the other Consumer Electronics groups had been made public.

4. Eco-efficiency brainstorming sessions and their impact on product development

To generate ideas for eco-efficiency improvements, each BG management organised brainstorming sessions in 1996-1997. These sessions were prepared by the authors of this article, who were affiliated to the Environmental Competence Centre of Philips Consumer Electronics.

4.1. Monitors

The eco-efficiency brainstorming session for Monitors on the basis of STRETCH took place on 9 September 1997. The BG CEO's message at that time was that "all relevant items had to considered". The management had already approved the inclusion of an environmental paragraph in the BG strategy, and on the basis of this approval and other considerations, Monitors had decided to develop and market LCD-based monitors as well.

Other than this strategic information, data obtained through a thorough environmental benchmark on 17-inch monitors formed a solid basis for a creative brainstorming session. In total some 25 to 30 main environmentally friendly options were generated and ranked in the so-called Eco-design matrix. (See below.)

Green Options	Benefit				Feasibility	
	Environmental	Business	Customer	Societal	Technical	Financial
First option						
Second option						
Third option						

Figure 1 The Eco-design matrix

In this matrix, the columns were filled in from left to right. First of all, management checked whether the proposed environmentally friendly options actually contributed in a positive manner to the environmental performance of its product. A positive score was preferred for the other columns as well, which served primarily as a tool for ranking priority from a business and feasibility perspective. With the aid of the eco-design matrix, management selected 12 main options for further investigation, of which seven were incorporated in a new product concept approved in January, 1998. Due to the fact that the concurrent engineering started in the autumn of 1997, the product creation period was to be fairly short. In May 1998, the new product, the A580BQ Brilliance Monitor, was launched. It was a huge success due to its favourable product characteristics and its environmentally friendly characteristics, evident in the table below:

Table 2 Improvements in 17-inch monitor resulting from eco-efficiency brainstorming session (STRETCH).

Specification:	
- Scanning range:	8% increase
- Maximum resolution:	5% increase
- Brightness:	15% increase
Bill of materials (incl. CRT):	12% decrease
Component count:	32% decrease
Assembly time:	35% decrease
Energy consumption:	6% decrease
Material:	
- Weight of plastics:	18% decrease
- Weight metal:	42% decrease
Hazardous substances:	
- PCB total:	decrease from 8 to 6
- Component count:	32% decrease
Packaging weight:	10% decrease
Recyclability:	
- Screw total:	40% decrease

Based on the results in this table it can be concluded that an extremely good result has been achieved with the 17-inch monitor. Contributing to this success (in terms of table 1) were favourable business conditions, strong management support and the positive advantages that could be derived from the Eco-design matrix. These conclusions could only be drawn at the end of the implementation process.

4.2. Audio

The brainstorming sessions for Audio took place from 21 to 24 May 1996. The initiative for holding these sessions had been taken by the Environmental Competence Centre of Consumer Electronics. The Centre had detected a high eco-efficiency potential for audio products. The organisation itself was, however, rather indifferent about the idea. In contrast to Monitors, Audio decided from the very beginning to focus on three areas:

- Standby energy reduction for audio sets;
- Portable audio battery replacement with human power;
- Durability improvement (in particular for audio sets; defined in this meeting as the decrease in environmental load over the life cycle per hour of use).

The brainstorming sessions on the standby energy reduction yielded initially 20 reduction options, of which four were selected. Since the brainstorming session had a more voluntary character compared to Monitors, the results were not phrased as clear proposals to management. This resulted in serious delays in the standby energy reduction program. Environmental benchmarks in 1997 and 1998 indicated that Philips Audio's market position was slightly better than that of the competition. (See Stevels, 2000.) Nevertheless there was still substantial unrealised potential.

Similar conclusions were drawn in 1996 but then business conditions were more favourable than they had been. New product and program managers had effectively taken over and aimed to realise good business results. Moreover, the environmental 'technicalities' were better elaborated and put in clear management perspective: it could finally be shown that the substantial standby reductions were feasible and cost effective. In 1999, the FW870 Audio set was launched with very low energy consumption (0 W in the power save mode; 2 W in the passive standby mode). Moreover, other energy improvements were made with respect to on-mode energy consumption, weight and packaging reduction, etc. The resulting life cycle environmental load of this product is 15 per cent lower than the best competitor in its range. On a life cycle basis, the cost of ownership for the user is approximately USD 35 less than for the best competitor.

It can be concluded based on the standby power example above that apart from more favourable business conditions and motivated managers, technological progress, the definition of an appropriate business rationale, and a value proposition to the customer were crucial to realising the eco-efficiency potential.

In 1996 the ideas for human-powered portable products were examined in a predevelopment study by Philips Corporate Design. This study showed good prospects for audio products. However, housing was not demonstrated due to the lack of interest from Audio.

Almost simultaneously a human-powered radio named Bay Gen was launched. This radio was intended for the reception of information broadcasts in Third World countries where batteries and/or electricity are not available or too expensive. However, this product was soon marketed as an environmentally friendly product in the electronics mass market as well. Although the first product was attractive from the point of view of avoiding the hassles associated with battery use, it received negative reviews from professionals in the field. They talked about the unattractive design, the high weight due to the heavy metal spring storing the energy and the winding crank which did not look very durable, and expressed doubts about its environmental friendliness on a life cycle basis (Jansen & Stevels, 1998). This movement in the market combined with the restructuring of the audio business and the revamping of the product line put on hold the development of a human-powered product within Philips Audio. However, since that time the human-powered radio has been intensively discussed within Audio. After the BG had gone through the turnaround process, the business prospects became more favourable and led to new initiatives. As a result, the decision was made in 1999 to develop a product for mass markets. In February 2000, the Philips AE1000 wind-up radio was launched with the following characteristics:

Table 3 Characteristics of newly developed Philips AE1000 wind-up radio.

	Philips AE 1000 (wind up)	Philips AE 2130 (conventional)	Competitors product	Bay Gen product latest version
Energy Consumption (W)	57	58	90	57
Product weight (g)	350	600	1500	900
Hazardous Substances	0	0	Contains Ni-Cd cell	Wiring contains CD (Cadmium)
Packaging	Cardboard only	Cardboard and 1 kind of plastic	Cardboard and 1 kind of plastic	Cardboard and 2 kinds of plastic
Life cycle load (Eco-indicator mPt)	20	40	25	49

It can be concluded from table 3 that the Philips human-powered portable audio product is competitive in environmental load with both conventional and other wind-up products. In the case of this human-powered product, the progress in product development have strongly influenced competitors' behaviour and internal issues.

As far as durability and possible durability strategies for audio products are concerned, it was concluded in 1996 that insufficient insight existed in these matters. Also due to the input from BG Audio it was decided at the division level to financially support a research project at the Design for Sustainability Lab at the Delft University of Technology. By then, definitions, conceptual models for the influence of product characteristics on replacements decisions and the impact of intensity of use had been published (Van Nes, Cramer and Stevels, 1999).

Recently a case study on audio product durability has been carried out (Smeels, Van Nes and Stevels, 2000). The study proposed conceptual designs that have a 60 to 75 per cent lower environmental load over a period of 15 years for the full audio functionality (including DVD), compared to traditional products with the same function.

In conclusion, the Audio case shows how unpredictable the eco-efficiency improvement process can be. At the start of the brainstorming sessions the potential was high, but the interest of management limited. In the course of time, the responsiveness of the BG increased due to the combination of factors as described above.

4.3. TV

The eco-efficiency brainstorming sessions for TV, initiated by the development department, took place on 2 February and 10 May 1996. An important catalyst for organising these sessions was the participation of one of the preferred plastic materials suppliers. In these brainstorming sessions, Fussler and James' approach was closely followed (Fussler and James, 1996). All fields of the eco-fitness compass were considered: raw materials, manufacturing, distribution, use and end of life. The following subjects were prioritised:

- Materials and manufacturing: future housing designs;
- Materials and manufacturing: alternatives for the current glass based CRT;
- Recyclability: 100% recyclable TV.

Thirty-eight ideas were generated in the field of future housing designs. In the first session, these were reduced to 24 and a further selection brought this number down to seven. The endeavour to find alternatives for the current glass-based CRT resulted in the proposal to investigate the feasibility of a plastic picture tube. For this project, 21 items to be researched were defined. For full recyclability there were initially 12 ideas.

By the summer of 1996, further progress on the eco-efficiency brainstorming sessions and other related efforts were strongly influenced by TV management, who decided to consolidate all eco-efficiency efforts into one effort: the 'Green TV' project. In this project the chemical, physical and electronic limitations had to be explored based on the existing concept of a glass CRT.

As a result of this decision, the proposals for future housing and for 100 per cent recyclability got a clear boost. However, the planned feasibility study on a plastic CRT was replaced by efforts to reduce the products' further energy consumption. The output of the eco-efficiency brainstorming sessions and the contributions from other sources (e.g. the TV development department) led to the huge success of the Green TV, having the following performance results:

Table 4 Achievements of 'Green TV' compared with standard TV (1996)

Energy consumption reduction	39%
Plastic weight reduction	32%
Hazardous substance reduction	100%
Recycled material	69% (of total weight)
Recycling potential	93%
Reduction of life cycle environmental load	30%
Reduction of cost price	5%

The strategic success of the Green TV was primarily that 'it could be done'. As such, it was one of the powerful impetuses for the Philips-wide "Eco Vision Program" (Stevens, 2000).

The technical success of the Green TV was that after 1996 many inventions and improvements to the Green TV concept have been introduced in conventional products, qualifying the best of them now as 'Green Flagships' - products with superior environmental performance.

However, the Green TV was never brought to the market due to the fact that the environment value chain had not been properly addressed (Ishii and Stevens, 2000). The reasons for this were:

- A lack of clear value propositions to the potential customer;
- An unclear product line-up positioning at that time;
- Insufficient involvement of suppliers;
- Insufficient attention to the consequences for production (investment, factory layout);
- Problems with logistics (e.g. availability of recycled material).

For the TV group, it can be concluded that the brainstorming sessions for implementing eco-efficiency strategies worked out in a different way than originally anticipated. Instead of leading to technology-oriented projects, the improvement options were merged into advanced product development activities. Moreover, the corporate strategy and program development were strongly affected by the outcomes of the brainstorming sessions and other related activities.

5. Conclusions

The examples from Philips Consumer Electronics presented in this article show that processes of implementing eco-efficiency strategies have resulted in a positive but unpredictable outcome.

In terms of achievements, internal factors ('culture') had a strong influence in all three cases. Particularly, management interest, decision-making and cross-functional capabilities were major determinants. This "Internal Value Chain" seemed in fact to be more important than the external one. Moreover, it can be concluded from this study that business conditions, external influences and the possibility to get a competitive edge influenced particularly the time scale on which eco-efficiency was realised. Room for manoeuvre on the issue of product functionality did not play a major role in the case studies. However, if the main thrust is to realise eco-efficiency through radical housing system changes this aspect may become very dominant.

In hindsight, four years after the eco-efficiency programs actually started at Philips Consumer Electronics, it can be concluded that although the paths taken have been different in each case, good results have been obtained. Finally, an assessment of the catalysts for eco-efficiency and an appropriate structuring of the potential environmental and economic benefits can contribute positively to the process of change. However, such activities cannot predict the real outcome of the eco-efficiency programs. In this respect, the implementation of the eco-efficiency approach will remain a real adventure.

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Cities, 4

Bilbao, a city of transformation

Bilbao is in the north of Spain, tucked away in an estuary of the Gulf of Biscay. It is one of the most important cities, or even the most important city, of the Basque Countries. It has a mix of the proud traditions of the Basques and the almost equally proud (but different) traditions of the immigrants from elsewhere in Spain.

It used to be a smokestack city. Iron ore and coal dominated the scene. Iron smelting and the production of products made from iron are still important today, but clearly declining. This also holds for the shipping activities. There are still daily direct flights to the Ruhrgebiet, the cradle of the iron and steel industry in Europe.

When I traveled to Bilbao, my prejudice told me that this could not be a very cheerful experience with its' derelict factories, social tensions, political tensions, and crumbling buildings in the inner cities I expected little.

This turned out not to be true, a lot of the steel industry had been turned into a recycling industry. Looking to their operations the conclusion I drew was regarding their leadership in technology. For example, direct smelting routes of metal rich electronic products was pioneered in the region. The Gaiker Research Institute near Bilbao is considered to be leading in plastics recycling as well.

In the city, slogans and graffiti on the walls looked to be old and were fading away. The new Guggenheim Museum with its remarkable architecture (and content) has been an anchor for urban renewal. Step by step dilapidated buildings are restored and old rubbish is moved away. Progress is impressive; a good balance between new and old will be found soon. For me the visit to Bilbao was much more than just a business trip.

Check your mindset and remember what can be seen in Bilbao. Refresh, develop new ideas and avenues of thought and get rid of the rusty ones in which you have believed so long!

City walk: Start at the head of the abandoned railway station, go R over the Arenal bridge and L to San Nicolas church go to the L at the backside, go R and walk Askao and La Cruz street, pass the two churches (on L and R) wind your way through the "seven streets" as you like, but make sure you end at the river front near Mercado de La Ribera. Cross the Park de San Anton and start here river walk all the way to the Guggenheim Museum.

Favorite restaurant: Restaurante Bikadi, Calle Somera 21 (in the 'Seven Streets' area).

Country walk: Either go with the local Metro (red line, northern direction) to Algorta or Bidezabal, walk along the coast till you find the special geological formations and beyond.

Or: go by RENFE train to Durango, let you take by taxi up to the monastery and walk in the Urkiola National Park surrounding it (recommended in spring).

4.2 Integration into processes

4.2.1 Product Creation Processes

In the period between 1998 - 1999 there was an interesting situation concerning Applied EcoDesign. On one hand activities in this field brought environmental gains as well as cost reductions for the company engaging itself in this field (see also 4.2.2). On the other hand it had become clear that 'green' as such did not sell in the market. 'Green' benefits had to be linked to other items that are beneficial for the consumer (see also chapter 5.4.1)

Although awareness and positive response by the organization were getting better and better, real positive outcome of Eco-drives were by no means sure (see chapter 4.1.3). Moreover, when management in a group - which had taken 'Eco' on board - was changed, often the process of confidence building in EcoDesign had to start all over again. Also employees successfully dealing with 'Eco' were moving on to new jobs like everybody today. Through this process a lot of experience was lost.

In order to make the 'Eco' activities more effective, it is therefore necessary to closely integrate EcoDesign into business processes and the ways of working. At Philips Consumer Electronics this has been done by a simple 'add on model'. For each activity an 'environmental paragraph' has been added to existing procedures. In this way all the basic processes (like strategy, product creation, purchasing production, marketing and communication) became environmental. As an example such an add-on scheme is given below for Product Development.

Feedback / continuous improvement	→	Stage 1: Planning	Get facts, prioritize according to benefits and feasibility, align with company strategy, consider environmental aspects, life cycle thinking
	→	Stage 2: Conceptual design	Brainstorming, life cycle screening, consolidate into specification
	→	Stage 3: Detailed design	Applying design approaches
	→	Stage 4: Testing / Prototype	Evaluation of results against targets and specification
	→	Stage 5: Market launch	Release, communication plans
	←	Stage 6: Product review	Consider environmental aspects and effects

Figure 4.1 Generic model of integrating environmental aspects into the product development process

This diagram builds on the existing procedures and simply adds environmental activities to each step. The power of doing it this way is that it introduces EcoDesign as something 'natural'. Simultaneously the effect is that it takes away fear that the usual way of working would be changed or disturbed in some way or another by 'Eco'.

This type of approach has been worked out in much more detail. The publication below gives a full account of it.

Experience has shown that full integration of 'green' into processes has substantial benefits. This could have the danger that a focus on environmental issues could be lost simply through the multitude of tasks which have to be accomplished to be successful in business today. 'Eco' is still immature when compared with business items like quality for instance. Due to this immaturity a special Environmental department is needed to drive further integration internally and to absorb and translate the rapid developments in the outside world (science, regulation, consumer perception). For the same reason specific environmental roadmaps and specific environmental requirements in executive incentive schemes will be needed as well (see also chapter 4.3 and 4.4).

Application of EcoDesign in the Electronics Industry

Ab Stevels

I. Introduction

Environmental care in industry has been in existence for many decades. In the early sixties, the detrimental effects of emissions to air, water and soil was recognized at a global scale and since that time legislation, regulation and voluntary programs have been initiated to abate pollution.

For more than twenty years the main focus has been on production processes and hence on industry sectors involved in basic production (chemicals, materials like steel, paper etc). The environment was seen as part of industrial engineering; solutions to environmental problems were sought in "end of pipe" cleaning solutions through investment in installations.

The Brundtland report (1987, see ref. 1) called attention for the first time to the fact that products (the result of production processes) can also cause substantial environmental loads. Product embodiments sometimes use scarce resources and can contain environmentally relevant substances as well. Packaging, packaging waste and transport to the user can contribute considerably to the overall life cycle burden of products. For products using consumables like water, gas, electricity this holds in an even more outspoken way for the so called user phase. Finally, the end of life phase is relevant as well (recycling of discarded products, adverse environmental effects of landfill and incineration).

Due to the very nature of its products, environmental issues in the electronic industry started to get more attention in the early nineties. Improvement programs focused (and still do) on prevention, that is reducing environmental effects upfront by appropriate product specification and design. In this way product management and development groups got involved with the production departments. Due to the fact that products, once produced, can potentially move all over the world, environmental product issues have a global character in contrast to production/manufacturing issues, which are primarily local/national.

Authorities and consumer groups were the first to move after the awareness phase. In the early nineties in various countries around the world the first drafts of legislation on electronics products started to appear. Test magazines started to include environmental paragraphs in their tests reports.

The reaction of the industry was primarily cautious; compliance with legislation/regulation and preventing bad test scores ranked high on the agenda. Basically this represented a defensive attitude; in this stage (1992-1996) the environment was primarily seen as a cost rather than as an opportunity to enhance business.

Around 1995, the electronic industry started to realize that environmental and economic interests run parallel to a large extent:

- Resource reduction (energy use, materials, packaging) also means cost reduction.
- Reduction of disassembly times also means reduction of assembly times.
- Reuse of subassemblies, components and materials is cheaper than buying new ones.

This provided momentum for cost oriented environmental programs.

A new type of program that was customer oriented or proactive were started by several companies as of 1997-1998. The basic idea here its to increase market share through offering environmental benefits (which are communicated in terms of financial, immaterial and 'emotional' benefits as well) to the customer.

In 2 the general characteristics of the defensive, cost oriented and proactive approaches are discussed and elaborated on.

In 3 examples will be given of a typical defensive activity: setting up a basic environmental organization, mandatory rules and establishing chemical content of electronic products.

In 4 examples of cost oriented activities are addressed: Environmental Management Systems (ISO14001), energy reduction and packaging reduction.

In 5 examples of proactive activities are presented; an Eco Vision Program, environmental benchmarking and a strategy for environmental communication.

The examples given in 3, 4 and 5 are from the authors practice at Royal Philips Electronics, Product division Consumer Electronics. Activities there have developed starting from a defensive approach in 1992 towards cost oriented programs in later stages (from 1995 onwards) and the current proactive approaches have been added. In 6 the 'cultural' effects of the introduction of these programs is discussed, both in terms of successes as well as in terms of items further to be improved.

On the basis of these experiences a general model for integration of EcoDesign into business has been developed. This model has turned out to be widely applicable outside the electronic industry.

2. General characteristics of environmental approaches in the electronic industry.

The general picture of environmental approaches in the electronic industry are summarized in the table below.

Table 1 General characteristics of environmental approaches in the electronic industry.

Item	Defensive approach	Cost oriented approach	Proactive approach
Driver	Legislation/Regulation	Money/cost	Market/customer
Management	* Environmental declaration * Command and control	* Policy * Projects	* Vision * Integrated into the business
Main objectives	Comply	Improve with respect to previous generation	Be better than the competition
Organization	Formal structure	Delegated responsibility	Management of processes
Core processes	Manufacturing Suppliers (purchasing)	Product creation process	Chain management
Control	Afterwards	Built-in	Upfront
Activities	* Substances reduction * Standby energy reduction * Take back of discarded products * ISO 14001 (partly)	* Material reduction * Energy reduction * Reduction of (dis)assembly time * ISO 14001 (partly)	* Designs with lower cost for user * 'Green' designs which are easier to operate or fun * Durable products * Products with emotional benefits ('green' image)
Supporting Tools	* Checklists * Chemical content tool * Environmental weight calculation	* Manual * Packaging reduction tool * Energy reduction tool * End of life cost analysis tool	* Greening your business handbook * Eco indicator software * Benchmark tool * STRETCH creativity tool
Training	How to comply	How to reduce	How to integrate with business
Communication to the outside world	Compliance beyond minimum	Environmentally friendly but not more expensive	Greener and other benefits combined
Language of communication	Environmental ('scientific green')	Reduction of resources	Perceived 'green'
Main benefits delivered	'Green' & societal benefit	'Green' & company benefit	'Green' and customer benefit

In practice individual companies in the electronic industry operate environmental affairs in a way which is a mix of the approaches shown above. The exact structure of the mix both depends on external and internal factors.

External factors include:

- Geography (regions, countries of the world where business is done)
- Product characteristics (environmental potential)
- Customer awareness
 - private customers
 - professional customers

- Position in the market (competition)
- Position in the supply chain (power, leverage)

Internal factors include:

- Business focus, ambition and ethics
- Management style
- Availability of skills

Due to the fact that integration of the environment into the (electronic) industry is also a cultural process, the three approaches are sequential. From this perspective the defensive approach is to be seen as a minimum approach to start with and to be done by all companies. Based on the experiences built up in this phase, further steps can be taken to introduce the cost related 'green' programs. For instance, a proactive approach can be developed.

Practice has shown that jumping directly into the proactive mode of operation fails in the market. When the defensive items are not appropriately addressed such programs are very vulnerable.

The drivers (item 1 in table 1) are strongly geography dependent; generally speaking legislation and customer awareness are best developed in Europe, liability and cost reduction are most important in the USA whereas resource reduction is highest on the agenda in Japan.

Management style strongly influences items 2-4 of table 1 (management & organizations): centralized organizations operating top-down can move swiftly in the defensive approach, decentralized ones with a bottom-up culture do well in proactive approaches. This is also due to the fact that for such an approach tailor made solutions, dependent on product characteristics, have to be developed.

Items 5 and 6 (processes and control) depend externally on the position of the company in the supply chain and internally on the business focus.

The activities (item 7) to be done have a strong relation with product characteristics and with the customers. Products of a complex nature, with substantial volume, weight and energy consumption, often have the highest potential for resource and cost reduction. Especially in professional markets such activities will be highly rated. Environmental tools for cost related activities (item 8) are the ones which are the most easy to develop and operate. The same holds for training (item 9).

In the field of environmental communication (item 10-12) there are clear distinctions. The electronic industry is perceived as high-tech and professional, therefore it is well-positioned to perform in compliance and in cost reduction. Especially in societies with a high income per capita (brand), image plays a tremendous role in these markets. Being seen as a "caring" company (through a proactive approach) is of primary importance in this field.

3. Examples of a defensive approach

3.1. The organization of environmental responsibility in a global electronic company

In order to make corporate environmental goals visible and deployable one of the members of the Group Management Committee, preferably the President and CEO should be responsible for environmental affairs.

By nominating a 'green' standard bearer it is clear that the company takes 'green' issues very seriously and wants to integrate them into all operations.

At a corporate level support to the chief environmental officer should be given by a Corporate Environmental Office/(CEO).

An appropriate headcount in the electronics industry is approximately one person per 5 billion USD of revenue.

Tasks of this CEO include:

- To develop the corporate policies, strategies, programs
- To handle external affairs (legislation, communication)
- To monitor progress of company programs.

A replica of the corporate structure should be made at division and business group levels:

At the division level a member of the Senior Management Team should be responsible for environment. Support at the division level is to be given through the Environmental Competence Center; the headcount of such an ECC should be in the order of magnitude of 1 person per 2 billion USD of revenue. Tasks of such an ECC are:

- Support of the division level environmental steering team.
- Making of division level programs, roadmap.
- Support of implementation at Business Groups.
- Ensuring availability of know-how and supporting tools.
- Training and audit.

At the Business Group level environmental matters should be handled by a member of the Management Team. Support is to be given by a Division level Environmental Manager (1 person per billion USD) through revenue and a line of business /plant Environmental Managers. Most of the people in the last category will be part-timers, located in the quality or health and safety departments.

The main tasks of the division level environmental managers are supporting implementation and reporting on progress.

The structure sketched above shows that in the electronic industry environment it is seen as a line responsibility. This very line responsibility means that integration of environmental issues in the normal operations is the only way to successfully operate in this field. This holds irrespective of whether the environmental strategy of the company is defensive or proactive. In this respect the environment will follow developments similar to what has happened with quality issues. It started as something separate, to be addressed by specialists, but it has now become fully integrated into the tasks of all employees.

3.2. Mandatory rules

In order to ensure a minimum of environmental care in all operations companies should have minimum mandatory rules. Application of these rules should be checked on product release and/or in manufacturing operations reviews.

For the electronic industry these mandatory rules include:

- Banned substances
 - brominated flame retardants of certain types
 - heavy metals (Cd, Hg,...)
 - ozone depleting chemicals
 - organic solvents and liquids (PCB, PCT,...)
- Availability of environmental information:
 - energy consumption
 - environmentally relevant substances (see also 3.3.)
 - recyclability
- Packaging
 - material application
 - printing inks
- Marketing and labeling of products and/or product parts
- Customer information
 - for optimal environmental operation
 - disposal of discarded packaging and products
- Batteries
 - marketing
 - handling

The precise formulation of the mandatory rules vary from company to company; some of them stick to strictly fulfilling legal requirements and have regional policies if requirements differ. Others go beyond the minimum and have global mandatory environmental rules.

3.3. Chemical content of electronic products

Knowing the chemical content of electronic products is not only important to fulfill actual legal requirements. It will also be helpful in anticipating future developments. It is crucial to start elimination efforts well in advance of the passing of laws because finding alternatives will involve a lot of work.

Some substances will not be legislated in the future, for instance because a scientific basis for forbidding them is not available. However using such substances ('the suspects') could do harm to the brand image of the company.

The vehicle used by Philips Consumer Electronics to find out about chemical content is the so-called chemical content questionnaire (see annex 1). This questionnaire has been sent to all components and materials suppliers. This action included hundreds of suppliers all over the globe and some 20,000 code numbers.

Apart from the list, the supplier gets an accompanying letter explaining the procedure. It is essential to make clear that if in any category the supplied items exceed the threshold limits on the list, this means that PCE wants to start improvement actions with the supplier and does not want to terminate relationships.

On the contrary, it is stressed that

- We want to know the chemical content of our products.
- We want to improve our products in close cooperation with the supplier.

The answers given by the suppliers are processed by specialists of the Environmental Competence Centre. When information has been considered to be complete, the component/material concerned is given a so-called environmental indicator (E.I.).

E.I. = 9 Component/material contains no environmentally relevant substances.

Fully released

E.I. = 6 Component/material contains environmentally relevant substances, but no Philips banned substances. There are no good alternatives.

Temporarily released

E.I. = 1 Component/material contains environmentally relevant substances. There are good alternatives or component/material contains Philips banned substances.

In both cases: Rejected

The results of this environmental classification are communicated to the organization through:

- Updates of the Environmental Design Manual.
- A computer database to which all S&V/CE development groups are connected.

In the Product Creation Process (PCP) Environmental Performance is checked at the milestones. In so-called product cross sections the chemicals used in the product are described in terms of fully released, temporarily released and rejected components/materials. When rejects are still present the milestone cannot be passed!

A physical example of a chemical content project has been the work on the composition of printed wiring board in GFL-V2 (in 1997). This board has been used for several years in mid range TVs (21, 25 inch). Environmental indicators have been as follows:

Table 2 Chemical content of printed wiring board G.L. - V2

	Number in %	On weight basis (%)	Target % (number)	Target % (weight basis)
Total number of components 3637				
Chemical composition known	95	98	98	99.5
of which fully	64	87	80	92
Temporarily released	36	13	20	8
Released rejected		0.2	0.0	0.0
Total	100%	100%	100%	100%

After the determination of the E.I. it was concluded that the design of GFL-V2 still contained some rejected components. Moreover, the % of temporarily released components and materials was still pretty high (36% and 13% respectively). On the basis of this information the decision was taken to reduce the number of rejected code numbers to zero and to reduce the temporarily released ones to 20% (number wise) and 8% (on weight basis). This project was successfully executed before release in the beginning of 1998.

4 Examples of a cost oriented approach

4.1 The Environmental Opportunity program of Royal Philips Electronics

This program has been introduced in 1996 as a follow-up after a period in which defensive attitudes were dominant. The main items are given below:

Table 3 The environmental Opportunity Program of Royal Philips Electronics

Corporate part

1. All factories EMS certified (ISO 14001 or EMAS)
2. 25% energy reduction in all operations
3. 15% packaging reduction in all operations

Product Division Part

- Eco design according to business needs
4. Supplier requirements
 5. Creation of internal, external network
 6. Active participation in legislation, regulation discussion

In the program a clear distinction is made between the mandatory corporate part and the part that is at the discretion of the Product Divisions. In practice the corporate part was the dominant one, with energy saving and packaging reduction as the carriers for the ISO 14001 program. As will be explained in 6.2, starting with the cost savings side of ISO 14001 rather than with the more formal part offered many advantages in practice. In this way environmental management systems become a logical result from integrated practice oriented activities instead of a set of upfront stand-alone items.

4.2 Energy saving in manufacturing operations

Energy savings in manufacturing operations has been treated as the core platform on which the ISO 14001 certification was to be obtained. This means that these projects have been organized in such a way that they fit in both "upstream" and "downstream" ISO 14001 activities. This can be sketched as follows:

Table 4 Energy saving as core activity in ISO14001.

ISO14001 activity	
Vision, Policy	Upstream
Legal and other requirements	
Objectives, target and programs	
Structure and responsibility	
Training, awareness	
Operation Plan, Do, Check, Actions	CORE Platform Energy saving
Communication	Downstream
Documentation	
Operational control	
Emergency preparedness	
Monitoring	
Records	

This table shows that on the basis of practical experiences in the factories, the ISO elements, as far as not yet present, are organized or built as structures. Experience has shown that this 'carrier' approach is very effective indeed.

In order to create the platform for energy saving actions a so called Energy Potential Scan (EPS) has been carried out in many Consumer Electronics factories. This EPS is in fact making a detailed and systematic inventory of all energy flows in the production system. Data collection sheets were organized in such a way that these could be used for both 'upstream' and 'downstream' activities.

A general observation has been that the very fact that comprehensive data are brought together in one concentrated form means that awareness, creativity and effectiveness in saving energy have been stimulated enormously.

The results of such an EPS is a list of prioritized options to save energy, both in terms of its environmental effect and in terms of payback time.

The items to be prioritized strongly depend on the location (need for air-conditioning/heating in winter), the type of products manufactured (assembly, processing), degree of automation, etc. So execution of locally, tailor made action plans is necessary.

On average for Royal Philips Electronics energy reduction programs have brought savings of USD \$40 M/year with an average payback time of investments in two years.

4.3 Packaging reduction

The packaging of products has a multitude of functions. Apart from its protection function, it can also play a role in handling, communication of messages to the customer and creation of brand image. These items should be mapped out in detail before starting reduction actions. This should prevent that such "add on functions" of packaging disappear in the process.

A first step in packaging reduction is getting facts. In the Philips Consumer Electronics case these include the following basics:

- Integral environmental load and cost of packaging and transport
- Ratio's (see also 6.2)
 - * packaging weight/product weight
 - * packaging volume/product volume

- Environmental weight ratio. This is a number that takes into account material application, substances in packaging and recyclability.

These numbers (and subsequent simulations) are used to establish the main strategies for packaging reduction. These include:

- Material reduction (works out on integral load and weight ratio)
- Increase in amounts of recycled materials (affects environmental weight)
- Volume reduction (works out on integral load and volume ratio)
- Material replacement (affects environmental weight)
- Improving fragility (shock resistance) of the product or matching fragility better with the packaging concept. (works out on all categories).

For audio products the following figures for integral environmental load and costs have been established for products manufactured in Asia and sold in Europe.

Table 5 Integral environmental load and costs of transportation.

	% of integral environmental load	% of integral cost
Packaging material	48	42
Packaging operation	<1	3
Transport	45	43
Storage	1	12
End of Life	6	<1

This table shows that both for environmental load and costs the potential is approximately equal for material reduction and for volume reduction. Also the data in table 8 points in the same direction.

Fragility measurements showed that in fact the packaging was over dimensioned, especially in with respect to the EPS buffers. This means that in the execution the volume reduction strategy was preferred. Design avenues for material reduction were derived from the benchmark (see 6.2).

In total the effort yielded a reduction of environmental load and integral costs of 8%, of which 6% is to be attributed to volume reduction and 2% to weight reduction.

5. The proactive approach.

5.1 The Philips Eco Vision program (1998-2002)

The formulation of the Philips Eco Vision program as a proactive approach to environmental issues was a result of several paradigm shifts:

- Environment is business rather than a technicality.
- Environmental benefits as perceived by other stakeholders are key rather than scientific calculations of environmental gains.
- Best environmental care means to be measured in comparison with the competition.
- Understandable communication of environmental results is just as important as achieving the results themselves.

The current Eco Vision program is presented in Table 6:

Table 6 The Eco Vision program of Royal Philips Electronics.

Products (per Line of Business)

- 'green' focal areas in product communication
- 'Green Flagships' in 1998
- X% of products fully Eco designed in 1999
- Y% of products fully Eco designed in 2001
- 15% packaging reduction in 2000 (ref. 1994)
- $Y > X$ to be determined by each division

Manufacturing (reference 1994)

- 35% waste reduction in 2002
- 25% water reduction in 2002
- Hazardous substances reduction in 2002
 - Category I 98%
 - Category II 50%
 - Category III 20%
- 25% energy efficiency in 2000 (stretch to 35% in 2002 to be decided upon)
- ISO 14001 on all manufacturing sites in 2000

The corner stone of the program is the communication of top achievements in 'green' to customers and other stakeholders, as embodied in 'Green Flagship' products. These achievements are to be realized through management of the cross functional processes around creation, production and marketing/sales of these products. In the creativity phase, environmental benchmarking (where do we stand with respect to the competition) is a key element, this is described further in 5.2. In 5.3 an example will be given of communication about 'Green Flagships'.

5.2. Environmental benchmarking

The relation of environmental benchmarking with EcoDesign is sketched in the figure below:

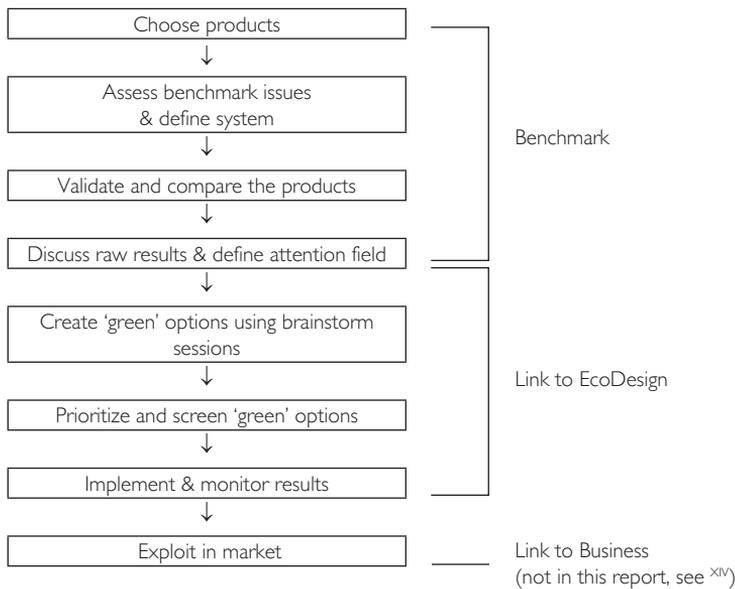


Figure 1 Relation of environmental benchmarking and EcoDesign

In order to do a proper benchmarking, the system boundaries should be well defined and the functionality of the products to be compared should be as identical as possible (see also ref. 2). Also a list of items to be benchmarked should be available; this list contains the items which will be used later on in communication with stakeholders. For this purpose, the Eco Vision program has defined five focal areas:

- Energy consumption
- Weight/material application
- Packaging and transport
- Substances in particular hazardous substances
- Recyclability

For electronic products benchmarking items have been divided into five groups as well, see the table below.

Table 7 Benchmark items

<p><u>Energy</u></p> <p>Energy consumption 'off' mode</p> <p>Standby mode</p> <p>Operational mode</p> <p>Energy consumption of subassemblies</p> <p>Energy consumption for user scenario's</p> <p>Battery life and costs</p>	<p><u>Packaging</u></p> <p>Packaging material weights</p> <p>Packaging volume</p> <p>Packaging weight/product weight</p> <p>Packaging volume/product volume</p> <p>End of Life costs of packaging</p>
<p><u>Materials</u></p> <p>Weights of plastic applications</p> <p>Weights of metal applications</p> <p>Weights of subassemblies, speakers</p> <p>Weights and surface area of printed wiring boards</p> <p>Weights of cables and wiring</p>	<p><u>Substances</u></p> <p>Number of weight of suspect</p> <p>Components, subassemblies</p> <hr/> <p><u>Recyclability</u></p> <p>(Calculated) disassembly times</p> <p>Estimated material recycling efficiencies</p> <p>Estimation of end of life cost</p>
<p><u>Life cycle calculations</u></p> <p>Environmental impact (Eco indicator) of the various life cycle phases</p> <p>Environmental impact (Eco indicator) of total life cycle for various user scenario's</p>	

The example given below of products on the market in 1997 demonstrates that environmental benchmarking can be very powerful, both in terms of generating data and ideas for further improvements, but also for product positioning in the five focal areas. In the table below the main properties of traditional Audio Systems are compared. The four products selected have approximately the same functionality and features and consist of a tuner/amplifier, a double tape deck, a CD changer, and two loud speakers.

Table 8 Example of benchmarking results for Audio Systems.

Benchmarking items	Product of competitor 1	Product of competitor 2	Product of competitor 3	Product of competitor 4
<u>Energy (W)</u>				
Standby	2	11	8	12
Operation	21	22	30	23
Tuner	20/25	31/28	18/50	23/24
CD	25/27	25/28	31/60	26/34
Tape decks	23/24	22/27	31/43	25/34
<u>Weight</u>				
Parts total	4300	4100	4600	6200
Of which transformer	1800	1800	2100	2800
Sound system	6887	9988	5612	9453
<u>Packaging</u>				
Number of boxes	1	2	2	1
Weight total (g)	2895	2607	1804	3401
Packaging weight/ Product weight	0.17	0.14	0.12	0.15
Volume ratio box/ Product volume	2.06	1.89	2.02	2.56
<u>Environmental weight ratio</u>	0.91	0.95	0.98	1.11
<u>Disassembly time (sec)</u>				
Total	160	90	100	150
Of which due to screws	90	40	50	90
<u>Life cycle score (mPT)</u>	600	1200	1600	1300

The results of this table show that in spite of the fact that products of this type have been on the market now for more than ten years, there are substantial differences in almost all focal areas and categories. Apparently the companies active in this field have completely different design strategies, using them to meet environmental objectives is relatively new.

For Philips Consumer Electronics (Audio Group) the benchmark results mentioned above clearly showed the strategy for how to develop 'Green Flagship' products, that is bringing products to the market which have superior environmental performance with respect to the competition. This strategy included:

- Keep the lead in standby energy consumption.
- Increase the small lead in energy consumption in operational mode
- Stay among the best in weight issues.
- Reduce packaging weight and volume so that it becomes at least on par with competition.
- Drastically improve disassembly times

(Since energy consumption is a major contributor to the life cycle impact score, the lead in the score will be automatically kept).

5.3 Environmental communication

5.3.1 'Green' communication at Company level

'Green' communication at company level should particularly contribute to enhancing the brand image. "Putting more green" into the brand can be realized by:

- Leadership:
 - Top management shows visible involvement in 'green'
 - Communication of environmental vision
 - Visible proactive attitude in trade associations
- Programs:
 - Communication of corporate environmental programs (see 4.1 and 5.1)
 - Communication of awards, ISO14001 certificates obtained etc.
 - Having a supplier requirement program
 - Communication of successes obtained through programs
- Making documentation available
 - Examples in the Philips Electronics case are:
 - 'Green' product brochure
 - (Public) Ecodesign guideline book "from necessity to opportunity"
 - Environmental Annual report
 - Internet 'green' homepage
- Sponsorship
 - Examples in the Philips Electronics case are:
 - Sponsoring of chair in EcoDesign at Delft University of Technology
 - Sponsoring of environmental conferences
 - Sponsoring of cleaning up the Antarctica
- Hardware:
 - 'Green Flagship' products (see 6.3.2)

5.3.2 'Green' communication at Product Division level

'Green' communication at Product Division level should be directed towards the methods and tools which are applied to ensure that the 'green' products brought to the market are really outstanding with respect to competition (or to conventional products).

In the case of Philips Consumer Electronics particular attention is paid to:

- Communication of the benchmarking method used (see also 6.7).
- Explaining what the life cycle principle means in terms of combining the five focal areas: energy, materials, packaging and transport, substances and recyclability.
- Explaining the Ecodesign procedure followed.
- Communicating what a 'Green Flagship' means and presenting these products.

5.3.3. 'Green' communication of specific products

This type of communication refers to scores in the focal areas. One example is provided here of the Audio System type nr. FW870C produced by Philips Consumer Electronics, data are given below. This is a product which was launched in September 1999. This product was developed on the basis of the benchmarking results presented in 6.2 and the resulting design strategy.

Table 9 'Green' communication focal areas.

Focal area	Unit of	Message
Energy	kWh/\$	Over the life cycle of the product energy costs are \$35 lower than for the best competitor
Weigh	Kg	The weight of the product is 15% lower than that of the best competitor (this saves resources)
Packaging	Kg	The packaging weight is now 5% lower than that of the best competitors (this saves resources)
Substances	Concentrations	N.A.
Recyclability	%	Now better than the competition
Life cycle performance	Eco-points %	This product has a life cycle impact score which is 35% lower than the average of competitors

6 Effect of environmental approaches on the organization

6.1 The defensive approach

Philips Consumer Electronics started with what was basically a defensive approach to environmental issues in 1992-1993. Basic elements of the environmental program were at that time:

- Formulation and deployment of an environmental declaration
- Setting up of an environmental organization (see 3.1)
- Formulation and monitoring of mandatory environmental (design) rules (see 3.2)
- Start of making an inventory of banned and environmentally relevant substances in materials and components (see 3.3).

The effect of organizing this defensive program in the organization is summarized in the table below.

Table 10 Effects of defensive approach

<u>Good:</u>	<u>To be improved:</u>
• Awareness created	* Perception as threat by organization
• Action taken, first mover	* Benefits for company doubted
• Environmental managers in place	* "This is technical"
• Collection for information	* Philips, what is in for me?
• Program further developed	

An immediate result of implementation of the program was that a strong environmental awareness was created. In spite of urgent cost cutting and restructuring efforts taking place at the time of introduction, 'green' earned a solid place on the business agenda.

Outside Philips CE was from the very beginning perceived as a caring company. "This is one of the first companies in the electronic industry to take real action." In particular this was achieved by sending letters to all of the suppliers about the chemical content program and by communicating this to the outside world, in particular to authorities in various countries.

A further advantage was in the systematic and the comprehensiveness of the approach. Through the presence of a network of full-time (in only few cases) and part-time (in most of the cases) environmental managers throughout the organization, all kinds of environmental information were gathered and improvement actions going beyond the mandatory program we started. In such a way, the basis for further development of 'green' activities was created.

All these positive effects could not prevent that pending legislation was seen as a threat; benefits for the company were doubted. Particularly because of the fact that the introduction of the program coincided with a major restructuring proved to be a serious handicap. The content of the program with chemical content as the core meant that it was seen as something of a technical and highly specialized nature. This mentality had to be turned into a perception of 'green' and as a business item in later stages.

6.2 The cost oriented approach

The environmental opportunity program (1996) (see 4.1) substantially widened the scope of the environmental opportunities. Effects on the organization are given below:

Table 11 Effects of environmental opportunity programs

Good:

- Business groups systematically confronted with environmental concerns through EMS
- Clear cost saving through saving energy
- Clear cost saving through reducing packaging
- EcoDesign taking off, manual in place
- Supplier requirements
- Internal and external network built

To be improved:

- * Sometimes bad experience with ISO9001, why should ISO 14001 be better?
- * "It works in the factories, why not for products"?
- * EcoDesign manual too static
- * LCA turns out to be difficult, need for more practical approach
- * Business rationale, resistance from purchasing
- * EU/government inflexibility backfires internally

The obligation to put an operational Environmental Management System in place according to the internal ISO 14001 standard confronted the Business Groups with a systematic way to deal with environment. Of particular significance was that an ISO standard is a global one and as such is much more appealing to a global business, like Consumer Electronics, than national or regional (draft) legislation.

By linking energy savings activities in manufacturing directly to ISO 14001, through the introduction of appropriate organizational structures and reporting formats, the cost saving potential of ISO 14001 could be made very visible. A similar effect was reached through the packaging reduction programs. The programs got an environmental flavor through increasing the amount of recycled materials used and by eliminating, to a large extent, expanded polystyrene (which is perceived as an environmentally unfriendly material).

With the momentum created in this way EcoDesign in general received more attention. Also the presence of appropriate metrics and supporting tools contributed towards this end. Achieving a strong environmental image also worked out positively for Philips in terms of supplier relations. Requirements were accepted as an opportunity to learn and to improve rather than as a threat and source of cost increases.

The internal and external network were further strengthened by the Environmental Opportunity Program. Through its performance, authorities took proposals and initiatives seriously – although this did not always work out in final regulation. In spite of all the successes there were still items to improve:

- implementation problems (in spite of a practical approach through the savings)
- side rather than addressing the more formal part first) with ISO 14001 occurred in situations where business units or factory locations had a mix of negative experiences with the ISO 9001 quality programs. Also, savings in factories (utilities!) turned out to be easier to achieve than in product design itself.

This was to a large extent due to the fact that the EcoDesign (Design for Environment) tools and manuals were formulated in environmental rather than business language so that it was sometimes difficult to get the message across and boost creativity. This was enhanced by the fact that in spite of all potential savings, a clear strategy to exploit savings both upstream (suppliers) and downstream (in the market) was not yet in place.

In the mindset of many employees, environment activities were positioned clearly in the technical domain and not

seen as a real business item. Therefore sometimes other (non-technical) internal stakeholders were resistant to the idea. This was enhanced by external events; in this period authorities still took a formal attitude towards the electronic industry, thinking in principles rather than solutions. Particularly in Europe this was perceived by industry as unjustified and unfair.

6.3 The proactive approach

The EcoVision program (1998) see 5.1 created a tremendous shift in the mindset of the organization. The fact that the President and CEO introduced Eco Vision personally contributed substantially to its success. Soon it turned out that an introduction of the first 'Green Flagship' products lead to increases in market share (+2%), price premiums (an average +3%) and a lower bill of materials (approx -5%). Therefore the outcome – also in the cultural sense – has been very positive as set forth below:

Table 12 Effects of the proactive approach.

Good:

- Vision, strategy, roadmaps in place
- Environment integrated into business
- Broad based actions – fantastic results
- EcoDesign works well feasibility remain hard to fight
- 'Green' marketing put into practice

To be improved:

- * Deployment to improve
- * Need to keep it separate in the beginning of process
- * A lot of strain on the support organization
- * Consolidation into concepts,
- * Special strategy needed to circumvent prejudice

On a strategic level the environment was integrated into business, vision, strategy and roadmaps. This received further support by results obtained in practice (see above).

In fact Eco Vision's success strained the support organization; not all initiatives, requests and questions could be adequately handled in the beginning because of the volume of all the work involved.

It also turned out that in spite of all integration efforts in later stages, environment should be kept separate in the very beginning of the design process. In this stage 'green' creativity is a basic issue. Too many day to day business issues had a negative impact on out of box thinking and specifically for environmental thinking.

Special attention needs to be paid to deployment as well. In the beginning of the program the basic mindset of many employees was still that the environment is a threat rather than an opportunity for the organization. Only the communication strategy of joint benefits, environmental as well as others, is able to overcome this.

8. References

General references: Proceedings of the IEEE Conference on Electronics and Environment, held each year in May, somewhere in North America.

1. The Brundtland Commission, "Our common future", Report of the world commission on Environment and Development Oxford University Press, Oxford U.K., 1987.
2. A.J. Jansen and A.L.N. Stevels, the EPass Method, a Systematic approach for Environmental Product Assessment, Proc. CARE environment '98, p313-p320, Vienna, Nov. 1998.

Annex I

Philips Consumer Electronics List of Environmentally Relevant Substances

Component (family):

Supplier:

Supplier type number:

Date:

Component weight (excl. packaging):

Compound	Threshold conc. ppm (mg/kg)	Tick off if actual conc. > threshold	Actual conc. ppm (mg/kg)
Antimony and –compounds	10		
Arsenic and –compounds	5		
Beryllium and –compounds	10		
Cadmium and –compounds	5		
Chromium (hexavalent) compounds	10		
Cobalt and –compounds	25		
Lead and –compounds	100		
Mercury and –compounds	2		
Metal carbonyls	10		
Organic Tin compounds	10		
Selenium and –compounds	10		
Tellurium and –compounds	10		
Thallium and –compounds	10		
Asbestos (all types)	10		
Cyanides	10		
Benzene	1		
Phenol (monomer)	10		
Toluene	3		
Xylenes	5		
Polycyclic aromatic hydrocarbons	5		
CFC's and halones	0		
Acrylonitrile (monomer)	25		
DMA, (N, N)- dimethylacetamide	10		
NMA, (N)-methylacetamide	10		
DMF, (N,N)- dimethylformamide	10		
NMF, (N)-methylformamide	10		
Diethylamine	10		
Dimethylamine	10		
Nitrosamide	10		
Nitrosamine	10		
Ethylene glycol ethers and –acetates	10		
Phtalates (all)	25		
Formaldehyde (monomer)	40		
Hydrazine	10		
Picric acid	10		
PBBE, poly brominated biphenyl ethers	10		
PBB, poly brominated biphenyls	10		
PCB, poly chlorinated biphenyls	1		
PCT, poly chlorinated triphenyls	10		
Pentachlorophenol	10		
Dioxines	0		
Dibenzofurances	0		
Other halogenated aromatic hydrocarbons	20		
Epichlorohydrine (monomer)	10		
Vinylchloride (monomer)	1		
PVC and PVC blends	1000		
Other halogenated aliphatic hydrocarbons	10		

Bryce Canyon, UT, USA - Respect for Nature



4.2.2 How to make money with 'green'

Up until present day there has been a strong need to demonstrate that working on the environment brings in money for the organization involved with it. Often – even in proactive organizations – it is asked to demonstrate this in a bookkeepers way.

As such this cannot be done. However, there is a strong correlation between sound environmental activities and reducing costs for the company involved. For the electronics industry, I estimate the correlation coefficient to be 75%. The rest is either intangible (for instance image) or simply not profitable, or even represents a cost. This can either be the result of regulation (but then it is rather the cost of operation rather than of environment) or a matter of ethics and perceived licence to operate.

Whatever it is there is still a high demand to demonstrate the positive contribution of environmental activities to the bottom line.

For the audience of the Philips Global Environmental Conference, I wrote the following paper *"Five ways to be 'green' and profitable"*.

Of the five ways to make money with 'green', the EcoDesign and the 'Green' Supply Chain Management ones are very well known as approaches combining 'green' and profit. 'Green' marketing and communication is more tricky in this respect. Publicity emerging from companies can be counterproductive if the messages are formulated from a one sided 'green' perspective and other benefits for consumers are not mentioned (see also chapter 5.4).

A subject neglected in most environmental considerations is increasing the quality of the production and correspondingly reducing the amount of rejects. With the increased sophistication of many products, production processes get more complicated as well. After energy consumption in the use phase, the production phase ranks second in the environmental load over the complete lifecycle (see chapter 3.1 and 3.2). Improving yields in production is therefore a high ranking environmental priority.

A striking example of this is the production of Liquid Crystal Displays (LCD screens). Theoretically, TV

sets with such screens would have a total environmental load which is 3-4 times lower than the traditional products with Cathode Ray Tube screens. However up until a few years ago LCD TVs had a load which was even higher than CRT based TVs. This was due to the very low yields in the production processes of the screens. By now, the yields have increased substantially and LCD TVs are clearly below CRT based TVs regarding their environmental loads. Better production yields are also one of the reason that prices of LCD TVs have also dropped.

The fifth opportunity mentioned in the article basically has to do with conservatism and risk avoiding behaviour in industry. The requirement to lower the time to market has enhanced this problem. In many electronic companies there is simply not enough time to rethink decisions taken in the past and to come up with new approaches. This would greatly help the environment and would avoid unnecessary cost as well!

In the article several examples are given where 'green basics' have a clear and positive outreach to completely different business aspects. This is because the environment is relatively new and "neutral". This is another reason to reconsider decisions made in the past. In such a process it is often discovered that the world has changed much more than just with the emergence of 'green'.

Five ways to be 'green' and profitable

Ab Stevels

Abstract

In this paper five ways to make money while being 'green' are described. These include a form of EcoDesign (Design for environment) in which company, customer and societal benefits are taken into account, a new way of dealing with suppliers, 'green' marketing and sales focusing on add-on benefits, increasing product quality through 'green' and paradigm shifts in creative thinking both for improved and alternative products. These concepts can be applied separately but when combined there are substantial ramifications of the results.

I. Introduction

In the last 10 years, environmental care in products has changed substantially in its approach.

- Upstream (supplier involvement) and downstream ('green' marketing and sales)
- To business level (strategy, roadmap) and support level (tools and tools development)
- To higher levels of sustainability (alternative functionality) and quality improvement (less rejects).

In a related development, environmental improvement ("creating green options") is now seeking to realize combined stakeholders benefit and is considering feasibility upfront. This is shown in the figure below:

Green Options	Benefit				Feasibility	
	Environmental	Business	Customer	Societal	Technical	Financial
First option						
Second option						
Third option						

Figure 1 The EcoDesign matrix.

From this figure it is clear that in order to be realized in practice, 'green' options should bring environmental benefit as a first priority, as well as company, customer and societal benefits. On top of that they should be feasible from a technical and financial point of view.

With this consideration environmental benefit is defined as a lower environmental load over the life cycle of the product or system concerned (see ref. 1). The other benefits can be classified as being material (money), immaterial (advantageous but difficult to express in monetary terms) and emotional. These items are described in more detail in the table below.

Table 1 The benefits matrix.

	Company	Customer	Society
Material	Cost reduction	Lower cost of ownership	Use of fewer resources
Immaterial	Simpler to produce, simpler to sell	Easier, convenience, more fun	Better compliance
Emotional	Better image	Feel good, quality of life, less fear	We make progress in green

In practice it turns out that there is a strong correlation between environmental benefits and other stakeholder benefits as specified above (at least in the electronic industry). This is creating the platform for the present paper which describes five ways to make money while being 'green'.

Paragraph 2 sketches the five ways and their interrelation; paragraphs 3-7 give more details.

2. Five ways to make money while being 'green' and their interrelation

The five ways to make money while being 'green' and their interrelation are given in the figure below:



Figure 2 Five ways to make money while being 'green'.

This figure shows that the five ways include:

- EcoDesign (design for Environment)
- Greening the supply chain
- 'Green' marketing and sales
- Increased quality through the 'green' perspective
- Introducing paradigm shifts; looking at functionality instead of embodiments.

These items are interrelated through enabling relationships; this means apart from having financial merit they will also enable improvements in the other departments. This is the reason that the five ways are positioned on a circle: improvements in one field create the basis for progress in other fields etc. Some examples are given which will be elucidated in paragraphs 3-7:

- EcoDesign will enable 'green' marketing and sales and increase production quality
- Suppliers' performance will enable better EcoDesign and 'green' marketing and sales
- Enhanced sales through green will stimulate EcoDesign and further functionality thinking
- Design for production quality leads to lower supply cost
- Paradigm shifts will open new lines of business lower supply cost.

There is a clear link between the five ways to make money of fig. 2 and the benefits matrix of table 1. This correlation is shown in the table below:

Table 2 Link between ways to make money and material and immaterial benefits

Way	Cost reduction	Immaterial / Emotion
Eco design	Resource reduction	Lower Life Cycle impact compliance
Suppliers	Supply cost	Enable EcoDesign
Green marketing & sales	Sell more	Caring, fun, nice to have
Quality	Less rejects	Easy, simple
Paradigm shift Functionality	Higher margins	Lower Life Cycle Impact

This table shows that being 'green' in the various approaches works out positively in different ways. However resource reduction, lower supply cost, more sales, less rejects and higher margins are all positive in monetary terms!

3. Making money through EcoDesign (Design for Environment)

In order to make EcoDesign operational in industrial organizations it is useful to split the field up into five focal area's (see ref. 2):

- Energy consumption
- Material application
- Packaging and transport
- Chemical content
- End-of-life / recyclability

Each of these area's has its own cost saving potential as evidenced by the following table.

Table 3 Environmental and cost benefits per EcoDesign focal area.

Focal area	EcoDesign action	Environmental benefit	Cost effect for producer	Cost effect for user
Energy	Use of more powerful IC's, miniaturization	Less energy used	Lower bill of materials	Lower electricity bill
Material	Less material	Less resources	Lower bill of materials	Lower price of product
	Material substitution	Less environmental load	?	?
	Use of recycled material	Closing the loop	Lower bill of materials	Lower price
Packaging & Transport	Less packaging materials	Less resources Less waste	Lower cost	Lower price of product
	Less packaging volume	Lower transport energy	Lower cost	?
Chemical Content	Mono material	Better recyclability	Volume discount	Lower price of product
	Elimination of flame retardants	Better recyclability	Lower bill of materials	Lower price of product
End-of-life, Recyclability	Design for disassembly	Higher recycling yield	Lower assembly cost	Lower end-of-life cost

From this table it is evident that a variety of activities can be envisaged to produce combined environmental and financial improvements. In order to structure this wealth of opportunity two issues should be considered in particular:

- Setting up an appropriate procedure for EcoDesign
- Setting priorities. A procedure for EcoDesign is given in Fig. 2 (taken from ref.).

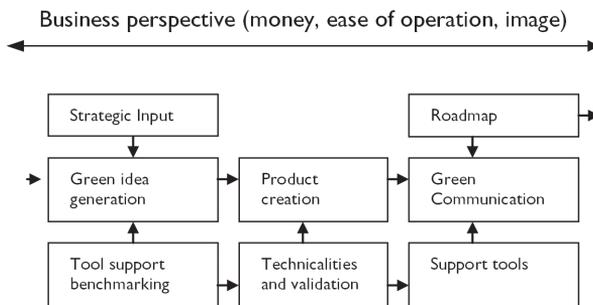


Figure 3 Flow chart for EcoDesign from a business perspective.

The basic idea behind this flow chart is to manage the processes in three ways:

- Strategic, managerial processes (roadmap)
- Execution of processes (ideas, creation, exploitation)
- Supporting processes

Particular significance is to be attributed to the processes at the very beginning of the whole procedure, that is idea generation supported by benchmarking and strategic input. In this stage positioning with respect to the environmental performance of competitors gives strong direction for what is to be achieved in later steps of EcoDesign. Apart from being the basis for ideas, benchmarking also provides "learning for free", flagging up improvements and solutions which competitors have already put into practice.

Table 4 gives statistics from 18 product benchmarks performed at Philips Consumer Electronics (PCE). In each case products are compared with 2 or 3 competitors, so with average performance PCE would be best in 25% or 33% of the cases. In practice the score is:

Table 4 Benchmarking score of 18 Philips Consumer Electronics products.

Benchmarking at Philips Consumer Electronics	
18 products compared with 2 or 3 competitors	
	Philips is best
Energy consumption	54%
Weight	56%
Packaging	44%
Chemical content	33%
Recyclability	57%

This table indicates that the performance of PCE products is clearly above average.

However, the table also shows that looking per focal area 8-12 products still can be brought up to competition levels – which is performance which has been proven in practice and is beyond any doubt regarding feasibility (see fig. 1). There is however more than just following the best competitors. In many cases, the analysis of benchmark results leads to ideas which when implemented clearly go beyond best performance of the competitors. Combining these has proven to lead, in practice, to substantial cost reductions in the product portfolio (if also table 3).

4. Making money through addressing suppliers

Currently the role of suppliers in ensuring good environmental performance has been generally recognized. Both inquiries about evidence for complying with legislation/ regulation and about implementation of Environmental Management System like on basis of ISO 14001 received an established position in Supply Chain Management.

It must be noted however that such an approach is basically 'top-down' and of a fairly defensive nature. Organizational and compliance costs resulting from single minded pushing through the items addressed above could lead to price increases rather than price decreases.

In this paragraph two avenues of action are proposed which will assist suppliers in bringing down prices while increasing environmental performance:

- The Environmental Quality Concept (EQC).
- The design for the supply chain concept (DSC).

The Environmental Quality Concept has been pioneered by Nagel (see ref. 3). It basically consists of a benchmark of suppliers in a similar product category. Inputs (energy, basic material, auxiliary material, water, packaging) and outputs (products, emission to air, water, solid waste) are analyzed quantitatively on the basis of a questionnaire. On the basis of the outcome quality indicators (I) are calculated for each input or output stream. (Normalized per unit of product delivered to the customer). I have the general form.

$$I = K* [\text{Product stream out} / \text{Stream of consideration (in/out)}]$$

In this equation K is an 'environmental quality constant' for the item considered. The quality indicators I can be consolidated into one "overall" quality indicator by adding all the I's per item in a weighted fashion. The weighting can take place in two ways:

Either based on * the "degree of perfection" of the different environmental items to be addressed in the category.

Or * The relative importance of the environmental items to be addressed in the category.

Or * The economic (monetary) importance of the environmental items to be addressed in the category.

The outcome of such calculations is a score I per category. Practice has shown that (note the similarity with product benchmarking in 3), no supplier scores 'best' consistently in all categories.

On the basis of such scores a customer can assist individual suppliers to define the meaningful avenues to improve. Since all environmental items involved are directly associated with cost items as well, a cost reduction potential can be defined:

$$\text{Price reduction (Pr)} = \text{Pr standard} + (I-E) \text{ Pr}$$

With E being the environmental performance as calculated with the formulae of ref. 3.

The Design for the Supply Chain Concept entails that the customer involves suppliers in making designs with the particular aim to lower the environmental load and costs to the supplier. Basically this involves similar process management as was described in §3 for EcoDesign, however with the difference that this is applied upstream rather than downstream. The paradigm shift (see also §7) in this is that supplier and customer investigate jointly how a certain functionality can be realized best rather than forcing a given embodiment down the supplier's throat. As specialists in their field suppliers can make substantial contributions to enable producers to lower the environmental load over the life cycle of the product. This is particularly apparent in the electronic industry where up to 70-80% of the bill of materials (and of energy consumption of the future users) is related to suppliers. Impressive results of such 'enabling design' by suppliers are for instance:

- Lowering energy consumption of TV's and increasing playing (use) time of portable products by making available dedicated ('smart', 'green') IC's.
- Decreasing the amounts of plastic needed for housings by applying gas assisted molding and by using recycled materials.
- Designing full cardboard packaging for consumer electronics products with weights below 10 kg.

5. Making money by 'green' marketing and sales

Basically this strategy comes down to selling more products (preferably with higher margins). Because they are 'green', at first sight, this strategy seems to be an abortive one since it is generally recognized that 'green' as such does not sell. As will be pointed out below, this statement is right. However, this should lead to eliminating the 'as such' (that is taking 'green' marketing out of its isolation) rather than refraining on developing 'green' products.

An analysis of consumer attitudes (see ref. 4) has shown that worldwide – fairly irrespective of the country concerned – for only 20 – 30% of the population the environment is really important in buying decisions. For another 40 – 50% of the population 'green' is nice to have whereas for 20 – 30% of the people 'green' is unimportant or even negative. These figures make clear that in order to cater to a majority (70 – 80%) of the public, particularly the 'nice to have' category, has to be drawn into the camp of interested buyers. This is done by the environment AND... strategy through linking environmental benefits with other benefits as specified in table I (see customer column). Such a link between environmental and other benefits is shown in a schematic form in the table below:

Table 5 Link between environmental and other benefits for the five focal areas in 'green'.

Item	Environmental effect	Benefits	% of buyers attracted
Energy reduction	Less emissions	Material = lower cost	80
Material reduction	Less resources	Immaterial = simply, easy	75
Packaging/ Transport	Less resources, less emissions	Immaterial = convenient	75
Substances reduction	Less emissions	Emotional = less fear	60
Durability/ Recyclability	Less resources	Emotional = quality, feel good	75

This table shows that for all 'green' focal areas (see §3) large proportions - up to 80% for energy reduction - of the buyers are interested.

It is to be realized however that in current markets brand image – in this case environmental brand image – is just as important or may be even more important than technical 'green' achievements.

Areas in which 'green' can contribute to brand image include:

Leadership:

- Top management shows, visible involvement in 'green'
- Pro active in industry associations
- Participation in international activities like the World Business Council on Sustainable Development
- Having a Corporate Environmental Vision, Policy and Roadmap.

Programs:

- Corporate programs like Philips' (Eco Vision).
- ISO 14001 certification
- Supplier requirements

Documentation:

- Environmental (annual) reports
- Brochures like the Philips' "Greening your Business"
- Scorecards/reviews
- Internet
- Press release/free publicity/technical, scientific articles

Sponsorship:

- Environmental research and teaching chairs at Universities/institutions
- Environmental related events (like EGG)
- Nature conservation groups.

Focus on company 'green' achievements and brand image turned out to be more instrumental to increasing sales than applying for Eco labels. In the table below the differences between a company run 'green' communication program (in this case the Philips Eco Vision program) and general Eco label programs is outlined.

Table 6 Comparison of effect of Philips Eco Vision communication program and Eco labeling.

Identity	Unique for Philips	One of many companies having Ecolabel
Scope	Global	Local, National, Regional
Nature	Technical, image	Political
Procedure & to obtain	Own control	Dependent on thirds
Language	Five focal area's (easy to understand)	Environmental (difficult to understand)
Accountability	Life Cycle Calculation	?
Transparency to customer	Big	Small

This table shows that the big gain from having a company specific program is the transparency provided to the customer both in terms of brand identity and language used.

6. Making money by increasing product quality, reducing rejects.

The three basic factors to product quality are depicted in fig. 4.

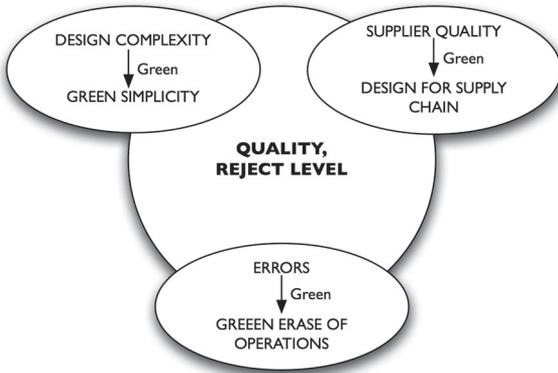


Figure 4 Basic factors determining product quality, reject level.

This figure is well known from considerations how to improve product quality. It is the basis for applying methods like as six sigma and Poke Yoke. Basically three items are addressed: supplier quality, human errors and design complexity. Two of them (supplier quality and design complexity) have a clear link with Ecodesign. Reversely, starting from the 'green' perspective can therefore have a positive effect on reducing reject levels:

- Design for the supply chain (see also 4) will increase supplier quality and therefore reduce the risk of high reject levels.
- Reducing design complexity for instance by resource reduction and modular design (see 3) will simplify assembly processes. Generally speaking this reduces the amount of errors in production. Specifically, design for disassembly will contribute towards this end.

Both items are examples of fields in which environmental thinking leads to improvements outside the very environmental territory. How reducing design complexity / design for the supply chain influences the number of rejects is shown by the Hinkley correlation (see ref. 5):

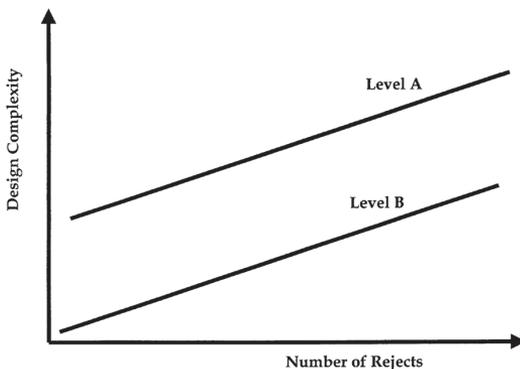


Figure 5 The Hinkley correlation

This diagram shows that for a certain level of supplier competence and skills in a production factory there is a linear relationship between design complexity and number of rejects. The diagram also shows that design complexity needs to be reduced when production is moved from a high level industrial environment to a lower level. The penalty for not doing so is a higher amount of rejects.

7. Making money by applying paradigm shifts

The meaning of the word paradigm is 'believing' that things should be as they are. A paradigm shift is therefore a change of mindset. As regards products 'green' thinking is stimulating such paradigm shifts because the environmental approach questions 'why are embodiments of products as they are' and are there ways and means to provide the same functionality in a more environmentally friendly way. This contrasts with the traditional approach in which first priority always has been to produce the chosen embodiments through more and more efficient production. The classic example is the packaging of electronics products. For more than 50 years the paradigm was that the box should consist of cardboard and the buffers of expanded polystyrene. In that period, optimization of the concept has been worked on continuously and in the nineties it was believed that further progress had become impossible.

When the environmental approach addressed these items the following questions came up:

- What is the maximum % of recycled cardboard that the boxes, given the climate conditions during transport and storage, can have?
- What is more important: reduction of volume, environmental load of transportation or reduction of packaging weight (environmental load of materials)?
- Can the buffer function of EPS also be realized by applying low impact materials like cardboard or molded fiber?
- Can the shock resistance of the product be increased so that less packaging is needed.

Looking in this way at this classic packaging issue brought impressive environmental gains and cost savings at Philips Consumer Electronics.

- The recycled content of cardboard has consistently increased to 60% worldwide.
- For TVs worldwide and for other consumer electronics products exported to a different part of the world, volume reduction is more important than weight reduction, both from the ecological and the economic perspective.
- In products with weight below approx. 10 kg. EPS can be replaced by other materials.
- The shock resistance approach works out well particularly for certain categories of audio products.

Paradigm shifts also play an important role in conceptual changes (next to the "improvement" approach as demonstrated above). Examples are:

- Apply different physical principles:
 - Human powered radio versus battery operated radio
 - Monitor with Liquid Crystal Display Screen instead of Cathode Ray Tube.
- Life cycle optimization
 - Create modular functionality, e.g. for Audio sets, so that only parts of the set have to be replaced with development of user requirements and technology developments.
- Services: capability of electronic products to download from the internet (music, film, information)

In all these cases environmental gains and economic benefits for producers and users go (or will go) hand in hand.

8. Current implementation of the five ways to make money while being 'green'

The following chart features a review of best practices for implementation of the principles to make money while being 'green' yields the following picture:

Table 7 Review of best practices of implementation of the "five ways":

Perspective \ Item	Awareness	Organization of processes	Business perspective	Customer perspective	Societal perspective	Overall result
EcoDesign	+++	+	++	0	+	++
Suppliers Questionnaires	+	+	0	0	+	0/+
Suppliers performance	0	0	0	0	0	0
Green marketing and sales	++	+	+	0	0	0
Quality/reject	0	0	0	0	0	0
Paradigm shifts	++	+	+	0	0	+

This picture shows that the overall implementation of the five principles is still weak; only EcoDesign is consistently addressed well, although organization of the processes and customer perspective are still weak. On the other hand supplier involvement does not surpass the questionnaire level and considerable economic potential has not yet been addressed. Using the environmental perspective to tackle quality and reject issues is virtually absent. 'Green' marketing, sales and forms of paradigm shift are well recognized as opportunities but are still weak at the execution level. Overall the customer perspective is still an unknown territory in environmental thinking. There is a need for drastic improvements here because customer care should be the basis for market driven environmental improvement. The business perspective and societal perspectives are weak too: this is an indication that the "environment" is an item, which is developing too much in isolation. Also in the organization of process there is still big improvement potential: it seems that technicalities are still dominating the management of 'green'.

9. Conclusion

This paper has shown that environmental approaches have tremendous potential not only for the environment as such but also for companies, consumers and society as a whole. Its significance is therefore going far beyond its original domain.

In order to realize all these benefits in practice, integration of the environment into business (product creation but also supply chain management production) 'green' marketing is an essential ingredient. Apart from widening the concept to include supplier performance and quality / reject this is the basic step to be taken in the years to come.

For EcoDesign this includes a shift from supply to demand driven activities which means that business should look at what sensible things can be done proactively in the environmental domain rather than waiting for things to be driven by external developments. For suppliers the big challenge is to come from a defensive approach to proactive chain management in which performance plays a big role. 'Green' marketing and sales will have to overcome the prejudices, which currently exist in this field.

An environmental perspective is also useful to come to real quality products and to reduce rejects. The first steps still have to be made and results can be expected not earlier than five years from now.

Paradigm shifts still have limited foothold mainly because they are revolutionizing the way companies are traditionally operating. This is however the field where the biggest environmental lessons and societal gain can be made. Currently there is a strong push in this sector, particularly on the basis of technology driven product service combinations. The examples given in this paper show however that also in the field of 'old-economy' products, using paradigm shifts as a management approach can be very fruitful.

Overall it is concluded that there are at least five ways forward in 'green'. All run in the same direction which combines environmental and economical gain. We are still at the beginning of these avenues. Five to ten years from now it will turn out that this will be a long but rewarding trip.

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Highlights of the year, 1997

Environmental benchmarking

The idea to develop an environmental benchmarking method came from Delft.

At that time my newly established chair had been positioned in the Design Engineering group and not in the Design for Sustainability group. The reason remains a mystery, most likely it is a kind of university dialectic which is difficult to explain to relative outsiders.

Anyway, one of the good things about Design Engineering was, and is, its desire to build on physical principles and its passion for metrics. This is helpful in an environmental world where talking about design paradigms, holistic principles and socially responsible design (whatever that may mean) continues to dominate.

Together with Arjen Jansen the 'EPass' method was developed. This is a systematic approach for the measurement of the environmental properties of products (see also chapter 6.3.1)

Its two elements are:

**Measurement of physical parameters in the five focal areas:*

1. Energy consumption in various modes of operation and of products and subassemblies (in watts)
2. Material application (on the basis of material type and subassembly function (kg)
3. Packaging and transport (weight, volume)
4. Chemical content (indirectly through weight of electronics and of cable and wiring in kg)
5. Recyclability (disassembly time (sec.) and efficiency (%))

**Measure on a relative scale: compare current products with those of previous generations but particularly with products of other brands.*

At Delft EPass had been successful so the method was ready to be tested at Philips Consumer Electronics. This approach however was initially rejected; prejudice against 'green' was still widespread. Finally, the Business Unit Monitors in Taiwan were prepared to do a test. The credibility that had been built up by the disassembly analysis (see chapter 7.3) was of great help in giving the E-Pass the benefit of the doubt. Student Rolf Namjeski was sent to Taiwan and his benchmarking work became an instant success. It was demonstrated that both in environmental design (and in overall design) Philips monitors were far behind those of Sony and Samsung. Rolf's report became the basis for brainstorming that resulted in the total revamp of monitor design (see chapter 6.3). The new products, the Philips 'Brilliance' monitors were 'green', had better performance than the competition and sold well.

This meant that the other Business Groups became interested too. In 1999 Environmental Benchmarking became mandatory for all groups of the CE Division. Even today it is the cornerstone of the environmental part of the Corporate Philips Sustainability Program.

4.3 Product Environmental Care Systems

In the year 2000 the integration of environment into business - according to the experiences and ideas described in the chapter 4.1 and 4.2 - had been completed at Philips Consumer Electronics. Activities for developing a planning and performance measurement tool to and providing visibility for that tool in company operations had been started (see also chapter 4.4).

It was still necessary to position the approach with respect to external developments. These included:

- The ISO 14001 standards. Several authors claimed the standards needed to more explicitly address product development.
- The ISO 14062 report, which was an attempt to fill the perceived gap for product development in the ISO 14001 standards.
- IPP (Integrated Product Policy). This was a European Union effort intended to promote Life Cycle Thinking and EcoDesign. In a later stage EEE and EuP were placed under this IPP banner. Both EEE (see below) and its successor EuP (see chapter 9.2.2) focused more explicitly on EcoDesign of electronic products.
- EEE, an initiative of the Directorate General Industry of the European Union, that intended to establish 'harmonized' standards for essential (Eco) requirements of electronic products.
- Eco-labels. The idea behind this is that when products satisfy Eco-requirements, they sell 'automatically' (this is highly doubtful, see chapter 5.4). Eco-labels were therefore thought to be strong drivers for EcoDesign.

A common denominator of all these systems is that there is a lot of emphasis on environmental issues. Balance with traditional business interests is almost absent, which meant implementation in all cases was pretty cumbersome. In spite of this, these systems got a lot of publicity. Inside Philips the question was raised "why do we need a special system?"

As a result I had to make several presentations to explain why our system was better suited for business than the others, which were pushed externally. Basically the argument is that the Philips System combines the best of all worlds. This means that all the elements present can be found in one or more of the EcoDesign/Product Environmental Care Systems described above. On top of that, there is more emphasis on organizational and business issues. In fact, the Philips system is rather more complete than less eco.

In light of all kinds of discussions going on at that time, it was also decided to communicate this idea at conferences and seminars. An example of such a paper is given on the next page. In this paper "*Product Environmental Care, A Praxis – Based System Uniting ISO 14001, ISO 14062, IPP, EEE And Ecolabel Elements*", it is concluded that the Philips system is in fact a combination of elements existing approaches, such as those mentioned above.

In a later development EuP has become the successor of EEE (see chapter 9.2.2) and has become a part of IPP. It contains a lot of enhancements. EuP puts the necessity of an environmental product life cycle analysis in pole position. Physical parameters are allowed in such an analysis, although impact analysis is still preferred. Moreover, EuP stated that environmental improvements needed to be balanced against economical, technical and social issues, which is in fact calling for business and societal integration. These basic items are important steps forward. Simultaneously, the EuP approaches still have several important practical drawbacks which are discussed in 9.2.2 as well. It is however my firm opinion that the current Philips Product Environmental Care system is a very practical way to serve the intent of EuP in an excellent way.

Product Environmental Care, A Praxis – Based System Uniting ISO 14001, ISO 14062, IPP, EEE And Ecolabel Elements

Ab Stevels

Abstract

Approaches addressing Environmental Care in products have been assessed according to requirements which were derived on the basis of practical experiences when implementing EcoDesign / Design for Environment (DfE) in the electronic industry. Systems examined include ISO standard 14001, ISO technical report (draft) 14062, the European EEE and IPP approaches and Ecolabels. None of the approaches as such fulfill all requirements in a satisfactory way. However, if elements with the best scores are combined into one system a very good basis for further tool development is created.

I. Introduction

EcoDesign / Design for Environment (DfE) has been addressed in the last ten years by a multitude of institutions either with an academic, standardization or governmental background. Academics have been focusing on design methodology and assessment (Life Cycle Analysis). Standardization has been looking to management systems such as ISO 14001 and EMAS. Public institutions (EPA, Directorates Environment of the European Union) have developed instruments like Energy Star, Ecolabels of various kinds as well as legislation developed. In the last category countries of the European Union are very active in fields such as packaging recycling, take back and recycling of electronics (WEEE) and cars, substances (the so called RoHS proposal) and so-called Environmental conformity initiative (EEE).

In spite of all these initiatives, EcoDesign / DfE has achieved only a limited foothold in industry. Proactive companies have shown excellent performance in this field – showing that when organized well EcoDesign / DfE really pays and enhances the business (see also II). However, on average the approach in industry has been fairly defensive so far. In the opinion of the author this unfortunate situation is due to the lack of integration between environment and business. Wanting to do good for the environment and focusing on the designer as the person who has to deliver, bypasses the realities of the business value chain and overemphasizes the technical part of the EcoDesign / DfE concept.

On the other hand there is a widespread misconception within industrial organizations, and by customers, that environmental activities cost money so that market forces cannot deliver more sustainability. This perception, which is fed by experiences in the process industry for more than 30 years, means that initiatives by academics and governments are sometimes contested by industry or at least placed low on the business agenda.

In this paper it will be shown on the basis of practical experiences that EcoDesign / DfE can provide substantial strengths for business. Its ramifications go far beyond environmental performance exclusively. When expanded and embedded in Environmental Care Systems it can be considered to be a new business management approach (II). Environmental Care Systems need to be organized. In III it is explored which issues need to be addressed. These issues include: Awareness, “Why” (should it be done), “What” (strategy, organization, programs and requirements) and “How” (idea generation, execution, validation and exploitation of the result).

As a matter of fact Product Environmental Care system should fit into usual business requirements to leave room for market forces, integrate with the business value chain and provides terms of reference to measure performance.

In IV it is explored to what extent current Environmental approaches fit into the outline of III. This includes:

- The ISO 14001 standard for Environmental Management Systems.
- The (draft) ISO 14062 report (version December 2000) on guidelines for integrating environmental aspects into product development.
- The (draft) Integrated Product Policy document of the European Union, version January 2001.
- The (draft) Environment conformity of Electronic and Electrical goods regulation of the European Union (version November 2000).
- Ecolabels of various kinds (average).

In V it will be concluded that none of the approaches cover all items in a satisfactory way (Structure, Business, Design principles) for a comprehensive Product Environmental Care System. However, if elements with the best scores are combined into one system a very strong tool can be developed. The ISO Technical Report 14062 as it stands now scores relatively well. Since it is still in a draft form it is expected that it will be improved further. In future it will form a strong basis for the development of Product Environmental Care Systems.

II. The strengths of EcoDesign / Design for Environment to be incorporated in a Product Environmental Care (PEC) system

DfE / EcoDesign is based on a number of principles which have significance for the environmental field as such but in practice have been shown to go far beyond that. Based on these principles substantial cost reductions have been achieved, products turned out to be simpler to manufacture and the image of the producer has been improved. In these cases there has also been lower cost of ownership, and more satisfaction for the customer.

The five EcoDesign principles are:

1. Prevention. Do more with less.

Two examples of the application of this principle are:

- Flame retardants in TV sets. By rearranging the position of the electronics within the set and lower energy consumption, the problems of internal "self heat" of electronics products can be mitigated. Several companies in Europe, including Philips, were so successful in this that all flame retardants used in the housing could be eliminated. As a matter of fact, the standards for fire safety were still satisfied by a wide margin. While satisfying with a wide margin the safety standards.
- CFC issues. The requirements of eliminating all CFC use has led many companies to a reexamination of cleaning practices. In the Netherlands and in Sweden this has led to a situation where in approximately 40% of the cases cleaning could be completely eliminated. By preventing contamination earlier in the process, water-based cleaning could be easily applied in 40% of the cases (also because for the first time the content of the requirement to be clean was clearly defined) and in only 20% of the cases substantial research for alternatives had to be done.

2. Functionality thinking. Look first at the function of the envisaged design instead of embodiments. Examples of this approach are:

- Replacing Expanded Poly Styrene (EPS) buffers used in packaging by cardboard buffers. EPS has been used for many decades. It is applied as the obvious solution to make packed products shock resistant. The environmental perspective suggested, as a possible design strategy, the use of lower impact materials which led to a reexamination on a functionality basis. It was concluded that cardboard buffers can be used in packaging of electronic products with a weight of less than 10 kg.
- In monitors, a metal "cage" was used in the past to ensure shielding of electromagnetic radiation from the electronics. Simultaneously this cage was used as a mechanical support in the construction. Due to the lower energy consumption of the electronics, the shielding function can be fulfilled by using less material. However to realize this environmental and cost improvement, product architecture, in particular the mechanical support functions had to be redone.

3. Life Cycle thinking: Check whether design improvements in one of the five focal areas (energy, material packaging and transport, chemical content, recyclability) really brings a positive environmental effect on a life cycle basis.

- Design effects for improving TV packaging were redirected when it turned out that the integral environmental load of packaging and transport were 70% volume related and only 30% material related. The focus became reducing volume rather than reducing packaging weight.
- High recycling percentages can more easily be achieved by applying metal rather than plastic in products. However in the department of material application the environmental load of metals is higher than that of plastics. On a net basis improved recycling cannot compensate for that.

4. Chain management. Upstream (suppliers) and downstream (recyclers) activities can contribute substantially to lowering the environmental load.

- By making and executing a common roadmap with their IC suppliers, consumer electronics companies have been able to lower the energy consumption of the standby function substantially. Energy consumption in the operational mode has also been decreased.
- Recyclers have requested not to attach cables /wires to a product's housing so that recyclability is higher. This has inspired many to pay much more attention to cable /wire configurations, resulting in less material use as well.

5. Paradigm shifts. Question: Why are things as they are?

- Investigation of the limited application of energy saving lamps in living rooms (replacing with incandescent lamps) led to new business directions to support this development:
 - a) develop energy saving lamps with a better color rendition.
 - b) extend the energy saving lamp, product line-up in the low Watt range.
 - c) introduce lamp shades taking into account the slightly different form of the energy saving lamps.
 - d) produce checklists through which users can determine for themselves where the application of energy saving lamps is beneficial from an environmental and economic perspective.
- Further penetration of portable products is hampered by their battery power. These batteries are a source of discomfort and are considered to be environmentally unfriendly. This means that the application of solar cells, fuel cells (methanol) and human powered products are now considered. A first result of this is the availability of human powered radios, which are a huge commercial success.

All these examples show first of all that the application of the EcoDesign / DfE principles can bring advantages during all phases of the lifecycle (production, packaging and transport, use and end of life) and on all major items contributing to environmental impact (energy consumption, materials application, substances and chemicals and recycling).

A second very important item is that the benefits are not restricted to the environmental field exclusively, but are combined with those for other stakeholders, according to table 1.

The benefits matrix in table 1 is on one hand the key for the selection and prioritization of 'green' design possibilities. On the other hand it is the key to successful 'green' marketing strategies; only when environmental benefits can be combined with other benefits (or vice versa), will 'green' products sell well (see ref. 1).

In the examples given above there is another element which is inherently linked to EcoDesign / DfE: cross functionality. In all cases combinations of disciplines play a crucial role, for instance designers and purchasers, production and production engineering, logistics and packaging designers, electronics engineering and purchasing, mechanical engineering and product managers etc. Organizing such crossfunctional processes to bring primarily environmental improvements pays dividends in a number of other fields. This is giving EcoDesign / DfE significance far beyond its own field.

Table 1 The benefits matrix

Stakeholder	Company	Consumer	Societal
Type of benefit			
Material	Costs reduction	Lower cost of ownership	Less imports
Immaterial	Easier to produce Easier to sell	Easy, convenience, fun	Better compliance with 'green' policies
Emotional	Enhancement of image	Feel good, quality of life	"We make progress in green"

III. Requirements for Product Environmental Care (PEC) systems

Requirements of PEC systems can be split in three parts:

- 1) The five EcoDesign principles, as set forth in II, should be addressed.
- 2) The processes ensuring cross functionality and prioritization, according to the benefit matrix, should be organized.
- 3) The conditions for successful integration into a business should be fulfilled.

In this section items 2 and 3 will be examined. The basis for formulating the requirements are studies on the implementation of EcoDesign / DfE in the Netherlands. These include:

- Integration of EcoDesign into the business (ref. 2).
- Application of EcoDesign in the electronics industry (ref. 3).

These studies propose a detailed systematic approach for making product environmental care happen in business. Particular attention is to be paid to drivers why to do it, to separation of idea generation and validation and to benchmark to set terms of references.

- Environmental Value Chain Analysis: A tool for product definition in EcoDesign. Here the necessity of aligning internal and external value chains is addressed (ref. 4).
- The unpredictable process of implementing Ecoefficiency strategies (ref. 5).

In this study conditions for success which can be derived from cases studies are formulated. These conditions include; management of the internal value chain, responding to external drivers favorable to business conditions, product characteristics which allow room to maneuver and the potential to gain competitive advantage.

- Product oriented Environmental management systems (ref. 6).

This work emphasizes management support, the necessity to have clear strategies and the importance of information systems.

Organizing the elements on these studies requirements on PEC systems can be described in the following way: Starting EcoDesign / DfE processes should begin by creating awareness. People in an organization should realize that there is an opportunity out there and that it can be done, for instance by showing that e.g. competitors did it already. A next step is examining relevant external and internal drivers. External drivers can be customer requirements and legislation / regulation. Internal drivers are, for instance, cost reduction and a better image. Analysis of such drivers already provides a first direction and first priorities for the activities. This is very relevant because for each activity in a company – including 'green' – limited budgets, capacities and time frames are available.

Using these limited resources properly is the goal of the next chapter to be addressed, the 'what' items:

- * strategies: What goals are to be set.
- * organization: What responsibilities are to be defined.
- * programs: Definition of scope and items to be realized.
- * requirements: Translation of strategies, programs into specifications for individual products.

Last but not least the 'how' items are to be considered. These items are closest to traditional EcoDesign / DfE, however there are some remarkable differences:

- Idea generation: Develop ideas on the basis of facts acquired from suppliers or through environmental benchmarking (see ref. 7). When these are tested according to the benefits matrix, see fig. 1, the ideas can be prioritized and fed into product specifications (note that this is a process different from applying upfront LCA – addressing of non environmental items in this phase is ensuring business integration!).
- Execution: Apply technical EcoDesign / DfE principles to the prioritized targets.
- Validation: Validate the result on the basis of environmental common sense (reduction of W, kg, see, % etc.), factor methods or abbreviated or full Life Cycle Analysis.
- Exploitation in the market: 'Green' marketing and sales on the basis of the benefits matrix (see fig. 1) according to the principles outlined in ref. 1.

By operating in the way that has been studied above the conditions for successful business integration and operating in the market with 'green' items are fulfilled. What needs to be added to this is defining terms of reference. Most traditional validation methods work on an absolute floating scale which has no significance for internal and external stakeholders and is as such difficult to communicate. Such terms of reference can be:

- Products of a previous generation (focus on "internal improvements").
- Products / comparable functionalities of competitors (focus on "external" improvement).

IV. Rating of current systems addressing Product Environmental Care

In this chapter five systems addressing product Environmental Care in one way or another are rated according to the criteria and requirements developed in II and III. These include:

- The ISO 14001 standard for environmental management systems.
- The draft ISO 14062 report (version Dec. 2000) on guidelines for integrating environmental aspects into product development.
- The draft Integrated Product Policy (IPP) document of the European Union, version January 2001.
- The draft Environment conformity of Electronic and Electrical goods regulation of the European Union (version Nov. 2000).
- Ecolabels of various kinds (average).

First, the EcoDesign / DfE items are examined. Results are summarized in table 2:

Table 2 EcoDesign / DfE principles in current systems considering Environmental Care

Item/Approach Principle	ISO 14001	ISO 14062 Version Dec. 2000	IPP Version Dec. 2001	EEE Version Nov. 2000	Ecolabels
Prevention	0	+	0	++	0
Functionality thinking	0	+	0	0	+
Life cycle thinking	0	++	+	+	+
Chain management	0	0	0	0	0
Paradigm shifts	0	+	0	0	0

+++ = addressed very well ++ = addressed well + = addressed 0 = not addressed

First conclusion from table 2 is that with the exception of chain management the EcoDesign / DfE principles are all addressed. Since ISO 14001 is primarily a management system it is natural that it does not score in this table. In ISO 14062 there is clearly room for further improvement. IPP, which is chiefly about policy instruments to foster EcoDesign / DfE clearly needs to be beefed up which also holds for EEE. Ecolabels specifically consider products with similar functionality brought to the market rather than business processes. Many chain management activities and design paradigm shifts are not rated at all. However prevention, functionality thinking and life cycle thinking should be enhanced.

In table 3 the PEC requirements of current systems considering Environmental Care are assessed.

Table 3 PEC requirements in current systems considering Environmental Care

Item	ISO 14001	ISO 14062 Version Dec. 2000	IPP Version Jan 2001	EEE Version Nov. 2000	Ecolabels
Approach					
Awareness	+++	+	+	+	+
Why to do it	0	+	0	+	+
<i>"What"</i>					
Strategy	0	+	0	+	0
Organization	+++	+	0	0	0
Programs	+	0	+	0	+
Requirements	0	+	0	+	++
<i>"How"</i>					
Idea generation	0	0	0	+	+
Execution					
Validation	0	++	0	0	0
Exploitation of result	0	++	++	++	+
	0	+	0	+	++

+++ = addressed very well ++ = addressed well + = addressed 0 = not addressed

Due to the fact that ISO 14001 is a well established global system its awareness power is maximum. The other systems can only score higher by increasing their appeal or by giving up their regional or national character (Ecolabels). The "why" items (the drivers) get surprisingly little attention, which also holds for strategy. There is a clear need to further stress these items.

In terms of organization ISO 14001 scores very well both through the required structure and the plan-do-check-act approach. The European IPP and EEE are too focused on the design process as such (see "how") whereas the "whats" are addressed to a lesser extent in the current drafts.

For programs and requirements the current status is pretty poor as well. Structured approaches are not widespread and there seems to be too much confidence in "designers staring out of the window wanting to do something good for the environment".

In the field of "how" the table shows that there should be more attention paid to systematic idea generation and prioritization. ISO 14062 scores particularly well for execution. Attention for validation is high although the scores in this department are not at their maximum. This is because generally speaking those LCA approaches that are promoted are difficult to carry out in an industry.

For exploitation of results only Ecolabels get an "addressed well" score – this could be further enhanced by linking 'green' with other benefits (see fig. 1). The business items are reviewed in table 4.

Table 4 Business items related to current Environmental Care systems

Item	ISO 14001	ISO 14062 Version Dec. 2000	IPP Version Jan. 2001	EEE Version Nov. 2000	Ecolabels
Approach					
Leaving room for market forces	0	+	+	+	+
Integration with business	+	++	0	+	0
Defining terms of reference	++	0	0	+	+++

+++ = addressed very well ++ = addressed well + = addressed 0 = not addressed

In this category the item "leaving room for market forces" is a difficult one. On the one hand it is generally recognized that better environmental performance should be rewarded. On the other hand there is a lot of leveling of the playing field observed in practice: ISO 14001 has lost its character as a qualifier. Labels and conformity marks will most likely go the same way. From this perspective ISO 14062 and IPP have the best potential.

IPP and Ecolabels so far link up primarily with business process as occur in practice. ISO 14001 has in this respect a limited appeal due to its formal character. ISO 14062 scores well because it focuses on product creation processes. In the department: defining terms of references general scores are poor with exception of ISO 14001. This is related to the fact that EcoDesign / DfE has started addressing absolute items like "environmental load" rather than the improvement idea.

V. Synthesis

In spite of the fact that quite some criticism is possible on the present systems addressing Product Environmental Care, there is also a lot of good news:

- Three of the five systems are still in their draft stage (ISO 14062, EEE and IPP). It is expected that further discussions among the stakeholders will result in improvements of these approaches, resulting in higher scores in the tables 2, 3, and 4.
- Although there are gaps in each of the systems considered, a combination of the best scores for each element could result in one comprehensive system for Product Environmental Care.

The Design for Sustainability group of Delft University in the Netherlands will further develop such systems on the basis of the best combination and test these in industrial practice. Key elements in the system to be developed will:

- Assist in defining the key 'green' (design) avenue and setting their priorities
- Assist in building strategies, programs and requirements.
- Assist in fostering creativity / idea generation and defining terms of reference for validation.
- Assist in defining key processes and their alignment, including overall 'green' performance scores.

It will ensure that other stakeholder benefits will be considered jointly in this Delft Product Environmental Care systems. This will empower the PEC to be developed when tested at the business level. Results of such tests will be helpful to enhance standardization and public policies in this field.

VI. Conclusion

EcoDesign / DfE principles can be a strong basis for enhancing business. When introduced in the form of Product Environmental Care systems the benefits of this concept can be systematically exploited. Current standards (ISO 14001, ISO 14062), policy approaches (EEE, IPP) and Ecolabeling schemes individually fulfill only part of the requirements to be set (from a practical perspective) in a satisfactory way. However, if elements of all these approaches are combined through a 'best score' approach, a very good basis for further development is created.

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Leendert Cornelis ('Leen') Dronkers Sr. (1885-1955): Creation and nature

Leen Dronkers is my grandfather (and the father of my mother, see Personalities 6). From him I learned a love for nature and respect for Creation. He was born in a little village in the southwest of the Netherlands (Nisse, Zeeland, see also Pictures, 14). As the son of the local baker he had limited possibilities for development. Social mobility was uncommon in those days. One of the few ways to achieve this was to become a schoolteacher. That was what he became and what he really was, with all his heart and soul.

*I was his favourite grandson and when my grandparents moved to Eindhoven to live close to their children and grandchildren I went every Wednesday and Saturday afternoon to see him. I got taught how to grow herbs and plants in the garden, how to pick apples and other useful things, or we went out of town (nature was still close to the place where we lived). He could tell endless and interesting stories about trees, wild plants, mushrooms and butterflies (both still abundant). He knew the names of all the species. If I found a plant that he did not know the name of I got paid ten cents. I almost earned some money with what turned out to be 'witte rapunzel' (*Phyteuma spicatum*). This was because he was very surprised that it was growing in the Eindhoven region and not because he did not know the name of the species.*

Opa (the Dutch name for grandfather) was also a Calvinist with strong patriotic feelings. He thought that it was very well possible that one of the ten lost tribes of Israel had turned up in Zeeland. He was proud of the Republic of the Seven United Provinces (from 1677 – 1795, the glory days of the Netherlands). His sense of duty was even stronger: "Work till you have finished it". "There is always more to learn". "If you can walk for ten kilometres do not compromise for five". He was not optimistic about society but nevertheless he always wanted to look forward: "From the past you can learn little".

When Opa Dronkers died, I was almost 11 years old, the impact on my life was enormous and it still is.

The 'Dronkers' Walk: go to Nisse (Zeeland), 6 km south of Goes. Start at the village square, go past the Dutch Reformed Church on the Zuidweg, cross the N666 and go R (Palmboomseweg), go R (Koedijk), go L, go R than first L (Zwaaksedijk), go R (Vreelandsedijk), go L, go R (Nieuw Vreelandsedijk) and direct L. Go straight ahead and in the end R. Go straight to Kruijpuitse Dijk, go R (Oudelandsedijk) and first R. At the end of the road R (cyclists path), direct L (Ambachtsherendijk), and R (Brilletjesdijk). Go L (Valdijk), go L and directly L again.

After that go R and R again (footpath Paardekerkhofwegeling) , go L Akerweg and L to Nisse.

4.4 Managing the Environment and Business today: planning and performance measurement.**4.4.1 Introduction**

Interest in what companies are really doing in 'Eco' products was further stimulated with the start of the research project of PhD candidate Oriol ('Uri') Pascual. Coming from Barcelona he was immersed in the Delft mentality and style, but soon added flavor to DfS with his Catalan/Spanish style. The first part of his work (the second part is focusing on EcoValue, see chapter 2.3) has been dealing with 3 research questions:

- What do electronic companies publish on Applied EcoDesign?
- How far the implementation and performance measurements of EcoDesign in electronic companies have progressed?
- For companies having mature EcoDesign activities, what is the style of their operations?

The approach to finding answers to these questions has been mainly empirical. As was pointed out in chapter 2.1, little has been published about this subject. There is still active debate about all the findings we have had - and still have. However, the main issues are very clear and should be interpreted in a comprehensive way. The complete results will be published in Uri's thesis to be published mid 2008.

In the paragraphs below three publications are presented with information referring to the research questions presented above. The information for these results was obtained through literature reviews, checking websites and other cooperate information and through interviews.

From Human Power to Consumer Power

Portable devices represent convenience, however their batteries are seen as being a nuisance. This is not only from an environmental point of view but particularly from a user perspective (you always run out of power at the wrong moment) as well as a cost perspective (batteries are relatively expensive). Human powered products could offer an alternative for these inconveniences. Literature however offers little guidance about where human power can be applied with success. Therefore, at Industrial Design Engineering in Delft, such products have been studied intensively. In the course of several years, some 20 graduation projects have been carried out on the subject. One PhD dissertation summarizing it all, and putting it into a broader ergonomic and physical framework, is still underway (see chapter 4.6).

There are a lot of physical principles to choose from however to generate the power, both by active movements (finger, thumb, hand, arm, foot, leg) or passive ones (chest, heat emission, airflow). In physical language there rotation, translation and are all available. In fact there is an embarrassing amount of choices. Several projects had difficulties in matching the energy generation principle and the functionality required.

Not for student Eelco S however. His approach for designing a human powered remote control was a very pragmatic one. In the spirit of Delft's engineering tradition - take big steps and try to get home quickly - he established 13 principles for generating energy. The principles ranged from 'wind-up' to 'break-up' and he explained the principles to users and asked them what they would like most. The selection of the six preferred principles included the wind-up, the pull, the roller, the push button, the trackball and "shake-it". A further selection was made by applying other design criteria like reliability and price. At the end of this exercise only three concepts survived: the wind-up, the roller and the "shake-it". The next step was to build real prototypes and have them tested by users. Eelco observed each meticulously and drew the following conclusions. Shake-it drops out. Roller seems best but has some problems with usability. The end result was the design of a TV remote control that was powered through a combination of the wind-up and roller principles.

The lessons learned for the designer from this project was do not be arrogant and do not think that you know better than anyone else. For the engineer the lessons were let practice show the way and do not try to calculate everything upfront. For the design engineer it was let the users feel, touch and speak.

So what happened with the design and the well resolved prototype? It landed on the desk of a product manager in Singapore who concluded - without any real arguments - that it was a nice product but that there was a market for it. Not invented here? Lack of entrepreneurship? Mediocrity? Fear? Risk avoiding Philips? Who knows?

Anyway, the 'Consumer Power', which proved to be so helpful in the design phase was not reciprocated by 'Marketing Power'. I still believe however that one day human powered products will be a hit!

4.4.2 What subjects are addressed in Applied EcoDesign activities by industry?

This publication shows that industry pays a lot of attention to 'end-of-life' and recycling issues and relatively little attention to energy reduction issues. This is in spite of the fact that life cycle considerations show – irrespective of the analysis tools used – that 50-90% of the life cycle impact of electronic products is due to energy consumption. This phenomenon is analysed further in the paper "Electronics Ecodesign Research Empirically Studied" below.

Electronics Ecodesign Research Empirically Studied

Oriol Pascual; Casper Boks; Ab Stevels

Abstract

An extensive literature analysis has been carried out, encompassing over 850 papers published at ecodesign community conferences. Using a classification framework based on academic and industrial processes of fact-finding, analysis, implementation, and exploitation of ecodesign knowledge and adjacent topics, insight has been generated as to the distribution of research attention across these topics. This information has been used to discuss propositions related to under- and overemphasis of research topics.

1. Background

In the past decade, ecodesign research has been focusing largely on what could be addressed as technicalities. What has been accomplished and what presently exists is a wealth of idea, tools, methods, pilot studies, information, and knowledge about the integration of environmental aspect into product design. These technicalities mainly refer to environmental impact data, technological improvements, material substitution, ecodesign tool development and a variety of other elements. However, it can also be observed that ‘...even in countries where method development, education and dissemination are reasonably mature, actual environmental product design still scores relatively low in the maturity profiles [1].

A small number of recent publications [2-9] have addressed this discrepancy. In these papers, causes have been identified such as an excessive focus on complex tools and methods (also when not needed), lack of life-cycle thinking caused by organisational complexities, insufficient cooperation by actors (in terms of communication, exchange of experience and mutual cross-fertilisation), gaps between supporters and executors, a lack of industrial context, a lack of clear target groups, lack of stakeholder inclusion, an overestimation of manoeuvring room in industry, a lack of testing tools and an overall lack of simplicity.

Some of these findings have been accumulated from company interviews and other sources of industrial experiences. Some also reflect the opinions and ‘gut feelings’ of those involved in ecodesign for a substantial amount of time. In any case, these findings address the fact that there is a certain gap, or discrepancy, between the bulk of ecodesign-related research (either by academia or industry itself) and that what is needed by the industry to actually implement research findings.

2. Goal of the paper

For the purpose of this paper the above observations from literature have been summarized in a number of propositions given below.

- Proposition 1: In research focusing on ecodesign issues for the electronics industry, there is an excessive focus on complex tool and method development (e.g. after Mathieux et al., 2003).
- Proposition 2: In research focusing on ecodesign issues for the electronics industry, there is an excessive focus on end-of-life issues.
- Proposition 3: In research focusing on ecodesign issues for the electronics industry, there is a lack of examples of successful ecodesign that will stimulate a wider application throughout the industry.
- Proposition 4: In research focusing on ecodesign issues for the electronics industry, there is lack of research attention for the complete industrial stakeholder chain when designing solutions for ecodesign implementation (e.g. Mathieux et al., 2003, Cramer and Stevels, 2001).

As indicated, these propositions are derived from statements in literature that are or are not substantiated by empirical evidence. The goal of the present paper is to find additional empirical evidence to either attack or defend these propositions, other than by the results of a single study or by someone’s experience or ‘gut feeling’. It is believed that this will contribute to a better foundation for opinions that seem to emerge in the ecodesign community lately. It is no coincidence that this paper is prepared at a time when on various levels there are signs that (successful) attempts are being made to overcome the above indicated discrepancy by specifically addressing the problem areas listed here. For academia this means for example addressing implementation issues and doing

practical surveys rather than conducting stereotypical ivory tower research.

The emergence of these relatively new topics in the ecodesign community is by some, in particular those with an engineering attitude and/or background, addressed as the *soft side of ecodesign*, referring to a variety of sociological, psychological and perhaps intangible factors that research should address as well. Surprisingly (or perhaps not), those with a designer attitude and/or background are more inclined to refer to these issues as the *'hard' side of ecodesign*, referring to the hard reality of business life, deadlines, budgets, and sceptical or smirky attitudes towards environmental issues. This is yet another discrepancy, caused by a difference in backgrounds and attitude between engineers and designers, and it may very well illustrate the task that indeed lies ahead; namely the synchronisation of content, form, context and time when communicating ecodesign [9].

3. Research method

In order to do so an extensive literature analysis has been carried out, encompassing about 850 conference papers that addressed ecodesign issues for the electronics industry in the 1998-2002 period. In all of Ecodesign literature, literature surveys are frequently devoted to the identification of the state-of-the-art of technological progress, implementation schedules, legislative processes, etcetera. However, literature analysis in a more bibliometric fashion is seldom seen. However, it can be shown that such an overview, done regardless of topic but rather encompassing all of ecodesign, can be insightful for a number of reasons. One of example of this type of research is found in [10], where a literature survey was done on order to determine in what type of scientific publication media the topic of (Applied) Ecodesign is most alive.

For the present study, most of the Ecodesign literature published in the 1998-2002 period has been classified using a detailed classification scheme in which all main and other ecodesign research topics are covered. In Figure 1, the classification scheme is graphically shown. An important feature of the classification scheme is the division in the industrial and academic background of authors of publications. Both parts of the classification scheme reflect the process of fact-finding, analysis, implementation and subsequent operationalization and exploitation of ecodesign knowledge, such as for example found in [11]. The classification scheme depicted in Table 1 reflects the main categories in which publications have been divided. Subdivisions (up to five levels) have been made for each of the 15 categories as well, resulting in over 100 categories. As an example, below the subcategories for topic category 5: Technicalities and Validation is given. Similar subcategories were created for all 15 topics.

Table 1 Division into subcategories

5 Technicalities and Validation			
5.1	LCA in general	5.2.2.3	Product recycling
5.1.1	LCA tools	5.2.2.4	Modularization (upgradeable products)
5.1.1.1	Abridged approaches	5.2.3	Legislative issues
5.1.1.2	Method comparisons	5.2.3.1	Labelling
5.1.2	LCA Databases	5.2.3.2	Draft legislation review
5.1.3	LCA Software	5.2.4	Remanufacturing/refurbishing
5.2	End-of-life issues	5.2.5	Reuse
5.2.1	Disassembly issues	5.2.5.1	Product reuse
5.2.1.1	Theoretical analysis	5.2.5.2	Component reuse
5.2.1.2	Practical evaluation	5.2.6	Logistics/take back
5.2.2	Material recycling issues	5.2.7	EOL Management
5.2.2.1	Material recycling process	5.3	Usage stage/Energy issues
5.2.2	Chemical/toxicity issues	5.3.1	Alternative energy sources
5.2.2.2.1	Glass recycling	5.4	Material Content
5.2.2.2.2	Plastics issues	5.4.1	Halogen-free/Flame retardants
5.2.2.2.4	General PWB issues	5.4.2	Lead-free solder

4. Justification of chosen literature base

It has been chosen to focus on literature published in conference proceedings only. Reasons for this are twofold. Firstly, especially in the field of ecodesign proceedings are a main platform for publishing research results. In [10] it was shown, based on a sample of 3000 references of which over 500 were journal publications, that 29% of these references were published in proceedings, constituting the largest category, with references to journals making up 21% and books 16%. This supports the argument that by including in the present analysis a number of relevant journal articles - which are pretty scattered over a number of journals mostly not specifically addressing ecodesign - the relative distribution of topics will not significantly change. Secondly, it is in the nature of science that often research results are presented in proceedings before they are refined and published in journal articles or book chapters. Including the latter in the analysis could then even imply double counting certain research efforts, something which is preferably avoided (although it could be in argument in favor of weighing research efforts according to their importance).

The sample of literature has involved proceedings from the European CARE Innovation conferences in 1998 and 2002, Electronics Goes Green conference in 2000, and Electronics Goes Green conference in 2000, the American IEEE International Symposia on Electronics & the Environment 1999-2002, the Japanese Ecodesign conferences in 1999 and 2001. These conferences have been chosen as they are commonly accepted to be the main platforms for the community of researchers involved with ecodesign for the electronics industry. Papers presented at these conferences that were clearly outside the scope of ecodesign of electronics products have been omitted from the sample.

5. Empirical results

It was found that 36.4% of all papers originated from academia (i.e. the principal author had a university affiliation), whereas 57.4% originated from industry. Furthermore, 6.2% of all papers were classified as case studies that involved academic as well as industrial research partners. The empirical results from the literature survey are displayed in Table 2. In these tables, the percentages are given of all scanned literature, divided over the topical categories given in Table 1.

A factual interpretation of the results presented in Table 2 provides the following observations:

- Considering **industrial contributions**, the majority of the papers (60.5%) is devoted to technicalities and validation. Within this category, 3.9% is devoted to (alternative) energy issues, 2.3% to LCA issues, and 54.3% to end-of-life issues. The majority of this percentage is devoted to material recycling issues (30.1%), including such topics as lead-free solder (9.7%), specific process issues (7.1%), and halogen-free issues (6.8%).
- With 13.5% the category 'environmental management and integration' constitutes the second biggest part of the industrial literature. In this category, papers addressing supply chain issues (3.5%), and papers addressing the issue of combining economic and environmental considerations (without a tool context) (4.8%) constitute the biggest subcategories.
- Furthermore, it appears that the further away topics are from design and manufacturing, the less attention they get. This seems to hold for the strategic issues, green idea generations, and green communication topics.
- Considering **academic contributions**, the majority of the papers (68.8%) is devoted to operationalization of knowledge and theory. Within this category, 6.5% is devoted to LCA issues, 3.3% to supply and environmental chain issues, 3.5% to various business perspectives, and 38.5% to end-of-life issues. A further subdivision of this latter category shows 12.0% of these papers devoted to material recycling issues, 10.0% to specific disassembly issues, and 6.1% devoted to remanufacturing and reuse. The remainder is divided between smaller topics like EOL management and EOL logistics.
- The identification of societal phenomena and external factors receives with 8.8% relatively limited attention. Out of this percentage, 6.4% was devoted to legislative issues, with the remaining 2.4% devoted to other societal issues. An interpretation of this could be that in the subdiscipline of ecodesign, research is based on findings and paradigms that are either originating from other (environmental) disciplines, or are originating from the time period before 1998. Apparently, legislative developments are considered an exception to this as they receive a lot of attention within ecodesign literature and up to now.

Table 2 Division of research attention across topics

	Perc. per subsample (ac./ind.)	Perc. of all scanned literature
<i>Industrial Contribution</i>		
1. Strategic input	2.9%	1.1%
2. Roadmapping	5.1%	1.9%
3. Green idea generation	1.0%	0.4%
4. Tool support and benchmarking	7.4%	2.7%
5. Product creation	7.4%	2.7%
6. Technicalities and validation	60.5%	22.0%
7. Green communication	2.3%	0.8%
8. Environmental Management & Integration	13.5%	4.9%
<i>Subtotal industrial contributions</i>	<i>100%</i>	
<i>Academia Contribution</i>		
9. Identification of societal phenomena/ external factors	8.8%	5.0%
10. Gap identification and analysis	1.8%	1.0%
11. Survey of existing knowledge	3.9%	2.2%
12. Operationalization of theory and knowledge (tools & methods)	68.8%	39.5%
13. Theory development, real-life abstraction	13.0%	7.5%
14. Information transfer for educational purposes	3.7%	2.1%
<i>Subtotal academic contributions</i>	<i>100%</i>	
15. Case studies		6.2%
Total amount of papers		100%

6. Empirical evidence for the propositions

In this section it will be investigated to what extent the empirical data presented in section 5 does or does not support the propositions presented in section 2.

It would be most useful when for this purpose a frame of reference would be available that could be used for validating whether a certain amount of research attention for a certain research topic is for example 'too much' or 'too little'. Such a base line could for example look like

- 'when a topic Y receives more than x times as much attention in comparison to topic Z, it receives relatively too much attention'; or
- 'when a topic Y receives more than xx% or less than xx% attention, it receives too much or too little attention'.

However, several reasons exist why it has been chosen not to operate such a base line, the main one being that setting boundary percentages would be arbitrary as no consensus exists on what topics should receive more attention than others. This choice brings about that the discussions on the verification of the proposition is done on an ad-hoc basis, based on what the authors consider as fair arguments.

6.1 Proposition 1

Proposition 1 proposes that there is an excessive focus on complex tool and method development in recent literature. From the result it can be observed that papers, written by industry and devoted to technicalities and validation, constitute 22% of all papers. At the same time, papers devoted to operationalization of theory and knowledge constitute 39.5% of all papers. This means that over 60% of all papers to some extent focus on capturing knowledge and information into tools and methods with the intent of being utilized by industry. Without a baseline it is difficult to discuss whether this is an excessively large percentage or not.

Taking a closer look at the data it becomes clear that many papers focus on specific issues (see for an example again Table 1). When filtering out papers that specifically address (complex) tool development - according to the authors of the present paper - we arrive at the count presented in Table 3.

Table 3 All categories focusing on tool development

Category (incl. subcategories)	Name	Paper count
3.4	General DFE tool prototypes	15
5.1.1	LCA tools	5
5.2.1.1.	Disassembly issues - Technical Analysis	4
12.1.1	LCA tools	17
12.1.3	LCA software	10
12.5.1.1	Disassembly issues - Technical Analysis	14
12.5.7	General EOL tool prototypes	8
13.3	General DFE tool prototypes	31
Total papers		104 (12.2%)

Again, without a frame of reference it is difficult to state whether 12.2% of all papers is or is not an 'excessive' amount of attention for tool development. But if we consider that methods and tools are intended to facilitate product development of ecodesigned products and we use as baseline case studies and examples of ecodesigned products found on this review (6.82%), it gives the impression that the effort on methods and tools it is not translated on a relevant amount of ecodesigned products, as it was supposed to be. (I.e. 54% of the electronic and communication companies at Global Fortune 500 that claim to use ecodesign on their PDP, demonstrate it by showing examples [12]).

6.2 Proposition 2

Proposition 2 proposes that there is an excessive focus on end-of-life issues. In the categorization, categories 5.2 (for industrial papers) and 12.5 (for academic papers) were especially devoted to end-of-life issues. The paper count for these categories has been 169 (54.3% of all industrial papers) and 189 (38.5% of all academic papers), respectively. This means that 41.9% of all papers in the sample have been specifically devoted to end-of-life issues. It should be noted that in this count, papers devoted to WEEE legislation as a strategic issue or as a societal phenomenon (in total 17 papers) are not included.

As with the previous proposition, without a frame of reference it is impossible to classify this figure as being 'excessive' or not. When however compared to papers addressing other life-cycle stages, for instance papers addressing energy issues, it can be observed that in this latter category a mere 23 papers were classified, 2.7% of all papers.

This at the least supports the argument that there is very little attention for the usage phase, especially considering the environmental impact for this stage, which for consumer electronics is 50-80%. However, this is just a scientific perspective of what is important from an environmental point of view. There are several other perspectives of 'what is green' as well, including a customer and a governmental perspective. From these perspectives, end-of-life scores often much higher on the priority ladder, because of political and emotional reasons.

6.3 Proposition 3

Proposition 3 proposes that there is a lack of examples of successful ecodesign that will stimulate its dissemination throughout the electronics industry. This proposition is supported by the fact that what seems to be a relatively small number of papers is devoted to case studies (6.2%). A closer look to this result shows that of this amount of papers, roughly one third was devoted to LCA studies, and the remaining two-thirds were examples or pilot studies of eco-designed products.

It remains a question however to what extent these examples provide insights for less experienced companies on how to do ecodesign, and to assess the learning effect. To some extent, the presented case-studies can be considered window-dressing, where only the end result is promoted without attention for the underlying processes and what could have been learned from that. Therefore it is suggested that there even successful ecodesigned products are poorly communicated.

6.4 Proposition 4

Proposition 4 proposes that there is lack of industrial context when designing solutions for embedding ecodesign in industry. Papers that do have attention for the industrial perspective have been categorized in various subcategories. For example, academic subcategory 12.7 (2.0% of all papers) is devoted to papers discussing the alignment of economical and environmental perspectives (12.7.1) and the aligning of ecodesign with traditional business perspectives (12.7.2). Also, industrial subcategories 8.3 and 8.4 (2.0 % of all papers) have a similar topic. So, in fact there is attention for this industrial context in relation to specific ecodesign topics although not in large numbers. This shows "environmental apartheid".

Papers specifically devoted to discussing supply chain issues (23 papers; 2.7%) or environmental value chain issues (9 papers, 1.1%) have also been categorized in specific categories in categories 8 and 12. Topics relating to 'green communication' and 'green marketing' result in a total count of 19 papers (2.2% of all papers).

According to whatever baseline one might choose, it is clear that these topics receive little attention in literature. The question whether this is a 'bad situation' or not is a much harder to answer. 'Mitigating circumstances' would apply when the discussion on how to put ecodesign processes in industrial context would take place in adjacent scientific disciplines such as business and economic sciences; although the present study does not address this, it can be observed that this is only partly true. Product oriented environmental management is a discipline that is indeed studied in management sciences, but it can be motivated that without engineering and design perspectives, practical applicability will be limited. And if indeed this multidisciplinary approach is taken, papers of this nature could be expected to be published in the proceedings that have been analyzed in this study.

7. Conclusions

The present paper is intended to empirically test some propositions found in ecodesign literature and to bring food for thought and discussion about what could or should be ecodesign's main future developments.

The main conclusions from the present study are:

- Most of the developments in ecodesign appear to be based on paradigms that already exist for many years. Issues that have a high legislative and/or emotional priority appear to dominate the choice of research topics - something which cannot always be justified from a scientific point of view (i.e. end of life vs. energy consumption).
- Ecodesign discipline was developed and launched by academia some fifteen years ago, nowadays it seems that based on quantitative argument (with 57.4% of the papers written by industry) that industry (at least, in the electronic industry) is taking the lead of its evolution.

- Generally, it can be said that most of the attention is put on technicalities and validation, while the alignment of ecodesign with business operations is still rating low. It is suggested that ecodesign's potential may achieve its maximum expression when its cross-functional characteristic is fully explored. Therefore, alignment of ecodesign with business operations needs more attention.
- Examples of ecodesigned products that successfully perform on the market are available in literature in very limited numbers. Apparently, it is still difficult to empirically demonstrate that embedding ecodesign in business operations lead to improvements and competitive advantage, as has been claimed by academia.
- Research on energy consumption of products receive little attention, when it is a dominating factor on the environmental impact at product life cycle and it will become a future issue due to international agreements (Kyoto).
- It seems that the current main driver for adopting ecodesign at organizations is Environmental legislation (latest EU developments). Other aspects as consumer demands (marketing studies) receive little or no attention.

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The Gang Dinner

PhD Students love to go conferences abroad. It is an adventure. You can get in touch with experts, the travel is paid for and a private holiday can be connected to the trip. International experience before starting professional life is very important in my opinion. Moreover, the student should realize that the Netherlands is not the center of the world (and Delft is not its intellectual capital). On a European scale, the Netherlands is a small country, on a world scale it is a peanut. Delft University is pretty famous, but not the top in global rankings. Culture and style, in which technical and environmental issues are dealt with, is vastly different among countries and in regions of the world and it is important for students to experience this early on.

Yes, I have generously supported the PhD students in their traveling. I have only one condition: contribute to the event in the form of a paper and make a presentation which is able to catch the attention of the audience.

Saying "yes" to such challenges has grueling consequences: in the first instance the paper has to be written by the student him or herself and the presentation has to be rehearsed (see Personalities, 1). As a co-author, I only give comments with the aim to improve; in the end the students have to do it their way. Many years ago, I used to write comments with a red ballpoint; this had a negative psychological effect – it was perceived that a lot was wrong. When I made comments in blue, better results were achieved.

This is not the end of the story. When students present, several people are listening, making notes, for instance on the frequency of the presenters use of "eh" (see Rituals and Habits, 4). They hate you for doing it and at the same time they appreciate it!

Finally there is the reward. When all the Delft speakers at a conference are done, a Delft Gang Dinner is organized at night. Friends from other universities can be invited, also one 'lonely boy or girl' at the conference who is completely unrelated to the Gang is always invited as well. There is a lot of eloquence, a lot of fun, but the night is too short. See you next year at the Delft Gang Dinner table!

4.4.3 Maturity of implementation of Applied EcoDesign in electronic companies

Between the years 1990-1995 the first electronic companies took Applied EcoDesign on board. Some ten years later (in 2003) only 30% of the 37 companies considered have become reasonably mature in the field. This observation is substantiated in the paper "Measuring Implementation and Performance of ecodesign in the Electronics Sector" on the next page.

On the other hand 26% continued to show virtually no interest at all. Today (2007) the situation has slightly improved but the general impression is that proactive Applied EcoDesign in the electronics industry still has a long way to go.

Measuring Implementation and Performance of ecodesign in the Electronics Sector

Oriol Pascual; Ab Stevels; Casper Boks

Abstract

From the beginning of the ecodesign discipline it is been claimed by academia that its adoption on industrial contexts leads to improvement of competitive advantage by the organizations adopting it. At the same time, it seems that after more than ten years of ecodesign developments, the discipline is not as spread as it was expected and the benefits of it still unclear. This paper empirically explores which are the rates of ecodesign implementation in the electronics sector and wishes to define the different strategies adopted by the organizations when doing it.

1. Background

Applied ecodesign adopted on day-by-day basis by companies brings, according to experts [1] [8], strategic/economic benefits (reduction of production costs, competitiveness, and improvement of image) while reducing environmental impact.

Currently many large organizations spend time, economic resources and knowledge creation on applied ecodesign and launch products to the market that perform environmentally better than previous models or products of competitors, while retaining their functionality. Nevertheless, after more than ten years of developments by academia and industrial organizations, literature and expertise [1], [2], [3] suggest that ecodesign is not as spread as could be expected. Therefore clear that a gap exists between academic/theoretical developments (and claimed benefits) and ecodesign applicability.

A study is carried out at Delft University of Technology, in which a mid-term goal is to benchmark organizations according to their ecodesign performance in order to understand who is successful applying the ecodesign discipline. The final goal is to define conditions of success for ecodesign in business contexts. Here, "successful in ecodesign" is defined as being able to produce an ecodesigned product -to deliver a certain function- and to be successful in the market at the same time.

The aim of the paper is twofold: to present an initial study which measures the rate of ecodesign implementation in large organizations, and to discuss the different strategies used when applying ecodesign.

2. Approach

To understand the size of the defined gap, i.e. between academic/theoretical developments and ecodesign applicability, it is crucial to analyze what the current levels of performance of applied ecodesign are. Assume a situation where a company simply uses common sense to develop products that have a lower environmental load than its competitors, and compare it to a situation where similar results are achieved using various ecodesign guidelines, tools, and methodologies. The question is whether both companies have the same level of applied ecodesign. As in literature this issue is not dealt with, it is suggested that more insight here is needed in order to understand the current situation of this discipline at a business level. Hence, the present study uses a methodological approach based on practical examples to get novel insight of the current situation of ecodesign at large industrial organizations.

3. Methodology

To facilitate the study, it is needed to define scope and size of industrial organizations:

The electronics and communications industry is selected due to its perceived expertise in the ecodesign discipline and the emerging legislative requirements for the industry. It is decided to choose "large manufacturing organizations". "Large" can be defined by the number of employees working on an organization, revenues generated, stock value, etc. In this case the authors decided to select the world's top organizations by revenues (Global Fortune 500, time period: 2002).

The companies studied were those included in the industry sectors as organized in the Global Fortune 500:

- Electronics & electrical equipment
- Computers & office equipment
- Semiconductors & electronic equipment
- Network & communications equipment

Environmental reports (either in print or via official websites) of all companies present in the above categories in the Global Fortune 500 were studied in detail. For each environmental report, we analyzed the level of ecodesign implementation and determine whether:

- a) An organization claims in its environmental report that it uses ecodesign in their product development process (PDP),
- b) Evidence is presented of doing so (examples of ecodesigned products),
- c) Managerial elements of the ecodesign process are mentioned (such as programs, goals, and roadmaps).

a) *Claiming to use ecodesign:* studying the Environmental Report and Corporate web sites of the studied organizations, it was determined whether the use of the ecodesign discipline was mentioned using terms as ecodesign, Design for the Environment, and Design for X.

b) *Examples of ecodesigned products:* it was determined whether examples of ecodesigned products were provided in the environmental reports of all the studied companies. The original intention of the authors was to empirically measure rates of ecodesigned products launched to the market, but it is been found that organizations do not clearly specify when a product has been ecodesigned (therefore it is not possible to know the rate of electronic ecodesigned products launched to the market), but some companies do show examples. It is assumed that if an organization is proactive on the ecodesign discipline and develops ecodesigned products that perform better than previous models or that competitor, they will state so, or at the least they will give an example.

c) *Set up of managerial targets:* it was determined whether one or more indicators for measuring presence of managerial elements of ecodesign were given, by means of established targets. A differentiation related to ecodesign of products is made between quantitative, e.g. "our target is to reduce 15% energy consumption of our products by 2005" and qualitative targets, e.g. "we'll improve energy efficiency". Targets may refer to a certain amount of ecodesigned products or to the product itself (reduce energy consumption, stand-by).

4. Results

Table 1 gives the results according to these three aspects:

Table 1 Overview of results

Element	Number
Total companies studied	37
1. Companies that claim to use ecodesign	28
2. Companies showing examples	20
3. Companies publishing targets	19

Based on the three scores, it was found that six different profiles exist among the companies studied, see Table 2.

Table 2 Summary of empirical results

Group	Claiming Use Ecodesign	Publishing Examples	Setting-up Quantitative Targets	Setting-up Qualitative Targets	RESULTS
1	x	x	x		30%
2	x	x		x	18%
3	x	x			6%
4	x			x	6%
5	x	-	-	-	14%
6	-	-	-	-	26%

For each of the profiles the characteristics are indicated. Moreover, a list of companies is provided¹.

Group 1- Companies that CLAIM to use ecodesign in their PDP, SHOW EXAMPLES of ecodesigned products and SET-UP QUANTITATIVE TARGETS related to ecodesign of products. They represent 30% of the electronics and communications companies in the Fortune 500.

Companies under this cluster:

IBM	Fujitsu
Sony	Mitsubishi
Matsushita	Philips
NEC	Canon
Sharp	Sumitomo
Ricoh	

Group 2- Companies that CLAIM to use ecodesign in their PDP, SHOW EXAMPLES and SET UP QUALITATIVE TARGETS related to ecodesigned products. They represent 18% of the electronics and communications companies in the Fortune 500.

Companies under this cluster:

Siemens	Intel
Hitachi	ABB
Motorola	Ericsson

Group 3- Companies that CLAIM to use ecodesign in their PDP, SHOW EXAMPLES of ecodesigned products do NOT PUBLISH/CLAIM to SET UP TARGETS (of any kind). They represent 6% of the electronics and communications companies in the Fortune 500.

Companies under this cluster:

Hewlett Packard	Toshiba
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Group 4- Companies that CLAIM to use ecodesign in their PDP, but do NOT PUBLISH EXAMPLES, and SET UP QUALITATIVE TARGETS. They represent 6% of the electronics and communications companies in the Fortune 500.

Companies under this cluster:

Nokia	Dell Computers
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¹ **Disclaimer:** the information presented in this study has been gathered from official web sites and environmental and/or sustainability reports from the selected companies. If a company is being proactive on the ecodesign discipline and this is not reflected on this study, it may be due to a lack of information on their web sites or in their environmental and/or sustainability reports. At this stage of the present investigation, no other verifying research has been done.

Group 5- Companies that CLAIM to use ecodesign in their PDP, do NOT PUBLISH EXAMPLES, or SET UP TARGETS. They represent 14% of the electronics and communications companies in the Fortune 500.

Companies under this cluster:

Compaq Computer (HP company)	Nortel Networks
Lucent Technologies	Sun Microsystems
Cisco Systems	

Group 6- Companies that do NOT PUBLISH/CLAIM to use ecodesign. They represent 26% of the electronics and communications companies in the Fortune 500.

Companies under this cluster:

Tyco International	Emerson Electric
Samsung	Onex
LG Electronics	Flextronics Int.
Sanyo	Whirlpool

5. Discussion

5.1 Defining “ecodesign”

Due to the diversification of terminology found on the environmental reports of the studied organizations, and the variety of strategies linked to this terminology, questions rise about what is understood as ecodesign.

Literature offers many definitions of “ecodesign” [4], [5], [6]. Most of these definitions (if not all) have been developed by academia, and the general aim can be summarized in the definition formulated by Brezet & van Hemel: “ecodesign is understood a design process that ecological aspects are integrated into the conventional product design process [4]. Apart from this widely recognized definition, the International Standard Organization (ISO) offers a similar definition of the term on the ISO 14062 (“integrating environmental aspects into product design and developments”).

Both definitions are too vague to allow a classification of organizations, even knowing which managerial process is behind an ecodesigned product, as it is intended in this paper. Therefore, this study intends to establish a novel system to classify the distinct organizations. Any kind of ecodesign “level” or “stage” fits under these generic definitions. The application of a clean technology in the Product Development Process, e.g. lead-free soldering, can be considered an element of “ecodesign”, and at the same time an organization that sets up a program to reduce their environmental load, that benchmarks its products in order to develop new ones with lower environmental load every time, or that uses specific tools with that objective, fits as well under this concept. However, there are clear differences between both organization types, i.e. the scope of activities is different, the effort applied is not equal, and the integration with other business activities is distinct.

It is interesting to understand which drivers lead to these organizations to adopt ecodesign. A differentiation can be made between organizations adopting ecodesign as a proactive approach towards environmental aspects and organizations adopting it due to external pressures (i.e. legislative issues).

Under this situation, and due to the lack of a specific definition accepted and standardized, it is difficult to classify organizations according to the managerial aspects behind an ecodesigned product. Thus, the lack of a standard definition of ecodesign leads to a wide range of interpretations of whether and to what extent a company is involved in ecodesign. Consequently, without this common understanding of what ecodesign is, most of the organizations name their ecodesign process in different ways, for instance misunderstanding and confusion by stakeholders.

Interestingly, from the study presented here, some conclusions regarding what ecodesign is can be drawn. All companies studied use the term “ecodesign”, or any of its possible synonyms, referring exclusively to products. However, in the case of Sony, a broadening of the concept is visible. The company talks about “Environmentally Conscious Products & Services”, escaping from the classical technical view and adopting managerial aspects towards services (delivery of functions without ownership of a product).

Most the studied companies that claim to use ecodesign on their PDP demonstrate it by showing examples of ecodesigned products. Nevertheless, most of the times the examples presented do not give detailed information about its characteristics.

Terms referring to ecodesign (found on reports) include:

Environmentally Conscious Product Design
 Environmentally Compatible Product Design
 Environmentally Conscious Products & Services
 Design Energy Efficiency
 Environmentally Conscious Products
 Green Products

Figure 1 Variety of terms used to refer to ecodesign

5.2 Showing Examples

54% of the studied organizations show examples of ecodesigned products in their public communication media. Examples include products that have been totally re-designed from a previous model to a new concept, products were new materials with lower environmental impact it is being used, products in which new technologies are being used at process level, and products that without being re-designed are considered “green” due to new take-back systems on the market that allow their collection and recycling/energy recovery, etc. Of interest for this paper is to realize which is the rate of ecodesigned products that a certain organization is launching to the market. Another relevant aspect would be to know which is the rate or number of products labelled as “green” for the manufacturers. This kind of information has not been found in any of the environmental reports of the studied organizations. Further steps of research may focus on how performance of ecodesigned products is shown and which methodology it is being used in order to measure it. This fact leads to the question if costumers are requesting “green” products to EOM or are interested on performance and benefits perceived from ecodesigned products. When showing examples of ecodesigned products and giving information about them, it seems clear that ecodesign may be found at different levels of integration at the different organizations. This aspect can also be linked to setting up of targets.

5.3 Managerial aspects

According to the results obtained in this study, propose two levels of ecodesign implementation or maturity:

1- *Ecodesign Rules Level*: under this cluster we find the most known aspects and elements of ecodesign, manuals, tools, methods and training programs to understand what ecodesign means. Pilot projects are carried out by organizations to analyze whether the discipline “really works” and understand the advantages that it may have. Most of the organizations fall into this category.

2- *Ecodesign Management & Integration Level*: this level accomplishes the use of the discipline on daily basis. Personnel knowing about ecodesign, uses the tools (software), and environmental programs are set up. Subsequently, quantitative or qualitative ones targets are defined and we may consider that ecodesign is no longer a separate discipline from the organization, but rather integrated on daily activities.

With the compiled data, the authors wish to qualitatively define strategies used by companies regarding applied ecodesign. This classification is not absolute and the aim is not to rate organizations as “good ecodesign performers” or “bad ecodesign performers” we propose the first steps to set up a framework that may help to understand better the role of ecodesign at organizations and therefore, fulfil the gap between academic promises of the ecodesign discipline and real implementation (up to which extent applying the ecodesign discipline helps to gain competitive advantage).

Based on the three chosen variables (claim to use ecodesign, showing examples, and setting up targets), a description of companies’ efforts on the ecodesign discipline can be drawn:

Group 1- Relatively mature organizations (30%)

Companies previously referred as being on *Ecodesign Management & Integration level* of ecodesign’s implementation. Organizations falling into this category are known to be first movers on ecodesign implementation, usually working hand by hand with academia, developing methodologies and tools to facilitate implementation and test-

ing academic developments on real business operations, and they can do it because own resources (economic, personnel, knowledge, and time).

All the organizations under this cluster claim to use ecodesign on their product development process, they demonstrate to do it by showing examples of ecodesigned products launched to the market and a managerial system is in place that helps them to define their environmental strategy (where it is possible to find quantitative targets related to ecodesign of products).

They demonstrate that ecodesign becomes integral part of the overall environmental/company's strategy exploiting its cross-functional characteristic when setting up qualitative targets.

Diversity seem to be found in this category according to the drivers that lead to apply ecodesign (comply with legislation or being proactive). This profile should be studied in more detail in order to define conditions for success.

Group 2- On their way to maturity (18%)

Companies under this cluster claim to use ecodesign on their PDP and show some examples of ecodesigned products. When observing their compromise on the managerial area, targets and goals are set-up on qualitative basis. This gives an indication that the organization is proactive on the ecodesign field, and that it is relevant on the overall strategy of the organization (due to the fact that goals are set-up on the environmental management system/program).

Nevertheless, the nature of the qualitative targets gives indication of the intentions of the organization, without compromising themselves to achieve a quantitative goal.

Group 3- First movements (6%)

Here we find companies that claim to use ecodesign on their PDP and they show examples of ecodesigned products. At the same time, there are not evidences of self-compromising themselves to a continual improvement of their product's environmental performance, neither to increase the rate of ecodesigned products.

It seems that ecodesign is not included on the overall strategy of the organization, due to a lack of targets and goals related to ecodesign of products.

It is suggested that an organization that show examples of ecodesigned products, but do not publish targets, may be experimenting with the discipline and do not feel secure about the benefits that the discipline may bring to themselves.

Group 4- Starters with good intent (6%)

Organizations under this cluster claim to use ecodesign and include the discipline on the overall company strategy by setting up qualitative targets. In this case, no examples have been found that demonstrate what has been claimed on their environmental report.

It can be interpreted that the organization is starting with the discipline (ecodesign's rules level), there is not enough expertise on the organization to launch or demonstrate that they applied the discipline (therefore they do not show examples) and as starting point (good intent) they define qualitative targets.

Group 5- Basically publicity driven (14%)

Organizations under this cluster claim to practice ecodesign during their PDP, do not publish any example of ecodesigned product, neither set-up targets on their managerial system. Therefore it is doubtful that the organization spends resources on this area. It is suggested that organizations under this cluster use ecodesign as a marketing driver.

The advantage for organizations under this cluster is to use environment as a marketing strategy in order to appeal customer's sensitivity towards issues like environment (everyone likes environment-green!).

Group 6- Not published/not interested (26%)

According to the measurements done in this study, most of the large OEM lay down under this cluster. The fact that such amount of organizations (26%) falls into this category, supports the idea presented in literature that Applied Ecodesign is still on an immature stage of implementation.

Furthermore, literature suggests that the organizations to move towards environmental management will fail on accomplishing legal and customer demands, and therefore will not be competitive. But it has to be shown in practice if this will be materialized, and this strongly depends on enforcement policies on different countries.

6. Future directions

It is stated by the authors that there seems to be a gap between what academia and theory developers claim as direct benefits for the company due to implementation of ecodesign at the product development process and the real benefits perceived by management. To understand the size of the gap, measurements are needed.

Is of interest of the authors to focus on understanding the diversification of maturity of organizations under the first cluster (relatively mature organizations), how this organizations measure performance of their ecodesigned products and which are the drivers that lead them to adopt the discipline. A maturity grid is under development at the Applied Ecodesign group of Design for Sustainability Program (TU Delft).

The authors focus its measurements on three elements: ecodesign at process level, ecodesign at product level and business benefits related to ecodesign activities.

About process: it is suggested that maturity of ecodesign implementation is reached when the manufacturer influences all the life cycle of a product due to ecodesign. Raw materials extracted in an environmentally sound way, supplier involvement, manufacturing, user phase and at the end-of-life of the product. That means that ecodesign broadens its context and overpass the technical dimension and gains relevance as managerial element, dealing with its goal: reduce environmental load per monetary unit at every stage of the life cycle. Therefore, measurement of ecodesign influence on the life cycle is discussed, as well as which role ecodesign adopts at the organizations, just as a marketing strategy or it adopts a *cross-functional dimension*.

About products: it may be that at process scale, all the classical elements of ecodesign implementation (procedures, training, tools, etc.) are in place, but not reflected at the final product, or that a company without any element in place of the ecodesign process is producing high rates of products that have a lower environmental load that competitors or previous models. The aim of this section is to make clear which rate of ecodesigned products are placed in the market by the electronics industry.

About business: according to academia and pilot projects [1], [8], ecodesign implementation improves competitiveness, reduces costs, avoids regulatory fines, improves image and market share. The aim in this section is to measure which business improvements can be directly link to ecodesign.

7. Conclusions

- A variety of attitudes can be found on the business world regarding ecodesign.
- Tangible benefits of applying the ecodesign discipline are not yet clear
- There is a lack of a clear-specific definition for the term ecodesign, this hampers the judgment of what it is published on the environmental reports
- Standard definition of ecodesign and a standard definition of maturity grid may help to discriminate more sharply within the categories which have been defined in this paper
- A general lack of published ecoperformance results makes difficult for the consumer to base their decisions on the right criteria

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Brussels, two faces, or even three?

Brussels used to be the capital of the 17 provinces forming 'the Lower Lands' till 1584. Then the north (the Republic of the Seven Provinces) separated: subsequent wars continued the split between north and south. The south oriented itself towards the continent under Spanish and Austrian rule, the north looked overseas. Calvinists dominated the north, Roman-Catholics the south.

Mentalities grew apart and it was quite logical that the attempts to unite again after Napoleonic times failed. Now the south had to wrestle independence from the north. The new state, with Brussels as its capital was conceived as a Unitarian one but had two cultures: Wallon (French speaking) and Flemish (Dutch speaking). It took the Flemish almost a hundred years to get equal status for their language. In the meantime Brussels turned slowly from a predominantly Dutch speaking city into a French speaking city.

Nowadays Belgium is a federal kingdom with 3 regions (Vlaanderen, Wallonië, Bruxelles/Brussel) of which 2 consider Brussels as their regional capital. There are 3 cultures (including a German speaking one in the east of the country) and all of them come together in Brussels, where the federal government is.

How do you feel in Brussels as a person with a Dutch passport? At the 'Grote Markt' in Brussels there is that feel of communality in early history but there is also a clear perception of the differences found today. Belgians generally seem more successfully combine the pleasant things of life and capitalism. Maybe this is because they have been invaded and occupied so many times. For this reason they also seem to embrace Europe more easily than the Dutch who have this strong feeling of wanting to be independent and of wanting to do a better job than somebody else (or at least are perceiving themselves as doing so).

Brussels is also the capital of the European Union and in that respect it has two or even more faces. One face is the necessity to accommodate European rules and lift national barriers, which are an unfortunate legacy of the past. On the other hand there is lack of decision-power, inability to deliver straightforward policies. There is always horse-trading among Member States, the complicated and sometimes weird compromises can cost the European taxpayers billions.

In the environmental field all of this seems to be even more pronounced.

Brussels has one face looking to history and one to the future – and that can be seen wherever you go. The European Union is still chiefly busy, very busy, with its past. What may have been wise policies in the last century are unwise today. Subsidizing agriculture, which is operating at costs far above world prices and trying to keep industries alive that cannot compete, are losing propositions. Fostering quality infrastructures and stimulating activities with real added value could make Europe a winner. Too little of that is being delivered today.

Implementing environmental policies based on principles of the nineties of last century will result in disasters in the realities of today (see chapter 9).

Brussels is slowly turning a positive face, for Europe it is not too late to follow.

City walk : Start at the Central Station, go through the Ravenstein exit, Horta Street, Cross the Kingstreet, pass through the Park of Brussels, follow Beliard Street, go somewhere R and L to Beliard street, go Right at Aarlen street, pass under the European buildings, go Left on Wiertz street, go R to Leopolds park, cross the park to Waverse Steenweg, go R and follow the road to Naamse Poort, go L and cross the ring at Louise Place to the town centre, go to the Justice Palace, go R to Regent street, walk through Grote Zavel (R), go straight Rollebeek/Alexis street, go R to Stooftstraat and end at Grote Markt.

Favorite restaurant: De Koning van Spanje, Grote Markt.

Country walk: Go with tramway no. 44 to Tervuren and walk any distance you like in the Colonial Park – if it rains, visit the museum.

4.4.4 Integrated Process Management; the Soft Side of EcoDesign

Further developments in dealing with 'eco' at the companies considered in 4.4.3 include the arising of different styles of operation, of different levels of integration in processes and of various ways in which the "Soft side of EcoDesign" is being considered.

The different styles, ranging from EcoDesign primarily for competitive advantage to EcoDesign primarily for legal compliance have been described in chapter 2.1

Integrating Ecodesign into the processes is aiming particularly at organizing for success and for reaping benefits and has little to do with the more technical aspects.

The same holds for considering the "Soft Side of EcoDesign"; this terminology has been introduced by Casper Boks. This is about considering all kind of contextual aspects in which EcoDesign activities are taking place like the internal and external value chains. Also a lot of communication issues can be put under this notion.

In many companies today, these process management and "soft side" activities are dominating. Addressing the technicalities has got a lower priority. This observation made that at the "Electronics Goes Green Conference in Berlin in 2004 in the paper below with the provoking title *"EcoDesign in Industry is not an Environmental Issue"* has been presented. It shocked part of the audience but is has been an eye-opener for some participants as well.

Ecodesign in industry is not an environmental issue

Oriol Pascual, Ab Stevels

Abstract

The existing paradigm for ecodesign research remains to focus on technical and physical issues. Design and technology receive most of the attention, especially in the community that attends electronics oriented conferences like the IEEE/ISEE, Ecodesign, CARE Innovation, and Electronics Goes Green. At these conferences, a more managerial focus towards integrating ecodesign considerations in the electronics industry is generally limited to discussions about environmental management systems, ISO standards, and of course EU legislation like EuP, WEEE and RoHS, leaving on a side the wider stakeholder benefits issue and value chain problems.

This paper highlights the observation that ecodesign activities at large electronic manufacturing organizations have little to do with environmental considerations. The rationale behind ecodesign is of a self-protective nature.

I Introduction

The aim of ecodesign practice is to reduce the environmental load of products "from cradle to grave" (i.e. from raw material extraction and purchased components, design and manufacture, to distribution, use and end-of-life). Life-cycle thinking is the scientific principle behind this practice.

Environmental management related to ecodesign is a twofold dimension:

- *Environmental dimension:* related to technicalities like physical units, materials, energy, efficiency, environmental load, and environmental validation.
- *Managerial dimension:* related to business aspects of the discipline like goals & targets, EMS, legislative requirements, and value chain management issues.

The *environmental dimension* of ecodesign has been widely explored by academia and practitioners. In the past decade, ecodesign research has been focusing largely on what could be addressed as technicalities. What has been accomplished and what presently exists is a wealth of idea, tools, methods, pilot studies, information, and knowledge about the integration of environmental aspect into product design.

In a study carried at Delft University of Technology [1], an extensive literature analysis was carried out, encompassing over 850 papers published at electronics ecodesign community conferences. Using a classification frame-

work based on academic and industrial processes of fact finding, analysis, implementation, and exploitation of ecodesign knowledge and adjacent topics, insight has been generated as to the distribution of research attention across these topics.

The study shows that over 60% of contributions at leading ecodesign conferences address technical issues (i.e. LCA, materials, recycling, lead-free soldering, etc.). It also shows a lack of priority setting supported by scientific evidences; energy in electronic products represents 40-80% of total environmental load, meanwhile a rough 2% of the papers address the issue.

The *managerial dimension* does not receive much attention. It represents roughly a 10% of the contributions (i.e. alignment of ecodesign with traditional business perspectives, supply chain, EMS, green marketing, etc.).

Among others, the study concludes that alignment of ecodesign with business operations is still rating low. It is suggested that potential of ecodesign may achieve its maximum expression when its cross-functional characteristic is fully explored. More attention is needed on the alignment of ecodesign with business operations.

In practice, the managerial dimension is about drivers (externalities) and organizing for success (internalities). Organizing for success is about money (how to optimize investments and get reward from it), information (how to get the right information for decision making purposes; prioritization) and intangibles like emotions and feelings. That is known as the value chain.

Companies design for functionality and aim to optimise the value of products at the shop. To do so, optimization of the value chain management is significant. Ecodesign is in practice beyond the superseding functionality issue.

Managing properly the value chain (internal and external) is a question of dealing with opportunities and self-protection. Opportunities relate to issues like competitiveness, reorganization of business (paradigm sift), and improved image. On the self-protective side; compliance, legitimacy and market requirements issues are present.

This paper focuses on drivers for engaging ecodesign on business contexts, explores both perspectives and discusses the misconnection between listed drivers and environmental considerations. Special attention is paid on the so called self-protective perspective. Here, self-protective perspective refers to avoidance or control of negative effects of environmental activities on the organization (i.e. legislative issues, customer perception, and market demand issues). In literature, the self-protective perspective of green is merely stressed. The goal if this paper is to demonstrate the existing misconnection between drivers and environmental considerations.

2 Research method

Information presented in this paper originates from authors' experience on applied ecodesign field. Academic developments are combined with industrial practices and observations.

The outcome from a recent project carried at DUT is used. The aim of the project is to collect specific information (from three organizational levels; corporate, members of environmental support departments, and business units) on ecodesign operationalization from the electronics and electrical equipment categories of Global Fortune 500. In addition, a previous study from DUT [2], in which we were able to map maturity levels at electronics industry, ranging from complete integration to lack of attention to the issue, is used. Moreover, empirical observations from more than ten years of ecodesign introduction at Philips Electronics are deeply analyzed.

The electronics industry is selected due to its perceived expertise in the ecodesign discipline and the emerging legislative requirements for the industry.

3 Observations

An ideal process of product ecodesign (or re-design) takes into account environment during the entire life cycle, since its primary objective is to reduce cumulative negative impacts of products. Roughly, the process involves; product selection, analysis of environmental load from a lifecycle perspective, identification of improvement options, re-design, and product realization. The result is a product with lower environmental load than its predecessor; a more efficient product.

In practice, an organization claiming to perform ecodesign activities is not necessarily familiar with the whole process, neither with lifecycle thinking. Experience shows that the set up of a take back system by an organization, or a technological evolution, is considered as ecodesign. Consequently, the result is not necessarily a product that

performs better from an environmental perspective. Therefore, there is need to set up environmental priorities for action.

A survey carried in 2002 by Dutch consultancy firm KPMG [3] points risk reduction, among others, as a driver for companies to engage sustainable actions and reporting. This called the attention of the authors, who as part of a study [4] identified drivers at large manufacturing electronic organizations for engaging ecodesign activities with current business practices. A self-protective perspective was found in all of them.

Since lifecycle thinking is not the core element of ecodesign activities in most organizations, it is suggested that priorities are not set on environmental basis but on a variety of other purposes;

- 1- Compliance issues
- 2- Potential competitiveness
- 3- Legitimacy
- 4- Imitative behavior
- 5- Market requirements

Discussion follows on misconnection of listed issues with environmental aspects.

3.1 Compliance issues

Environmental considerations related to products rate high on current legislative requirements. Take-back systems and ban of hazardous substances in Europe, energy efficiency and end-of-life programs in United States, and labeling schemes in Japan, are on top of the agenda of electronics sector managers. Companies are global actors: manufacturing of products in country A, shipped and/or used in country B, and finally disposed in C. Therefore, regional legislation becomes relevant for global companies.

The effects of mentioned regulatory initiatives rarely play a key role stimulating ecodesign activities among electronics industry. In the case of recycling initiatives, ecodesign is of minor relevance after issues like creation of economies of scale and treatment technologies [5]. For the rest, the goal of managers is to keep compliance costs under control and as low as possible.

Avoidance of threats due to a lack of institutional initiatives response seems to be the rationale behind this attitude. Early adopters make cognitive changes [6] and may gain competitive advantage.

3.2 Potential competitiveness

Some authors (Elkington, Porter, Bonifant) base environmental management benefits on win-win strategies where both the environment and the bottom line get positive results. Following that claim, proactive organizations decided to invest resources on environmental management activities expecting to gain competitive advantage, defined as "potential for ecological responsiveness to improve long-term profitability" [7].

A dimension of tangible competitive advantage is determined by identifying, measuring, accumulating, analyzing, preparing, interpreting and communicating financial and non-financial information used by management to plan, evaluate and control the environmental aspects of an organization [8]. This practice is known as environmental accounting. In countries like Japan and US, national governments launched environmental accounting guidelines. As a result, first sights of information disclosure in companies' environmental reports can be found. Checking environmental reports [9] it is found that information presented is immature and refers mostly to investments, lacking examples of economic effects.

From a business perspective, tangible economic benefits of ecodesign are difficult to be demonstrated. The main reason relates to the fact that cost reduction applies to selected fields like packaging, transport, and disassembly activities. Gaining competitive advantage is also about doing a bit better than competition. Once higher level than competitors is achieved there is not incentive to improve further.

The environmental pro-activeness is not just a question of market opportunities but managing environmental related threats and avoiding negative consequences. Managing properly the value chain (internally and externally) is a relevant area to explore potential competitiveness.

A less tangible dimension of competitive advantage gain relates to legitimacy.

3.3 Legitimacy

Effects of negative environmental related information or lack of companies' environmental performance disclosure is perceived by organizations as a threat to business operations. Different cases of organizations that failed complying with regulations and/or disclosing environmental related information are frequently mentioned in conversations with industry (i.e. the case of a Japanese electronics manufacturer that had hard times due to negative publicity related to hazardous content on its product's wire, or a Japanese car manufacturer that also had negative reactions from stakeholders due to the company's position of non-disclosure of environmental information). Legitimation refers to the desire of a firm to improve the appropriateness of its actions within an established set of regulations, norms, values, or beliefs [10]. Implications of such attitudes are perceived as negative for the business, and lessons are learned from them.

Legitimacy is strictly related to image of the corporation and reflects on products launched to the market. Image of an organization plays even a more relevant role in purchasing decisions than in (environmental) performance of products. A study done at DUT shows that image counts for more than 50% of the product perception by consumers.

Legitimacy is also enhanced by imitating successful competitors.

3.4 Imitative behaviour

Imitation of other companies' attitudes from the same sector is a common practice among industry. In several occasions authors noticed that organizations perform certain environmental activities because "competition is also doing it". Bansal and Roth [7] mention that "firms operating in close proximity are usually subject to the same regulations and social norms; they often operate with similar standards in a social cohesive environment".

It is also true that a lot can be learned from competitors' facts. A company, successfully embedding ecodesign into business, is more credible that studies and recommendations from university environmentalist. A practical example is the reduction of energy consumption on TV at 1 Watt in stand-by mode. Without a proper study, it is not know if reducing energy consumption to 1 Watt is the perfect balance between environmental aspects and investment required. But currently, every company is doing it, so you do it.

Examples of imitative behavior are usually related to the use of certain methods, participation in institutional activities/ proposals and, green claims in public communications. Authors experienced that Asian organizations are more mimetic than European and American.

A mimetic approach aims to reduce risks of being a front runner or lacking behind common industry practices.

3.5 Market requirements

In business operations where final consumers are product users, a market pull for environmentally efficient products has not been identified. Some surveys [11] reflect willingness by consumers to purchase "green" products. These are socially desirable answers. Green as such does not sell and in general this argument is used as an excuse to avoid extra efforts on the environmental arena. This situation can be efficiently improved by linking green to other benefits of what a demand exist.

However, price, functionality, and service are top in purchasing decisions [12].

Furthermore, in a study carried at DUT [13] within large electronic manufacturing organizations it was found that a lack of demand is considered the main obstacle for successfully bringing ecodesign products to the market.

In the case of business-to-business operations, environmental performance of products is relevant and usually a criteria for selecting suppliers. The reason is of a legislative nature; regulation like the European Directive on the ban of hazardous substances (RoHS) originates an increase of control on the supply chain ensuring that environmental requirements are fulfilled at all levels. It is for that reason that most large electronic manufacturing organizations require to their suppliers to demonstrate a certain degree of environmental commitment and proper environmental management. Middle management and business units' personnel of some organizations visited by DUT mentioned to stop commercial activities with suppliers that could not demonstrate fulfilment of company's requirements in environmental aspects.

On the demand side, public procurement is gaining momentum as market pull for environmentally efficient

products. Certain administrations from all over the world are starting green procurement programs; a market for environmentally efficient products is created. In 2001, the European Commission estimated that public authorities in Europe spent some € 1,000 billion on goods, works and services. This includes, for example, 2,8 million computers and monitors purchased each year by public authorities in the European Union [14]. A common strategy for green procurement has been established at EU. In US, an environmental criterion is used by the Environmental Protection Agency to sign contracts with suppliers. Recently, Dell Computers became official EPA computer supplier due to the implementation on a take-back system by the company.

Opportunities can be created in a demanding market by expanding creativity on new business areas and undertaking paradigm shifts. Organizations lacking awareness of the current market demands put into risk potential alliances and contracts with strategic partners.

4 Discussion

In previous sections it has been shown the presence of a self-protective approach as a driving factor for large electronic organizations when deciding to engage ecodesign activities in current business practices.

Analysing drivers is as important as paying attention to technicalities, but ecodesign in industrial contexts is also about:

- *Technical issues*; how to do ecodesign from a technical perspective.
- *Integrated process management*; how to organize ecodesign for success.
- *Manage the value chain*; how to get benefits from the efforts done.
- *Soft side of ecodesign*; how to communicate properly on a two-way communication and cooperation, rather than a top-down approach. [15]

From a business perspective, the dimensions of green include; scientific green (technicalities), customer green (perception and feelings), and governmental green (legal requirements) [11].

Threats for the organization are present in all three dimensions. Moreover, in the ecodesign community, a lack of attention on how to manage them efficiently is lacking.

On previous sections, the relevance of issues like compliance, legitimacy, market demand and competitiveness in relation to with ecodesign has been shown. All factors are present on the value chain and have little to do with an environmental dimension. We propose to broaden the ecodesign dimension and not rely merely on technicalities for success (ecodesign does not happen just with technicalities). Success in the ecodesign area consists also on:

- *Prioritization*; too much attention on emissions and little on materials (resources). The same applies for recycling versus energy.
- *Link environmental and economic considerations*; eco-efficiency concept as a decision making tool based on the bottom-line.
- *Environmental value chain management*; managing stakeholder value internally and externally.

In general, attention is needed on how to systematically manage properly the environmental value chain in the process of designing environmentally efficient products. It is not a question of how to ecodesign a product (technical aspects), or how to engage environmental thinking in business activities (environmental management practices), but how to be in control of threats and opportunities associated to the whole lifecycle of a product. These issues need attention and will be covered in future publications [16]

5 Conclusions

Based on the evidences presented in this paper, it can be concluded that ecodesign is more than technicalities and drivers play a minor role when engaging ecodesign in business contexts. In addition, the managerial dimension of ecodesign is not receiving the required attention.

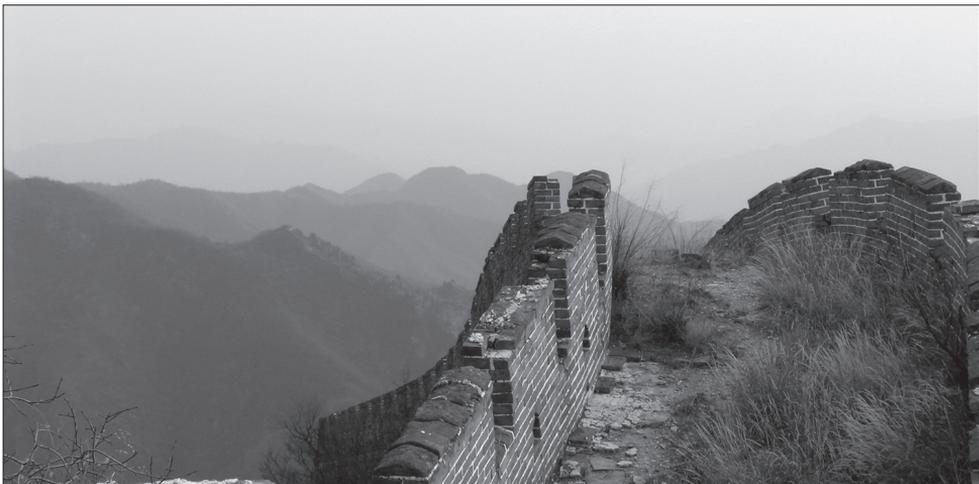
As literature states [17], a lack of alignment between ecodesign and existing business activities exists. Further research in value chain management would help this alignment process. Therefore Delft University of Technology is drawing an initial model that will be the basis of future research.

6 Literature

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Pictures, 5

China, an Ecodesign Adventure on the Great Wall



4.5 Product lifetime and life time extension

4.5.1 Life cycle optimization

One of the central dogmas of traditional EcoDesign is product lifetime extension. Keeping products in the hands of their 'first owner' is thought to be 'green' because the materials (and components) remain in the 'techno sphere' longer so that the depletion of resources (the 'ecosphere') is at least postponed.

Traditionally, several design strategies are recommended to achieve this:

- 'Upgradeability' (the possibility to add more functions to keep up with increasing requirements).
- Attractive design (so that products are not thrown away because users do not like them anymore).
- Easy repairs when products have broken down.

Priorities in these options can be set by finding out for previous product generations; how many products were discarded by their first owner because of technical breakdown, how many are discarded because they are 'not liked anymore' after a given period of time and for which products upgradeability is needed. Subsequently the prioritized strategy can be determined

It should be noted that a lot of electronic products today have much better environmental characteristics than in the past. This is achieved through high levels of function integration. Such kinds of design hamper good reparability, upgradeability and to some extent achieving an attractive design. Moreover, most electronic products today degrade as a result of 'wear and tear' (of electronic components and subassembly), rather than break down outright because of mechanical failure.

These reasons also suggest that modular construction – frequently recommended to enhance reuse and recycling – is often not a good idea. The functionality of many electronic products deteriorates slowly as a function of time. This cannot simply be remediated by reuse design strategies .

There is however, for electronic products, an even more overriding issue: energy consumption. This represents 50-90% of the total environmental load over the product's life cycle. For a TV this represents 80% of the total load for user scenarios with 3 hour viewing time and 15 hrs standby. When viewing is one hour a day it is still 60%. When it is 6 hours a day (hopefully it is better to say in this case with the TV 6 hours on) it increases to 90%.

This means that from an ecological perspective, as well as life time extension perspective, energy consumption – not material consumption – should be the primary design driver. Due to technological developments the energy consumption of TVs drops as a function of time. This is partly undone through the addition of more and more features but on balance there is a clear net decrease. It was estimated on the basis of actual data that from an ecological perspective it makes sense to replace a TV after 8-10 years of use. In such situations, trying to extend lifetimes can even be considered to be anti-environmental.

In order to establish whether life time extension can really contribute to 'green', it is necessary to know how much the energy of the product concerned has dropped from subsequent product generations. Simultaneously it should be assessed how much environmental load is avoided through life time extension.

Such considerations led to the concept of 'ecological payback' times. Here the work of Nicole van Nes comes into play. She was a PhD student at Delft and later at Erasmus University in Rotterdam. She started more detailed and conceptual work on the pay back concept (see also chapter 4.5.2).

In chapter 2 of her thesis Nicole gives detailed mathematical formulae for the ecological effects of product transition. These formulae were not tested by case studies so the concept of 'ecological payback' for life time extension stayed unfortunately in the domain of qualitative considerations.

Recycling

From the very beginning of the environmental activities at Philips Consumer Electronics (PCE) a lot of attention has been paid to recycling efforts (design rules, cost models, etc., see chapter 7) and recyclability of materials (products, plastics, glass). PCE was also an important player, on behalf of industry, in discussions with the Dutch Environmental Ministry about the Dutch Electronics Recycling Law. In 1998 this law was agreed upon and recycling operations started on January 1, 1999.

Inside Philips we had numerous discussions about the proposed laws and about the system to be organized. Initially Philips, like all other electronics companies, were opposed to such a law. Soon after Philips became the first company in the electronics industry to realize that take-back and recycling were fads promoted by environmentalists and ministries. However, these calls represented a much broader societal interest that required a positive response. Management decided to strongly support the take-back and recycling pilot in the Netherlands in 1997. This decision was followed up with more realistic legislation (see chapter 8.3).

As regards the recycling system, a so called 'let the competition go to hell' scenario was developed initially. Philips had a high market share in the Netherlands, had in-house recycling facilities and last but not least its products were designed in such a way that the recycling cost of Philips products was lower than that of the competition. Therefore the obvious conclusion was, in the tradition of the idea of Individual Producer Responsibility, go for a Philips-only system. However, soon this idea began to crack (see also chapter 8.1).

- In the past the market share of Philips CE in the Netherlands was even higher, so recycling cost per piece would be lower, but total cost would be high compared to newcomers to the market.
- It was decided by the Board of Management that the Philips recycling operations were to be divested; no in-house advantages anymore.
- A projection of cost for the future showed that recycling costs would drop. However, even with the best Ecodesign it would stay far from cost neutral for glass (TV's, monitors) and plastic dominated products (the structural deficit, see chapter 8.3.1).
- Logistics costs were projected to be high, contrary to earlier expectations, (up to 50% of total cost) adding to the structural deficit.
- It was also calculated that economy of scale pays (see chapter 8.2).
- If take-back had to be introduced elsewhere stand-alone systems would be disadvantageous in countries where Philips CE had a low market share.

Conclusion: whatever systems is chosen, Philips always needs fees to be paid by the consumer due to the structural cost deficit.

The next issue became: how can we ensure we get the fees? This discussion was brought to a quick end by a ruling made by the Dutch Environmental Ministry. Fees can only become mandatory for a product category if producers representing a market share of more than 75% support the idea.

In practice this means that the only way to get fees is to set up recycling systems jointly with your competitors. This is the basic reason why Philips CE stepped into the so called 'collective systems'. CE does not like collectivism but in this case it cannot afford to go alone.

So it happened!

4.5.2 Discarding behavior of first users

In the studies of Nicole van Nes it was realized from the very beginning that the discarding behavior of first users is in fact decisive regarding the presence of opportunities which can be qualified as 'green'. In her work studying the discarding behavior of first users therefore received priority. First a conceptual model for discarding was developed which was published in the article below.

The model in this publication was quantified later by extensive empirical research. For a wide variety of household appliances, consumer electronics and IT equipment the motives for discarding were tracked down via questionnaires. Motives can be clustered into four groups :

- wear and tear (physical functionality) dominated, on average 30% of consumers.
- utility (economic and immaterial functionality) dominated, on average 15% of consumers
- expression (immaterial and emotional functionality) dominated, on average 20% of consumers
- new desires (combination of all functionalities) dominated, on average 35% of consumers.

In her dissertation it is concluded that there are opportunities for influencing the discarding behavior of consumers through design, particularly for cases where 'expression' and new desires are the chief reason for discard. The old design rules for life time extension are too simplistic, but there is ample evidence that it is worthwhile in the functionality analysis (see chapter 2.2) to consider how the ecological lifetime optimization of products can be achieved best. The paper below "A Practical Approach to the Ecological Lifetime Optimization of Electronic Products" is a first analysis in this respect.

A Practical Approach to the Ecological Lifetime Optimization of Electronic Products

Nicole van Nes, Jacqueline Cramer and Ab Stevels

Abstract

In order to be able to answer the question of whether to 'extend or shorten the product lifetime', one must first analyze the gap between the ecologically optimum lifetime and the current usage time. The ecologically optimum lifetime is defined as 'the time until replacement is considered ecologically sound' and is determined by two factors: the reduction in the efficiency of the product itself due to use and the improvement in the efficiency of new products in the market.

When trying to find a way to close the gap, it is helpful to distinguish between the different dimensions of the product that can become obsolete. This information forms the basis for the development of directions for redesign.

1. Introduction

Every new product that is developed and produced has an impact on the environment. Natural resources (energy, materials & water) need to be extracted and the production, use & disposal all have an impact on the environment. There are several eco-design strategies that can be followed in order to reduce the environmental burden (Van Hemel, 1998). One of these is 'product lifetime optimization'.

Ecological lifetime optimization is a matter of finding the best moment for replacement from an ecological perspective, and subsequently influencing the moment of replacement in favor of this point in time. In so doing, it is important to realize that it is not only the technical state of the product that influences the replacement decision. Nontechnical aspects also have a role to play, as proved by the research carried out by Blonk (1993). It is often suggested that aspects such as esthetics and features are important in the replacement decision (Hinte, 1997; Creusen, 1998).

At present little is known about the range of different factors that influence the product lifetime. As a result, there is a lack of 'guidelines' to support designers in the development of products with an optimum product lifetime, in both ecological and economic terms.

This paper aims to elaborate on the relevance of lifetime extension and to explore the possibilities for such guide-

lines, particularly for electronic products. The first paragraph discusses how one can determine the ecologically optimum lifetime in comparison with the current usage time. The second paragraph explores which factors influence the product lifetime. Finally, indications are given of how the gap can be closed between the current usage time and the ecologically optimum lifetime of a particular product.

2. Extend or shorten the lifetime?

Generally speaking, the positive environmental effects of designing longer-lasting products lie primarily in the area of reduction in the use of raw materials and (toxic) waste by decreasing the number of replacements. However, lifetime extension of products does not always represent an environmental improvement. The washing machine and the refrigerator are well-known examples. This leads to the question of when it is ecologically sound to extend or shorten the product lifetime (Cramer, 1996).

This question is particularly relevant for those products that ‘consume’ something and generate an environmental effect during use, such as the consumption of energy, paper, chemicals, water, etc. In such cases it is possible that the environmental investment in the production, distribution and disposal of the replacement product is earned back by a higher environmental efficiency during use. These products can be characterized either by:

1. A significant reduction in the efficiency of the product itself due to use, or by
2. A significant improvement in the efficiency of new products (with the same function) in the market.

These two factors are independent and can be put together in a two-by-two matrix as shown in figure 1.

	<i>NO reduction in the efficiency of the product itself</i>	<i>Reduction in the efficiency of the product itself</i>
<i>Replacement by identical product</i>	- Category I - Lifetime extension always constitutes an environment benefit	- Category II - Calculate whether replacement is environmentally sound
<i>Replacement by new more efficient product</i>	- Category III - Calculate whether replacement is environmentally sound	- Category IV - Calculate whether replacement is environmentally sound

Figure 1 Ecological Lifetime Optimization Matrix (ELOM)

For products belonging to category I, lifetime extension is always of benefit to the environment. For products belonging to category II, III and IV the environmentally sound moment for replacement can be calculated on the basis of the use of the environmental pay-back time. The environmental pay-back time (T) is the time it takes to earn back the environmental investment in the replacement product (P) by the improvement of the environmental efficiency during use (ΔE). This can be expressed in a formula as: $T = P / \Delta E$ or $P = \Delta E * T$. The replacement is considered to be environmentally sound when the expected usage time of the replacement product is greater than the environmental pay-back time.

Ecological pay-back time:

$$T = P / \Delta E$$

- P – the environmental impact of the replacement product, including production, distribution and disposal.
- ΔE – the improvement in efficiency created by the replacement
- T – the environmental pay-back time

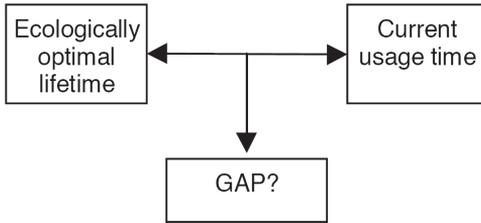


Figure 2. The gap between the ecologically optimal lifetime and the current usage time

The model described in this section can help us to find the best moment of replacement from an ecological perspective. In practice, there is usually a gap between the current usage time and this ecologically optimum lifetime. This is visualized in figure 2.

3. Understanding the gap

In order to bring the current usage time closer to the ecologically more desirable lifetime we need to understand whether and how to influence the current product lifetime. We are in particular interested in the question how the product lifetime can be influenced by the product design. In order to come to grip with the problem a conceptual model is developed by Van Nes e.o. (1998) based on a literature review and expert interviews.

This model focuses in particular on product-related aspects that influence the replacement decision. The model (figure 3) distinguishes several dimensions of a product that cause dissatisfaction, or in other words that can lead to obsolescence. The first factor, technical obsolescence, relates to changes in the product itself as a result of usage. The other factors relate mainly to changes in the market, with the effect that current products are perceived to have become obsolete.

The different types of obsolescence that can be distinguished include:

1. Technical obsolescence: the product itself is worn out and no longer functions properly. E.g. hard disc of computer crashes.
2. Economic obsolescence: new products in the market are more economic in terms of cost, they have a lower cost of ownership. E.g. energy-saving lamp.
3. Ecological obsolescence: new products in the market have a less harmful impact on the environment E.g. refrigerator, energy-saving lamp. Ecological obsolescence and economic obsolescence often go hand in hand, although this is not necessarily the case.
4. Esthetic obsolescence: new products in the market have a nicer look or a more fashionable design in the perception of the consumer E.g. coffee-maker in style of 70's in kitchen in style of 90's.
5. 'Feature' obsolescence: new products have come onto the market that offer more or better features E.g. faster computer, cd-rom drive, high density TV).
6. Psychological obsolescence: a new product has greater emotional value (e.g. present/gift or inheritance) or the present product has a negative emotional value.

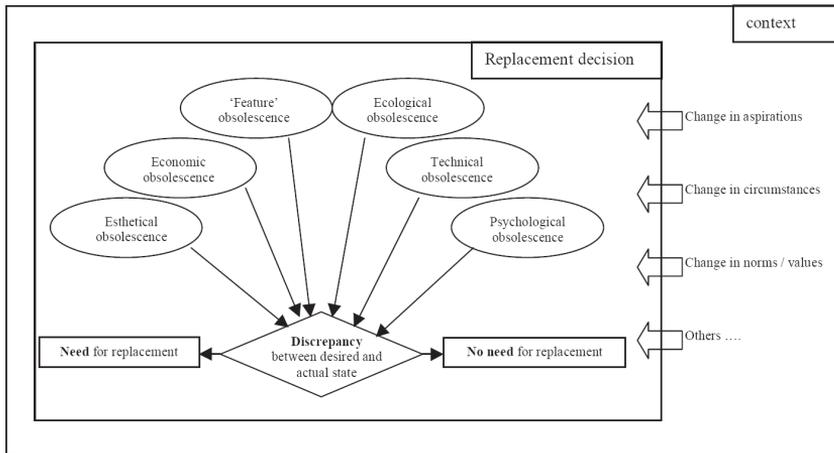


Figure 3 - Conceptual model of the influence of product characteristics on the replacement decision

The above model shows the set of factors that can potentially cause dissatisfaction. A single factor can cause dissatisfaction, but the dissatisfaction can also be caused by a combination of different factors. The different factors can also strengthen or counterbalance each other.

The weight that is given to each of these factors varies per product. For example, for a coffee-maker the visual state is considered to be important, whilst for a vacuum cleaner it is mainly the technical state and for a computer it is the functionality. The weight given to the different factors also depends on the user. A 'techno freak' may regard an audio system as obsolete, whilst the 'no-nonsense consumer' perceives the same audio system as satisfactory.

The factors within the model are product-related factors that influence the replacement decision. However, the deliberation within the model is influenced by the context.

For example: moving to a new house influences the desired state of a great many products, and as a result discrepancy with the actual state arises. Other examples of circumstances that influence the deliberation within the model are, for example, the neighbor purchasing a new car, having children or a rise in income. There is therefore a context around the model that contains the non product related factors that influence the replacement decision.

4. Directions for improvement – how to close the gap?

Once we have understood the reason for dissatisfaction it only takes a small step to formulate design directions to extend product lifetime. In order to do so, one must anticipate this on dissatisfaction by adapting the product to the relevant aspects. Design directions can be drawn up to make only the obsolete part repairable or upgradable, and replacement parts can be offered instead of replacement of the whole product. Design directions to be considered are:

1. Technical obsolescence → e.g. improve repairability, self repair by consumer
2. Economic obsolescence → e.g. replace printed circuit board with a more efficient one
3. Ecological obsolescence → e.g. replace printed circuit board / engine with a more efficient one
4. Esthetic obsolescence → e.g. replace the front or the housing
5. 'Feature' obsolescence → e.g. add new features through software or hardware (modular design)

The business concept behind this approach is to sell a reduced quantity of materials, offer the same added value for the consumer and make greater profit. This requires a change in paradigm within business from 'selling boxes to selling a function'. In spite of the current tendency towards faster replacement cycles, this approach has a lot of business and consumer benefits. The benefits to be achieved include:

- improving product quality,
- increasing consumer satisfaction,

- brand loyalty,
- postponement of the moment of dissatisfaction with the product,
- stronger bonding with consumer,
- opportunity to move from hardware to service with a higher profit margin.

5. Continuation

The ecological lifetime method as presented in this paper is now being tested on audio products and lighting products. The experience gained will be used to further refine the approach. More cases will be selected to enable the general applicability of this method to be evaluated.

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Tidbits, 6

Info about women is on the Internet

Around the year 2000, we did quite a bit of work on 'green' marketing (see chapter 5.4). It turned out, amongst a lot of other things, that generally speaking women are much more environmentally conscious than men, particularly between the ages of 18 and 40. Simultaneously it was observed that the percentage of female buyers purchasing consumer electronic products was rapidly increasing. Today buying cars, whisk(e)y and gin are the last strongholds 'for men only'.

Finding out how to link 'green' marketing and gender seemed to be therefore a great graduation project. To my surprise only male students turned out to be interested. Eelco H. ultimately took on the subject. The initial problem was to gather loads of detailed information? Asking fellow students is not good enough and doing random interviews takes too much time for a six month project. Eelco H. was a smart guy however, and he managed to convince the marketing people to post a (temporary) pop-up on the Philips CE product website. He was able to ask his questions there. The results were stunning:

- *In a short period of time there were almost 1,000 reactions, 91% women, 9% men.*
- *40 % of the respondents were single.*
- *Of the women with a partner, 50% made consumer electronics purchasing decisions together, 20% did it alone, and 30% left it to their partner.*
- *In a ranking of 25 products shown on the net, 'green' products (it was not specified which products were 'green') scored low for attractiveness. The main comment was 'they look so lousy'.*

The last conclusion is a real killer! The physical functionality of the 'green' products is OK, the economical functionality seems to be OK however, the emotional functionality turned out to be seriously neglected: 'green' was associated with misery, not with quality. The lesson for product realization is not 'go for the absolute minimum in environmental load'. Instead, make sacrifices to design a product which is attractive for potential buyers while being greener than standard products. Several business groups took this lesson on board with surprisingly positive results. Eelco, thank you very much!

4.5.3 A market for services to extend lifetime?

In the studies about discarding behaviour at Philips Consumer Electronics a shortcut has been taken. Based on the 7 archetypes of environmental behaviour of consumers (see chapter 5.4.1) and the traditional consumer behaviour characteristics, as used by PCE, correlation matrices between the two were plotted. These included a general correlation matrix (table 3 of the publication below) and a specific one showing replacement behaviour of a TV set's first user (table 4). The aim was to find out which consumer group would be interested in services aimed at postponing replacement. Secondly, when a positive result was obtained to tailor design strategies for future products towards these strategies.

The results of this study are given in the paper "Service to extend the life of TV sets" below. Conclusions suggest that there is, even in affluent societies, some 50% of first users who have interest in services to extend product lifetime. However, the ecological and economic payback of lifetime extension efforts is, at least for TVs, very limited. As a result the 'service project' has been abandoned.

Service to extend the life of TV sets

Ab Stevels and Michel Boekee

Abstract

Based on an in depth user research, two upgrading scenario's for TV's which are currently discarded by first owners have been identified. Due to the fact that energy consumption is dominant in the environmental load over the total life cycle, the environmental and economical gains are limited for the current models, that is 22% and 5% respectively when lifetime through the upgrading service is extended by 50%. Future models should allow easier replacement of Printed Wiring Boards so that an upgrade service offers more value for producers, customers and society.

1. Introduction

It is widely assumed that, in our affluent society, a lot TV sets that are replaced by the first owner still function more or less properly. This is due to the fact that apart from irreparable breakdowns, repair is thought to be too costly in comparison perceived (rest) value or to be too inconvenient or too much a hassle.

Apart from that increased functionality ambition of the user is another chief reason to discard products (see also refs. 1 and 2)

In this paper it is explored what services or design approaches could prevent 'premature' discarding. This strategy is ranking the highest in the environmental preference for end of life strategies which is as follows:

Table 1 Environmental ranking of end-of-life strategies.

I Strategy	Environmental Rank
Prevent replacement	1
Product reuse	2
Product repair	3
Product remanufacture	4
Subassembly/component reuse	5
Recycle (with disassembly)	6
Recycle (without disassembly)	7
Incineration with energy - recovery	8
Disposal	9

In ref. 3, it has been calculated on basis of Eco-indicator 95 (see ref. 4) that although in absolute terms the ranking of strategies 2-9 in the correct one, for TV's in relative terms the difference between the strategies 2-6 is small, a few percent difference only. This is due to the fact that the environmental effects of energy consumption in the user phase are dominant (approx. 80% of the total load) and in the sector materials the environmental load of

mining and producing materials (the 'kilograms') is much higher than bringing form and function into these materials. It is also shown in ref. 3 that due to developments in technology which make that – at equal functionality- the energy consumption of TV sets goes down under circumstances the ranking of the preferred strategies could be reversed so that for instance recycling of materials of old TV's is from an environmental perspective is better than keeping them in use.

From these considerations it is concluded that the best chance to improve to prevent discarding at the first user is to offer as service functionality upgrades which simultaneously enables to lower overall energy consumption of the TV.

In order to explore this opportunity a pragmatic research approach is followed. First actual consumer discarding behaviour is studied in detail. On basis of this target groups are identified for which the availability of the service as described above is in principle an interesting value proposition. Next the design possibilities to enable TV upgrading are identified and rated according to user benefit, company benefit and feasibility. The preferred option is subsequently rated according to their environmental and value potential.

2. Consumer categories

In our research the Philips Consumer Target Segmentation method has been used to identify buyer/user groups in the consumer electronics market. Each buyer group has different priorities and criteria and it is expected that this also will apply when describing buyer behaviour.

Six buyer/user groups have been identified.

The overall characteristics of table 2 turned out to be strongly correlated with the archetypes of environmental behaviour as described earlier (ref. 5). In the correlation matrix below, crosses indicate the interrelationship.

Table 2 Buyer/user characteristics

Group name	% of total	Remarks
Home aesthetics	13	Design and ease of use are important, average education and age, females dominate
Enthusiasts	16	Latest technology/features are important, averages education, younger age, males dominate
Techno-connoisseurs	20	Knowledgeable, require high quality, above average education, younger age, males dominate
Rationalists	13	No outspoken priorities, average education/demography
Prudents	20	Want value for money, average demography
Uncertain	18	Price and ease of use are important, below average education, elder age dominates

Table 3 Correlation between general buyer/user characteristics and environmental attitudes about consumer electronics (see also ref. 5).

Environmental Characteristics \ General Characteristics	Home Aesthetics	Enthusiast 16%	Techno-connoisseurs 20%	Uncertain 18%	Prudents 20%	Rationalists 13%
	15% Green engaged ++		x			
15% Optimists +					x	x
13% Disoriented +				x	x	
15% Too complicated 0			x	x		
15% Pessimists 0		x			x	
10% Growth optimists -	x		x			
17% Enjoy life --	x	x				
Environmental attitude of buyer/user group	--	-	-	+	+	++

With two exceptions all crosses in table 3 are located on the diagonal running from bottom left to top right.

3. The replacement behaviour of first users of TV sets

In table 4 below data about replacement behaviour of first users of TV sets are given

Table 4 Replacement behaviour of first users of TV sets

Consumer segment		Life time at replacement (years)	Discarding due to low functionality (%)	Discarding due to irreparability (%)	Viewing time/day (hrs)
Home Aesthetic	13%	9	50	50	3.6
Enthusiast	16%	8	67	33	2.3
Techno-connoisseur	20%	9	46	54	2.4
Prudent	20%	11	34	64	4.4
Uncertain	13%	11	31	69	4.6
Rational	18%	10	46	54	3.7

This table allows some remarkable conclusions:

In the group with generally negative environment attitudes (Home Aesthetics, Enthusiasts, Techno-connoisseurs, the HAET's) products are replaced earlier (average 8.7 years) than for the environmentally positives PUR's (Prudents, Uncertains, Rationalists), the average being 10.6 years. This correlates with the fact that more TV's are still functioning at the PUR's (37%).

Surprisingly the table allows also the conclusion that user groups with a positive environmental attitude have their TV's switched for longer hours (average 4.2 hours/day).

It is concluded from table 4 that design -allowing postponement of replacement at the first user should primarily cater to the Home Aesthetics/Enthusiasts/Techno-connoisseurs target group. Items as good styling, new technology/features and quality are more important than for instance energy consumption (although from an environmental perspective the opposite is true).

4. Design strategies to postpone replacement

Although 3 is already giving some general indications about the design strategies to be followed to postpone replacement, an in depth and detailed analysis of all strategies has been pursued to get better clues what tot do in practice to make the service offered to the market really successful.

Following items will be explored:

1. Do the design strategies fit with the target group (Home Aesthetics, Enthusiasts, Techno-connoisseurs)

1a. Appeal to needs

1b. Deliver benefits

1c. Costs of upgrades

2. Do the (design) strategies fit with the competence and business interests of the producer

2a. Does the design strategy fit with the current business strategy and is the technical know how/market access available.

2b. Financial consequences. How does the design strategy link out a sales, profitability and market position.

3. Are the strategies really green that is:

Will the strategy lead to a longer lifetime before replacement and will the strategy lead to a lower environmental load per hour of viewing.

The results of this assessment are summarised in the table below. On the left hand side the 'durability' strategies are mentioned – entries in the various columns are indicated qualitatively.

Table 5 Evaluation of design strategies to postpone replacement

Issue \ Strategy	Ia need	Ib benefit	Ic cost to user	2a strategy fit	2b financials for producer	3 green?
Functional upgrading	++	++	-	0	+	++
Tailor made functionality	+	++	--	-	0	+
Styling upgrade	++	+	0	+	+	0
Tailor made styling	+	+	--	-	0	++
Timeless design	+	0	-	+	0	0
Emotional bonding	+	+	0	+	+	--

In the considerations, a central issue has been that the energy consumption in the user phase is much more important in the environmental load over the life cycle than the materialisation. The design strategy chosen should fulfil the needs and benefiting the target groups in more general but also include the possibility to lower energy consumption in line with latest technology available. This condition makes that all strategies related to styling and function integration are getting low scores, irrespective whether they fit to the producer interests.

In fact in this way only two strategies can be selected: functional upgrading and tailor made functionalities. Due to the costs both for the user and the producer the final choice becomes a functional upgrading design strategy – also in this strategy a clear condition is that the user can earn back the additional cost of the upgrade by the lower electricity use in the phase after postponement of replacement.

5. Design for functional upgrading

The functional requirement for upgrading were identified as follows:

- Digital video receiver
- New services which require identification of user
- Web browser/ E-mail
- Dolby surround processing
- Reviewed interface

These should be combined with styling requirements:

- Variable styling (front)
- No separate additional boxes
- Upgrade must preferably be suited to be installed by the consumer

It was found that these functional requirements could be met in two ways:

I Replacement upgrading. This is the most radical method because several printed circuit boards need to be replaced. The advantage is that a new Small Signal Panel/tuner module can be installed which will be more power-efficient due to miniaturisation and integration of functions (technical developments). Also the power supply can become (when replaced) relatively more efficient due to better matching with the new electronics.

II Additional upgrading. This basically means that extra modules can be plugged into the existing electrical chassis. Such smart card extension system already exists; problem will be however that the interface with the upgrading system will need to be compatible for a long time. This is unlikely to occur - in view of all the technical developments taking place.

For the style upgrading several proposals were worked out based on either adding a new front or replacing the complete encasing. Just replacing the front with a slot to enter a 'smart card' is to be preferred due to lower environmental impact.

6. Environmental & economical validation of the design proposals

In the environmental validation several scenarios have been considered. Starting from the expectation that by the chosen upgrading strategy life is from 8.5 years to 12.7 years (50% increase) it has been calculated that:

The replacement upgrading brings an improvement of (an average – dependent on user scenario's) 22% of the environmental impact per hour of functionality (=TV on). This 22% is the net result of:

- Lower environmental impact per year of the overall materialisation/production
- Higher environmental impact due to the environmental investment in new small signal panels etc. (which gave to be written of in 4 years)
- Lower energy consumption in the last four years due to introduction of new energy saving technologies.

The additional upgrading brings an improvement of only 5%. This is the result of:

- Lower environmental impact per year of the overall materialisation
- Higher environmental impact due to the 'environmental investment' of modules added which is as such small compared to the pcb investment in case of the small signal panels in the replacement scenario's
- Increase in power consumption due to the additional functions
- The changing in style (new front or even complete new encasing) has relatively little negative impact (1-5% depending on the choice).

In the economical validation the total costs for the consumer consisting of initial purchasing costs of the basic set cost of the upgrades (priced with margins allowing the producer to take-in absolute terms-the same overall profit as in the situation without postponement of replacement), costs of power consumption and the costs of the upgrading service (installation).

In this approach the initial costs (basic sets and the upgrades) will be higher compared to the situation without postponement. However the total cost of ownership turned out to be lower in the upgrade scenario's:

- for the replacement upgrading the advantage is 6%
- for the additional upgrading the advantage is 5 %

In fact the scores for both upgrading scenarios are more or less equal. This is because the lower investment costs of the additional upgrading scenario are offset by higher power consumption costs.

7. Conclusions

This study has shown that it is possible by carefully studying consumer behaviour to develop upgrading concepts for TV sets that lead to an increased lifetime. At the current state of technology the environmental impact of TV watching can be reduced up to 20-25% per unit of time. The total cost of ownership can be reduced up to 5% / year. Since for TV sets energy consumption is dominating in the life cycle impact, increase of life time (which basically involves a better use of the materialisation) through upgrading scenario's as the ones proposed here results in relatively modest environmental and economical gains. Future efforts should be concentrated in products where the ratio of:

$$\frac{\text{Environmental load of materialisation /production}}{\text{Total environmental load over the life cycle}}$$

is low.

When in future TV concepts are developed which are more suitable for upgrading (basically this means bringing down the relative by contribution to the total environmental load) than the existing types, this will increase the benefits for the environment and the consumer of an upgrading service approach.

Companies doing so well will be perceived by the consumer as a leader in environmental care and as a manufacturer of top quality products.

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Personalities, 6

Suzanna Bastiana (“Suze”) Dronkers (1913-1991) - Curiosity and language

She is my mother. All of her life she stimulated in me all kinds of curiosities and interest in languages.

I was brought up in an atmosphere of respect for science and high esteem for universities. Broad knowledge was highly rated and knowing seemingly useless facts was highly appreciated. As a boy in elementary school, I was already reading the daily newspaper, de Nieuwe Rotterdamsche Courant (enlightened conservative at that time), in great detail and spent many hours reading the Winkler Prins Encyclopedia. The only popular magazine in our home was Donald Duck. Still today I do not understand why my parents immediately subscribed to it when it was edited in Dutch (1952). It was supposed to be utterly popular and not for ‘intellectual families’.

Of course my sisters and I were sent to the ‘gymnasium’. In Eindhoven there was not a ‘real one’ but instead it was integrated into an ordinary highschool. You had to study ancient Latin and Greek for up to ten hours a week. This is not as useless as it seems; it sharpens your mind and creates a solid basis for picking up languages quickly. Last but not least it keeps relatively intelligent children busy as well.

Ma had a degree in classical languages herself and was an archeologist by profession. The war, outdated employment laws (kept alive by the Christian parties, in particular the catholic ones) and a crippling tax system (introduced by the socialists) caused her to abstain from taking a paid job. Without being a feminist she fought for women’s equality through committees, but without regret she stayed home. I felt happy at home, not at school.

Heartless teachers dominated in the schools. Moreover, the quality of the municipal schools was low in the south of the country.

My mother always had high ambitions for me, but she understood the job changes in my professional life better than my father; maybe it was due to the same restlessness and inclination to experiment she had as well.

She was proud when I told her that I took books of the Antiques on my business trips, like Xenophon and Homer. Many years later it was revealed that I read Dutch translations rather than the originals written in Greek. My mother was upset and emphatically gave me advice to go back to the real sources. Real civilization can only be found there!

My mother died one year before I started in my job at the Environmental Competence Centre. She would have seen that as a great move for me and would have asked me a thousand questions about what I was doing and how I was progressing...

The ‘Suze Dronkers walk’: Drive (there is no public transport there) to either Valkenswaard or Leende, both south of Eindhoven. Halfway between these villages there is the entry of “Boswachterij Leende”. Start from the car park with the Loofhout walk (green leaf walk) but switch at the appropriate moment to the Heide walk (heather walk). Include Laagveld and the Hasselsvennen in your route. Make it up to Grote Heide or if you want to proceed even further go to the Achelse Kluis and go back by the path of your choice.

4.5.4 Influencing the replacement behaviour of consumers

When analysing the marginal results of the study above, the conclusion is – in retrospect – that much more attention should be paid to the combination of environment and cost. Repair/upgrading generally involves high costs due to the labour cost involved, and to a lesser extent the cost of materials. These costs have to be earned back by energy savings. Electricity is still relatively cheap, therefore sufficient economic payback is often problematic.

For environmental payback the opposite holds true. Electricity has a high environmental load compared to its costs. Materials score average in this respect, and components below average whereas labour is the lowest environmental impact/ cost ratio

For a TV this works out so that energy in the use phase constitutes 80% of the environmental load over the life cycle but only some 35% of the life cycle cost (for 3 hrs/day in 'on' mode). For one hour/day the cost is reduced to roughly 15% of the life cycle cost. Even for 'heavy use', energy cost barely exceeds 50% of total cost.

Through repair/upgrading energy savings can be achieved. The ecological payback time of repair/upgrading is much shorter than the economic one. This difference between ecological payback and monetary payback means that essentially repair and upgrade services face an uphill battle.

For products to be replaced by services, which involve more transportation, the same conclusion applies. Also 'dematerialization' is not a generic strategy. When it involves more energy consumption it fails. On the contrary – against traditional 'Eco' beliefs -materialization strategies can be very successful. The best example is replacement of incandescent lamps by energy saving lamps. The last ones have a very high environmental payback (although lots of material is used) and still an acceptable environmental payback.

High-speed trains are another interesting case. When flight transportation is replaced by high-speed trains, there is a short ecological payback (even when all the materials to build tracks are taken into account); whether there is an economic payback is highly doubtful.

Applying such considerations to consumer electronics products leads to interesting conclusions as well. Changing for instance from Cathode Ray Tube based TVs to Liquid Crystal Display ones has a high ecological payback (LCD TVs production facilities today have economies of scale comparable to CRT TVs) and has no economic payback, since the current price difference cannot be earned back by the lower energy consumption of the LCDs.

Criteria other than economic influence replacement. Immaterial and emotional functionalities play an important role (see chapter 2.2). Apparently these work for LCD TVs; today CRT TVs are in rapid decline. In the case of LCD TVs (and of plasma TVs for which the same holds with respect to CRT TVs), the fundamental driver for environmental gain is the physics used to realize the functionality. Design supports in the immaterial and emotional dimensions of functionality, see chapter 2.2. This is needed to overcome economic issues such as high prices. It looks as though it is a modest role but it is an essential one!

In Delft we are deliberately more radical in 'green' design. Such radical designs are meant to be a challenge and provide stimulus for the design of products which have to adapt themselves to the market. Radical design is perfectly suited to gaining all kinds of new insights. Going back to reality after this kind of learning leads to better results than starting in an adaptive mood straightaway. This is the approach of the Applied EcoDesign group and in my opinion that approach that must be taken.

The paper on the next page "*Influencing Product Lifetime through Product Design*" presents a design proposal for an electronic product, which can be carried along throughout someone's whole life and is 'green' for that reason. It is sufficiently integrated enough to allow environmental and economic savings and modular enough to allow the required functionality changes

The general reaction to this design proposal was very positive. Even the most anti-environmental diehards among the product managers had to admit that a lot has been solved at the product level. Now the next level has to be addressed; the strategic level. Which company dares to invest massively in such approaches?

Influencing Product Lifetime through Product Design

Erik Smeels; Ab Stevels

Abstract

The lifetime of the current generation of audio systems is far away from its ecological optimum. Replacing a product for a better, nicer or just more cosmetically pleasing one is the order of the day. The question this paper addresses is whether optimising the lifetime of audio systems is an interesting concept to gain environmental and business benefit. The paper concludes that in the case of audio systems lifetime optimisation can be used to bring about innovative new ideas that at the same time reduce environmental impact substantially.

1. Introduction

Research shows that 60 percent of all audio systems still function when first users want to dispose of them. This means that many audio products are discarded for other reasons than technical malfunctioning alone. Moreover, those products that have a technical malfunction (like a broken switch) cannot easily or economically be repaired. And when on top of that a new technological feature is being added to new audio systems (like MP-3), the only option is to replace the whole product with a newer one. In other words the current generation of audio systems is not designed to be repaired or to be upgraded. This suggests that upgradability of audio systems may offer opportunities from both an environmental and a business perspective. These opportunities are explored further in this paper.

2. Design for longevity

Optimisation of the lifetime of a product considers bringing the moment of replacement of a product closer to the ecological sound moment of replacement and thereby taking customer and company benefits into account [van Nes, 1998].

Design for longevity involves designing a new product that has the ability to change over time. The product has to be made adaptable to changing technological possibilities and changing user preferences. In this report a new concept audio system, the Sound 2000, is presented that has the ability to change over time, thereby postponing the moment of replacement.

3. Design approach

As stated earlier a new product concept has been designed with an expected prolonged lifetime. The introduction of which could lead to a new consumption pattern that offers opportunities from both a business and environmental perspective.

Before a design solution can be developed to optimise the lifetime of audio systems, understanding what influences the moment of replacement is essential. In general, the moment of replacement of a product is determined by product-related and user-related factors. The product-related factors are those factors that define the change in performance of a product, whereas the user-related factors relate to the way the user changes over time. Both changes in performance and changes in user needs and expectations can lead to obsolescence of a product. During the lifetime of a product the performances start to diminish. Six different types of product performances that a product offers to the user can be distinguished:

1. technical performance
2. financial performance
3. ergonomic performance
4. aesthetical performance
5. technological performance
6. ecological performance

The two underlying design strategies that enable product lifetime optimisation are:

1. design for upgradability
2. design for emotional product attachment

Each strategy is individually described in more detail below, as well as in relation to its application on audio systems.

3.1. Design for upgradability

Upgradability can be defined as the ability to add extra functionality to a product during the life of that product. The difficulty with design for upgradability is that future developments are usually unknown, simply because they have not yet been developed. Design for upgradability thus involves assessing future developments. Trends must be analysed on all six product performance areas in order to be able to design a product that in the end can be upgraded rather than being discarded.

When designing for upgradability it is important to assess the relative importance of product performances for the specific product. The relative importance indicates which product characteristics have to be made upgradable. In the case of audio systems the most important types of product performances are the technological and the aesthetical performance [Blonk, 1993].

3.2. Design for emotional product attachment

Emotional product attachment can be defined as the extent to which people are emotionally related to a certain product. In relation to the lifetime of products it is interesting to know how product attachment affects the length of time a possession is kept. Attachment processes cannot be directly influenced by product design. Whether or not people develop strong feelings of attachment largely depends on accidental circumstances. It is however possible to design unique products that trigger feelings of attachment.

4. Design proposal

The objective for the new product concept was to design a new audio system that triggers feelings of attachment and is adaptable to changed user needs and new technologies.

To be able to assess the benefits of the new product concept, a reference product is needed. For this paper the Philips FW-870 audio system is chosen as a reference product.

How design for upgradability and design for emotional product attachment is applied in the design of the new product concept is described below.

4.1. Design for Upgradability

For an upgradable product architecture a division has been made between fast-changing technology and slow-changing technology (see figure 1).

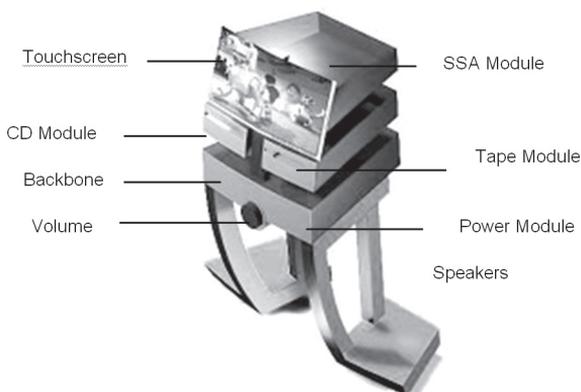


Figure 1 The Sound 2000

The slow-changing technology (transformer, the tuner board and the amplifier, together with the main printed circuit boards) is also referred to as the power module. The fast-changing technology is individually packed in technological modules that can be attached to a vertical backbone. Power- and signal distribution to and from the power module will be provided by the backbone. At the time the product is launched, it will contain a single CD-module and a single Tape module.

The new product concept can be upgraded with new technological features that become available, through replacement and additional upgrades. Replacement upgrades are upgrades that replace existing modules, whereas additional upgrades are added to a product without replacing an existing module.

An example of a replacement upgrade is the CD-recorder. Trend analysis shows that it is to be expected that the CD-recorder will, in time, replace the recording function of the tape module. DVD players are also capable of playing normal audio CDs; as a result the CD-module can be replaced by a DVD-module.

When the technological performance changes as a result of the addition of new (not yet developed) modules, the control options of the hifi system must change as well. The new product concept is controlled through buttons on the touchscreen. The user is able to alter the buttons and the background of the touchscreen to meet his or her personal preferences. Consequently, when new technological modules have been added, the control buttons can be adapted to these new technologies.

Software upgrades also provide an interesting opportunity from both a business and an environmental perspective. Software upgrading facilitates a reduced time-to-market of new functionalities. Extra, not yet developed features can be added later. From an environmental point of view, software upgrades are also preferable, due to the low environmental impact of the upgrade itself. The environmental impact of software upgrades is negligible compared to the impact of hardware upgrades. In the case of hifi systems two types of software upgrades can be imaginable, music [MP 3] and technological upgrades. A technological software upgrade that could, for example, be added to the new product concept in future is speechcontrol. This kind of control requires mainly software to function. The software can be downloaded from the internet. The conditions of success for this type of upgrade are secure payment through the internet and the finalisation of copyright issues. Software updating should be as easy as running a new application on your home PC.

4.2 Design for Emotional Product Attachment

As stated earlier attachment processes cannot directly be influenced by product design. The new product concept has two characteristics that trigger feelings of attachments. The first characteristic is the option to change the position of the speakers, which has a substantial influence on the overall appearance of the product. Each individual can thus change the appearance of the product to meet his /her personal preferences. This way people can personalise their own hifi system (figure 2).

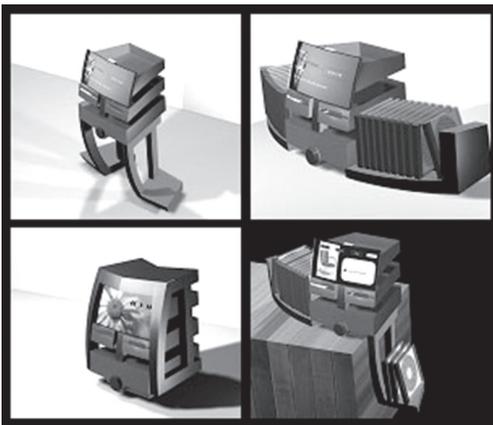


Figure 2 Possible speaker positions

In addition, users are able to personalise their product through influencing the design of the touchscreen. They are able to create their own display, define their own buttons, according to personal preferences.

5. Environmental benefit

The environmental impact of the new product concept, and consequently the environmental benefit in comparison to existing products, cannot simply be determined by performing an LCA on both products. The total environmental impact depends on how many times the user has upgraded the product. The type of technological upgrade chosen also influences the total environmental impact. It is therefore important to make an assessment of various upgrade scenarios. The possible upgrades are visualised in figure 3.

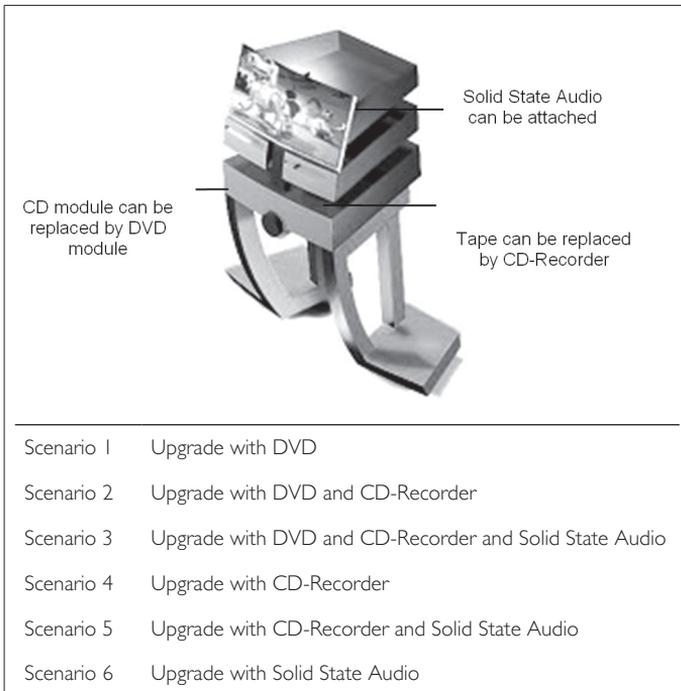


Figure 3 Upgrading scenarios

The maximum and the minimum environmental benefit that can be achieved by the new product concept depend on both the upgrade scenario and the environmental impact of the upgrade modules [DVD, CD-R and Solid State Audio].

In order to be able to come to clear conclusions involving the environmental benefit, several assumptions have to be made. These assumptions are outlined below.

5.1. Initial lifetime of the reference product

In this case an average initial lifetime of 7 years is chosen. A functional unit of 7 years is often used when calculating an LCA made of hifi mini systems [Ram and Looren de Jong, 1999].

5.2. Energy usage

It has been calculated that that replacement of hifi systems for more energy efficient ones is not preferred from an ecological point of view [Smeels, 2000]. Therefore the environmental impact as a result of the energy usage during the lifetime of the product is assumed equal for both the reference product and the new product concept.

5.3. Impact compared to reference product

As the environmental benefit in this project results from the optimisation of the initial lifetime of products, no extra attention has been paid to decrease the environmental impact of the product itself. Therefore the environmental impact of the new product concept is assumed to be equal to the impact of the reference product. Figures 4 and 5 outline the environmental benefit of the new product concept according to a simulation. In these figures two consumption patterns are simulated. Consumption patterns reflect the way in which customers acquire new or extra functionality. In the case of the current generation audio systems people are only able to acquire new or extra functionality by replacing one product with another. The new product concept however provides the customer with the ability to upgrade the technological performance and to change the appearance of the product. In order to get a clear impression of the environmental benefit, only two scenarios will be presented; the best case scenario representing the highest environmental benefit [fig 4] and the worst case scenario representing the lowest environmental benefit [fig 5].

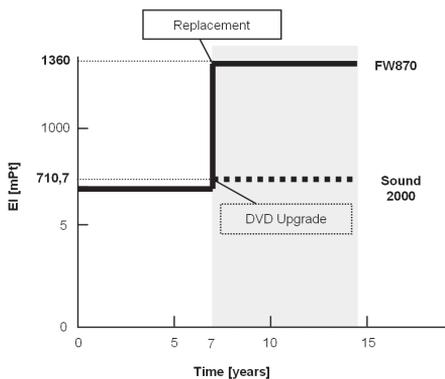


Figure 4 Best Case Scenario

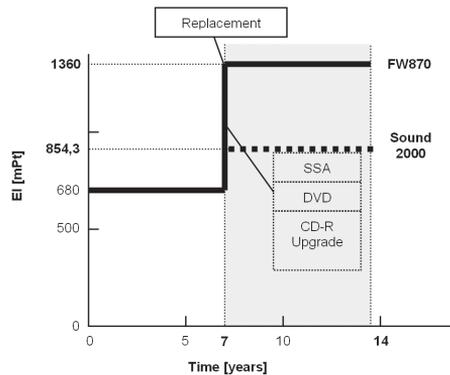


Figure 5 Worst Case Scenario

From the scenarios displayed above it can be concluded that upgrading a product in order to acquire extra functionality instead of replacing the entire product will reduce environmental impact by 95 percent if the product is upgraded one time (best case), to 70 percent if the product is upgraded three times (worst case).

5.4. Long-term perspective

As mentioned before, the introduction of the new product concept will change the consumption pattern of consumers. People will upgrade their products instead of replacing them. The change in consumption pattern results in a slowdown of the throughput of energy and materials. For this project, the different consumption patterns are characterised by the material- and energy throughput. This throughput can be judged by calculating the environmental impact as a function of time as a result of the current and the new consumption pattern. In the equation below the term 'material and energy throughput' has been defined.

Material- and energy throughput = EI (until replacement) [mPt] / Initial lifetime [years]

EI (until replacement) = The total environmental impact of a product before it is replaced [including environmental impact as a result of upgrades and repairs]

In the calculation below the material- and energy throughput has been calculated for the current consumption pattern (based on the reference product).

$$\begin{aligned} \text{Material- and energy throughput} &= 680 \text{ mPt} / 7 \text{ years} \\ &= 97, 14 \text{ mPt} / \text{y} \end{aligned}$$

Figures 6 and 7 reflect the effect postponement of the moment of replacement has on the material- and energy throughput for respectively the best case scenario (if the product is upgrade only once) and the worst case scenario (if the product is upgraded three times). The throughput is listed for the new consumption pattern (varying from one-year lifetime extension to seven years). The proportional slowdown compared to the current throughput is displayed.

Lifetime extension	Absolute	Proportional slowdown
1 year	106 mPt/y	-9 %
2 years	94 mPt/y	3 %
3 years	85 mPt/y	12 %
4 years	77 mPt/y	21 %
5 years	71 mPt/y	27 %
6 years	65 mPt/y	33 %
7 years	61 mPt/y	37 %

Figure 6 Best Case Scenario

Lifetime extension	Absolute	Proportional slowdown
1 year	89 mPt/y	8 %
2 years	79 mPt/y	19 %
3 years	71 mPt/y	27 %
4 years	65 mPt/y	33 %
5 years	59 mPt/y	40 %
6 years	55 mPt/y	43 %
7 years	51 mPt/y	48 %

Figure 7 Worst Case Scenario

As can be concluded from the figures above the proportional slowdown of material- and energy throughput, compared to the current generation of audio systems, varies from 48 percent [seven years of lifetime extension, one upgrade], to 3 percent [after two years of lifetime extension, three upgrades].

6. Business benefit

The business concept behind the approach of upgrading is to sell a reduced quantity of materials, offer the same added value for the customer and make more profit. Producers can sell upgrades (hardware and software) with the same profit margins as the current hifi systems. If upgrading purchases will be done more frequently than replacement purchases, overall profitability will increase.

In the current situation consumer only contact retailers for replacement purchases. With the introduction of the new product concept however, these contact moments will increase with the number of upgrades. This closer contact gives companies more insight in the behaviour of its customers and are able to continuously monitor their satisfaction. This provides companies with a tool to establish a sound brand image and to strengthen their position in the market.

In highly saturated markets, such as the audio market, producers are always looking for new markets (market development strategy) or are developing innovative new product offers (product development strategy). The proposed design concept is a good example of the latter strategy.

7. Conclusion

The consumption pattern (upgrading instead of replacing products) resulting from the introduction of the new product concept, provides companies with the opportunity to sell extra functionality with reduced environmental impact. However, the total environmental benefit of the proposed product concept is closely linked to the need people have for new technological features and a change in product appearance. Regarding the long-term perspective it can be concluded that the material- and energy throughput will start slowing down after some time if

the moment of replacement is postponed by upgrading the product. The proportional slowdown compared to a reference audio system varies from 48 per cent to 3 per cent.

If the introduction of the proposed product concept will be picked up in the market it can lead to a new consumption pattern with a reduced environmental impact, On top of that it also provides important advantages for the manufacturer. In the highly saturated market of audio systems the new product concept can be used as a differentiating product. Moreover, through increased upgrading purchases the producer has closer contact with its customers. This way the company can get more insight in consumer behaviour.

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Rituals and habits, 6

The Garden Session

There are three good reasons to have garden sessions with PhD students. The first one is an obvious one. During most of our professional life we have to sit in mostly dull, occasionally functional but always overheated offices. This is terrible and after forty years I still have not adjusted to it. Fresh air is a relief.

'Die Luft der Freiheit weht' is the motto of Stanford University. This means 'the air of freedom is drifting' and there is deep truth in it. Even if the air outside is cold or hot the essential thing is that it moves. This is never found inside buildings and even if there is moving air, it is unpleasant.

A second reason to have garden sessions is the possibility to shut off electronic communication and use much more in-depth communication. Cell-phones, email, and the internet all increase the intensity of information and most of all speed. Simultaneously it makes work a lot more superficial. No time to think, no time to write, the next item is already waiting, without every previous announcement your mind has to switch again. Electronics make it almost impossible to concentrate and to work for several hours on one specific item.

The third reason for the garden sessions is to provide a personal touch which includes: discussions with students in an informal atmosphere, having a drink and a meal together, fun.

Garden sessions typically take place in summer. Either it is (under a big sunshade) on the lawn or on a covered terrace when it rains. All forms of electronics are prohibited; the maximum allowed is paper and pencil.

Typical subjects addressed are the tentative organization of their dissertations (chapters and content), balancing of methodic and empiric approaches, but most of all creative thinking about any issue of the PhD.

The PhD student has to take the initiative. I am a challenger and sparring partner only, who also continuously checks on the consistency of arguments and the soundness of their reasoning. The session goes on for hours and hours, mostly with great results.

It is intensive, it digs deeply and it addresses the essentials of PhD research.

A great experience!

4.6 Human powered products

4.6.1 Portable Radios

People love portable products; they can be used wherever you go. They allow you to be independent of the electricity grid and the nasty wires which have to be plugged in all the time! This freedom means that even batteries are accepted although they are hated almost equally. You always run out of batteries at the wrong time; even 'rechargeables' have a similar problem. It is necessary to have batteries changed appropriately – those bloody springs, they get loose all the time. When it rains batteries can get wet which leads to car door opener failure and other disasters out in the wild (see Personalities, 2).

Batteries cost little - at least for most equipment users - but are perceived to deliver little in comparison to their cost. In developing countries it is a different story; the relative cost is high for many users in those regions of the world. Many of these users own portables out of necessity (information, education) and not for leisure.

On top of all this arrived environmental awareness, in the nineties of last century. Batteries and battery production turned out to consume a relatively high amount of resources; they contain potentially toxic substances and sometimes outright hazardous substances as well.

This awareness has been an important driver for consideration of human powered products. Generating energy by yourself is an attractive idea for many people: 'Zap yourself fit', it must be fun!

The first foray into the field came from Trevor Baylis, a British inventor. His 'Bay Gen Freeplay' radio was presented to the industry but it found no support. This was because of the clumsy nature of the product (it had a big metal spring, which had to be wound), that and its 'terrible' exterior design. Not a particularly trendy product for a new generation, to say it mildly.

Industry's rejection showed that it did not grasp the underlying message. This message was: human power is an opportunity to create a product line combining 'green', high-tech, fun and utility. It has market potential for a wide range of potential customers, from rich to poor, all over the world.

Of course the energy generation mechanism of Baylis's product had to be drastically improved or changed; from winding to - for instance - pushing or pulling. The electronics themselves could be much more effective in drastically improving the ratio between play time and winding time. Most importantly the product needed to look more attractive and associate good environmental design with quality lifestyle.

In contrast to industry at Delft University we were excited about human powered products. Arjen Jansen picked up the issue and he has since become the 'Guru' in this field. Many students have completed their graduation projects under his guidance. He has done some relevant research in the field. Guru's do not publish PhD dissertations however I still hope that it will happen; it will be a treasure trove for designers.

When moving into this field the first issue addressed was the academic question: are human powered products really as 'green' as they are claimed to be? The products need more material in manufacturing than traditional radios. Can this additional environmental load be 'earned back' through less impact during use?

The answer to this question is a clear yes (see the paper on the next page "*Renewable energy in portable radios, an environmental benchmarking study*"), which would be an even stronger yes in the case that the load associated with battery waste could be assessed more accurately than was possible at that time.

Calculations, as presented in the following article, created a platform to lobby at Philips Consumer Electronics for producing human powered radios. In 1999 the AE 1000 product finally (it took three years to convince the management) hit the market. The product functioned well, in particular because the energy generating mechanism was made more elegant. The mechanism was difficult to produce in large numbers however (an example that supply chains issues had insufficiently been addressed in the early design stage, see chapter 2.2), which lead to delays and thus to the irritation of dealers. In terms of free publicity and 'green' image the AE 1000 was a great success. It sent a clear and positive signal to the outside world about the environmental intent of Philips Consumer Electronics. From a commercial perspective it was a different story. Most of the sales organizations took the product on board (not all of them did so) but were not investing enough in distribution. As a result their availability in shops was limited. People reading or hearing about the radio in the media, wanted to buy it but could not find it.

Moreover, the immaterial and emotional value of the product (see chapter 2.2) was not recognized to its fullest extent. The product was priced at average margins. A higher margin would have been possible if the apparent benefits for the consumer had been properly valued. Evidence that higher prices could be commanded in the market was found by store checks done by Delft students. Philips marketing people did not believe these results however.

Nevertheless almost 500,000 of the products were sold.

The human powered radio AE 1000 experience produced valuable lessons regarding the public reception of the product. Being 'green' is not good enough. Even if there is market acceptance, there is need to invest in distribution. The complete internal value chain (including production and marketing/sales) has to stand behind the product whole heartedly, any hesitation will be punished by the market. Most of all the reward must be reaped to the fullest extent. If a product has clear value, dare to ask a price in accordance with that value!

The AE 1000 did not have a successor at Philips in spite of the many attempts of the environmental departments who pushed for it. Proposals for human powered MP3 players, human powered cell phones or integrated MP3/cellphones (a human powered iPhone) were all turned down. Missed opportunities!

Renewable energy in portable radios, an environmental benchmarking study

Ab Stevels and Arjen J. Jansen M.Sc.

In this paper the results are presented of a environmental benchmarking study of 4 portable radios, 2 of these radios are powered by an alternative system, the others are powered by batteries. The study shows that there is considerable room for the improvement of both electronics and (human powered) alternative energy systems. It also shows an interesting environmental trade off between the use of batteries and alternative energy sources.

The analysis of these four radios is a first result in a research project at DUT on the subject of 'human powered energy systems in consumer products'. Ongoing research on this subject will focus on the analysis of physical constraints of the human body, new systems for converting human power into electricity, possibilities for the application of these systems in consumer products and assessment of the environmental consequences.

Introduction

At the Department of Engineering Design of the Faculty of Industrial Design Engineering, research within the Technical Product Analysis group (TPA) concentrates on the technical analysis of products, particularly addressing the environmental aspects of product design.



Figure 1 The analysed radios

Methods

The radios were “environmentally benchmarked” using the TPA method and by determining the EcoIndicator 95 value [Goedkoop 95], using EcoIndicator 95 classification factors [Goedkoop 95]. The SIMAPRO software version 3.1 [Pré consultants 95] was used for calculating the Life Cycle Analyses (LCA). The TPA method is set-up at the Faculty of Industrial Design Engineering in order to obtain a combination of LCA and various other product analysis tools. It focuses on a practical approach in gathering and analysing data of products with a similar or comparable functionality. A draft version of the TPA manual, in which the TPA method is described, will be available from the authors at the end of 1997.

Description of the analysed radios

The **BayGen Freeplay** is produced in South Africa. The radio is designed to be used in remote areas where batteries are hard to get or very expensive. The BayGen received world wide attention because of its alternative energy system, invented by Trevor Baylis. Although the radio was not primarily designed as such, it is seen as a “green” alternative by West-European consumers and specific environmental organisations [Benjamin 96], [Belgiovane 95]. In the analysis we focused on the “green” perception of this radio.

The BayGen Freeplay is charged manually by winding a constant-torque spring. The spring can be wound up to a maximum of 60 revolutions, average charging/winding time is 40 seconds. The required input torque is 1.66 Nm, total required input labour is 628 Joule. The output drum of the spring delivers a constant torque to a gearwheel transmission, which is coupled by a small driving belt to a dynamo (Mabuchi RF 500TB). Total gearing ratio i is 1:904 (dynamo speed is approx. 1800 rev/min). A fully wound-up spring allows the radio to play for 30 minutes. By dividing the output at the dynamo of 162 Joule (90 mW × 1800 sec) with the input of 628 Joule, an efficiency of 26% for the total energy system is found.

The **Dynamo & Solar** radio is produced in China. It has a versatile energy system, it can be powered by batteries (2 penlights) or by a build in NiCd battery (2 Varta V280R cells, capacity 280 mAh). The build-in NiCd battery can be charged by a solar panel (amorphous Si, 25 cm²), by net-current or by a hand-powered dynamo. When winding the handle at maximum speed, the NiCd batteries are charged with 100 mA. Winding the handle at a sustainable speed, it takes about 11 hours (at 25 mA) to charge the build-in battery. The solar panel is able to charge the batteries with 0.5 mA (cloudy day) to a maximum of 48 mA (bright sunshine).

Both the **Grundig Boy 55** and the **Philips AE 1595** are small portable radios powered by batteries only (2 Penlights, AA/R6). These radios served as the benchmark for the analysis because they have a functionality similar to the BayGen and the D&S radio (AM/FM, portable, no use of net-current). The Grundig and Philips radios are produced in China.

Table 1 Power consumption, weight and stored energy

	Power consumption at 70 dB(A) [mW]	Weight of the energy system [gram]	Stored amount of electrical energy [Joule]	Energy/Weight factor [Joule/gram]
BayGen Freeplay	90	1670	162	0,09
Dynamo & Solar	32	68,8	2670	38
Grundig	58	37,0 (= 2 ZnCl batteries size AA)	10500	284
Philips	33			

Assumptions and data for LCA

The LCA is based on the assumption that the radios will be used in the Netherlands. Containers are used to ship the radios from country of origin to Rotterdam harbour (at 0.44 mPt/tonkm). Inland transportation of the radios in the country of origin and from Rotterdam harbour is not considered. End-of-life (EOL) data are based on the assumption that the radios will be treated as household waste. However, these EOL data do not include the electronics of the radio. Because the availability of data for the environmental assessment of electronics is limited, the data used in this paper for PCB's is supplied by the Philips CFT EcoDesign group. A value of 1350 mPt/m² was used for the production of PCB's.

The environmental impact of the use of the radios is compared by defining the following “functional unit”: **1 hour radio at 70 dB(A) a day during a five year period.** ($5 \times 365 = 1825$ hours). This five year period is based upon estimated life time for the radios.

The battery consumption of the radios was measured by playing the radios until the batteries were exhausted. In the case of the Dynamo & Solar radio, the alternative energy system has not been used. Power consumption (see Table 1) was measured in order to compare the measured and calculated life time of the batteries. Only small differences (<10%) were found between the life time test and the calculated values. The number of batteries used in the five year life cycle is an extrapolation of the average of tested and calculated battery lifetime; the Grundig radio uses 62 batteries in 5 year, both Philips and D&S use 32 batteries in 5 year.

Studies show that the environmental impact of batteries mainly depends on EOL scenarios. In this report, the EcoIndicator 95 value for the production of batteries (0,44 mPt/battery, ZnCl, AAtype) is generated by the Philips CFT EcoDesign group. Full-recycling has been chosen as EOL scenario, assuming 1,6 mPt as EcoIndicator value for EOL (source: Philips CFT).

LCA results

In figure 2, the results of the SIMAPRO analysis on production are presented. The high BayGen score is due to its large and heavy energy system (3,7 mPt due to steel spring) and resulting large and heavy housing, compared to the other radios (also see fig. 1). The difference between D&S, Grundig and Philips are mainly due to a larger PCB and the energy system of the Dynamo & Solar radio (2 mPt estimated for the production of the solar panel, 1 mPt estimated for the production of the NiCd battery).

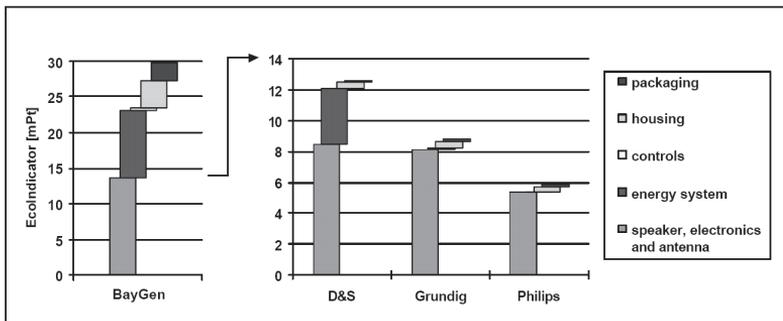


Figure 2 EcoIndicator 95 values for production. Notice that the y-axis scale has a different range for the BayGen (0-30) versus the D&S, Grundig, and Philips radios (0-14).

The EcoIndicator values for the total life cycle of the four radios have been calculated using SIMAPRO. The transport value for BayGen is high, due to its size and weight. EOL value for D&S is assumed 1 mPt for solar panel and 2 mPt for NiCd battery. EOL values for Grundig and Philips are too low to be visible in the graph.

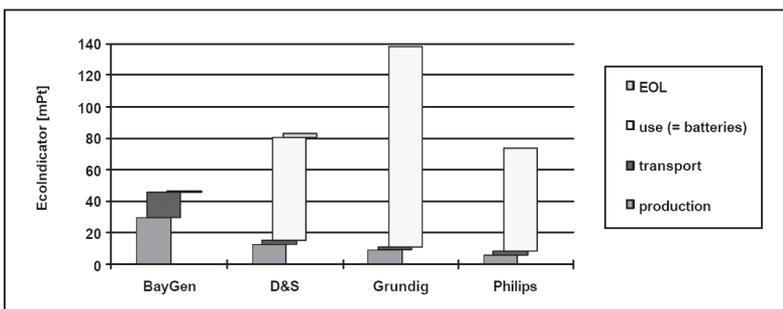


Figure 3 EcoIndicator 95 value for total life cycle of radios

The next step is adding the EcoIndicator values for Production, Transport, and EOL for each radio. Add to these totals the EcoIndicator values for the equivalent use of Batteries each year. The result is shown in the graph in Figure 4.

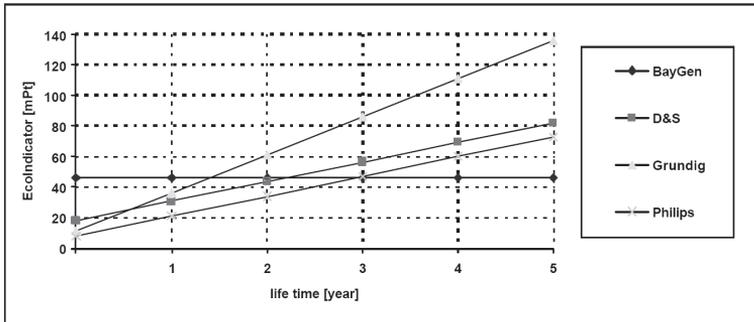


Figure 4 EcoIndicator 95 value during life time (starting point at 0-year consists of the sum of production, transport and EOL values)

Conclusions

The technical product analysis shows there is considerable room for the improvement of the design of radios with alternative energy sources;

- The NiCd battery inside the Dynamo & Solar radio can not be taken (unless soldered) out before discarding the radio. This means that the battery will end up at a landfill or will be incinerated. Recently, products containing non-removable batteries have been prohibited in the Netherlands [Dutch Government 95].
- Improvement potential for the BayGen Freeplay consists of reduction of the size and weight of the housing, upgrade of the electronics and better packaging (no PS foam). In this way reducing the EcoIndicator value for production with approx. 8 to 10 mPt. Reduction of the weight of the radio will also affect the EcoIndicator value for transport.
- In case the environmental load of products is dominated by the use of batteries, reduction of the power consumption has to be the first green option (also see table 1).

When consumers consider products with energy systems other than batteries, they often conclude that only the absence of these batteries makes the products "greener". This conclusion is not necessarily correct. Renewable energy systems based on Human Power may be an alternative for batteries in some products, but the environmental trade-off has to be watched carefully.

The conclusions of this benchmarking study mainly depend on the chosen EOL scenario for batteries (in this case full-recycling). Further studies should chart the effects of different EOL scenarios.

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Delft, in the name of her Majesty the Queen

Delft is a middle-sized, typical Dutch city, which shows that it dates back to the Middle Ages. It is also the town of the House of Orange. Prince William I started the 80-year war of independence from here. He also was assassinated here and buried in the 'New Church', which actually dates from the 14th century. After him, all members of the Royal House have been buried here as well.

For me however, Delft is the town of the University of Technology, THE UNIVERSITY.

This is because its contributions to society are based on a combination of technical know-how, science and a mental attitude - the Delft Engineering Mindset. 'University democracy' which came into existence in the Netherlands in the seventies of last century could not jeopardize it and the Delft Mindset is very much alive today. I am really proud to represent its traditions.

The sociology of the seventies did a lot of other damage to universities in the Netherlands and Delft especially has been slow in recovering from it. Even today there is denial that science is basically a meritocracy. Whether you like it or not, that is the way it works. It has to be accepted, the penalty for not doing so is mediocrity.

At Philips Consumer Electronics, I barely survived the drastic and brutal restructuring of the early nineties (see Highlights of the year, 1993). The company with this family flavor and its often inconsistent management almost went broke in the early nineties. This unleashed forces under which some people were simply pulverized or crushed. Almost everybody working for the company got at least a few or more bruises, including me. It was a necessary bloodshed.

Delft was the avenue to a new future. I grasped the opportunity to become a part-time professor in Applied Ecodesign and I got appointed on December 1, 2005.

In the old days - when a professorship was still an office - you were appointed by the Queen with the order to be 'active in you professional area'. Not anymore. Things are now supposed to be more rational, even at a university.

Not for me. I experienced my professorship as highly emotional. At elementary school we learned a song: 'Het is plicht dat iedere jongen voor de onafhankelijkheid van zijn geliefde vaderland zijn beste krachten wijdt' ('It is the duty of every man/boy for the independence of his beloved country that he dedicates the best of his abilities for that'). Although this sounds weird, it represents my emotion in Delft.

It is weird because in this song girls do not exist. Yes, for many Dutch including myself independency is more important than power or wealth, 'beloved' is a supposition at best and at the time of writing of the song there was no awareness of the European Community or mankind as a whole. But most of all it states that you have to work to the best of your abilities. That for me is Delft, and Delft University. Although I have republican inclinations I support this idea, in the name of Her Majesty the Queen. To the best of my abilities!

City walk: Start at the railway station, cross the square and walk into the very narrow street at the opposite side (Barbarasteeg). Go L on Oude Delft till the Old Church. Go R (Oude Kerkstraat) and L (Hypolytusbuurt) and R (Voldersgracht). Go R (Vrouwenregt) and directly R (Kerkstraat). Cross the Grote Markt in a diagonal way to Jacob Gerritstraat, go L, Burgwal, Beestenmarkt, Boterhuisstraat, Go Oosteinde, through the Oostpoort L across the Groene Brug, go R and L and arrive at the Julianabaan.

Keep R, go into the Mijnbouwstraat and R (Michiel de Ruyterweg). Go L below the bridge (do not cross) follow the Kanaalweg. Cross the bridge, go through the tunnel and go over the bridge L and again L to Giststraat. Go R (Lange Geer), L over the bridge Breestraat and back through the Barbarasteeg.

Favorite restaurant: de Kleine Griek, Oude Delft. (has in summer a boat in the canal which acts as a restaurant)

'Country walk': Take tram 1 and ride it all the way to Scheveningen. Go to the beach and walk either north as far as you like (and back) or south and board tram 11 to Hollands Spoor railway station where you can go back to Delft by tram 1 (or by train).

4.6.2. Human power and user centered design

Where Philips kept on hesitating, Delft moved on. A fine piece of work was the design of a human powered remote control. Apart from its environmental and technical success, it moved the spotlight towards another theme: 'user centered design'. Like 'green' this is part of immaterial and emotional value (see chapter 2.2) which makes a product more valuable in the market. As the article below demonstrates, user centered design can be combined in a very natural way with 'green'.

User Centred Ecodesign: Experiences from the Design of a Human-Powered Remote Control

E. Smit, Prof. A.L.N. Stevels, Dr. C Sherwin

Abstract

This paper presents early results from research into the design of Human-powered Remote Control product. This is a collaborative project between the Environmental Competence Centre, Philips Consumer Electronics, Philips Environmental Services at CFT, Philips Electronics and undertaken as a graduate project at the Design for Sustainability group, TUDelft. Previous research has indicated the feasibility of Human-powered technology for small electronic product applications. There are a number of Human-powered products and technologies emerging now on the market. However there are a number of technological, user input options and ways to generate energy that would dramatically alter the product design and interface. Little research has previously considered these more user centred human-powered technology questions, or these more market-related issues in EcoDesign more generally. For examples, what kind of energy generation is acceptable for a particular human-powered devices and how much effort are consumer prepared to input? This paper presents early results from a research project aimed to explore these issues, and also shows a way in which EcoDesign research and methodologies can and should move more from their roots into greener technologies, processes and materials towards market, consumer and user-related issues.

I. Introduction

This paper describes early research findings and the methodology from a graduate student project at the Design for Sustainability program, TU Delft and undertaken as a collaboration with the Environmental Competence Centre, Philips Consumer Electronics and Philips Environmental Services at CFT, Philips Electronics. To begin, an introduction will provide some background information on the project, on human power and on the conception and motivation for the project.

I.1. What is human power?

Human powered energy systems or human power for short, refers to energy generated with the human body. A human powered energy system describes the entire system that makes it possible to transfer the energy of the human body into usable energy for a product. An important distinction for human powered energy systems is the storage of energy, which makes it possible to use this energy instantly or at a later time. This distinguishes them from products such as staplers or bikes, might also be referred to as 'human powered'.

Probably the best-known example of a human powered product is the human powered radio (Figure 1).

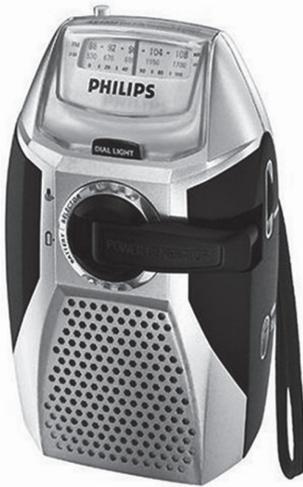


Figure 1 The Freeplay radio

At first the human powered radio was developed by the Freeplay Company for remote areas where electricity or batteries are not available. Encouraged by the good results other companies have since introduced human powered radios – see above.

1.2. Reasons for this project

The last years have seen vast quantities of handheld electronic devices flood the market. Many use batteries as a power source because this is an easy, small and relative high energy density way of powering the product. The main disadvantage of batteries is that they contain a limited amount of energy; meaning they have to be replaced or charged every now and then. The second disadvantage is from an environmental point of view; the batteries have to be collected as chemical waste. When we look for a solution to these problems human power is a possibility. The human body can serve as an inexhaustible, 'green' (environmentally friendly) power source for some of these handheld devices.

Previous research has shown that a remote control is a product for which human power can be a good alternative power source [1] [2] (For more information on human power see: www.humanpower.tudelft.nl). Calculations have shown that introducing human power into a remote control can save up to 0.5 mPt per product [4]. This means that if the human powered remote control would penetrate 10% of the market a profit of 50 Pt per year could be reached [3].

While there are several technical details to be 'ironed out' before human powered technology becomes completely viable, what is increasingly clear is that the key problems are not technological at all. In fact the key obstacles to the uptake of human powered products are cultural – in that perceptions of human powered technology and products conjure up images of returning to the 'dark-ages', of lack of progress or of 'hardship culture'. So, is it possible to make human powered technology attractive and acceptable to users? And following this, which combinations of energy generation and product design and interface are accepted by which consumers?

1.3. Project description

Building on previous research into human-powered products at Philips Electronics, resulting in the Philips AE1000 human-powered radio, the goal of this project was to design a human powered remote control that is aligned with customer needs and expectations. Because of the innovative character of the product, and quite specific uses of remote controls it is important to know what the customer wants from this, otherwise it will never be accepted. In attempting to answer these complex research and design questions, the project draws on both issues of traditional EcoDesign as well as from areas more usually from the marketing domain.

2. Designing from the Environment - Ecodesign

EcoDesign is a relatively new design phenomenon of some 10 or at most 20 years old.

Whilst its details are still emerging, we do know perhaps two key concepts about its theory and practice. For the theory side – there are more than one ways to approach designing for the environment, with Brezet [5] describing a 3-step approach of:

- Product improvement: existing products (material or technology) are improved and impacts are reduced.
- Functional innovation: the function or service (cars=mobility) is delivered in new, innovative ways (from letter to email). New concepts result.
- Systems innovation: the system (not the product) is optimised across traditional business and sector boundaries (transport system not cars). New business results.

Practice and companies tend to be at stage 1, product improvement or EcoDesign [6]. This is largely based on incremental improvements to existing products and is most often based on Life Cycle thinking or Life Cycle Analysis.

What EcoDesign and LCA, etc., can do is highlight a products main impacts. What it cannot do is answer much more complex questions about user behaviour or consumer acceptance of certain technologies. In short, EcoDesign methods are not sufficiently adequate for the problems of human-powered technology and products. If you really want to know about the acceptability of human powered technology, why not just ask consumers?

3. User Centred Design

As mentioned in section 1.2 it is important to know what the user expectations and needs are when designing a product. If a product is designed without this knowledge there is a possibility that the product will never be accepted and its introduction will be a disaster. Getting familiarized with the user expectations and needs is especially essential for innovative products that are never before used by customers. In such a case the designer cannot fall back on their experience with designing similar products, so other information sources are required.

Information can be collected in a number of ways and most of these methods can be summarized as 'user centred design'. Central questions in user centred design are:

- What does the user want?
- Why does the user want this?
- What does the user expect?

3.1. User-research methods

There is a lot literature on user centred design that it is not possible to introduce in this paper. (For more information see references Presence [7], and Empathic Design tool [8]) The decision on what method to use is mostly based on what results the designers want. Some examples of well-known methods are discussed below with the possible results.

- Usability testing: Testing usability involves observing and questioning sample users as they use past or planned products in typical daily situations. Typical results for this method are data on acceptability, adjustability, ease of use and dimensional compatibility. [9]
- Scenarios: Constructing stories can help design teams project forward to design concepts from an understanding of people's present experience. They help prevent professionals making assumptions based on their own, limited experience. [7]
- Questionnaire: These are broadly focused, quantitative surveys of people's attitudes and behaviours asked through a number of different media to find general opinions at a point in time. Surveys are most often used for mass interest events, like elections. [8]

3.2. Use of model

A lot of the user centred design methods use some sort of model of the product to explain to the user what the product is about. These help visually and materially describe the usage and appearance to the user. Again there

are a number of possibilities on what sort of design model to use. Rooden [10] concludes that each modelling effort may yield equally useful information for usage-centred design.

3.3. Targeting specific group

Because people are diverse it is almost impossible to design a product for all. Products designed for all are most of the time products full of compromises meaning the product does not attract anyone. A solution to these problems is market segmentation.

Kotler [11] describes market segmentation as:

“dividing the market into different groups of buyers with different wishes, characters or behaviours who might need different products or marketing mixes”. (Translated from Dutch text)

Kotler [11] also describes three advantages of market segmentation:

- A company can market more efficiently by focusing their products or services, channels and communication on those customers who can then be served best.
- A company can market more efficiently by adjusting the prices and programs to the needs of the carefully defined segments
- A company has less competition, if less competitors focus on a specific segment.

Almost all the larger companies already have market segmentation tools available. The data in these tools is specific for the products, markets and the geographic location of the company. Philips has developed its own market segmentation tool in cooperation with RISC International [12]. In this tool the market is segmented into five specific focus groups – which can be quite unique and different. The tool gives extensive details of the values, beliefs, lifestyles, purchasing patterns, product and visual preferences for each of these groups. It is intended for use in new products, concept and marketing development to ensure that new business matches the expectancies of an increasingly diverse, but demanding group of consumers. This tool also describes the focus groups Philips wants to target and which not. In providing extensive data on users and market segmentations, these market segmentation tools can be invaluable for design.

Somewhere between EcoDesign (in this case human powered technology), user centred design and market segmentation methods lies the key to this research task and to designing acceptable and desirable human powered energy products. We call this ‘user centred EcoDesign’.

4. Human Powered Remote Control Concept

A good way to explore this issue of user centred EcoDesign is via the methodology used in this human-powered remote control project. At first the research questions will be introduced, followed by the method, the type of models and the user groups – which brings together all the 3 design spheres described above.

4.1. Research questions

There are a number of ways to generate and input human powered energy (turn handle, push button, spin wheel, etc) for a remote control system and a number of ways to embody that within the product design and architecture. This project aimed to provide insight into which human powered energy generation methods were most relevant and attractive to certain users. Specific research questions were:

1. How do people interact with the human powered remote control with the emphasis on problems with usability?
2. Which human powered remote control concepts do the users accept and for what reason?
3. Are the input forces accepted? The amount of energy generated by the consumer depends on a few parameters one of these is the input force of the interaction.
4. Do specific user groups better accept some concepts than others?

5. The Methodology

The project would be completed over 9 months and result in a concept proposal for a human-powered remote control that would match and be acceptable to certain users needs. The following project stages were defined:

1. Define energy generation/input concepts
2. Design concepts and build models to embody the energy generations
3. Test with users and identify user groups
4. Conduct interviews
5. Analyse data and select best concepts from results
6. Refine and further develop concepts from results.
7. Test again with users
8. Select best concept and develop into concept proposal

As the research is on going, this paper reports on progress to date – chiefly stages 1-6.

5.1. Defining the energy generation and input

The first stage was to brainstorm on the possibilities of human powered energy generations for a remote control system. These refined and amalgamated into 13 key concepts, which were then recreated as models for the following user tests.

5.2. The design models

As discussed in section 3.2 Rooden [10] has researched design models and set-up guidelines for designing models for user tests. Two conclusions were:

1. **Show changes in appearance during the interaction:** Information about manipulation is difficult to verbalise. When the manipulation is an important part of the interaction, full-scaled models should be considered. For this reason full-scaled models were used in the human powered remote control project (Figure 2).
2. **Stimulate manipulation:** The interaction is made more lifelike if the changes are made visible (most important for drawings). For this reason all the energy input interactions of the concepts were possible to manipulate.

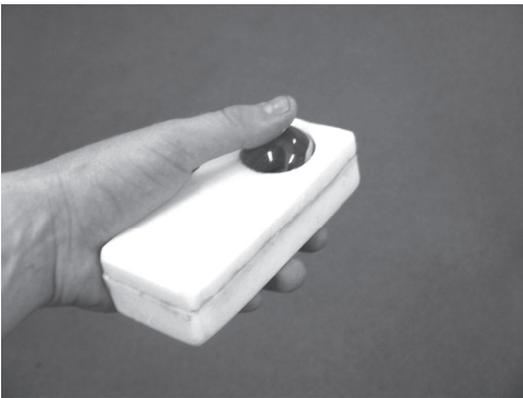


Figure 2 Design model of a concept

5.3. Testing with users

The first part of the user test was aimed at finding out to what user group the participant belonged. For this part the Philips allocation tool – part of the Philips market segmentation tool (RISC [12]) was used.

5.4. User groups

As mentioned in section 3.3, Philips has developed its own marketing tool especially for audio and video equipment. This was used in the human powered remote control concept. During the user test the participants were allocated into one of the focus groups. These results were used for further analyses later and to target specific groups.

5.5. Conducting the interviews

Next the human powered energy generation models were introduced to users via a series of 30 minute (approx.) interviews. Various products were shown to make the participants aware of the possibilities of human power. After this all the models were shown to the participants and the users could hold and manipulate the models. For all of the models a few questions were asked:

- What is your general opinion for each concept? (What do you think? How would you use this? Etc.)
- What is your opinion on the input force? (Too hard? Etc.)
- Do you want an alternative input force? (Would you like more or less input power if you consider the effect on the usage time, this is interesting to know for further development of the concepts)

At the end the participants were asked to divide the design models in three groups; wanted, neutral or not wanted. This way it was possible to determine which models were accepted.

All tests were taped on a digital video camera to make it possible to analyse the tests at a later stage. The user tests were held in different locations, this to minimize travel time for the participants. The setup of the room was the same in all locations. A corner of a table was used for the interview (Figure 3.).

On the short side of the table the participant took place and on the long side the interviewer. The camera filmed this corner of the table. This way the entire "working area" of the participant was taped.



Figure 3 User test location

This user test is a combination of different user centred design methods. A problem with new products can be that participants of the user test think that it is not possible to make such a product. As a result of this they do not take the test serious and the data will not be useful. A solution to this problem can be educating your participants; show them that it is possible to design such a product.

Asking your participants to suggest changes (in this project the input force) is a form of co-design. Participants get the possibility to change the product to their own opinion. This data can be used to improve the concepts.

This part is analysed by using video ethnography; all tests are taped on digital video and the tapes are analysed at a later stage. The results of these methods are data on acceptability, adjustability, ease of use and dimensional compatibility. [9]

The human powered remote control project used a meta-method, where the user centred methods are combined into one - making it possible to combine methods until you can find the results wanted for the project.

6. Results

The data gathered in the human powered remote control concept was analysed in a few ways – all with the purpose of concluding on certain concepts and further developing those most promising (the current project status at time of writing). The opinions of the participants on which concepts were accepted and rejected were processed into a table. This table showed which concepts were accepted (+), neutral (0) and rejected (-) by all the participants (table 1).

In combination with the data from the segmentation tool it was possible to crosscheck and determine which concepts the Philips target user groups accepted individually and which concepts combinations of Philips target user groups liked.

Table 1 Sample of the results table

PP	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Participant 1	+	-	+	-	+	+
Participant 2	-	-	+	0	0	0
Participant 3	+	0	+	+	-	+
Total yes	2	0	3	1	1	2
Total Neutral	0	1	0	1	1	1
Total No	1	2	0	1	1	0

All the videotapes were analysed and summarised into tables also. These tables showed data on problems, suggestions and remarks of the participants. Some concepts had small problems and comments meant these could be easily refined and improved. Other concepts were just not good enough.

When this data was combined with the other two tables it was possible to determine which concepts were accepted and which were rejected. From the thirteen concepts that entered the user test six were accepted. These concepts will be further developed in the next months. Topics to be discussed will be the environmental impact of the concepts, manufacturing, existing patents, costs, etc. The best three concepts will be developed into semi-working models, which will be used in another user test. The result of this project will be a human powered remote control that is:

- Accepted by the user
- More environmental friendly.
- Fits in the Philips product line and target audience.

7. Conclusions

It is always difficult to design a new product and make sure the user accepts it. Designing will always be a speculative task, decisions will have to be made not only on scientific data but also on the designers experience and knowledge. This level of difficulty is increased with a relatively young design discipline such as EcoDesign, and the difficulty is doubled when dealing with 'new' technology and concept applications such as human power energy generation. This paper shows that 'user centred EcoDesign' can be a solution and can offer a series of suitable methods.

For Philips, this project offers a promising new product application for a technology that it can and should invest more in for the future. It also offers new, more visible ways to articulate the company's 'green' credentials and promote the sustainability of the Philips brand via the most powerful way to do that – the product.

There are further implications for EcoDesign. This project moves EcoDesign theory and practice from its comfortable roots in materials science and technology, towards a more marketing, user and consumer-related arena. When you do this, traditional EcoDesign methods and models are less appropriate and new methods, approaches and models are necessary - for example, can LCA ever tell us anything about users? Indeed, these issues of behaviour, acceptance and desirability can rarely be found in EcoDesign literature. In another way, the methodology used here brings EcoDesign more into the 21st century – where products are not 'sold' on their technical specifications, but on immaterial qualities such as brand, styling or appearance. In this new arena, the questions are less so

what is technically possible and more so what is socially acceptable and culturally desirable. More than anything else – these are questions for designers generally, and for 'user centred EcoDesign' specifically.

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Pictures, 6

Delft, Disassembly Session



4.6.3 The significance of human powered products

A lot of experiences with human powered products were consolidated in the paper below. The applications shown here indicate the wide range of energy generating mechanisms which can be applied. The variety of functionalities for which human power can play a role is apparent as well.

It is concluded in this article that human powered products have a special significance in Applied EcoDesign. Their psychological significance gives the consumer a feeling of empowerment and freedom. Their environmental contribution is their ability to reduce the consumption of batteries and, to a lesser extent, energy saving. But most of all human powered products are the token of a mindset. Grasp the opportunities and have fun!

Human Power, a Sustainable Option for Electronics

A.J. Jansen, A.L.N. Stevels

Abstract

The decreasing power requirements of consumer electronics combined with an increasing environmental mindedness of consumers and the increasing use of portable electronic products has set the opportunities for human power as a viable alternative to batteries. No use of batteries means an environmental benefit as well as a consumer benefit. It will lead to new product concepts offering real portable products that can be used anytime and anywhere.

I. Introduction

The research into human powered energy systems is one of the PhD projects within the DfS (design for sustainability) research program at the sub-faculty of Industrial Design Engineering at DUT, it started in 1997 and is due to be finalised in the year 2000. The main research question is: For what products and how can human power be a viable alternative to batteries in portable consumer products? The research will explore into ergonomic, mechatronic and environmental issues of human powered energy systems in consumer products.

It is taken as an example because its functionality has not really changed in all these years. The limit in power consumption will be determined by the amount of energy used by the mechanical parts of the Walkman®.

II. Relevant developments

In the last years we can see an increasing amount of handheld electronic devices (GPS, cellular phones, palmtop computers), increasing mobility, and need for communication and information. Also the percentage of products fully based on electronics is rising. For obvious reasons, the majority of these portable products is powered by (rechargeable) batteries; batteries are small, light and have a relative high energy density. The number of batteries, sold throughout the world is steadily growing. In 1996, in the Netherlands only, 1 10 million primary batteries have been sold (a 3400 miles chain, twice the distance between Boston and Denver!).

One other relevant development is the decreasing power consumption of portable consumer electronics. An example is given in fig. 1, it shows the decreasing power consumption during play mode of different types Sony Walkman® during 16 years [1].

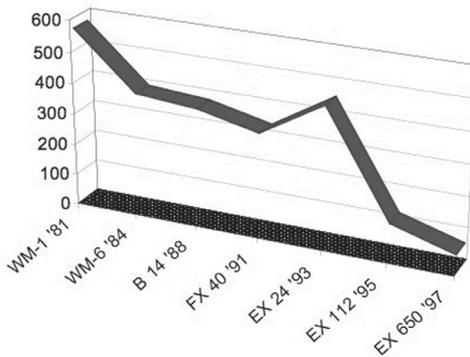


Figure 1 Power consumption Walkman® during play mode

III. Why replace batteries by human power?

Besides their plus points (small, high energy density, freely available, standardised), batteries also have disadvantages. The first one is given by the fact that primary batteries contain a restricted amount of energy resulting in a limited life time. So, they have to be replaced regularly (a fact of life is that this always happens when you need the product most). Also without using the product, batteries slowly discharge. Replacing batteries means discomfort for the consumer (costs, inconvenience).

The second disadvantage is from an environmental point of view. Empty batteries have to be discarded in an environmental sound way; they have to be returned to the shop or collected as chemical waste. In 1996 in the Netherlands (having a battery take back system), only 54% of the batteries was returned in one way or another [2]. In many countries the collection system for empty batteries is not as organised and therefore many batteries will end up at the land fill or be scattered in the environment.

IV. Human power

As shown in table I, the human body acts as an energy producer in different ways.

Table 1 Energy production by the human body

Energy source	Forms of energy			
	Mechan	Electric	Thermal	Chemical
Muscles (active)	x			
Movement (pass.)	x			
Skin potential		x		
Perspiration				x
Body heat			x	

In the human power project we concentrate on the active use of the muscles. The amount of energy obtained from the human body depends on which body segments are used, the physical and mental condition the user and the design of the interface between the user and the generator. For short term tasks (up to 2 minutes) a number of specific measurements [TUD] is presented below.

Table 2 Measurements of required human power for various tasks

Description of task	Required human power
Pushing button with thumb (as with ballpoint)	0,3 Watt
Squeeze hand generator (Alladin power, Fig. 3)	6 Watt
Turn handle on BayGen Freeplay radio	21 Watt
Ride bike at 25 km/h	100 Watt

Data from literature in most cases focuses on the maximum force applied by users. We estimated the human power potential by using the maximum force exerted by an average male user in-between 20 and 30 years of age. The generated power for very short periods is given in Table 3.[3].

Table 3 Estimations for maximum power

Description of movement	Maximum human power
Push (16 N x 40 mm)	0,64 Watt
Squeeze (400 N x 30 mm)	12 Watt
Rotate crank or handle (30 N x radius 100 mm x $1,5 \times 2\pi$)	28 Watt

In a recently started ergonomical research project we will chart the potential of the human body as an energy generator, related to perceived comfort.

V. Power consumption of portable consumer electronics

At DUT a number of recent measurements of the power consumption of portable consumer electronics have been collected, it is presented in the next table.

The power consumption represents the average power consumption during use. A first comparison between the figures from table 2 and 4 already shows the possibilities for human power. This will be described in the next paragraph.

Table 4 Measurements of power consumption

Product	Power consumption
Small portable FM radio [4]	30 mWatt
Walkman (play mode) [1]	60 mWatt
TV remote	100 mWatt
Cell phone (talk /stand-by) [5]	2 W / 35mWatt
Electric torch (flashlight)	4 Watt
Video 8 (no LCD screen) [6]	6 Watt
Laptop computer Tecra 8000	10 Watt
TV (53/67/wide screen) [6]	50 / 74 / 111 Watt

VI. Human powered products

Combining the data from the previous two paragraphs will result in a number of opportunities for human powered products, as presented in Fig. 2. We assumed a 40% efficiency for the human powered energy system.

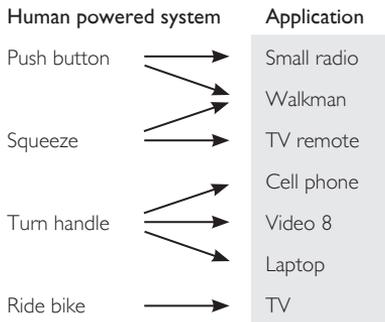


Figure 2 Opportunities for human powered products

The combinations presented in Fig. 2 will give a direction for projects in the near future. In these projects, the concept of human power will replace power systems of existing products, but also lead to totally new product concepts, combining an improved environmental profile and convenience for the consumer.

A good example is the design of a car remote control using alternative power. This project is now conducted at Volvo Car Company near Goteborg in Sweden. The main reasons for Volvo to investigate the possibilities of human power are environmental concern and the current discomfort of batteries experienced by the user. The new remote control will feature an improved quality and environmental profile during its life cycle.

The analysis of existing human powered products learned there still is room for improvement. From the analysis of the BayGen radio, we found an overall efficiency of 26% for the human powered energy system and a high environmental impact of the human powered energy system in the production phase of the life cycle. Compared to radios powered with primary batteries, the average environmental 'return on investment time' of the human powered energy system was over 2 years [4].



Figure 3 Aladdin power by Nissho engineering Co.

One of the human powered products, now available on the market is the Aladdin power (Fig 3). When squeezing at 90 Hz, the output power will be approximately 1,6 Watt, sufficient for some cellular phones.



Figure 4 Interactive storyteller and bedside projector, Philips Design and Olivetti Italy

The interactive storyteller and bedside projector are results from the combined Philips and Olivetti project called Vision of the Future. One of the ideas was that children should have just as much pleasure winding up their toys as when they are watching the projected images.



Figure 5 Wind-up shaver by MOY concept and design

VII. Discussion

Human power offers a range of opportunities as presented in Fig. 2, in this figure the main directions for the application of human power were identified. These directions will be explored in projects by Delft University of Technology in corporation with industry, as in the mentioned Volvo project.

From the analysis of existing products we conclude that human power also provides challenges to industry; improve on energy conversion techniques in order to achieve a higher efficiency and find ways to produce human powered energy system with less pollution.

Green marketing will have to emphasise the environmental advantages of human powered energy systems. Designers will have to take away existing prejudices against human powered products by strengthening the fun factor in these products.

"Human power is green, it's fun and it can be done".

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Highlights of the year, 1999**Stanford, the Value Chain**

I had been working for several years with Catherine Rose, a PhD candidate at Stanford University. Her subject was to make a model through which the most suitable end-of-life strategy for products can be derived (see chapter 7.2).

This cooperation developed into a visiting professorship at Stanford in the fall of 1999. The agreement was that I would do a training course on Ecodesign, support Catherine and work with the crew from the Manufacturing Modeling Lab (MML). Philips Electronics, agreed to the plan, provided that I do some work for them during this period. Additionally they required that I use the holidays I had accumulated over the years for this visiting professorship. Delft University (for which the employment formula was that I was made 'available by Philips to them' for two days in the week) opposed the visiting professorship. I had organized it in such a way that all my obligations at Delft could be fulfilled as well. After fruitless discussions with the Dean I simply went to California, expecting the worst. Nothing happened, apparently it had all been theatre.

Stanford was inspiring and it was fun. A major insight for me turned out to be the value chain concept. We quickly applied it to environmental issues (see chapter 5.1). Apart from the 'green' TV case the concept also proved valuable in analyzing take-back and recycling systems (see chapter 8.1) and thus became effective for negotiating take back agendas with other actors.

The most interesting result was however, obtained by applying the value chain concept to Catherine's work. So far this had been something very technical. The optimum strategy was supposed to be related to a combination of product characteristics, product life and to speed technology development. It turned out that in many cases the recommended strategy was not implemented in practice, which was very puzzling. With this problem still outstanding the PhD work could be brought to a logical conclusion. Including value chain considerations provided a way out. For cases where there is a misfit between recommendation and implementation, there is at least one player in the chain which does not benefit (or even suffers) from following up on the best strategy. In such circumstances improving the technicalities will be of little help; active value chain management has to solve the problem.

Final conclusion: for doing the best job for the environment, technicalities are a necessary but insufficient condition for success.

After this breakthrough, Catherine could finalize her work. She came to Delft to write her dissertation and some other publications on the subject.

Her successful defense was held on October 25th, 2000!

4.7 Environment and Sustainability

In the new millennium, environmental activities were placed within a much wider perspective. Environment and EcoDesign became only one of the dimensions of sustainability. Social responsibility and economic responsibility became important sustainability themes as well. This is summarized in the following scheme:

Table 4.1 The 3 Dimensions of sustainability

Economic Dimension	Commitment to customers: employees, shareholders, suppliers, business, partners
	Business integrity: honesty, transparency, fairness
Environmental Dimension	Products: Reduction of energy, weight, packaging, substances, increase recyclability
	Production: Reduction of energy, water, auxiliary materials
Social Dimension	Listening to stakeholders: politics, consumer groups, generic public, labor unions, universities
	Employees: employment/careers diversity and inclusion (gender, regional origin of executives)

This figure shows that the content of the environmental dimension remains unchanged; it is about products (EcoDesign) and production (processes). The dimension of economic responsibility includes 'commitment' (to all stakeholders) and 'integrity'. The social dimension is represented by 'listening' (taking into account views from stakeholders) and 'care for employees'.

My involvement in sustainability kept its focus on the environmental issues. Therefore my adventures in the wider sustainability field were very limited, so in this book little is to be told about it. The best reference to find out more about sustainability in general at Philips is: www.philips.com/sustainability.

For sustainability planning and performance measurement I have been involved in an indirect way; I had developed the methods to do so for the environmental part and these had already been implemented in the organization. After a period of short research and some experiments it turned out that exactly the same approach could be applied in the economic and the social dimension ('mutatis mutandis' of course).

Since methods for planning and performance measurements inside companies are proprietary, little information about the methods applied for sustainability can be communicated here.

In the short paper on the next page "*Managing Sustainability in Electronic Companies*", the general principles are described including environmental dimension only.

Managing Sustainability in Electronic Companies

Ab Stevels and Casper Boks

Abstract

In this paper a systematic approach to manage sustainability in electronics companies is described. The systematics for the environmental part have already been fully developed; it is shown that health and safety aspects and social issues can be simply introduced in the same schemes. The corner stone for operationalization are roadmaps which are partly based on corporate programs and targets but also are partly tailored to specific business circumstances and product characteristics of individual Business Creation Units. Progress in roadmap realization is measured by an Environmental Key Performance Indicator (EKPI). With help of an example it will be demonstrated how EKPI helps to integrate Environment in a business concept and how it contributes to improving performance.

I. Introduction

In the last years the meaning of the word "Sustainability" has substantially widened. Being focused on environmental issues as emissions, resources and potential toxicity, a couple of years ago, it now includes health and safety issues and social issues as well.

Managing sustainability in Electronic Companies has therefore to be put into a much wider context. An integrated approach can be structured as follows:

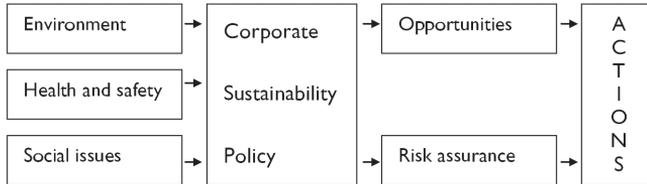


Figure 1 Integrated approach of Sustainability.

This figure shows that health and safety and social issues can be basically addressed in the same way as has been done so far for environmental issues. This also holds for integration of sustainability in its new meaning in the business as a whole. To do so, important lessons can be learnt from what happened to environment and Eco Design in the electronic industry in the last ten years.

Primarily environment and EcoDesign were seen as technical issues which made that as regards implementation engineers in the factories (for production) and designers in product development (for products) were seen as the key. It was realized in proactive companies that this is by far not good enough to make it really happen and that close attention should be paid to:

- Creating awareness
- Analysis of enablers and drivers of green (the "why this")
- Formulating strategies, organization/definition of responsibilities, defining programs, roadmaps and formulating requirements (the "what items")
- Detailing and embedding the execution: systematic idea generation, specifications and targets, environmental validation and exploitation in the market (the "how items").

By now this comprehensive approach has been formulated in for instance the ISO 14062 report, based on ideas a.o. formulated in ref. 1.

When addressing health and safety and social issues much time can be gained when bringing them to high maturity and assurance levels by leapfrogging the developments which took place in the environmental field and go for a comprehensive approach directly. This will be helpful to bring all three sustainability items into so-called Business Excellence models which are currently applied in industry to gain and audit progress and to create a basis for incentive schemes for senior managers.

Such models look as follows:

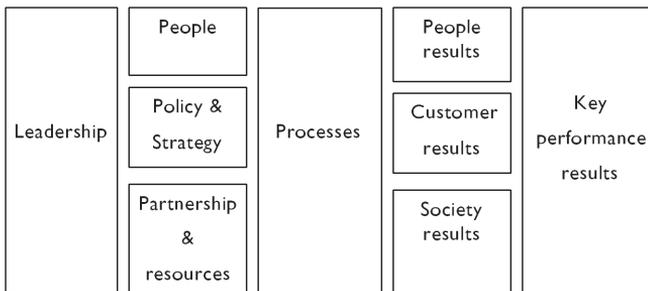


Figure 2 A Business Excellence model.

In the business excellence model presented above, sustainability is to be located in the box society results. In order to score well here, it has to be addressed in left hand boxes like leadership, people, policy & strategy and partnership/resources and be well integrated into all management processes.

In proactive electronic companies like Philips, Sony and others sofar the environmental issue has been fully developed to a mature part of the business excellence approach. How this looks like and what results have been scored will be discussed in this paper, particularly based on the experiences of the author in his capacity as Senior Advisor at the Environmental Competence Centre of Philips Consumer Electronics.

It is to be noted that the model for managing environment (and to be extended to sustainability) presented here represents the result of a development which started as bottom-up approach in the form of execution of technical projects. Subsequently awareness has been created, the first "what" items have been added (strategy, organization), than execution has been deepened, drivers and enablers have been identified and finally programs, roadmaps and requirements have been defined. In this paper particularly to last-named two items attention will be paid to.

2. Environment as part of vision, policy and strategy

Environment can be easily integrated into a companies vision and strategy by hooking up to the usual procedures for this purpose and simply adding "environmental paragraphs" (or extending to "Sustainable paragraphs") to current analyses. This is defined in the picture below.

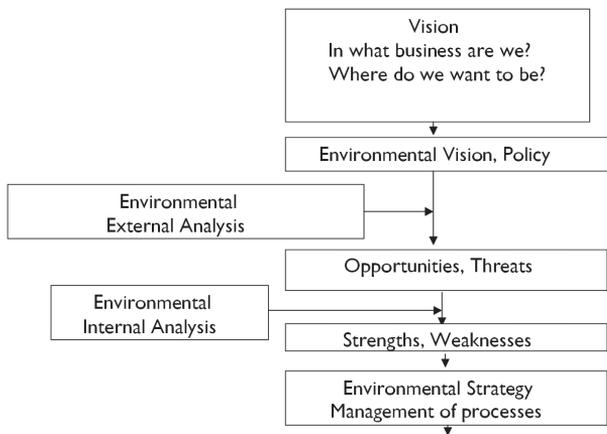


Figure 3 Environment as part of vision and strategy

An example of an environmental vision is given in the box below.

Example of Environmental Vision

Philips shall be the leading eco-efficient company in lighting and electronics industry

Background

- Good for the environment (more sustainable)
- Company value (enhances brand image)
- Customer benefit
- Pro-active to the society (it can be done)

Box 1 Example of Environmental Vision

The basic principles for implementation and execution can be formulated in an Environmental Principal as for instance in the box below.

Example of Environmental Principles

Sustainable development – finding optical balance between ecological impact and environmental growth
 Prevention is better than cure – from raw materials to manufacturing, to use and disposal
 Cooperation – with governmental and non governmental organizations.

Box 2 Example of Environmental Principles

The operationalization can be given further 'hand and feet' by adding an implementation policy, see box below.

Example of Implementation Policy

Set technically and economically viable objectives to optimize environmental performance
 Products should be evaluated as regards their total life cycle creating a basis for more efficient use of materials, including packaging, reducing energy consumption, reducing or eliminating potentially toxic substances and improving recycling and disposal
 Manufacturing should address consumption of utilities and auxiliary materials and business to air and water and the reduction of waste
 Establishment and maintenance of environmental management systems and of audits of these systems
 Compliance with all laws, regulations and voluntary agreements.
 Communication of policies and performance to various audiences and publishing of results in environmental reports.
 Education and training of employees in the environmental field.

*Box 3 Example of Implementation Policy***3. Environmental Roadmaps, general items**

Roadmaps basically describe where a company is currently situated as regards a certain issue and describes how progress should develop for instance 5 years time. From this perspective it contains issues, owners (the persons responsible to move the subject forward) and targets, for instance formulated on a year to year basis.

Positioning of companies in the environmental field should preferably done on a relative scale (for instance with respect to competition).

A procedure to do so is for, are described in refs 2 and 3; key element is that performance is described in tangible physical units well recognized throughout the organization (W, kg, sec, %, ..) instead of environmental language (ecodicators, lifecycle profiles) and that environmental issues are addressed which are in the scope of influence of the company ('internal' versus holistic perspective). This technical analysis should be combined with a thorough analysis of development taking place in the outside world. These include:

- Awareness, interests of the customers (private, OEM's)
- Development of labeling schemes
- Legal/regulatory requirements
- Development in management systems, environmental tools, environmental services / consultants, recyclers) and auditing.
- Developments in technology en in the Information society
- Strategies of competition

Roadmaps can be written on various levels. In practice it is useful to make a distinction between:

- Corporate roadmaps (chiefly strategy and program oriented)
- Product Division roadmaps (chiefly business oriented)
- Business Unit roadmaps (oriented chiefly towards products, manufacturing and deployment)

Practical experience has learnt that for operational purposes it is useful to organize the roadmap items into three parts: the defensive (compliance) related ones, the cost driven (reduction) items and the proactive actions (aiming

at gaining market share on the basis of green). Similarly strategy items organizational items, technical items and items related to green marketing and communication should be clearly distinguished.

4. Environmental Roadmaps, content

On basis of the principles for environmental management (2) and for roadmaps in general (3) it is now possible to formulate the specific context of the roadmap chapters.

Chapter 1 is about strategy, specifically about the availability and implementation of policies, programs and roadmaps and their updates. Particularly regular strength and weakness analysis and performance measurement (see 5) is to be addressed as well.

Chapter 2 is the business chapter. There is the planning of "green" products (significantly better than the competition), availability of evidence for "green performance", scores in the field of cost reduction and evidence of legal compliance is relevant.

Chapter 3 is the product chapter. Here tangible improvement targets are formulated in for instance a focal area approach:

- Energy consumption
- Materials application
- Packaging and transport
- Environmentally relevant substances
- Durability, recycling

Chapter 4 is the manufacturing chapter. The two parts are here: reduction of consumption (of energy, water, solvents, auxiliary materials), reduction of emissions (to air and water) and waste.

Chapter 5 is specifically about programs. This can include items ranging from generic programs like the introduction of ISO 14001 management systems to specific ones (approaches for green marketing and communication) or targeted ones (like for reduction of manufacturing, office energy or for packaging reduction)

A different form of a program is the consolidation of roadmaps of lower discussions or BU levels into a corporate program (example: the Philips EcoVision program)

Chapter 6 is about organization and deployment. This includes status of responsibilities, hiring of skills and budget performance of environmental activities. Included in this chapter are also internal communication and training issues.

5. An Environmental Key Performance Indicator

Progress in key performance realization can be measured with help of an Environmental Key Performance Indicator. At Philips Consumer Electronics EKPI is defined as follows:

$$EKPI (\%) = \sum A_i * \text{score per item.}$$

In this formula A_i is the weight of importance of roadmap item i . The sum of all A 's totals to 100%.

The score per item can be:

Either 1 = OK = "green"

Or 0,5 = more or less fulfilled = yellow"

Or 0 = not fulfilled = "red"

Values for A_i are to be set dependent on product characteristics (relative importance of the different focal area's and of manufacturing), the status of environment in the business (starting/mature, behaviour of competition, customer interest, etc.) and on legislation/regulations. By tailoring in this way to environmental impact profiles and to needs, a maximum relevance of the EKPI is ensured. The calculated percentages (on a 0-100% scale) allow to set overall targets allowing flexibility to the business concerned in how to improve the score.

The mapping of the score items in green, yellow and red allows to identify in one glance where the weak spots are located and to go for focused action. Initially the EKPI of the various business units inside Philips Consumer Electronics showed a big diversity in scores, see the table below where a anonymized sample of results are presented.

Table 1 Environmental key performance indicator scores of various groups at Philips CE

Score	Projected score Target		
	Beginning 2001	End of 2002	1/1/2004
Group 1	56	75	80
Group 2	32	62	75
Group 3	37	51	70
Group 4	55	69	80
Group 5	76	75	75
Average	51	66	76

At the start of EKPI in the beginning of 2001 scores in the Division were ranging between 30% and 70% (average 51%). In 2 years time – by making the issue visible and by targeted actions – the spread has narrowed from 44 to 24% while the average has moved up to 66%. A further increase of the score to score 75% is expected by 1/1/2004.

For correct implementation it is to be realized that roadmap targets are moving targets. In fact therefore EKPI shows how well the set targets are followed. The example above shows that in 2001 some groups were still not to full grips of the comprehensive target system, will be pretty well in control by the end of 2002 and will be capable to follow-up on the ambitious targets in the year to come. This performance is the result of active management by Environmental Steering Committees at Business Creation Units and Product Division level through the well known Plan-Do-Check-Act circle.

6. Conclusion

Leading Electronic companies and Philips Consumer Electronics in particular, have in the last years done substantial effort to come to comprehensive and consistent environmental systems which are integrated in overall business models. Following items have been crucial in achieving success:

- Positioning of Sustainability in the box "society results" of an overall business model
- Developing of a vision, of principles and an implementation policy.
- Availability of deployed roadmaps (based on benchmarks) giving clear targets and owners
- Availability of a weighted Key Performance Indicator allowing proper management of outstanding issues.

The concept described above can be easily put into a wider sustainability approach which includes Health and Safety and Social issues. Consolidating the current scattered initiatives into similar systematics as developed for environment and expanding them full which will be an important task in the years to come.

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Is there environmental justice in the world?

Very early on in the Nineties Philips Consumer Electronics managed to eliminate flame retardants from the housings of TVs and other electronic products.

This was realized through 'design for thermal balance', that is, by avoiding "hot spots" inside products. In this way elimination of the retardants was achieved while staying well inside the requirements for product safety.

We were praised for such initiatives from NGOs like Greenpeace and Friends of the Earth because traditional flame retardant plastics contain substances like brominated organics and antimony. Both of these substances rank very high on lists of potentially toxic materials or even outright hazardous materials.

The elimination of flame retardants also added to the recyclability of the products; so called monomaterial plastics without additives recycle well.

However, happiness did not last long. TVs without flame retardants were suggested to be more unsafe than those with retardants. Statistics emerged that asserted that the self ignition of TVs in Europe was more frequent than in the USA, and there were even twisted environmental calculations suggesting that TVs with flame retardants were worse for the environment. Then there was the film showing that a burning candle placed on top of a TV without a candlestick can easily set it afire, if there were no flame retardants in the housing. Suddenly letters started to arrive at Philips asking questions about the issue. It all gave the impression of a well orchestrated campaign against Philips. Our products also made it to the front page of the most popular daily newspaper in the Netherlands: Japanese products have more fire safety. The CEO of the company called us and asked, what are you bloody environmentalists doing? Product managers got nervous – emails began flowing in and out. The NGOs kept silent, apparently there were no points to be scored for them anymore.

We had to give in. Flame retardants were reintroduced, but not of the bromine/antimony type. It had to be acknowledged that perceived safety prevails over the environment in peoples minds. Publicity effectively hit that nerve and the environment suffered as a result.

Where is environmental justice in this world?

Ph.D. Students

Working with Ph.D. students is for me the best part of the tasks which a professor is supposed to do. Exploring new territory, discussing conjectures, trying to keep logic in reasoning, the joy of discovery, the hard work in writing, being sparring partners, the expected and unexpected creativity, ... it is all there. It has been a deep sense of fulfillment and I owe all these young folks a lot.

I had four full time Ph.D.'s at Delft University :

**Casper Boks, Ph.D. on April 15, 2002*

**Jaco Huisman, Ph.D. on June 20, 2003*

**Oriol Pascual, Ph.D. in 2008*

**Renee Wever, Ph.D. in 2009*

One Ph.D. student did her thesis in cooperation with Prof Jacqueline Cramer of Erasmus University (Rotterdam): Nicole van Nes got her degree on June 6, 2003.

There have been two "external" Ph.D. students as well. This means that they combine a regular job with Ph.D. research. This is tough, but they managed to do it and did it with glory. Respectfully to be mentioned are:

**Menno Nagel, Ph.D. on September 18, 2001*

**Otmar Deubzer, Ph.D. on January 30, 2007*

Catherine Rose got her Ph.D. at Stanford University in the USA; together with Prof Kos Ishii I was her supervisor. On October 25, 2000 she did a succesfull defense of her thesis.

Through their research all these folks have been contributing substantially to this book and I would like to thank them for that. Evenmore, I would like to thank them for their trust, patience, endurance and most of all friendship.

What I like to do very much as well is being a member of the Ph.D. committee of candidates of colleagues. This means that there is a short time only to get acquainted with their research subject. This should allow to make contributions to the evaluation report but also to ask questions which lead to interesting discussion at the defense of the thesis itself.

This is great sports! Thank you Troels Kjeldmann and Claus Pedersen (TU Denmark), Bernadete Castro and Ewoud Verhoef (TU Delft), JiwHan Kim (Erasmus University, Rotterdam), Hanna Leena Pesonen (University of Jyväskylä, Finland), Trond Lamvik, Rolf Bohne and Ottar Michelsen (NTNU, Trondheim, Norway) and Mark Martin and Sören Petersen (Stanford University, USA) to have me invited to be on your committee!

Chapter 5: The Value Chain

5.1 The Concept of the Value Chain

5.1.1 Development of Environmental Value Chain Analysis

Between 1997-1998 the disaster with the 'Green' TV (see Tidbits, 1) was a painful confrontation with value chain issues in business practice. Up to that moment the concept was known in the environmental world as 'chain management', which was a pretty soft philosophy suggesting that all parties in a chain should work together to serve the common goal of improving the environment.

A hard landing, in the case of 'Green' TV, showed that the environment is just another battle not unlike the many battles being fought in business, be it with other weapons. 'Eco' turned out not to be a kind of alternative boy or girl scouting: 'doing something green everyday'. Instead it is a brutal power game: the one who has the most material or immaterial power in a chain wins. And there is little likelihood that everyone in a chain will win through 'green', in many cases there will be 'losers' as well.

The manufacturing Modeling Lab of the Mechanical Engineering School at Stanford University was using Value Chain Analysis as part of their Improvement and Change Management studies. When I was a visiting professor there I applied such ideas to making Environmental Value Chain Analyses (EVCA's). Both internal and external environmental value chains were identified and defined. A test employing the so-called Issue Correlation Matrix (ICM) (see below) showed how poorly EVCA was implemented for the 'Green' TV. In a similar way an ICM was used to come up with a proposal to further enhance the first company-wide EcoVision program at Philips.

This work at Stanford has been described in the following article with the title "*Environmental Value Chain Analysis: A Tool for Product Definition in EcoDesign*". The chief conclusion is that Environmental Value Chain Analysis can be very helpful in enhancing the effectiveness of environmental programs.

Environmental Value Chain Analysis: A Tool for Product Definition in EcoDesign

Kos Ishii and Ab Stevels

Abstract

This paper proposes the method of Environmental Value Chain Analysis (EVCA) which aids the product definition stage of EcoDesign. Key elements EVCA include: 1) The mainstream flow and stakeholder's impact, 2) the internal value chain, and 3) the issue correlation matrix. EVCA helped to transform Philips Consumer Electronics from an environmentally defensive organization in 1994 into a proactive one at present. The 'Green' TV project (1996) and the current Eco Vision program serves as an illustrative examples of EVCA. The analysis enables us to formulate the lessons to be learned from the past and also in which way current programs can be further enhanced.

1 Introduction

In the past decade, Environmental Design ('EcoDesign' or 'Design for Environment') has become one of the most significant items on the agenda of many manufacturing companies. Yet, there is a much variety in their approaches, strategies and in levels of execution.

The Brundtland report [1] pointed out that environmental impacts, in terms of emissions and use of resources, are not only used by production processes as such, but also by products in the various stages of their lifecycle: raw materials, manufacture, use and disposal. In the early nineties, authorities in several countries started to react with various types of product legislation/regulation, most of them in draft form. Consumer unions followed by introducing 'environmental paragraphs' into their product performance evaluations.

Around 1992, the concepts of Environmental Design emerged: designers should look at products from a total life cycle perspective. They should consider all aspects including energy consumption of products, material application, packaging, transport, hazardous substances, recyclability, durability, and production processes.

However, most people see Environmental Design as a set of technical issues. This view led to most companies positioning EcoDesign within the product development departments. The focus of most companies has been fairly defensive, with legal compliance and preventing negative publicity dominating the agenda. From this perspective, most companies perceived the environment as a cost issue rather than as an approach to enhance business.

Around 1995, people realized that environmental and economical interests run parallel regarding many issues:

- Resource reduction (energy case, materials, packaging) also means cost reduction.
- Reduction of disassembly times usually means reduction of assembly times.
- Reuse of subassemblies, components, and materials is cheaper than buying new ones.

The result is a strong impetus for additional environmental activities and this led to many examples that link ecology/economy programs. So far, proactive programs aimed at selling more and increasing market share through 'green' have been less successful. Two reasons for this seem to exist:

- An internal reason (company): lack of cross-functional programs to really make this happen.
- An external reason: 'customer green' needs/requirements inadequately addressed. The present paper is organized as follows:

Section 2 analyzes the move from a defensive to proactive environmental stance in more detail. An example of developments at Royal Philips Electronics is used. It will be shown that introducing environmental issues is not only a matter of technology and strategy, but a "cultural" process (how to get people to buy in to this?) as well.

Section 3 outlines the basics of Environmental Value Chain Analysis. 'External' as well as 'internal' value chains will be considered. Also the Issue Correlation Matrix will be introduced to map out commonalities and potential conflicts of interest between the main players in the value chain. On top of that an enlarged Issue Correlation Matrix (ICM) will be presented. This matrix considers the interest and impacts of stakeholders indirectly linked to the main value chain.

Section 4 applies EVCA and the Issue Correlation Matrix (ICM) to the Philips Consumer Electronics 'Green' TV project of 1996-97. Although this project has been very beneficial to the company, the product did not reach the

market. The paper shows that the main reason for its lack of success was the insufficient analysis and management of the internal value chain.

In this respect, the company wide program for Eco-star products (in section 5) was a much better success. EVCA and ICM will show how this program has more potential for further success.

2 From Defensive to Proactive

Table 1 shows the evolution of approaches to Design for Environment (DFE) at Philips Consumer Electronics.

Table 1 Developments in Environmental Design at Philips Electronics

	4-7 yrs. ago	1-4 yrs. Ago	Now
Management Involvement	+	++	+++
Program	Policy & interpretation	Environ Opportunity	Eco Vision
Orientation	Defensive	Cost-Oriented	Proactive
Approach	Procedures	Technical	Business

The Defensive Period (1992-1996)

Four to seven years ago, management’s involvement in environmental issues was limited. There was a policy statement and a detailed interpretation of it, however, its actual implementation was left to the divisions and business groups. This resulted in a principally defensive attitude: efforts were focused on legal and regulatory compliance and preventing bad environmental press. They achieved these objectives by applying mandatory environmental design rules, to be checked at product release. Subjects to be considered included (and still include): banned substances, packaging rules, marking and labeling, customer information and batteries.

Although the orientation of this program was chiefly internal, particularly on product development technicalities, its effects were wider. The effort created environmental awareness and, while the scope was limited by present standards, the outside world saw the company as a first mover on environmental issues. Compliance requirements also led to the formation of an environmental organization and the collection of all kinds of environmental information. In spite of the perception of the environment being a threat, as was perceived by parts of the organization, and doubts about benefits the company further developed its environmental program.

The Environmental Opportunity Program (1996-2000)

This program showed stronger management involvement. The aim was to further strengthen the environmental organization and to achieve cost reductions through an environmental approach. The major goal was that all factories should have an environmental management system in place per ISO 14001, achieve 25% energy reduction in all operations, and reduce packaging by 15%.

Furthermore, the program called for the creation of internal and external networks and active participation in legislation and regulation discussions. Life cycle design and supplier requirements were mentioned as well, but these were still on a voluntary basis for divisions and business units. The big step forward was that this program,

- forced business groups to confront various environmental concerns systematically
- brought clear cost savings through energy reduction and packaging reductions that were visible for the organization, and
- substantially enhanced the internal profile of the environmental programs.

In spite of its voluntary character, the practice of life cycle design (EcoDesign) started to take off. The program produced an environmental design manual that provided guidance during these processes. Although the program was a big success, two elements were substantially lacking:

- Creativity. Both the ISO 14001 standard and a design manual (providing information, recommendations and establishing “rules”) are both fairly formal and static, as such they do not challenge people to unleash their creativity.

- External orientation. Since the program was to a large extent organizationally and technically oriented, the programs did not cater downstream (to customers and other stakeholders who should be the environmental beneficiaries) and upstream (to suppliers who should contribute proactively). If the concept of EVCA existed at that time (the beginning of 1998), an analysis according to the principles described in Section 3 would have immediately identified the strengths and weaknesses of the programs and showed which avenues to pursue. Because the EVCA was not available at the time, the organization intuitively developed a program called Eco Vision (1998-2000) that was a major step forward despite the lack of a systematic methodology. Several paradigm shifts brought about this breakthrough based on the following awareness:
- Design for environment is business oriented rather than purely technical.
- The environmental benefits as *perceived* by customers and stakeholders are key rather than scientific calculations of environmental gain.
- Being the best in environmental care means being the best when compared with the competition rather than in absolute terms.
- A clear communication of results is just as important as obtaining the results themselves.
- Top achievements are possible only when the effort involves the total value chain (from supplier up to end of life processors).

The current Eco Vision program (1998-2000)

The cornerstone of the Eco Vision program is the communication of top achievements as embodied in 'Green Flagship' products to customers and other stakeholders. These achievements come primarily from management of the cross-functional processes around creation, production and marketing and sales of these products (see ref. 2).

The Eco Vision program has been introduced in the organization using a top-down approach, that is through initiative and commitment of the president and chief executive officer of the company. Its implementation is now well underway; the Consumer Electronics Division as already achieved some fine results in the form of following Eco Star / 'Green Flagship' products:

- a 32 inch TV set PW9515
- a videocassette recorder VR860
- an audio system FW870/C.
- the Kala and Onis DECT telephones.

The following sections illustrate how EVCA and the ICM can further enhance this program.

3 Environmental Value Chain Analysis

Environmental Value Chain Analysis (EVCA) has been developed from Customer Value Chain Analysis (CVCA). The method seeks to identify pertinent customer and other stakeholder interests, their value perceptions and the relationship between these parties in 'green' product or processing development projects. Most leaders in manufacturing agree that an appropriate definition of product attributes is an essential key to providing high (environmental) value to all the stakeholders in any new product or process. Wilson [2] cites that identification of the deficiencies in understanding the value proportions for the stakeholders is the most prevalent and critical failure during product development. This section first describes the basic concept of CVCA, then adapts it as a tool to analyze the environmental value chain.

Basic steps involved in CVCA

CVCA facilitates the first steps of product definition and feeds into other structured methodologies such as Quality Function Deployment. CVCA should be a team effort involving multi-functional teams and top level management. Figure 1 shows a typical example of a customer value chain graph for an automotive interior component (panel) manufactured by a supplier and assembled into a vehicle by a product integrator:

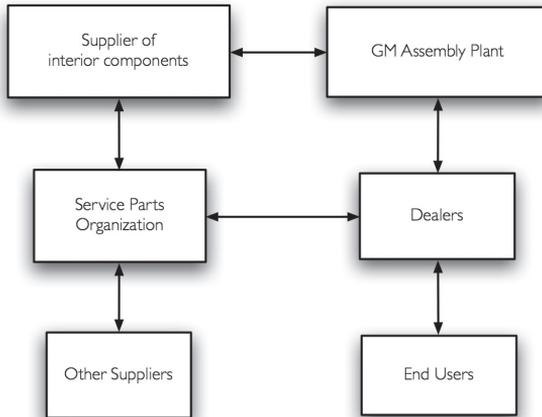


Figure 1 Automotive Components CVCA

The basic steps involved in generating such a graph and analyzing them are as follows:

- 1) List the pertinent parties involved: stakeholders, customers, partners, regulatory bodies, etc.
- 2) Identify the relationship amongst these parties by defining the flow of the following:
 - Money or funds (indicate the flow by \$)
 - Stuff: machines, materials, services, or information (use appropriate icon)
 - Complaints, regulatory influences, votes, etc. (!)

Note: Most often \$ and ! come in pairs in exchange for some stuff, but not always. These exceptions create very interesting implications in the stakeholder structure.

- 3) Analyze the resulting CVC "Graph" to address the following questions:
 - Who are the customers that are critical to the project?
 - Trace the \$ and ! from your own position
 - What are the value proposition of these parties?
 - Look at the input/out of \$, !, and other icons.
 - How are they going to make money?
 - Use this information to generate the Voice of Customers (VOCs).
 - Use the flow of !, particularly complaints to identify negative VOCs.
- 4) Feed the information into Product Definition Assessment (PDA)
 - The CVC Graph should facilitate the completion of the PDA checklists
 - Use CVC results to identify partners and management needs
 - Do not be afraid to cancel the project if the value proposition is weak
- 5) Use the CVCA results down stream in the Development Process (Flow Down)
 - Use Quality Function Deployment to flow down the VOCs
 - Use Failure Modes and Effects Analysis on negative VOCs and generate robust designs.

Adapting CVCA to Environmental Value Chain

Now let us adapt the CVCA to environmental values. The general form of an Environmental Value Chain looks as follows:

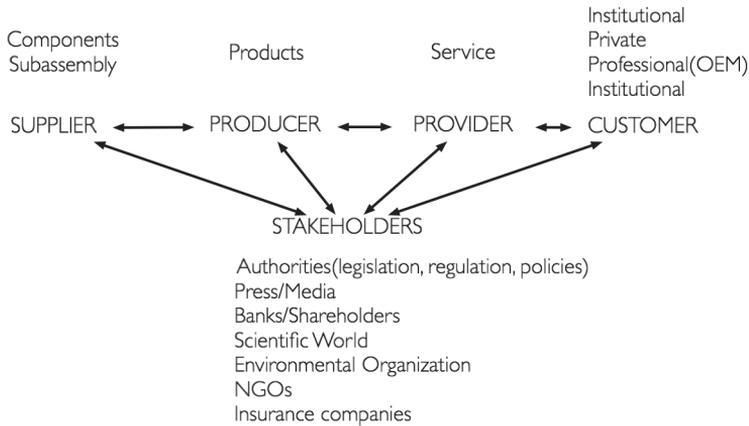


Figure 2 General form of an Environmental Value Chain

The upper part of the graph represents the main stream of values between suppliers, producers, providers and customers. Stakeholder interactions with the players in the main stream mostly involve one of these information flows, as defined above.

One must also address the organizations' internal value chains. For manufacturing companies, Figure 3 shows this chain focuses on the main stream between suppliers, producers, providers and customers.

The interaction between internal stakeholders is mostly focused on information flows. Note that individual internal stakeholders communicate with different stakeholders outside the company.

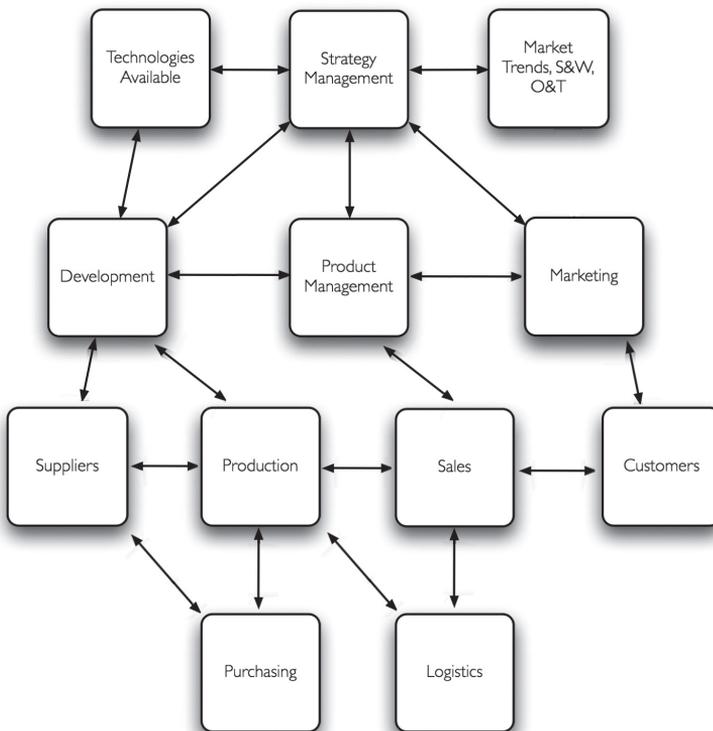


Figure 3 The Internal Environmental Value Chain

This fact shows that significant cross functional exchange is needed to form a unified position with respect to the outside world. This challenge is a major issue for the environment that covers many disciplines. In order to make this interaction more transparent, an Issue Correlation Matrix (ICM) has been developed. The ICM shown is for environmental and related Business items in 1996. The rows represent the environmental and business issues. The columns represent the various departments involved. For each department, crosses indicate which environmental and business related issues rank highest from their perspective. The number of crosses per department is 'normalized'. The numbers rank the departments' priorities with a score of 1 to 5.

Table 2 An Internal Issue Correlation Matrix (ICM) for Environmental and related Business issues (1996)

	Environmental Department	Strategy Management	Product Management	Development	Purchasing	Production	Marketing	Sales	Total
Environmental Strategy	X	X							2
Specification (Functionality)	X		X	X	X		X		5
Quality	X				X	X	X	X	5
Environmental Score	X								1
Project Management	X		X	X		X			4
Environmental Communication/Competition		X	X				X	X	4
Production Technology		X	X	X					3
Cost		X	X		X	X	X	X	6
Investment		X			X			2	
Time to Market			X	X			X	X	4
Suppliers				X	X				2
Logistics					X	X		X	3

The ICM in Table 2 is set up based on the priority perception of the Philips Consumer Electronics Environmental Department in 1996. One can see that during this period, only the specification and quality items have high correlation among the departments. At the time, the Environmental Department did not adequately address issues such as the competition, communication, cost issues and time to market. The Eco Vision Program (section 5) substantially resolved this deficiency. As will be shown, the company must still address the supplier and logistics.

4 EVCA for the Philips 'Green' TV (1996-1998)

In terms of the development of Environmental programs, the Philips 'Green' TV used a revolutionary approach when it began. The program started when the Environmental Opportunity Program (c.f. section 2) replaced the defensive approach.

The initiator of the program was a very strongly motivated employee of the TV development department. Implicitly, he had recognized the four level structures of EcoDesign activities [3].

Level 1: Improvement of existing products

Level 2: Maintain the existing concept but redesign from a radical environmental perspective up to what physics, chemistry, electronics etc. allow you to do.

Level 3: Go to alternative functional realization, either by providing functionality based on a different (environmentally friendlier) physical principle or by moving from products to services.

Level 4: Redesign to sustainable systems.

The team positioned the 'Green' TV project at the top of level 2, it was meant to explore the possibilities for maximal environmental improvement of a CRT based TV, putting aside - at least in the beginning - business integration. In terms of EVCA, the value proposition to stakeholders to be delivered by this project was unclear for all aspects excluding 'green'.

In terms of the Environmental Value Chain (see fig. 1), support was chiefly sought out of the mainstream, with success. The Dutch Environmental Ministry supported the project financially and it was observed by the press and environmental organizations that the electronic industry finally started to move.

In terms of the Internal Value Chain (fig. 2) there was strong support for the project from the management of development, because of its strategic value. Product management was lukewarm about it because it anticipated big problems in communicating an environmental success. Also fears that the product would become too expensive played an important role. The production department also shared this view. When the project started, the concept of supply chain management (let alone environmental supply chain management) was still in its infancy. Suppliers were simply requested to deliver what was ordered.

In terms of the Issue Correlation Matrix (Table 2), the items (strategy, functionality, quality, environmental score and project management) were clearly or at least sufficiently addressed. The other items (environmental communication and competition, production technology, cost, investment and time to market) were not mapped very well, whereas the last two items (suppliers and logistics) were not addressed at all. In spite of all these deficiencies, the 'Green' TV project was a huge success both in strategic and 'technical' terms. In one year, the program produced prototypes following characteristics:

Table 3 Environmental Improvements for 'Green' TV

Achievements for Green TV	Percentages (%)
Reduction of energy consumption	39
Reduction of plastic weight	32
Reduction of hazardous substances	100
Use of recycled materials	69
Recycle potential	93
Reduction of life cycle impact	30

The strategic success of the 'Green' TV, which proved that 'it can be done' and products ranking high in level 2 are substantially greener than the ones in the market at that time, became one of the strongest drivers for a company wide 'Eco Vision Program' (see section 5). The technical success of the 'Green' TV is that after 1996, many inventions and improvements in the 'Green' TV concept have been introduced into conventional models - qualifying the best of them as 'green'.

The concept of the 'Green' TV, as such, has never brought it to the market however. The chief reasons for this are basically the ones that an EVCA - if available at that time — would have yielded up-front:

- Lack of a clear value proposition to the potential customer. Unclear position of the product in the line-up.
- No involvement of suppliers, therefore necessary changes in supplier base not foreseen.
- Cost issue not addressed in a way in which criticism and prejudice ("green' products always cost more") could be dealt with.
- Consequences for production (investment, factory lay out) not very well addressed.
- Logistics (e.g. availability of recycled material) turned out to be sometimes problematic.

Although the 'Green' TV has been a partial success, it brought tremendous knowledge to the organization. The main lessons have been:

1. Integrate environmental concerns into all business aspects
2. Focus clearly on the customers and benefits for customers from environmental programs. These benefits are not just environmental but can be material (money), immaterial (easier, fun) and emotional as well.
3. Formulate environmental messages in the language of the receiver (and not of the 'environmental' sender).

5 The Eco Vision Program at Philips

Eco Vision is a company wide program at Philips focused on environmental communication for details. The program requires the 'green' performance of its flagship products to be significantly better than that of the competition. Such effort necessitates a thorough benchmarking of the product [3], the results of which are not only used to facilitate communication internally and externally, but also form a backbone for target specifications and roadmaps. These efforts are managed through steering committees and cross-functional teams, thus ensuring that the internal value chain is well covered.

The particular embodiment of Eco Vision is in the 'Green Flagship' products. Per product division there are tailored requirements to qualify in five focal areas:

- Energy consumption
- Weight reduction
- Packaging and transport
- Environmentally relevant ("hazardous") substances
- Recyclability

In all cases, the reference is the environmental performance of best commercial competitors on an equal functionality basis. The qualification process also forms the basis for communicating details to customers and other stakeholders. The five focal areas enable analysis in a single language (kWh, kg and percentage). Stakeholders with specific environmental interest may also adopt a "life cycle score" (expressed as an Eco indicator in mPt), which is a single point LCA score.

Because Eco Vision is a company wide effort, and all Business Groups have to develop and launch at least one 'Green Flagship' product, the effort significantly enhances the brand image of the company. The results obtained so far indicate that 'Green Flagship' products lead to an increase of market share by 2% and margins of 3% in the relevant categories.

In terms of Environmental Value Chain Analysis, it means that the value proposition to the customer and the stakeholder issues are well addressed now. Further enhancement of the program is possible by involving suppliers more intensively. These enhancements are a necessary ingredient in increasing the performance of 'Green Flagship' products even further.

The approach and the structure of the Eco Vision program have made it possible to tackle to a large extent the internal value chain issues (fig. 2) and to remedial the flaws of the 'Green' TV program.

Therefore, the items of the internal Issue Correlation Matrix are much better addressed and resolved. Currently, ICM shows that there is significant room for improvements in the supply chain. Appropriate environmental chain management will be setting the pace for the.

6 Conclusion

This paper presented the principles of Environmental Value Chain Analysis (EVCA). ECVA has proven to be a powerful tool to analyze the development of Philips Consumer Electronics from an environmentally defensive position to a very proactive one. This analysis not only helped us understand our history, but guided us to formulating the lessons to be applied in the future. The authors firmly believe that ECVA can contribute to further enhancements of the environmental programs.

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Personalities, 7**Jeanette Duttlinger & Roger Burri: ambitious and well-organized**

Be ambitious, work hard, organize to perfection and insist on what you want. That is what I learned from Jeanette and Roger.

It all began in 2001. I got a flyer via EICTA, the European Information Technology, Consumer Electronics and Telecom (Industry) Association that asked, "who is interested in contributing to a Recycling Congress?" Equipment manufacturers were encouraged to get involved. The organizer was ICM, well known from their battery and car recycling congresses. Could this be interesting? It was intriguing at least. Why not try?

I decided to send a bit of a provocative abstract as a test. As a response, the organizers decided to test me. My story was accepted. Now, I had to show what I really stood for.

So I went to Davos in wintertime. The snow was great, the conference was even better. It turned out to consist of a community with relevance for electronics manufacturers: recyclers and treatment technology vendors were well represented. Such stakeholders in electronics recycling are not found in the more scientific oriented conferences.

There was a lot of learning therefore. Not only the first year, which was a kind of experiment, but ever year since. The IERC (International Electronics Recycling Conference) has grown to be the best of its kind.

This is due to its content, their drive to attract the best speakers and to involve the most relevant exhibitors. The powers behind this drive are Jeanette Duttlinger and her organizing team and Roger Burri, the president of the Conferences. The ambiance contributes as well with excellent conference centers, good hotels, perfect networking dinners with plenty of fun as well.

And what about the Steering Committee and the Program Committee? I became a member of both. It was the same story: be ambitious, go for quality and perfection and it will work out to the satisfaction of the participants.

In 2005 IERC made the jump to China. After a start up period the Shanghai World Recycling Congress is now well established; it will expand in the near future.

Go for the best, be consistent in your criteria, and maintain the standards. Jeanette & Roger, thanks!

The 'Duttlinger & Burri' Walk: No, it is not walking, it is not skiing either. Go on a sledge downhill, either at the Grindelwald or the Davos sledge track, preferably at night. Control your sledge carefully, look at the stars, breath the crisp and cold air! Enjoy, it is fun for everybody!

The Davos track is most famous. We did it in 2002 with the whole conference group, after the networking dinner at 10.30 p.m. The dinner was good, Huesmusigg Kolleger played great Swiss tunes, the drinks were the best. Participants of the event still make a distinction: the world before and the world after the Davos sledge ride.

It was a big risk, but all going down arrived unscathed. All of us were exhausted but exuberant!

5.1.2 Lock-in in the Environmental Value Chain

After Stanford EVCA issues have been taken further and special attention has been paid to so called 'lock-in' situations. These are situations in which environmental improvements result in overall benefits for the chain, but do not entail (or are not recognized as such) environmental and or monetary benefits for each individual stakeholder in the chain. Such stakeholders tend to therefore oppose implementation of these measures in practice.

Lock-ins occur in many 'green' value chains. It was determined that there are two reasons for the 'lock-in'. Either the value chain actors are insufficiently aware of the benefits of 'going green'. Here the basic action to break the lock-in is to convince them of the benefits (see the benefit matrix in chapter 4.2.1). Most of the time this meant simply collecting information and disseminating it.

Use of power is an issue if there are overall benefits for the chain but not for every actor. In such a situation it is to be investigated whether applying power can help.

The first example of how a lock in was broken is about identifying the prioritized design strategy in a packaging & transport (P&T) chain. Goods are produced in China and sold in Europe. Every actor pays for part of the P&T chain. The cost for some of the actors involved are dominated by the cost of the boxes; these actors prefer an EcoDesign strategy geared towards material reduction. Others pay chiefly for transport or warehousing as a result they have a preference for a volume reduction based EcoDesign strategy.

Action/Interest	Payment of transport	Chief requirement on box	Design Emphasis
Factory in China	Transport to harbor	Solid box (shocks)	Materials Reduction
Business Unit	Overseas transport	Low cost (load)	Volume Reduction
National Sales Organization	Transport to warehouse customization	Pallet load, easy to unpack	Materials/Volume Reduction
Retail Chain (60% of sales)	Warehousing cost	Sell from box	Materials/Volume Reduction
Retailer (40% of sales)	Nothing	Easy to unpack	Materials Reduction

Figure 5.1 The value chain China – Europe for packaging & transport.

The only way to resolve this materials/volume contradiction was to involve a student from Delft University to dig out all the facts. Most of the facts are in place but distributed over several locations, and sometimes not accessible for other members of the value chain. As often is the case 'the environment' is a neutral banner under which these data can be obtained. Moreover in the case of Packaging and Transport 'green' and money run almost completely in parallel. This means that out of this a clear 'transparent green' business case can be constructed which is the basis for a management decision. In this case it was 'go for volume reduction first' (price and environmental load of container transport dominating).

A second example is the issue of the incandescent lamp versus energy saving lamps. Energy saving lamps are efficient; often more than four times more. (factor 5) but the upfront price is higher (4-6 times higher). Nevertheless energy saving lamps have not penetrated private households so far – a lot of consumers do not believe the efficiency calculations that have been published by producers. Moreover, the product line-up of energy saving lamps is not complete (few low watt energy saving lamps, poor color rendition and the size of the lamps do not fit existing lamp shades). As such these advantages are such that a 'convince' approach would be appropriate. However, in practice the progress of penetrating the domestic market has gone at a slow pace: after twenty years it is still low. Therefore the only way forward to save gigantic amounts of power in the field of lighting is that governments forbid the use of incandescent lamps ten years from now. With such a time frame industry can adapt its product line-up, depreciate current investment and plan effectively for the transition. Consumers will change, will have to change, there is no alternative.

Also at the supply side both situations can occur. An example of a 'convince' strategy was the transition from brominated flame-retardant plastics to bromine free material around 1995. The bromine free material was – apart from being environmentally friendly – cheaper than the bromine (and antimony) containing material. However start-up and transition costs initially blocked the deal: several actors in the internal value

chain, including the purchasing department opposed. After a detailed study of the transition cost it was decided to distribute these over the volume purchased in the next three years. This worked out in such a way that in this period there was a small price decrease followed by a larger one after this period. This was good enough to convince all parties involved.

How power can work out in the supply chain in relation to 'green' is demonstrated by recycling issues. Philips Consumer Electronics is for display suppliers a big account, for instance in the field Cathode Ray Tubes. As such it can force suppliers to take back post-consumer glass. Initially the suppliers resisted because of quality fears about the secondary glass. After applying pressure money was invested to allow use of the glass. Simultaneously the recyclers were obliged to give quality guarantees (grain size, metal fee etc.) so that the secondary material could be adopted.

This contrasts with the situation in plastics where Philips CE uses ten thousands tons but remains a small customer for the big plastics producers in terms of the percentage of the total production purchased. Requests to assist in plastic recycling (see also Cities, 10) have never been met with a very positive answer.

Rituals and habits, 7

Graduation Day

The first purpose of a university is to deliver graduates who are well trained in academic thinking and, in the case of a University of Technology like Delft, develop appropriate engineering skills. A successful graduation project at the end of their last year is the best way for students to demonstrate what they have learned in this respect.

At the Faculty of Design Engineering the project and the final exam are individualized and rightly so. It is the best way to ensure final learning and allows the best method of assessment as well.

A team of 3 or 4 mentors takes care of the prospective graduate and helps him or her until 6 weeks before the exam when there is a 'green light' meeting. Here they check whether there is sufficient substance present to ensure a positive graduation day. The 'green light' is a very serious meeting. Substance (there should be 'flesh on the bones'), content (no gaps, no 'inventions still to be made'), completeness (the outline of the final report should be present as well as sufficient text to allow it to be finalized just by putting in hours) should all be in place. Last but not least something new or creative has to be demonstrated.

'Green light' meetings can easily turn into 'orange' or even 'red light' meetings. This is to protect the candidate, whether you like it or not it is better to fail in the mentor group than when your family and friends are in front of you.

After a positive 'green light' meeting, a lot of work is still to be done, but a pleasant graduation day is pretty likely ahead. After finishing a 45 minute presentation you have to survive fifteen minutes of questioning by the 'general public'. The mentors ask questions for another 45 minutes and grade the project. Marks are given for your approach, your dedication, your results, your report, your presentation and the answers you provide to questions. It is all consolidated into one final note.

This very individual approach takes a lot of time but it is worthwhile to invest in it. It allows for deep insight into the capabilities of the candidate. Marks given by individual mentors for the different aspects do not vary much, if at all. Accord within the mentor group is therefore reached fairly quickly. Only in exceptional cases there is little consensus; in such a case the professor is given power by the regulations to make the final decision.

Today, universities are streamlined and made more efficient. In many cases there is a lot of justification for that. However, please maintain the treasure of individual graduations.

Hands off!

5.2 Involvement of suppliers in 'green'

Electronics companies ('the producers') manifest themselves more and more as 'system arrangers'. More and more focus is being placed on core technologies and R&D in general. Also, achieving economies of scale to become a leader in the market (and a leader in profit margin) is receiving a lot of attention. For this purpose building a specific brand identity is thought to be important as well.

Traditional industrial activities such as (integrated) production, which involves making components, parts, subassemblies and assembling products, are becoming subcontracted and outsourced. Even parts of product design and product specification, which are judged to be irrelevant for making a difference with competitors, are sometimes done by third parties.

Subcontracting and outsourcing therefore allow the focus to be placed on capital investment. Moreover when the outsourcing takes place in lower wage countries, substantial reductions of labor cost (manual labor, overhead) can be achieved as well.

All these changes, with respect to the past, mean that in the industry today 60-90% of the value of products and services sold originate with suppliers and subcontractors; so too does the environmental load in the manufacturing phase.

The important consequence of these high figures is that producers have to actively involve their suppliers in cost and environmental management.

In the environmental field there are basically three forms of supplier involvement:

- Defensive: prevent that bad things happen: introduction of an ISO 14.001 environmental management system, mandatory requirements for chemical content control and legal compliance in general.
- Pro-active: assist by contributing to EcoDesign.
- Cost-Reduction: Reduction of inputs and unwanted outputs of production:
 - Utilities (electricity, water...)
 - Basic materials
 - Auxiliary materials
 - Waste and waste water
 - Emissions to air.

Defensive action is to be taken irrespective of the type of suppliers and type of markets in which a producer is operating.

Proactive action will mostly take place with key suppliers where costs can be shared and exclusivity can be guaranteed.

Cost reduction actions can take place with a variety of different parts suppliers but chiefly in markets where there are many vendors so that benchmarking of suppliers is possible.

Currently, the general involvement of 'green' suppliers is surprisingly low, but it is increasing.

Defensive actions have been addressed for some time through the requirements of Environmental Management Systems certification (ISO 14.001, EMAS) and chemical content requirements as well through the European Directive on Restriction of Hazardous Substances (RoHS), see chapter 9.2.1.

Few published examples exist of efforts that jointly involve a proactive approach and reduction efforts. This will be addressed further in chapter 5.3.1.

Around 1995, a wide spread idea was that introducing an ISO 14.001 environmental management system to suppliers would be sufficient. At that moment this was at least one bridge too far for most suppliers. The ISO system is pretty formal and looks at organizational issues rather than enabling the development of an improvement agenda on a practical basis. Moreover it focuses on the process industry rather than on the manufacturing of products.

Also in the factories of Philips Consumer Electronics there were considerable difficulties in becoming certified. These problems were solved by focusing first on practical items like energy savings and moving from there to the more formal ISO 14.001 parts like Vision and policy (the 'upstream' items) and record keeping (the 'downstream' items), see the figure on next page.

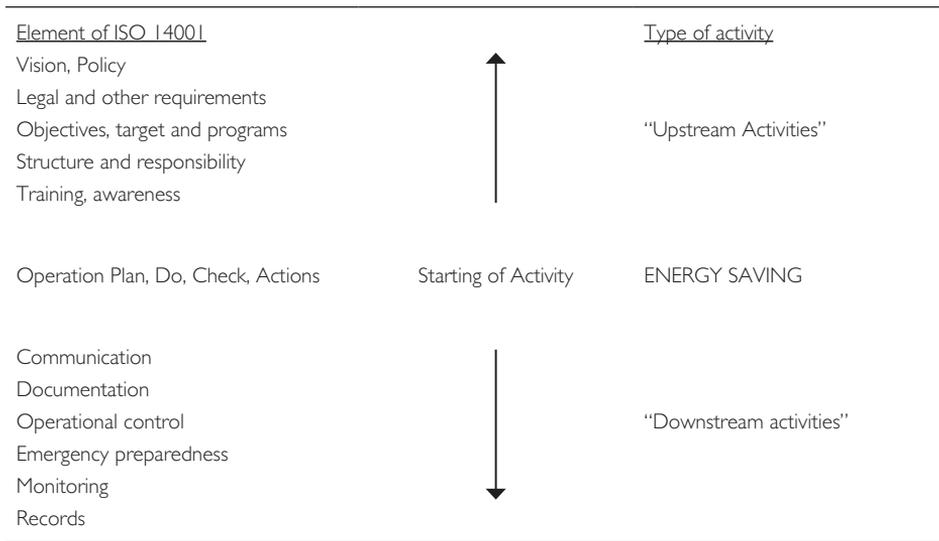


Figure 5.2 Setting up an ISO 14.001 activity in a practical way at Philips Consumer Electronics

This figure demonstrates how Plan/Do/Check/Action and 'Energy saving' were taken as the core actions. Directly after this training and awareness were added to the action platform and subsequently more and more activities both in 'upstream' and 'downstream' direction were included into the activities.

For the involvement of 'green' suppliers in, Delft University has been focusing primarily on creating awareness about EcoDesign. For this purpose a so-called do-it-yourself '3S-guide' was developed. By answering a limited number of questions suppliers could get an idea of how to start tackling the EcoDesign subject. Soon afterwards, 3S was transformed into an internet-based self audit tool called EcoQuest. It is described in the publication on the next page with the title: *"Eco-quest, an Ecodesign Self Audit Tool For Suppliers of the Electronics Industry"*.

EcoQuest has become a success between the years 1998-2002. It raised awareness. It was a do-it-yourself tool which did not require help from third parties. EcoQuest was a natural guide towards EcoDesign and had an action oriented basis.

Two factors caused it to lose its initial momentum:

*Pressure from academia to adopt more sophisticated environmental analysis tools (for instance Life Cycle Analysis)

*Pressure from the industry for more focus on defensive items (see above).

In my opinion however, it is still a useful tool today and it would be appropriate to bring it up to date.

Eco-quest, an Ecodesign Self Audit Tool For Suppliers of the Electronics Industry

Suzanne Brink, Jan Carel Diehl, Ab Stevels

Abstract

ECO-QUEST for Electronics, an ECOdesign QUESTIONnaire for suppliers of the Electronics Industry, has been developed by the Delft Research Laboratory for Sustainable Product Innovation with the support of some major manufacturers in the Electronics Industry. Basically it is a self-audit system to establish the relative environmental merit of a supplier's goods and services. The system has been organised in such a way that it does not take more than 30 minutes to arrive at a meaningful result.

ECO-QUEST provides an initial and easy to understand introduction to more comprehensive environmental product analysis and is therefore also a basis for product improvements through Design for Environment.

1 Background

Suppliers of the Electronics Industry are confronted by their clients (OEMs) throughout the world with questionnaires concerning the environmental issues of their products and services. OEMs will select their suppliers in the near future not only on quality, price and delivery time but also on these environment-related issues (like materials application, packaging, energy consumption, take-back and environmentally relevant substances).

Presently, most suppliers have a lack of know-how and staff to analyse and improve the environmental profile of their products and services. EcoDesign suppliers' tools so far have been very complicated and therefore time consuming, and only available in paper-versions. To support the suppliers of the Electronics Industry, Delft University of Technology in co-operation with some major manufacturers has developed the ECO-QUEST software.

ECO-QUEST Electronics is intended for suppliers of goods and services to the Electronics Industry (OEMs), particularly SMEs in Newly Industrialising Countries (NICs) and for purchasers and environmental managers of OEMs.

The audit aims to establish a relative environmental score of goods and services delivered by the supplier. The results of the audit can form the basis of an EcoDesign strategy for improvement within their company. It can also be used to discuss the results with the clients in the Electronics Industry, in order to work jointly on life cycle management to create 'green' options.

EcoDesign tools

Existing EcoDesign tools have been developed to make environmental analyses of the products and are concentrated on the OEM purchasers. They offer a selection procedure for choosing suppliers on the basis of environmental issues.

None of the existing tools support the supplier. A supplier supporting tool should be easy to use, not too time consuming and with a tangible outcome which can be communicated within the company and to their clients.

Based upon the environmental questionnaires of OEMs and the experiences of Delft University of Technology and the Electronics Industry, ECO-QUEST has been developed as an EcoDesign software tool for suppliers. ECO-QUEST is an improvement tool, offering the suppliers solutions to improve the environmental profile of their products.

Internet

By making a computerized version, user tasks can be facilitated when they fill in the questionnaire. ECO-QUEST calculates the score, gives a clear overview of the sub-scores in graphs and offers first steps towards improvements.

ECO-QUEST will be available on the Internet in order to:

- Facilitate the distribution and availability of the tool throughout the world.
- Make it possible and easy to update the environmental data, new legislation and the state-of-the-art.

The limitations of communications via the Internet in the NICs have been taken into account. A reasonable amount of time is necessary to use the program which may be difficult in countries where the internet is inconsistent and potentially hard to find. Therefore the software program will be downloadable and will fit on a floppy disc. Special attention has been paid to the user-interface of the Web-Site and the Software Tool.

2 ECO-QUEST

ECO-QUEST is split up in two parts: The ECO-QUEST Site and the ECO-QUEST-Electronics Software Tool (downloadable from the Site).

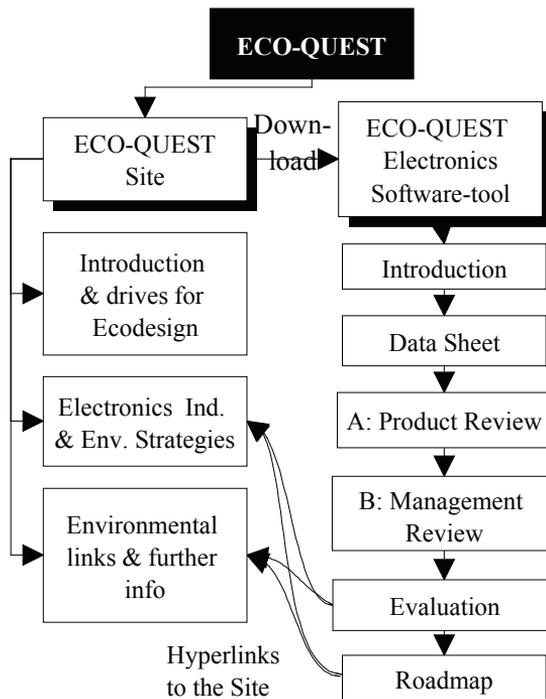


Figure 1 Structure of ECO-QUEST.

ECO-QUEST Site

The ECO-QUEST Site contains background information on environmental issues and drivers that concern suppliers of OEMs. Suppliers of the Electronics Industry can visit the ECO-QUEST Site to download the Software Tool.

ECO-QUEST Electronics

ECO-QUEST Electronics is a questionnaire program for suppliers to conduct a self-audit of their environmental performances. It can be downloaded from the ECO-QUEST Site. After downloading, the user does not have to stay connected to the Internet. The program is a stand-alone application.

3 Goals of ECO-QUEST

The two parts of ECO-QUEST each have their own goals to support suppliers in improving the environmental profile of their products:

ECO-QUEST Site

- To introduce EcoDesign concepts to suppliers (mostly SMEs) of the Electronics Industry.
- To support purchasers from OEMs to foster the environmental quality (sustainability) of their suppliers' companies worldwide by introducing a simple, first step audit tool, and by providing introductory ideas and suggestions for improvement.
- To introduce a simple first step audit tool.
- To provide ideas and suggestions for improvement.
- To function as a guide for EcoDesign by including literature references and addresses of environmental information providers relevant to suppliers of OEMs.

ECO-QUEST Software Tool

- To supply a practical self-audit questionnaire for suppliers to determine the actual environmental profiles of their goods and services.
- To stimulate suppliers to improve the environmental profile of their "products" to provide innovative products with a low environmental impact and entrepreneurial benefits (lower production cost, new market opportunities) as a win-win option.
- To give a quick insight regarding environmental options for product improvement to be realized by joint ventures of suppliers and OEMs.

4 Contents of the ECO-QUEST Electronics

ECO-QUEST Electronics has been built up out of several tabs, which show the different steps, the user has to go through. ECO-QUEST is not meant as a pass or fail environmental test of a supplier's products. ECO-QUEST has been developed to encourage the supplier to provide a realistic and open response to the questionnaire. It helps to stimulate environmental responsibility throughout the total supply chain.

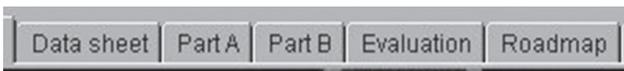


Figure 2 The tabs show the step-approach of the ECO-QUEST Software Tool.

Environmental data sheet

This tab will help the user to set up a list of product specifications which they need in order to be able to answer the questions in part A. The data sheet will make the user conscious of the consistency of the product by letting them answer some basic questions regarding various characteristics of the product, like the energy consumption, the number of screws, weight of the materials and packaging.

Part A of the questionnaire

Part A of the questionnaire, the product review, which consists of 25 questions, asks specific questions about:

- Product Design Review.
- Materials application and environmentally relevant substances.
- Energy consumption.
- Distribution, packaging.
- End-of-life, durability.

Introduction Data sheet **Part A** Part B Evaluation Roadmap Help

Question 25

Are the following parts/components easily (quickly, without special tools) removable / dismountable from the returned product?

housing

PCBs including their hazardous components

batteries

flat displays

none

End-of-life system **evaluate**

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Figure 3 Question of part A with 'radio-buttons'.

It can be filled in for parts, components, sub-assemblies and modules.

Part B of the questionnaire

Part B, the management review, which consists of 10 questions, addresses the environmental policy practices and progress on the introduction of Environmental Management System and EcoDesign programmes within the company.

Evaluation

All the questions of part A & B are multiple choice. After answering all of them the user will end up at the evaluation tab. The evaluation tab shows an indicator of the environmental profile based on the responses to the questions in part A & B for the product and a score reference.

Depending on the final score, ECO-QUEST will provide the supplier with:

1. Environmental priorities for the product.
2. Some ideas and suggestions for the first steps towards EcoDesign improvements.
3. Hyperlinks to the ECO-QUEST-Site for relevant information.

Roadmap

Finally the roadmap tab will help the user to report the findings and future strategies.

5 Testing the prototype

The prototype version of the ECO-QUEST Software Tool (named Suppliers' Sustainability Self-Audit (3S)) has been tested in several supplier companies in Asia, Europe and in the USA and is now qualifying for official status from the United Nations Environmental Programme (UNEP).

To avoid misunderstandings during use because of cultural differences, the Software Tool has been tested during the First Asian Roundtable on Cleaner Production in Bangkok, November 1997.

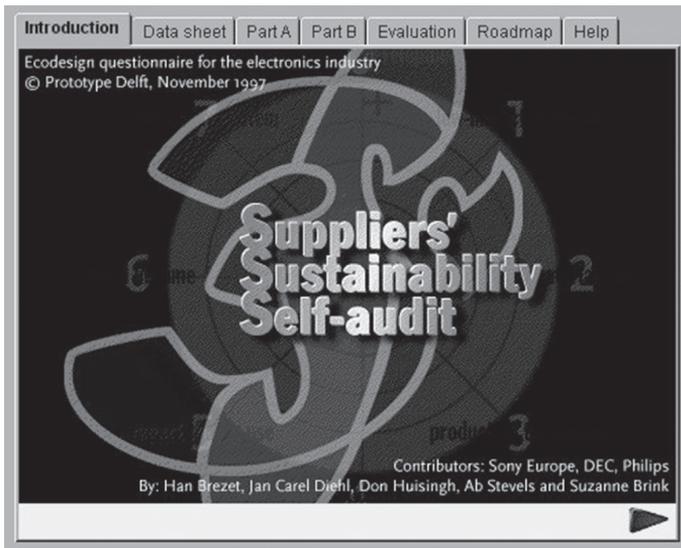


Figure 4 Prototype of the software tool as tested at the First Asian Roundtable on Cleaner Production in Bangkok November 11th – 14th 1997.

General conclusions based upon the remarks of the participants of the test are:

1. Industry is looking for tools like ECO-QUEST to start greening their supplier chain.
2. Both bottom-up and top-down approaches are required for making suppliers environmentally aware.
3. ECO-QUEST covers both approaches because it is easy and fast to work with.
4. ECO-QUEST has a lot of potential for further development for other industry branches.
5. ECO-QUEST is fast and easy to work with, it does the job for you.
6. Inexpensive dissemination by the Internet.
7. User interface proved to be user-friendly even for the less experienced computer user.

Requested improvements from the participants of the test were:

- more hints for the use.
- more graphical explanation.
- adjusting the questions to local languages.

The test results have been used to adjust the ECO-QUEST Software tool to its final version.

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Eindhoven, the smell and sound of industry

Eindhoven is the town where I was born and where I have lived all my life with the exception of a three-year PhD period in Groningen, NL. Moving abroad for professional reasons has been in the cards several times when I worked for Philips during 38 years, but it never materialized.

In my experience Eindhoven is an industrial town. In reality it used to be when I was a boy, and I became strongly immersed in that idea because of the schools. My parents were 'immigrants' from the west of the country. They put me in municipal schools. The locals, who we called southerners, were Roman Catholic so they went to Catholic schools. Since there were many more locals than immigrants there were relatively few 'neutral' schools. Therefore, both my elementary and my high school were pretty far from our home – half of the town had to be crossed to get there.

This offered the opportunity – before and after school – to see what was going on. Industrial activities impressed me; there was the smell of the tobacco and cigar industries, the stench of Philite production, the odor of vapors used to paint trailers (DAF), the scent of the soap factory (Redele), the smell of wood processing (Picus) and steam all over the place. There were also sounds: from the metal working industry (which is penetrating), from the textile industry (rattling), from Philips Glass (bangs from pressing TV-screens) and the humming of electric motors.

It is all gone. Companies went out of business, production has been moved out of town, to other countries, overseas. There is still some industrial production left, but you don't smell or hear it anymore. Today it is all 'knowledge economy'. This is inevitable, there is no alternative. High-tech campuses, brain ports, start-ups, IT solutions do not take away the dominant feeling I still have however. If all this knowledge is not applied in production, it will die in the end.

Most likely this has also branded my environmental activities: start from the practical perspective and build your concepts from that perspective. Distrust holistic frameworks which do not lead to design agendas (there are a lot of them in the environmental world). Keep your feet on the ground and just do it...practice will show the way.

City walk: Start from the Central Station (city side), walk across the station square, L to the Dommelstraat, over the bridge to directly R (Nachtegaallaan), go L, walk along the canal, go R Tongelresestraat, go R where it ends (Geldropseweg), go over the busy street crossing and go next R (Stratumseind), go L at the Church (Kerkstraat), go over the crossing and go first R (Bergstraat), go L (Kleine Berg) and R (Prins Hendrikstraat), keep R at the Wilhelminaplein and go R on the Willemstraat, go L to the Emmasingel and R back to the Central Station.

Favorite Pub/Restaurant: 't Rozenknopje, Hoogstraat at the corner of the Gestelsestraat.

Country walk: Start at the fountain at the most southern part of the Leenderweg (Floraplein, there is a bus to this place). Walk east (Floralaan Oost) and go R (Hindelaan) and directly R, Rendierveld. At the end of this lane is the trailhead. Follow the yellow trail, Kunnunneksenven, Riel, Gijzenrooi, Stratumse Heide and go back to the trailhead.

5.3 'Green' supply chain Management

5.3.1 Cooperation in 'green' between producers and suppliers

Like many environmental initiatives from the nineties of last century EcoQuest was focusing on 'green', however from a wider supply chain perspective it had gaps. It was important to realize that close cooperation in producer-supplier relationships regarding environmental issues requires a change in attitude from both the producer and the supplier. On one hand, producers have to give up the 'shot-gun approach' through which the purchasing department produces one-sided requirements for the supplier. On the other hand the supplier has to give detailed insights regarding their operations and to deliver evidence of 'green'. This is to be done against the background of sharing the benefits of environmental actions.

In this context the following article about 'green' supply chain management, much more than questionnaires and ISO 14.001 has been written and presented to several audiences both in Europe and the USA.

It clearly demonstrates that a wide and intense cooperation between producers and suppliers in 'green' is not only beneficial for the environment itself, but also contributes to better performance in the market.

Green Supply chain management, much more than questionnaires and ISO 14001

Ab Stevels

Abstract

Green supply chain management clearly goes beyond substance questionnaires and ISO 14001. In this paper it is demonstrated that supplier-producer cooperation in the fields of EcoDesign (Design for the Environment) and in benchmarking of manufacturing processes can yield impressive ecological and economic gains. Examples are shown in the fields of energy consumption of products, application of recycled material, take back and recycling and use of utilities in production. In all these fields it is shown that "what is measured is better managed".

1. Introduction

EcoDesign (Design for Environment) is gaining momentum; it is becoming rewarding to be environmentally proactive.

In the ten years since its emergence it has developed from a design-rule and compliance oriented technical activity into a business-integrated one that involves cross functional management of 'green' creativity processes (see ref. 1). Currently this approach is consolidated in Product Environmental Care systems (see ref. 2 and 3) and initial steps have been made for it to be subject to further international standardization (see the draft ISO 14062 Technical Report).

With EcoDesign and Product Environmental Care now in the process of being well established among producers a foundation has been created to expand the concepts among the Value Chain.

Downstream this means better exploitation of the results in the market. First studies for electronic products (see ref. 4 and 5) indicate that 'green' does not sell, but when combined with other product benefits it can strongly enhance business. On the upstream side, which addresses suppliers of materials, components and subassemblies for better environmental performance, activities should contribute to lowering the life cycle impact of goods brought to the market. So far, activities have been focusing on two items:

- ISO 14001 certification of suppliers. This is to make sure that they are well organized in the environmental field. Although continuous improvement is one of the elements of ISO 14001, certification is no guarantee that such improvements are really delivered.
- Making sure that supplied articles do not contain 'banned' substances. Often substance checklists and supplier certification (free of banned substances) has to do with legal requirements and as such can be characterized as being defensive rather than contributing to environmental progress.

A substantial widening of joint supplier-producer environmental activities is however justified by the mere fact that it is estimated that for electronic products suppliers activities contribute to 60-70% of the total environmental load (and value) in production - with the current trend of increased outsourcing of production of finished products. This percentage will mean even higher figures in the future. This figure gains further prominence if it is realized that a majority of the suppliers have so far shown little ambition in the environmental field and do not see the 'green' opportunity as part of their strategy. For instance a study of a couple of years ago (see ref. 6) showed that in Western Europe 70% of the suppliers of a leading electronic company did not have well established environmental policies.

In the present paper it will be explored what can be done to improve the situation as sketched above. To a large extent this will draw on experiences from inside the internal value chain of companies. In §2 it will be explored how the 'driver' and 'benefit' concept can be extended. In §3 joint road mapping will be explained as the key to success. In §4 and §5 examples of successful supplier-producer relationships will be given.

2. The driver and the benefits concepts

Understanding the drivers and benefits of 'green' supplier-producer relationships is a process which should help inform collaboration. A primary driver for such cooperation is the supply chain concept which is included in the five Eco management principles (see ref. 3).

Here the concept means that the parties involved – through collaboration – enable each other to improve overall environmental performance of the supply chain. The other four Eco management principles which include, thinking in terms of functionality instead of embodiments, frugality (doing more with less), life cycle thinking and paradigm shift (asking 'why are things as they are') can be operated independently and separately by each part of the value chain. But it will be clear that when operated jointly this will greatly contribute to the results.

When having grasped the Eco management principles it is important to understand the potential benefits for joint activity. This is important particularly because currently most joint environmental improvement is not identified upfront with lower costs, which currently dominates supplier relationships. On the contrary, there is still widespread fear and prejudice that environmental activities will add cost, in spite of the fact that several activities have demonstrated that they actually return money to the electronics industry. (see ref. 7).

Benefits of cooperating do more than just lower cost. Quality improvement (less rejects) and better image in the outside world should be considered as well.

External drivers to stimulate greening of the supply chain final customer requirements and (draft) legislation. As things stand now these are still underdeveloped and/or immature.

A good example of this is the draft Directive on Environmental Conformity of Electronic and Electrical Equipment (EEE) of the European Union.

Amidst a lot of other "essential requirements" – most of which are very ill defined – producers are asked to collect life cycle data from suppliers. As such there is nothing against it- what is measured is better managed. From the language in the EEE draft is it becoming clear that collection of the data is not meant for management purposes but to allow detailed 'life cycle analysis'. As will be shown in §3 this is not the beginning of joint processes but rather the end.

The absence of clear requirements for customers of final products and by legislation does not mean that these stakeholders group should be neglected. Benefits of supplier-producer cooperation should be delivered, either materially, immaterially or emotionally. Similar to the EcoDesign Matrix as discussed in ref. 1, the following Supply Chain Matrix is proposed to evaluate and prioritise proposals for joint environmental improvement.

Table 1 The Benefit matrix for 'green' supply chain cooperation

Benefit for Benefit category	Environment	Supplier	Producer	Customer	Society
Material	Lower environmental load	Lower cost price	Lower cost	Lower cost of ownership	Less consumption of resources
Immaterial	Overcoming prejudice and cynicism	Less rejects	Easier to manufacture	Convenience, fun	Better compliance
Emotion	Motivation of stockholders	Better image	Better image	Feel good, quality of life	Industry in on the right (green) track

This table shows that a multitude of aspects are considered. This multitude (and limited experience thus far) means that it is advised to start the process in meetings which are separate from the usual supplier. Producer con-

tacts, although the key individuals from the sales department of the supplier and the purchasing department from the producers, should remain the same. Environmental specialists should support the processes wherever they can but the very integration of environment into business (see ref. 1) requires that they do not take the lead.

3. Developing the 'green' supply chain agenda

In order to develop an adequate 'green' supply chain agenda it is crucial that the producer has an environmental vision and has environmental policies and roadmaps in place. In particular the roadmap which describes in details where the organisation stands, where it wants to go in a few years time and who is the 'owner' of the roadmap items. Due to their very tangible nature, environmental roadmaps transform all defined concepts such as "doing good for the environment" and "contributing to sustainability" into targets and processes, which can be managed and monitored. Joint roadmap items could include the following:

1. Organisational items
 - 1.1 Joint programmes (content)
 - 1.2 Defining responsibilities
 - 1.3 Deployment and managing the common processes
 - 1.4 Monitoring and corrective actions
2. Delivering performance
 - 2.1 Performance indicators
 - 2.2 Ensuring compliance
 - 2.3 Rewards and penalties
 - 2.4 Contracts
3. Enabling better product design
 - 3.1 Energy consumption (of final product)
 - 3.2 Material application (id)
 - 3.3 Chemical content and substances (id)
 - 3.4 Take back and recyclability
4. Manufacturing at suppliers
 - 4.1 Benchmarking and data acquisition
 - 4.2 Use of auxiliaries
 - 4.3 Use of utilities
 - Energy
 - Water
 - Other
 - 4.1 Waste, emissions
 - 4.2 Packaging and transport

Chapter 1 and 2 closely relate to usual management practices (be it that the wording environmental or 'green' has been added) and need no further elaboration.

For the product design items (chapter 3) 'enabling' nature is the prominent feature. In the field of energy consumption (3.1), alignment of component/subassembly development with printed wiring board/product development is the key element in the competence of the supplier is a success factor. In the materials department (3.2), application of recycled material plays an important role. Here the producer has to adapt product designs to enable the supplier to incorporate such materials. Chemical content and substances, item (3.3) "concerted transformation", are crucial both in terms of the logistics of change and of absorbing the extra cost involved in this.

Take back and recycle item require that the supplier is prepared to take back and upgrade materials originating from product defects from products discarded by consumers after use.

For chapter 4, "Manufacturing at suppliers", a benchmarking activity is of key importance. Benchmarking means that for different suppliers (of the same material, component or subassembly) physical parameters of environmental interest (like kWh, kg, % etc) are measured on a relative scale that relates to the net amount of articles

delivered. These measurements allow for the identification of best practices and to make these best practices communicable. This approach contrasts with a Life Cycle Analysis approach, which takes a holistic, specific environmental perspective and uses absolute ('environmental profiles') instead of relative terms. Apart from its complexity it uses language which is difficult to understand for non-experts and as such violates the principle that environment should be integrated into day-to-day practices.

4. Examples of successful 'green' Supply agendas I. Enabling better product design

Most examples given below relate to experiences by the author in his capacity as Senior Advisor of Philips Consumer Electronics.

In the fields of [energy consumption](#), the ambition to be among the best among global producers led to a close alignment of the roadmap targets with IC suppliers. This resulted in the following scores with respect to competitors' products with similar functionality and features.

Table 2 Energy consumption of products where joint supplier-producer roadmaps for ICs were implemented.

	Our product	Competitor 1	Competitor 2	Competitor 3
<i>Audio System</i>				
Operational energy (W)	35	37	37	
Standby energy (W)	2.1	4.6	4.6	
<i>Portable radio</i>				
	3.4	2.8	3.7	8.1
Operational energy on (W)	5.9	6.5	6.5	6.8
Operational energy off (W)	1.8	2.0	2.1	2.5
<i>32" TV</i>				
Operational energy (W)	132	150	157	
Standby energy (W)	0.3	1.5	1.9	
<i>Portable phone</i>				
Use/talk energy (W)	0.63	1.10	1.47	1.04
Standby energy (W)	8	14	11	9

[Recycled material](#) has been used now for several years in the interior parts of TVs. In order to allow for this, the design of the parts had to be adapted to the slightly inferior mechanical properties when applying such materials. Also the moulding procedures used by the suppliers had to be adapted. Application of recycled material for outer parts like housings turned out to be feasible when similar adaptations were applied. This effect did not work out in practice however because customer acceptance (quality perception) turned out to be low ('negative immaterial benefit', see §2). Joint efforts in the field of [chemical content and substances](#) focus on the following items:

- Lowering of the size of printed wiring boards and of the number of components on the pwbs by joint planning of more integrated ICs, see for details for instance ref. 1.
- Transformation from halogen-containing pwb materials to halogen-free. In high-end applications in TVs and monitors, transformation costs could be absorbed since the replacement materials were cheaper than the halogen containing ones. In low-end applications there are opportunities as well but much will depend on economies of scale and negotiation skills.
- Introduction of lead-free solders. Technically this is possible and the current roadmap plans complete elimination of lead containing solder by the end of 2004. However there is still a lot of hesitation particularly because environmental benefits are unclear and the outcomes of studies on the subject are diverging (depending on whether emissions, resources or potential toxicity is considered to be most important).

In the field of take-back and recyclability, 'take back in turn' items play a major role. This means that when producers buy certain amounts of materials or components, they are entitled to give back to the supplier a proportion of such amounts as a secondary stream. Such streams arise after treatment of factory rejects, transport damages or from products discarded by the consumer for which legislation makes the producer responsible. Currently the 'take back in turn' issue is hotly debated for Cathode Ray Tube glass (TVs, monitors) and engineering plastics like high impact Polystyrene and Polycarbonates. It may also emerge as an issue for components like electrolytic capacitors and Liquid Crystal Displays in the near future.

5. Examples of successful 'green' supply agendas II. Manufacturing at suppliers

Determining the environmental quality of suppliers has been pioneered by Lucent Technologies. Full details of the methodology applied are given in ref. 6, specific parts are addressed in refs. 7 and 8. The basis of this approach is to benchmark suppliers with regards to their performance in the following fields:

1. Material use ('substances' which are potentially toxic)
2. Use of auxiliary materials
3. Water use
4. Energy use
5. Emission to air, water
6. Waste
7. Packaging

In all cases scores are related to the output (weight or number of products produced). Where relevant, ratios are multiplied by a "quality ratio" which represents specific items (for instance use of lead, bromides, nickel, and organic solvents in lacquers in 1, use of ozone depleting chemical, organic solvents, water purification chemicals in 2 etc.).

In this paper two examples are cited from the references given above.

The first one is about the comparison of the four top-ranking suppliers of finished printed wiring board materials. In the table below their scores in the seven departments are given.

Table 3 Relative Environmental performance of four suppliers of finished printed wiring board materials (100 = best)

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
1. Material use	37	24	100	39
2. Use of auxiliary materials	30	35	82	100
3. Water use	25	18	100	4
4. Energy use	10	100	10	100
5. Emissions to air	100	67	<1	39
6. Waste	6	2	<1	100
7. Packaging	14	4	16	100

This table shows first of all that there are big differences among the suppliers - the application of the quality constants make this very obvious. No supplier scores best consistently which indicates what the most urgent area of improvement from a competition should be for each of them.

In all four cases the underlying effect of collecting data to calculate performance was that a broad awareness was successfully achieved. On top of that the principle of "what is measured is better managed" was fully applied – even without having data of the competition available improvement actions were initiated. Since, in all seven categories, environmental improvements almost correspond to cost reductions, the other managerial effect turned

out to be that suppliers discovered a new and effective tool for cost reduction.

Application of environmental benchmarking to a broader range of suppliers of printed wiring board materials yielded even more managerial insight.

Out of 25 suppliers invited to respond 4 were not prepared or incapable of providing the required information, which was a starter to review the supply relationship in its totality.

In 7 cases the materials balances constructed from the answers were way off balance showing serious flaws in data control.

Remediation of this has resulted (or will result) in substantial improvements including environmental ones.

In a further 5 cases some answers determined to be unlikely were consistently high (when compared with average scores). In this category the same items apply as those for the 'mass-balance' category.

Satisfactory answers were obtained in only 9 of the cases and similar processes such as those in the case of the four printed wiring board materials suppliers could be started.

This example of the printed boards suppliers shows that an approach which is primarily aimed at environmental improvement can have a much wider significance.

6. Conclusions

This study shows that widening and intensifying 'green' supplier / producer relationships can be beneficial for the environment but also can contribute to better management practices in general.

This conclusion both refers to Product Design (EcoDesign/ Design for Environment) and to Manufacturing. Cornerstones underlying the yield of a variety benefits are developing a common understanding of the drivers and issues, developing common product design roadmaps and programmes and environmental benchmarking of manufacturing operations.

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Fascinated by Applied Ecodesign**5.3.2 Environmental performance of production processes at Suppliers**

This subject has been recognized to be an important one from the very start of Applied EcoDesign. However, it took some five years before it was really addressed. Menno Nagel of Lucent Technologies did trailblazing work in this field in the period 1998 – 2003. We started working together to put his empiric result into a general framework for environmental performance measurement of production processes. On basis of this a methodology was developed to estimate both environmental and economic improvement potential.

With these quantifications, it is possible to bring up the issue in a well defined way into negotiations between suppliers and equipment manufacturers.

Lucent Technologies was so generous to allow Menno to publish results in the form of a dissertation. We discussed a lot about its content; Menno did not give up his views easily, neither did I. It was an intense intellectual fight in which we tested each other to the full. The outcome of this was a high level dissertation. I still disagree with parts of it, but in the Dutch Ph.D. system, showing capabilities to do research independently, is more important than agreement with the supervisor.

I had to hurry back from the USA for his defense was fixed shortly after Sept. 11, 2001 (see Cities, 1); I managed to do so, Menno did a successful defense and got his degree.

A glimpse of what has been achieved is in the following publication which is about *“Environmental Quality in the Supply Chain of an Original Equipment Manufacturer”*.

This example demonstrates again what is well known but not consistently practiced, especially in the environmental field: what is measured is also better managed.

Environmental Quality in the Supply Chain of an Original Equipment Manufacturer

A Discussion and Application of Environmental Performance Tools at Suppliers' Production Facilities from a Management Perspective

M.H. Nagel

Abstract

This paper approaches the supply chain from an Original Equipment Manufacturer's perspective as the requesting party in the scope of environmental quality. From the customer as well as the supplier's perspective, aspects as price, delivery, service, technology and quality play an ongoing role, while environmental quality is a new aspect. The existing environmental situation in the supply chain is discussed, like the use of environmental management systems, the notions environmental performance and green procurement and environmental quality in relation to cost structures of production facilities. A new environmental supply chain approach is introduced based on the eco-supplier development cycle, which embodies six steps. The activation and continuation of the cycle is executed with Environmental Performance Tools, which collect the supplier data and generate an environmental performance per supplier. The environmental performance expresses the total production behaviour of the supplier. Based on the environmental performance suppliers can be ranked, compared, classified etc. and a proposed price reduction can be derived. The linkage between an environmental performance and a proposed price reduction transfers environmental quality into a business perspective. In this scope the result of a worldwide assessment of 25 printed board production facilities is discussed and a conclusion is drawn.

Keywords: business, components, costs, electronics industry, environmental performance, environmental quality, ISO14000, management, products, supply chain

1. Introduction

A study of the environment of a company identifies customers, suppliers, competitors, shareholders, governments etc.. Several relationships exist between the company and all these entities. Within this setting, a company operates in terms of product sales, production, procurement, legislation etc. With respect to the customer-supplier relationship, this contains both sales and procurement aspects. In general, relationships are cornerstones of the global operating economic process, because this process can be described in terms of the sum of customer-supplier relationships. From the perspective of the customer as well as the supplier, aspects as price, delivery, service, technology and quality play an ongoing role, while environmental quality is a new aspect. This paper approaches the supplier or set of suppliers, the so-called supply chain from a customers' perspective as the requesting party in the scope of environmental quality, see Figure 1. Each company producing products or delivering services has its own set of suppliers. The set of suppliers of an Original Equipment Manufacturer (OEM) of telecommunication products differs from the supply chain of an automobile factory. The production of a telephone handset or a car has its own specific supply of different materials, components and subassemblies. Materials use is mostly linked to different groups of comparable suppliers. Analysis of a telephone handset, for example, will show that it contains electronic and mechanical components. Each component can be supplied through one or more suppliers.



Figure 1 Customer-supplier relationship

Management of the supply chain of an OEM is a complex activity because an average telecommunication product contains roughly 10 000 different components. Because the supply chain delivers these components, it should be approached from different viewpoints. The total purchase turnover should be as low as possible and the delivered components should have the appropriate quality level. In the scope of price, delivery, service, technology and

quality, suppliers should be ranked and classified in terms of good, insufficient or bad. Suppliers should be ranked and classified also in relation to environmental aspects [1]. This paper focuses on environmental aspects in the supply chain, which means that primarily the existing environmental activities in the supply chain will be discussed. Secondary, a new environmental-business oriented supply chain approach is outlined. Furthermore, a global application of this new relative approach in the printed board industry will be shown.

2. The Existing Situation in the Supply Chain

2.1 Introduction

The notion of environmental quality in general is driven from the environmental concern related to the human ecosphere. The quality of air, soil and water plays an ongoing role, as does the use of resources and energy. Currently, environmental concern is a reality in the society, which also results in attention to the supply chain of an OEM. Regarding the current supply chain of an OEM, many different components are procured and included in the products. Semiconductors, cables, printed boards, housings, capacitors and various types of subassemblies are required to assemble a telecommunication product. This diversity of components is produced in different kinds of processes. These components are a sum of base materials. The raw materials are procured through a supplier of the supplier. In some cases, like copper, the next chain can be outlined: copper extraction, pure copper production, lead-frame production for semiconductor devices and lead-frame preparation before use. Several customer-supplier relationships exist in this chain, see Figure 2. Environmental quality plays a role in each customer-supplier relationship. For example, supplier S_2 is the customer for supplier S_5 . The whole supply chain of an OEM contains the suppliers S_1 through S_{11} , i.e. from raw-material extraction to the produced components. Regarding the current supply chain approaches of OEMs, the contacts with the supply chain are limited mostly to the first tier of suppliers, i.e. S_1 to S_4 .

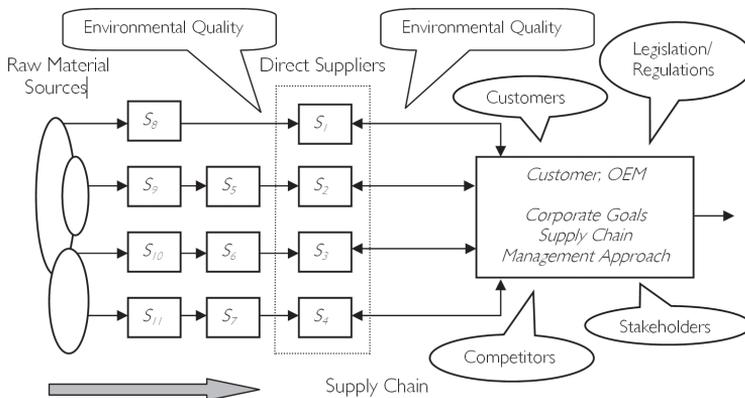


Figure 2 The supply chain as a sum of customer-supplier relationships

The introduction of the concept of environmental quality in the OEM's direct supply chain, S_1 through S_4 , shows a large opportunity from an environmental-business perspective because the environmental load of a supplier's production facility can be linked to a proposed price reduction on the purchase turnover. Suppliers S_1 through S_4 generate environmental load in their different production processes, as well as the suppliers deeper in the chain. Each process step in the chain produces solid and liquid waste, air emissions and components, and each process step needs energy, auxiliary compounds, water, raw materials and/or subcomponents. Each produced component can contain environmentally relevant substances or can use too much energy or can be non-recyclable. The introduction of the concept of environmental quality to each customer-supplier relationship in the chain offers an environmental-business opportunity when the suppliers' environmental performances are measured and integrated into the suppliers' negotiations. This paper focuses on the environmental quality of processing methods for components in the supply chain.

2.2 Environmental Management Systems, ISO14000 Series of Standards and Eco-Management and Audit Scheme (EMAS)

A model of an environmental management system is outlined by an International Standardization Organization (ISO) approach, see Figure 3. The ISO14000 series of standard has been established with respect to environmental management systems. Standards ISO14001 is central to the framework of the ISO14000 series of standard. ISO14001 contains the basic requirements for an environmental management system [2]. When, for instance, senior management of a globally operating semiconductor supplier decides to introduce an environmental management system in each of its eight waferfabs across the world, the process can be started from the ISO model with the initial principle, *commitment and policy*, see Figure 3. Once initiated, the process can be followed by principles such as *planning*, *implementation*, *measurement and evaluation* and *review and improve*. Based on the ISO approach, the element of continual improvement should be leading.

Following the realization of an environmental management system in each waferfab and by executing the five mentioned ISO principles, the result will be that each waferfab can show its ISO14001 certified environmental management system to customers, governments etc. From an OEM's supply chain management perspective all the suppliers' waferfabs have an ISO14001 certified environmental management system in place, but they are different when compared in depth because terms like environmental performance, environmental impact, continual improvement etc. have been measured, interpreted and implemented in different ways. This emphasizes that when all the suppliers' facilities of an OEM have an environmental management system in place, this does not mean that they have the same *metrics*. This teaches that supplier selection, qualification, ranking and comparison based on an ISO14001 environmental management system does not make sense. Many suppliers are currently working towards an environmental management system, which will be certified according to ISO14001. To have such a certified system in place will distinguish them from others, who do not have such a system in place. However, within a period of 5 years each production facility in an OEM's supply chain round the globe will be certified according to ISO14001, from a totally different content of the five principles. This paper describes the *metrics* for determining the environmental performance of comparable production processes of different suppliers from the operational analysis of production facilities. When numerical environmental performances of suppliers' production facilities are available, the fourth step in the ISO model, measurement and evaluation and the concept of continual improvement becomes measurable from a supply chain management perspective. Based on environmental performance suppliers can be selected, qualified and benchmarked and the concept of continual improvement gets value.

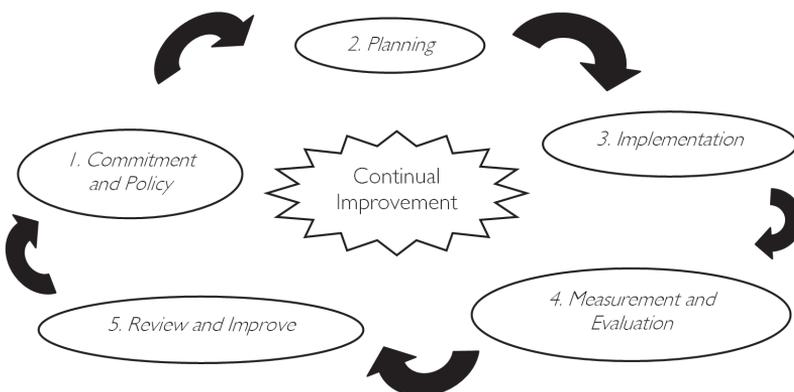


Figure 3 ISO model of an environmental management system

Eco-Management and Audit Scheme (EMAS) exist alongside the ISO14000 series of standard [3]. The history of the Eco-Management and Audit Scheme has been closely linked with that of the ISO14000 standard. This standard will also play a minimum role within the scope of supply chain management. Another aspect, which is

not covered by an EMAS or an ISO 14001 environmental management system, is the environmental quality of the delivered product. The mass, energy use, environmentally relevant substances, recyclability, recycled content, and quantity of substances of a delivered product, which represents the environmental quality, is not addressed by the five mentioned ISO principles.

2.3 Environmental Performance and Green Procurement

With respect to environmental performance in the supply chain, Sun Microsystems, Inc. has started to integrate environmental considerations into its supplier management process [4]. The main impetus was to develop a capability to respond to customer inquiries on environmental aspects of the company and its products. Another impetus was the measurement of the use of ozone-depleting substances in the suppliers' product manufacturing processes. These direct impetuses form the basis to adjust the supply chain, but *not from an own supply chain strategy*. These two issues received the greatest attention, but also provided an avenue to initiate a longer-term discussion regarding whether, and how, supplier performance with respect to environmental issues could be addressed. Many ideas are circulating in relation to supply chain aspects, like the development of environmental questionnaires [5, 6]. The questionnaires have been focused on obtaining compliance and mostly contain questions relating to the availability of an environmental policy and product design, and nothing more. Examples are:

- Does the facility/corporation have a written environmental policy statement?
- Does the facility have written environmental performance objectives/targets and implementation plans to reduce costs or risks?
- Does your product contain lead?

Furthermore, notions of "green purchasing" and "green procurement" are circulating, but nobody has outlined this in depth and specified the notion of "greenness" related to suppliers [7]. In most cases, green procurement is linked to a large variety of product and process aspects of the supplier. These aspects are: eco-labels, the avoidance of environmentally relevant substances, energy use, use of recycled materials, product mass, re-usability of some parts, recyclability, the use of environmental management systems and the application of Design for Environment (DfE) or Life Cycle Assessment (LCA). Green procurement is embodied by supplier questionnaires related to the mentioned aspects. In practice it means that one or more questions have been defined per aspect. Some questions are open, but others enable the supplier to respond with "yes" or "no". In general, green procurement can be described as several short-term actions, driven from the OEM to the direct supplier, which are activated by drivers from outside the company, such as customers, competitors, laws, regulations and directives. When an OEM influences its supply chain from the external driver, it shows a defensive supply chain approach, not based on vision, strategy, innovation and leadership of the company. The OEM's green procurement approach is to be compliant with customers, laws and regulations because non-compliance is a threat to the business.

2.4 Environment Quality in relation to Costs

The production of electrical energy results in the emission of CO₂ and acid compounds such as NO_x and SO₂. A minimization of energy use results in the minimization of CO₂ ejection and a minimization of the greenhouse effect, while minimization of material use results in less dissipation. The supply chain can be divided into printed boards, capacitors, coils etc. The production of these components needs energy, materials and water and produces waste. This shows that the supply chain can be approached from both an environmental and an economic perspective. It also shows that an internal driver can operate alongside the external environmental driver. Within the scope of supply chain management, an internal driver is defined as a driver which is not triggered by external sources like legislation, customers, competitors or stakeholders, but by supply chain goals such as cost reductions linked to environmental improvements and vice versa. See for instance, the costs for of energy use for heat and power by eight selected sectors in the electronics industry in the United States of America (USA) during 1991 in Table 1 [1,27].

Table 1 Energy costs in the electronics industry in the USA, during 1991

Total Supply Chain of OEMs	Costs (million \$) Fuel/Electrical Energy	Costs (million \$) Electrical Energy	Costs (million \$) Fuel
1 Printed Boards	126.8	103.8	23
2 Semiconductors	467.3	420.7	46.6
3 Capacitors	33.1	28.7	4.4
4 Resistors	14.8	12.9	1.9
5 Coils and Transformers	10.5	8.6	1.9
6 Connectors	46.8	39.9	6.9
7 Other Electronic Components	186.6	158.6	28
8 Original Equipment	338	304.8	33.2

The sector original equipment in Table 1 contains computers, computer storage equipment, terminals, peripheral equipment, office machines and calculating and accounting equipment. "Other electronic components", is a sector that includes crystals, filters, switches, piezoelectric devices, microwave components and printed board assemblies. Table 1 shows the *energy costs of the suppliers* of the OEMs. The sectors, printed boards, semiconductors and original equipment have the highest energy costs. These energy costs influence the selling prices of the components and products. The main part of the energy costs is related to the electrical energy. When the energy costs per produced component in the supply chain are managed, environmental quality is linked to a business perspective. The *material use in the supply chain* is another element, which can be influenced from a supply chain approach. When, for example, wafer production process needs 100 kilograms silicon per hour and produces 75 kilograms wafer per hour, what has happened to the 25 kilograms silicon? When this mass of silicon is scrapped, this means no efficiency with respect to use of resources. An efficient use of material resources is coupled to the cost price and the selling price of a component or material. When the material costs per produced component can be reduced, environmental quality is linked to the business perspective too. The management of the necessary materials per kilogram produced product constitutes an opportunity, along with the necessary quantity of water and auxiliary compounds per kilogram produced component. The use of materials, auxiliary compounds, water, energy and packing materials determines a part of the cost structure of each production facility, as well as the costs for solid and liquid waste handling and for measuring air emissions. Minimizing this use will decrease the environmental load and the cost structure on the long term.

3. An Environmental Supply Chain Approach

3.1 Introduction

The management of environmental quality in the supply chain can be driven from own corporate goals or from customers, competitors and/or legislation. Customers, competitors, stakeholders, legislation are external drivers for a company, while the corporate goals are internal drivers, like realization of cost savings from an environmental perspective. When a customer of an OEM has specific questions relating to the material content of the delivered product, the questions should be answered directly or when for instance, the use of chromium in products is forbidden in Europe, the OEM should take action immediately. When the OEM carries out activities in compliance with its customer's request, and complies with the legislation, but does not study the backgrounds of these requests and laws, the OEM puts itself in a reactive position. A reactive mode involves what one has been asked to do and nothing more. The choice for such a mode does not require an own strategy or approach. Independent of customer questions, regulations and laws, but linked to corporate goals, the above major question relating to the material content of products can be the trigger for a company to develop an environmental business strategy. To have in place an own environmental business strategy means to operate from an offensive leading position, see Figure 4. An environmental supply chain strategy, a product strategy and a marketing strategy can be derived from a company's environmental business strategy. The linkages between costs and environmental impact should be a leading element in these strategies. Because the material content of the OEM's products is mainly determined by the supply chain, it emphasises that a supply chain approach is necessary. The new environmental supply chain

approach was developed from the concept of life cycle thinking, with a focus on direct suppliers' production processes.

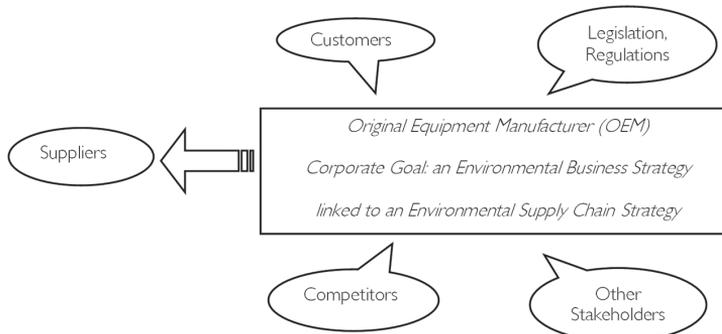


Figure 4 An environmental supply chain strategy is linked to a corporate goal

When the production processes of suppliers are comparable, the environmental load per kilogram produced component is also comparable. For instance, supplier A and B produce comparable printed boards. Supplier A uses 5 kilogram base materials and supplier B uses 7 kilogram base materials for 1 kilogram printed board. Comparison of A and B shows that supplier A has a better environmental performance than supplier B. This also means that supplier A has lower costs for the base materials and less solid waste. Less solid waste results in less waste handling costs. Production processes in general use materials, auxiliary compounds, water, energy and packing materials to transport the product to the customer, and generate air emissions and solid and liquid waste. These seven environmental load elements determine the environmental performance of supplier's production facility. These environmental load elements form the basis for a supply chain management model or Environmental Performance Tool. The generated environmental load of 1 kg component by the use of materials, auxiliary compounds, water, energy and packing materials etc. is inversely proportional to environmental performance, which is general expressed by (1).

$$E_{P_SUPPLIER} \propto \frac{1}{E_L} \quad (1)$$

Based on an environmental performance per supplier, suppliers can be managed because an environmental performance is a measurable tangible. The supplier management problem is determined by a lack of Environmental Performance Tools. Without the application of Environmental Performance Tools it is impossible to determine the environmental performance of a supplier's production facility, which means the supply chain policy cannot be executed and the supply chain strategy has no content. An Environmental Performance Tool for supplier assessments should contain two parts:

- A set of specified questions related to the use of materials, auxiliary compounds, water, energy, packing materials, air emissions and waste, the so-called data collection process related to the seven environmental load elements.
- A model, which generates a numerical environmental performance value.

When an environmental performance per supplier is available, suppliers can be ranked, classified in terms of good or bad and development from bad to good. Based on environmental performance, a linkage to the supplier's purchase turnover can be made, which results in a proposed price reduction. Environmental quality can only be integrated into the supply chain based on the supplier's environmental performance *and* the linkage to the purchase turnover. Proposed price reductions linked to bad environmental performances trigger suppliers to improve themselves competitively. Without this linkage, the supply chain policy will receive no content from a business perspective.

Supplier development from an environmental perspective is defined as eco-supplier development, which is based on continual improvement. Eco-supplier development suggests two or more different measurable environmental situations of a supplier and the method of changing from environmental situation A to environmental situation B, see Figure 5. The challenge for the OEM is *how* to activate suppliers in such a way that they initiate innovations in their processes and components from an environmental business perspective, which results in a reduction of the environmental load for the existing chain.

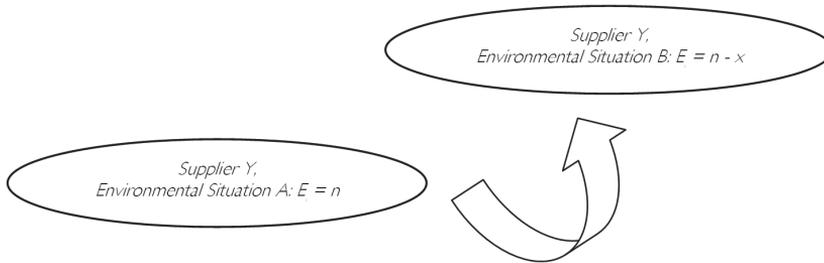


Figure 5 Eco-supplier development

Figure 5 determines environmental situation A for supplier Y with $E_L = n$, while the environmental load in environmental situation B has been decreased by x until $E_L = n - x$. Eco-supplier development is a core competence in a supply chain policy and creates a supply chain management approach. Eco-supplier development should be integrated into the supplier development cycle, which also exists for elements such as quality etc. The eco-supplier development cycle embodies six steps, see Figure 6. The first step is the execution of supplier measurements. Environmental performances per supplier can be calculated and compared from these measurements, which activities represent the second and third steps. Based on the environmental performance proposed price reductions relating to the supplier's purchase turnover can be determined and negotiated with the supplier, see fourth step. This linkage puts environmental quality in the scope of a business perspective and results in an agreed price reduction, after negotiation, see fifth step. When the supplier has been classified as very bad and the proposed price reduction is 10% the primary intention is not to cut off the business with the supplier, but to realize an agreed price reduction and on the basis of this to support the supplier with an eco-supplier development plan. Such a plan contains actions for improvement, such as reducing energy consumption by 5% at the same production level, see sixth step. The execution of an eco-supplier development plan is the supplier's responsibility. After, 3 or 4 years, for example, the supplier will be measured again and compared with its competitors. *The essence of the eco-supplier development cycle is to realize environmental improvements by price incentives in the scope of continual improvement.* The activation and continuation of the eco-supplier development cycle cannot take place without Environmental Performance Tools.

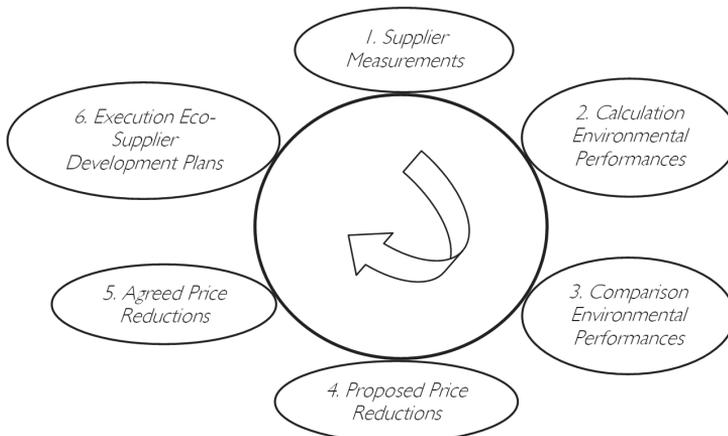


Figure 6 Eco-supplier development cycle

3.2 Environmental Process Modeling based on the Relative Approach

The contribution to the environmental load of a production process can be approached from the absolute and the relative approach. The absolute approach makes a direct linkage to environmental effects, like ozone depletion, greenhouse effect etc, while the relative approach assumes that a minimum use of materials, water, energy etc. always delivers an environmental benefit. From the relative approach a random supplier's production process has five different input flows and three different output flows, see Figure 7. The five input flows are the quantity of base materials used, m_t , the quantity of auxiliary compounds used, m_{ac} , the volume of water used, U_w , the amount of energy used E , and the quantity of packing materials used, P_m . The undesired output flows are air emissions, E_m , and the total amount of solid and liquid wastes, W_t . The desired output flow is the mass of manufactured products or components, m_{pcc} . All these input and output flows are a function of time. These input and output flows are defined as follows:

1. Input flow of base materials: The desired component is produced from these materials for sale to the customer.
2. Input flow of auxiliary compounds: These chemical compounds are necessary to produce the desired component, but are not included in the component.
3. Input flow of water: Water in combination with chemical compounds is necessary to produce the desired component, but is not included in the component.
4. Input flow of energy: Energy is necessary to produce the desired component.
5. Output flow of air emissions: The production of the desired component generates an undesired flow of air emissions.
6. Output flow of waste: The production of the desired component generates a liquid and solid waste flow of water, chemical compounds, metals, plastics and paper etc.
7. Input flow of packing materials: These packing materials are used to transport the produced component from the production facility to the customer.

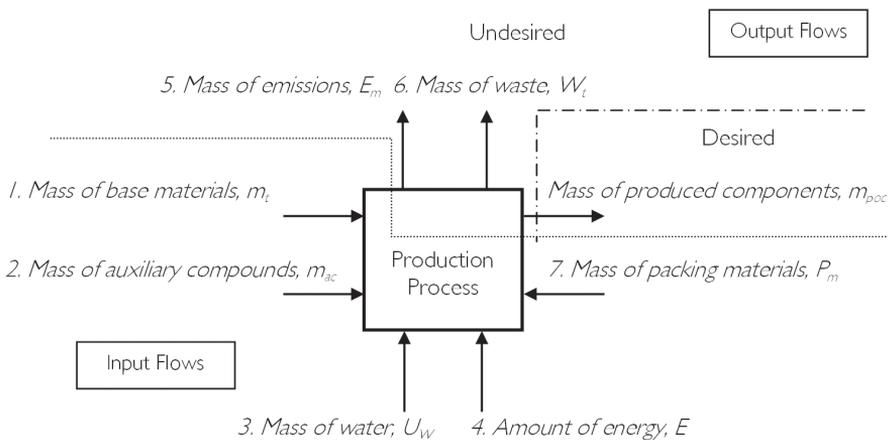


Figure 7 Environmental balance production process

The rate of production depends on the rates of the use of materials, auxiliary compounds, water and energy, while the generated waste and air emissions per unit time are also linked to the production rate. The production rate, R_p , and its relations to the other flows per unit time can be expressed by equations (2) to (8).

$$\text{production rate : } R_p = \frac{dm_{poc}}{dt} = I_1 \cdot k_1 \cdot \frac{dm_t}{dt} \quad (2),$$

$$R_p = I_2 \cdot k_2 \cdot \frac{dm_{ac}}{dt} \quad (3), \quad R_p = I_3 \cdot k_3 \cdot \frac{dU_w}{dt} \quad (4), \quad R_p = I_4 \cdot k_4 \cdot \frac{dE}{dt} \quad (5),$$

$$R_p = I_5 \cdot k_5 \cdot \frac{dE_m}{dt} \quad (6), \quad R_p = I_6 \cdot k_6 \cdot \frac{dW_t}{dt} \quad (7), \quad R_p = I_7 \cdot k_7 \cdot \frac{dP_m}{dt} \quad (8)$$

In these equations, I_1 to I_7 are defined as the environmental indicators, while k_1 to k_7 are constants, during a fixed time period. The definition, dimension and determination of a constant depend on environmental research from a life cycle perspective. The percentage of bromides in the resin of a laminate, for example, can determine k_1 and thus influence environmental indicator I_1 . For a time period, Δt , the equations (2) to (8) can be rewritten, through integration. The result is equations (9) to (15), which show a linear system. The mass of produced products or components, m_{poc} , during a time period Δt , is described by seven linear equations. Each equation shows a multiplication of environmental indicator I and an environment load element m_t , m_{ac} , U_w , E , E_m , W_t and P_m . Environmental indicators, I_1 , I_2 , I_3 , I_4 and I_7 are defined as output-input indicators, while I_5 and I_6 are defined as output-output indicators. The environmental output-input indicators describe the relation between the produced output, m_{poc} , and the input flows. The environmental output-output indicators describe the relation between the produced output, m_{poc} , and the other output flows. The linear system of (9) to (15) can be transferred to a matrix and two vectors, which is expressed by (16). Component vector, P , of a produced mass of components, during period Δt , can be described by multiplying an environmental load matrix, E_{LM} , of the produced mass, and an environmental performance vector, E_p , of the produced mass.

$$m_{poc} = I_1 \cdot k_1 \cdot m_t \quad \text{or} \quad I_1 = k_1 \cdot \frac{m_{poc}}{m_t} \quad (9)$$

$$m_{poc} = I_2 \cdot k_2 \cdot m_{ac} \quad \text{or} \quad I_2 = k_2 \cdot \frac{m_{poc}}{m_{ac}} \quad (10)$$

$$m_{poc} = I_3 \cdot k_3 \cdot U_w \quad \text{or} \quad I_3 = k_3 \cdot \frac{m_{poc}}{U_w} \quad (11)$$

$$m_{poc} = I_4 \cdot k_4 \cdot E \quad \text{or} \quad I_4 = k_4 \cdot \frac{m_{pb}}{E} \quad (12)$$

$$m_{poc} = I_5 \cdot k_5 \cdot E_m \quad \text{or} \quad I_5 = k_5 \cdot \frac{m_{poc}}{E_m} \quad (13)$$

$$m_{poc} = I_6 \cdot k_6 \cdot W_t \quad \text{or} \quad I_6 = k_6 \cdot \frac{m_{poc}}{W_t} \quad (14)$$

$$m_{poc} = I_7 \cdot k_7 \cdot P_m \quad \text{or} \quad I_7 = k_7 \cdot \frac{m_{poc}}{P_m} \quad (15)$$

$$E_{LM} \cdot E_p = P \quad (16)$$

The vector, E_p , represents the environmental performance of a mass of produced components, m_{poc} , during a period of time Δt and contains the seven environmental indicators I_1 to I_7 . The operating ranges of the environmental indicators I_1 to I_7 , the environmental performance vector, as a function of time, gives an environmental impression of the produced mass of products or components. The higher the ratios between the produced mass of products or components, m_{poc} , and the number of environmental load elements, the more efficient the production will be. This means in theory, that the environmental indicators I_1 to I_7 will operate between $0 \leq I_1, I_2, I_3, I_4, I_5, I_6, I_7 \leq \infty$, when $k_1, k_2, k_3, k_4, k_5, k_6, k_7 \geq 0$.

Regarding the vector, E_p , in (16) the measured environmental indicators I_1 to I_7 should be compared with environmental reference indicators I_{1R} to I_{7R} , the 'best practices'. When in practice the reference indicators I_{1R} to I_{7R} are chosen so that $I_{1R}, I_{2R}, \dots, I_{7R} > I_1, I_2, \dots, I_7$, the ratios x_1 to x_7 between the measured and the reference indicators vary between $0 \leq x_1, x_2, x_3, x_4, x_5, x_6, x_7 \leq 1$. This results in expression (17).

$$x_n = \frac{I_n}{I_{nR}} \quad \text{for } n = 1, 2, 3, 4, 5, 6, 7 \quad \text{and} \quad 0 \leq x_n \leq 1 \quad (17)$$

The vector, E_p , can also be based on the ratios x_1 to x_7 , see equation (18). When x_1 to x_7 are equal to 1, the norm of environmental performance vector, $\|E_p\|$, becomes 7, which represents the best performance value in terms of best practices. When x_1 to x_7 are equal to 0, the norm of the environmental performance vector, $\|E_p\|$, becomes 0, which represents the worst performance value in terms of best practices. A normalized environmental performance vector, E_{PN} is shown in equation (19). The property of this vector is that its norm, $\|E_{PN}\|$, is equal to 1, when x_1 to x_7 are equal to 1. The normalized environmental performance, $\|E_{PN}\|$, can be determined from equation (19), see equation (20). When expression (17) has been filled in equation (20), equation (21) exists. Here, each measured indicator I_1 to I_7 is compared with its reference indicator I_{1R} to I_{7R} .

$$E_p = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \end{bmatrix} \quad (18) \quad E_{PN} = \frac{1}{\sqrt{7}} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \end{bmatrix} \quad (19)$$

$$\|E_{PN}\| = \sqrt{\frac{1}{7} \cdot \{x_1^2 + x_2^2 + x_3^2 + x_4^2 + x_5^2 + x_6^2 + x_7^2\}} \quad (20)$$

$$\|E_{PN}\| = \sqrt{\frac{1}{7} \cdot \left\{ \left[\frac{I_1}{I_{1R}} \right]^2 + \left[\frac{I_2}{I_{2R}} \right]^2 + \left[\frac{I_3}{I_{3R}} \right]^2 + \left[\frac{I_4}{I_{4R}} \right]^2 + \left[\frac{I_5}{I_{5R}} \right]^2 + \left[\frac{I_6}{I_{6R}} \right]^2 + \left[\frac{I_7}{I_{7R}} \right]^2 \right\}} \quad (21)$$

In expression (20) each ratio x_n has the same environmental weighting. This means in theory that each ratio x_n is multiplied by $1/7$. But in practice it means that the consumption of materials is equal to the consumption of auxiliary compounds, water, energy etc. from an environmental perspective. Application of the same environmental weighting indirectly implies application of a quality approach, which means that the consumption of materials, auxiliary compounds, water, energy and packing materials and the generation of air emissions and waste should be equal to the established *perfect* reference indicators I_{1R} to I_{7R} . If $I_1 = I_{1R}, I_2 = I_{2R}, \dots, I_7 = I_{7R}$, the $\|E_{PN}\| = 1$, which represents the best performance value is 1. The operating range of the normalized environmental performance is given by (22). The operating range of $\|E_{PN}\|$ offers a simple solution with respect to supplier classification.

$$0 \leq \|E_{PN}\| \leq 1 \quad (22)$$

The $\|E_{PN}\|$ can be applied to the supply chain of an OEM. $\|E_{PN}\|$ expresses the environmental performance of a mass of produced components in a production facility during a period of time. When for instance, 25 printed board suppliers are assessed by means of a data collection process for each environmental load element, and the answers provide the information that allow a normalized performance to be determined, the suppliers can be benchmarked and classified in an easy and understandable way. Table 2 contains an example of classification of suppliers. If, for instance, the deviation of the assessed supplier, i.e. environmental indicators I_1 to I_7 , is less than 10% of the reference indicators, the supplier is classified as E1. This means that $\|E_{PN}\|$ operates between 0.9 and 1. In such a way, each $\|E_{PN}\|$ of a supplier can be redirected to an E-level and classified as good, sufficient, insufficient, bad and very bad.

Table 2 Classification of supply chain

Classification Supply Chain			
#	Environmental Indicators I_1 to I_7	$\ E_{PN}\ $	E-levels
1	0 to 10% deviation of I_{1R} to I_{7R}	0.9 - 1	0.9 < E1 ≤ 1, good
2	10 to 20% deviation of I_{1R} to I_{7R}	0.8 - 0.9	0.8 < E2 ≤ 0.9, sufficient
3	20 to 30% deviation of I_{1R} to I_{7R}	0.7 - 0.8	0.7 < E3 ≤ 0.8, insufficient
4	30 to 40% deviation of I_{1R} to I_{7R}	0.6 - 0.7	0.6 < E4 ≤ 0.7, bad
5	Larger than 40% deviation of I_{1R} to I_{7R}	0 - 0.6	E5 ≤ 0.6, very bad

4. A global Application of an Environmental Performance Tool based on the Relative Approach in the Printed Board Industry

Based on an Environmental Performance Tool a global implementation of environmental quality in the OEM's printed board supply chain has been applied. The objective of this step is to establish normalized environmental performances for several printed board suppliers. In this scope, 25 suppliers' production facilities, A_1 through A_{25} , were selected for the execution of environmental assessments. These facilities are located in different regions around the globe and produce different kinds of printed boards. These 25 suppliers' production facilities were assessed with the aid of a well organized procedure. These suppliers have answered the questions in the so-called data collection process of the Environmental Performance Tool related to the seven environmental load elements.

The well organized procedure yielded a 100% result as *all* suppliers responded. Based on the procedure, supplier A_{13} has been classified as very bad, which means the environmental indicators I_1 through I_7 will be established as 0, the normalized environmental performance becomes 0 and the proposed price reduction in the negotiations will be 10%. Supplier A_{22} exhibited comparable behaviour. Supplier A_{22} has also been classified as very bad and the proposed price reduction will also be 10%. Neither suppliers exhibit supportive behaviour. The other suppliers did respond to the questions of the data collection process. A study of the answers identifies inconsistencies in delivered supplier data. This means that some answers are not given or are unreliable. Different answers contradict each other in some cases. Another aspect is that some suppliers did not read the explanation of the data collection process carefully. The mass balance provides insight into the suppliers' self-management behaviour. The mass balance per supplier exhibits an initial impression of the inconsistency. In this case independent of the inconsistency, the answers delivered were used to calculate indicators I_1 to I_7 for each facility.

Table 3 Calculated normalized environmental performances of assessed suppliers

#	$\ E_{PN}\ $	Proposed Price Reduction PPR	Classification	Region	Difference Δ (%)
Supplier A ₁	0.3	7% of PT _s	E5: very bad	USA	+35.1
Supplier A ₂	0.41	5.9% of PT _s	E5: very bad	USA	+18.3
Supplier A ₃	0.39	6.1% of PT _s	E5: very bad	USA	+27.2
Supplier A ₄	0.29	7.1% of PT _s	E5: very bad	Asia	+23
Supplier A ₅	0.49	5.1% of PT _s	E5: very bad	USA	-1.1
Supplier A ₆	0.24	7.6% of PT _s	E5: very bad	USA	+11.1
Supplier A ₇	0.35	6.5% of PT _s	E5: very bad	Canada	+31.4
Supplier A ₈	0.32	6.8% of PT _s	E5: very bad	Europe	-5.1
Supplier A ₉	0.23	7.7% of PT _s	E5: very bad	Europe	+15.5
Supplier A ₁₀	0.2	8% of PT _s	E5: very bad	Europe	-22.9
Supplier A ₁₁	0.07	9.3% of PT _s	E5: very bad	USA	+2.9
Supplier A ₁₂	0.66	3.4% of PT _s	E4: bad	USA	+0.1
Supplier A ₁₃	0	10% of PT _s	E5: very bad	USA	-
Supplier A ₁₄	0.41	5.9% of PT _s	E5: very bad	Europe	+13.3
Supplier A ₁₅	0.46	5.4% of PT _s	E5: very bad	USA	+0.7
Supplier A ₁₆	0.43	5.7% of PT _s	E5: very bad	USA	-2.8
Supplier A ₁₇	0.62	3.8% of PT _s	E4: bad	USA	-89.8
Supplier A ₁₈	0.64	3.6% of PT _s	E4: bad	USA	+36.3
Supplier A ₁₉	0.4	6% of PT _s	E5: very bad	USA	-2.1
Supplier A ₂₀	0.46	5.4% of PT _s	E5: very bad	Europe	-33.3
Supplier A ₂₁	0.34	6.6% of PT _s	E5: very bad	Europe	+24.8
Supplier A ₂₂	0	10% of PT _s	E5: very bad	Asia	-
Supplier A ₂₃	0.38	6.2% of PT _s	E5: very bad	Asia	+48.3
Supplier A ₂₄	0.37	6.3% of PT _s	E5: very bad	Asia	+20.5
Supplier A ₂₅	0.53	4.7% of PT _s	E5: very bad	Europe	-98

Based on a set of selected reference indicators, which have been provided by the suppliers A₁₆ (I_{1R}), A₂₅ (I_{2R}, I_{7R}), A₂₃ (I_{3R}), A₂₀ (I_{4R}) and A₁₈ (I_{5R}, I_{6R}) the calculated normalized environmental performances vary between 0 and 0.66, see Table 3. Supplier A₁₂ has the highest performance, followed by suppliers A₁₈ and A₁₇. The other suppliers have performances, that vary between 0 and 0.53. Within this range, suppliers A₁₁, A₁₃ and A₂₂ have the lowest performances, while supplier A₂₅ has the highest. But all these suppliers exhibit more than 40% deviation from the reference indicators. When the suppliers are ranked, as shown in the Table 2, all suppliers with exception of A₁₂, A₁₇ and A₁₈ are classified as very bad, i.e. level E5. Suppliers A₁₂, A₁₇ and A₁₈ exhibit 34%, 38% and 36% deviation from the reference indicators respectively, which means a classification of bad, i.e. level E4. None of the suppliers can be classified as sufficient or good. These performances determine "environmental situation A" of the supply base,

see for instance Figure 5. Furthermore, normalized environmental performance can be integrated into the business by a link to a proposed price reduction. The result is that the supplier with the lowest performance receives the highest proposed price reduction of purchase turnover per supplier's facility (PT_s), see suppliers A_{10} , A_{11} , A_{13} and A_{22} . *From a business perspective the five suppliers' facilities, which can deliver the highest cost savings should have the first attention in the scope of the eco-supplier development cycle, see Figure 6.* After an agreed price reduction with the supplier, a required "environmental situation B" can be established and eco-supplier development plans can be developed. The last column of Table 3 shows the "quality" of the mass balance of the suppliers. When a measure of inaccuracy is accepted within the range of -15% to +15%, only suppliers A_5 , A_6 , A_8 , A_{11} , A_{12} , A_{14} , A_{15} , A_{16} and A_{19} have a correct mass balance.

5. Conclusion

This paper has shown that environmental quality can be integrated into the existing supply chain of an OEM by the use of an Environmental Performance Tool. Application of this Environmental Performance Tool has shown that suppliers can be ranked, classified and compared on the basis of an environmental performance and proposed price reductions can be derived and used in the supplier negotiations. It also shows however, that only nine of the 25 assessed printed board facilities know what their mass balance is. So the added strength of this Environmental Performance Tool is that the accuracy of the supplier data can be checked. In this case, the environmental indicators and the normalized environmental performance were calculated independent of inaccuracies in supplier data. Inaccuracies in the data do not constitute a reason for not calculating the environmental indicators and the normalized environmental performance. Inaccuracies in data will be eliminated when the eco-supplier development cycle is activated and continued, see Figure 6. In the future, the business impact in terms of proposed price reductions can be expanded widely when suppliers deliver inaccurate data. In this case, it means that sixteen printed board facilities have no insight into their mass balance, which should result in a normalized environmental performance of 0, a proposed price reduction of 10% and classification of very bad. The normalized environmental performances can be calculated and compared for the other nine printed board facilities, and proposed price reductions can be derived.

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Green Marketing

From the very start of EcoDesign and 'green' marketing have been big issues. Contrary to the results of a lot of opinion research, where a fair majority of consumers claimed to be interested in buying 'green', actual practice showed only limited success for environmentally friendly products. It was a niche market at best.

A lot of communication styles have been tried: from sentiment about flowers, butterflies and smiling (or pitiful) seals up to doom and gloom, from 'education of the consumer' to communication of LCA scores, from green labels to telling that a 'green lifestyle' is better. None of them have worked.

For Philips Electronics in the year 2000 it was time to dig deeper into this issue. The first 'Green Flagship' products, which were significantly greener than comparable products from the competition (and standard products of the own brand), were developed. Several questions arose: how to present them to the market in a positive way, how to circumvent prejudice that 'green' products were more expensive or had less quality, how to avoid being seen as a 'green' freaky company?

Leads for the answers came from a combination of earlier internal research results and the work of Jacqueline Ottman, the green marketing 'guru' in the USA.

When these insights were put together it was concluded that individuals split 'green' experiences into two parts:

- *A collective one: societal 'green' scores high, so people give 'politically correct' answers when asked about the environment in general and 'green' products in particular.*
- *An individual one: here only approx. 25% of the public is prepared to change lifestyle to become greener. For some 50% 'green' is only regarded as nice to have. In this case the conditions established that there are no further material or immaterial consequences. For some 25% of the public 'green' is negative anyway you look at it.*

In chapter 5.4 these archetypes of 'green' consumer behavior are further detailed.

When buying products, people expect 'benefits' from the purchase. Providing 'green' benefits is not enough for most people. The analysis above shows that if the 50% of the public for which 'green is just nice to have' can be given a 'benefit' alongside 'green', or if 'green' is put into a wider benefit package, this will build a majority of buyers interested in 'green' products!

5.4 'Green' marketing and communication

5.4.1 Seven archetypes of consumer behavior

It is a well-known fact in the market place: 'green' as such does not sell, or at least it does not sell well. 'Green' products seem to be the equivalent of niche products. It is a kind of paradox because when asked a large number of consumers say they would buy 'green' products even if this would cost a little bit more. In practice consumer behavior is different: only a minority of the buying public turns out to be interested, even in countries where environmental awareness is high. Is this due to the existing prejudices that 'green' products are a lot more expensive or if their price is equal their quality is less. Is it simply a lack of awareness? Should the consumer be educated? Or is the explanation of this behaviour a combination of 'political correctness' combined with underlying selfishness: the environment is a collective good whereas consumers/buyers are individuals.

Such contradictions and questions have meant that in the years between 1994-1996 Philips Consumer Electronics decided to do in depth interviews with consumers about their attitudes regarding 'green'. It took some time to put the results into the right perspective and to agree internally. Around the year 2000 the first strategy was formulated to enhance sales of a broad variety of products through 'green' (which is something else than selling 'green' products).

The analysis underlying this strategy is shown in the paper "Green Marketing of Consumer Electronics" on next page. The chief conclusion is that 'green' benefits of products have to be linked closely to other benefits of the products. This creates a much broader platform of buyers interested in 'green', or at least it

creates a product image where overriding benefits dominate prejudices about 'green' which are still present with certain consumer groups.

The ideas about 'green marketing' as described above support the quest for real integration of 'green' into the business (see chapter 4.1). Once this has been achieved in the product creation process, integrated communication about 'green' attributes of products is a logical consequence.

On the other hand 'green marketing' studies such as the one presented in 5.4.1 gave a strong impetus for developing the functionality concept as described in the chapter 2.2 (physical, economic, immaterial and emotional functionality).

The studies also explained why energy labeling is much more successful in the market than Eco-labeling: energy is directly associated with economic functionality (money) where Eco-labeling does not. This does not necessarily make energy labeling the universal instrument to engage consumers in 'green' because in their mindset other functionalities than the economic one can prevail. The two examples below demonstrate this:

Vacuum cleaners: Perceived physical functionality (suction power) prevails over economics: the more power the better! This is a 'perception' because studies both at TU Darmstadt and TU Delft have shown that by optimizing geometry of the tubes and accessories the same suction power (physical functionality) can be achieved at approximately half the power of the equipment now on the market.

TVs: These are watched mostly for fun. Low energy is associated with poor picture quality (lower emotional functionality) and smaller sizes of the with inconvenience (less immaterial functionality).

Promoting purchasing of energy efficient TVs through for instance just energy labelling is therefore a tricky issue. It will only work if put into a more general perspective of quality.

The best chance is for applying energy labels to washing machines and fridges. These are seen as 'utility' items and therefore 'utilitarian' thinking about energy prevails.

Green Marketing of Consumer Electronics

Ab Stevels

Abstract

'Green marketing' strategies and Eco-labeling schemes for Consumer Electronics products have been relatively unsuccessful so far. Analysis of consumer behavior confirms that only approx. 25% of consumer is sensitive to specific 'green' performance of products. A vast majority is prepared to give up their prejudice that 'green' products cost more (or perform less) at the moment other benefits are linked to environmentally friendliness and vice versa.

On the basis of this analysis, the role of 'green' in product creation processes and in business has been repositioned. This leads to new strategies in which 'green' brand image and benefits-from-the-perspective of the consumer play a key role.

The example of Philips Consumer Electronics shows that such strategies are successful in the market.

1. Introduction

Companies in the field of Electronics began with EcoDesign (Design for the Environment) initiatives in the early nineties. Initially their activities were chiefly technical and of a defensive nature.

Compliance with laws and regulations, ISO 14001 based schemes, environmentally relevant substances lists and impending take-back/recycling obligations were the main items on the agenda. As such this created tremendous awareness within the organization. Environmental managers were put in place as well and information about the environmental effects of products in their various life cycle phases began to be collected. At that time environmental concerns were mainly seen as a threat and benefits for the company were doubted. This perception changed during the mid-nineties; it was recognized that in many respects ecology and economy go hand in hand. Clear cost savings could be achieved through energy and other utility reductions in production operations, and

by reduction of material use in products and packaging. Reducing disassembly times also generally contributed to lower assembly costs.

Taking action on such items raised the environmental profile of the consumer electronics industry amongst internal (management, commercial departments) and external (government, NGO's, scientific/technical world) stakeholders but failed to make an impact on the key player in the value chain; the (private) consumer. Various attempts to market products as 'green' in Europe, particularly in Germany, failed or were only temporarily successful. Ecolabel schemes did not work out as well in the consumer sector in spite of the fact that interviews showed high levels of environmental awareness, particularly in northern Europe.

In this seemingly conflicting situation it was decided to dig deeper into consumers' 'green' attitudes. This research resulted in the definition of seven archetypes of consumers, see §2.

On the basis of this 'green marketing' and communication have been fully integrated into the Product Creation Process see §3.

In §4 the current 'green' strategy of Philips Consumer Electronics is reviewed. This strategy is to a large extent concerned with integrating 'green' (including 'green' communication) into the overall business strategy, which focuses on brand image.

In §6 the communication strategy is reviewed in more detail. In §7 this approach is compared with communication based on Ecolabels. The results of this work obtained thus far in the market are presented in §8.

2. Seven archetypes of environmental consumer orientation

The seven archetypes of environmental consumer orientation have been defined on the basis of in depth research commissioned by Philips Consumer Electronics to be done in Northern Europe in the mid-nineties. The main thrust of this work was to take 'green' issues out of their isolation and to link them with the three items which concern customers most: price, performance and service. This approach was taken because in earlier research it turned out that when environmental items were specifically addressed, respondents give politically correct answers and hide themselves rather than reveal more candidly selfish attitudes.

Similar research has also been done in North America (see ref. 1). It is remarkable that a similar diversity of attitudes has been found – even the percentages as presented below for the various groups tend to be very similar. As things stand now, there are strong indications that this segmentation of the population applies worldwide; only the intensity of the feelings differs strongly per region and sometimes even per country. The seven archetypes of consumer orientation are presented in the table below:

Table 1 Seven archetypes of environmental consumer orientation

Archetypes	Average percentage in North Europe
Environmentally Engaged (E.E.)	15
Environmental Optimists (E.O.)	15
Disoriented Consumers (D.C.)	13
Environment too Complicated (E.C.)	15
Environmental Pessimists (E.P.)	15
Growth Optimists (G.O.)	10
Enjoy Life (E.L.)	17

The environmentally engaged (EE) Group has a strong interest in environmental issues and has adapted their lifestyle to include more environmentally conscious practices. There is strong support for 'green' organizations here. On the contrary trust in governments and technology is very low. This group has strong information needs, is prepared more for 'green' but will not buy from big multinationals.

The environmental optimists (EO) share environmental interest with the EE but are far more positive about future solutions and their trust in governments and technology is high (so there is less fear). An important feature of this group is that their education and income level is clearly above average.

This contrasts with the third group which is still on the positive side with regards to 'green'; the disoriented consumers (DO). This group, with a below average education and income, recognizes that there is an environmental problem but is not capable of handling it. There is a sense of 'fear'; trust in government and technology is high (as well as information needs, but this group is definitely not prepared to pay more for 'green'). Neutrality towards environmental issues starts with the Environment too complicated (EC) group: "Yes, there are green issues but stakeholders like governments, industry and the scientific world might (also) use the issue to extract more money from us".

Environmental pessimists (EP) take a more positive attitude than ECs but doubt strongly the effectiveness of environmental programs. "In the end we will be all swamped by the population increase". Growth Optimists (GO) and the Enjoy Life (EL) groups basically have a negative attitude towards environment. GOs advocate that economic growth is necessary to pay for environmental measures and reproach environmental proponents that want to block just that ("back to pre-industrialization"); the ELs basically deny environmental problems or provide statements such as "if there is a problem will be in future, however each generation has to solve its own problems". In making cross sections among the items following table could be constructed:

Table 2 Consumer scores on items related to 'Green Marketing'.

Item	% proactive	% neutral	Proactive % Recruited from group(s):
Positive interest in environmental issues	50	25	EE, EO, DC and EC
Fear for environmental disasters	60	10	EE, DC, EC, EP
Change of lifestyle	20	30	EE, (EO, DC)
Trust of Government 'green' policies	40	30	EO, DC
Trust of Technology to provide solutions	60	10	EO, DC, EP, GO, EL
Information needs/ Sensitive to 'green' marketing	45	15	EE, EO, DC
Pay more for 'green'	25	10	EE, EO
Buy from multinational	55	30	EO, DC, GO, EL

It is concluded from this table that:

- The majority of the general public (5%) is positive or neutral toward environmental issues
- Fear ('emotion') is widespread
- Preparedness to change lifestyle is limited
- Technology based solutions get a slightly better score than government initiated solutions
- There are clear information needs and there is sensitivity to 'green marketing' (although pertaining to 50% of the total group only)
- A vast majority of consumers will buy 'green' products from multinationals but only a minority prepared to pay more
- The groups making up the item scores as mentioned above are of different compositions

The analyses above also shows that there is a lot of sympathy for 'green' (nice to have) but that environmental issues only play a decisive role in a minority of the buying decisions of customers. This makes that environmental benefits should be linked the other benefits for the consumer to make 'green' a positive force in marketing for the majority of customers. Such benefits are:

- Material: lower price, lower cost of ownership
- Immaterial: convenience, fun
- Emotional: feel good, quality of life, less fear.

The problem is that environmental issues in their totality are difficult to link with these items. Philips Consumer Electronics has therefore taken the decision to split 'green' product attributes into five focal areas:

- Energy consumption
- Materials application
- Packaging and transport
- Chemical content / substances
- Durability recyclability.

When coupled with the benefits, this works out in the following way:

Table 3 Link between environmental and other benefits for the five focal areas.

Item	Environmental effect	Benefits	% of buyers attracted	Recruited from category
Energy reduction	less emissions	Material = lower cost	80	EE, EO + DC, EC, EP, GO
Material reduction	Less resources	Immaterial = simply, easy	75	EE, EO, DC + EC, EP
Packaging/transport	Less resources, less emissions	Immaterial = convenient	75	EE, EO, DC + EP, EC
Substances reduction	Less emissions	Emotional = less fear	60	EE, DC + EC, EP
Durability/recyclability	Less resources	Emotional = quality, feel good	75	EE, EO, DC + EC, EP

This table shows that the linkage between environmental and other benefits in the five focal areas means that in each category there is now a substantial majority of buyers interested. These majorities are recruited both from customer types with a positive environmental attitude but also from those with neutral or even negative attitudes (note that the DG group, in terms of the price aspects, counts to the neutral/negative side).

These linkage strategies have important consequences both for the product creation process as well as the corporate environmental programs. These will be described in the subsequent paragraphs.

3. Positioning of 'green' marketing in the Product Creation Process

From the consumer research done in §2 following conclusions process (PCP):

- EcoDesign (design for environment) should not only bring benefits for the environment but also for the consumer. There should be benefits for the company involved and for society as a whole as well.
- Customer benefits should be a mix of material benefits (lower cost of ownership), immaterial benefits (convenience easier to handle, operate/more fun) and emotional benefits (feel good/less fear, quality of life).
- The benefit issue needs to be addressed upfront, that is, in the very beginning of the product creation process (idea generation phase).
- Benefits are perceived by the general public on a relative scale, which involves the offer in comparison with the benefits than the competition. This makes environmental benchmarking an item ranking high on the 'green' marketing agenda.

These considerations have led to following EcoDesign matrix which has become by now the core of 'Green' design at Philips Consumer Electronics

Green Options	Benefit				Feasibility	
	Environmental	Business	Customer	Societal	Technical	Financial
First option						
Second option						
Third option						

Figure 1 The EcoDesign matrix

This matrix is used to analyze the 'green' options in the idea generation phase of the PCP which can be graphically represented by the following figure:

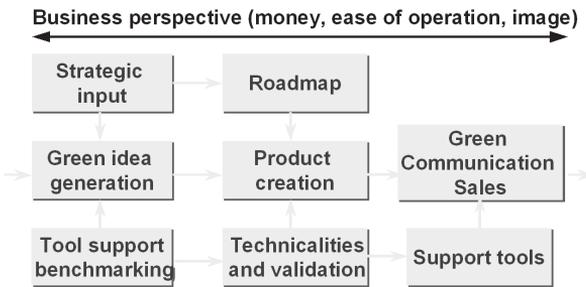


Figure 2 Embedding of EcoDesign in the Business

'Green' options are generated based on supplier information, 'green' benchmarking, strategy input and by brainstorming sessions using the so-called STRETCH methodology (see ref. 2). Environmental benefits are assessed using the so-called Eco indicator (abridged LCA) method, see ref. 3. Material benefits can be assessed in monetary terms, immaterial and emotional aspects on a descriptive scale.

The results of this analysis are organized in such a way that they form the basis of marketing and communication messages for various stakeholders (particularly the consumer) when the 'green' option in question is realized in the product creation phase itself. In this phase an additional validation step has been built in because ideas from other perspectives, i.e. mechanical, the electrical and software, could have an impact on environmental performance as well.

However, experience so far shows that generally speaking there is a positive environmental effect of product improvement options generated through other channels and vice versa. In practice feasibility items are often more difficult to cope with -in particular- technical ones.

4. Eco Vision, a customer oriented environmental program

Parallel to integrating EcoDesign and benefits approach into the Production Creation Process, Royal Philips Electronics has also redefined in Corporate Environmental programs. In 1998 a new program called Eco Vision was launched by the CEO Mr. Cor Boonstra. For products the core elements are as follows:

Table 4 Philips Eco Vision program (product part)

'Green' focal areas in product communication
'Green' Flagships in 1998
x% of products fully EcoDesigned in 1999
y% of products fully EcoDesigned in 2001
15% packaging reduction in 2000 (ref. 1994)

The core philosophy of Eco Vision is to offer to the customer environmental benefits alongside related material, immaterial and emotional benefits by selling products that are better than the competitions in this respect. This philosophy includes two important paradigm shifts.

- Widen the scope from strictly environmental to broader appealing benefits
- Go from absolute Eco scores (as done for instance by traditional Life Cycle Analysis) to relative Eco performance (better than the competition).

The core of the program are the Green Flagships products. Through an extensive benchmarking program (see ref.

45), these have to be proven to be outstanding for Consumer Electronics products, particularly in the focal area of energy consumption. As shown in the previous paragraphs, energy consumption has the most tangible benefits next to the environmental one (lower cost of ownership).

The Eco Vision program requires that each Business Group has at least one Green Flagship. Apart from that an increasing number of products have to be EcoDesigned, that is having environmental requirements in their target specification and following strictly the PCP procedure described in §3.

An example of a Green Flagship product in the 'green' 32" TV, some basic data are given in the following table:

Table 5 Characteristics of the 32" TV Green Flagship.

Benchmarking	Philips	Best Com- petitor	Other Com- petitor
Energy on mode (W)	132	150	157
Energy standby (W)	0.3	1.5	1.9
Packaging weight (kg)	7.3	6.6	6.3
Product weight (kg)	51.8	57.1	54.2
PWB area (dm ²)	17.7	20.9	29.2
Recyclability (%)	92	91	92
Life cycle impact (mPt)	4856	5567	5759

As can be seen from this table, the performance is superior in all five focal areas. Note that the chemical content issue has been addressed through the item Printed Wiring Board area. When flame retardants have been eliminated from the housing of products it has turned out to be a good yardstick for measuring the presence of environmentally relevant substances.

Next to the score in the five focal areas an Eco-indicator (a bridged LCA), see ref. 3 has been added. This is done to assess overall performance and to enable communication to other audiences than the private consumer such as authorities, the scientific world etc.

5. A modern and 'Green' communication strategy

In the previous paragraphs it has been demonstrated how environmental issues can be taken out of their scientific/technical domain and be used to enhance the benefits and expectations of prospective buyers.

In a similar way environmental issues can be used to enhance brand image. Areas in which 'green' can contribute include:

Leadership

- Top management shows, visible involvement in 'green'
- Pro active in industry associations
- Participation in international activities like the World Business Council on Sustainable Development
- Having a Corporate Environmental Vision, Policy and Roadmap.

Programs

- Corporate programs like Eco Vision
- ISO 14001 certification
- Supplier requirements

Documentation

- Environmental (annual) reports
- Brochures like the Philips one "Greening your Business"
- Scorecards/reviews
- Internet
- Press release/free publicity/technical, scientific articles

Sponsorship

- Environmental research and teaching chairs at Universities/institutions
- Environmental related events (like EGG)
- Nature conservation groups.

A study commissioned by Philips Consumer Electronics has shown that the mix of “green image building” and ‘green’ performance/benefits should be approximately 50/50, where in the future the importance of the image part will increase further.

Creating an appropriate mix of both elements and developing an underlying corporate culture that includes actions and results is therefore essential for success.

6. Comparison of the new communication strategy and Eco labels

The traditional tool to promote environmental performance to potential customers are Ecolabels. Both government supported and private labeling schemes exist, whereas industry is also adding to these through self declarations.

So far most labeling programs have had little success. The main problem seems to be their lack of transparency to the consumer; all items are consolidated in an all or nothing score. As shown in the present study this makes it impossible to associate ‘green’ with benefits (material, immaterial, emotional) as perceived by the consumer. An indirect confirmation of this is given by the fact that label programs which focus on one item, particularly energy consumption generally work quite well – these labels offer the customer a clear judgement from their own perspective.

From the perspective of companies with global products there are problems with Ecolabels as well:

- There are many programs (now more than 30 worldwide)
- Criteria of the programs are different and not always really environmentally relevant
- A diversity of – sometimes costly- test procedures
- Procedures take a long time compared with the time that products are available the market (fast follow-up of generations).

The most outstanding problem is however that Ecolabels level the playing field and do not attribute to specific brand image. This is completely contrary to the strategy described in the previous paragraphs where environment is linked to other customer benefits and to a single brand on a global scale.

7. Results obtained so far

Under the umbrella of the Philips Eco Vision program, the Consumer Electronics Division has so far developed six Green Flagship products. A further increase in product numbers is expected in the near future.

The new ‘green’ communication strategy was kicked off last year with a presentation at the International Trade Fair (IFA) in Berlin in 1999.

Although the very integration of environment in the business means that it is difficult to disentangle how much this approach really contributes to market success. A preliminary analysis by the Corporate Environmental and Energy Office indicates:

- Margins for ‘green’ products are higher (+3%) (mainly due to material and packaging reduction)
- Market shares of Green Flagship go up by average 2 percentages points.

8. Conclusions

The study on ‘green’ consumer behaviour presented in this paper has lead to new ways and means to integrate environment into the Product Creation Process. The Eco Vision approach of Royal Philips Electronics has allowed for the development of a ‘green’ communication strategy which differs strongly from e.g. a traditional Ecolabel strategy. Preliminary results show that the new strategy is successful in the market.

9. References

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Tidbits, 8

Keep it clean!

We were euphoric at Delft University. Finally one of the business groups of Philips Consumer Electronics had allowed our EPAss-method to be tested on their products (see chapter 6.3.1). Surprisingly the group was located in Taiwan, at that time not a frontrunner in environment.

Geert-Jan was the student to be sent to Taiwan. This was a double risk because it included the usual risk, that the student is not capable of showing that he or she is a good designer and engineer in a sixth month project in industry. On top of that there was also the geographical risk. Being in Taiwan means that the mentors and the supervisor are far away. Moreover, the project has to be executed with people who have a different way of working than the one we have in the Netherlands. Dutch universities do not prepare one for that!

Geert-Jan did it. He simplified the EPAss-method (see chapter 6.3) by taking the academic part out and reducing it to industrial essentials. He put in long hours along with the local crew and achieved astonishing results (see chapter 6.4). In this way he was one of the contributors to the big success of the Philips' "Brilliance" monitor products.

Apart from that, there was great conceptual learning for us too. The number one question in EcoDesign is always: what is the real functionality I have to design for? Once having started the design, a basic principle is not to mix different (sub) functionalities in an improper way.

These basic notions were demonstrated in a pathological way through environmental benchmark of the monitor products. The baseline Philips monitor product had a solid iron 'Cage of Faraday' around its electronics. In old models, where monitors were still 'energy guzzling monsters', this was badly needed because of the electromagnetic radiation of the electronics. The cage was a blessing in disguise because parts could be fixed to it. It was a rock solid anchor that helped prevent against a spaghetti of wires inside the product.

With the development of more smart electronics, energy consumption of monitors went down and the electromagnetic radiation issue lost importance. In the competitors' products analyzed by Geert-Jan there were still metallic conductors present, but size and weight had been reduced by only 10%, in comparison with the Philips product. The conclusion was obvious: take the cage, in its old form, out of the design and replace it by something much smaller and thinner to achieve substantial environmental and economic gains. Nice theory, but how to do this in practice – the cage had become a hall-stand especially for wires and cables. After huge discussions it was decided that a radical redesign was necessary; however, time to market makes this very problematic. On the other hand it had to be done, otherwise there would have been no exit of this cull de sac like design avenue. Finally it happened; and it happened on time. The new Philips "Brilliance" monitors became a huge success.

Functionality analysis is also 'prevention'. Keep the designs 'clean!' Keep it clean over the generations!

5.4.2 Gender, what happens in the shops with 'green'

One of the conclusions of the research in 5.4.1 was that generally speaking women have a much more positive attitude toward 'green' than men. In general also other products attributes which are ranked high differ from those of men. This observation led to the study of student Eelco Hoedemaker (see also Tidbits, 6). Parallel to this study also buying processes in shops have been studied particularly the role of sales staff in recommending or discouraging 'green'. This work has been part of the graduation project of student Richard Agema. The results of these projects were combined into the paper "Green marketing of Consumer Electronics II" which is presented on the next page.

The work shows ample evidence that women participate much more than in the past in buying decisions of electronic products. Due to this and due to the bigger interest of women in immaterial and emotional product attributes (including 'green'), this development makes that there are increased opportunities to enhance sales of 'green' products.

Environmental aspects of products still play a minor role in advice in the shops. Best chance to enhance sales of 'green' products through such advice is to put emphasis on low energy consumption in the use phase.

Green marketing of Consumer Electronics II

Ab Stevels, Richard Agema and Eelco Hoedemaker

Abstract

In the last years women are taking a more and more active role in buying decisions on consumer electronics. Since they attach on average more value to environmental attributes than men this is an opportunity to promote 'green' products. Environmental benefits have to be presented in conjunction with other benefits. It has been identified that well designed, durable and easy to use products are important for woman in this respect. Other aspects as features and amount of power clearly count less.

Sales staff in shops turn out to have an important influence on buying decisions; in approx. 50% of the cases their advice counts strongly.

In their communication environmental issues play a subordinate role so far -which leaves room for improvement.

Energy consumption in the use phase is ranked both by customers and sales staff as the most important issue to be addressed. This has implications for EcoDesign (Design for Environment) which up to now has put strong emphasis on materials application and recyclability.

I. Introduction

In an earlier publication (ref.1) the environmental attitudes of consumers were investigated. Seven archetypes of consumer behaviour were identified, ranging from environmentally engaged, positive, neutral, sceptic to outright hostile. The analysis explained why green as such does not sell and why schemes strongly focussing on just environmental product characteristics as Ecolabels are relatively unsuccessful.

When however other benefits of the products are linked to the environmental ones, a vast majority of the consumers is prepared to give up their prejudice that green products cost more (or perform less) than traditional ones.

On basis of this analysis the role of 'green' in product processes and in business in general has been repositioned. This lead to new commercial strategies in which green brand image and benefits – from - the perspective of the consumer play a key role.

In the present paper two aspects in the sales process are further explored that is the role of gender and the role of trade, particularly the one of the sales staff.

§2 Shows that women are overrepresented in consumer categories with a positive attitude towards 'green' in §3 this is translated into product benefits which have to be offered to make environmentally friendliness a real enhancer of sales. In §4 design guidelines are presented. Paragraph 5 identifies the role of 'green' in the sales process from the perspective of the sales staff. Information about 'green' technical product attributes by staff turns out to be more important than design, warranty, ease of use and convenience about which items many consumers already have their own opinion. On basis of overall ranking of the importance of focal area's (energy, material, packaging, substances, recyclability) can be made which is helpful for evaluating design improvement (§6).

2. Gender, environmental friendliness and buying behaviour.

Our research has shown that average women are over represented in the consumer archetypes with a positive environmental orientation, see the table below (and ref.1 for the basis elaboration on these 7 types):

Table 1 Representation of women in consumer archetypes.

Consumer Archetype	Environmental attitude	Representation of women
Environmentally engaged	++	+
Environmental optimists	+	-
Disoriented consumers	+	+
Environment too complicated	0	+
Environmental pessimists	0	-
Growth optimists	-	0
Enjoy life	--	0

+ means overrepresented, - means underrepresented

In a numerical evaluation its shows that more than 50% of women has a positive environmental attitude against less than 40% for men. In the 'neutral' group as in the negative group women represent approx. 30% and approx. 20% respectively where as men account for approx. 30% in the both cases.

This is a relevant item because in the last years buying decisions for consumer electronics are increasingly taken by females in the age group over 20. Only five years ago men accounted in Europe for 70% of buying decisions, in only some twenty percent decisions were taken jointly (partners) whereas women (mostly singles) accounted for some 10% only. Recently things have changed dramatically; men account now for 50%, partner decisions for 25% and women for another 25%. This shift has also caused that the traditional customer group segmentation (in home aesthetics, enthusiast, technoconnaisseurs, uncertain, prudent and rationalists, see ref. 2) has started to change percentage wise.

Table 2 below shows the traditional segmentation correlated with the environmental archetypes.

Table 2 Correlation between general buyer/user characteristics and environmental attitudes about consumer electronics.

Environmental Characteristics	General Characteristics	Home Aesthetics 13%	Enthusiast 16%	Techno-Connaisseurs 20%	Uncertain 18%	Prudents 20%	Rationalists 13%
		15% Green engaged	++		x		
15% Optimists	+					x	x
13% Disoriented	+				x	x	
15% Too complicated	0			x	x		
15% Pessimists	0		x			x	
10% Growth optimists	-	x		x			
17% Enjoy life	--	x	x				
Environmental attitude of buyer/user group		--	-	-	+	+	++

Increased participation of women in the buying process of consumer electronics results in increase of the size of the rational, uncertain and the home aesthetics group (although the latter does not completely correlate with the on average stronger positive environmental attitude of women found earlier). This has consequences for the product mix which has to be sold to the market in general and particularly for the environmental performance which have to be offered in the connection with the traditional benefits.

3. Product aspects and gender

The investigation of the relation between product characteristics and gender has been focussed on Audio products. Out of twelve product characteristics six were rated by women to be relatively important, six relatively unimportant:

Table 3 Relatively important and unimportant product aspects for female buyers.

(Relatively) Important	(Relatively) Unimportant
* Sound quality	* Ease of use
* Durability	* Remote control characteristics
* Price	* Amount of power
* Warranty	* Size
* Build quality	* Latest features
* Attractive design	* Brand name

Subsequently it has been identified what the big differences are with the average buying public (dominated also by males). Also the extent to which women take really own decisions without taking advice from others. The results are as follows:

Table 4 Difference from average of selected product aspects for female buyers.

Item	Difference from average (+ = more important, - = less important)	Take decisions without advice of others (partner, friend)
* Sound quality	=	No
* Durability	+	No
* Price	+	Yes
* Warranty	=	Yes
* Build Quality	-	No
* Attractive design	++	Yes

From table 4 it is concluded that particularly design and price are important for women - from the sales perspective it is also relevant that they take their own decisions on these items and do not rely on the advice of others like partners or friends. The importance of design was underscored by a test in which 21 products of well known brands were presented to a panel of 26 members with following result:

- Majority likes design / wants to buy : 3
- Neutral : 2
- Majority does not like design / does not want to buy : 16

This result allows no other conclusion that this is a devastating judgement by women about current design of audio products.

In a second important group rank durability and warranty; like design these preferences clearly rank as 'immaterial' benefits; positive emotion and quality of life dominate – note that typical technical features like amount of power and latest features did not even make it to the preferences list. Sound quality and build quality rank third in the listing of table 4. Although this was not directly found in the comparison presented in table 3 an underlying item of build quality (and also of durability/warranty) and sound quality was ease of use, 'convenience', this correlates as well with the high representation of women in the categories uncertain and rationales.

4. Design guidelines for Audio products preferred by women.

In the category 'well-designed' following general design rules were identified:

- Use metal housing; it depends on the product segment whether a metallic finishing is preferred.
- Use soft touch control.

- Decrease the number of buttons.
- Plain and simple design.
- Consistency in size, shape (rounded) and colour.
- Place important buttons on a more prominent place; structure buttons.
- Do not use many (display) colours.
- Speaker cloth is a must.

At first sight several of the design guidelines mentioned above seem to be anti-environmental; use of metals instead of plastics and more sophistication in finishes will result in a higher environmental load. It should be noted however that functionality requirements as regards output power and latest features availability rank relatively low. Since energy consumption of audio products make up approximately 60% of the environmental load an materialisation only approx. 30% (the rest being packaging, transport, end-of-life), balanced product concepts will combine 'better outlook' with lower environmental load.

Guidelines for more durable (or more perceived as being durable) products include:

- Higher weight (perceived solidity).
- Separated components.
- Visible mechanical parts should not shock.
- Solid knobs.
- The system should be easy to clean. No 'difficult' edges and corners.
- Place buttons near their components.

Again several guidelines seem to speak anti-ecological language. With the same reasoning as further 'design/outlook' rules this can be compensated for in the overall product concept (lower output power).

Design rules for ease of use/build quality include:

- Product should be self explaining (no manual explicitly needed).
- Relate size of buttons to their importance.
- Place buttons on the top or on the front (not both).
- Do not use abbreviations/difficult terms.
- Do not use buttons which are too small.
- Use pre-sets
- The display should only contain the needed information.

Generally speaking implementation of the 'ease of use' design rules will not affect very much the environmental load over the lifecycle of the products.

On basis of the general design rules as developed in the current research the Applied EcoDesign group at Delft University of Technology has proposed four design concepts. These were meant as a challenge to the sponsor of the project: Philips Audio Systems. As a result of this challenge designs of products brought to the market in the years to come will be influenced. Both new customer groups (women of different lifestyle, environmentally interested customers) are thought to be better served by this development.

5. Green marketing from the trade perspective

In the previous paragraphs it already appears that a lot of customers do not take buying decisions on their own but take the advice of relatives and friends. More important seems to be the role of sales staff. Our research showed that for the more expensive items like TVs costing more than 500 ECU approximately 50% of the buyers has already decided on basis of information gathered outside; the shop in this case therefore degrades basically to a 'box shifting institution'. For cheaper items like for instance portable audio this percentage drops to some 15-20% only. Apparently consumer spend less time in preparing for buying cheaper items or last minute decisions (on basis of outlook for instance, the 'fashion aspect') override functionality. Sales people say themselves (based on interviewing a 30 persons sample) that on approximately half of the buying decisions they have influence of

a strong influence, more or less irrespective of the price of the product. Apparently this is the customers group going to the shop having vaguely in mind that they want to buy (for instance what functionality they want to buy) but being undecided about the precise item. This is also the group where environmental information provided by shop assistants could play a role in buying decisions. In order to link with the research on gender in green marketing, below results for audio products are presented again. In the table below the importance of product aspects is ranked in two ways. The left hand column represents how sales staff ranks this importance for the customer they get in touch with, the right hand column what (all) customers rank themselves as important.

Table 5 Ranking of product attributes of customers as perceived by sales staff and by customers themselves.

Rank	Ranking of customers as perceived by sales staff	Ranking by customer themselves
1	Sound quality	Sound quality
2	Reliability/durability/ build quality	Reliability/durability/ build quality
3	Design	Ease of use
4	Brand name	Price
5	Technical/ specification/ features	Design
6	Price	Output power
7	Output power	Technical specification/ features
8	Ease of use	Environment
9	Environment	Brand name

From both perspectives sound quality and reliability/durability/build quality rank high and environment ranks low. A first conclusion is therefore that there is still ample room for education of (prospective) buyers about environmental aspects of products.

Since the average rank of standings 3-7 is small there only are two significant differences; sales staff ranks the importance for the brand name much higher than the consumers, whereas for ease of use the opposite observation can be made (do customers not want to admit in a shop that they have sometimes difficulties in using electronics), apparently they talk more about differences between brands that they think there are. Table 5 also supports the conclusion made in ref.1 that environmental aspects should preferably be promoted as enhances of other product benefits than as an isolated item. Table 6 specifies what product attributes are thought to be relevant as anchors for environmental messages by shop assistants:

Table 6 Product Attributes thought to be suitable for linking environmental messages

Rank	Item	Mentioned by (% of total)
1-3	Price/Cost of ownership	77
1-3	Reliability/durability/build quality	77
1-3	Design	77
4-5	Sound quality	67
4-5	Technical specification/feature	67
6-8	Brand name	43
6-8	Ease of use	43
6-8	Output power	43

It is concluded from this table that price (going against the prejudice that environmentally product are more expensive), reliability/durability/build quality (less repairs, long life) are important for linking 'green' messages with. Design can send important green messages as well. Of the other items it is surprising that brand name ranks low – apparently sales staff seen the producers image not related to the environmental domain. Apparently their opinion is as well that output power should not be sacrificed for environmental reasons. When asked what type of environmental information should be presented to the customers following scores were obtained. Within brackets the scores are given for the question what do customers address when they ask about environmental aspects.

Table 7 Relative importance of environmental aspects according to sales staff.

Rank	Item	Mentioned by (%)
1	Energy consumption	100 (100)
2	Hazardous substances	60 (53)
3	Material application	53 (37)
4	Recyclability	47 (23)
5	Life cycle impact	23 (37)
6	Packaging	17 (30)

Energy consumption is concluded to be the environmental item to be preferably addressed followed by hazardous substances, materials application and recyclability. Life cycle impact and packaging ranked as relatively unimportant. When compared with customers environmental questions, energy consumption and hazardous substances stay clearly on top. Recyclability is ranked higher by the sales staff, most likely because of the fact that for instance in The Netherlands a take-back and recycling system was in the process of being started at the time of questioning – shops have to charge the buyers a recycling fee in this system. The only explanation for the difference in the ranking of life cycle information is that this is thought to be on a difficult subject.

When detailing energy consumption further following order of importance was indicated:

1. Number and size of batteries (portable audio!).
2. Energy consumption in operational mode.
3. Standby consumption.
4. Cost of energy

This ranking is an indication that human powered products will have a good chance in the market/actually the issue 'users hate batteries' was one of the chief drivers for Philips Consumer Electronics to develop a human powered radio (see ref. 3) which is very successful in the market.

6. Prioritisation of design improvements

The analysis in this paper can form the basis for market driven criteria to evaluate and prioritise proposals for environmental design improvements. Simultaneously this is creating a dilemma for producers: this 'market driven green', differs from 'scientific green' (for instance based on Life Cycle Analysis) an 'government green' (proactively dealing with legislation and regulation). This is illustrated by the following table in which the five 'focal areas' are ranked (1= first priority, 5= lowest priority) according to the different perspectives (for audio products):

Table 8 Environmental priorities from various perspectives

Perspective	Item				
	Energy	Hazardous Substances	Materials	Packaging	Recyclability
Customer	1	2	3	4	5
Trade (sales staff)	1	2	3	5	4
Scientific green (LCA analysis)	1	5	2	4	3
Government policies (EU)	3	1	5	4	2

Energy is ranking on first place, with exception for governmental policies - at least at the moment. This lower ranking of energy by governments is due to recent emotion about food safety and animal diseases and by the efforts currently done to shift the responsibility for electronic waste from the public to the private sector. Substances rank (approximately) second, the deviating priority yielded by LCA is due to the fact that this methodology has

difficulties in dealing with potential toxicity. For materials and recyclability the scores are fairly diverse; this points to big differences in perceptions and opinion about resource issues.

In order to handle these differences a compromise was made that improvements having an affect on energy consumption were weighted with a factor 10, for materials with a factor 6 packaging with a factor 3 and for recycling with a factor 1. The hazardous substances category was excluded from this weighting because it is difficult to rate on the usual scales – it has been dealt with separately. To the environmental weighting were added expected company benefits (cost, immaterial ones); factor 10, consumer benefit factor 4 (cost of ownership, ease of use, feel good), societal benefits factor 8 (resource and compliance issues) and feasibility; factor 8. The weighting of all these items was chosen in such way that double representation (both in the environmental factors and the benefits/feasibility factors) was avoided. The environmental benchmark in audio products was performed in the way described in ref. 4. In the brainstorm in total 45 idea's for environmental improvement were generated which were evaluated according to the scheme outlined above and multiplied by their expected environmental impact in terms of Ecoindicator score (see ref. 5).

The top idea's include (for reasons of propriety these are not detailed further):

- Introduce on/off switches in all equipment.
- Reduce the number of components in the Printed Wiring Boards by defining a new IC base more functions on board.
- Introduce transformers with high efficiency
- Reduce the weight of the cabinets
- Reduce the amount of wire and cable (partly enabled by the new IC).
- Reduce battery consumption for portable products.

This list shows that the top idea's are located in the domain of energy consumption in contrast to the 'classical ecodesign' where much emphasis is put in material applications and recyclability issues.

7. Conclusion

The vastly increased participation of women in buying decisions of consumer electronics offers increased opportunities to enhance sales of green products and consequences for the product attributes to be developed. Well designed products which are more durable (and more environmentally friendly in general) and which are easy to use are getting more important, whereas traditional aspects as features and amount of power relatively loose. Sales staff in shops turn out to have an important influence on buying decisions; in approx. 50% of the cases their advice counts strongly. Environmental issues are brought up relatively infrequently by customers which have leaves room for information and education on this subject.

Energy consumption in the use phase is ranked both by customers and by sales staff as the most important environmental issue. As demonstrated for the case of audio products this has serious consequences for EcoDesign which has to orient itself much more in the direction of printed wiring board and IC design instead of the 'classical' material application and recyclability fields.

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Johan Diederich ('Joop') Fast (1905 – 1991): look at a molecular scale first

My education as a chemical engineer at the Technical University of Eindhoven was a pretty dull affair. It was technically solid and scientifically sound, but the general atmosphere was not very exciting and in particular it lacked an inquisitive academic spirit. Frankly speaking I learned more from the activities of the student societies like the 'Eindhovens Studenten Corps' and the 'Protestantse Gespreksgroep' than through classes and practical exercises.

There were a few exceptions, like the classes of professors Zwikker, Schuit and Fast.

Joop Fast was the most special of the three. He was a self made man and had move himself up through the ranks at Philips Research: from a laboratory assistant to a chief researcher and part-time professor (later he got a doctorate from Delft University on a honorary basis).

Joop Fast was an independent thinker and it showed in many respects. He made revolutionary contributions to thermodynamics (they are laid down in his book 'Entropy') and the chemistry of metals. He was also able to convey the secret of his success to the students: when planning experiments or analyzing results go back to molecular chemistry and build your ideas from there.

When giving his elective course, Joop Fast refused to give class in the traditional way. At the start of it he produced a book with the title, "Physics and chemistry of metals" and said each of you has to present the contents of one chapter. He said, "Only if necessary I will assist to make sure that your fellow students understand what you are trying to communicate." Who will be first to take this challenge next week?

This type of approach was unusual and all the students were hesitant. I volunteered finally. I had to struggle for many hours in order to get control of the subject. The presentation went better than anticipated, Joop Fast's interruptions were helpful to get the essential messages across.

This type of class proved to be a great way of teaching! It puts the focus on active self learning. Metals became one of the first fields that I really became enthusiastic about.

The 'Fast' Walk: Start at Eindhoven Central Station, north exit, go R to the Technical University, take the Limbopath, follow de Wielen, L to het Eeuwseel, R to Lismortel and leave through de Zaale. Go R on the Ring Road (Insulindelaan), go directly R after the rail underpass and directly L to the Parklaan. Return to the station through this lane and the Dommelstraat (go R at its end).

5.5 Communicating 'green' through design

At Industrial Design Engineering, the question of whether 'green' can be communicated through design style and appearance has been a hot issue for several years. It turned out to be a subject that was difficult to tackle – we have been struggling with it for a long time. Margot took it on board as a student, first as her literature research project and later as her graduation project.

Discussion continues even after the completion of her work. The big issue in these discussions was whether there is a common denominator for the product attribute 'nice design'. This refers to both individual tastes and a (general) benefit for consumers in the sense of chapter 5.4. The results are consolidated in the publication "Visualising the Environmental Appearance of Audio Products" on the next page.

It is concluded in this paper is that 'environmental appearance' of products can be brought about by design. The attributes of such designs can be identified in general terms although differences in taste, in particular among genders, should be taken into account.

Visualising the Environmental Appearance of Audio Products

Margot Stilma, Ab Stevels, Henri Christiaans, Prabhu Kandachar

Abstract

Can environmental friendliness be communicated by the design style and appearance of products? (such as form, colour, style or material)? Consumers are interested in buying environmental products and design styles might be used as communicative tools. However, current 'green' products show something else. Environmental aspects are chiefly promoted by marketing programs based on technical items like the use of materials, hazardous substances, energy consumption, etc. By a qualitative and exploratory research the environmental design styles according to consumers' opinions were analysed with larger audio products as case study. Visible distinctive differences can be identified between the most and the least environmental rated products. A 'Green flagship', which claims to be environmentally orientated, wasn't recognised as such by consumers. And women and men perceive environmental friendliness in another way. From this research can be concluded that more attention is needed to visualise the good technical environmental performance of products.

1 Introduction

A group of people is interested in buying environmental products. The environmental decision point comes in when two similar products are rated identical on other aspects. (price, quality, etc) A difference occurs in opinion per gender. For men, an environmental orientation is more about a separate issue rather than an integrated approach in their buying behaviour, which is the case with women. Women are acting environmentally in a wider perspective. [3, 7, 9, 12, 18, 21, 22]. At the moment, the companies' approach to environmental products is mostly technically (weight, energy consumption, etc) or organisationally based. Promotion of environmental friendliness to consumers has mainly been achieved through means of adding technical information to the product: labelling and logo's, folders, advertisements and information on the Internet.



Figure 1 Company promoted larger environmental audio products of different brands in 2001. [11, 14, 16, 19] From left top to right bottom: Matsushita, Philips, Pioneer, Pioneer, Sony Company

Several environmental products are currently present in the market, either claimed to be by the producing companies or selected by other experts as such. Larger audio products, hifi and portables - the case study of this research - were rare and can be seen in figures 1 and 2. [1, 6, 11, 14, 16, 19]



Figure 2 Larger environmental audio products selected by (not company related) experts in 2001 [1,5]. From left to right: Glasplatz, Philips, Sony

Based on the information with the selected products and the green product books, it became evident that next to general design style directions no environmental appearance characteristics have been derived yet. [1, 5, 10, 23, 24] Nevertheless it became clear that it was very useful and feasible to do research in this area. There must be a reason why products were selected by other experts as environmental friendly considering that not always all technological data could be validated. Is there a possibility through physical aspects of the product to make clear to consumers that this product is technical environmental friendly? Design can be used as a good communication tool that can express the value of the system within its functions. Look for example at the products during the 'Space Age' in the seventies with many shapes resembling space travelling equipment. (see figure 3) [5, 8, 17, 20, 25].



Figure 3 A 'Space Age' clock

There are environmental friendly produced products, such as 'Green flagships', which were not perceived as such. Also considering the communicative power of design styles this subject deserves more attention. How will consumers recognise a product's environmental friendliness when there is no connection between the technical environmental aspects and a visual recognition? The aim of this study is therefore to define a set of visual product characteristics which according to consumers express an 'environmental' look. The study focuses on consumer electronics products and in particular on the design style of larger audio products. Information from literature will be combined with an observational study among consumers. Results can be used in a wider perspective and in a proper manner to better transfer the message of a product's environmental friendliness to consumers.

2 Research Approach & Methods

An empirical study was conducted. The aim of this study was to investigate if consumers were able to recognize environmental friendliness in products on the basis of visual characteristics. The design of this study was a mixture of interviewing and active participation by the participants. With the qualitative and explorative character of this research, results will be indicative rather than distinctive. [2].

2.1 Participants

Participant selection was based on the literature regarding environmental consumer research and on the company's target group description of the most environmentally orientated consumers. [15] A first selection was made on the basis of a sample of subjects from the consumer panel, which is part of the Product Evaluation Lab of Delft University (PEL). Second, in order to narrow down the sample according to the company's criteria, an Internet questionnaire was developed to use the company's specific consumer selecting criteria. The original sample received a request and entering code by e-mail to fill in the questionnaire. Ten environmentally motivated consumers were selected, 5 women and 5 men. Participants' ages ranged from 25 to 45 years and they had completed higher education (Bachelor/ Masters). All were compensated for their participation.

2.2 Instruments

The study was conducted, recorded and analysed at PEL of Delft University [13]. The products to be assessed in the consumer research were presented as full colour pictures, printed as large as possible and relative in size to each other per product type, on 6,5 cm x 6,5 cm x 1 mm cards. Among the products were consumer products such as lamps, (larger) household products, cars, bicycles, chairs, solar wind-powered products and different kind of audio products. The total selection, including all larger audio products consisted of 85 products. In the general grouping were 71 products and 54 of these products were selected by other experts or promoted by the producing companies as environmental friendly. 17 products were used as a baseline (including products of the larger audio selection.) 21 larger audio products (hifi and portables) were used for the specific larger audio product analysis. To prepare participants for the grouping of cards, 8 practising cards were used. These cards had the letters {a} and {b} shown in three colours, in 2 letter types, and in capital or non-capital. All these items were mixed across. At the end of the experimental session participants were given a questionnaire as a kind of checklist with semantic words. They were asked to characterize environmental friendliness in the appearance of products by valuing the impact of the listed words and by adding comments.

2.3 Procedure

Beforehand only the description: "Design style of environmental friendly products" was given in the invitation to the study. The one hour lasting session took place with one participant per session. Before starting of the session, the design of the study including interviewing and grouping of cards was explained. Part of this introduction was a grouping exercise where participants had to group the practising cards in, to their opinion, matching groups. The study itself consisted of four parts in total. First, general questions related to the subject were asked, followed by two grouping sessions and ending with the semantic questionnaire. In the rest of this paragraph these four parts will be described in more detail.

The session started with a short interview asking for opinions of the participant regarding examples of environmental friendly products. (With less 'closer' examples, excluding food related products for instance) Next, the participant was handed over the aforementioned pile of 71 cards with the images of products. The participant was asked to group these cards on environmental friendliness, regarding the design appearance of the products only, in as many categories as wanted. No questions were asked by the experimenter during this first grouping yet. Explanations of the categorization were asked only after the participant had finished. In case the groupings appeared no longer to be valid during this detailed analysis, they could be rearranged. When the grouping was finished a digital picture of it was be made. The groupings were kept in sight during the third part of this study: the grouping of the larger audio products. In this part a pile of 21 cards with larger audio products was given and the same procedure was followed as in the second part. Finally a semantic questionnaire had to be filled in and explained afterwards.

With the participant's permission the sessions were videotaped.

3 Results & Data analysis

This paper will focus on the larger audio products. However at the same time it will have a broader significance as well. Details of the research and results/ data analysis have been published in a report, which is available on request. (m.d.c.stilma@utwente.nl, +31 53 489 3072).

3.1 About the research method

Participants learned to analyse the visual aspects of products during the research. At the end they could all describe and give a qualified opinion regarding the environmental friendliness of products' appearances, which could be fully used during the analysis of their audio product grouping.

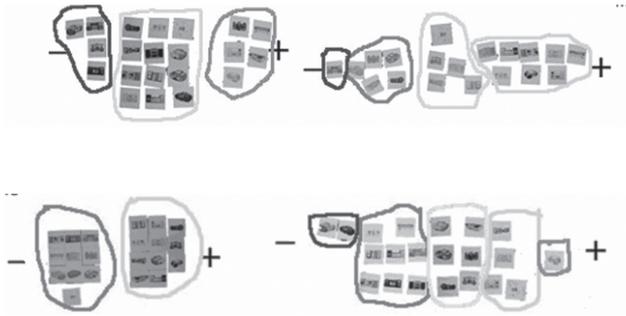


Figure 4 Four examples of grouping classifications. The squares represent the cards with the audio products and the surrounding circles the different levels. The minus (-) on the left represents the least and the plus on the right (+) the most environmental friendly appearance sides.

To analyse the results of this research, a classification system with five levels of environmental friendly appearances was used. Participants were left free to group and organise the products to their liking resulting in all kinds of varieties. The classification system is based on the groupings in combination with participants' comments. The five levels were represent the appearance impressions on a scale from most to least environmental friendly (EF): dark green = clearly EF; light green = EF; light blue = is or is not EF; orange = not EF; red = absolutely not EF. Products could now be compared and analysed against each other. Figure 4 shows some of these groupings made by different participants with the different levels shown as example.

The data of the audio products was analysed per gender and in total, because from literature it is clear that both groups show a difference in opinion. For each product is analysed how many times it was classified at what level. An overview can be seen in figure 5.

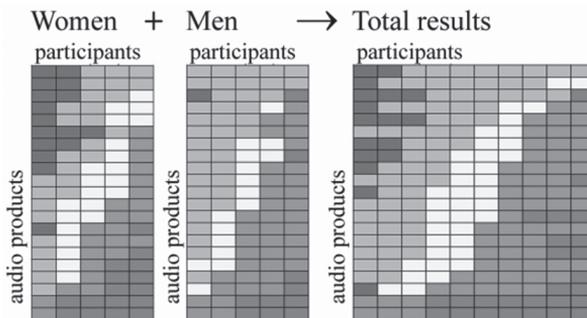


Figure 5 Classification results of audio products. From left to right results for female, male and in total. Each square represents the opinion of one participant for one product. Vertically the different products are ranked to their environmental impression. (On top the best and at the bottom the worst environmental impression) Horizontally the opinions of the different participants are ranked per product. (On the left the positive rated products and on the right the negative)

The next and important step was to combine the comments of the participants with the specific products. Visual distinctive aspects were characterized from the most to the least ranked environmental appearances. Also remarkable and interesting ideas of the participants appeared during this study. The used combination of grouping cards with interviewing now shows its value and both information sources shouldn't be analysed separately but as a whole.

3.2 Results

First of all it is important to know that in the general grouping hardly any larger audio product (a selection of the total audio collection) was classified in the positive environmental groups. The participants' environmental appearance descriptions of the larger audio products are given in the following overview. For the best and for the worst appearance characteristics three main comments are given first, followed by the other comments. The product groupings in figure 6 (total) and figure 7 (per gender) show on top products ranked as being most green products and at the bottom the least green ones.

Most common comments for the positive environmental appearance:

- Smaller products / women: compact designed products;
- Functionality and Usability;
- Plainness.

Other positive environmental friendly appearance characteristics were: Wood and metal appearance; Quality appearance; Balanced design; Simplicity in design and impression; Unity in design; men: Modern design; Rather rounded than sharp edged - not too roundly; men: smaller products use less energy; women: colours may be used, as shapes are more important;

Most common comments to avoid the negative environmental appearance:

- No aggressive appearance;
- No boasting or screaming design;
- Not many colours or colours screaming for attention.

Other comments to avoid the negative environmental appearance characteristics were: No plastic appearance (~low quality; bad recyclability); No transparent materials; No noisy impression; No contrasts in design; No distraction by design, no domination of elements; No useless elements/ not too much decoration; Not too coarsely shaped; men: No use of colours others than material colours; No black or yellow colouring (yellow: Cadmium story of Heineken crates)

3.3 Examples of visual clues

The previously shown comments of the participants already showed a difference in opinion per gender which explains the location of some of the products in figure 7. The second product on the top for women for instance has more colouring (orange circles around the boxes) and the second product on the top for men is rather sharply edged.

A good example of miscommunication can be seen when looking at the 'Green flagship' of Philips that was not perceived as being 'green'. The opinion per gender differs though. To men the appearance of this product is more neutral (light blue level), where to women this product was really not having an environmental appearance (orange level), with respect to the environmental appearance. Men didn't gave many comments to this product. The reason for women was, because it is large, it is black, and sharp edged in design. It looked like plastic. The appearance was also related to a lot of fuss and the product had a 'noisy' impression.

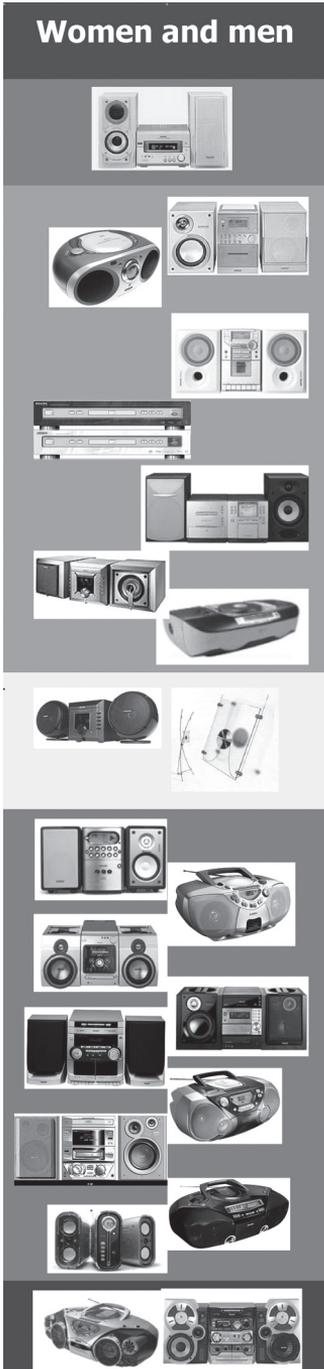


Figure 6 Total results both gender: product ranking and appearance criteria



Figure 7 Total results both gender: product ranking on appearance impression. On top the most and at the bottom the least environmental appearances are grouped.

4 Discussion

Design has a communicative quality linked to the social domain, which currently has a strong environmental component. In spite of this, environmental design styles didn't seem to be analyzed, described and consciously used so far. Of the selected environmental products (including consumer electronics products, with few larger audio products), hardly any comments by the selectors were given and not all could even be technically validated. Just the design style of these products must have 'communicated' its environmental friendliness and convinced the selectors of its environmental friendliness. Yet on the other hand, an environmental design style didn't seem to be explicitly and consciously used as well, as it appeared that a claimed to be green product, such as the 'Green flagship', wasn't recognised in consumer research as being environmental friendly.

And there is a group of people interested in buying green. Even though their inclusion of environment into their decision point is rather late in the decision process, they are still an important group to focus on. Next to consumers' willingness to buy 'green' it is important to realise that consumers are sceptical to claimed 'technical green' product attributes, being deceived too often. Women, today an increasingly important target group of consumer electronics products, have a different environmental appearance opinion than men, as is demonstrated by the current research. This should be taken into account with further development of environmental products.

Illustrated in this research is that consumers do have outspoken opinions regarding environmental appearance characteristics. The final audio grouping showed a very clear distinction between the best and the worst 'environmental' design styles. This is an important platform for further detailed research as it can be seen that distinctive environmental appearance characteristics exist that can be used when developing new environmental products. The appearance characteristics described in this research would fit to the 'high tech' environmental design style: using new technology to improve.

The results regarding the environmental appearance analysis showed design style characteristics, which can be applied to a wider spectrum of products. They might seem obvious but apparently they are not used yet. This is demonstrated with the 'Green flagship', which is the best technical environmental product in its range, but was not recognised as such. The results of this report should be implemented in a proper manner.

5 Conclusions

The environmental conscious companies, which are innovating and mass-producing should take this 'high tech' environmental design style with its specific appearance characteristics into account when developing (new) environmental products.

Environmental products should not only be technical validated as to be really green but the 'environmental appearance' should be implemented in the development of new products as well. Difference in taste by genders is an important aspect that should be taken into account as well.

6 Recommendations

The environmental appearance characteristics of products should be further investigated in detail and put in a broader perspective.

The different design style perceptions per gender should be taken into account when developing new products. More research should take place to determine specific environmental appearance characteristics and its related aspects in more details and directions.

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The Inaugural Address

When you get appointed professor at a Dutch University work starts straightaway. However, tradition says that this does not mean that your office has been accepted, so you are not yet supposed to be a faculty member yet. This can be achieved only in one way and that is through presenting an Inaugural Address.

In this address the activities of the chair to which you have been appointed are expected to be explained to the general public. Moreover, it can be used to explain plans for the future, to pay respect to all those who have helped you and to address the students.

The content of the address is supposed to be about generally agreed items. Some 'observations' can be made as well. Having strong opinions is not encouraged. You are considered not to be mature, at least not as a professor. Save such opinions for your Farewell Address and remember: science is impersonal, never use the word I.

Eloquence is highly appreciated; using computer sheets to express yourself is a tolerated concession of modernity.

After preparations, the great day is finally there. Fully dressed professors and their spouses, today called 'partners', assemble in the Senate Room. Five minutes before the address begins, the 'cortege' is formed. The spouses go first, most of the time there are few present. At my Inaugural Address Annet was supported by a group of ten, an absolute record. The official cortege follows preceded by the Beadle, Rector, Dean and the Orator.

The procession is then organized according to a certain order. Guests first, then professors from outside Delft, followed by the different faculties, in order of the year these were established. The cortege strides in. Your colleagues sit in the front of the auditorium. They prevail over family and the rest of the audience.

You go to the left of the podium and deliver your speech from behind a desk. For forty five minutes the bonnet is to be kept on. Only with covered head is the real truth is spoken. There is no time to adjust, the start is straight away: "Mijnheer de Rector Magnificus, (...), collegae hoogleraren, (...), dames en heren, ..."

This is an address, not a presentation. For me it appeared to be highly emotional, I did it with heart and soul and with passion.

Therefore, the border between observation and opinion was crossed without me noticing it. Most likely I may have violated a couple of unwritten rules. In this holy temple of science I said, for instance, that family is for me the most important thing in the world. Students were encouraged to learn more outside than inside class.

At the end the finish is simple,..."ik heb gezegd" (I have said).

A great tradition!

Chapter 6: Ecodesign Tools

6.1 What is 'Green'?

6.1.1 'Scientific green', 'green' perceptions and 'government green'

In 1993, I started my environmental job on the basis of common sense. My assignment was to look at what was going on in the environmental world of electronic products and to make a first action agenda for Philips Consumer Electronics on the basis of these observations. A surprising first discovery was that stakeholders had different perceptions about the idea of 'green'.

For instance, at that time a large part of the buying public had a strong negative attitude towards plastics in general and in particular PVC was seen with considerable suspicion. These materials were seen as not being 'natural' and suspected of containing hazardous additives. PVC was singled out in particular because of its chlorine content. Greenpeace's opinion that 'chlorine chemistry is bad' was widely accepted by the consumers. It was much more widely accepted than the contrasting viewpoint of the chemical industry, which tried to argue on the basis of science that plastics were 'innocent' or at least fulfilling all kinds of functions in an ecoefficient way.

'Green perceptions' versus 'scientific green'. The electronics industry was caught in the middle of such debates. What to do? Be rational and stick to the use of plastics ('scientific green') or follow the ideas of a majority of the customers and go back to increased usage of metals ('customer green'). The first balancing act for Consumer Electronics was born. Attempts to reduce the use of PVC as much as possible were attempted. Some overzealous purchasers sent letters to suppliers that PVC was 'hazardous'. This forced lawyers of the PVC industry to become active: Philips is not just a company, it is an institution and as an institution the opinion that PVC is hazardous is not a 'private opinion' anymore.

Prove your statement or you will be taken to court. Consumer Electronics had to withdraw, from then on we called substances like PVC 'environmentally relevant' which is true for sure.

In the same period it turned out that there is also 'government green'. It is the priority which is given by a country's governments to the environmental issues to be tackled.

In the Netherlands, for instance traditionally there was (and continues to be) high priority placed on heavy metals control – this is closely related to the abundance of water in the country. The fact that several big rivers in Europe flow through the Netherlands after having passed through other countries (and having picked up pollution there) is adding to this concern.

In Switzerland, abatement SO_2 and NO_x generated by traffic and electricity production ranks high on the public agenda. Trees high up in the mountains die because of high concentrations of such gases.

Such priorities are 'natural' but mean that industry is confronted with a broad variety of regulations in different countries. Environment is a difficult issue to deal with when it comes to creating single markets and level playing fields!

Hong Kong, a place to be!

Hong Kong is well organized so that you can move easily around as an individual. Simultaneously, it has this charming lack of total perfection which would make you feel unhappy. It is modern and wealthy with high rise buildings, four lane roads, lots of cars and a lot of well dressed people. In between however, there are all kinds of little things pointing to a different past. It was British; the trams, the walking trails and the pubs are still there. It is Chinese, you can eat everywhere and have fun everywhere. It is Chinese in its knack for trade and its ability to adapt to its new role in the region: from the gateway to China to orchestrating added value achievements in the regional economy.

And there is water. Stare at night from Tsim Sha Shui to the illuminated buildings at Victoria islands. Relax and organize your thoughts after a busy day. Go with a ferry to one of the outlying islands and recharge your energy.

I love to be in Hong Kong. In the period of technology transfer and joint ventures in China (1990-1994) travel was through Hong Kong. I was nervous when going to China, and exhausted when coming back. Hong Kong was to prepare and to wind down.

When starting my work in the field of environment I thought I would never be back in Hong Kong again. It did however work out in a different way. My first successes in the implementation of 'Eco' were in Taiwan but soon after in Hong Kong as well. The Business Group Audio had its head office there and operated several factories in nearby China. Activities included packaging-reduction on the basis of the environmental weight tool (still the best!) chemical content discussions, and formulating environmental requirements for subcontractors. After a lot of internal discussion the human powered radio was also developed. It sold well on the market.

I still can find the way to the Audio facilities which were in Kun Yip Street with my eyes closed. The sound of the closing doors of the MTR (metro) is so typical that it cannot be forgotten.

After 1999 somebody else took over the Business Group contact. I missed Hong Kong. New opportunities to meet came with the implementation of the European Environmental Directives for the Electronics Industry. Asian Companies are puzzled by it. Hong Kong Industry took the lead to get a grip on the matter. After retirement from Philips, I gave several seminars on WEEE, RoHS and EuP implementation (see chapter 9). I also supported an EcoDesign project with Hong Kong Polytechnic University and members of the Federation of Hong Kong Industries. It is still fun, I still love it, Hong Kong, a place to be!

City walk: Start in Central, on central square. Take the train in a western direction, get out at Western Market, go up (Morrison Street), go Right, Wing Lok street, go Left and directly Left, Bonham Street, go Right (Possession street), Left to Hollywood Road, proceed along the road till the mid level escalators, go down, get out at Stanley Street (Right), Left to Pottinger street, Right back to Central (check out Li Yaun Street, East and West.

Or: start in Central, on Central Square. Take the train into an eastern direction, destination Happy Valley. Get out at the terminus, walk up the street, Left to the Jewish Cemetery and go back, walk west of the Race Course along the Hindu and Parsee cemeteries. Enter HK-Cemetery, cross it, go out at the back side and take bus nr. 15 to the Peak. Make the circular walk here (Lugard Road & Harlech Road) and go back by the Peak Tram or walk Lugard Road and down (Hotton Road) and go back to Central with bus 13.

Favorite restaurant & pub: Kangaroo pub, East Chatham Road 37, Tsim Sha Shui and Deutscher Biergarten, Hanoi street, Tsim Sha Shui.

Country walk: Start at East Tsim Sha Shui Railway Station (KCR). Take the train to Tai Po Market. Take a taxi to the entrance of Tai Po Kan Nature Reservation. Make one of the walks indicated here. Recommended: the brown walk (2,5 hours).

6.1.2 What is 'green', what is really environmentally beneficial?

In the exploration about 'What is green?' it soon turned out that on the environmental side itself there are several dimensions. These relate to time horizon and to 'for real' or just 'risky' concerns.

- Short term ones: emissions to air, water
- Long term ones: resource depletion
- Potential toxicity: this is basically a risk, the toxic potential can materialize under circumstances or not.

Therefore from a real environmental perspective the answer to the question 'What is green?' is not obvious, nor it is univocal either.

The final answer to the question 'What is green (really)?' is therefore dependent on subjective judgments regarding what is most important even when assessed purely on environmental dimensions.

This is depicted schematically in the diagram below:

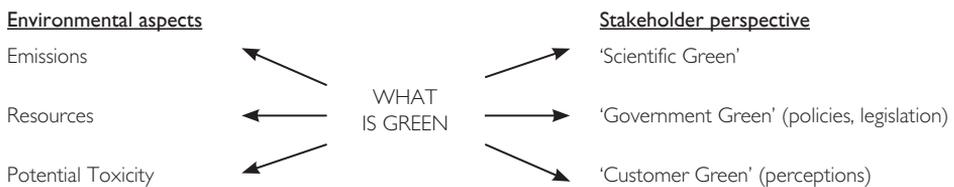


Figure 6.1 Aspects of 'What is green?'

The environmental aspects include emissions, resource aspects and potential toxicity aspects. For all three, descriptive models exist; the most well known is Lifecycle Assessment (LCA), which concentrates chiefly on emissions. For electronic products a typical Life Cycle Analysis based on single scores according to the Dutch Eco-indicator '95 method, would read as follows in Table 6.1:

Table 6.1 Life Cycle Analysis according to the Dutch Eco-indicator '95 method

Life Cycle Item	Life Cycle impact (% of total)
Energy consumption	40-98%
Materials and parts	20-60%
Packaging and Transport	2-12%
End-of-Life / Recycling	-3 - -15%
Substances, potential toxicity	N.A.

In LCA however, stakeholder opinions (see 6.1.1) are not addressed. This suggests that doing an LCA alone to underpin environmental decisions, can be misleading and even counterproductive. The European environmental Directives for the Electronics Industry (see chapter 9.2) have in their wording a strong inclination to rely on life cycle analysis (written with small letters this refers to the approach and not to the methodology, which is written in capitals).

As shown above great care should be taken when applying results of such analysis without checking a holistic environmental perspective (including resource and potential toxicity analysis) and stakeholders analysis. In view of this it is recommended to instead use the wording 'life cycle thinking' or 'lifecycle and stakeholder perspective' to avoid confusion.

Resource aspects can in principle be incorporated in an LCA (for instance by including future extra emissions which will arise due to mining of resources with low concentrations) but this opens up a new debate and adds to uncertainty about what depletion rates should be taken into account.

Even potential toxicity can be incorporated as well but here the debate will be how risk of emissions is to be incorporated on top of actual emissions in the future and to what extent 'natural' absorption levels have to be deducted.

It is concluded therefore that real comprehensive models are far away and that it is best to consider the three separate dimensions of 'green'.

In a lot of EcoDesign issues this solution is sufficient although not perfect. However, there are important policy issues for which the three dimensions pose inherent dilemmas. In such cases there is no escape from the necessity to make a judgment about real priorities.

A few aspects related to existing societal debates in Europe are listed below:

Table 6.2 Examples of Environmental dilemma's

Environmental dimension Issue	Emissions	Resources	Potential Toxicity
Using natural gas instead of coal to generate energy	+ (less CO ₂)	- (high energy resource sacrificed)	+ (no fly ash)
Replacing metal by plastics	+ (less energy needed for production)	- (recycling becomes a problem)	- (additives in plastic)
Lead-free solder	- (more energy needed for process)	- (use more source resources)	+ (lead eliminated)
Use of flame retardants	- (less production energy)	+ (less material needed)	- (more potential toxicity)

The dilemmas shown in this table can be described as follows:

- Fulfilling the Kyoto requirements for CO₂ reduction (these are a case in point, but will not be discussed here further) will put pressure on the use of more high quality resources which in fact should be used for applications with a higher added value than just electricity generation.
- Replacing plastics to better fulfill the European substance (RoHS) and recycling (WEEE) Directives will result in more emissions in the production phase.
- Lead-free solder applications reduce the amount of potential toxic substances but it is their positive impact is doubtful from an overall environmental perspective, particularly when it is considered that a constituent like silver in lead-free alternatives is produced as a by-product from lead mining. Also, increased demand as a result of the lead free for tin could pose a resources problem.
- Eliminating flame-retardants will result in the use of more primary materials and thus in the use of more production energy.

So far, the drafts of the European Policies and Directives have been one sided in the sense that they concentrate on a single environmental dimension. RoHS has the potential toxicity perspective, WEEE the resource perspective. Both EuP and IPP claim a holistic perspective, but are in practice strongly emission/LCA oriented in their environmental analysis approach. Although in both cases recommendations and design rules also address the two other dimensions, no balancing mechanisms are proposed. The way in which this could be done is discussed in chapter 6.5.

Graduation at Delft University



6.1.3 What is 'green' and the application of EcoDesign tools.

As explained in 6.1.1 the stakeholder perspective basically has three dimensions: a scientific one, a governmental one and a customer one. Each of these contributes to the outcome of the debate regarding, 'which environmental issues need to be prioritized'.

'Scientific green' is best represented by LCA based EcoDesign tools (although this is a methodology rather than a science, in the end a subjective recycling step has to be taken to allow produce conclusions). For resources a variety of depletion models exist for which there is no consensus in the form of standards such as there is with ISO 14000 standards.

Potential toxicity models start to appear but here consensus is even further away.

In practice, 'Scientific Green' approaches will therefore prioritize emission related environmental issues.

'Governmental Green' strongly depends on a variety of factors like population density, availability of energy sources, geographical position (near the sea, mountains), availability of landfill sites and/of incineration capacity and the status of the economy. Such circumstances determine the priority of items on the agenda.

'Green' perceptions of the general public are strongly linked to emotions. Environmental issues related to Health and Safety (therefore potential toxicity) score particularly high. Resources are long-term and score low, emissions generally score medium. Perceptions also relate to events, for instance when energy taxes are raised, energy issues score high. When incidents involving toxicity/food safety occur, toxic dispersion steps are advocated. When shortages of fuels or materials occur, the resource aspect takes over.

In view of what has been said above, it is concluded that it is unlikely that the stakeholders' debate will result in the setting of clear 'fundamental' environmental priorities. This is badly needed however to align environmental policies and directives and to allow stability in time, so that investments in technology and product design can be appropriately prioritized.

The situation as depicted above leads to a complex situation for practitioners. Several questions emerge: what has priority, where to go, which 'green' purpose to serve best and what tools will support best the EcoDesign process aiming at the chosen 'green' ambition?

In 1997 the figure below was made to facilitate discussions about tool choice and tool development:

Table 6.3 Relevance of tools for the various types of 'green'.

Green Perspective Method	Scientific green			Government green	Green perceptions
	Production	User	End-of-Life		
Common sense	+	+	+	+	+
Environmental Weight, chp. 6.2.2	+	--	++	++	++
Ecoindicator, chp. 6.2.1	++	++	+	--	--
Chemical Content, chp. 3.4	+	--	++	++	++
End-of-Life Evaluation, chp. 7.1	+	--	++	+	--

The Common sense approach covers all aspects but has a low level of sophistication. Philips Consumer Electronics decided to test the Delft EPass method (see chapter 6.3.1). In fact this is a common sense performance measurement. It can also be seen as a life cycle inventory, which is not transformed into impact categories, as is occurring with the LCA.

The Environmental Weight (see chapter 6.2.2) method was already applied successfully in EcoDesign practice. Although not complete (energy is not considered), it yielded interesting and relevant clues for improvement.

The Ecoindicator tool (one- score LCA) was still under development. Although covering only 'scientific green' and excluding 'government green' and 'green' perception, a considerable amount of money was invested in developing the method and the data bank necessary to operate such systems. This was done because it was realized that in the future scientific validation of designs would be necessary for stakeholders dialogues.

The chemical content system (see chapter 3.4) was already in place and had been set up from the very beginning in such a way that it served not only 'government green' (compliance with legislation) but also dealt with the 'green' perceptions of customers and end-of-life issues.

End-of-life evaluation of designs (see chapter 7.1) had already scored its first successes before 1997. PCE decided to proceed with further tool development at the Philips Centre for Manufacturing Technology, but also to sponsor more fundamental work at Delft University. Finally, this led to the ecoefficiency tool described in chapter 7.5.

Highlights of the year, 2001

EcoDesign revisited, ISO 14062

After 8 years in Applied EcoDesign, many developments have taken place: from design rules to manuals, from defensive to proactive, from (self chosen?) apartheid to business integration, from environmental analysis to benchmarking in physical parameters. Simultaneously, it can be observed that industry and academia have grown more and more apart in EcoDesign (see chapter 2.2).

In 2001 a committee from the International Standardization Organization was given the assignment to prepare a report on the integration of EcoDesign into product development. Product design had not been well represented in ISO14001, the general standard for environmental management in industry. This was deliberate. Some representatives had posed the threat to vote against this standard if products were clearly addressed – so as a compromise products were left out.

However later, the subject was raised again. Some countries wanted a separate standard for products. Again there was opposition. Again there was a compromise: make a technical report, not a standard.

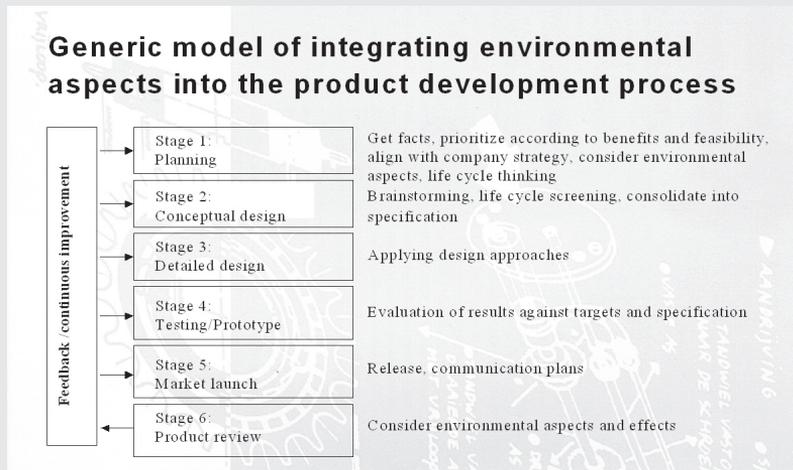
The Netherlands initially did not want to be represented because their original position had been that products should be in ISO14001, so it voted against ISO TR14062. How stubborn the Dutch can be: to take nothing rather than at least something if your views have not been fully acknowledged.

Anyway, I was invited to present at a seminar of the ISO TR14062 committee about applications of EcoDesign in industry. My presentation worked out, as a complete surprise. How could this be?

The answer is simple: through reduction in overhead costs, the budgets of standardization departments in industry has been reduced over time. Particularly for new subjects like environment, industry representation in the standardization committees has become poorer and poorer. Representatives of universities and research institutes supported by governments are gradually taking over.

This development enhances the scientific character of the standards but lowers their practicality. A good example of this is the ISO standard ISO 14042. It has a high degree of sophistication but the net result of this standard has been that it has decreased interest in the use of LCA in industry.

The indirect effect of the seminar presentation was that I was invited to participate in the committee. With a 5 to 4 vote in the national committee I even became the official Dutch representative. The work was intense and took a lot of energy. As one of the few people with an industry background the most important thing was to communicate what was really going on in industry with regards to EcoDesign. It was also a fight against what I considered to be outdated and theoretical approaches. In my perception, the committee's work was not intended to be a beauty contest for which EcoDesign tool or method was the best one. It was about stimulating industry to put more 'green' into their product. A breakthrough came when the following item was produced; it is about the 'processes' when introducing EcoDesign, not about the tools to enable it:



Agreement about this generic integration model was quickly achieved. The method and tool discussion was ended by producing a number of tools/methods for each action or process. All of these were listed in the report. In this way the requirement of 'non-prescriptiveness' was fulfilled as well. Practitioners can make their own choice and really test whether an approach or tool was valuable and whether it had moved to where it belongs: practice.

ISO 14062 was saved and it became much more than just a flexible guideline allowing all kinds of levels of sophistication. It became a strong and helpful document!

6.2 Factor methods and Lifecycle Analysis

6.2.1 Factor methods, environmental weight

The environmental weight method was set up in an effort to link lifecycle stages (production, end-of-life), address impending legislation ('government green') and 'green' perceptions of customers (see 6.1). At the time environmental weight was implemented, abbreviated LCA and Ecoindicator methods were still under development. In contrast to academia, there was serious doubt in industry about whether these methodologies could support applied EcoDesign processes.

Using a stand-alone energy analysis alongside environmental weighting was thought to be a good alternative for the LCA of complex systems such as electronic products, because energy dominates in the use phase. In my opinion this is still a good idea today, especially as a method to better support EcoDesign in small and medium sized enterprises.

Bert Sondern, the environmental manager of the Business Group TV was the inventor of the Environmental Weight method used at Philips Consumer Electronics. Its scope is formed by three focal areas: material application, chemical content and end-of-life (recycling). For packaging materials a similar 'Environmental Packaging Weight' can be established.

The information needed to operate the system consists of:

- The weight of the (main) materials and components applied
- Their chemical content release status (see chapter 3.4)
- Information about marking of materials (for recycling)

In the design evaluation the weight of a material or component is transformed into an 'environmental weight' by multiplying using 'factors'. Factors lower than 1 represent environmental improvements with respect to the application of a monomaterial or component (for instance application of recycled material the multiplication factor is .5). Extra environmental loads with respect to the standard result in the use of factors bigger than 1, see the table below:

Table 6.4 Summary of weight factors in the Environmental Weight method.

Environmental weight factor to be applied	
< 1.0	major environmental improvement
1.0	monomaterial
1.0-2.0	factors for various types of surface treatment
3.0	temporarily released components
4.0	release status unknown
5.0	no marking (plastic parts)
10.0	rejected components

More than one factor may have to be applied to any one material. For instance a recycled plastic, which has been lacquered but not marked will get three multiplication factors. After application of the factors to all materials and components (above a certain weight, for instance 1g) the total Environmental Weight of the product can be calculated. An example of this is shown in the following figure:

Environmental Weight Calculation Sheet HOUSING							DATE: 30-jul-97
Code #	Material type	Env. Status y/t/r*	Marked yes/no	Actual weight (g)	Multiplication factors	Env. Weight (g)	Remarks
Back Cover	Styron 5168	Yes	Yes	2736	0.83	2270	Not painted, sticker
Cabinet	Styron 5168	Yes	Yes	2630	1.33	3132	Water paint, insertsm, tampo
Bott. Plate	Styron XZ94030	Yes	Yes	800	3	2400	Temp. Rel plastic
L S Front PP	EPF 30R	TEMP	Yes	150	1.21	181	Cloth, other palstic
Contr Door	Lexan 121R	Yes	No	45	0.83	37	Other plastic, not painted
Woof Cover	ABS	Yes	Yes	125	1.65	206	Other plastic, paint
LS Grilles	Zincd Steel	Yes	/	230	2.25	517	Zincd, painted
Front Plate	Remex NR200	Yes	Yes	150	0.83	125	Recycled, water plaint
Total actual weight		6866		Release status		8874	
Total environmental weight		8874					
Tio environmental weight		1.29					
Release criterion		1.35					

* y=released, t=temp. released, r=rejected

Figure 6.2 Example of an Environmental Weight calculation

After calculation of the Environmental Weight (EW), the ratio between EW and the actual (physical) weight (AW) can be determined. This ratio EW/AW has turned out to be very useful for design management. The fact that the calculation is transparent makes it easy to identify the big contributions to a score and to generate ideas for improvement. Working out the scores turned out to be fun for most practitioners. The numbers can be played with and the effect on the score is directly visible. At the CE business units experiments were also done with setting targets for the ratio to be realized after redesign. This had a mixed result – even when targets were fixed at the right level (ambitious, but not too ambitious = unrealistic). In some cultures (Anglo-Saxon, most continental European) setting targets stimulates creativity although the game element is somewhat stifled. In other cultures (Asian, some continental European) a target is felt to be more of a threat and is therefore counterproductive for creativity.

Environmental Weight has been very successful between the period 1995-1999. After that it has been gradually replaced by environmental benchmarking (see chapter 6.3). This method is more complete (includes a wider range of items including energy) but separates the balancing of 'scientific', 'government' and 'customer green' from the 'green' idea generation itself. This is done when the 'green' options generated are evaluated through the EcoDesign Matrix. In EW this is included directly in the calculation.

For this reason, I believe that Environmental Weight still has value. Its essential significance is that it balances environmental issues that are seemingly incompatible. In the end this is what society will have to do: balance energy issues (in the EU predominantly EuP), resources issues (in the EU chiefly WEEE) and '(potential) toxicity' issues (in the EU RoHS). Requirements in these three fields will become conflicting, particularly if they become more and more ambitious. Therefore, society will have to determine mutual priorities for the three dimensions. Since science will fail to give a basis for this, the weighting scheme applied explicitly or implicitly will be a subjective one. The Environmental Weight principle (a factor method) can be of help here to demonstrate in a simple way the effect of making a set of choices. This is worked out further in chapter 6.5.

Is the Law the law?

It was a distracting trip, but it was necessary. Going two days from Trondheim, where we had such a good time (see cities, 14), back to the Netherlands.

The agenda of this trip was a very mixed one:

a graduation student in Delft was in trouble and needed to be helped out.

There was a presentation at Philips about the issue of what standardization could bring for progress on environmental issues within the company (not a lot in my opinion – I would be an unwelcome messenger because most attendees would have a different opinion). There was also a discussion planned about the focus of the Philips' Sustainability Strategy. I was in favor of placing energy savings inside and outside the company as priority number one. The general tendency among senior managers was, however, to favor more socially oriented projects like the so-called Bottom of the Pyramid activities. I would do a sales pitch for my ideas but was most likely to lose.

And then there was the real challenge; the challenge to speak at the celebration of the 5th anniversary of the Dutch Take Back and Recycle Scheme NVMP. Friend and enemy agreed that its performance has been better than anticipated – that was the good news. Underneath the surface, however, there was smoldering discontent: NVMP had been a pretty shaky, typical Dutch compromise. There was a chance that the old differences of opinion between industry and the government could flare up again. I had not been neutral in this debate and had backed most of the industry positions, so I could guess that the Ministry of Environment would not be amused upfront.

The Secretary of State for Environment was the speaker after me in the program, so it would be a very interesting afternoon.

I started my presentation deliberately with a provocative title: 'Is promoting Ecoefficiency (relating environment and money) criminal or is it environmental heroism?' It explained that products can have a high recycling efficiency on a weight basis (MRE) but a low efficiency on an environmental basis and vice versa (high environmental gain, low MRE). There are products with a high MRE at a low cost or a high MRE at a high cost as well. So, there is lots of work to do on NVMP operations, but also for the Ministry in rule making. In particular public policies on recycling should pay more attention to input of the recycling systems (collection), for the level of reapplication of the resulting secondary materials (output) of the recycling systems and the eco-performance of recyclers (both the ecological and the economic performance, not just cost alone). As a final message it was added that the Netherlands should promote its relatively good system more effectively in the EU (see also chapter 8.3).

And what did the Secretary of State say? He repeated the old ideas about recycling of electronics. About Individual Producer Responsibility, Polluter Pay Principle, the importance to reward EcoDesign, about design for disassembly and necessity of the modular construction of products. All of the Eco-beliefs of 1995 were included. Already around the turn of the century it had already been identified that completely different issues like achieving economy of scale, investing in high-tech treatment technology and high level reapplication of secondary materials were the real critical success factors for ecoefficient recycling systems. Apparently his speech was written by the traditionalists in the Ministry which had not caught up with latest developments. The body language of the Secretary of State showed that he himself felt in one way or another that there was something wrong with his speech. Also in the conference hall a kind of uneasy atmosphere seemed to build up among the audience. The Secretary of State did not have the improvisational talent to modify his speech while talking, he continued "to play the old gramophone record."

The gap between the two speeches could not have been wider. At the reception afterwards, the Secretary of State came to me and said: "Professor, I understood your messages very well and will do something with it!" He earned my respect - nevertheless I will never vote for the political party he represents.

6.2.2 Application of Life Cycle Analysis

In the nineties of the last century the status of the Life Cycle Method (LCA) has been a subject of continuous debate both at the Design for Sustainability Lab at Delft University and at Philips Consumer Electronics (PCE). On one hand, LCA and the methods derived from it (mostly simplified methods) were most commonly recommended by academia and consultants. On the other hand it was realized that LCA chiefly reflects 'scientific green', partly reflects 'government green' and does not reflect 'green' perceptions, for instance 'customer green' (see chapter 6.1).

Common sense and benchmarking methods (see chapter 6.3) allow for better results in this respect, as well as the 'Environmental Weight' method that was already applied at PCE which turned out to be successful as well (see chapter 6.2.1). Both benchmarking and Environmental Weight had the significant advantage that environment and business were linked.

In this respect Life Cycle Analysis and also one-score LCA methods are one sided, focus is on the environment and in particular on the emissions dimension. Concepts to link life cycle loads and prices paid by consumers (the Ecovalue concept, chapter 2.3) could add a lot to the societal relevance of LCA. Unfortunately the Ecovalue concept was virtually unknown at the time the crucial discussion described above took place. Research to link environmental load with costs in that period was focused on Life Cycle cost and linking Eco-impacts with remediation costs as well as on 'virtual Eco-cost' models.

In 1999, it was time to take stock of the situation and to position LCA methods in the EcoDesign practice as implemented inside Philips Consumer Electronics. It was necessary to find out how LCA based methodologies could contribute to the formulation of action agendas, policy and strategy making and how it could be used as a 'communication tool'.

A study done by the Design for Sustainability Group with the title "*Application of LCA in eco-design: a critical review*" concluded that LCA based methods were not really suitable to drive these issues in business.

In fact it was one of the first times, that it was highlighted that a gap between the industrial and academic approaches of Applied EcoDesign was starting to develop (see also chapter 2.1).

Inside PCE, LCA (through Eco-indicator '95 and later Eco-indicator '99) achieved the status of a tool for validation only. The tool used to fasten Eco-creativity and link it to the business became Environmental Benchmarking together with the EcoDesign matrix (see chapter 6.3) Environmental Weight (chapter 6.2.2) was gradually phased out.

Application of LCA in eco-design: a critical review

Ab Stevels, Han Brezet and Jeroen Rombouts

Eco-design has now become a business issue in various sectors. To enable eco-design requires a wider range of tools, most of which are in their early stages of development. Life Cycle Analysis (LCA) has emerged as a key tool. The article is based on Delft University of Technology's (DUT) experience of working with industry on eco-design projects using LCA. DUT's experiences are highlighted illustrating the strengths and weaknesses of LCA and the growing gap between industry needs and academic research in this area.

Introduction

Within the Delft University of Technology's (DUT) Design for Sustainability (DfS) programme, at the Sub-faculty of Industrial Design Engineering more than a hundred industrial eco-design case studies have been undertaken between 1993 - 1998, through graduates, PhD students and staff.

DUT's eco-design approach advocates several types of Life Cycle Analysis (LCA). This refers both to the selection of 'attention fields' and the creativity phase (finding green options) as well as to the environmental validation of design improvement recommendations.

Research has highlighted that consideration of *both* the technicalities of eco-design and the management of eco-design processes are crucial for success or failure. This relates to both the front end (idea generation and concept development) and to exploitation of the results in the marketplace. In all these processes the availability of appropriate manuals and tools plays an essential role. DUT's contribution to these include:

- PROMISE, a promising approach to sustainable production and consumption (Brezet and von Hemel, 1997)
- EPAAss, a manual for environmental benchmarking (Jansen and Stevels, 1998)

Tools include:

- LEADS, Lifecycle Expert Analysis of Design Strategies (Rombouts, 1998)
- IDEMAT, a material and process database for product developers containing mechanical, physical, financial and environmental data
- EcoQuest, a supplier ecodesign self-audit tool (Brink, Diehl and Stevels, 1998)
- STRETCH, a methodology for advanced environmental product development (Cramer and Stevels, 1998).

The LCA methodology has a pivotal position in the ecodesign process and tool applications at present. Particularly, in the selection of 'attention fields' and in the validation stage, the use of LCA is essential for environment-oriented product development. To a lesser extent this also holds for the creativity phase itself.

In this article, the DfS Programme's experiences of the use of LCA in industry-based eco-design projects are evaluated. This has led to the identification of both limitations and opportunities for LCA and directions for action and further research.

The following seven aspects related to LCA will be discussed in this article:

- LCA from the problem solving perspective
- methodological issues
- data issues
- LCA from the business perspective
- LCA as a stakeholder communications tool
- standardisation
- future of LCA.

LCA from the problemsolving perspective

- LCA is a very effective tool for the selection of product-related environmental impacts that need to be prevented or reduced. It is also useful in validating green design options when a mix of energy and, material application and process related aspects play a role. In a wide range of linear problems, good solutions can be found with a high level of sophistication and practicality.

- LCA is less effective in situations where toxic/ hazardous substances are involved (embedded toxicity with time dependent release) (Tukker, 1998). Its use in tackling recycling issues is also fairly cumbersome due to assumptions that have to be made to satisfy system boundary requirements. A main problem with LCA is that it is primarily based on an inventory of flows as at a moment in time ('in-out') and not on a balance sheet principle. As a consequence, taking the future into account is problematic, particularly for resource use ('environmental investment').
- In terms of environmental validation and prioritisation of green design options and product performance, current LCA approaches generally provide satisfactory information, provided that the analysis is made organisation-internal and on a relative base (Stevens, 1999). There is also evidence that a single figure LCA score like the Eco-Indicator '95 performs well in this respect. The obvious advantage of indicators and abbreviated LCAs is their need for limited expertise, time and money, which makes it a very practical solution for internal product comparisons despite all the criticism from the scientific point of view. Tools that can be used are EcoScan, SimaPro (see References) and others. Due to a lack of a standardisation LCA is not yet appropriate for external comparison or absolute calculations.
- LCA is not suitable for generating green design options, because ideas generated by LCA often go beyond the influence of designers. This is due to the lack of separation between internal (eg. Product properties) and external (eg. electricity generation and waste treatment) issues in LCA applications (Stevens, 1999). As a consequence, linking the eco-design concept with the creation of sustainable, new 'business' coalitions (joint ventures with suppliers, recyclers, users etc.) and markets cannot be done through LCA. Therefore this link, which ultimately defines the overall net environmental benefit of 'ecodesigned' product-market combinations, needs to be based on additional models and tools, like 'scenario making' (simulation of future user perspectives and preferences), environmental accounting (assessing the environmental and financial-economic benefits of eco-design concepts) and innovation management theories. Good results have been generated by benchmarking followed by supplier contacts (Brink, Diehl and Stevens, 1998) and green brainstorming (Cramer and Stevens, 1997). This generally leads to options within the designer's sphere of influence. In addition, the societal green context can be determined by using, for example, the Eco-Indicator 95.

Methodological issues

Currently worldwide efforts are being undertaken to enhance LCA methodology. It is the authors' opinion that some basic problems with LCA will remain which cannot be fundamentally solved (like time dependence, system boundary and momentary bases). The rating of impact categories, as one of the steps in LCA procedure, is and will remain a subjective issue, as long as environmental sciences are only able to provide a very complex impact model.

With the progress currently being made all these issues can be solved, but the application by non-expert users (like policy making bodies and industry) will become too complicated and too costly. For LCA to progress, this will be a fundamental issue eg. how to balance a maximum of scientific truth with a maximum of user friendliness while keeping cost and capacity involved within reasonable boundaries.

A further problem with the methodology is that LCA works reasonably well on the product level, however on the level of service systems, analysis is very problematic. In developing product-service combinations, like car-sharing services in neighbourhoods or at work, consideration of the infrastructure available (roads, parking lots) is an essential precondition for success. Other variables are also important, for example, the number of supportive products within the service (number, type of cars), the service co-ordination centre (space, use, energy) and the number and activities of employees involved. In selecting the products (cars), LCA can help us, but for making infrastructure choices standard LCA procedures are not or are less appropriate (only with a lot of artificial modifications). In addition, the effects of human labour should be included, which at this moment is usually omitted. When more fundamental system changes are discussed the exclusion of capital goods or infrastructure changes from the analysis makes discussion problematic (Goedkoop, 1999). To gain large improvements in sustainability there needs to be a move to more innovative solutions on a higher level than the product level. To improve eco-efficiency by a factor 20, which is often quoted as a sustainable level, an impact reduction of 95% needs to be gained

which will be impossible by just improving our present day products (Brezet, 1997).

There is a big opportunity for universities and research institutions to develop new methodologies, which can operate meaningfully on the system level.

Data issues

Both data accuracy and data accessibility (databases) are both issues currently posing dilemmas. On the one hand there is a clear need for higher accuracy and reliability of data, but this will drive up the cost of data collection tremendously and only in a few cases will LCA practitioners be able to afford such a high standard. Data collection for LCA goes to the heart of business and enterprises, and many proprietary items will have to be discussed, especially when a high level of accuracy and reliability is required. In Europe many of the parties involved in LCA are willing to cooperate; however the condition is that the data acquired will only be used in private/proprietary relationships and will not be made public. A key question is: what is the best choice for the time being? and what is the best compromise?

LCA from the business perspective

There has been an evolution in thinking by business about environmental methodologies like LCA.

Leading industries have moved from a defensive to proactive position, from necessity to opportunity, and from the standalone to full integration into the business.

The academic community (including the LCA community) has generally been (and still is) slow in following this shift of thinking. Therefore we are now confronted with a gap between the proactive industry approach and academic approach. See also Figures 1 and 2 (Stevens, 1999).

Industry		
step1 start with creative approach to environmental issues you can influence (benchmark, brainstorm)	step2 validate and prioritise according to LCA	step3 check prioritised options against company, customer and society benefits
step4 check feasibility (physical, financial)	step5 implement in programme	
Academia		
step1 do LCA analysis, holistic approach	step2 select internal and external improvement options	step3 start stakeholder discussion
step4 come to solutions	step5 implement in programme	

Figure 1 Industry and academic approaches: issues which can be influenced

The proactive industry approach is actor based with an emphasis on effective implementation (with ownership). LCA has a useful but not a dominating role. The academic approach generally is holistic (with no specific ownership) and is centered around LCA. With respect to business there is generally a self chosen 'green apartheid' or specialisation within companies which seriously hampers practical implementation. This gap is deeply concerning and DUT is focussing part of the DfS programme on closing it.

LCA as a stakeholder communication tool

- In all parts of the world (even in the most environmentally conscious countries) environment as such is an appealing factor to a minority (25 % or less) of the potential customers. A majority (75 % or more) of potential customers however are attracted by a combination of an environmental benefit and other benefits (like money, fun/ease/ comfort or other positive emotions). For successful marketing and sales of eco-designed products the creation of a mix of the above consumer variables and values is an essential step. This also establishes the direction that environmental communications needs to develop. Environmental policy tools like ecolabelling should be replaced by a segmented approach, communicating an attractive mix of users' values, for instance:
 - lower energy: good for the environment and good for your 'wallet'
 - less packaging: fewer resources, easier, less hassle with waste
 - more recycling: waste reduction, fewer resources, feels good'
 - less hazardous: good for the environment, no fear any more
 - less material: fewer resources, cheaper, etc.

It has been argued that the lack of buying of eco-labelled products by the general public is due to a lack of scientific thoroughness and as a result LCA based eco-labels have been proposed.

The authors believe the contrary: the general public is calling for simplification rather than for sophistication and wants to be communicated to in terms of a world they live in.

When communicating to professionals the approach should be different. Professionals which are intermediates between policymakers and manufacturers (journalists, environmental experts of consumer organisations, etc.) generally appreciate environmental issues in terms of LCA. As such this category is likely to be well disposed to receive more specific information.

This picture changes at the moment the target group for communication consists of the environmental specialists (for personal interest). In this context, LCA is likely to get a sympathetic reception but the methodology applied and data accuracy will be critically reviewed. In general it will be argued that the actors have not sufficient thoroughness in their approach and apply over simplifications. From their perspective this always remains true whatever action a company takes.

Standardisation

Before touching upon the issue of standardisation in the field of LCA, we will go back to the origin and nucleus of standardisation. This is an industry interest because standardisation makes it easy to compete on a global level playing field. Therefore initially, industrial representatives took a strong interest in standardisation issues and were - for instance - strongly represented in the International Standards Organisation (ISO) committees.

In the present wave of cost cutting and 'lean and mean' approaches, industrial participation in standardisation authorities has declined. Their position has been taken over gradually by institutional (often government sponsored) and academic representatives. This has resulted in a shift in character of the ISO standards (the ISO 14.000 series): standards have become more comprehensive, have a highly scientific context, but their applicability is diminishing.

This is leading to a strong criticism from industry of the LCA standards under development. As a result, industry is considering initiatives to develop a separate (sub)standard which is more workable/applicable in practice (Lehni, 1998).

From the governmental side there is also criticism. Ideally an LCA based legitimacy of environmental policies would be a good basis for policy. However even in countries where this has been seriously attempted (eg. The Netherlands) this point has not been reached. Apart from the politics - including environmental politics - there are strong emotional and social components. Both components are part of real life and as such are legitimate but they also are very difficult to reconcile within a rigid LCA approach.

Altogether the future of LCA standardisation and related items is unsure, there will be either a single set of standards, which will be difficult to apply, or two sets with a continuous debate about the shape and significance of them. Neither of these two scenarios is attractive.

Example

An example given in the table below (Figure 2) shows the shortcomings of LCA/Ecoindicator. This example refers to the development of the Green 'Brilliance' monitor at Philips Electronics Monitor Division located in Chungli, Taiwan. This project was undertaken by DUT and Philips Consumer Electronics (PCE) Environmental Competence Center (ECC) in Eindhoven, the Netherlands.

This table (Figure 2) shows the complete environmental design process with all the LCA issues cited in this article playing a role. The column 'remediation' indicates that the weaknesses of current LCA/Eco-Indicator can only be partially compensated for other ways and means.

Stage	LCA issues/problems	Remediation
Idea generation		
Collect data (benchmark, suppliers)	Toxics, scope, methodology	Separate assessment of hazardous substances and 'end of life'/recycling
Brainstorm	Methodology	None
Concept consolidation, execution of eco-design		
Address focal areas: - Energy - Materials - Packaging - Hazardous substances - 'End of life'/recycling	Not applicable, use common sense	Not applicable
Address lifecycle perspective	Toxics, scope, data	Separate assessment of hazardous substances and 'end of life'/recycling
Exploitation of results		
Validation of results	Methodology, scope	None
Communications, marketing	Business perspective, private customers, scientific community, standardization	Very partly, communicate in bases of common sense (= 'unscientific')

Figure 2 LCA issues in the eco-design process.

Future of LCA

As things stand now, the future for the application of LCA in industry looks fairly bleak. The basic reason for this being is that LCA is a 'mix', that is a mix of scientific and practical elements, a mix of present and future, a mix of tangible and intangible issues. As things stand now this will be very difficult to sort out based on a consensus between stakeholders at a global level.

What should companies do now? Two approaches are recommended:

- Develop 'environmental accounting' (which in the authors' opinion is the fundamental reason for LCA) identical to accounting systems in the financial world. It can be done and a tremendous benefit would be the comparability in treatment of ecological and economic issues - as it is the authors' belief that ecology and economy are highly correlated (approximately 75%). Within the DUT DfS pro-gramme part of the research effort is focusing on this issue (Vegtlander, 1998) (Gielen, 1999).
- Create a 'living space' for different levels of sophistication of LCA (as a validation method). This will prevent endless discussions between practical, fundamental and politically oriented practitioners, as described in the study on the adjustment of LCA methodology of Bras (Bras-Klapwijk, 1999).

The authors' experience indicates that there is one effective solution to the many problems that seem to be associated with LCA (and also for instance ecodesign) - that is: experience of 'practice will show the way'. The DUT

DfS programme will research industry's experiences with LCA, and will model them into computer-aided tools (like described by Rombouts, 1998; Brink, Diehl and Stevels, 1998; and others) for both large industries and SMEs and will thus play its role in the development of a more sustainable future.

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Hans-Jörg ('Torsten') Griese: civil values and curiosity

In 1995, at the Environment & Electronics Conference in Edinburgh, a person speaking English with a strong German accent approached me to become a board member of his Institute, the Institute for Zuverlässigkeit (Reliability) and Mikrointegration (IZM) in Berlin. Its special focus would be environmental issues. The guy turned out to be Hans-Jörg (Torsten for friends) Griese, head of the environmental department.

I answered that I would like to visit IZM first so that I could get a better idea of what my responsibilities would include. Soon after that, I was in Berlin, my first time after the "Wende". IZM turned out to be a positive surprise – a combination of solid traditional German style science and technology and the strong drive to move forward into new territories, including the environment.

IZM was also an amalgamation of an East German (Humboldt) and West German (Fraunhofer) Institutes with all the problems associated with that. If you have grown apart for 40 years, coming together in a short period of time is difficult.

At night we had a group dinner at a good restaurant and it was wonderful – it was as though all of us had already known each other for many years. There was a lot of communality, although IZM is very German and I am very Dutch.

Torsten is the personification of this communality. We both grew up after the war period, we both learned never to throw away food, to close the door (save energy), to be modest in your requirements (common sense), to be ethical in your work and to believe that reason will win in the end. These were all civil values, which were engrained both in the heads and minds of citizens. This climate still helps to deal with a lot of societal phenomena today. Being proud of what is normal, declaring special what is standard, asking a lot of money for what is your duty and responsibility, all represent the craziness of today, which has little to do with 'bürgerliche Anständigkeit'.

I would never want to go back to the fifties. That period is history. With all its goodies, it was dull, petty, 'klein kariert' (why do Germans have these nice words you cannot translate?), gloomy, and full of political threat from the East. Students revolted against this type of society in the sixties, which was rightly so. In the end so called 'alternative thinking' brought more damage than benefit and still today considerable 'repair work' needs to be done.

What do Torsten and I share most? We share curiosity, a desire to learn new things, care for the future, the dream to create (a little) a better world, 'Sehnsucht in die Ferne' (longing for what is far away), travel, Iceland, China, the Baltic sea countries and the 'Boddenlandschaft' (a region in the north of Germany at the Baltic Sea coast). Finally, we share a commitment to hard work, working to the best of your abilities, having fun and memories of completing the Great Spur walk on the Great Wall of China (see Cities, 2).

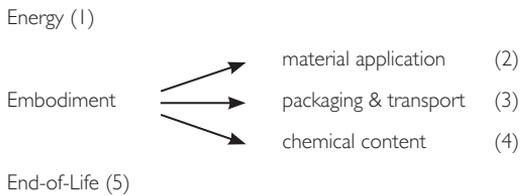
Yes, I became a board member. IZM remains intriguing. Berlin continues to be emotional (Cities, 3). Torsten and I became friends, including Angelika and Annet. The environmental group at IZM earned a special place in my heart.

The 'Griese' Walk: Go with the S-bahn (S7 or S1) to Nicolaussee, walk along Schlachtensee, Krumme Lanke, Fennggraben, Langesloch, Grunewaldsee, Hundekehlesee to S-Bahnhof Grunewald. If you still have courage to proceed on the other side of the Avas avenue, follow the Schildhornweg, climb the Teufelsberg, go north, and return through the Teufel-seestrasse to S-Bahnhof Heerstrasse.

6.3 Environmental Benchmarking

6.3.1 The EPAss method

The origin of Environmental Benchmarking is at Delft University for obvious reasons. As a University of Technology, Delft has a strong engineering tradition. Engineers want to measure upfront to do a better engineering job and to measure performance at the end to show that results are according to specifications. Making calculations is not good enough, it must be shown through measurements that it is alright. Applied EcoDesign is an engineering activity as well; therefore it fits extremely well in this Delft tradition. From very early on, activities at Delft were aimed at creating a systematic approach for environmental product assessment. To make this easier the product life cycle was deconstructed and reorganized into five fields to which physical and chemical parameters could be more easily attached. These five fields are:



[In a later stage this would grow out to the five focal area's approach at Philips.]

Students carried out several projects in order to see whether environmental product attributes could be measured in terms of simple metrics. Subsequently it was investigated whether such measurements could be used as a basis for EcoDesign creativity.

In this way a wealth of data was generated. On the basis of this data vacuum cleaners, coffeemakers and audio equipment were redesigned. The measurement procedures and their 'translation' into design approaches were consolidated into one benchmark procedure which was given the name EPAss (Environmental Product Assessment).

The EPAss method is explained in the article on next page. It has the title: *The EPAss method, a systematic approach in environmental product assessment*.

The EPAss method, a systematic approach in environmental product assessment

A.J. Jansen and A.L.N. Stevels

Abstract

This paper presents the EPAss method, a systematic approach in environmental product assessment. It consists of 6 comprehensible steps and provides design engineers with a clear method to assess consumer products on various environmental aspects. The method aims at identifying environmental redesign opportunities, the so called "green options". The EPAss method has been applied to various electronic products and has produced very good results, both from the academic and the business perspective.

1. Introduction

In the past years there has been a changing focus in environmental awareness. In a rapid pace the 'end-of-pipe' thinking has been redirected towards the earlier stages of the product lifecycle. It is realised now that environmental responsibility starts with the product design stage and we can see a rising number of methods directed towards environmental improvement of product (re)design. The Environmental Product Assessment method

(EPAss) originates from the Subfaculty of Industrial Design Engineering (IDE) at Delft University of Technology (DUT). The EPAss method offers a framework for the analysis of existing products and provides opportunities for the definition of (re)design options. The EPAss method aims both at academics and business professionals in the field of bench marking competitor analysis or environmental analysis. Due to the same approach for and the use of the functional unit, the

EPAss method offers a easy link to the Eco-scan Life Cycle Assessment (LCA) software package (Turtle Bay, 1998). The EPAss method has been documented in the EPAss manual. It contains the six steps of the EPAss method divided in a number of clearly described actions. At the end of each analysis step the manual contains a description of the so called 'short track' (overview of main items) and a check list.

2. Overview of the EPAss method

The EPAss method is divided into six steps (Fig. 1), which will be explained in the next paragraphs. The core of the method consists of the 3-e fact sheets. In these sheets, data concerning energy, embodiment and end-of-life are presented. The sequence of the analysis steps is empirically determined in earlier analysis sessions at DUT. Due to the nature of the method, some overlap will occur between various steps.

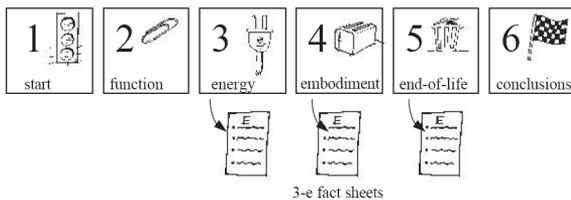


Figure 1 The six steps of the EPAss method

2.1. Start (step 1)

The starting position of the EPAss session should be defined clearly by knowing all available information on the product and its use. This information will also provide a starting point when defining the functional unit in step two. It is essential to be aware of the goal, the expected results and whether there should be any emphasis on specific aspects of the EPAss session. Besides these aspects, attention is paid to the acquisition of the product (packaging, price, documentation, manuals, remote control, accessories like batteries, grease, etc.)

2.2. Function (step 2)

In the second step of the EPAss session, the product is analysed on its functional aspects, the emphasis is on the definition of "the service provided by the product". A well defined description of the analysed function is of key-importance in the correct (environmental) assessment of products. The EPAss method uses four approaches to perform this task:

- the definition of the product-system and system borders,
- the input/output diagram,
- the functional unit and
- the life cycle of the product.

All four conceptions contribute in their own specific way to clarifying the functional aspects of the product. They will be discussed briefly in the next four paragraphs and will be illustrated by using examples from the EPAss session on fruitjuicers.

Analysing the product-system and its borders is one way of defining the scope of one specific EPAss session. The borders of the product-system are defined by the number of process levels and the scope of the process tree. Besides these main issues, product-system borders are also determined by time and space. Will we look at the

product now or in the future? Will we look at the product in a global scope, or do we focus geographically? See fig. 2. In this example, the product system is defined as the combination of fruitjuicer, knife, cutting plate, oranges, electricity, water and the user. Outside the system border we can see the power plant, the waste water treatment, etc.

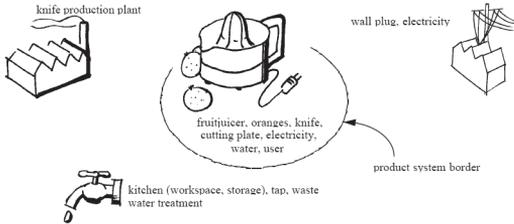


Figure 2 Example of product-system description of an electric fruit juicer

The product life cycle describes 'all the stages of the life of a product'. A standard life cycle is defined by the following steps; production (extraction of raw materials, purchase of components and sub-assemblies and production/assembly of the product itself), distribution (packaging, transport, handling, ..), use (purchase, installation, use, maintenance, repair,.....) and end-of-life (re-use, recycling, incineration, landfill,.....). The system boundaries of the life cycle can be varied in three dimensions: length; in time ('cradle to grave' approach or just use-phase), wide; in number of related processes or product life cycles taken into account and depth (number of sub-assembly levels).

Life cycle and product system borders are closely related. The description of the life cycle helps in defining the (borders of the) product-system and the other way around; the definition of the product-system (and its borders) helps in defining the number of related processes to be taken into account. In the case of the fruit juicer; the kitchen knife to cut the oranges *does* belong to the product system, (Fig. 2) but its production (an additional life cycle) is *not* taken into account when describing the life cycle of the fruitjuicer.

In the input-output diagram, the product is seen as a black box, interacting with its environment (Fig. 3). The total input needed to reach the required output can be divided into: material, energy and data (information). The product is described as the (physical) embodiment of the chosen functionality. The total output has to be divided into: required output (required by the user of the product, which also can be defined as: the service provided by the product) and unwanted output, not pursued by the user but inevitable when using the product and sometimes offering unexpected (re)design opportunities.

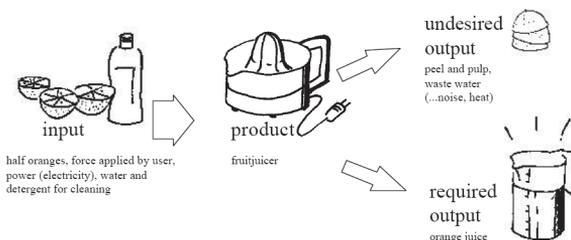


Figure 3 Example of input-output diagram fruit-juicer

One of the definitions of a product is based on the perceived benefit(s) of the product to the user(s). A product should provide a service or utility to the user(s), it is the reason for its existence. A service or utility, however, can be provided in many ways (Tab. 1). This offers the opportunity for environmental product assessment to com-

pare the environmental consequences of products and services and vice versa (Wenzel, 1997). Quantifying the magnitude 'service' gives the 'functional unit'. This quantification is necessary in order to make different products and services comparable. The functional unit acts thus as a fixed reference point for analyses and assessments. The functional unit also offers the possibility to take different life spans into account.

A functional unit should include both: a qualitative description of the service delivered by the product (also defining the quality level of the required service) and a quantitative specification of the duration of the service and the amount of products used, based on the expected life span of the product (Wenzel, 1997). Keeping this in mind it is useful to ask if there is a difference in life-time of the compared products.

Table 1 Various examples of functional units

Service provided by the product	Functional unit	Product	Alternative product(s)
fresh teeth	"..giving the impression of clean teeth, twice a day, for one year...."	0,25 electric toothbrush, tooth-paste, electricity, ...	two toothbrushes, toothpaste,
amusement	" ..providing amusement during two hours in the evening, three evenings a week, for three years...."	0,2 TV sets, electricity, 1 remote control, batteries for remote control, 156 TVguides,	24 books
clean dishes and pottery	"..cleaning a specific amount of plates and dishes, once a day for one year...."	0,1 dishwasher, water, electricity, detergent,	two brushes for washing up, water, detergent, drying cloths

2.3. Energy (step 3)

In the third step of the EPAss method, the focus shifts towards the energy consumption of the required functionality. The results will be charted in the first of the 3-e fact sheets. This step starts with the description of the energy system and type of energy used. A full description of all energy conversion taking place in the product should be made; what type of energy goes in and type of energy comes out, how does the energy conversion take place and what is the total efficiency. An example (Fig 3) is given from the 'portable audio benchmarking study' (Jansen et. al., 1997).

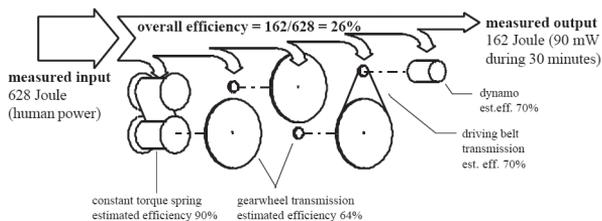


Figure 4 Input and output of energy, and estimated efficiency of transmission of the BayGen Freeplay radio

When analysing the energy consumption of a product, the process tree of the life cycle (Roozenburg and Eekels, 1995) proves to be a valuable tool in providing structure. Therefore, the analysis step concerning energy is divided into production, distribution, use and EOL. For various products large differences exist in environmental burden caused during production, distribution, use and EOL (Tab. 2) Finally, special attention is to be paid to batteries.

Table 2 Energy consumption during use phase as a percentage of total energy consumption

Product	% of total env. load caused by energy consumption in the use phase
Telephone (table top model, no portable)	22
Vacuum cleaner	70
Domestic electric water cooker	90
Light bulb	99

2.4. Embodiment (step 4)

In the fourth step of the EPA_{ss} method, the analysis is focused on the embodiment of the required functionality, in many cases this means the product itself. In this step, the actual disassembly of the product will take place. The results of this step are documented in the second e-fact sheet. Step 4 'embodiment' is divided into:

- product design; Take a holistic approach towards all aspects of the product, including e.g. quality and durability. These aspects can only partly be described into technical terms because the impact of the product is -for a considerable extent- determined by user behaviour and even consumer perception (van Nes et al., 1998).
- product structure chart; When analysing the embodiment of a product, insight should be gained into the products' physical structure by making a schematic representation of the product (product structure chart). This scheme contains main components (or subassemblies), their physical/ mechanical principle of operation and their relation(s).
- materials application, production, assembly; Used materials, presence of hazardous substances and the number and type of attachments are specified.
- electronics; Specification of electronics technology and materials.
- packaging and directions for use; Packaging materials and material and contents of the directions for use are specified.

2.5. End-of-life (step 5)

The chapter end-of-life, concerning the last step in the life cycle of a product consists of three series of actions. The results of this step are documented in the third e-fact sheet. They are divided into:

- before the disassembly of the product; The disassembly sequence of the product needs careful consideration, this sequence can be documented in a disassembly plan.
- during product disassembly; Difference between destructive and non-destructive disassembly should be marked. Record the disassembly session (on video) and register all components or sub-assemblies for later analysis purposes.
- end-of-life scenario; Based on gathered data, the most probable EOL scenario can be determined. A choice should be made for the most likely collection system and processing route.

2.6. Conclusions (step 6)

The sixth and last step of the EPA_{ss} method consists of:

- definition of (re)design opportunities ('green options')
- the green options matrix
- sensitivity analysis on used benchmarks
- conclusions and evaluation

(Re)design opportunities or so called 'green options' must consist of an objective environmental benefit, coupled to possible benefits for the consumer and the company. These benefits are analysed based on physical parameters as described in the 3-e fact sheets. Besides the benefits, investments and technical feasibility take part in the evaluation process (Stevens, to be published). The presented Green Options Matrix (Tab. 3) can be filled using data from an LCA software package (e.g. EcoScan) (second column) and conclusions from the analysis of the 3-e fact sheets.

Table 3 The Green Options Matrix

Green Options	Benefit				Feasibility	
	Environmental	Business	Customer	Societal	Technical	Financial
First option						
Second option						
Third option						

After having completed the green options matrix, the sensitivity of used benchmarks and assumptions has to be analysed. Will the results show major changes when altering the functional unit slightly? Will the conclusions remain the same? At the end of the EPAss session look back at the start, step 1; Has the goal, as described when starting up the EPAss session, been reached? How did the EPAss method suffice?

3. Experience so far

Recent experience with the EPAss method in analysing various products (portable audio products, computer monitors, VCRs and audio systems) show good results. For instance the monitor benchmarking project (Eenhoom, 1997) resulted in approximately 50 green options which -when fully implemented- will result in savings of: energy consumption (15%), less weight of plastics applied (33 %), less packaging materials (35%) and shorter disassembly time (42%). The product resulting from these improvement actions, the Brilliance Typhoon II monitor has won the Philips Environmental Award 1998.

Especially, the careful definition of the functional unit, as described in step 2 of the EPAss method, makes the results valid in helping to make design decisions. Ongoing use of the EPAss method by graduate students at the Subfaculty of Industrial Design Engineering will extend the experience with this analysis method.

When linking LCA results (EcoIndicator calculations) and other data in the Green Options Matrix at the end of the EPAss session, it is of greatest importance to make sure that the way in which the functional unit(s) have been defined is identical. The EcoScan software package (Turtle Bay, 1998) offers a complete match, this is one of the reasons why we use this package.

Our goal at Delft University of Technology is to keep improving the EPAss method based on practical experiences. Therefore we are looking for extensive co-operation with companies, for example in projects done by graduate students. Our experience so far shows good results, for the environment as well for business. These results are achieved with relative little efforts and small investments.

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Jyväskylän Yliopisto

Finland has a special place in my heart because of its people, nature and history. Therefore I was particularly delighted to be invited to participate in a PhD committee at Jyväskylä University.

The preparations for the event went as usual. The manuscript had to read and comments and feedback had to be given to the candidate. If these are taken into account satisfactorily, the appraisal of the thesis can be written. This is the basis for a letter of approval stating that the thesis is in a form such that the candidate can be admitted to participate in a defense.

Parallel to this, the questions to be asked at the ceremony are prepared.

In the Jyväskylä case, things took a different turn when I got the PhD regulations two weeks before the defense. The good news was that the ceremony would take place in an auditorium and that as a committee member you were supposed to wear your gown and other university paraphernalia like a bonnet and a sash.

I like this great tradition which exists at Delft (and at other Dutch universities), and apparently at Jyväskylä too. It always feels a bit uncomfortable to have a defense in a class room in a business suit (like in many countries in Europe). To see committee members wearing polos and sweaters, like sometimes happens in the USA, is a weird experience.

The challenging news was that I was the only committee member allowed to ask questions; in Finland there is only one opponent and only one debate!

The real threatening news was that the minimum time for the disputation was set at two hours (maximum five hours). Realizing that Finns generally are not the most talkative people in the world exacerbated the problem. I wondered how to set up an interesting debate involving the candidate which tested the content of the dissertation in an in-depth way. What had to be done anyway was to prepare many issues to be raised in the debate.

Two weeks later the day arrived. It was a glorious day, the sun was shining on that day in June; giving that special light shimmering through the trees – so characteristic in Nordic countries near the mid-night summer.

For the defense, the PhD procession went into the auditorium, which turned out to be a chapel. Jyväskylä University started as a college to educate Ministers and Preachers. It was all there: Bible texts on the walls, the Ten Commandments, Lutheran sobriety. In this hall, the candidate, Hanna-Leena took the position at a desk at the left hand of the promotor/committee chairman. I stood at a desk on the right hand side: the numerous audience members were gazing at us with tense expectation. The debate started at one o'clock sharp and went the way I feared most. In the beginning Hanna-Leena always replied by saying, "Dear opponent, you are raising a very interesting point", then she added two or three sentences and that was her full answer. The debate ran quickly through one item after another. Disaster was looming, I would run out of steam after half an hour or so. I looked around the room and thought in the best tradition of the Old Testament, 'from where will my rescue come?' And then I saw in the corner that there was a blackboard, barely visible, but it was there. I left my desk and moved it to the front and started writing on it. It helped; the complexity of the issues could be addressed better.

Academic tradition says that a defense should rely on the power of the spoken word, but the board helped a lot. Our disputation was enriched through the use of it and the arguments gained depth and sharpness. After two hours and fifteen minutes it was enough for a clear 'iudicium', although proceedings could have taken longer. Both the candidate and the opponent were judged to have done 'very well'.

The final conclusion of the committee: the Doctorate is awarded with high honors!

For the opponent there is still one surprise waiting: the dinner party that night. This party is primarily in your honor, rather than for the young doctor.

It turned out to be a cozy candlelit quiet family style affair, with relatives and friends having prepared the dishes. There were no big speeches as the wine slowly changed to vodka. At the latitude of Jyväskylä the sun just goes under in the mid of June; what remains however is a violet light skimming over the horizon giving these weird shadows. This contributed largely to the wonderful mood in which my wife Annet and I walked to our hotel.

Vivat Academia Fennica Scientiorum!

6.3.2 Environmental Benchmarking and Design Improvement

The internal success of the EPAss method led to the idea of setting up an EPAss test lab at the University. This lab should support industry. Before doing so, the concept was to be tested in industry and it was obvious to do this at Philips Consumer Electronics.

PCE initially resisted the idea. It reminded them too much of their own testing lab, which was scrapped during the 'Centurion' reorganization because "it was not contributing to the business". This, as such, was true. However, this was not due to lack of interesting or challenging items in the findings of the Test Lab. It was due instead to the lack of communication with the product managers and with the development labs, the internal value chain issue, see chapter 5.1.

In view of the experience described above, it was difficult to sell the EPAss idea.

However, it was an opportunity which had already been demonstrated by the Delft students to have much wider implications than just 'green'. In practice it was a big difficulty. Who was prepared to take these ideas on board? Graduation students work almost for free, there is no risk, but even pointing to that did not take away their reluctance to try EPAss out.

Finally, Business Group Monitors in Chungli (Taiwan) agreed to do a test. On one hand this was due to credibility that had been built up earlier (see Tidbits, 11), on the other hand the fact that the business group was losing ground to Sony and Samsung and needed a helping hand. This circumstance brought in a new element as well; not just benchmark (as EPAss did), but compare also with EPAss results of products from the competition.

Soon the student Geert-Jan was allowed to come over to Taiwan and carry out the project together with a local crew. He did a great job, converting the relatively formal EPAss approach into a more practical one. The results were transformed into design ideas through a brainstorm (see Tidbits, 12) in which the EcoDesign matrix (see chapter 6.4) was developed as well. In 1998 BG Monitors won the Philips Prize for the Best Environmental Product of the Year.

The results at Monitors meant that the other Business Groups became interested too. Several Delft students then got the opportunity to show their skills through environmental benchmarks. The Delft EPAss manual was transformed into a Philips Consumer Electronics focused environmental benchmark manual. It gained wide acceptance. In this way benchmarking became the cornerstone for PCE's EcoDesign activities. Moreover, it was used to select products for obtaining a Green Flagship status. These are products of which the environmental performance was significantly better than the ones of the competition – for 'significant' there are well defined (proprietary) criteria in all focal areas.

In terms of the methodology the core position of Environmental Benchmarking was a breakaway from traditional EcoDesign. Gone were design rules, no upfront LCA analysis and no specific EcoDesign-projects anymore. Both the link established between 'eco' and the traditional Product Creation Process and the use prioritized design options and thinking in physical quantities in 5 focal areas were new. A 'life cycle check' at the end of the Product Creation Process was kept in place. It is based on an Ecoindicator (abbreviated one-point score LCA) calculation. In this way LCA is being used for validation purposes rather than creativity purposes. How did it all this work out in practice?

First of all benchmarking created tremendous awareness in the organization. It took two forms; "I never realized that" and "my competitor is better in...". Especially realizing that the competitor is better turned out to be very 'powerful'. In this way environmental issues are taken out of the charity for society domain (which even today at proactive companies is the perception of many employees) and moved into the business domain.

An important finding was that there are big differences in the properties that are measured - even for products (like Cathode Ray Tube based TVs), which are at the end of their learning curve. Indirectly this is an indication that in practice the designs of electronic products have more determinants than simple physical or economic rationale; design tradition and insufficient drive to update supplier bases seem to be very important as well.

With regards to improvement potential, experience suggests that no company scores best consistently in all departments. Products which rank number one overall score best in only some half of the individual parameters. The application section (chapter 6.4) will show that the combination of environmental benchmarking and brainstorms are very powerful tools to generate proposals for product improvement both inside and outside the environmental domain.

Casper Boks has made tremendous strides to bring together all the experiences with Environmental benchmarking and its applications into one document. The results of this effort are described in the publication “*Theory and Practice of Environmental Benchmarking for Consumer Electronics*”.

Theory and Practice of Environmental Benchmarking for Consumer Electronics

Casper Boks and Ab Stevels

Abstract

Environmental benchmarking has since 1997 been the basis of many EcoDesign related activities at both Delft University of Technology (DUT) and Philips Consumer Electronics in Eindhoven, The Netherlands. Cooperative efforts have led to a robust, reproducible and practical Environmental Benchmark method. The method is based on the assessment of the five focal areas Energy, Material & Weight, Packaging, Potentially toxic substances, and Recyclability. The generation and prioritisation of 'green' improvement options is done by addressing consumer and societal feasibility as well as technical and financial feasibility. Ongoing research continuously stimulates the methodology and practical implementation. This has created a tremendous awareness in the Philips Consumer Electronics organisation regarding product related environmental matters, because the method is embedded in an overall strategy that considers the interests of all internal and external stakeholders.

Keywords: *Environmental Benchmarking, EcoDesign, Feasibility analysis, Consumer Electronics*

1. Introduction

Since 1997, environmental benchmarking has been an ongoing activity at both the Delft University of Technology (DUT) and the Environmental Competence Centre (ECC) at Philips Consumer Electronics in Eindhoven, The Netherlands. Cooperation during this period has resulted in an Environmental Benchmarking Method that is robust, reproducible and practical to work with. Currently, environmental benchmark studies are carried out frequently at the ECC. The most recent work in cooperation with DUT involves the synthesis of results from individual benchmark studies.

This article provides an overview of the activities carried out since 1997. Commencing with some background on the motives for environmental benchmarking, it reports on the frameworks for environmental benchmark approaches that have been developed at DUT and the ECC. Thirdly, the practice of environmental benchmarking is shown. Also, it will be explained how the further elaboration and synthesis of benchmark results that are currently available can provide additional data. Finally, attention is given to Philips' view as regards the implementation of environmental benchmarking in a corporate (EcoDesign) strategy.

2. Background

In the early nineties, leading electronic companies started with EcoDesign (also referred to as Design for the Environment). Early activities were primarily defensive such as organizing compliance with upcoming legislation and regulation, making mandatory design rules and setting up an internal organization to ensure that such items are followed up. For electronics companies in Europe the issue of take-back and recycling of waste of electrical and electronical equipment (WEEE) in particular received an increasing amount of attention, providing the necessity for such actions. In many respects, the first initiatives that led to the German 1991 draft ordinance for recycling of WEEE can be seen as the starting point for the societal, technical, juridical and scientific debates about these issues (Stevels and Boks, 2000). Soon it was discovered however that 'green' offered far greater potential both for cost saving and for enhancing sales – and consisted of more than just end-of-life related issues. It was revealed that saving made on resources directly related to price reduction. Strong environmental performance was realized to be a good vehicle for enhancing brand image and sales. These notions initiated some important paradigm shifts for the EcoDesign activities at Philips Consumer Electronics (Eenhooorn and Stevels, 2000):

- It was found that focus should be on business aspects as well rather than just on technicalities;
- It was found that focus should be on those environmental parameters which can be influenced by the companies themselves -- rather than just the holistic perspective of Life Cycle Analysis;
- It was found that splitting into five focal areas was of the utmost importance to properly manage processes

with respect to EcoDesign. These areas are Energy, Materials application, Packaging and transport, Potentially harmful substances and Durability/Recyclability;

- It was found that in order to externally communicate these five focal areas, a language should be used which is understandable for customers and other audiences that are generally non-experts;
- It was found that market driven environmental performance means being better than the competition rather than scoring on an absolute scale, as most traditional environmental considerations do.

At the same time the Design for Sustainability Lab at Delft University was looking for ways and means to enhance creativity and idea generation for integrating environmental aspects into product design. Additionally they were looking to bring EcoDesign closer to the attention of the designer in general, and Industrial Design Engineering students in particular. Although some level of awareness was already in place – chiefly as a result of lists of environmental design rules and guidelines that had been set up based on earlier case studies (Brezet and van Hemel, 1997) – it was also found that such guidelines failed to deal with specific product characteristics and with priority setting, especially in a corporate environment. Environmental benchmarking was seen as the ideal link between creating awareness and design itself because a proper benchmark tells where current products stand thus creating a platform for discussions and brainstorming to determine where to go.

From the very beginning at the ECC and DUT tools have been in place that are aimed at fostering the progressing of knowledge and insight about environmental issues. For early benchmark-type initiatives, the then-called Environmental Weight Method was used at the ECC up until 1997 for determining environmental impact in combination with the End-of-Life Cost Model for assessing end-of-life costs (Brouwers and Stevels, 1995). The Environmental Weight Method consisted of criteria such as the number of wires to cut, the number of different packaging materials, the number of environmentally rejected and (temporarily) released components according to a company internal data registration system, as well as a few other criteria. For each product benchmarked its performance based on all criteria was reflected in a one-figure score, on the basis of which products (including those from competition) were compared and evaluated for improvement.

Simultaneously, at Delft University of Technology the need was felt to develop a structured method for the technical evaluation of products, specifically aimed at (but not limited to) environmental attributes. The need for comparing analysis results retrieved by different staff and students was a particular driver for this. In 1997, this resulted in the developments of the Environmental Product Assessment (EPAss) method (Jansen and Stevels, 1998). This method was comprised of six elementary steps, as indicated in Figure 1.

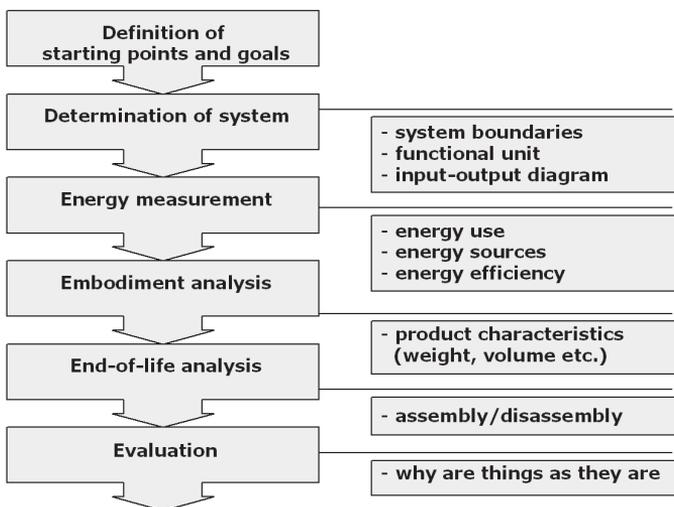


Figure 1 The EPAss method (1997)

The EPAAss method in particular stressed the importance of the functional unit as the basis of each benchmark approach. Although by nature it was a method to evaluate products based on technical aspects in general, it provided the basis for the generation of 'green' improvement options and was as such used by several DUT graduate students during their final projects at several companies, including Philips CE.

At the ECC, one of those very students combined elements of the DUT EPAAss method, the ECC Environmental Weight Method as well as scientific theories on benchmarking (e.g. Kotler, 1994) into the basis of what would become known as the Environmental Benchmark Method (see Figure 2). Fed continuously by practical experiences, the Environmental Benchmark Method grown to become by 2001 a robust, reproducible and practical method that has resulted in over 40 benchmark studies, and has been used as the basis for over 10 student graduation projects. In the next chapter the Environmental Benchmark Method in its current form will be explained in detail.

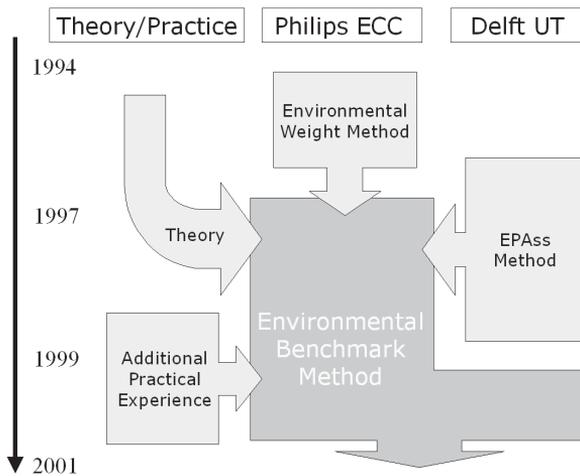


Figure 2 History of the Environmental Benchmark Method

3. Benchmark Theory and Methodology

The environmental benchmark method, as recorded in an official Philips document (Ram and Saleminck, 1998), is laid out in the Environmental Benchmark flowchart as depicted in Figure 3. The method does not only comprise the benchmarking of products itself, but it positions this activity within an integral approach that facilitates the exploitation of the benchmark results. The flowchart explains that there are three main elements: the actual benchmark procedure itself, the link to EcoDesign and the exploitation of the results in the market.

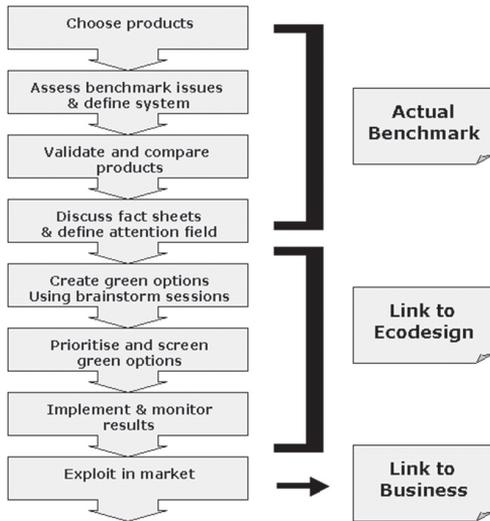


Figure 3 The Environmental Benchmark Method

3.1 The Actual Benchmark

The actual benchmark procedure consists of four elements: the choice of products, the system definition, comparing and validation of products, and the review of results.

Choice of products

The first element of the actual benchmark procedure is to decide on the products to be benchmarked. In the Philips context, one of the reasons to perform benchmark studies is the determination of so-called Green Flagships – the selection of Philips products that perform on environmental criteria better than competitors' products. The selection of the Philips product which potentially qualify as a Green Flagship is left up to the product management. This product is then compared with 3 to 4 competitors' products that are selected as follows: first of all, the best commercial competitor should be included. The additional products should preferably be chosen based on known or expected performance on environmental criteria. In addition, all products in the same benchmark study should display similar characteristics in the following areas:

- Functionality
- Commercial availability
- Price/performance ratio
- Size
- Product generation

Assess benchmark issues and define system

This step includes two elements. First, it is important to consider which are the important criteria to include in the benchmark. The five focal issues packaging, energy, materials, potentially toxic substances and recyclability are always included, but additional issues can be relevant as well for particular products or product groups. Environmental perception from the consumer market (including consumer test organisations) as well as legislative bodies should be considered an important indication for relevant issues. Secondly, these considerations are to be used in the definition of the system boundaries and functional units (which are for example required for the energy analysis).

Comparison and validation of products

In this step the actual comparison of products is done, according to the five focal areas and possibly additional criteria identified in the previous step. The analysis should include product characteristics as given in Table I.

Table 1 Issues to be checked in the Environmental Benchmark Method

FOCAL AREA	ISSUES CHECKED IN THE BENCHMARK PROCEDURE
Energy	<ul style="list-style-type: none"> • Consumer behaviour (usage scenarios) • Power consumption <ul style="list-style-type: none"> ◦ On-mode ◦ Stand-by mode(s) ◦ Off-mode • Battery and adapter applications • Alternative energy sources
Materials/Weight	<ul style="list-style-type: none"> • Per (sub)assembly <ul style="list-style-type: none"> ◦ Embodiment ◦ Picture tube (if present) ◦ Drives (if present) ◦ Electronics subassembly ◦ Electrical components ◦ Accessories ◦ Directions for use ◦ Remote control (if present) ◦ Functional parts (antenna, speakers) ◦ Wiring and connectors (mains cord etc.)
Packaging	<ul style="list-style-type: none"> • Packaging materials (documentation, box, buffer, bags) • Product weight and volume • Box volume • Number of materials • Presence of recycled cardboard
Potentially toxic substances	<ul style="list-style-type: none"> • Type of plastics and metals • Use of recycled materials • Presence of PVC • Chemical content <ul style="list-style-type: none"> ◦ Check for released components ◦ Check for banned components
Recyclability	<ul style="list-style-type: none"> • Plastics application <ul style="list-style-type: none"> ◦ Mono-materials ◦ Halogenated flame retardants ◦ Markings • Type of connections • Disassembly time for selected components • Check for valuable electronics • Material recycling efficiency • Processing yield

In addition to checking the five focal areas, it is recommended to use some LCA method for the validation of the environmental performance of the benchmarked product. At the ECC, this is always done. The main idea behind this is to include the life cycle perspective in the final assessment of the product, and also to enable the determination of its environmental feasibility, which is one of the steps preceding the prioritization of the 'green' (re)design options as explained below.

Review of results

In the Philips benchmark procedure, fact sheets are made on which of the measurements derived in the preceding step are compiled. From these fact sheets, per focal area all measurements for all benchmarked products can be seen at a glance, which makes them easily interpretable. In Chapter 4 examples are given of fact sheets that were derived for a VCR environmental benchmark.

3.2 The Link to EcoDesign

The second main part of the Environmental Benchmark Method comprises the creation, prioritisation and implementation of 'green' (re)design options.

Creation of 'green' options

Brainstorms and screening sessions are useful methods to create opportunities for environmental improvements. Two major sources exist for doing so:

- *Learn from competition:* experience tells us that in practice, no single product outscores – on all criteria – all other products against which it is benchmarked. This means that from benchmarking options for improvement can always be generated, based on design solutions found in competitors' products.
- *Smart technological alternatives:* these can include alternative plastics applications, alternative fixing solutions, alternative energy sources, alternative finishes, et cetera.

Prioritisation of 'green' options

Apart from environmental considerations, a multitude of other considerations are to be taken into account in product design. Whereas in the first instance the generation of improvement options should not be hampered by, financial restrictions for example, in the second instance the improvement options generated are to be assessed regarding their feasibility. For each option, at least the following aspects should be verified:

- *Environmental feasibility:* a (qualitative) assessment whether the improvement option indeed reduces the impact on the environment, also when the full life cycle is considered.
- *Consumer feasibility:* an assessment whether the consumer is likely to accept the option as a benefit to him or her.
- *Societal feasibility:* an assessment to what extent society as a whole will benefit from the proposed improvement.
- *Company feasibility:*
 - *Technical feasibility:* an assessment whether the improvement options are technically feasible in a way that timely implementation can be ensured.
 - *Financial feasibility:* because of the implementation of the improvement options no unwanted costs or investments should be incurred.

For each type of feasibility it is generally possible to indicate a score per improvement option. Depending on the weight factors that can be appointed to the various types of feasibility, an overall score can thus be derived. Based on these scores the improvement options can be ranked.

After improvement options have been generated, ranked and validated, the results of this process need to be deployed in the actual core business. In Chapter 7 this issue is further elaborated.

4. Benchmark Practice

In this article, the main purpose is not to supply extensive benchmark results, which is partly due to the proprietary nature of the data. Instead, selected results from one particular benchmark report (for VCRs) are shown to illustrate the practicalities of the method itself and how results are communicated to the readers of the benchmark reports. For this purpose, four out of eleven fact sheets are displayed below in which any reference to individual products and brand names have been altered. In the figure, it is shown how important differences can be visualized using tables, graphs and text.

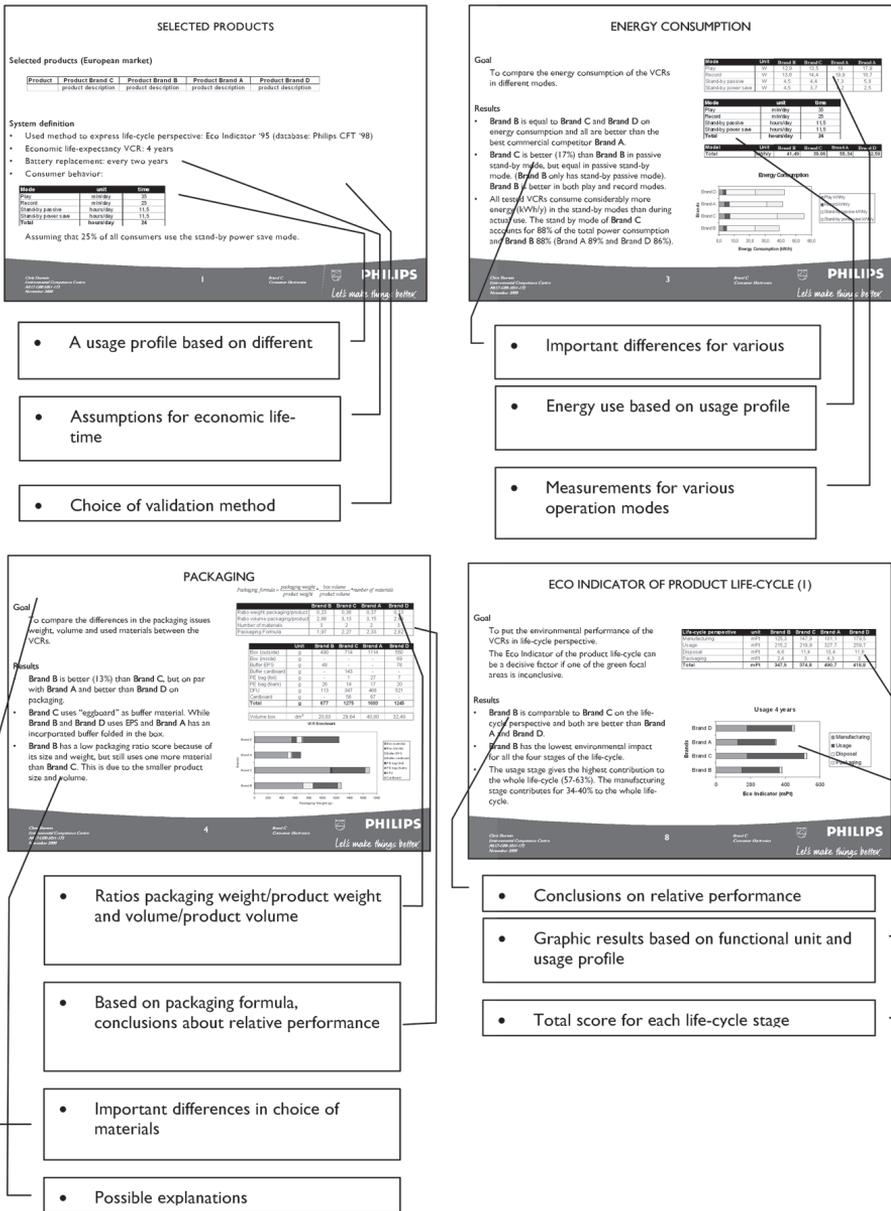


Figure 4 Examples of Environmental Benchmark fact sheets

5. Synthesis of benchmark studies

To date, about 40 environmental benchmarks have been performed and reported on at the Philips ECC (see Figure 5). Products covered in these benchmark reports cover most of the brown goods consumer electronics category, ranging from cellular phones to large 55" projection TVs, including audio sets, VCRs, CDRs, DVDs and a large range of TV sets and monitors. This has resulted in a large reservoir of information. Whereas the individual benchmark reports have contributed to product improvements, cost reductions and general environmental awareness through the organisation, it is believed that from combining data from individual benchmark reports

additional data and pointers for improvement can be generated. This umbrella view would in theory provide information about the following items:

- Structural over- and/or underperformance in relation to competitor performance;
- The performance according to environmental characteristics of products over time;
- Opportunities for further exploitation of results for communication purposes (internal and external);
- The effects of, as well as the need for, (structural) design improvements;
- Priority setting for further research.



Figure 5 Philips Environmental Benchmark Reports

The large amount of available benchmark reports would make it possible, in theory, to obtain information about these items would for individual products, as well as per product category but in particular also across product categories. Starting in the summer of 2001, projects are underway to synthesize the available data. At this time these projects are focusing on packaging and energy issues in particular. In the following subparagraphs, this work in progress is reported on briefly. Although not yet part of an established procedure, it shows what type of additional information can be derived from synthesizing benchmark data. In the future, these approaches may be incorporated into the standard Environmental Benchmark procedure.

In addition, it also proved useful to extend existing benchmark datasets with data from consumer test organisations in order to increase the number of observations and to obtain even more meaningful results.

Correlation between benchmark variables

One possibility of synthesizing benchmark data is to investigate how the performance of the various benchmark variables is correlated, in particular those variables where distinct design efforts are focused but that are related to each other in practice. In this way, interesting results have been obtained by for example:

- Dividing product volume and packaging volume
- Dividing product weight and packaging volume
- Dividing TV screen size and energy consumption

The large number of benchmarks enables the derivation of what can be observed to be best practice in a certain field. At the same time, it also enables the identification of results for individual products that show a significant

underperformance – results that otherwise might have remained unnoticed. For example, from Figure 6 (displaying the performance of Philips products next to those of the competition in terms of product volume /packaging volume) it was learned that for 7 out of 9 product categories Philips products score better than the competition, suggesting room for relative improvement for the remaining categories. Also in absolute terms conclusions can be drawn. From a similar graph for product weight/packaging weight it became clear that Philips portable CD players performed significantly better on this ratio than the competition. At the same time it became clear that this ratio was quite unfavourable for Philips DVD players, for no apparent reason. Results like these can be meaningful starting points for the further generation of 'green' options, in addition to those generated already by the established benchmark procedure as discussed in Chapter 3.

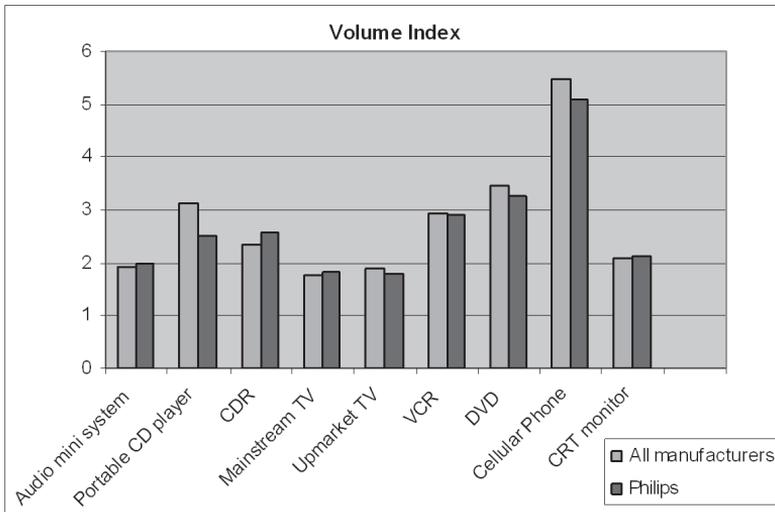


Figure 6 Correlation between product and packaging volume, based on multiple benchmarks

Trends

Another possibility is to trace trends related to particular benchmark issues, provided that sufficient benchmark data is available. For example, analysis has shown how power consumption data (in this case for audio sets) from various benchmarks over time have developed. Although those measurements appear to show a downward trend, it was also quite clear that there is a wide spread of measurements. Observations like these give rise to questions addressing correlations between functionality and energy consumption as well as the effectiveness of redesign efforts that have been made in the past.

6. Environmental benchmarking in relation to market research

In the form described in the previous chapters, environmental benchmarking is already a powerful tool on its own. However, an extended application is to combine the results from environmental benchmarking with market research data. In the benchmark procedure itself no distinction is made regarding importance across the five focal areas. Market research enables weighing a product's performance per focal area, and can thus form a basis for

- (Further) evaluating and prioritizing proposals for environmental design improvements
- Enabling the communication of benchmark results to the customer market.

On this topic, a number of research projects were carried out in cooperation with the Delft University of Technology (see also Stevels et al., 2001). The fundamental idea behind including market research data with environmental benchmark data is the notion that environmental issues are perceived differently among the relevant stakeholders

in society. 'Customer green' or market driven 'green' (what the customer perceives as important) differs from 'scientific green' (for instance based on Life Cycle Analysis) and 'government green' (what legislative bodies perceive as important). As an example, in Table 2 it is illustrated for audio products how the five focal areas are ranked (1= first priority, 5= lowest priority) according to the different perspectives.

Table 2 Environmental priorities from various perspectives

	Energy	Hazardous substances	Materials	Packaging	Recyclability
Customer	1	2	3	4	5
Trade (sales staff)	1	2	3	5	4
Science (LCA-based)	1	5	2	4	3
Government policies (EU)	3	1	5	4	2

The differences in perception create a dilemma for producers in terms of how to prioritize the 'green' improvement options derived from the environmental benchmarking procedure (as is done in "the link to EcoDesign"), and for product managers how to exploit them in the market. In order to deal with this dilemma a compromise can be made by weighing improvements having an affect on the various 'green' focal areas. In the case of the environmental benchmark of audio products, a total of 45 ideas for environmental improvement were generated during a brainstorm which were evaluated according to a weighing procedure and multiplied by their expected environmental impact. This resulted in a ranking of redesign priorities that were in the domain of energy consumption - in contrast to 'classical' EcoDesign solutions where much emphasis is put on material applications and recyclability issues.

7. The implementation of environmental benchmarking in a corporate EcoDesign strategy

Historical perspective

Before Environmental Benchmarking was developed into the powerful methodology it is today, environmental issues related to design were believed to be best introduced in organizations (design bureaus, industrial development) through projects with a specific focus on environmental issues (Stevens, 2001). In later years it turned out that the main weakness of this approach was in the follow-up - the projects were mostly carried out in relative isolation from the day-to-day business. After completion, project teams were disbanded and team members were dispensed in their organization - with little opportunity to disseminate the 'green' experiences and skills acquired in often very successful projects.

To ensure that environmental thinking and EcoDesign became more widespread within the projects of the Philips Consumer Electronics, an Environmental Design Manual was developed at the ECC. The general purpose of this manual was to achieve better environmental performance than for previous product generations, particularly by stimulating learning by doing. This Environmental Design Manual consisted of the following elements:

- Environmental Vision, policy and strategy
- Environmental organization
- How to deal with:
 - power consumption
 - materials application
 - environmentally relevant substances
 - packaging issues
 - end-of-life/recycling
- How to do environmental design evaluation

- Supplier, purchasing issues
- Manufacturing issues (use of chemicals)
- Customer information, working, labelling

Design manuals as environmental specialists of the organization usually write the one described above. The same people are generally in charge of implementation and development of tools to support these processes. However, the responsibility of releasing products to which the Environmental Design Manual refers, rests within business management. As a result, the link between environment and business was sometimes ill-interpreted, resulting in unsolved issues like environment being a boundary condition or a business opportunity, a technical or a strategic issue, or even a legislation or customer driven activity. It became clear that in order to make EcoDesign in industry a success, an additional translation step was a necessity in order to provide business management with the proper yardsticks to base their decisions on.

Current vision and implementation strategy

At Philips Consumer Electronics the insights sketched above resulted around 1998 in a new EcoDesign approach, in which environmental benchmarking has grown to be a fundamental cornerstone. This approach involves the following steps:

1. Fact-finding mission using environmental benchmarks
2. Creativity approach towards (environmental) performance improvement, based on benchmark results and brainstorming
3. Validation of environmental improvement options against scientific methods such as LCA or other methods
4. Feasibility checks against customer and societal benefits
5. Feasibility checks against physical and financial boundary conditions
6. Implementation in the product creation process

In this approach the first three steps, and in particular the order in which they were executed, were as novel as they were essential to ensure a proper translation from environmental facts into something that the business management was ready to understand, accept and implement. The fourth and fifth steps are based upon the prioritisation of 'green' options, as explained above in paragraph 3.2. By inclusion of appropriate feasibility checks – other than just environmentally related – the groundwork is done for further implementation in the product creation process. From Table 3 it becomes clear that environmental benchmarking, as it is described in this article, is the first essential element on which the remainder of the steps of the approach is based. The key to embedding the EcoDesign of products in the business is by linking the 'green' idea generation stage, in which the focus is exclusively on environment, into the standard product creation process. Assessing 'green' options for improvement in terms of company, customer and societal benefits and in terms of technical and financial feasibility, do this. A next crucial step is the transition from product creation to 'green' communication/sales. This is done by assessment of tangible benefits, intangible benefits, perceptions and emotions for the company, customers and other stakeholders in society. In relation to this issue, work has been done in cooperation with Stanford University to develop the Environmental Value Chain concept (Ishii and Stevels, 2000). In short, this concept entails the mapping of physical (= goods), money and information flows between stakeholders. In an environmental value chain the main stakeholders are suppliers, producers, customers and authorities. By making an issue correlation matrix, priorities given by involved parties to the various aspects of the system are ranked. By aligning the various flows and stakeholders, the success or failure of 'green' product development and environmental programs can be predicted. Current research at Philips Consumer Electronics and Delft University of Technology addresses the application of the Environmental Value Chain Concept to examples from industrial EcoDesign practice, both internal and external to the company.

8. Conclusions

In the present article it has been shown how an environmental benchmark procedure was developed in a cooperation between Delft University of Technology and Philips Consumer Electronics. The cooperation has resulted in an established, robust, reproducible and practical Environmental Benchmark Method that is frequently used. The many environmental benchmark reports that have been produced since have created a tremendous awareness in the Philips Consumer Electronics organisation regarding product related environmental matters. It is believed that the representation of results in terms of relative performance against the competition (instead of 'just' absolute figures) has been a major contribution to this.

At the same time, the method has been particularly helpful for many DUT students in preparing and finishing their graduation reports. The comments and suggestions for improvements made in these reports have often proved useful for product redesign, and have improved and added to the environmental benchmark procedure itself as well. Current work addresses opportunities for extending the method, in particular to incorporate lessons to be learned from the synthesis of benchmark data.

In addition, it has become clear how the actual gathering of benchmark data is not an isolated process, but is best embedded in an overall strategy. In this strategy, interests of stakeholders other than the company itself should be clearly addressed. Also within the company, issues other than environmental ones are important to consider for a successful implementation of environmental benchmarking in an EcoDesign strategy, and of the successful implementation of an EcoDesign strategy in an overall business strategy.

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San Francisco, sempervirens

If there are no clouds an aerial view of San Francisco is spectacular. It is an amazing city clamped between a big sea and a big bay which are split by the Golden Gate bridge. The city has a regular pattern of avenues and streets.

There is color, all over the place, like the green or yellow gold on the hills (depending on the season). The buildings seem to have colors too.

BART (Bay Area Railway Transport) is finally ready and brings you to town. It is a special one. Everything is nicely built, no dirty parking lots in between dilapidated buildings. The earthquake of 1905 has done thorough work. After the quake, a lot has been rebuilt in a consistent way. It is the nice architecture of the beginning of the century, 'American Jugendstil'. It is everywhere. It seduces you to walk, or take the tram, and enjoy the smell and the noise of its brakes and most of all the sound of its bell. You find yourself looking, looking and looking again.

Both the early morning and late evening have a hazy atmosphere so unique to San Francisco. In and of itself it makes the trip worthwhile.

In San Francisco several environmental conferences took place which were important to me. There is ISEE 1977, where I realized for the first time the necessity of the integration of EcoDesign into business. There is ISEE 2000 and 2002, where Stanford and Delft University presented their ideas about the value chain (chapter 5.1), recycling strategy (chapter 7.2) and environmentally weighted recycling quotes (QWERTY, see chapter 7.4). In 2006, the paper 'What went wrong with the implementation of WEEE in Europe' was presented in San Francisco as well; it had tremendous impact on both sides of the ocean.

And then there was the famous meeting in San Francisco of the Electronic Industry Alliance about a voluntary initiative on take back and recycling in the USA. Held behind closed doors, it was very sensitive. I explained the experiences in Europe and made a pitch for a collective system with an Advanced Recycling Fee with an opt out clause for those products which can be treated more cheaply individually. There was almost an agreement, but not a total agreement. It was not good enough. Due to lack of agreement the industry also lost the initiative in the USA, and will have to pay dearly for this in the future.

Anyway, San Francisco, is always alive, it is sempervirens!

City & Country walk: Do not walk, rent a bike at a place near the Cannery (Fisherman's Warf), Jefferson street around the corner of the cable-car-terminal. Bike along the shore (Fort Mason, Marina Green), Mason Street, Crissy Field, Long Avenue, Marina Drive, At Fort Point get up to the Golden Gate bridge.

Bike over the bridge and back to Long Avenue, go R to Lincoln Boulevard, L 25th Street, Right Clement Street, L&R Lobos Avenue to Cliff House. Go South, enter Golden Gate Park near the Windmill, follow the John F. Kennedy Drive (or alternatively the Martin Luther King Drive) all the way through the Park, go L and R to Fulton Street, L at Steiner Street, all the way (approx 1 mile), R Chestnut Street, Magnolia Street, left (Van Ness Street), R back to North Point.

6.3.3 Environmental Benchmarking and the soft side of EcoDesign

After some five years of implementation of Environmental Benchmarking in industry it was felt that the benchmarking method was ready for a make over. Particularly the results of applying it should be more successfully exploited. Until recently the focus has been a technical one with a clear link to product development.

In a recent study a link was made to a general framework in order to study environmental benchmarking from a socio-psychological perspective with the special goal to facilitate better acceptance of benchmarking results in the complete internal value chain (see also chapter 5.1). Factors to be considered were: 'Culture', 'Strategy', Structure, Technology, Goals and People. In the paper "Environmental Benchmarking in the Electronics Industry: Integration in Business Processes for Design Improvement" on next page the outcome has been described.

On the basis of this work the benchmark procedure has been reformulated in order to achieve a better fit with the organisation. It is a clear example that, apart from technicalities, the 'soft side of EcoDesign' (the terminology and a lot of trailblazing work in this field has been done by Casper Boks) plays a very important role.

Environmental Benchmarking in the Electronics Industry: Integration in Business Processes for Design Improvement

Frouke van den Berg, Casper Boks, Jaco Huisman, Ab Stevels

Abstract

The integration of environmental issues in mainstream business processes in the electronics industry is a process with ups and downs. In addition to known approaches to study this process, which are mainly of a technical and strategic nature, company cultural and people-oriented aspects have been used to come to a more complete understanding on how this integration process can or should be studied. A framework for analysis is proposed, introducing explaining factors taken from occupational and organizational psychology. A detailed case study, focusing on improving an established but suboptimal environmental benchmarking process in a major electronics firm, is reported on. It illustrates the benefits of the new research approach, when an increased attention for communication issues directly influences optimal goal-setting and operationalisation of the environmental benchmarking process. Based upon the results for the case study, the generic value of this new approach for studying the integration of environmental issues in mainstream business processes is discussed.

Keywords: Environmental benchmarking, electronics industry, product design, ecodesign, environmental management

1. Introduction

Environmental Benchmarking as a tool for environmental product improvement has gained an increasing amount of interest in the past years. It involves the systematic analysis of a company's own products in relation to competitor's products to stimulate creativity for finding, ranking and implementing feasible improvement options (Boks and Stevels, 2003). Since cooperation between Delft University of Technology and Philips Consumer Electronics in the mid-nineties resulted in a dedicated method for environmental benchmarking, it has also gained interest outside these institutions. Nowadays, the so-called EcoBenchmarking methodology features prominently in the second edition of the United Nations Environmental Programme EcoDesignManual, which is to be published by the end of 2005 (Boks and Diehl, 2005). Here, environmental benchmarking of products has been applied beyond the context of multinationals in the electronics industry, to include a wide range of product categories and a wide range of audiences, both in terms of industry type, size, and geographic location.

Meanwhile, environmental benchmarking research *within* the context of the electronics industry has continued at Delft University of Technology, in close cooperation with the Sustainability Centre at Philips CE. In recent years, research attention has expanded from a purely methodical approach, to include a focus on implementation, more or less given current methods and tools for incorporating environmental criteria in product development processes. In this context, research has been done based on two pillars. Firstly, it has been studied to what extent environmental benchmarking has indeed contributed to greening of Philips CE' product lines. Secondly, research has been done to better understand and address the so-called soft side of ecodesign. This relatively new research perspectives aims to investigate, more than is done traditionally in sustainable product design literature, the role of a number of 'sociopsychological factors' present in the internal value chain of a company that may obstruct or facilitate the acceptance of sustainability criteria in product development processes (Boks, 2006). This is done as one of several possible explanations why ecodesign implementation in recent years has not fulfilled its expectations; since the end of the 1990s, where it was still common to express optimism about opportunities for competitive advantage from ecodesign activities, researchers and practitioners have increasingly expressed dissatisfaction about the frequency, quality and speed of the process of implementation of DFE practices, particularly in the electronics industry.

Whereas in the late nineties the focus was on showing that products with improved environmental attributes could indeed be made at little or no extra costs, little evidence was created that such individually successful activities could deliver the promised competitive advantage when integrated in existing business. Evidence was mainly created in the form of prototypes and/or in niche markets; the lack of convincing evidence remains especially persistent in mainstream industrial business-to-consumer activities.

Although repercussions of economic recession undoubtedly contributed to this retrenchment of environmen-

tal optimism, the lack of demonstration that existing paradigms can successfully materialize in regular industrial activities should be likely the principal source of dissatisfaction. This observation is shared by fellow scholars like Tukker et al. (2001), stating that '...even in countries where method development, education and dissemination are reasonably mature, actual environmental product design still scores relatively low in the maturity profiles...'; and Baumann et al. (2002), stating that '...there has been a lot of talk of environmental product development, but relatively little change in practice...'

In McAloone et al. (2002) it was pointed out that the academic community has produced great numbers of increasingly sophisticated modelling tools and methodologies, assessment techniques and design rules/guidelines over the past fifteen years, but that relatively little focus had been given to how ecodesign as a discipline ought to be implemented into industry – in particular: beyond the environmental departments, into product development, marketing and sales departments, and in fact, throughout the whole business. Although the importance of integration of ecodesign in an industrial context has since the 1990s always been stressed by most scholars active in this field (e.g. Brezet and Rocha (2001), Ehrenfeld and Lenox (1997)), research so far has apparently not been able to explain why the integration of ecodesign activities into mainstream business processes has been cumbersome until now. The use of scientific disciplines like change management, organizational control, and occupational and organizational psychology to explain this lack of integration is so far virtually inexistent; the ecodesign research community is indeed persisting in focusing on the role of the designer and experts tools (e.g. Lindahl, 2005).

In the period between February and September 2005, in order to increase knowledge about the soft side of ecodesign, recently acquired insights such as reported in Boks (2006) have been used in a case study at Philips CE with the aim of incorporating these newly acquired insights back into methodological development of environmental benchmarking. Philips CE hires undergraduate trainees, graduates and research students on a continuous basis to evaluate and optimize the status of the environmental benchmark procedure. This is done to make sure that their environmental benchmark procedure remains a state of the art procedure, aimed at decreasing the environmental impact of all Philips CE's products. Furthermore Philips uses this opportunity to fulfil their social responsibility, by offering on-the-job training to undergraduates and PhD students and increasing the academic knowledge on environmental design in a company context. This paper reports the results of this case study.

In chapter 2, some background and explanation on environmental benchmarking in general and at Philips CE in particular will be provided, and will conclude with the present status of environmental benchmarking in that company. Using this background information, in chapter 3 the research question underlying this case study will be refined and further motivated. Chapter 4 discusses a theoretical framework for analysing areas of improvement of the current environmental benchmark practice, resulting in a recommended action path for adaptation of the methodology as well as for implementing the subsequent result.

2. Environmental Benchmarking

For reasons of clarity, in this chapter environmental benchmarking is first discussed in the context of Philips CE, after which Philips' practices are discussed in a scientific literature context.

2.1. Environmental benchmarking at philips consumer electronics

Environmental benchmarking of products has been systematically done at Philips CE since the mid- 1990s, when the so-called Environmental Benchmarking Method was developed in cooperation with Delft University of Technology (Boks and Stevels (2003)). Since the 1998 launch of the EcoVision corporate program within Philips, environmental benchmarking has also gradually been embedded in mainstream business activities. Today the environmental benchmarking serves mainly as a means to verify the presence of so-called Green Flagships in the Philips product line. These are Philips products that outperform their direct commercial competitors on the five environmental focal areas, which are energy, weight, packaging and transportation, potentially toxic substances and recyclability.

The results of environmental benchmarking are integrated in the Business Excellence Model which is used to evaluate business performance. This Business Excellence Model – initiated by the European Foundation for Quality Management (EFQM), and founded by amongst others British Telecom, Renault, Philips and KLM– is becoming

an international standard of best practice performance (www.efqm.org). Through self-assessment, or third party assessment, this model is a practical tool to help organizations identify where they are on the path to excellence, helping them understand the gaps, and initiate systematic continuous improvement programmes and then monitor the areas that they want to improve.

The integration of environmental benchmarking in this Business Excellence Model has created one of few examples so far where a multinational has succeeded in structural integration of environmental performance criteria into mainstream business criteria. As such, environmental benchmarking has been successful in generating environmental improvements for numerous products, but has also provided eyeopeners for cost reductions and opportunities for innovation outside the environmental context. One of the first examples where environmental benchmarking as been successful this way has been reported by Eenhoorn and Stevels (2000).

Since the start of benchmarking at Philips CE over 100 benchmark studies have been performed, solely on a product level. The standard procedure involves the identification by a business division of a candidate product for benchmarking analysis, which is then carried out by the Sustainability Center. The Philips product is then benchmarked against its best commercial competitor and one or more other direct competitors. The environmental performance of these products is compared on five focal areas, namely energy, weight, packaging and transport, potentially toxic substances and recyclability. For each focal area standardized environmental indicators have been developed by which the products are judged. Each benchmark study results in a report which concludes whether or not the Philips product under evaluation can be named a "green flagship". For further explanation on Philips' environmental benchmarking procedure is referred to Boks and Stevels (2003).

2.2. The original environmental benchmarking procedure

The environmental benchmark procedure, as it was originally designed in cooperation with Delft University of Technology and Philips CE consists of different steps. In Figure 1 these steps are visualised and ranked on their level of green. First there is the actual benchmark, involving the choice of products to be benchmarked, taking measurements, and analyzing these. This part of the method addresses a relatively low level of environmental improvement, as environmental performance is measured only, and no action towards environmental improvement is taken yet.

In the second part of the procedure, the link to ecodesign is made. Suggestions for environmental product improvements (so-called green options) are generated and prioritised using the eco design matrix (Stevels, 2002). In this eco design matrix green options are compared and ranked on environmental, consumer, business and governmental benefits and technical and financial feasibility. The level of 'greenness' in this step is higher than in the previous step, because of the active search for green product improvements.

Finally the green options with the highest priority are implemented in the business and exploited on the market. This step has the highest possible level of green, because here environmental improvements are actually achieved.

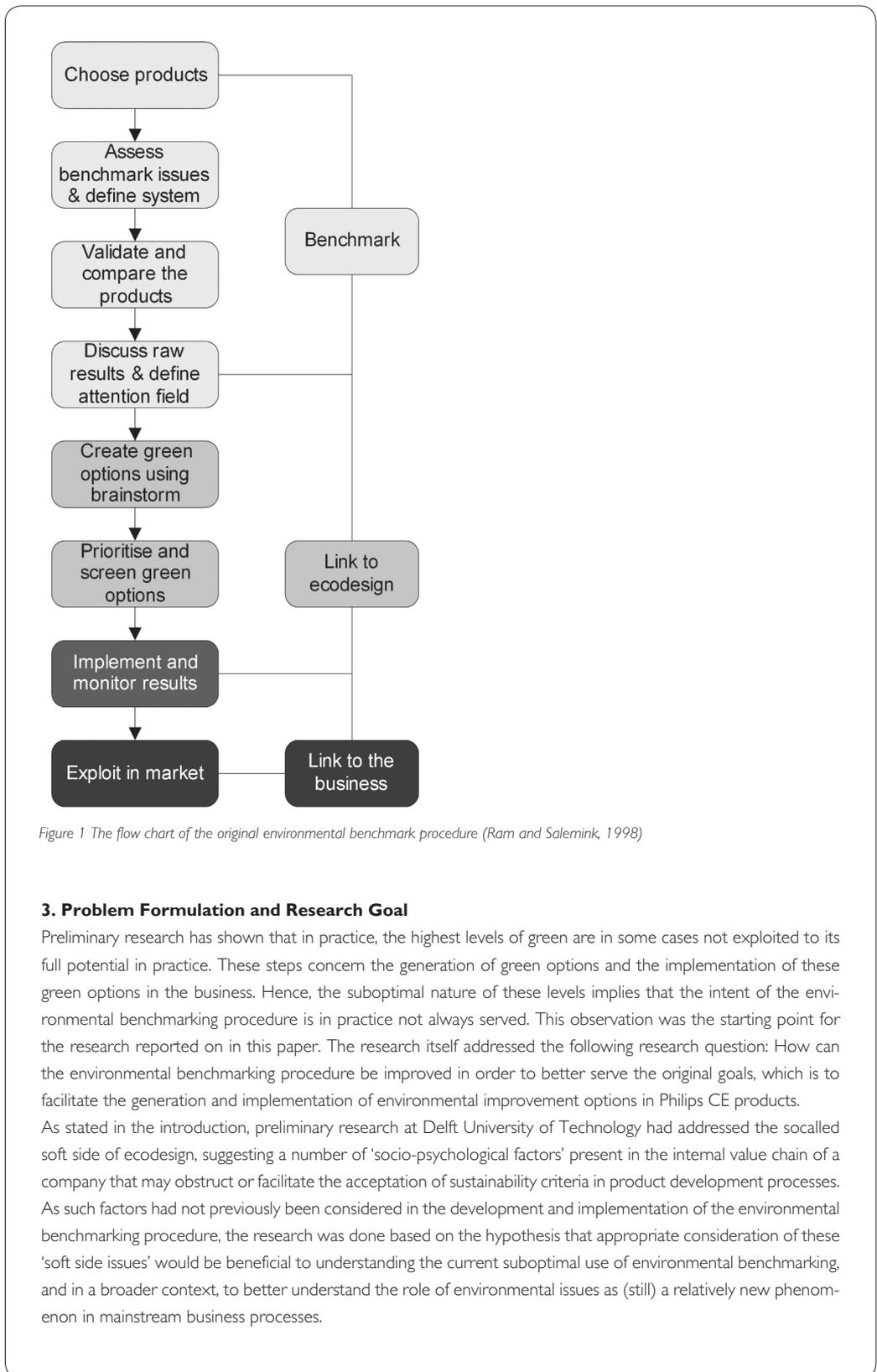


Figure 1 The flow chart of the original environmental benchmark procedure (Ram and Saleminck, 1998)

3. Problem Formulation and Research Goal

Preliminary research has shown that in practice, the highest levels of green are in some cases not exploited to its full potential in practice. These steps concern the generation of green options and the implementation of these green options in the business. Hence, the suboptimal nature of these levels implies that the intent of the environmental benchmarking procedure is in practice not always served. This observation was the starting point for the research reported on in this paper. The research itself addressed the following research question: How can the environmental benchmarking procedure be improved in order to better serve the original goals, which is to facilitate the generation and implementation of environmental improvement options in Philips CE products.

As stated in the introduction, preliminary research at Delft University of Technology had addressed the so-called soft side of ecodesign, suggesting a number of 'socio-psychological factors' present in the internal value chain of a company that may obstruct or facilitate the acceptance of sustainability criteria in product development processes. As such factors had not previously been considered in the development and implementation of the environmental benchmarking procedure, the research was done based on the hypothesis that appropriate consideration of these 'soft side issues' would be beneficial to understanding the current suboptimal use of environmental benchmarking, and in a broader context, to better understand the role of environmental issues as (still) a relatively new phenomenon in mainstream business processes.

3.1. Research methodology

Chapter 4 discusses the theoretical framework used to analyse the situation sketched above. To this end, in section 4.1 a general framework has been constructed based on factors known from the field of occupational and organisational psychology. In sections 4.2 to 4.4, this framework has been made specific for analysing the environmental benchmark procedure at Philips, using specific knowledge and insight from ecodesign literature. In chapter 5, it is reported how this specific framework has been applied as a method within Philips. Results of this application will be discussed in chapter 6, and in chapter 7 conclusions are presented, both for the generic approach and the case study.

4. Towards a Framework for Analysis

With the research goal being the analysis of the current operationalisation of the environmental benchmark procedure with the aim of improving the likelihood of implementation of green design options in Philips CE products, a theoretic framework was required to start the analysis. Particular attention would have to be paid to the organisational setting in which the phenomenon to be studied was taking place. In order to determine a proper framework the problem had to be categorised in a more abstract way. It became clear that the environmental benchmark procedure matches the definition of an organizational change process and can best be studied with a contingency approach. This contingency approach is deducted from the general contingency theory (Morgan, 1986). This approach can be described in three statements (Morgan, 1986):

- "Organisations are open systems that need to be studied carefully to satisfy, balance and adapt internal needs to the conditions of its environment".
- "There is not one optimal way of organising. The most appropriate way depends on the nature of the task or its environment".
- "The management needs to create tailored solutions. Different types of management may be necessary to perform various tasks within the same organisation, but other types of organisation are needed in another environment".

It can be concluded from above statements that each company and situation in a company is unique and needs a tailored solution. However, general theoretic frameworks can be used to create this tailored solution (Morgan, 1986).

Based on the contingency approach the following method could be created, see Figure 2. In light grey all steps needed to come to a tailored method are represented. In dark grey the application of the tailored method was explained.

The steps mentioned in this flow chart will be elaborated in more detail in the subsequent sections. Each step is represented in one section. The methodology steps will be described in chapter 4 and the application steps will be described in chapter 5.

4.1. The general framework

From the field of occupational and organisational psychology an appropriate model was chosen for creating the required framework to come to a tailored approach for this case study. This model was based on the contingency approach and is called 'the octahedron model' (Van der Vlist, 1981). In this model the six important factors in analysing a change process are visualised together with a description of the relation between the factors. This description of the six factors will be used as theoretical framework, the suggested relations between them will not be included in the theoretic framework. The description of the six factors was provided by Allegro and Van Breukelen et al. (2000) in the sixth version of the Leiden Organisation Checklist.



Figure 2 Research methodology for creating a tailored method to study the environmental benchmark procedure

These factors are:

- Culture can be defined as a combination of values, beliefs, expressions and behaviours that also determine how people within an organisation deal with each other and to what extent they put energy in their work and the organisation.
- Strategy can be defined as the decisions made on the way targets can be met by deploying people and means, taking into account the demands from its environment.
- Structure can be defined as the internal differentiation and mutual relations between departments and organisation units.
- Technology can be seen as a combination of technical facilities, the machinery, work procedures and work methods. But also procedures like purchase- and sale procedures, or procedures and tools related to human resource management are part of technology.
- The organisational goal is to be regarded as a set of primary tasks of an organisation in society (producing products, offering employment options)
- People are individuals and groups within the organisation (number, education, capacities, motivation and tasks)

With this general theoretic framework in mind a tailored step-by-step approach was created to analyse the environmental benchmark procedure at Philips CE. In order to generate this approach a quick scan of the case study was needed. In this quick scan several assumptions regarding the definitions of the factors were made that highly influence the way of approaching the problem. After creating the approach specific for this case study, the case study was analysed in depth using the tailored approach.

4.2. The specific framework

First a short introduction to the case study situation will be given. In this case study the environmental benchmark procedure can be seen in two parts. Firstly, there is the benchmarking itself which aims at defining the benchmark

criteria, measuring, comparing and finding best practices. Secondly, there is the analysis of best practices in the product design processes in the industry.

The first part of the benchmark procedure was studied at the Sustainability Center of Philips CE in Eindhoven. The second part was studied at one part of one of the three Philips CE' Business Groups involved in the environmental benchmark procedure, the Business Line of Upmarket Flat Displays in Brugge, Belgium. In this case study the approach was used to come to a series of guidelines and boundary conditions for optimising the environmental benchmark procedure at Philips CE. In the subsequent subparagraphs the application of the step-by-step approach will be explained.

In this quick scan the factors of the octahedron model are discussed specifically for this case study.

- **Culture:** In this case study culture will be defined as company culture. The company culture of the sustainability centre and the business line will be assessed individually, in order to identify any significant differences in culture between the two departments.
- **Strategy:** In this case study the strategy on the issue of environmental responsibility, as described by the Philips Corporate Sustainability Office will be described. This will be done to verify if the strategy is in line with the environmental action programme found in practice.
- **Structure:** In the case study structure was defined as the internal value chain and the flows between the different players in this value chain. Describing the internal flows facilitates the identification of common and conflicting interests within the internal value chain.
- **Technology:** In this case study technology was defined as all procedures related to the environmental benchmark procedure both at the Sustainability Center and at the business line.
- **Organisational goal:** In this case study the primary task of Philips CE will be considered.
- **People:** In this case study the capacity and motivation of people at the sustainability centre and the business line, directly related to the environmental benchmark procedure will be considered.

4.3. Verification of the specific framework

To verify whether the specific framework covers all relevant factors, a literature study revealed one particular case study quite similar to the present case study. In previous literature success factors for applied ecodesign at Philips CE were determined (Cramer and Stevels, 2001). In this project, these factors were used to verify whether the current list of factors is complete. The factors found by Cramer and Stevels are described in Table 1. For each factor it is verified whether it is in the specific description of the octahedron model or not.

Table 1 Factors influencing the implementation of applied ecodesign

Factors (Cramer and Stevels, 2001)	Matching factors in octahedron model
1. Internal factors	Strategy
Management attention	Organisational goal
Environmental skills	People
Cross-functional linkages	Structure
Eco-efficiency activities already in place	Technology
Personnel motivation	People
2. Business conditions	
Profitability	Organisational goal
Market share	Organisational goal
3. External influences	
Customer pressure	Not in yet, Structure
Legislation	Not in yet, Structure
4. Room to manoeuvre	
Product functionality	Not in yet, Technology
Product alternatives	Not in yet, Technology
5. Competitive edge	
Competitive environmental benchmarking done?	Not in yet, Structure
Is competition active?	Not in yet, Structure

From the above analysis, it was concluded that external influences, room to manoeuvre and competitive edge should be added to the list of factors resulting from the octahedron model, to complete it. Furthermore the culture component was not considered as an important success factor by Cramer and Stevels, whereas in the octahedron model this is an important factor. Previous research by van Hemmen (2005) on the influence of culture on change processes, indicated that this factor is very important for the success of a change process. Given the fact that it is not known yet whether this factor will be important or not in this case, it will be included in the approach used for this case study.

4.4. Creation of tailored method to analyse factors

The factors, as described for the case study in the previous step, need to be analysed. For some steps a tailored method was needed, for other steps a qualitative description of the factor was sufficient to analyse that factor (see Table 2). In this section the composition of these methods will be described. First a general overview of all factors and its general approach (tailored method of general description) will be provided.

The results of this search for tailored methods will now be described in more detail for each factor.

Culture

In describing the company culture two important directions can be distinguished. In the first direction culture is seen as something a company has and in the second direction culture is seen as something a company is. The first implies that culture can be changed, the second implies that culture must be seen as a boundary condition and cannot be changed (Hofstede, 1991; Van Muijen, 1992). In this case study the second direction will be assumed to be true, because eventual changes as a result of this optimisation process will take place long after this case study. As a result this influence of the optimisation process on the company culture is not within the scope of this case study.

Table 2 The general approach for each factor

Six factors	General approach
Culture	In order to describe the culture an existing model was used in a new way.
Strategy	Strategy was described qualitatively, without tailored method.
Structure	A stakeholders' analysis (inspired on an existing stakeholders' analysis method) was used to analyse the structure of both the internal and external value chain.
Technology	The benchmark and resulting environmental design process were analysed with the help of two descriptive evolutionary process models.
Organisational goal	The organisational goal was described qualitatively.
People	The human capacity was described qualitatively.

In the case study of Van Hemmen (2005) on the relation between company culture and change processes, the company culture model of the Focus group was described as a way to analyse the company culture. In this case study this model will be used as well to qualitatively describe the company culture of both departments. In this model four dimensions are described to measure company culture. These dimensions are visualised in Figure 3.

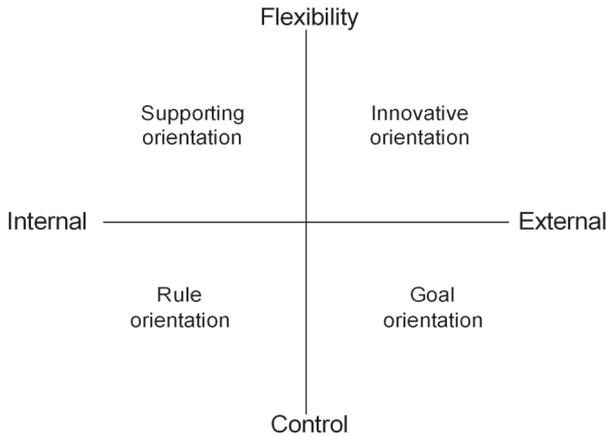


Figure 3 The company model of the Focus group (Van Hemmen, 2005)

The four orientations can be considered as dimensions. This means that every company has elements of all orientations in its company culture (Van Hemmen, 2005). In his case study Van Hemmen uses a validated questionnaire to assess the scores of the company on the four dimensions. Based on Van Hemmen's description the four orientations can be summarised as follows:

- Supporting orientation: An informal culture aimed at cooperation and mutual growth.
- Innovative orientation: An informal culture aimed at individual development and innovation.
- Rule orientation: A rule-oriented culture aimed at rational procedures. The culture is hierarchical.
- Goal orientation: A culture aimed at realising targets in a rational and well-thought way.

Given the fact that in this case study more factors need to be analysed than just company culture the dimensions were described in a shorter, qualitative way, based on discussions with all people involved at the Sustainability Center and at the business line.

Strategy

The environmental strategy of the company will be described qualitatively.

Structure

A stakeholders' analysis is used to describe the main players and flows both in the internal and external value chain. In this stakeholders approach, theory on environmental value chain analysis (Rose and Stevels, 2000) is used to describe the different common and conflicting interests of stakeholders both internal and external.

Technology

In this factor the room to manoeuvre is defined qualitatively. Furthermore the two relevant processes: environmental benchmarking and the implementation of ecodesign are assessed as follows.

Preliminary research revealed that both the benchmarking process and the resulting actual application of ecodesign should be seen as evolutionary processes.

In this first step the primary goal is to put the environmental benchmark procedure in larger context to be able to position current Philips activities and forecast the future steps in the evolutionary cycle.

Two models resulting from previous research studies are used to describe the evolutionary process of environmental benchmarking at Philips CE. Both evolutionary processes can be summarised in two main characteristics:

- All phases should be run successively, no phases should be skipped.
- The higher the level, the more effective and efficient the process. The goal is to reach the highest phase. To describe the benchmarking evolution the model of Watson (1993) is used, see Figure 4.

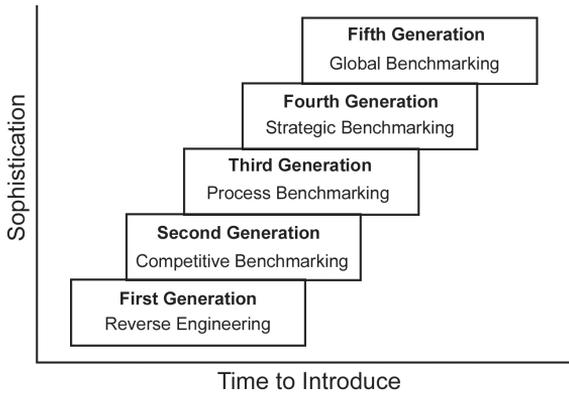


Figure 4 Evolutionary process of benchmarking (Watson, 1993)

To describe the evolutionary process of the company culture needed to enable applied ecodesign (resulting from the environmental benchmark procedure) the evolutionary model of safety culture is used. In this model the cultural values and beliefs (expressed in trust and informedness) within the company is linked to the company's performance (not the management strategies, but the actual implementation) on safety aspects. According to Hudson five general phases can be distinguished for the safety culture, see Figure 5. In this paper these phases are translated for the situation of applied ecodesign.

- The pathological phase: The company does not see environmental design as an issue.
- The reactive phase: The company considers environmental design as important, but reacts in a defensive way.
- The calculative phase: The company has a system to address environmental problems structurally. This system is applied in a rather mechanical way. As a result the system is not used to its full potential.
- The pro-active phase: The company starts to act in a pro-active way on environmental design. People start to become convinced of the importance of environmental aspects.
- The generative phase: People are convinced of the importance of environmental aspects and no system is needed anymore to deal with ecodesign.

With the help of these models the current position of the benchmark procedure and the current level of applied ecodesign resulting from it can be described and a rough indication of the next step in evolution can be discussed.

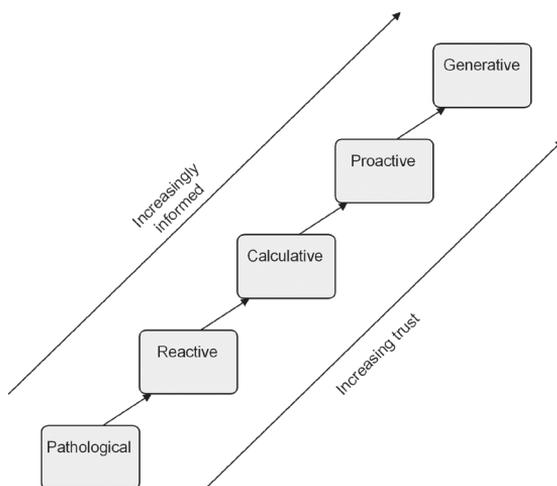


Figure 5 The evolutionary model of Safety Culture (Hudson, 2001)

In finding the right evolutionary step it is important to find the right balance in level of progression. If a next evolutionary step is too progressive people will become discouraged, because they will never succeed in making such a big leap forward at once. Besides too big leaps forward will harm the continuity of the current processes. If the evolutionary step is too small simply nothing will change.

With the help of these two models also the size of the gap between the environmental strategy and the environmental actions in practice can be monitored. Within each multinational there is a difference between the talking (strategy) and walking (actions). This is because strategy aims to set targets for the future, whereas the current actions aim to solve problems in the present (which is often far more difficult). However procedures like the environmental benchmark procedure can be used in a positive way to minimise this gap.

Organisational goal

The organisational goal will be described qualitatively. This will be done to check if the benchmark procedure is in line with the organisation goal of the company.

People

The issues related to the people, number, educational level, capacity and tasks will be described qualitatively.

4.5. Conclusion

In this chapter, all tailored methods have been described for each of the six factors. It turned out that especially the factors of culture, structure and technology were difficult to measure and needed a tailored method to guide the analysis process.

In the next step results from the application of this tailored approach in the Philips case study will be summarised.

5. Application of the Tailored Method

In this chapter it will be described how the application of the methods was performed in practice. For reasons of company confidentiality only some of the results can be used to illustrate the application of the method. The goal of this chapter however is not to describe the current environmental benchmark procedure of Philips in full detail, but to describe how such a problem can be tackled in practice. Though lots of descriptive models are available in literature, very few prescriptive and relevant approaches and methods could be found for this case study.

5.1. The tailored method in practice

In this section the application of the method in practice is explained in more detail.

Culture

The four dimensions of Van Hemmen were used to qualitatively describe the company culture within the internal value chain. In order to do this it is necessary to visit the departments personally. Only if you have been part of the culture you can describe the cultural dimensions for each department qualitatively without time-consuming validated questionnaires. In this case study it turned out that the Sustainability Center and the case study Business Line could best be used in this analysis. This is because the first part of the benchmark procedure had to be performed at the Sustainability Center, whereas the second part had to be performed at the Business Line by the product designers.

Though the dimensions itself can not be changed it turned out to be useful to adapt the environmental benchmark procedure to the differences in cultural dimensions. In this case it became clear that the benchmark part (the product measuring) needed to fit in other cultural dimensions than the environmental design part of the procedure (the creation of green options and the implementation in the business). Several differences in company culture were identified between the two Philips departments with the help of the company culture model.

In order to illustrate the usefulness of the model one example of an important difference will be provided. This

was the difference in scores on rule orientation and goal orientation. The Sustainability Center scored higher on rule orientation and the business line scored higher on goal orientation. Whereas the Sustainability Center focused on performing the fixed procedures in the best possible way, the focus of the Business Line was more on redesigning the product in the most environmentally friendly and profitable way.

Strategy

In this factor the current environmental strategy was described qualitatively. This description is used later on in the evolutionary process models to analyse the gap between the environmental talking and walking. In the case of Philips CE the part of the current environmental strategy relevant to the environmental benchmark procedure could be found. Philips CE wants to be on par or better than her best commercial competitors on all green focal areas. These green focal areas are: energy, packaging, weight, hazardous substances and recyclability.

Structure

In this factor the groups of players and relations in the internal and external value chain were analysed in a stakeholder analysis. Furthermore the influence of the environmental activeness of competitors was evaluated and the influence of this factor on the environmental design within Philips CE. The stakeholders in the environmental benchmark procedure can be split up into people in the internal value chain and people in the external value. Furthermore it turned out to be useful to divide the internal value chain on several levels as well. In this case the internal value chain was split into three levels, Philips corporate, Sustainability Center and the Business Line. For all levels the flows (money, product and different types of information flows) were visualised. An example of such a flow chart of the external value chain is shown in Figure 6.

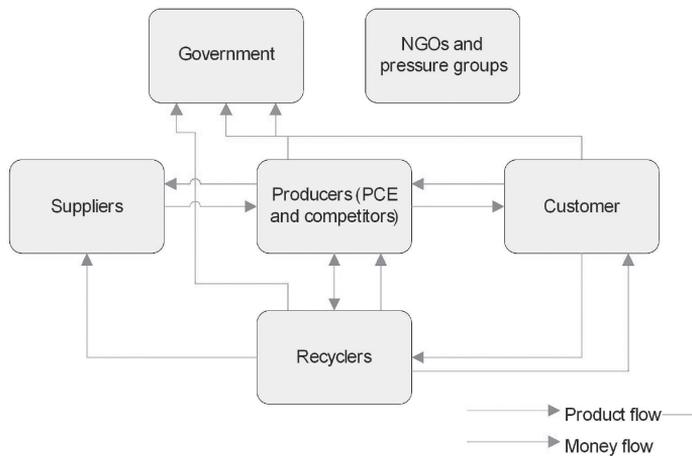


Figure 6 Overview of the main stakeholders and flows in the external value chain

The same thing was done for the internal value chain containing all stakeholders within Philips CE. In both value chains several conflicts in interest can be traced between the different stakeholders. Mainly due to these conflicting interests the creation of green options and the implementation of green options in the product design process are facilitated or obstructed. In the stakeholder analysis both the common and conflicting interests were all described and ranked on relative importance.

For the external value chain the following main conflicting interests could be found, using the stakeholder analysis. Firstly there is the difference in perception of green between the consumers and the government. Secondly there seemed to be a gap between what can be seen as environmentally friendly from a scientific point of view and the previous two perceptions of green.

This ranking is based on money, product and information flows. In general it can be concluded that the more money is involved, the higher the priority of the conflicting interest.

It is difficult to evaluate how active competitors are on environmental design, because of lack of opportunities to verify what they are actually doing in practice. However there are some indications of their environmental performance that will be described next.

The level of green activeness of the competitors was evaluated based on the amount of their green marketing actions. Furthermore their environmental awards and labels were benchmarked against the environmental awards and labels Philips has. This information is used in discussion with environmental policy experts within Philips to verify the level of influence of the competitors green involvement on Philips' green involvement.

Technology

In this factor both the room to manoeuvre in the production design process and the processes related to the environmental benchmark procedure were assessed.

Both the benchmarking part and the applied ecodesign part can be seen as part of a larger evolutionary process within Philips CE. With the help of the two evolutionary process models the environmental benchmark procedure and the environmental design process could be assessed.

First both models were used to sketch the historical evolution of both processes within Philips. Second the models were used to indicate the difference between the strategy on environmental design and the environmental benchmark procedure and the action programme that was performed in practice.

Based on this analysis the desired next step in evolution for the environmental action programme could be determined. In this step the gap between the strategy and the actual practice is minimised. The environmental benchmark procedure could be used to minimise this gap. This led to design guidelines for the environmental benchmark procedure. In section 5.2 examples of these guidelines will be provided.

Organisational goal

The primary organisational goal of Philips as a whole will be described. Furthermore the specific organisational goals of the Sustainability Center and Upmarket Flat Displays of Philips CE and the primary goal of benchmarking in general were described. The environmental benchmark procedure should fulfil all these goals.

It became clear that the overall organizational goal of Philips CE and the department of Upmarket Flat Displays was making profit, whereas the primary goal of Sustainability Center was more on improving the environmental performance of the CE products.

Under the factor of structure this information was used to verify if these goals are all met in the environmental benchmark procedure.

People

In this step only the capacity of people directly involved in the environmental benchmark procedure (the employees of the Sustainability Center and Philips Upmarket Flat displays) was analysed. Factors that influenced the environmental benchmark procedure turned out to be:

- The amount of full time employees available for performing the environmental benchmark procedure.
- The level of product/benchmark experience of the people
- The continuity of people: how long did they work in the environmental benchmark procedure on average?

Describing these factors led to important guidelines for optimizing the environmental benchmark procedure, which will be discussed in section 5.2.

5.2. Design guidelines and improvement options

All the information gathered in the analysis of the six factors was used to create design guidelines for the new environmental benchmark procedure. No specific information on the content of these design guidelines will be described in this paper, for reasons of company confidentiality. But it will be described which aspects of the environmental benchmark procedure were found that could benefit from optimization.

These factors turned out to be:

- The environmental benchmark criteria
- The environmental benchmark goal and steps
- The internal awareness on the benefits of the environmental benchmark procedure
- The incentive of the designers to involve in the process of environmental benchmarking
- The green marketing of the environmental benchmark results
- The usability of the environmental benchmark procedure

For each of these factors design guidelines were generated based on the analysis. These design guidelines were discussed with experts in the different fields and improvement options were generated by the people of the Sustainability Center and the Business Line. These solutions were discussed with some key stakeholders, at different levels of the internal and external value chain. Based on this discussion and the gap analysis resulting from the two evolutionary models, one redesign action programme for the environmental benchmark procedure was designed. This action programme was in the format of a roadmap, describing step-by-step what actions should be taken first and providing suggestions for the capacity that was needed to do this.

6. Conclusions

In this chapter the effectiveness of the followed approach in this case study will be evaluated and the general value of this approach will be discussed.

6.1. Effectiveness of method in this case study

In this case study the approach was effective in providing solutions to optimise the environmental benchmark procedure. In general it can be said that a lot of insights were gained and that Philips was happy with the pragmatic results of this analysis. The results aimed at aligning environmental benchmarking and design further in the organisation. It turned out that there is always a tension in the company between making profit and decreasing the environmental impact of the products. But some useful common interests could be identified and implemented in the environmental benchmark procedure.

Furthermore Delft University of Technology gained more insight in how these problems can be analysed in a systematic way. In this case study it was not only explored how the current situation could be described, but also how to come to a prescription of redesign steps based on this description.

6.2. Generic value of method

Though the tailored methods used in this case study will have to be redesigned specifically for every new situation, the general framework has a large general value. Furthermore some lessons could be learned from this specific case that may be interesting for similar case studies as well. These lessons will be described next:

- Visualising the evolutionary process is a good thing to do, because this forces you to look at both historical successes and future possibilities. In larger companies there are often a lot of historical developments that should be carefully evaluated to avoid reinventing the wheel.
- The stakeholders' analysis turned out to be a good and motivating way to set priorities and obtain a clear image of the situation. Especially the money flows between the different stakeholders are easy to visualise and give valuable information.
- The assessment of the company culture still needs more research. This is an extremely important issue in the success of proposed changes. It would be helpful to find a way to quantitatively describe this soft side of process changes.
- Though an external person is very suitable for identifying points of optimisation, people from the business are needed to create recommendations. This has two major advantages: The people improve their own process to certain extent, which will increase the acceptance of the proposed changes. And the people have a lot of implicit business knowledge that external people don't have. This knowledge is essential for redesigning a process.

- It must be said however that this approach cannot be followed rigidly without subtly changing the method all the time to reach optimal analysis results. The generic value of this approach is more in showing possibilities to analyse complex situations, like a stakeholders' analysis, and a description of the evolutionary processes, rather than prescribing rigid ways of approaching these problems.

6.3. Final conclusions

It was found that the contingency approach was very suitable in the present case study, because it does not rigidly prescribe a method, but accepts the fact that a more dynamic way is needed to analyse processes in depth. It was also found that concrete solutions for optimising processes like the environmental benchmark procedure should always be created in cooperation with people from the business. In that light, the present study has significantly contributed to the existing knowledge base on what was earlier referred to as the soft side of ecodesign. Understanding how ecodesign can be implemented and operationalized given existing culture, strategies, structures, technologies, organisational goals and people, and given external influences, room to manoeuvre and competitive edge, starts with the ability to understand these factors and to establish their relationship with ecodesign processes. Future research at Delft University of Technology will aim at extending the current knowledge base by combining theoretical insights from adjacent disciplines with practical case study work.

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Pictures, 9

Roxburgh, Selkirk and Peebles, sheep, green and electronics



6.4 Applications of Environmental Benchmarking

Since its inception, environmental benchmarking has been applied to far more than 100 consumer electronic products. It has been used at Philips Consumer Electronics for EcoDesign improvement, for product strategy making and for the selection of outstanding Green Flagship products (see chapter 4.4). A lot of that work is proprietary and therefore cannot be discussed in this book.

However, a paper with the title “*Environmental Benchmarking of Computer Monitors*” is presented on page 359. Although the paper was written in 2000 it represents very well what can be achieved through the completion of an Environmental Benchmark (The work is based on the very first benchmark done in Taiwan in 1997- see also 6.3 - and therefore refers to products from 10 years ago, see the figure below).

Apart from focusing on single products, combining data from a series of benchmarks can be used to derive conclusions for product categories (which ones are part of a general product line). Additionally this data can help to monitor developments as a function of time and identify structural (under) performance with respect to competitors. This ‘multiple benchmarking’ will facilitate communication between departments (better management of the internal value chain – product manufacturing, strategic developments, marketing and sales).

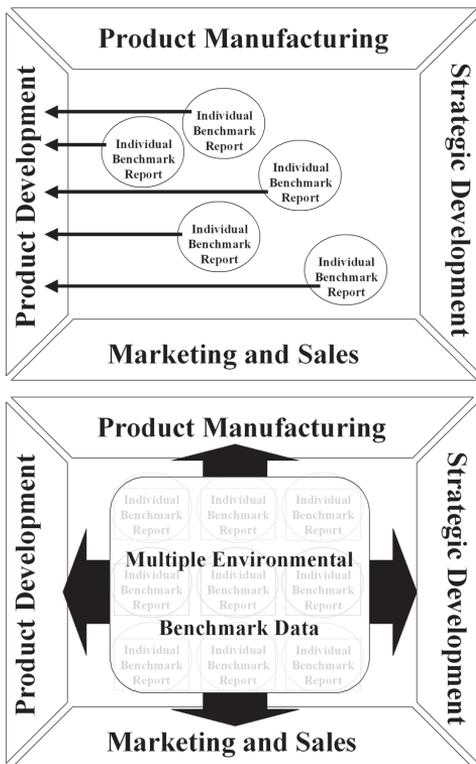


Figure 6.3 Process improvements in the internal environmental value chain through application of multiple benchmarking.

This figure shows that initial reporting from environmental benchmarking was almost exclusively directed towards product development (left hand side). Multiple environmental data sets facilitate the involvement of other departments (right hand side of figure 6.3).

The large number of benchmark reports available at Philips make it possible to obtain information about environmental issues, not only for individual products, but also per product category particularly across product categories. Starting in the summer of 2001, projects on packaging and energy issues were initiated to synthesize the available data. These are briefly reported on in this paragraph. Although not yet part of

an established procedure, it shows what type of additional information can be derived from synthesizing benchmark data. In the future, these approaches may be incorporated in the standard Environmental Benchmark procedure. In addition, it also proved useful to extend existing benchmark datasets with data from consumer test organisations in order to increase the number of observations and to obtain even more meaningful results.

One possibility of synthesizing benchmark data is to investigate how the performance of the various benchmark variables is correlated. Of particular interest are those variables on which distinct design efforts are focused but that are related to each other in practice. In this way, interesting results have been obtained by calculating indexes for variables such as product volume and packaging volume, product weight and packaging volume, TV screen size and energy consumption et cetera. The large number of benchmarks enables the derivation of what can be observed to be best practice for these indexes in a certain field. At the same time, it also enables the identification of results for individual products that significantly underperform – results that otherwise might have remained unnoticed. For example, from Figure 6.4 (displaying the performance of Philips products next to those of the competition in terms of product volume/packaging volume) it was learned that for 7 out of 9 product categories Philips products score better than the competition, suggesting room for relative improvement for the remaining categories.

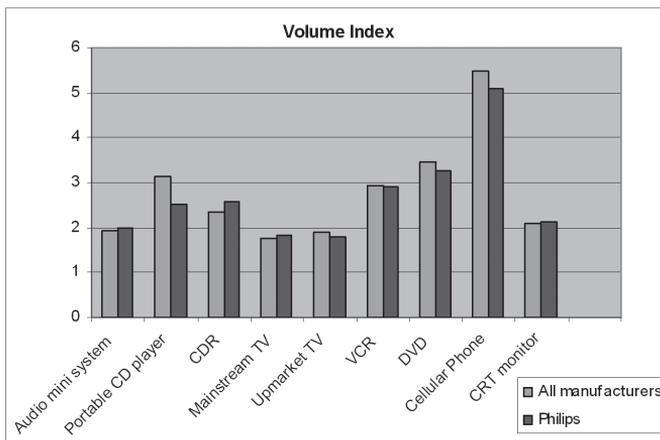


Figure 6.4 Correlation between product and packaging volume, based on multiple benchmarks

Also, in absolute terms conclusions can be drawn. From a similar graph for product weight/packaging weight it became clear that Philips portable CD players performed significantly better on this ratio than the competition. At the same time it became clear that this ratio was quite unfavourable for Philips DVD players, for no apparent reason. The results of this analysis can be meaningful starting points for further generation of 'green' options, in addition to those already generated by the established benchmark procedure as discussed in Chapter 6.3

Another possibility is to trace trends related to particular benchmark issues, provided that sufficient benchmark data is available. For example, analysis has shown how power consumption data (in this case for audio sets) have developed from various benchmarks over time. Although those measurements appear to show a downward trend, it was also quite clear that there is quite a spread in the results. Observations like these give rise to questions addressing correlations between functionality and energy consumption.

Environmental Benchmarking of Computer Monitors

Geert-Jan Eenhoorn and Ab Stevels

Abstract

The environmental benchmarking procedure, as developed by the Design for Sustainability Lab of Delft University of Technology has been applied to high-end monitor products of Philips BG Monitors of Chungli, Taiwan. The method has turned out to be a robust one in industrial practice. The results of the benchmark have created tremendous awareness in the organization and have prompted action to improve products. On a longer time scale the benchmarking results have formed the basis of an environmental brainstorm for new product generation. As a result of those brainstorms 'green' options have been incorporated in the specification of new products. This new product generation became the winner of the Philips best Environmental Product Award in 1998 and is a huge success in the market.

Introduction

In the early nineties, leading electronic companies started with EcoDesign (Design for the Environment). Early activities were primarily defensive, that is organizing compliance with upcoming legislation and regulation, making mandatory design rules and setting up an internal organization to ensure that such items are enacted. Soon it was discovered however that 'green' offered a far bigger potential both for cost savings and for enhancing sales. Saving on resources turned out to be directly related to price reduction. Strong environmental performance was realized to be a good vehicle to enhance brand image and sales. From these perspectives some important paradigm shifts took place in the Royal Philips Electronics EcoDesign activities:

- Focus should be on business aspects rather than just on technicalities.
- Focus should be on those environmental parameters which can be influenced by the companies itself (the 'internal' parameters rather than the holistic perspective of Life Cycle Analysis (internal + external))
- In order to communicate to the external world five focal areas in 'green' should be addressed in language which is understandable for customers and other audiences which generally are non experts. These areas are: Energy, Materials application, Packaging and transport, Environmentally relevant substances and Durability/Recyclability.
- Life Cycle calculations should take place to avoid suboptimization in one particular focal area and to communicate the expert audiences.
- Market driven environmental performance means being better than the competition rather than scoring on an absolute scale.

At the same time the Design for Sustainability Lab at Delft University was looking for ways and means to bring EcoDesign (DfE) closer to the attention of the designer and industrial design engineering students.

The question of how to enhance creativity and idea generation in particular was addressed. Simultaneously it was realized that although at that time a lot of so called environmental design rules existed, they failed to deal with specific product characteristics and with priority setting. Environmental benchmarking was seen to be the ideal link between creating awareness (what is this all about?) and design itself (how to realize it?) because a proper benchmark communicates where current products stand, thus creating a platform for discussions and brainstorms focused on how to go forward.

In 1996-1997 the Monitors Division of Philips Consumer Electronics located in Chungli, Taiwan felt particular challenges. The business was strongly expanding, and highly successful in terms of revenue, market share and profit. It was felt however that product designs were gradually lagging behind and management was looking for a new impetus for strengthening the product line up, particularly in the high-end, high margin products. In view of this it was decided to commission an environmental benchmark project under the umbrella of the Delft University of Technology/DfS Lab – Philips Consumer Electronics cooperation.

In this project – which is explained in the present paper – the goal was to drastically improve, from both an ecological and economic perspective, the design of 17" monitors, taking the Philips 107A/CM88 product as a reference. DfS lab carried out the benchmark, thus enabling it to test the concept of the method and its applicability. The result, including first redesign proposals, were agreed upon to be used as the core of brainstorm in Taiwan

for the development of the next generation of computer monitor products.

In the present paper, benchmarking in general is considered in §2. In §3, environmental benchmarking is elaborated on. Results of the benchmark of the I07A/CM88 monitor and those of three competitors product are presented in §4. In paragraph 5 it is shown how these results have been used to indicate product improvement and feed into the standard Product Creation Process.

Benchmarking

The definition of benchmarking used in this paper is the one used by Kotler (see ref. 1) "Benchmarking" is the art of finding out how and why some companies can perform tasks better than other companies". This definition is broader than what most people using the term mean by it. In general when talking about benchmarking people refer to a process in which products are compared to similar products of direct competition: competitor analysis. In this way insight is obtained in the relative position of the company with respect to its competition. This insight is then used to improve product performance.

According to Kotler the basis is wider. Benchmarking should go beyond investigating the level of the competition and create the basis for insights how to be better than that. The following steps are to be taken in such an approach:

1. Determine which aspects and properties are to be benchmarked (system definition).
2. Identify key performance variables to measure.
3. Identify and position the most important competitors in the market
4. Measure your own performance as well as competitors.
5. Specify programs and actions to close the gap or even to surpass competitors.
6. Implement and monitor results. On the basis of these principles the DfS Group at Delft University has defined its approach for environmental benchmarking (see ref. 2 and 3).

Environmental benchmarking of monitors

For the environmental benchmark, 17" monitors with similar technical specifications were chosen: the Philips product to be improved, 2 products from Japan of which one was selling very well in the market and one originating from Korea. As a functional unit the monitor (including its packaging and user manual) was chosen. For the life cycle a period of 5 years before discarding was taken. In order to calculate total energy consumption and energy costs associated with that, a user scenario was assumed including a number of hours in full use, standby, shut off and complete off mode. Costs for the disposal of packaging were calculated on the basis of the so called DSD tariffs in Germany (the highest in the world). End of Life disassembly times and overall end of life costs were calculated on the basis of Philips proprietary calculations programs.

For the measurement of the product performance the following focal areas were distinguished:

1. Energy

Energy consumption in: operational mode
standby mode
sleeping mode
off mode

Energy cost in the 5 years use scenario.

2. Material application

Weight of plastics applied
Cost of plastics applied
Weight of ferro applications
Weight of non ferro applications
Weight of CRT.

3. Packaging

Card board weight of box
Weight of EPS buffers

Weight of plastic bags etc.
 Weight of manual/user book
 Cost of packaging recycling. According to DSD tariffs.

4. Chemical Content

Presence of flame retardants in housing
 Area of printed wiring boards
 Weight of printed wiring boards
 Number of printed wiring boards
 Length of cable and wiring.

5. Recyclability

Calculated disassembly time
 Calculated cost/yield with respect to reference disposal cost (mix of landfill and incineration).

6. Life cycle performance

Ecoindicator score (see ref. 3) of production phase.
 Ecoindicator score over the whole life cycle.

4.1 Results from the environmental benchmark

Energy

The results from the environmental benchmark for energy can be summarized in the following table:

Table 1 Environmental benchmark of energy consumption

Items	Philips	Competitor 1	Competitor 2	Competitor 3
Operational mode (W)	78	82	81	77
Standby mode (W)	4	10	12	11
Sleeping mode (W)	1	4	3	1
Off mode (W)	1	4	1	0
Energy cost (USD) (European tauffs)	94	122	97	87

The energy consumption differences in the operational mode are very limited (less than 7%). However, in terms of cost this means a difference of 35 USD, corresponding to 30-40% on a relative scale.

This is due to high amounts of energy consumption in standby, sleeping and the modes of competitors 1 and 2; Philips is doing relatively well with respect to the best competitor.

4.2 Materials application

The results for the environmental benchmark for materials application can be summarized in the following table:

Table 2 Environmental benchmark of materials application.

Item	Philips	Competitor 1	Competitor 2	Competitor 3
Weight of plastics applied (g)	4597	3283	3123	3592
Costs of plastics applied (USD)	16,0	6,0	5,5	8,0
Weight of ferro (g)	2303	840	452	757
Weight of aluminium (g)	348	606	404	1698
Weight of CRT (g)	9200	10600	9400	9200

These results show that for Philips there was plenty of room for improvement in terms of plastic application in the housing; both weight and price/kg were far too high with respect to the competition. Also the amount of ferro was very high because the metal electromagnetic shield had not yet adapted to the development of modern electronics (note that competitor 1 and 3 use also aluminium for EM shielding). On the other hand Philips has thermal management of these products well under control; the amount of aluminium used for this purpose is

relatively low. In the field of CRT weight one producer is stepping out in terms of weight due to different tube concept (tri nitron).

4.3 Packaging

The results of the environmental benchmark for packaging can be summarized in the following table:

Table 3 Environmental benchmark of packaging

Item	Philips	Competitor 1	Competitor 2	Competitor 3
Cardboard for weight of box (g)	2590	2468	2768	2645
Weight of EPS buffers (g)	576	705	430	411
Weight of plastic bagd etc. (g)	55	47	69	47
Weight of manual / user book (g)	282	106	214	180
Cost of packaging recycling according to DSD tar offs (DM)	260	300	250	250
Ratio packaging weight/product weight	0.17	0.18	0.19	0.17

The packaging results show the biggest differences in the way EPS buffers are applied; this also has impact on the cost of recycling of the packaging in Germany because tariffs for plastic based materials are high. None of the producers had replaced EPS by cardboard. This would result in halving the recycling cost to approx DM 1.10 - 1.30. Also the user manuals have strongly diverging paper weight differences, varying by almost up to a factor of 3.

4.4 Chemical Content

The results of a chemical content analysis and of A benchmark of materials applications which are strongly related to chemical content issues are as follows:

Table 4 Environmental benchmark of chemical content.

Item	Philips	Competitor 1	Competitor 2	Competitor 3
Presence of flame retardants in housing	No	Yes	Yes	Yes
Area of PWBs (dm ²)	15.5	9.8	12.5	12.0
Weight of PWBs (g)	2800	2300	2050	2250
Number of PWBs (g)	6	2	7	5
Length of cable/wiring	4000	2200	2800	2070
Number of components	1300	850	1100	800

With the exception of Philips, which has a flame retardant free housing, all other manufacturers are using brominated flame retardant housing materials, to which antimony oxide Sb₂O₃ is added. This represents a serious environmental load and will also hamper recycling of housing components.

Regarding electronics and components competitor 1 achieves the best score; due to a high level of electronic integration, area, weight and low numbers of PWBs. In particular for Philips there is a vast improvement potential. This also applies for the reduction of cables, wiring and the number of components applied.

4.5 Recyclability

The results from the recycling benchmark are summarized in the table below:

Table 5 Results of recycling benchmark.

Item	Philips	Competitor 1	Competitor 2	Competitor 3
Calculate disassembly time (S)	750	470	580	480
Calculated cost/yield (with USD respect to reference disposal)	-1.2	+2.1	-1.4	+3.1

Due to its complex construction the heavy EM shield the disassembly time for the Philips monitor is long and receives a negative value in comparison with the reference scenario.

4.6 Life cycle impact

Ecoindicator calculations showed the following results:

Table 6 Ecoindicator calculations.

Item	Philips	Competitor 1	Competitor 2	Competitor 3
Ecoindicator of production phase (mPt)	575	756	599	541
Ecoindicator of user phase (mPt)	437	357	369	387
Life cycle score	1085	1161	1015	984

The Ecoindicator calculations show clearly that the user phase is the most important part (53-65%) of the total life cycle impact. This means that the Philips product still scores relatively well in spite of its improvement potential, as shown in the tables 2, 4 and 5. For competitor 1 the opposite holds; a good score for the production phase is reversed in by an unfavourable performance in the user phase.

5 Follow-up of the benchmark

When the results of the benchmark were communicated to the organization, they provided a positive shock. It was realized that the competitor was substantially better in several focal areas like material application, chemical content, wiring and disassembly. It was decided therefore not to wait until the creation of the next generation of products but to make an improved version on the basis of the present concept. Due to the lack of time not all proposed improvement options proposed by the DfS lab could be implemented in the short term. An "emergency" program in June 1997 brought the performance of Philips Monitors closer to the competitor. Results are summarized in the table below:

Table 7 Product characteristics of Philips monitors after the benchmark.

Item	Philips old	Philips adapted	Best competitors performance	DfS proposals	New generation (increased specification)
Energy life cost (USD)	94	91	87	85	80
Plastic materials cost (USD)	16	10	5.5	7	8
Metal Environmental Impact (mPt)	54	32	23	28	19
Aluminium environmental impact (mPt)	13	13	15	12	13
Total packaging weight	3563	3470	3283	3810	3120
Area of PWB (dm ²)	15.6	14.3	9.8	13.5*	11.0
Number of PWB	6	3	2	2	2
Length of cable/wiring (cm)	4000	2270	2070	1925	1900
Number of components	1300	1250	800	900*	800
Item	Philips old	Philips adapted	Best competitors performance	DfS proposals	New generation (increased specification)
Calculated disassembly time	750	570	470	440	350
Production Ecoindicator score (mPt)	575	439	357	388	375
Life cycle indicators score (mPt)	1085	934	984	846	838

*Further improvement dependent on availability of a new IC generation.

This table evidences that the adapted version of the Philips 17" monitor is gaining on the best competitor (and in many respects, to other competitors). This particularly holds in the areas of energy, life cycle cost, metal environmental impact, number of PWBs, length of cable and wiring, calculated disassembly time and production Ecoindicator score. Plastic material weight/cost, printed PWB area and component count still lag behind due for various reasons such as increased usage of plastics as a result of the elimination of flame retardants and the lack of a new IC generation. However, due to the fact that the overall best score is not coming from one competitor but is a mix of several ones, the overall environmental score of the adapted Philips product is already the best (approx. 5%). The best overall score would be even better if all DfS proposals had been taken into account; this would have increased the gap with the competition to around 15% with further potential ahead if a new IC would be available (see fourth column of table 7).

Across the board improvements would take place because the proposals refer to all focal areas as are substantiated in the following table:

Table 8 Number of benchmark suggestions for improvement.

Focal area	Number of (DfS) benchmark suggestions for improvement
Energy	6
Materials application	16
Packaging/transport	3
Chemical Content	8
Recyclability	9

After the product adaptation it was decided that the remaining suggestions of table 8 (approximately half of the total) would be used as the basis for a brainstorm on the basics of a new product concept to be held in September 1997.

It turned out however that the functionality requirements on 17" monitors had to be increased in order to be successful in the market. In particular, the scanning range had to be expanded by some 5-10%, resolution was upped by some 5% and brightness had to be increased by some 15%. This meant that the outstanding proposals could not be implemented straight-away.

Parallel to this development procedures for doing brainstorms and incorporating strategic environmental intent were put in place (see refs 4 and 5). This meant that the outstanding options were combined with newly generated 'green' options into one consolidated list.

In the brainstorm of September 9, 1997, a consolidated list of some 25-30 'green' options were generated, out of which 13 were selected on the basis of the so called EcoDesign matrix. Which analysis combined environmental, company, customer and societal benefit (see ref) In the last quarter feasibility of the 13 selected options were investigated further with the result that 8 of them were incorporated in the product concept complication in January 1998. In view of the large amount of concurrent engineering being done in 1997 the Product Creation Process in itself was very fast and the new product could be launched in May, 1998. The result of this development was excellent. The properties of the new generation surpassed – in sight of tightening the specification – the properties of the best competitors in almost all departments. Life cycle impact exceeded even the best score by 16%. (see last column of table 7).

This result gained wide recognition internally because the product was the winner of the Philips best EcoDesign award in 1988. Later on the product became a huge success in the market both in terms of numbers sold and in terms of margin.

7. Conclusions

The present paper shows that environmental benchmarking results in a tremendous increase in awareness within the organization, particularly because it focuses on comparing performance with that of the competition rather

than focussing on absolute environmental score. Simultaneously it is instrumental in generating straight forward and completely environmental improvement options which are analysed in terms of environmental, business, customer and societal benefits. Environmental benchmarking has turned out to be a solid basis for creating source material for environmental brainstorming. These sessions have resulted in monitor designs which were superior to those of the competition and could be marketed as such.

From an academic perspective the Philips monitor case shows that the methodology developed at Delft University of Technology proved – with some minor adaptations – robust in industrial application.

8. References

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Highlights of the year, 2002

Roadmap, performance

It was 2002 when the integration of EcoDesign into product creation processes started to be well established in proactive companies. What this means is that the full range of EcoDesign actions are being considered. This ranges from defensive actions (for instance chemical content), cost reduction actions (less material, packaging, simpler product architecture) to proactive activities like radical redesign and product alternatives. Environmental benchmarking is the basis for contributing to the formulation of appropriate 'green' requirements for future product generations (see chapter 6.3). The EcoDesign matrix (see chapter 4.2.1) helps to set prioritized action agenda's.

Having achieved all this all this on a product level, a follow up step is to plan on a wider time horizon. Where do we want to go in the mid and long term? What actions have to be taken (for instance in the supply chain) to realize the technical targets and what has to be done to better communicate the results to customers and other stakeholders?

As of 1997, the first attempts were made to create roadmaps – that is tables with objectives (for instance reduce X across the whole product range), numerical targets (%), a timeframe (for instance to be realized in Z years time) and specific people responsible for doing the work.

Gradually, more items were included in the roadmap beyond the technical ones (strategy, communication, education, progress in corporate environmental programs). In 2002 roadmaps were considered to be fully developed and mature. As a consequence environmental roadmaps were broadly introduced in Philips Consumer Electronics. As a next step, a performance measurement was linked to the roadmaps through the so-called traffic light system, green (target reached), yellow (target not completely reached) and red (target far away).

Through a weighting scheme for the different items a 'balanced score card' can be developed. In turn, the balance score can be used for determining individual incentives as bonuses. At PCE this environmental roadmap score is being used as part of the performance measurement of senior executives. Its contribution to the total score is relatively modest but the good news is that it exists in practice, every senior executive is monitored on basis of it.

6.5 EcoDesign tools, new style

6.5.1 Introduction

In this chapter ideas are presented for EcoDesign tools, new style. It includes three items:

- A proposal for how to link the emissions, the resources and the potential toxicity dimensions, keeping in mind that apart from 'scientific green' there is 'government green' and 'customer green' as well (see chapter 6.1).
- Introducing environmental load and environmental value ratios (see also chapter 2.3)
- Introducing environmental 'bookkeeping' methods similar to the ones used in the financial world.

All three have the status of ideas. In view of time and budget pressures none of these ideas could be studied in very much detail. I feel unhappy with that. In order to move Applied EcoDesign forward, we have to dig deeper into such subjects. Unfortunately, this type of fundamental research will not be sponsored by industry. Attracting money from the university is possible at Delft in theory, but not in practice (see chapter 10.2). Gaining support from Science Foundations is difficult because the EcoDesign field is still perceived as a set of engineering tricks rather than real science. This is partly correct; Applied EcoDesign is surely not a 'discipline'; there are no set rules or commonly agreed conventions yet. I sincerely hope that in the end a breakthrough in this financing stalemate will happen. The subjects deserve it!

Tidbits, 10

Sandra made it!

It was an interesting subject: decrease the energy consumption of an electrically heated grill. Several students applied for it, including Sandra. She was not bothered either by the technical difficulty nor by the cultural risk – the project was to be carried out in Gelsenkirchen, Germany, in a very traditional 'male dominated' company. German would be the language of communication as well. Few Dutch students today speak this language fluently.

Sandra stated that she had finished more difficult jobs before. In order to make some money she had worked as a luggage handler at Schiphol Airport, a typically physical, male type occupation. I was convinced, she got the assignment.

There she went to conquer the world, starting with Gelsenkirchen. Her special appearance: showy clothes, short skirt, and piercings, was not the traditional idea of a female student in technology, at least not in traditional industry. Soon, people at the factory stopped working when Sandra walked in. In the canteen she was gazed at and her Dutch directness surprised many.

Her results were great. Soon she could demonstrate that the excessive energy consumption of the product was not due to lack of insulation. Instead, it was due to bad positioning of the grill elements, wrongly designed heat cycles, an energy guzzling internal lamp and an old fashioned time clock. In fact it was the same story as conveyed in different forms in this book: revisit decisions of the past, address the application perspective better, and exploit enablers (modern technology, supply chain).

The director of the organization called me, not to congratulate me on the success of my student, but to complain about the upheaval Sandra caused in the organization with her appearance. He asked whether I would be so kind as to correct this. The guy had a point. I had a problem, how to convey the message? Students have their own responsibility in such matters and have to learn it the hard way if necessary.

Sandra did not deserve that. I talked to her – not in my official capacity.

'If you are a guest somewhere, please adapt to the 'culture' of your host without giving up your identity – there are however various ways to express your identity, please change.'

Sandra made it. Sandra made it with high marks!

6.5.2 Linking the three dimensions of 'green'

In order link the three dimensions of 'green' (emissions, resources and potential toxicity), see also 6.1 the following formula is proposed for products:

Environmental impact = A × B × energy consumption over the lifecycle + C × D × weight of the product concerned + E × F × weight of electronics boards and flame retardant plastics.

In this formula, energy is to be expressed in kWh; this parameter includes the production phase, (including production of components, subassemblies, transportation, the user phase and the end of life phase). Since for the majority of electronic products the energy consumption in the user phase is dominant, evaluating this phase exclusively will suffice in many cases.

The weight of the product is a very crude representation of resource consumption. Material which will be recycled in the future can be deducted from the amount; the weight of packaging materials can be added. The resource term can be made more sophisticated if environmental weighting according to resource scarcity indices, or to Ecoindicators, is applied to the (physical) weight of the various materials.

Potential toxicity in electronic products is, to a large extent, found in the electronics (incl. connectors, wiring) and flame retardant housing. Again sophistication of this term can be increased by introducing weighting on the basis of toxicity indices and by deducting potential toxicity, which ultimately will be brought under control by appropriate end of life treatment.

The coefficients A, C and E are normalization constants. A is in 1/kWh and refers to the way energy is generated in a certain country (for instance A is relatively low in Norway – hydro power – and high in countries where coal is used as a fuel for electricity generation).

C (in 1/kg) reflects the materials mix; it is higher when sophisticated or high impact materials are used (for instance in cell phones) and relatively low when a lot of standard materials are applied (for instance TV).

E represents the toxicity in a certain product category.

B, D and F represent social priority factors ('government green' and 'customer green', see chapter 6.1). Basically it is a political decision what numerical values these get. In my opinion such a decision should be taken explicitly; this will create a stable basis for the EcoDesign of products, which will last for many years. Currently such a decision is taken implicitly. In the European Union, D seems to be high (recycling, WEEE Directive) as well as in Japan, but remains low in the USA. F seems to be moderately high in the EU and Japan and seems to have a relatively high value in the USA. With the advent of the European EuP Directive and the nearing of the date by which the Kyoto targets (emissions) have to be fulfilled, B is now getting more important in Europe. This means that the relative importance of D and F is currently decreasing.

The importance of the proposed formula lies in its 'relative' character. In this way the various perspectives are balanced and it is appropriately expressed what environmental practitioners know: 'you cannot have it all'. Both physics (see the environmental dilemmas in chapter 6.1 and budgets (which have in practice a ceiling) make this a reality.

The proposal also demonstrates that political popularity of an environmental issue (which is often short term) is not a good driver for Applied EcoDesign (which has a much longer time horizon). The reason is that in political processes B, D and F have short term fluctuations in time.

For instance, in response to sentiment from the general public, it is seductive to assign a high value to F (temporarily) in comparison to B and D. This is what most likely has happened with the European RoHS Directive, because in the earlier European WEEE Directive, B and F have been put set at zero at the time of its introduction.

Although EcoDesign in general is supposed to be fostered through WEEE (in fact in its current form it is not a real Waste Directive, it is a kind of Design Directive) the life-cycle principle is ignored.

In the EuP Directive, currently energy consumption is placed in the limelight, which means B is high with respect D and F. As an undercurrent, material and potential toxicity are still present in the recommended design rules. It is not clear whether this is a held over from the time that a draft Energy Directive for EE (electronic equipment) and a draft design Directive EEE existed concurrently, or that there is a specific thought behind this.

Proper application of the proposed formula could prevent such priority setting. Once the coefficients in the formula have been fixed, it is possible to validate the effect of any 'actions' considered on a 'green societal basis'. Such actions can be EcoDesign efforts but also technology improvements, changes in the supply chain and proposed legislation. The effect of an action can be described simply as

$$\text{Effect (action)} = \frac{\text{Outcome of application of the impact formula before the action}}{\text{Outcome of application of the impact formula after the action}}$$

If this ratio is above 1, the action is basically environmentally sound.

It will be even more important to assess the outcome of different actions which are or could be envisaged. In this way the **priority of items** in an action agenda can be determined.

Personalities, 10

Konosuke ('Kos') Ishii: if it cannot be modeled, it cannot be sold

It is all Catherine's fault. She was working on a dissertation on recycling and was looking for support outside Stanford University. She stumbled across me and as a result I stumbled across Kos. I learned two things from him which few people in the environmental world have come to grips with, even today: it is about value chains (see also chapter 5.1) and about making recycling strategies (see chapter 7.2).

Why is dealing with these issues such a problem? Why are there still so many 'beliefs' in these fields? It seems that this is because both items cannot be modeled with quantitative formulae.

That kind of challenge fits very well in the great tradition of American universities in general, and of Stanford University in particular. If this could be done it would create a clear baseline and from that foundation you could tackle every issue in a pragmatic way. Even in territories where the model is not applicable in a precise fashion it will be helpful.

Kos and his group excel at this type of work; they are one of the best, if not the best, in the world.

I was taken on board as a visiting professor of Kos' group with the idea that EcoDesign would be the main subject. The initial assignment was to find out what it could mean for American industry. Soon the attention turned however to models of the value chain and recycling strategies.

The Delft engineering approach helped me – if you cannot 'enter through the front door' (with mathematical tools for instance) then 'try the back door' (through cases, studies and other empirics). If there is communality in the case studies you can develop a model or theory with a high likelihood of applicability in a wide field, or at least a direction for problem solving. It worked, Catherine's research became unstuck and she completed her PhD. Value chains turned out to be considered in a socio-psychological way as well, next to all the mathematics which can be applied. Kos learned that technical problems sometimes need a non-technical solution. The National Science Foundations got an excellent report on recycling strategies – unfortunately the Bush administration went in a different direction.

Annet and I had a great time at Stanford!

The 'Ishii' Walk: Kos is usually not up for a walk – except when it is for a round of golf. Therefore my favorite walk in the Bay Area, is one of 22 miles. It can be reduced to 11 miles (one way only) but you have to be picked up at either end.

Start at sea level at Waddell Beach, halfway between Half Moon Bay and Santa Cruz (highway 1). Walk the Skyline to the Sea Trail (in the opposite direction obviously) to Big Basin Park HQ and back to Waddell Beach again; do not miss the Small Redwood Trail near HQ as well.

*In April you should however see the spring flowers in the Foothills: Go by car from Stanford Avenue, all the way up Page Mill Road. Go right and park at Russian Ridge Open Space parking. Make a walk there of any distance you like (report to me if you have seen the *Fritellaria* flowering).*

As of January 2007 you may also drive from the Bay Area up to highway 35 (Skyline Boulevard). At Saratoga Gap Vista Point take highway 9 to Boulder Creek. Park your car at milepost 19.72 next to the metal poles. It takes about 20 minutes

walking to reach a very special grove in Castle Rock State Park. Go a bit further down the highway, cross it and follow the Skyline to the Sea Trail downhill till the Saratoga Toll Road. Walk this road up to the cabin. From the cabin take 80 steps to a sign, subsequently 60 steps to a giant fir tree on the L, and 230 steps to a Redwood grove at a curve to the L. Another 170 steps will take you to a steep earth slide on the R and another 215 steps will lead to another circle of Redwoods on the R. Then it is another 60 steps to 'Stevens Family and Friends Grove' on the L, walk 100 steps up the hill and you will see the sign in the centre of the Grove which is 5 acres around it.

6.5.3 Environmental load ratio and Environmental value ratio

6.5.3.1 Introduction

Beginning in the summer of 2001, I had more and more mixed feelings about the status of EcoDesign. On one hand, it had been successful. This success is chiefly due to the strength of the concept. Integrating it into business bestows on it a significance which is far beyond just the environmental realm. In fact, it has become a management method which contributes to the bottom line through its principles:

- Be frugal in design (runs parallel with cost-down).
- Think in terms of functionality instead of embodiment (stimulates creativity).
- Life cycle perspective (more focus on user phase, customer).
- Supply chain perspective (more focus on suppliers and recyclers).
- Paradigm shift (asking 'why are things as they are', creativity).

On the other hand, from pure environmental perspective, traditional Applied EcoDesign does not deliver enough to society. Usually, improvements reach only as far as 20-50% with respect to the existing situation, with a few exceptions going beyond that. This is not enough to make real progress towards a more sustainable world, for which it is estimated that the improvements should be a by a factor of four or even by a factor of ten.

There are two reasons why Applied EcoDesign does not deliver enough:

- * Limitations by "physics" (see chapter 2.1) and the business setting (focus on the supply side)
- * The rebound effect. Generally, EcoDesigned products have a lower cost of ownership. This is due to its very success: due to the use of less material and of less energy, for instance, the cost for the user will be lower. Since the disposable income of consumers does not change as a result, consumers can afford to buy more, thus reducing the overall environmental gain (on a societal basis).

This unease brought me to explore the relation between environmental load and consumer spending. This is a basic change in thinking; it is looking at the demand side rather than to the supply side. It was the beginning of the Ecovalue thinking as explained in chapter 2.3. Two ratios were defined: the Environmental Load Ratio and its inverse, the Environmental Value:

$$\text{Environmental Load Ratio (ELR)} = \frac{\text{Environmental load of product/service}}{\text{Value of product/service (price paid by the customer)}}$$

$$\text{Environmental Value (EV)} = \frac{1}{\text{ELR}} = \frac{\text{Value of product/service (price paid by the customer)}}{\text{Environmental load of product/service}}$$

6.5.3.2 Some values calculated for ELR and EV

In order to get a better feel about what can be done with ELR and EV some values of these ratios have been calculated. These are listed in the following table:

Table 6.5 Environmental Load Ratio and Environmental Value.

		Environmental Load Ratio (ELR), mPt/ECU	Environmental Value (EV), ECU/mPt
Materials (Kg)			
Iron		25-35	0.03-0.04
Aluminium		30	0.03
Copper		40	0.025
Lead		100	0.01
Engineering Plastics		3-5	0.2-0.3
Glass		3-5	0.2-0.3
Fuels (Kg)			
Natural gas		2	0.5
Petrol		5-6	0.15-0.2
Heating oil		10	0.1
Kerosene		20	0.05
Electricity (kWh)			
Generated by	Gas	3.5	0.03
	Coal	11	0.09
	Oil	16	0.06
	Browncoal	27	0.05
Products			
Consumer Electronics		2-4	0.25-0.5
Cars		3-5	0.2-0.3

In this table the environmental impact (in mPt) has been calculated on the basis of the Eco-Indicator '95 method. Prices (in ECU) are market prices paid in The Netherlands.

Price ranges reflect fluctuations in the market. The table shows that, in the materials category metals generally have high ELRs and low EV. This is the driver behind 'dematerialization' programmes, which intend to replace products by services. Table 6.5 shows however that if this results in more energy consumption (for instance by more transport) elsewhere in the system, dematerialization can become counterproductive.

Figures from consumer electronics show that they are products with high added value, realized with a material mix with a relatively low impact (plastics, glass). This means that although energy consumption is a dominant feature of the environmental load over the life cycle of the product the ELR ratio is low and the EV is high. This trend would even be further exaggerated if the environmental load and cost of hook-up to a cable system would be included. It is estimated that this would reduce the ELR by a factor of approx. 1.5 and corresponding increase value by a factor of 1.5.

However, it is not known exactly what the environmental impact is/has been of building the infrastructure which enables the delivery of the services (deliver TV signals for cable). This is an example of important gap which has to be bridged in order to establish the real environmental value of service systems.

For cars the situation is different; although both the purchase of a new car and petrol are heavily taxed, ELR and EV are still worse than for consumer electronics. Since the car owner's road tax (which is intended to support maintenance of existing roads and building of new roads) is relatively low, the improvement of ELR and EV through including environmental load and value of the 'car system' in the consideration will be very limited.

The introduction of the value concept leads to different design concepts for consumer electronics and car producers. For TV and audio the environmentally beneficial strategy should be that more functionality can be added without rebound effects from communication systems (for instance Web TV, MP3 player) so that the consumer will (or will have to pay) for communication systems and may pay for the product itself (this

is worked out in further in 6.5.4). For cars a similar strategy would be: let the owner pay more road taxes and build more roads. However, this is a strategy (apart from being not wanted from a societal perspective) which cannot be implemented by carmakers; the only strategy left for them is in the classical EcoDesign strategy of increasing fuel efficiency. If a car with improved fuel efficiency can not command a higher price, there will be rebound effects as well.

Table 6.5 also shows that labor has good ELRs and EVs. The category of services and systems, which is labor intensive, is costly in absolute terms. Only if such a service can offer more, such as material and/or emotional benefits like convenience, fun and quality of life, will consumers spend (more) in this category. It is concluded from the above mentioned examples that adding services and developing service system could improve ELR and EV and this could contribute to more sustainable consumption. There is an urgent need however to map out the environmental effects of introducing services, particularly the environmental effects of building and using infrastructures.

6.5.3.3 An application of Environmental value to product strategy

In view of the concepts development in 6.5.3.2, the company challenge is to shift the environmental strategy from direct company benefit (cost down in relation with 'green'), easier to produce products and improved image to enhanced customer value; more convenience, more fun and higher quality of life, keeping cost of ownership tightly under control. Basically this means move up market, include more functionality at limited cost and allow more functionality generated on externally computed services on board. This means that the 'absolute' goal of reducing environmental load is changed into a relative one. Reducing ELR equals a decrease of the environmental load per unit of value. An example of how 'moving up market' works out is given below for TVs. In the table, data are given for various screen sizes:

Table 6.6 Environmental Value for various TV sizes.

Screen size (inch)	Shop price (EU) (average)	Energy consumption* (kWh/year)	Load/life cycle (mPt)	Environmental Value, ECU/mPt
32	1100	230	4800	0.25
28	900	190	3800	0.26
25	700	170	2800	0.28
21	475	105	2100	0.25
14	325	70	1200	0.30

* based on average use scenario's

All products have environmental values in the range of 0.25-0.30. The higher environmental load of the sets with bigger screen sizes is almost completely compensated by the higher price. This contradicts traditional wisdom that the smaller the screen size the better it is for the environment.

The value aspect also suggests extending this to the cable service. If this network just delivers TV signals, the environmental value of the TVs with smaller screen size will increase more significantly than for the bigger sizes. If the cable network is an advanced one it can deliver functionalities which an up market TV can exploit and therefore higher prices can be demanded from the owners of these sets. The environmental value will increase for this reason making it reasonable to assume that the environmental value a cable network is higher than the one for TV.

Apart from delivering customer value, a second challenge for industry is also to create society value. This partly coincides with customer value: reducing resource intensity for instance is a general societal interest but it also reduces ELR and increases EV.

Reducing energy consumption can also be worked out in the same way. However the success of this approach is not always guaranteed. It has been reported for instance that in mobile phone systems the energy

consumption of the transmission grid is very high which causes a service system, which is attractive for customers, to show little in terms of environmental improvement.

A third internal challenge for companies is to transform their Product Creation Processes. Focus on value rather than on reducing environmental effects make that business aspects come much more into play than the technicalities Managing Cross functionality and management of the processes as regards strategy, programs on execution, or in total management of the internal Value chain (see chapter 5.1) is gaining even more importance.

6.5.3.4 External effects on ELR and EV, the role of infrastructures

Creating environmental value and reducing environmental load ratios also requires a close look at the External Enablers necessary to achieve this goal. Of these, electronic technology and IT developments are quite important in this category. More powerful ICs, digitalization and information technology empowers the delivery of more function per unit of environmental load. This can be exploited both at the product (and is then close to classical design improvement) and a service level. Replacing mechanical technology (MT) by IT and OT (optical technology) or combining MT, IT and OT in an intelligent way has big potential, provided that the necessary infrastructure does not involve significant environmental loads during construction or use. This infrastructure issue means that in order to create environmental value companies will have to reengineer their external relationships because the infrastructures needed will – generally speaking - be built and managed by a variety of third partners. These partners can vary from existing suppliers to new ones, from start-up companies to existing ones never dealt with, regulators, government agencies and other institutional stakeholders.

Management of the complete environmental value chain (see chapter 5.1) will be the key ingredient for success. Formation of alliances based on common goals will be the core of EV management. Big issues in this arena will be how to set up and manage the required infrastructures, how to manage and distribute the benefits of the system and how to keep track of the changing value perceptions of the users.

Convincing stakeholders to think in terms of mutual benefits rather than simple benefits is a difficult task, which is not executed overnight but is a 'cultural process' as well. The best example of how this needs to be improved is the current discussion of take-back and recycling of electronic goods in the European Union. Although there is a clear goal which is endorsed by all stakeholders, the discussions which have already taken place for many years did not end satisfactorily. In the years to come no system delivering real environmental value will be implemented.

Basically this is due to the fact that the authorities involved communicate in environmental terms while the industry is concerned with financial terms. The positive roles that technology and economy of scale (infrastructure issues) play are underestimated. Also the 'value' delivered to the consumer and society (which will have to be paid for either directly or indirectly in the end) is unclear and not permitting comparison between the effectiveness of the proposed schemes and the effectiveness of other joint environmental actions (such as reducing CO₂ emissions, or reducing the use of potentially toxic chemicals).

This example shows that the road to sustainable services and systems is most likely a rocky one. The good news is that by mapping out the sustainable future using the results of pilot projects a lot of common ground can be gained. The reason that this works so well that pilot change thinking in terms of principles (in which we in the western world are so well trained for) to thinking in terms of solutions.

An illustration of this is the case of take back and recycling in The Netherlands. A breakthrough in the discussions which dragged on for many years was achieved by agreeing on a common pilot for recycling white and brown goods. After completion, a single system was supported by all stakeholders. The system is now operating satisfactorily and can be developed to further serve its goal of offering environmental value by rewarding performance.

Rituals and Habits, 10

Lemons

When there are negotiations in China about joint-ventures, technology transfer or subcontracting a double challenge is to be faced.

One is the business one. All details have to be spelled out and intensively discussed. There are checks and double checks and as a westerner this is satisfactory for reaching an agreement. The Chinese party may not necessarily have the same perception. Such negotiation processes can take many days and include many rounds and one thing is for sure: you will travel home completely exhausted.

The second challenge is the hospitality challenge. During the day there are the talks, but at night your Chinese hosts demonstrate their great hospitality through food and drinks. Course after course of excellent dishes arrives with plenty of drinks. If you are an honorable guest the drink is Moutai (strong Chinese gin); 2 bottles per table of 8 (the lucky number), which means that ratio of toasts is 1:7. Be sure that bets will be made about how drunk you will get.

One strategy is to get modestly drunk. This satisfies your host (and gives themselves some opportunity too, it is accepted behavior), but your body and negotiations the following day only permit this occasionally. Therefore I had to invent something else to survive night after night. My lead was that the Chinese turned out not to like lemon juice. As a life long rugby player I was accustomed to swallowing lemons in pieces (during half time), so lemons were a source of competitive advantage. It was exploited to provide relief from Moutai drinking: if you want a toast with me, I would like that you swallow a lemon with me as well. This is the principle of trade: if I do something for you, you have to do something for me. It works! When excessive Moutai becomes a real threat this tactic seriously limits the number of toasts you will face. The net result is that in the end more Moutai is drank among the Chinese themselves and less with you.

In a short time I developed the 'lemon ceremony' (see below), it became famous in the city where I did a lot of negotiation (Foshan near Guangzhou). Once, directly after I arrived I was brought to the rotating restaurant on top of a big building in town. A lot of people were there. I was seated next to the mayor. Halfway through the dinner cut and peeled lemons appeared on a plate. I was requested to do the lemon ceremony with the Mayor. "Yes, of course!" I said. The spotlight went on and the lights went off. There we stood ... "Ya, Ba, Ha, Wa, ... in the name of her Majesty the Queen!" The next day we were featured on local television. It works. It works well in China; it works well for the inauguration of new members of my students-fraternity; it works well even in environmental circles!

The Lemon Ceremony

1. Order 2 lemons and a knife
2. Peel the lemons and cut them into 2 or 4 pieces depending on circumstances
3. Give pieces to the participants (first round to junior members, second round to more senior ones)
4. Stretch your arm holding the piece and focus your eyes on the piece
5. Make prolonged shouts and stamp with your feet on the floor. My recommended shout is "Ya, Ba, Ha, Wa, ... in the name of Her Majesty the Queen!"
6. Directly after "Queen" swallow the piece. Check whether your co-participants do this as well
7. Enjoy!

6.5.4 Environmental bookkeeping

For EcoDesign an impressive array of manuals, tools and software have been developed. Almost all of them work on the basis of output and input. In order to offer a certain functionality (to fulfill a 'need' or a 'greed'), which can be considered a benefit (a 'profit'), an environmental load has to be accepted (a 'loss'). When the functionality has been realized with a minimum environmental load the environmental 'profit and loss' account is being maximized.

What is missing in the environmental world seems to be an 'environmental balance sheet'. The idea behind this is that in order to have functionalities really work well, their need to be investments in infra-structures (involving environmental loads). Cars need roads, TVs and cell-phones need networks, agriculture uses

land, transactions/trade need shops and offices, Medicare needs hospitals. In fact, in all these cases infrastructures are externalities, which are not accounted for in determining true environmental load. Especially for 'services' these externalities can be substantial – it may be that their exclusion leads to the general belief that delivering services is better for the environment than supplying products.

If the parallel with the financial world is drawn further, environmental investment in infrastructure depreciates and in this way impacts profits and loss accounts.

In this way environmental and monetary spending could be compared on a yearly basis.

For a product /service system this could look as follows:

Table 6.7 Items in the yearly Environmental Value account

Environmental load (mPt) of Products/services/systems (PSS)		Costs (ECU) of Products/services/systems (PSS)	
Environmental load of use of PSS	...	Cost of use of PSS	...
Depreciation of environmental load associated with PSS	...	Depreciation of the PSS investment	...
Environmental load of use of specific infrastructure of PSS	...	Cost of use of specific infrastructure needed for PSS	...
Environmental load of use of specific infrastructure (in connection with PSS)	...	Cost of use of general infrastructure	...
Environmental load of services to keep PSS going (maintenance, repair, upgrade)	...	Cost of use services to keep PSS going	...
Environmental load of general overhead (personnel, floor space)	...	Contribution to general overhead	...
Total environmental load/year	...	Total cost/year	...

The Environmental Value account is partly based on specific items (use, depreciation, specific infrastructure, services), in some cases figures of a more general nature (general infrastructure, overhead) will have to be used. Depreciation can be either at 'historical load' or at replacement load.

The yearly accounts will allow identification of improvement options for environmental value. Since these can be clearly quantified, prioritization is possible.

Also discussions among the stakeholders in the environmental value chain will become more fruitful.

Mutatis mutandis also environmental balance sheet can be set up. This will allow 'environmental asset management' that helps produce an environmental rationale for remanufacture, and upgrading of replacement.

The principle of environmental bookkeeping can also be applied to investment projects – each financial investment represents an environmental investment simultaneously in the form of the 'fixation' of a certain amount of environmental load in products, services and infrastructure. Parallel to financial payback times, environmental pay back times can also be calculated, particularly in transition cases when investments in capitol goods or infrastructures replace earlier investment. Interesting cases would be the replacement of production machines by a more energy efficient new generation of high speed trains aimed at replacing short haul flights (for instance Amsterdam-Paris or Düsseldorf-Frankfurt). Also less complicated cases like the transition from a videocassette recorder to a DVD player. Including the replacement of the tapes by disks could be analyzed in this way. When the calculations are done in parallel with the corresponding financial ones, environmental and economic payback times can be compared:

- When the economic payback time is shorter than the environmental payback the environmental investment can be considered to be too big.
- When the environmental payback is much shorter than the economic payback, the financial investment is too high.
- Cases where there is balance between economic payback and environmental payback need further analysis as well. The big question here is why such a balance occurs: is it by accident or by good management?

In a similar way assets, which are already in place, can be analyzed with regards to their impact value for current accounts. The outcome will strongly depend on which application the system is used. The investments can contribute (relatively) positively to the system's value performance or just the opposite. In the last named case the assets are identified as candidates for upgrading or replacement. This is creating the basis for 'green asset management'.

As shown above, the environmental value concept leads almost automatically to an environmental book-keeping concept. It is believed that application of such concepts will lead to better management of operations and ultimately to 'greener asset management'.

Cities, 10

Milan, creativity and design

For me, above all, Milan is the city of plastic recycling. This is the subject that Philips Consumer Electronics worked on for many years in the nineties. Our work produced a set of requirements for the reuse of recycled High Impact Polystyrene (HIPS) in large quantities (up to 50% of total weight), for instance in housings for TV sets.

Unfortunately, recyclers at that time could not deliver the quantity nor the quality we required, so the company had to turn to the big plastic producers themselves. All of them listened politely and finally asked, how many tons do you already buy from us? Large amounts for us, but relatively little compared to others. Big Philips turned out to be a peanut in the plastic value chain. It was not even necessary to say publicly that the materials industry of this kind prefers to sell new plastic rather than to supply for recycled plastic as well. This viewpoint is implied in a lot of the plastics industry arguments in favor of incineration but as a dwarf Philips could easily be denied.

It turned out however, that one of the smaller producers located in Milan, was breaking rank. This producer even had a technology in place to do the necessary separation of mixed plastics necessary to produce material fractions suitable for reuse. It looked wonderful and promising... but the technology was not perfect. It needed further development and even more important application tests of the resulting materials were needed. It was decided that a consortium of stakeholders would apply for European funding for the project. As a consequence I made many trips to Milan to develop the project proposal with the partners. Scientific body, application value and strengthening of the European economy were all used as arguments for the proposal. These were wonderful creative sessions which opened new horizons. We devised a completely new industry with the boldness of Garibaldi and the wisdom of Cavour.

Like walking the streets of London, the streets of Milan give you a special feeling – your mind continues to grind until late at night. If it was possible, I visited the Duomo, with its wonderful mosaic floor. As a protestant I was always astonished by the many active confession booths. But most of all I went to climb to the roof. There you can sit between more than 200 sculptures of saints and angels. Some are big, others small, some are at protruding positions never to be reached by human beings, others are close. Once I fell asleep in this paradise, the guards had to wake me up at closing time. The sun was just starting to set.

The project never received funding. In the first round we got 42 of the 43 points necessary for funding. Our second try was better; however, in this round there were at least 7 competing plastic recycling projects. We were urged to cooperate with other consortia, which turned out to include the big plastics producers. Money cannot buy love... We decided to stop rather than to sell out.

City walk: Start at the Central Station and walk across the via Vittori Pisani to Piazza Republica, go R on Via Mocova and R via Via Volta. Walk in the Cimitero Monumentale and go back through Via Bramante, go R before the Arena or the park, where you have to end up at the front side of Castello Sforzesco. Go straight ahead to the Piazza Duomo or make a longer tour through the back streets.

Favorite Restaurant: La Porta Rossa, Via Vittori Pisani.

Country walk: Go by train to Pavia (the town itself is worth a city walk as well) and go by bus to Certosa di Pavia. Walk in this monastery complex and in the fields around it, till you can just make it back to town.

Chapter 7: Recycling of Electronics Products

7.1 Introduction, the years 1993-2000

Take-back and Recycling of Electronic products has consistently been a hot topic throughout the years between 1993-2007. It is estimated that, including the legislation aspects (chapter 9), this consumed approximately 35% of my time both at Philips and Delft University. Interest in this topic from societal, business and technical perspectives is big. Thus recycling ranks high in 'government green' and in green perceptions (see chapter 6.1). The figure below shows that from a **scientific** environmental perspective the average contribution of recycling to lowering the environmental load of electronic products is only 15%.

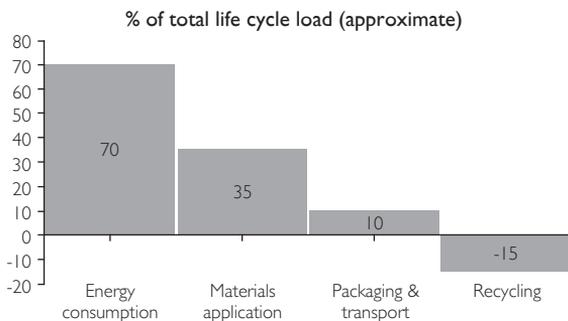


Figure 7.1 Average environmental load of an electronic product over its life cycle.

This figure indicates that for the total life cycle, load energy consumption in the use phase dominates (average 70%), materials application (mainly in the production phase) represents some 35%. Recycling (at a 100% collection rate) can compensate for approximately half of that. This is due to the fact that recycling never has an efficiency of 100%. Additionally, energy has been used to form those materials into various shapes and functions that is lost on materials recycling. Reuse of components and subassemblies can add little to that (see chapter 7.2).

However there are strong societal drivers drawing attention to take-back and recycling of electronics. There is lack of landfill space in densely populated areas like most of Western Europe. Moreover, conservation of resources and control of potentially toxic substances play an important role, both from a emotional and a rational perspective.

Moreover, it was (and today still a lot of people think this) thought that if producers are made responsible for the cost of take back and recycling the designs of the products will be improved with the result that recycling cost becomes lower and in the end can be reduced to zero or even lower the price of goods. From today's perspective such ideas and perceptions about take-back and recycling of electronics can be said to be simplistic. Knowledge on the topic has grown tremendously in depth and width leading to greater sophistication, which means that ideas today are quite different from the ones held in the early nineties. Unfortunately, many people - including legislators - are still stuck with notions which belong somewhere on the 1993-2007 time scale and do not consistently represent actual insight (see also chapter 9).

During 1993-1995 both Philips Consumer Electronics (ECC) and Delft University of Technology DfS were in a same initial stage and therefore activities were started in the following fields:

1. Disassembly (this was thought to be the chief treatment approach, see chapter 7.2 and 7.4) and mechanical shredding and separation at the end of the nineties.
2. Plastic recycling (avoiding volumes to be land filled; for a long time the incineration of plastics was perceived to be extremely negative as a result of the Soveso dioxine accident in the early nineties, amongst others) Other Member States consider incineration to be an unfavourable option for other reasons.
3. Reuse scenario for products (see chapter 7.2).
4. Models for recycling effectiveness and recycling cost (see chapter 7.5, 8.1, 8.2 and 8.3)
5. Organizational development of take-back and recycling systems, see chapter 8).

In 2000 I wrote, together with Casper Boks, a paper with the title '*Lessons learned from 10 years take-back and recycling*'. It is reproduced below. The chief conclusions of the paper are that for properly organizing take back and recycling systems social, economic and technological issues also have to be addressed alongside environmental issues. From actual recycling practice, valuable lessons can be learned. Taking these into account will lead to better outcomes of stakeholder discussions and thus to better societal value.

Lessons Learned From 10 Years Take-back And Recycling

Ab Stevels and Casper Boks

Abstract

Looking back on the first decade in which end-of-life issues of electronics goods have really gained substantial momentum, it can be observed that with increasing knowledge it is now really possible to pinpoint where the important issues are, whereas attention for a number of other issues has decreased. Based on these new insights, a number of important lessons can be or have been learned that ideally will direct research to where significant results can be scored. Issues addressed in this paper deal with priorities, the life-cycle perspective, technological issues, toxicity issues and the environmental value chain.

Keywords: Recycling, electronics, take-back

I INTRODUCTION

In the past ten years the issue of take-back and recycling of waste of electrical and electronic equipment (WEEE) got an increasing amount of attention. In many respects, the first initiatives that led to the German 1991 draft ordinance for recycling of waste from electric and electronic equipment (WEEE) can be seen as the starting point for the societal, technical, juridical and scientific debates about this subject.

The difficulties encountered among stakeholders to agree about such systems is reflected by the fact that so far in few countries public take-back and recycling systems really operate: Austria (refrigerators and freezers), Denmark, the Netherlands, Norway and Switzerland (all electronics). Although in the years to follow several countries (Belgium, Japan, Sweden and perhaps others) will join this list, it is clear that it will take many years before take-back and recycling of electronics will have been implemented on a comprehensive scale in the various

regions of the world. Parallel to the societal debate, take-back and recycling has also been addressed extensively from other perspectives. Primarily this included:

- The design perspective (design for X, where X is recycling, remanufacturing, reuse, end-of-life in general, etc.)
- The technical perspective (initially mainly from a disassembly point of view)
- The support tool perspective

Later it was realized that several issues had to be added to this list:

- Priority setting (in goals, design avenues and cost)
- Efficiency (environmental gains versus cost)
- Mechanical treatment of incoming WEEE streams
- Handling of material streams resulting of end-of-life processing

Combining all these aspects with the practical learning from pilot take-back projects as being done in many countries [1, 2], current knowledge and insights have substantially advanced compared to the situation a couple years ago.

In the present paper this progress is reviewed. In §2 the priorities for end-of-life systems are discussed from an environmental and a life-cycle perspective. In §3 design strategies are examined; the gap between preferable best practices and average business practices is explained in §4 with help of the Environmental Value Chain concept. In §5 the current status of end-of-life treatments (disassembly, shredding and separation) and its consequences for take-back organization and for product design are considered.

In §6 eco-efficiency concepts are discussed, including the effectiveness of potential toxicity control (§6.3). The conclusions (§7) strongly underline the necessity of an integrated approach that is that stakeholders should develop an agenda covering all relevant issues and compromise accordingly. The present state of knowledge and insights allows creating a sound platform to start take-back and recycling worldwide. It also allows indicating avenues for research and development to further grow eco-efficiency of the systems put in place.

2 PRIORITIES FOR END-OF-LIFE

2.1 The treatment perspective

In Figure 1 it is shown which priorities from an environmental perspective generally apply in end-of-life. Although this is general true, application of the life-cycle principle, as explained in §2.2, can sometimes lead to different conclusions.

1. Prevent discarding
 2. Reuse of the product as a whole
 3. Reuse of subassemblies and components
 - Material recycling
 - In original application
 - In lower grade application
 4. Back to feedstock plastics
 5. Energy reuse (use as fuel)
 6. Incineration (with energy recovery)
 7. (Controlled) disposal as waste

Figure 1 Hierarchy of end-of-life destinations

What end-of-life treatment will happen in actual practice is strongly dependent on consumer behavior (regarding discarding and returning of products) and on product characteristics (the way in which the required functionality is embodied).

As regards consumer behavior, studies by national consumer organizations in the Netherlands have shown that approximately only half of the first users discard their electronics products because of irreparable breakdown. Wear and tear plays only a little role in this. The other half consists about equally of increased functionality de-

mands (higher aspirations) and emotional grounds (“do not like the product anymore and can afford to buy a new one”). These percentages vary from product to product, but the lessons learned from this are the following:

- Analysis of irreparable breakdown cases at first users can lead to important clues for redesign for more robustness.
- Studying the discarding behavior of first users can lead to important clues for definition of new product generations.

Lessons Learned I

Also for the other issues of the priority list given above user issues and issues related to other stakeholders play an important role. These include:

- Kind of ownership (full ownership or lease)
- Type of owner (private, professional or institutional customer)
- Supply and demand in second-hand markets and trade-in programs
- Size of the product (is product transportable for customer, does it fit in garbage bins)
- Legislation and regulation, cost of discarding, cost of treatment
- Capabilities and capacities in secondary channels.
- Position that the manufacturers and their suppliers want to take.

As far as these are related to product characteristics and design, these issues will be discussed in §3. The remaining issues that are value chain related will be considered in §4.

The important learning in the last years from studying the environmental priorities for take-back in more detail has been that not only design items play a role in scoring a high as possible, but also the value chain items. It might even be that the last ones are more important.

2.2 The Life-Cycle Perspective

End-of-life is only one of many parts of a whole life cycle of a product. These include material production, parts and component production, subassembly and product manufacturing, the usage stage and transport (and other intermediary functions) between these stages. From a life cycle perspective it is therefore important to position improvements in the end-of-life stages (like reuse, recycling) with respect to the effects these will have in other life-cycle stages. This is particularly relevant when it is realized that for electronics products the environmental impact of end-of-life is only 2-5% of the impact of the whole life-cycle of these products - at least as calculated by methods based on the Life Cycle Assessment (LCA) methodology. Generally speaking for electronic products the usage stage is dominant (50-80%) whereas the stages related to production range between 10-35%. Packaging and transport account for 5-15%.

The usefulness of the life-cycle perspective is that it protects against mistakes through an absolute interpretation of the environmental priorities at end-of-life, as set forth in §2.1 and that it allows tailor-made interpretations for individual products. This is illustrated by the following examples:

- Remanufacturing or prevention of discarding of electronic products (a.k.a. life-time extension) should not be done when the energy consumption in newer product generations has been brought down substantially;
- Increasing recyclability of products by replacing plastics by iron or steel should not be done since in the production stage the environmental load per kilogram of metals is much higher than of plastics.

In other cases the LCA based evaluation can be of less help. This is because of the fact that LCA is primarily an emissions-based method; the role of embedded emissions (e.g. embedded toxicity) is less clear. For instance replacing lead-containing solder by lead-free alternatives eliminates a potential toxicity, which cannot be quantified very well by present LCA methods. However, based on traditional LCA it can be argued that the impact of the alternative solders most likely is higher due to a higher load involved in producing these materials and a higher load of the soldering process itself (because of higher temperatures involved).

Lessons learned from the life-cycle perspective include therefore:

- Choosing the best ecological end-of-life strategy for discarded products also depends on the environmental effects of new products replacing them.
- Proposals in the field of DFX (X = reuse, recycling, etc.) should be checked against DFE (E = environment as a whole).
- Describing “embedded” (= potential) effects is just as important as describing actual effects. It might be that in the future control of embedded toxicity will become more important than actual recycling

Lessons Learned II

3 The End-of-Life Design Advisor

The End-of-Life Design Advisor (ELDA) as developed at the Manufacturing Modeling Lab of Stanford University by Rose et al. [3,4] guides product developers to specify the preferred end-of-life strategies on which their work has to be based. ELDA allows to select in an early design stage end-of-life design options, which are most fitting to the product characteristics. Possible strategies are based on the ones listed in Figure 1 and include:

- Life-time extension (service)
- Reuse
- Remanufacturing
- Recycling (disassembly first)
- Recycling (shredding first)
- Disposal

ELDA uses technical product characteristics, that is, those aspects of a product which can be most influenced by designers and product managers. An extensive analysis [3,4] showed that the technical product characteristics given in Figure 2 are relevant for the strategy prediction.

- Technology cycle
- Wear-out life • Number of parts
- Presence of potentially toxic materials
- Design cycle • Reason for redesign
- Level of integration

Figure 2: ELDA technical product characteristics

An investigation of some 40 cases showed that the ELDA prediction of end-of-life strategies agrees for 90% with current best practices. This allows for the conclusion that ELDA can give in principle important focus in Design for End-of-Life efforts. For instance:

- Life-time extension (service) - easy accessibility of relevant parts and subassemblies;
- Remanufacturing - modular architecture of the product (complete or as far as relevant);
- Recycling (disassembly first) - choose fixtures with low disassembly time;
- Recycling (shredding first) - design for agreeable chemical content, good separability;
- Disposal - design for disposal

It is important to stress here that design strategies should relate to best practice rather than current (average) practice. Rose et al. show [4] that there is a substantial gap between the two; in more than half (54%) of the investigated cases current end-of-life treatment included a strategy that was lower on the list in Figure 1. This gap can be explained on basis of the Environmental Value Chain concept (see §4), it will be shown there that this gap is basically due to nontechnical issues which have not been resolved yet, either between stakeholders or in the internal value chain of one of the stakeholders involved. As it is to be expected that during the life-time of the

product to be analysed the value chain will improve and show more transparency, design for end-of-life has to be oriented to the future rather than to the present.

Developing redesign strategies for end-of-life should be oriented to best available practice, available now or in the near future.
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Lessons Learned III

4 The Environmental Value Chain

The Environmental Value Chain concept [5] has been developed into an instrument for better definition of products and services. When applied, it can be used to predict success or failure of "green" product development and environmental programs. Recently it has been applied to reverse environmental value chains as well.

Basically, a value chain description consists of two activities:

- Mapping of physical (= goods), money and information flows between stakeholders. In an, environmental value chain the main stakeholders are suppliers, producers, customers and authorities.
- Making an issue correlation matrix. This matrix ranks priority given by involved parties to the various aspects of the system. For take-back systems these are:
 - Scope and organisation (what **products and** responsibilities are involved)
 - Ecological goals (reduction of landfill, recycling percentages, control of potential toxics)
 - Industrial aspects (investment, economy of scale, outlets for secondary materials)
 - Financial aspects (costs and yields)
 - Performance (in absolute and/or relative (eco-efficiency) terms)

Alignment of flows in the value chain and alignment of priorities in the issue correlation matrix is the basic process in getting societal agreement about take-back and recycling systems. An important lesson learned from discussions in Europe in the last ten years is that lack of systematic value chain and issue mapping has led to long delays in implementation.

The value chain concept cannot only be applied to system definition but also to the making of decisions about design or technology. For instance, when it is decided on basis of ELDA to redesign products in such a way that they fit better in the ecologically best end-of-life strategy (as allowed by the product characteristics) this has consequences primarily for the design team as such. However, other stakeholders - in this case primarily in Ac internal value chain of the company -need to be involved as well. The new design strategy will have to fit into:

- Company strategy (do we want to be more involved in remanufacturing?),
- Product management (will this influence specifications, product styling?),
- Purchasing (do we need to change supplier relations?)
- Production (are there consequences for ease-of-production, quality?), and
- Marketing and sales (is a new market approach in order, is a change in outlet management required?)

So far only examples for product design in general are known and not specifically for design for end-of-life, but the results of this study indicate that considering internal value chains can substantially enhance the success of environmental programs.

Reversely, it might also be possible that reverse environmental chain analysis shows that the fact that the environmentally best end-of-life strategy is not realised in practice has little to do with unfit design or technological approaches. It might be that for instance the organisation of the producing companies is completely geared towards production and sales of new products. This is the case for the consumer electronics industry (TV, audio, VCR, DVD) where the best strategy indicated by ELDA is remanufacturing whereas actual practice is mostly material recycling with or without prior disassembly even in cases where in theory remanufacturing would be an extremely fitting strategy.

Without systematically taking the Environmental Value Chain into account implementation of take-back and recycling will see long delays

Lessons Learned IV

5 Technology Issues

As stated in the introductory words of this paper, at the end of the past decade it has become clear that the issues previously considered as being most important in the early nineties needed to be seen in a wider perspective. Increasing knowledge leads to both answers and new questions, and also to new focal areas. Apart from socio-political and strategic issues as laid out in the preceding paragraphs, this is also true for technological issues related to the product end-of-life stage.

In the first half of the past decade, focus has been given by the majority of researchers active in design for end-of-life to cost-based disassembly analysis leading to design for disassembly guidelines. Main reason for this was probably the fact that research in this field was mainly initiated in mechanical engineering and machine design environments – areas where traditionally manufacturing research took place, and where many started to focus on demanufacturing as a (at the time) logical step towards environmentally sound products. Alternative (or supplementary) processing technologies such as shredding and separation for material recycling did not receive much attention until several years later when researchers realized that cost factors and stakeholder opinions played a role as well – and still these technologies do not receive as much attention as they perhaps deserve. Also, a more life cycle oriented approach (see also §2.2 and §4) has only been adopted since quite recently, analyzing the reverse value chain from more than just product-based, engineering perspectives.

The disassembly versus mechanical treatment discussion will be addressed briefly in the next two subparagraphs. In §5.3, the importance of economies of scale and the ensemble issue will be explained.

5.1 Disassembly

As a result of the disassembly-oriented product evaluation methods that kicked off many design for recycling related research projects (mainly at universities but also within companies), a wide variety of disassembly focused support tools were developed in the 1992-1996 period. Initial attempts to design a generic end-of-life tool failed, mainly due to lack of sufficient and reliable recycler information, often accompanied by operating difficulties, lack of industry support and principally not taking environmental value chain and life-cycle perspective issues into account.

The fact that in theory, disassembly of end-of-life appliances serves the priorities as given in Figure 1 best has no doubt contributed to the heavy focus on these design for disassembly (DFD) approaches. By dismantling end-of-life appliances, environmentally relevant fractions can best be isolated and appropriately treated thereafter. Producers face however the fact that manual disassembly is very costly, and can therefore only be applied to a limited number of product categories. The fact itself that a significant part of the DFD research focused on other than these appropriate product categories also contributed to the fact that recycler data and support were limited.

Since this time, it has become clear to many people that from a total systems perspective, and without heavy subsidies, disassembly is often not a feasible option. In particular this applies to competitive, non-subsidized recycling markets. Because of these facts, in several Western European countries nowadays approximately half (on a weight basis) of all discarded electronic appliances are shredded and subsequently separated into various material streams. This has led to the approach that the determination of end-of-life scenarios requires primarily a perspective based on the output of the recycling process rather than on the input of the process. It has been pointed out in Ram et al. [6] that for shredding and separation, end-of-life processing is about material streams and about separating or joining them, rather than about individual products.

End-of-life considerations should not only include product characteristics but also appropriate use of secondary streams resulting from end-of-life treatments.

Lessons learned V

5.2 Mechanical treatment

With the emergence of ecodesign projects and take-back pilot studies funded by the European Union, possibilities increased to form consortia that included different stakeholders in the product's life cycle such as producers, recyclers and logistics operators. These co-operations enabled a better reflection of actual recycling practice, including all business-related aspects thereof. In some of the consortia, tools were developed that took actual recycling processes as a basis (rather than disassembly operations analysis performed at office desks with chronometers). This led not only to the understanding that mechanical treatment, i.e. shredding and subsequent material separation is in most cases the preferred end-of-life strategy based on economical considerations, but also to an increased focus on mechanical treatment processes as such, not only by recyclers but also by research groups focusing on ecodesign. In the most recent years this has led to the notion that with state-of-the-art mechanical treatment processes for most product categories acceptable recyclability scores can be obtained at acceptable costs. Tests have shown that on the basis of a mechanical treatment strategy WEEE can be divided in four product categories that each exhibit their own recyclability scores and costs/yield profile [7], as shown in Table 1 (in the case of products containing picture tubes the remainder of the product is mechanically treated after removing the CRT). This is an important notion towards establishing design priorities for different product categories.

Table 1 Overview of recyclability scores and end-of-life costs for different product categories.

Product category	Recyclability score	End-of-life costs
Products containing picture tubes	High	High
Plastics dominated products	Low	High
Metal dominated products	High	Low
Precious metals dominated (miniaturized) products	Low	Positive value

It should be noted that also here the life-cycle perspective concept applies and that without careful interpretation (partially) wrong conclusions are easily drawn; application of metals instead of plastics because they contribute to both higher recyclability scores *as well as* to lower end-of-life costs is not necessarily correct, as pointed out previously in one of the examples in § 2.2.

- Mechanical treatment of WEEE is for several product categories an alternative that is both economically and environmentally acceptable and to be preferred over disassembly.
- Perhaps the absolute amount of research in Design for Disassembly can be justified, but the relative amount of research in Design for mechanical treatment is probably unjustifiably low.

Lessons learned VI

5.3 Economies of scale and the ensemble issue

Two other concepts - economies of scale and the ensemble issue - are briefly discussed here as topics that have recently gained awareness, among others based on information from collection trials and pilot take-back projects.

Economies of scale

In the current context economies of scale are defined as the availability of large enough volumes of WEEE in a certain geographical region to make collection, transport and processing worth while activities. This may apply to either ecological efficiency or economical efficiency. Economies of scale in return logistics and end-of-life processing is an important issue. Several reasons exist for this:

- Without the availability of large enough volumes of WEEE, collection and transport costs might be too high to justify economical investment. Also, the environmental impact associated with for instance transport of WEEE

(fuel and material use) can not be justified if it is not balanced by environmental benefits from recycling enough volumes of WEEE.

- Without the availability of large enough volumes of WEEE there will be no satisfactory return on economical investment of setting up recycling facilities.
- Without the availability of large enough volumes of WEEE the capacity of end-of-life processing lines or technologies used might not be used fully which could lead to economical disadvantages (processing costs per kilogram processed might be too high, proceeds obtained from selling secondary materials might be lower if selling smaller quantities at once), but also to environmental disadvantages (environmental impact per kilogram of processed will be higher). For instance: on a laboratory scale good results can be achieved in separating certain waste streams, whereas in every day recycling practice the same separation process would result in costs out of proportion due to the fact that too little mass of the applicable waste stream is available.

All the above mentioned reasons make that the absence or presence of economies of scale can be the main determining factor in the ability to set up a really efficient return logistics and recycling infrastructure. Examples where the lack of economies of scale are hampering the set-up of such infrastructures can be found in for example the USA [8]. In Europe, Sweden is a good example [9] where logistics costs will be considerably higher in some less densely populated areas, due to the lack of favourable economies of scale.

Ensemble issue

The ensemble issue refers to the problems associated with the transgression from the in general product type dominated WEEE streams entering a recycling facility to an in general material type dominated stream leaving the same facility. Depending on the outlets and the specifications required for concentrations of materials mixing WEEE into separate batches or streams entering the recycling process is in many cases a relatively delicate matter. The important issue here is twofold:

- The concentration of metals, especially copper and precious metals is important as these materials yield the highest revenues, and therefore may or may not make the chosen end-of-life strategy viable. For example, copper smelters will generally accept a batch of printed circuit boards (or batches with other parts having relatively high concentrations of copper, like deflection units or wiring) if the perceived concentration of copper is 20% or higher. From a recycler's perspective, it may therefore prove worthwhile to mix a batch of products or product parts that has a copper concentration higher than 20% with a batch of products or product parts that have a copper concentration less than 20% -- to end up with a batch that has a copper concentration exactly or slightly over 20%. This would enable a recycler to obtain the same price for a batch of WEEE while also selling a stream that on its own would yield a considerably lower price. Further of importance is the fact that precious metals (Pd, Au, Ag) are being paid for even when present in very low concentrations, provided that they are in the copper stream. However, a threshold applies. Diluting the precious metals concentration below this threshold while enriching a fraction in copper could therefore be counterproductive.
- The concentration of potentially toxic substances is an important characteristic for a WEEE stream as the presence of these may dominate the way the stream is processed. However, for many recyclers mixing different WEEE streams in order to reduce the concentration of these substances is an integral part of business. Making sure concentrations are below certain threshold values could be in favour of a cheaper material treatment process with associated higher revenues or lower costs.

- Determination of preferable end-of-life scenarios should be done based on the output of the recycling process rather than on the input—material recycling is about materials rather than about individual products.
- Pilot projects and economical analysis have shown that achieving economies of scale in take-back systems is of crucial importance.
- Concentrations of various substances (in particular valuable, and penalty elements) should be carefully considered.

Lessons learned VII

6 Toxicity and Eco-efficiency

An abundance of information has become available in the past decade on all issues related to the product's end-of-life stage, as illustrated in this paper so far. Based on this information, it has not only become clear that efforts have to be put where they yield the most benefits, but also awareness has grown about which areas deserve the most efforts. This is also referred to as the eco-efficiency concept [10]. In search of what should be the main priorities in evaluating end-of-life scenarios and identification of the most relevant design strategies, leading research groups in the field of ecodesign have adopted the control of the toxicity issue as their main focus area since here the biggest environmental risks can be avoided. Whereas toxicity control was in some respects also the issue that in the first instance triggered legislative initiatives in this field (banned substances lists etc.), it has now been expanded to a full life-cycle based view covering in particular heavy metals and halogens (dominating environmental performance of WEEE) and precious metals and copper (dominating economical performance WEEE).

6.1 Environmentally Weighted Recycling Quotes

In §2.2 it was already stated that the traditional way of performing LCA studies does not always deal with toxicity issues in a satisfactory way – in particular where embedded toxicity is concerned. Another traditional misconception has been that the required environmental performance of electronic products has until now mostly been described using recyclability scores calculated on basis of weight only. Since the environmental load of various types of materials differs considerably and recycling itself has an environmental impact as well, this is an incorrect description from both a scientific and an environmental point of view.

For these reasons, at Delft University of Technology a methodology has been developed, tentatively called Environmentally Weighted Recycling Quotes (EWRQ) [11], that accurately reflects how much of the product is actually recovered in environmental terms and what the environmental impact of end-of-life treatment itself is. With this approach, it is also possible to assess specific toxicity issues in end-of-life of electronic products. For every individual fraction the content and impact of specific potentially toxic substances can be calculated. For instance the contribution of the amount of flame-retardants to the plastic fractions can be derived. With the EWRQ the role of substances in product design and the implications for the corresponding end-of-life phase can be substantiated. Ecodesign can help here to prevent toxic substances to be emitted into the environment.

7 Conclusions

The present paper has sketched the most relevant developments and debates in take-back and recycling of electronics, based on observation and participation in this field for many years. This has been done from different perspectives, of which the most important are the life-cycle perspective, and the notion that recycling and take-back only take place in a larger chain of stakeholders that all have their own interests and priorities.

Only by combining environmental, social and economical considerations resulting in an eco-efficient approach, the priorities in eco-design can be addressed properly. Since take-back and recycling is in many ways (still) a political issue, compromises need to be found between all stakeholders involved - but only by taking the full life cycle into perspective. This way it can be determined what is really important, for all parties involved:

- research (determination of focal areas, scientific back-up of take-back and recycling practice)
- recycling companies (investment in technologies, differentiation, economies of scale)
- manufacturing companies (prioritizing design issues, communication to consumer and politics)
- politics (initiation and/or expansion of legislation that companies are willing and able to adopt, communication to citizens)

The determination of priorities and compromising between stakeholders needs to be done on basis of accurate information reflecting actual take-back and recycling practice, rather than on basis of assumptions made in the past that now have been refuted. The "Lessons Learned" text boxes that have been placed throughout the text in the appropriate paragraphs address a number of important priorities in what directions to go.

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Pictures, 10

Eindhoven, Kannunekensven: next to sound and smell there used to be silence in Eindhoven



7.2 Making reuse/recycling strategies for products

7.2.1 Environmental ranking of end-of-life strategies

In practice, for electronics products, material recycling is the dominating end-of-life treatment. From a purely environmental perspective it ranks fourth in the hierarchy of preferred end-of-life destinations. The complete priority ranking is given in the figure below:

Table 7.1 Environmental hierarchy of end-of-life strategies for products discarded by their first owner.

<u>Priority rank</u>
1. Prevent discarding
2. Reuse of the product <ul style="list-style-type: none"> a. Reuse as complete product b. Reuse after servicing c. Reuse after remanufacturing
3. Reuse of parts of the product <ul style="list-style-type: none"> a. Reuse of subassemblies b. Reuse of components
4. Material recycling <ul style="list-style-type: none"> a. Back to original application b. In lower grade applications c. Back to feedstock (plastics)
5. Energy reuse (use as fuel, plastics)
6. Incineration <ul style="list-style-type: none"> a. With energy recovery b. Without energy recovery
7. Disposal as waste <ul style="list-style-type: none"> a. Controlled b. Uncontrolled

This figure gives priority to each end-of-life strategy based purely on environmental concerns. It does not take into account technical and value chain feasibility considerations or cost aspects. Most likely such issues play an important role in practice. Nevertheless it was determined worthwhile to investigate under what conditions higher ranking strategies (1-3) can be implemented. A first attempt to do this qualitatively was made in 1999. Type of ownership, product price, size, weight and average use time were identified as the main parameters to determine what is the best strategy possible.

Apart from product characteristics, value chain issues like relations with suppliers, recyclers and second hand markets, were demonstrated to have a big impact on identifying the best strategy.

A second study focused on the quantitative differences between the different end-of-life strategies. Taking disposal of the existing product as a baseline scenario, the environmental gains of applying higher ranking end-of-life strategies were calculated. In order to be able to make the calculations several assumptions had to be made, which as such can be contested to a certain extent. However, the primary goal was to get a feel for order of magnitude of the differences in environmental load when applying the different scenarios.

For 28" TVs, this led to the following outcome:

Table 7.2 Environmental gains of end-of-life scenarios for 28" TV with disposal (scenario 7) as a base line.

Scenario	Environmental Gain (according to the Ecoindicator 95 method)
2a. Reuse (doubling of life time)	396
2b. Service (extend lifetime 4 years)	357
2c. Remanufacture	344
4a. Recycle (disassembly)	291
4b. Recycle (shred/separate only)	77
7. Disposal	baseline

It is concluded from this table that for the scenarios 2a, 2b, 2c and 4a the environmental gains with respect to disposal are substantial. On the basis of these calculations scenarios 1, 3a and 3b can also be expected to show substantial gains too. Taking scenario 4a (material recycling with disassembly where appropriate) as a baseline, the gains of the reuse scenarios, with respect to materials recycling, are limited; even the doubling of the life time of the products provides only a 30% gain against the recycling scenario only.

There is a significant difference in the environmental effects of end of life strategies for TVs between scenarios 1-4a and 4b-7. This split is between materials recycling with disassembly and materials recycling with shredding/separation only.

It is important to realize that all gains in the table above are small, particularly compared with the total life cycle impact for 28" TVs (without any recycling or reuse bonus) which is approx. 4000 mPt. This is largely due to energy consumption in the use phase, which accounts for 80% of the environmental load. The study therefore concludes that it is a real priority to pay attention to the energy consumption of new generation TV products rather than to improve reuse characteristics.

For other electronics products calculations have been made which lead to similar conclusions. It is to be noted that in these calculations that costs of the different treatments have not been taken into account. This will be done in chapter 7.5. In anticipation of conclusions there, it is mentioned here that for products with low weight (less than 2000 g) and high content of plastics, materials recycling with disassembly is the preferred strategy from an environmental point of view. However, from a cost point of view this end-of-life treatment is not Eco-efficient.

In a second study, similar calculations have been made to determine the relative merit of reuse strategies for components and materials. In such calculations the environmental impact of producing the materials in the component/subassembly is determined (the material impact). This result is compared with the impact associated with manufacturing those materials to achieve the appropriate form and function (the processing impact).

Following results have been found:

Table 7.3 Comparison of environmental impact of materials and of processing of components/subassemblies.

Component	Material impact (%)	Processing impact (%)
IC	80	20
Diode	19	81
Line output Transformer	91	9
Deflection unit 28"TV	99	1
FR-2 print with copper strips	74	26
Electrical. Condensators	69	31
Connector	56	44
Potential meter	88	12
Copper wire	96	4
SMD components	51	49

It is concluded from this table that for most components the material impact is much higher than the processing impact. This suggests that the environmental difference between a material (only) recycling strategy and reuse strategies will be small. The deciding factors are therefore in practice often the economic aspects (for instance: there are small environmental gains but a rather big profit in reuse rather than in recycling) and the value chain factors (reuse of these components is profitable but an appropriate value chain cannot be organized).

The Proposition Dinner

PhD candidates have to add to their thesis a number of propositions. The idea behind this is that it gives evidence that you have a wider orientation in science and society.

Proposition should be challenging and debatable at the same time. In the debate about them arguments count, qualifications do not, and in the end eloquence should prevail.

In Delft the ideal number of propositions is something like 12; four relate to the subject of the thesis, four relate to technology, physics or engineering, two relate to society and two are funny in some form.

Unfortunately, at the defense usually little time or no time at all can be spent on the propositions. Time is often too short, after one hour it is 'hora est' in which it is better to address the core of the thesis.

This is a pity and does not value the tradition of propositions. Therefore, I organize for my PhD candidates, one or two days before the defense a proposition dinner. Participants include PhDs of an earlier date, special guests and the victim himself.

The location is always chosen to be a Greek restaurant – in honor of the ancient philosophers and because I like the food.

The way it works is: every participant selects one proposition and attacks, undermines, reformulates and bends it. The defendant has to fight back. As a result the victim has little opportunity to eat, usually drinking is easier.

Sharpen your mind, fight with all your brains and nerves, be fair and value your opponent, those are the rules. It is one of the best academic games!

7.2.2 The End-of-Life Design Advisor (ELDA)

In 1996, I got in touch with Catherine Rose of Stanford University. She was a Ph.D. researcher in the Manufacturing Modeling Laboratory of the School of Mechanical Engineering. Their activities were strong in terms of numerical modeling, but they were looking for more support from the environmental side and for more design details of electronic products.

Catherine did research on a methodology which would generate the end-of-life strategy best suited for a product's characteristics, such as the number of parts (complexity), technology cycle, wear and tear cycle. By comparing the recommended strategy with actual practice agendas can be developed. The agenda can concentrate on product design or the value chain to move applicable end-of-life strategies to the highest environmental level and to ensure the best economic result.

We worked intensively on this subject, in particular during my visiting professorship at Stanford University in the fall of 1999 (see Personalities, 10) and Catherine's stay at Delft University in the year 2000.

The work which was done has been published in her dissertation and has been summarized in the article on the next page. Its title is "Influencing Design to Improve Product End-of-Life Stage". It focuses on the link between product characteristics and end-of-life strategies and draws conclusions with regards to design and the value chain respectively in order to identify the preferred strategy or even to encourage a higher level of strategy. Catherine's work does not specifically address environmental gains. It is therefore not analyzed how the preferred strategy compares with material recycling and disassembly. As a result it is possible that the preferred strategy brings only limited environmental gains with respect to materials recycling. (see 7.2.1).

However, the material part of the total environmental load of components/subassemblies manufacturing is generally large to very large. This means that materials recycling alone will cover, to a great extent, the societal call for conservation of resources. However, from a value situation the conclusion can be different. It is concluded in this work that The End-of-Life Design Advisor which has been developed can be of great help for matching product design strategies in general with specific requirements to optimize end-of-life strategy.

Influencing Design to Improve Product End-of-Life Stage

Catherine M. Rose, Kosuke Ishii, Ab Stevels

Abstract

The main objective of this research is to develop a structured methodology to formulate end-of-life strategies, while still encouraging creative thinking. Current practices encourage general rules for a wide variety of products. This research identifies key characteristics that influence appropriate end-of-life strategies, in contrast to the 'one-size-fits-all' approach. The research results are divided into two core sections. First, the methodology determines what end-of-life strategy is possible according to the products' technical characteristics. Second, the classification of end-of-life strategies is compared with current industry practice, in order to evaluate and validate the method. The software developed, called the End-of-Life Design Advisor (ELDA), guides product developers to specify appropriate end-of-life strategies. The ability to classify end-of-life strategies enables designers to redesign products that move to end-of-life strategies with lower environmental impact. This paper presents recommendations for designers and product managers for specific end-of-life strategies. By understanding better the end-of-life strategy appropriate for the product, the research results can help designers develop appropriate (and profitable) end-of-life strategies for their unique position, systematically. Putting ELDA results into perspective identifies improvements in end-of-life are either through design innovation or value chain improvement.

Keywords: EcoDesign, End-of-Life, Strategy, life cycle planning, product design, recycling

I Introduction

Motivation for Environmental Change

Concern for future generations and alarming rates of nonrenewable resource consumption provide the impetus for research in sustainability and improving our natural environment. Countries and companies are establishing goals for achieving sustainable development and reducing resource consumption with the hope of preserving the natural environment for future generations. The environmental problem is an extensive, complex problem, and some areas of study are energy consumption, recycling, and environmentally relevant substance control.

In the marketplace where products are closely matched, the fact that a particular company has included environmental criteria into the product's design may sway the customer to purchase their product over the product of their competitors (Lucacher 1996). An increasing number of companies view the environmental aspect as an issue that could improve the market position of their products (Nilsson 1998). With the pressures on companies to 'go green' and the research and implementation costs involved, companies are looking for some kind of financial pay-back (Clegg and Williams 1994).

Increasing Focus on End-of-Life Stage

Life Cycle Engineering is the engineering and design of products and processes to minimize cost and environmental impact for the life cycle phases of a product. Generally, the stages of a product's life cycle include material extraction, manufacturing, assembly, use and end-of-life. A product being designed can be optimized for individual life cycle phases. However, life cycle engineering, or the life cycle perspective aims to optimize these stages together, instead of separately. Trade-offs are necessary in this process to develop the optimal product that balances the gains and losses in the focal areas: energy usage, material usage, packaging, chemical content and end-of-life. Products, under development, can be specifically designed to accommodate a preferred end-of-life, only by understanding the ramifications to other life cycle phases. The concern for product end-of-life has increased importance due to consumer interest and market activity. Market forces, especially in business-to-business activities, are encouraging companies to examine more closely the treatment of the product at end-of-life.

Research Approach

The current research emphasizes consumer electronic products including small electric appliances, such as cellular phones, larger consumer products, e.g. cars and white goods, and large industrial or institutional products, such as medical systems or aircraft engines. While this research focused on electronic products, similar research into construction products and consumer packaging is plausible.

This section will describe the research methods that were used to develop ELDA. One strong area of the case studies is the diversity of products that prove the wide application of the techniques and methodologies. A substantial amount of information has been collected through indirect and direct case studies. Indirect case studies include the case studies collected through the ELDA web tool, such as from Stanford University's Design for Manufacturability's student projects and other professional contacts. Several direct case studies were collected during six months at Philips Consumer Electronics. The literature study has been supplemented with interviews and discussions with people involved in the recycling business as well as through visits to recycling facilities around the world. ELDA has been built using a statistical technique to map the technical product characteristics to the end-of-life strategies.

2 Product End-of-Life

Definitions of End-of-Life Strategies

The definition of end-of-life used throughout this work is the point in time when the product no longer satisfies the initial purchaser or first user. This allows for reuse and service in addition to recycling as possible end-of-life strategies. Other definitions, starting from the last user, exist but do not include low environmental impact end-of-life strategies such as reuse and service. This definition is also chosen because user preferences change more rapidly than the product wears out in several product categories.

Table 1 Definitions of End-of-Life Strategies

Name	Definition
Reuse	Reuse is the second hand trading of product for use as originally designed.
Service	Servicing the product is another way of extending the life of a durable product or component parts by repairing or rebuilding the product using service parts at the location where the product is being used.
Remanufacture	Remanufacturing is a process in which reasonably large quantities of similar products are brought into a central facility and disassembled. Parts from a specific product are not kept with the product but instead they are collected by part type, cleaned, inspected for possible repair and reuse. Remanufactured products are then reassembled on an assembly line using those recovered parts and new parts where necessary.
Recycling with disassembly	Recycling reclaims material streams useful for application in products. Disassembly into material fractions increases the value of the materials recycled by removing material contaminants, hazardous materials, or high value components. The components are separated mostly by manual disassembly methods.
Recycling without disassembly	The purpose of shredding is to reduce material size to facilitate sorting. The shredded material is separated using techniques based on magnetic, density or other properties of the materials.
Disposal	This end-of-life strategy is to landfill or incinerate the product with or without energy recovery

The end-of-life strategy hierarchy, given in Table 1, is based on decreasing environmental impact as calculated using Life Cycle Assessment data from Philips Consumer Electronics (Rose and Stevels 2001). Philips Consumer Electronics Environmental Competence Centre performs extensive case studies that examine energy usage, environmentally relevant materials, end-of-life, material composition, and packaging. In order to quantify the product's environmental performance, the products are disassembled and the material content, manufacturing process and component weight are recorded. Philips researchers have performed this environmental benchmarking on approximately seventy consumer electronic products (for example (Reijnen 1999)).

Philips' Environmental Competence Centre then uses this information to perform a life cycle analysis on the product using Ecoscan (ten Houten 2000). The version of Ecoscan used is based on Ecoindicator 95 (Goedkoop et al. 1996). Ecoscan, like most Life Cycle Assessment (LCA) tools, examines the entire life cycle of the product, from extraction, manufacture, packaging, usage to end-of-life. The manufacturing environmental impact includes extraction and manufacturing processes. For some materials the extraction environmental impact is much higher than the manufacturing processing. The environmental impact quantifies the impact of usage conditions (batteries or grid electricity), as well. Packaging environmental impact accounts for the impact of plastic, cardboard and paper used in packing materials. In the current calculation, the end-of-life impact is only accounted for by the disposal through incineration.

The highest on the hierarchy according to calculated environmental impact is reuse, then service, remanufacture, recycling and last disposal either through incineration or landfilling. Ranking highest is product life extension, through reuse of the product. Moving towards reuse of the product as a whole is an ideal solution for the product end-of-life. As well, extending the product through servicing the product is second on the hierarchy. The next strategy is reuse of subassemblies and components through remanufacturing. Recycling with and without some disassembly first leads to two applications - into the original application, frequently called primary recycling, and recycling in a lower-grade application, or secondary recycling. In the case of secondary recycling, the material quality does not meet the original specifications, but still can be used in applications such as plastic park benches and garbage cans. Lowest on the hierarchy of end-of-life strategies is disposal of the product – through two methods: incineration and disposal.

The following graph shows the environmental impact (in millipoints) for televisions, audio systems, telephones, video and monitors. Each end-of-life strategy is represented by a differently shaded bar.

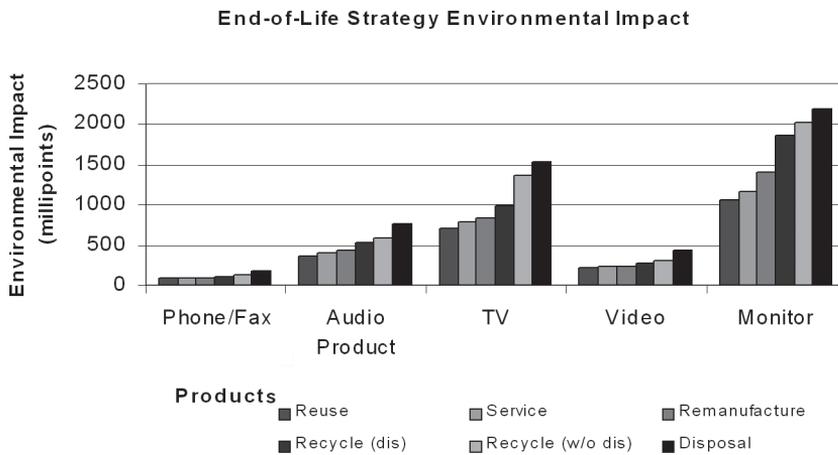


Figure 1 Environmental impact of End-of-Life Strategies

The end-of-life strategy hierarchy represents the lowest to highest ranking of the possible end-of-life strategies. These estimates of environmental impact of end-of-life strategies verify the end-of-life hierarchy.

End-of-Life Design Research

The life cycle perspective includes the take-back and reprocessing of the product at its end-of-life – from cradle to cradle. The product being developed can then be specifically designed to accommodate a preferred end-of-life route (Poyner 1997). The research areas for improvements to products are diverse. Researchers have attempted to incorporate end-of-life concerns into their design tools. These tools frequently fall short by delaying assessments

until detail design stage, requiring too detailed information from the user and requiring the user to input critical end-of-life data. Some research seeks to improve product modularity (Sosale et al. 1997). Product modularity can provide designers with easily detachable subassemblies and components that facilitate remanufacturing, reuse, material recycling and disposal. This research does not provide a mechanism to balance trade-offs between creating modules appropriate for different end-of-life strategies. The method sub optimizes because it ignores other life cycle phases, such as manufacturing and assembly, that are strongly affected by modules.

Harper and Rosen (Harper and Rosen 1998) describe a tool developed to link qualitative measures of remanufacturability to engineering information embedded in CAD systems. The tool is designed for implementation at detailed design and the user must indicate if the parts will be refurbished, recycled or land filled. Harper and Rosen suggest that the designer typically knows with some degree of certainty the post-life intent of the individual components. The post-life intent, or end-of-life strategy, can not be determined without extensive knowledge of end-of-life treatment techniques. While bringing together CAD information and product recyclability information is helpful, it is near impossible to know the post-life intent. Furthermore, the research results in specific information concerning the end-of-life of parts, which (1) ignores possible reuse of the product as a whole and (2) assumes the product will undergo some disassembly.

Other end-of-life product focused improvements demonstrate the use of product embedded sensors. Carnegie Mellon University and Bosch have investigated embedded sensors to monitor the conditions of possible reused components (Klausner et al. 1998). The use of embedded sensors shows promise in reuse of motors and other parts that are difficult to manufacture, costly to purchase, taxing to the environment, and have remaining use in the market. However at present, adding more electronics to products to sense the wear and store it in memory is not cost effective for all products and may cause more environmental impact over the product life cycle. This is a promising development for the future.

Unfortunately, these improvements exclusively focus on redesign of existing products and the improvements rely too much on designer perceptions. While their objective is to seamlessly integrate environmental concerns, they depend on the experience and knowledge of designers for critical input values relating to end-of-life strategies. Other efforts do not address product end-of-life issues until most of the design parameters are set.

Current research does not educate designers about end-of-life options or the impact of their decisions. Many designers do not have contact with end users and information from other groups in the company about end-of-life activities. Many DFE tools often rely heavily on information that designers do not know at early stages of design. Until now, designers made arbitrary assumptions about an end-of-life strategy, resulting in ineffective use of design for end-of-life tools.

3 End-of-Life Design Advisor (ELDA)

Development of ELDA

The acronym, ELDA, stands for End-of-Life Design Advisor. End-of-Life because it is focused on this stage of product life cycle. Design because it is focused on the contributors of technical characteristics in product design, including product managers and designers. Advisor because it is intended to support decisions with technical basis, in order to improve decisions made by companies. The timeline for the research, shown in Figure 2, describes the method of gathering case studies and analyzing the data using statistical technique called Classification and Regression Trees (CART). CART is described in more detail in section 3.2.

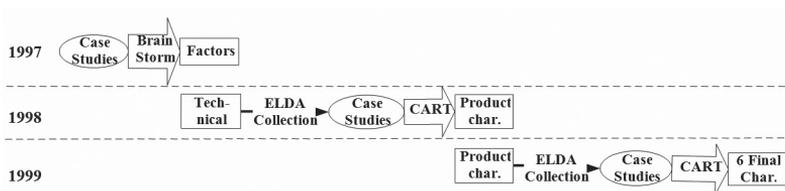


Figure 2 Timeline of Research

The case studies come from Stanford University's graduate level Design for Manufacturability course. Examples have been collected since 1996, with approximately ten case studies a year. Teams of four students apply the Design for Manufacturability concepts to projects provided by a wide variety of companies. Case studies have been collected as well through the internet with ELDA throughout the world. A total of thirty-seven case studies were collected for analysis and development of the ELDA classification methodology.

The End-of-Life Design Advisor (ELDA) is a web-based tool for evaluating and improving product end-of-life strategies, available at <http://dfe.stanford.edu>. The user inputs are reported back to Stanford using a Java applet and are compiled into a database. ELDA first asks users to evaluate product characteristics, giving examples for guidance. Figure 3 is an example of an input screen from ELDA. There are several ways the user can input data including typing the exact value, using a scroll bar, or by choosing a product that has similar attributes to the currently investigated product, as shown in figure 3.

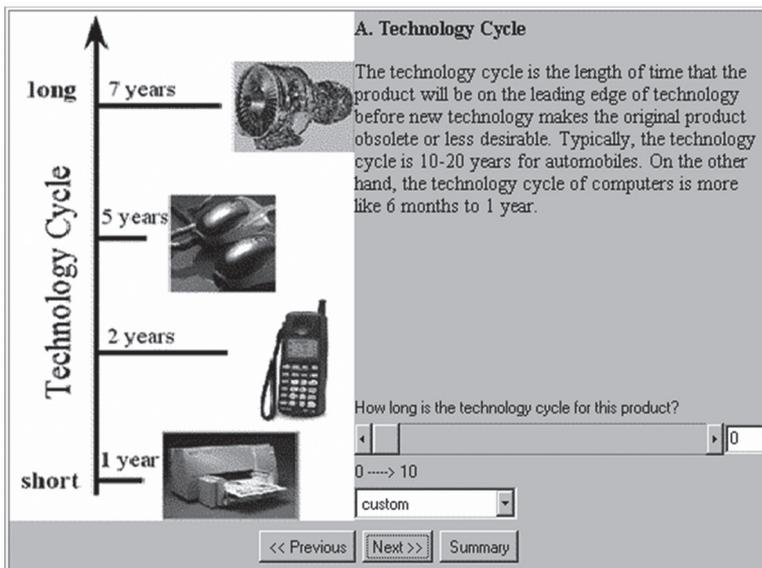


Figure 3 Example ELDA input screen - Technology cycle

From the determined end-of-life strategy, ELDA provides design recommendations and guidelines based on their particular end-of-life strategy. Individual web pages outline recommendations, for each end-of-life strategy, for design improvements and also give examples of other products that have the same end-of-life strategy.

ELDA is provided as a tool on the internet to allow product designers and product planners to communicate and collaborate about the end-of-life issues during product development. The internet is increasingly being utilized to synchronize efforts globally. Remote members of project teams can also update the product information online. Environment is only one of the many issues facing designers and therefore, any tool must be simple and quick. The ELDA tool takes approximately ten minutes to use and receive the recommended end-of-life strategy. It does not rely on existing knowledge of the designer, provides examples for the designers to use, and only requires six inputs. ELDA recommends an end-of-life strategy with examples, presented in an objective manner. Although ELDA takes advantage of the internet to facilitate communication and the use of the computer to speed data transfer and calculation, further application in terms of recommendations and industry best practice show designers how to improve or how improvement is possible. By providing information and guidance, with easy access, gives keys to improve end-of-life strategy decisions.

Technical Product Characteristics and Resulting Classification

The backbone of ELDA relies on statistical analysis of the case studies, their product characteristics and end-of-life strategies. The technique used is Classification and Regression Trees (CART), which is an example of a cluster analysis tools.

CART is a methodology commonly found marketing data or medical data analysis. Cluster analysis, in particular classification analysis, produces an accurate classifier or uncovers predictive structure of data to predict medical conditions, consumer behaviors and other complex patterns (Breiman et al. 1984). In most cases, researchers use CART to analyze sample sizes in the thousands. Currently, no method exists to identify directly or quantitatively the characteristics that have the most influence for classification problems. It is advantageous to use CART over other classification tree programs because the method is transparent, the user is able to change the parameters easily and the tool performs analysis quickly.

Evolution and selection of technical product characteristics has gone hand-in-hand with the collection of case studies. The original product characteristics (Rose et al. 1998) were based on examining similarities between case studies. These twenty-four characteristics were categorized by external, material, disassembly, and inverse supply chain (Rose et al. 1998). Later research revealed that six key characteristics could be used to identify the appropriate end-of-life strategy (Rose and Ishii 1999). Although not used in classification, another six were included in the implementation of ELDA, for further analysis. However, this classification method only agreed 46% with the industry best practice. The final research revealed that six final characteristics are necessary to classify product end-of-life strategies with higher accuracy and these characteristics are given in the following table.

Table 2 Technical Product Characteristics

PRODUCT CHARACTERISTICS	DEFINITIONS	INPUT RANGES
Wear-out life	The wear-out life is the length of time from product purchase until the product no longer meets original functions. For example, an automobile's average wear-out life is 10-15 years. For a computer, the wear-out life is approximately 7-10 years.	0-20 years
Technology cycle	Technology Cycle: The technology cycle is the length of time that the product will be on the leading edge of technology before new technology makes the original product obsolete or less desirable. Typically, the technology cycle is 10-20 years for automobiles. On the other hand, the technology cycle of computers is approximately 6 months to 1 year.	0-10 years
Level of integration	A product with a high level of integration has a single 'chunk' that implement many functions. Additionally, a product with high level of integration has complexly-defined interactions between chunks. Alternatively, a product with low level of integration has single 'chunks' that implement few functions.	High, medium, low
Number of parts	The number of parts is the approximate number of parts in the product.	0-1000
Design cycle	The design cycle is the frequency with which companies design new products or redesign their existing products. This product characteristic tries to address frequency in which design changes, as given in reason for redesign, are implemented.	0-7 years
Reason for redesign	Original design (new for company with no existing design history)? Evolutionary design (significant redesign of an existing or current product)? Is it function improvement or aesthetic change? Feature change (small feature or function change to existing product)? Is it function improvement or aesthetic change?	Users enter 1, 2, 3, 4, 5

The product characteristics are important because they can be used to classify products into end-of-life strategies with high accuracy. By analyzing the case studies' product characteristics and end-of-life strategies, these final characteristics were chosen because of their strong influence over end-of-life strategy. These product characteristics are used because they provide general information, describe the physical properties and describe the technology and design changes of the product. These product characteristics are generic and definable over a wide range of products with diverse functions.

The classification results were validated by comparing end-of-life strategies to current industry practice. One major factor in improving the accuracy in classification is the use of relative numbers. The addition of the ratio between wear-out life and technology cycle contributes to the improvement in agreement between classified and observed end-of-life strategy. By using a relative scale, or the ratio between technology cycle and wear-out life, it shows the critical issue is the relationship of these two product characteristics. Rather than an absolute scale, where some products have very similar numbers on either technology cycle or wear-out life, using the ratio shows how these are linked in the product developers and consumers mind-sets.

Examples of product end-of-life classification

The crucial ratio used in the classification is the ratio between product wear-out and technology cycle. Figure 4 shows graphically the first two levels of the classification tree. The diagonal lines divide the graph into three main groups. Group 1, in the upper left corner, consists of the products with wear-out life at least four times greater than the technology cycle. Group 2, in the middle, consist of products whose ratio of wear-out life to technology cycle is between 1 and 4. Group 3 products have wear-out life less than or equal to the technology cycle and are located in the lower right corner. These boundaries are drawn according to the classification of end-of-life strategies by the CART analysis.

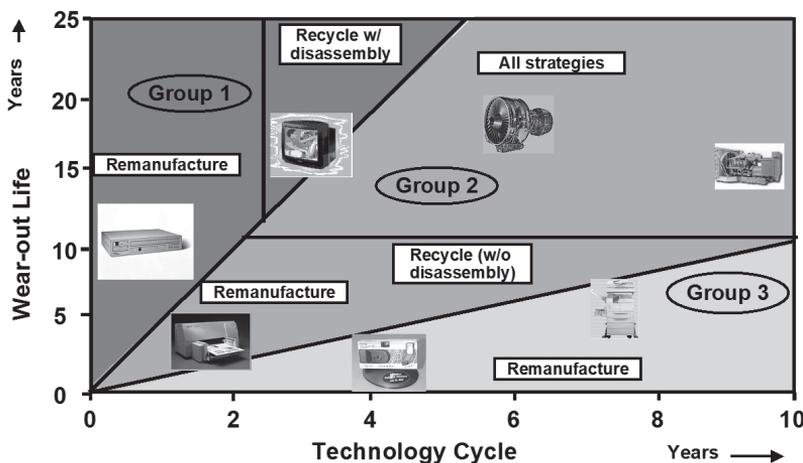


Figure 4 Wear-out Life and Technology Cycle for Variety of Electronic Products

The products in Group 1 include a network router, a network server, a computer and a television. According to the classification methodology, products within this category should be remanufactured or recycled, through disassembly. The products with technology cycle less than 2.5 years should be remanufactured. Twenty-six of thirty-seven products fall into Group 2. They include inkjet printers, a digital copier, a computer mouse, a washing machine, a generator, an aircraft engine and other products. Products with wear-out life less than 10 years should be remanufactured or recycled without disassembly according to the classification. On the other hand, products with wear-out life greater than 10 years have a diverse set of product characteristics and experience the complete range of end-of-life treatment options – from reuse to recycle (without disassembly). Examples in Group 3 include

a single use camera, a photocopier, a hand held vacuum cleaner, an electric power steering motor and a shipping container. According to the classification, products in this category should be remanufactured at their end-of-life phase to replace worn-out parts and return to use in the market before the technology changes. These recommendations and others are discussed in more detail in section 4.

4 Recommendations for Product Design

ELDA accurately classifies the end-of-life strategies for products by the technical product characteristics with an accuracy of 89%. Companies themselves decide end-of-life treatment based on external circumstances and pressures (consumers, government, recyclers). In some cases, business decisions rather than the technical characteristics of the product control the actual end-of-life treatment. The simple diagram below demonstrates the link between these two variables.

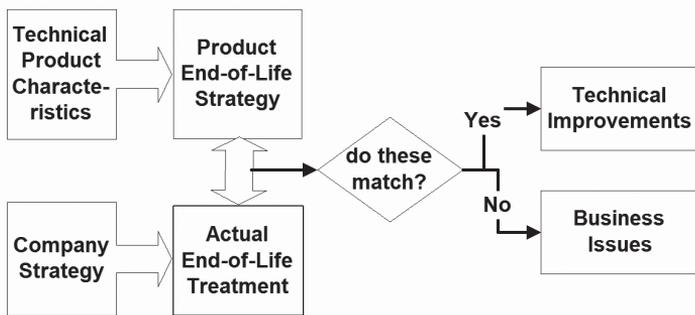


Figure 5 Relationship between ELDA and actual practice

In 11% of the case studies, the recommended end-of-life strategy and the industry best practice differed. The mismatch between recommended end-of-life strategy and the actual end-of-life treatment is due to:

- inefficiencies in the end-of-life systems,
- product characteristics,
- developing end-of-life systems for inappropriate end-of-life strategy,
- not having incentives for participation and
- innovation towards higher levels of reuse.

These bottlenecks, or inefficiencies, can be eliminated through work on the value chain, both internal and external. This mismatch between the recommended end-of-life strategy and actual end-of-life treatment pursued by industry is relevant to defining steps for improvement. The research included here is based on an in-depth analysis of consumer electronics in the Netherlands for Philips Consumer Electronics. As shown in table 3, for these consumer electronics products, the end-of-life strategy recommended by ELDA does not agree with the current end-of-life treatment practiced in industry. For televisions and VCRs, the recommended end-of-life strategy and industry treatment indeed agree. The audio systems, cell phones and monitors are actually recycled but their recommended end-of-life strategy according to their product characteristics is remanufacture. It is also important to notice for three of these example products (televisions, monitors and audio), legislation mandates the end-of-life treatment, recycling.

Table 3 Comparison of current end-of-life treatment and strategy recommended

PRODUCTS	CURRENT BEST END-OF-LIFE TREATMENT IMPLEMENTED IN INDUSTRY	END-OF-LIFE STRATEGY RECOMMENDED BY ELDA	ACTION NEEDED
TV	Recycle (with disassembly) ¹	Recycle (with disassembly)	Match
Stereo System	Recycle (without disassembly) ¹	Remanufacture	Mismatch
Monitors	Recycle (with disassembly) ¹	Remanufacture	Mismatch
Cell Phone	Recycle (with disassembly)	Remanufacture	Mismatch
VCR	Recycle (without disassembly)	Recycle (without disassembly)	Match

¹In the Netherlands, recycling is the mandated minimum end-of-life strategy required by end-of-life treatment regulation (however, companies can choose to implement other end-of-life strategies that have lower environmental impact).

Examining the difference between the industry practice and ELDA recommendation determines the focus for future efforts for product designers and managers, recyclers and policy makers. Table 4 shows the recommended actions if the ELDA classification corresponds to the best practice and in the cases that it does not correspond to best practice. If the two strategies match, then the focus should be placed on technical aspects of the particular end-of-life strategy, understanding items such as reason for discarding, functionality changes over time and recycling technology development. For the cases that the ELDA classification and industry best practice do not match, then the focus should be on the business issues including value chain concerns.

Table 4 Efforts needed from Product Management, Recyclers, and Policy Makers

MATCH OR MISMATCH?	PRODUCT MANAGEMENT & DEVELOPMENT	RECYCLERS	POLICY MAKERS
Match = ELDA classification corresponds to best practice	<ul style="list-style-type: none"> • reason for discarding • functionality over time • recycling technology, infrastructure 	<ul style="list-style-type: none"> • lower costs, improve yields 	<ul style="list-style-type: none"> • improve efficiency of system
Mismatch = ELDA classification does not correspond to best practice	<ul style="list-style-type: none"> • internal value chain • consumer, political issues 	<ul style="list-style-type: none"> • find new outlets • talk to producers • talk to organizers of take back systems 	<ul style="list-style-type: none"> • redefine system so that it can handle higher targets

Section 4.1 describes the issues and recommendations for action for product management within producing organizations. Section 4.2 summarizes the recommendations for recyclers and policy makers.

Product Management and Development

Technical Improvements

For products where the current treatment and strategy coincide, the future activity should emphasize design improvements. For products that have end-of-life strategies of reuse, service and remanufacture, the focus should be to understand the reason consumers discard products and the functionality changes over time. By focusing on these two issues, higher percentages of products to which the best strategy can be applied will be attained. For products with end-of-life strategy of recycling, product designers and managers must look into the recycling technology and the materials used in the products in order to harvest maximum conservation of resources and value.

For products that the recommended end-of-life strategy does correspond to the industry best practice, design improvements must be focused on the particular end-of-life strategy. Designers must understand the reasons consumers discard products at the end-of-life. Van Nes (van Nes et al. 1999) identifies nine reasons for obsolescence in her work; however, it can be simplified into three main categories: breakdown, functionality changes, or design aesthetics. Consumers may discard their products because they no longer function or are worn out. Increasing

product functionality encourages consumers to buy products that have more features and lower costs. Changes in design aesthetics affect consumers' liking or dislike of a product and there are some design improvements that can be made such as timeless design or modular design. Regarding consumer behavior, studies by national consumer organizations in the Netherlands have shown that approximately half of the first users discard their electronics products because of irreparable breakdown (Boks and Stevels 2000). The other half consists of increased functionality demands (higher aspirations) and emotional grounds ('do not like the product anymore and can afford to buy a new one'). As the below table shows, this is particularly relevant for the high end strategies, such as reuse and service strategies..

Table 5 Design Focus areas for End-of-life Strategies

END-OF-LIFE STRATEGY	RECOMMENDED STRATEGY IN CASE OF:		
	Breakdown, wear and tear	Functionality deficiency	Design Aesthetics not satisfying
Reuse	Robust design	Design for variety	Timeless design
Service	Design for service	Modular design	Modular design
Remanufacture	Design for disassembly, Robust design	Design for disassembly	Design for disassembly
Recycling with disassembly	Design for disassembly	Design for disassembly	Design for disassembly
Recycling without disassembly	Material selection	Material selection	Material selection
Disposal	Material selection	Material selection	Material selection

Tools for improving other facets of the product or other life cycle stages are applicable to the product end-of-life. Design for assembly, disassembly, design for service and material selection can greatly affect the end-of-life of the product. These tools, including guidelines, etc. are useful if applied for the particular end-of-life strategy appropriate for the product characteristics. For instance, design effort is lost when designing for disassembly when the product has the potential for the end-of-life strategy of reuse. While designing a product for the lower ranked end-of-life strategies such as recycling, there is not much affect caused by the reason the consumer is discarding the product. Therefore, more concern should be given to improving the material selection and disassembly process than understanding the consumer behavior. Tools, which can be helpful for a specific end-of-life strategy, are included in table 6.

Table 6 Example Tools for Design Improvements

END-OF-LIFE STRATEGY	EXAMPLE TOOLS
Reuse	Functionality-time diagram (Rose et al. 2000a) Optimizing product life time (van Nes et al. 1999)
Service	Best levels of disassembly and recovery of subassemblies, components, or materials for reuse or recycle (Ishii et al. 1994) Life Cycle Serviceability (Gershenson and Ishii 1991) Transforming services business (Wiggs 1999)
Remanufacture	Linking qualitative measures of remanufacturability to CAD systems (Amezquita et al. 1995) Remanufacturing operations at Electrolux (Sundin et al. 2000) Remanufacturing of Kodak Single Use Cameras (Martin 1999)
Recycle with disassembly	Planning disassembly using Petri Nets (Zussman et al. 1998) Understanding disassembly layout planning (Gungor and Gupta 1999) Integrating disassembly analysis tools in their software (ASME 1998) Experiences from demanufacturing operations (Grenchus et al. 2000)
Recycle without disassembly	Estimating product recycling costs (Boks and Stevels 1998) Shredding or disassembly of electronic products (Boks et al. 1999)
Disposal	Understanding environmental impact of hazardous materials (Huisman et al. 2000)

Other generic tools such as Environmental Benchmarking and EcoDesign matrix can help guide product designers. Environmental benchmarking rates products on energy usage, environmentally relevant materials, end-of-life, material composition, and packaging (Jansen and Stevels 1998). Environmental Benchmarking has been successful for many companies for comparing products of similar functions or in similar market segments, allowing designers to brainstorm opportunities for improvement. The EcoDesign matrix, similar to Pugh Concept selection, can organize the options for improvement by outlining the benefits to the environment, business, customer and society before assessing the technical and financial feasibility (Jansen and Stevels 1998).

Focus on business issues

For products where end-of-life treatment and recommended end-of-life strategy differ, the business issues dominate. The organization must first tackle the value chain items, using tools such as Environmental Value Chain Analysis (Rose et al. 2000b). Mapping the ideal product end-of-life system, necessary information and appropriate financial flows can identify the bottlenecks or inefficiencies of the current practice. Comparing the ideal with the current product end-of-life systems will help identify the bottlenecks or sources for inefficiencies. Benchmarking the end-of-life strategy with other existing end-of-life systems is another helpful activity. Making sure that responsibility for a particular issue is assigned or attributed to the actor who can manage the item the best is a helpful tactic for eliminating inefficiencies.

Internal challenges should be addressed first. The internal value chain items include but are not limited to the following: financial incentives, design incentives and information flow. After addressing these internal challenges, the external issues including government and consumer and political issues should be examined. External value chain issues include needs for product returns incentives (from consumer), relationship with government, incentives for processors and retailers incentives. Increasing the percentage of consumer returns will increase the economy of scale for the processing of the products. Better relationship with the government gives insights to future expectations and targets to be realized. Incentives for processing can be achieved by using materials with high potential recycling percentages and components that can be reused. Retailer incentives can come as discounts in purchasing, trade-in reimbursements and direct payment for storage and collection of the product returned by consumers. Understanding the relationship through product, information and financial flows from the consumer to the producer or other take-back organization can help improve the organization of the end-of-life system. The incentives for retailers and distributors include items such as understanding the purchasing and discarding decisions and items like value of preowned products.

Recyclers and Policy Makers

Although not directly related to product design, the decisions made by recyclers and policy makers affects the end-of-life stage and some initiatives place responsibility on designers to improve product end-of-life treatment. Therefore, the recommendations for recyclers and policy makers are included here.

In the case of products that the recommended end-of-life strategy corresponds to the end-of-life treatment, recyclers and policy makers should primarily seek to improve the efficiency of the end-of-life treatment. The recyclers must focus on specific technical issues associated with particular end-of-life strategy, identifying opportunities to reduce costs and improve yields of the process. Policy makers should work towards improving the overall efficiency of the systems through eliminating redundancies in the end-of-life systems and enable their smooth operation and execution.

Recyclers and policy makers must address a different set of issues when the products' end-of-life strategy does not correspond to industry's current end-of-life treatment. Recyclers must identify new outlets for the material or product stream needed for the higher level strategy, collaborate with producers and organizers of take back systems. Finding such new outlets for materials or the product streams requires creativity and business savvy. On the other hand, policy makers must work to redefine the conditions under which the end-of-life systems need to operate in order to be successful.

5 Benefits for Product Design

This section describes the benefits to product design. These benefits are broken into two main themes: building strategy and using existing design knowledge.

Building strategy

Designers increasingly have the responsibility for many aspects of products – and now environmental performance. Few tools address the need of the design for strategy and methods to help prioritize the conflicting goals associated with environmental aspects of a product. Generally, the current tools lack strategic thinking when it comes to environmental performance. While the tools provide information helpful to the particular end-of-life strategy, they do not guide strategic goals. The research field is divergent, some activities lack focus and are difficult to assess the implementation. The LiDS wheel (van Hemel 1998) gives designers a tool to help organize and prioritize general environmental goals. STRETCH (Cramer and Stevels 1997) helps with the strategic benchmarking and implementation of higher level environmental strategies in the business. The decision makers need methods to identify preferred strategies that prioritize options for the end-of-life phase of products.

Product characteristics and environmental value chain should be an important starting point. End-of-life treatment or systems are becoming more prevalent, data and know-how already exists within companies, providing an excellent beginning point.

Unlike other tools, ELDA guides product designers, recycling technology developers and policy makers to coordinate to specify end-of-life strategies and improve decisions influenced by end-of-life strategies. ELDA provides available technical information that is relevant for decision making on take back and recycling systems. Knowing the end-of-life strategy should in turn lead to redesigns which are better tailored to ecological and economical potential inherent to the product characteristics. This methodology for establishing characteristics that influence the end-of-life strategies for a variety of products helps engineers create products that achieve the recommended end-of-life strategy. As such, ELDA empowers designers to improve design according to the recommended product end-of-life strategy in contrast to other tools that only give numerical results that do not reveal avenues for improvement.

Using design knowledge

ELDA uses easy-to-attain knowledge from product designers to classify the end-of-life strategies. The information required is available very early in the design process, allowing designers to analyze the ramifications of design decisions on the recommended product end-of-life strategy.

ELDA contrasts traditional Life Cycle Analysis (or Assessment) in several ways. Primarily, ELDA provides a direct recommendation where LCA is typically top-down. ELDA is based on product characteristics and uses these product characteristics to determine the strategy appropriate. The redesign of the product according to the strategy results in monetary enhancements or environmental impact reduction at end-of-life. LCA is a validation tool that relies on a holistic approach and identifies external factors that influence the product. From these factors, attention fields are determined and then the feasibility is checked to see if the product characteristics actually allow for the improvements. Only after this stage does the LCA process affect product design. Figure 6 contrasts these two tools, the top one representing the ELDA approach and the bottom one the LCA approach.

ELDA Method



LCA Method

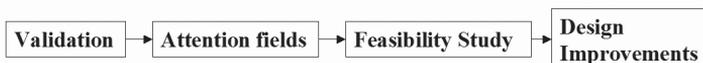


Figure 6 Comparison between ELDA and LCA method

6 Ongoing Work

A definite area of improvement for the ELDA tool discussed in this work is concerning hazardous material content or environmentally relevant material content. While researchers understand that presence of potentially toxic material content should affect the end-of-life strategy, methods to adequately account for these issues are still widely debated. An opportunity for improvement in ELDA is to include a ranking of 'hazardousness' in the analysis, this will be possible after the research community develops appropriate methods to balance the environmental impact of potential toxicity embedded in the product at end-of-life stage of life cycle. One technique under development at Delft University of Technology is the concept of Environmentally Weighted Recycling Quotes (EWRQ), which weigh every material fraction according to its real environmental impact and includes the environmental impact of recycling itself (Huisman et al. 2000).

7 Conclusions

This work is the first to develop strategies for product end-of-life management. Other work has focused on research into the specifics of end-of-life treatment but not into understanding the factors that control the end-of-life strategies possible for a product. By demonstrating what product characteristics influence the end-of-life strategy classification, ELDA provides an objective tool to help industry to match design strategies and gives clues how to organize proper end-of-life treatment systems. ELDA removes the guesswork involved in determining the end-of-life strategy, therefore, making the decisions more appropriate for the end-of-life treatment. With the accurate classification of end-of-life strategies, ELDA helps reduce cost of implementing end-of-life systems and to increase environmental performance.

The case studies, used to develop ELDA, show a need for tailor-made solutions. Because products' technical characteristics differ, the structure of the end-of-life system must be adapted appropriately. The results guide product designers to improve product design, recyclers to improve their processes and policy makers to develop more eco-efficient end-of-life systems and realistic goals.

Organizing end-of-life treatment systems require business savvy. Typical business issues such as organization development, program establishment, consumer-product interaction and financial concerns must be addressed in addition to the technical items. ELDA is creating a solid basis for just that.

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Jinhui Li and Duan Weng: China at its best

Both Jinhui Li and Duan Weng are professors at Tsinghua University in Beijing, the number one university in China. I learned a lot from them, particularly how to combine the best of two worlds - East and West.

How does it work for them? It is simple: make sure to be well informed about what happens in the world and pick out the best for China. How does it work for yourself? Be well informed about what happens in China and pick out the best for your company and your university.

How does it work for everybody? Base your activities on what you have available at the grassroots level in your country and develop them from the bottom up. Look from an academic perspective but also see how society can be best served. Chinese are masters in such dialectics and in the environmental world this is particularly helpful. For linear thinking Dutchmen this is difficult; my stay at Tsinghua provided training and a test in this respect.

Jinhui Li is in the field of recycling. Duan Weng is in the field of materials science. They have different characters and that is what you need for these specific fields. From an environmental perspective, materials application and recycling are sometimes in conflict. Finding the right balance is sometimes difficult. There is, however, one helpful common denominator: the life cycle principle. Whatever you do, wherever you are and irrespective of your ideas, all Eco-practitioners acknowledge this basic law of environmentalism.

In the end we are all equal: all human beings. Jinhui Li and Duan Weng made me realize this and moreover enabled me to gain an inside look at 'Eco' in China. There is a lot of attention being paid to the subject. There is a lot of activity going on at the basic level: water, energy and waste. A lot of the activities will have success, a lot will fail. It does not matter, there is a lot of activity; there is that will to move forward. Let us follow the 'green' flag. March forward, forward, forward.

The 'Li and Weng' Walk: They are not walkers but I take the liberty to propose one in their honor. Take the metro (line M13) and get off at Wadakou station. Walk in a western direction on Cheng Fu Lu, R to the entrance of the Tsinghua University, L in front of the main building, R at the end of this street, 3rd L, R at the old entrance, L in front of the old main building, R and L north of the pond, L at the crossroads. Proceed, either go R or go out of the West Gate and visit the old Summer Palace (across the street), go back after visit.

Or: cross the street, L, go straight at next street, bend in northern direction, go R (check on shops/restaurants at L), go straight all the way south till the road bends (is 3rd L), go left at the end, go out of the South West Gate (L) and go L. Return to Cheng Fu Lu, walk L back to the station.

7.3 Disassembly

7.3.1 Disassembly times

In the figure below a general scheme for the processing of discarded products is given:

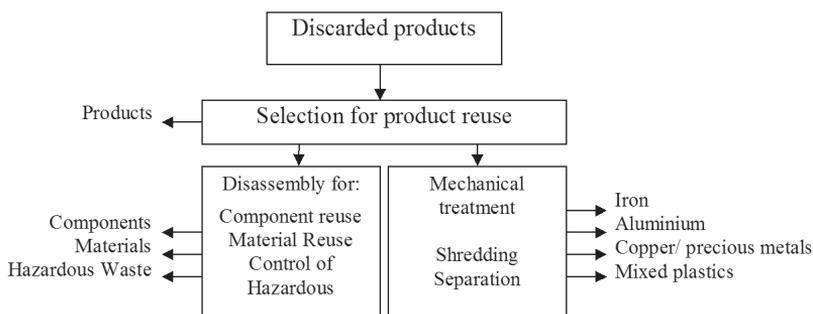


Figure 7.2 Processing of discarded products

This figure demonstrates the importance of disassembly, particularly in the early years of end-of-life treatment; the moment that the effectiveness of mechanical treatment was pretty low.

At the left hand side of the figure (disassembly) it shows that most of the environmental and economical value (components, pure materials) is to be realized, whereas disassembly is also an effective method to control potential toxic risks. Mechanical treatment (right hand side) ensures that additional amounts of metals and precious metals can be recouped.

Both for design purposes (lowering of disassembly times) and cost estimation (lowering of recycling cost) it is therefore of utmost importance to be able to calculate disassembly time upfront. Such a method would make data available in the early design phases. In this phase, changes in the product architecture can still be made relatively easy. Such calculations of the disassembly time will shorten the time to market. Therefore it is superfluous to do extensive measurements on prototypes in the release phase.

From the very start of Applied EcoDesign an important research question has been whether electronic products have a 'standard disassembly' time and if so, how these can be determined empirically. Another issue is, if such empirical standard times are available, can these be supported by some form of theoretical considerations.

In order to tackle the empiric part, Wendy Brouwers was hired by Philips; she is a graduate of Delft DfS and had already shown her capabilities during her graduation project which included a first attempt to calculate end-of-life cost (see also chapter 7.5.1).

At the International Seminars on Electronics and Environment I met Dr. Ehud Kroll, who approached the disassembly time issue from a theoretical perspective.

The article on the next page on "Disassembly Modeling: Two Applications to a Philips 21" Television Set" shows the results of this cooperation: a set of standard times for disassembly of electronic products could be identified by measurements on a variety of products. These empirical data were supported by Kroll's calculations.

Based on the data from this work many products were assessed with the help of the following formula:

Disassembly time of a product = $\sum N_j * t$ (standard)

with: N = number of joints j

and t (standard) = standard disassembly time for the joint of type j

This formula allows in a simple way to determine the effect of product architecture changes. This approach has turned out to be very fruitful in supporting design processes. It also assists in generating ideas for how to lower assembly costs of product.

The disassembly analysis is also a useful tool to track down differences in disassembly times between products of different brands. An example is shown in the figure below in which features the disassembly times for 28" TVs of five different brands.

Gross time (s) for :	TV1	TV2	TV3	TV4	TV5
Getting ready	18	24	38	32	34
Mains cord/ plug	18	20	12	16	12
Unscrew back cover	56	66	16	32	28
Clean and sort back cover	34	42	22	44	14
Take out and sort PWB	24	18	22	18	16
Take out and sort speaker	20	16	56	54	22
Deflection unit	34	26	32	30	28
Get CRT out	72	50	74	70	90
Clean and sort CRT	74	62	68	46	46
Clean and sort front cover	74	58	74	44	82
Total	424	380	414	386	372

Figure 7.3 Disassembly of 28" TVs of five different brands.

This figure shows that although the total disassembly time of all the products is almost identical (between $372 - 424 \text{ s} = 400 \text{ s} \pm 7\%$) the different items contributing to this total are vary greatly. This observation is a rich source of improvement ideas! A design combining the best practices has a disassembly time which is only some 260s, 35% lower than the average total.

Although there is no one to one correlation, the assembly cost of such a product will be substantially lower as well. This is another example that Eco considerations work out well for the environment but also for business more generally.

Disassembly Modeling: Two Applications to a Philips 21" Television Set

C.B. Boks, E. Kroll, W.C.J. Brouwers, A.L.N. Stevels

Abstract

Disassembly modeling is an important issue in environmentally conscious design. Two approaches to disassembly modeling are described in this paper. The first estimates disassembly times by applying work-measurement analyses to disassembly tasks. The second approach uses measurements of actual dismantling processes to predict the disassembly time of similar products. Both approaches are applied to a recent model Philips television set. It is shown that, although substantial differences exist between both approaches, similar results can be derived from both models for the case study. The paper concludes by discussing the applicability of both models.

I. INTRODUCTION

With legislative powers knocking on the door, producers will become more responsible for the take-back of their products in the future. Producers therefore need to be able to estimate the costs associated with a product when it enters its end-of-life phase. Accurate knowledge of the end-of-life phase will allow manufacturers to improve their products through the identification and implementation of new design rules.

The end-of-Me processing of a product can be divided into four stages [1]

1. **Logistics:** collection and transportation of the products from the final users to companies that process these products.
2. **Disassembly:** by using simple tools, the products can be disassembled into components or materials. This is still often done manually, although research is being conducted in the field of automated disassembly [2, 3]. This is an expensive processing step because of the high wages for manual labor, but it provides a means of isolating pure, and thus more valuable, secondary materials. Disassembly may also be necessary to eliminate hazardous substances.
3. **Mechanical processing:** these include shredding and separation techniques that can be applied to parts separated by disassembly, or even complete products. Mechanical processing is much less expensive than (manual) disassembly, but makes it more difficult to obtain pure and more valuable material fractions.
4. **Upgrading of secondary materials or disposal:** in this last step the materials or components that remain after the preceding steps are either processed further (for example, regranulating plastics and smelting glass and copper), incinerated or landfilled.

The focus of this paper is on the second stage of end-of-life processing, that is, manual disassembly. For a company in general, and for designers in particular, modeling of disassembly is one of the ways to gain insight into the end-of-life phase of a product. The first objective of disassembly modeling is to determine the ease-of-disassembly of a product, which will give an indication of the labor costs required to disassemble it. This is of importance since labor is often the largest cost driver in the end-of-life phase of products such as brown and white pods. Moreover, disassembly modeling facilitates the derivation of design rules which will ensure an easier-to-disassemble product.

A. Disassembly Modeling

Attention has been given to disassembly modeling in recent literature (see for example [2-6]). Disassembly modeling is a collective term which can be used, among other things, for disassembly sequence planning, disassembly operations planning, and disassembly evaluation. Disassembly evaluation models intend to assess a product on the basis of the time (or money) necessary to disassemble it. Roughly two different approaches used by disassembly evaluation models can be identified. One approach uses a methodology based on theoretical work, while the other is based on information gathered by observing actual disassembly practices. In this paper, representatives of both approaches are applied to a Philips 21" TV set. The objective is not only to present results and discuss differences between the two different approaches, but also to evaluate their applicability and usability. This evaluation will contribute to the discussion on the direction in which disassembly modeling should be heading.

Our study did not address the issues of determining a disassembly sequence and disassembly depth. The Philips 21" TV set was disassembled to a depth suitable for our analysis purposes, as explained in Section IV.

B. Time Estimates

In disassembly modeling, time estimates for disassembly operation are extremely important. Without them, one can neither determine the ease-of-disassembly of a product nor its disassembly cost. Two different ways to produce time estimates for disassembly operations are presented in this paper:

Theoretically derived estimations: Established motion-time analyses are used to estimate the time needed for hand and tool movements. Research has been done to elaborate these techniques into methodologies that describe disassembly operations and provide time estimates [5]. Others have combined similar techniques with simulation of disassembly operations to develop the time estimates [6].

Measurements from actual disassembly practice: These measurements can be derived from timing disassembly operations, preferably in a situation in which these operations are done on a daily basis (for example, by a recycling company such as MIREX in Eindhoven, The Netherlands). Only in such an environment one can truly gain insight into what operations are needed to disassemble a product. Publications describing attempts to gather such measurements from actual disassembly operations seem to be very rare. A methodology to estimate repair times based on actual tasks is described in [7]. In this study, videotaping many different repair tasks was used to collect data on many different operations such as screw removal, unclipping, unsnapping, etc.

II. KROLL'S DISASSEMBLY EVALUATION METHOD

This evaluation method for quantifying the ease-of-disassembly of products was developed following several years of manual disassembly experiments on small electrical appliances (e.g., toasters and popcorn makers), and computers and business equipment [8]. The method's primary objective is to serve as a design tool which highlights weaknesses in the design from the disassembly perspective and can be used during the design phase. Rationalizing disassembly began with compiling two lists, tasks and tools, early in the process of experimenting with disassembly: The tasks list includes 16 standard disassembly operations, such as unscrew, cut, and wedge/pry. Twenty-four tools – various screwdrivers, wrenches, pliers, etc. – comprise the tools list.

The numerous experiments indicated that four different sources of difficulty in performing dismantling tasks should be considered: accessibility, positioning, force, and basic time. *Accessibility* is a measure of the ease with which a part can be reached by the tool or hand. This is an indication of whether or not adequate clearance exists. *Positioning* measures the degree or precision required to place the tool or hand. For example, a higher degree of precision is required to engage a screw with a screwdriver than to simply grasp a loose part. *Force* is a measure of the effort required to do the task. For example, less force is required to remove a loose part than to free a part glued to the assembly. *Base time* is the time required to do the basic task movements without difficulty. This category excludes any time spent accessing the part, positioning the tool, or overcoming resistance (as when a thread-locking compound is used, or tight tolerances produce friction).

To provide quantitative design feedback and to be able to weigh design tradeoffs, all difficulty aspects needed to be rated on the same scale; and disassembly difficulty was found to have the meaning of time. A task that poses accessibility problems requires precise tool positioning, or calls for exerting large forces would take longer to com-

plete. Time, therefore, could serve as a common denominator for rating disassembly difficulty. Instead of providing detailed time estimates to the designer, however, it was decided to convert that information to difficulty scores on a scale of 1 (easiest) to 10 (most difficult). Comprehending integers on a standard scale seemed easier than examining time in seconds and fractions of a second. Since all the scores were defined on the same scale, acuity ratings for different tasks could be compared directly. For example, the *force* score for an unscrewing operation could be compared to the *base time* score for the operation of prying open a snap connection.

The chosen means for computation of the time spent doing various actions was work-measurement systems from the field of industrial engineering. Task difficulty scores for all the predefined disassembly tasks were derived from an estimation of task performance time using the Maynard Operation Sequence Technique (MOST) system [9]. MOST is a predetermined time system which provides standard time data for the performance of precisely defined motions. If a disassembly task is broken down into elementary movements, such a system can predict the time required for an average skilled worker to perform the task at an average pace. The term "average" is used in the sense that the standard time data represent mean values determined from motion-time studies of many workers of varying skill and effort, working under various conditions, in different industries.

The first step in the development of difficulty ratings was to identify and define standard models for each disassembly task. Task models were established through observation of disassembly experiments. Key steps in the performance of each task were noted and analyzed with the MOST system. Slight variations in the performance of the same basic task were often observed. For example, different methods for *W n g* a screwdriver were noted. The quickest and most efficient method for performing a task, as determined from the MOST analysis, was designated the *standard task model*.

Once the standard task models were defined, the effects of various disassembly conditions were investigated. Factors such as obstructions (e.g., inadequate clearance for the placement of the tool), handling difficulties (for example, a requirement for precise alignment), and heavy resistance were considered. The effects of these conditions on performance time were first assessed by using MOST, then categorized according to the aspect of task performance (accessibility, positioning, force, and base time) they influenced, and finally converted to difficulty scores on the 1 to 10 scale. This process was repeated until a database containing difficulty scores for each standard task classification was developed. Figure 1 is an example of the difficulty scores for the 'power-assisted unscrew' task. Each such chart is accompanied by a detailed description of the standard task models, definitions of the terms used in the chart, and instructions on how to account for deviations from the standard conditions. A fifth difficulty category, *special*, was added to cover special circumstances not considered in the standard task model. For example, if the standard model includes removal of screws with only six to nine effective threads and a screw with 12 threads is encountered, then a score greater than "1" would appear in the *special* category.

Power-Assisted Unscrew		Accessibility	Positioning	Force	Base Time
Single screw or nut	Clear	1	2	1	3
	Obstructed	2	2	1	3
Single bolt with nut	Clear bolt	Clear nut	1	3	4
		Obstructed nut	2	3	4
	Obstructed bolt	Clear nut	2	3	4
		Obstructed nut	3	3	4

Fig. 1 The chart of difficulty scores for the 'Power-Assisted Unscrew' task

General assumptions about the disassembly area and disassembler were required to perform the MOST analyses. It was assumed that a “knowledgeable” disassembler performs each task. This means that the disassembler has been specifically trained to dismantle certain products and is completely familiar with their disassembly process. Therefore, no time is wasted searching for parts or deciding which task to do next. It was assumed that all hand-held tools are placed within reach of the disassembler and that disassembly is performed on a workbench. Bins are provided around the disassembly area so that parts may be tossed aside as they are recovered. Other equipment, such as vises, band saws, and grinding wheels, are assumed to be positioned within one or two steps of the disassembler.

The method's implementation as a design tool consists of a spreadsheet-like evaluation chart and a catalog of difficulty ratings for all the disassembly tasks. During evaluation, the product is disassembled or its disassembly process visualized and simulated. The user specifies the task type and the tool used for each disassembly operation, and chooses difficulty scores from the tasks catalog. The evaluator must assess key aspects of task performance (e.g., force requirement and accessibility) when selecting the scores. In this way, specific sources of difficulty are captured and the designer gains a better understanding of how the form properties of the product will affect disassembly. Design weaknesses are identified by reviewing the chart entries, summarizing the results, and computing estimated disassembly times.

Because the difficulty scores originate from time-based work-measurement analysis of disassembly operations, it is easy to convert the scores back into time. The resulting mathematical expression allows calculating the time for each operation, including tool and hand manipulations which are the movements of the hand with and without a tool to and from the assembly. This type of analysis was applied to the Philips TV discussed in this paper, and used to generate the time estimates presented in Section IV.

III. THE PHILIPS ECC END-OF-LIFE COST MODEL

Being one of the world's largest manufacturers of consumer electronic goods, Philips is extremely concerned with gaining insight into end-of-life processing costs. A cost model for the end-of-life phase of consumer electronic goods has therefore been developed at the Environmental Competence Centre (ECC) of Philips Consumer Electronics [1]. Based on the cost related to the end-of-life phase, the optimal end-of-life strategy as well as the end-of-life cost for a product can be determined. However, suggestions for design changes resulting in lower end-of-life cost can be generated.

Consumer electronic goods consist of one or more of the following five types of subassemblies: housings, picture tubes, printed circuit boards, drives and sound systems. The end-of-life cost model uses a cost/benefit analysis in three hierarchically structured levels to determine whether a combination of subassemblies, or parts of subassemblies, should be separated or not. In this way, the most cost-effective way, not only to disassemble a product, but also to process the separated parts further, is determined. The end-of-life cost model focuses chiefly on material reuse. The reuse of components or subassemblies is not considered in this model. Materials which cannot be recycled will be incinerated or landfilled.

The application of the end-of-life cost model to a wide range of products has provided detailed information on which joints, materials and constructions can be used best in designing new products. With this information, end-of-life costs are brought down.

Users of the model include product designers, who can adapt new products to the available processes at the end-of-life phase. The model is also used for recycling companies to determine the optimal end-of-life strategy, for general management to assess future developments based on simulations by the model, and for assistance in developing generic policies in the field of the take-back of electronic goods.

The four stages of end-of-life processing discussed in Section I have been incorporated into the Philips ECC end-of-life cost model. When all routines of the model are applied to a product, the model can provide the optimal disassembly depth. For the purpose of comparison with Kroll's disassembly evaluation method, only the part of the end-of-life cost model concerning manual disassembly is taken into account in this paper. Estimates for disassembly of the test product can be produced by *a priori* indicating the parts of the product that need to be disassembled for this specific analysis.

To calculate the total disassembly time (and cost) of a product, the model provides the user with a database of a wide range (of common types of connections and their- related disassembly times. This database (see Fig. 2) was generated after doing disassembly projects at MIREC, the company which recycles consumer electronics goods and computer products, not only from Philips but also from other manufacturers. In addition to their general experience, specific disassembly projects with television sets and products such as video recorders and small audio sets provided information on all aspects of disassembly practice. During these disassembly sessions, time was measured for specific disassembly tasks (for example, undoing certain connections, part handling, tool and hand manipulations) as well as for the disassembly of complete products. Those times were measured by stopwatches during the disassembly sessions as well as during verification of the disassembly sessions on video. It was observed that time estimates for similar disassembly tasks of different consumer electronics products do not differ significantly. This can be very helpful, since now product designers have a single database at their disposal, from which to derive information for different products.

No.	Disassembly operation	Time
10	Screw removal	... sec
20	Screw removal (>10 cm below surface)	... sec
140	Separate by sliding	... sec
160	Remove clamping ring	... sec
180	Remove electrolytic component	... sec
... sec
... sec

Fig. 2 Partial Reproduction of disassembly times database

By selecting from the database of connection types those types which correspond with the connection types in the product to be analyzed, the product's structure is formatted into the end-of-life cost model. Then, the model automatically selects the required handling operations and tool or hand manipulations. By adding up all corresponding times from the database, the model can determine the total disassembly time needed for undoing the different connections in a product.

For example, if connection X requires undoing two snap connections and one pull operation, the model reads from the database the corresponding times and adds them up. It automatically adds the estimates for the required handling of the parts that were initially connected, and the estimates for the required tool or hand manipulations, to obtain the total disassembly time for all the operations related to connection X. Repeating this procedure for all the operations necessary to disassemble a product supplies the user with the total disassembly time of the product.

IV. RESULTS

The authors have separately applied both disassembly models described in Sections II and III to a Philips 21" TV set model 2IPT520A/00, further referred to as 'the test product'. This television set is a recent model from 1994. Fig. 3 shows a simplified exploded view of the test product. The design of the test product is relatively straightforward, with perhaps two extraordinary features: the speaker assemblies in the back cover are quite uncommon, and a heat shielding plate is heat-staked to the back cover.

In order to be able to compare both models, a disassembly sequence was agreed upon. This disassembly sequence was intended to approximately reflect the way TV sets are disassembled at the MIREC recycling plant in Eindhoven, The Netherlands. In reality, however, additional or fewer disassembly operations are often carried out, depending on the further treatment of the fractions that remain after disassembly.

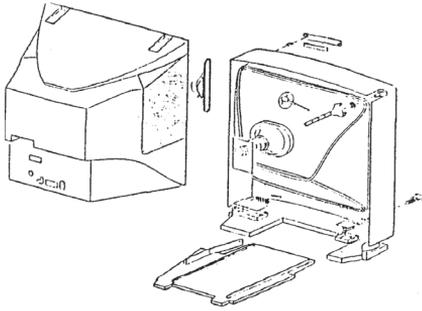


Fig. 3 Exploded view of the test product

For simplicity, the authors decided to refrain from analyzing the disassembly of the wiring in the test product. Both disassembly models are capable of handling wiring, and this abstraction does not influence any other results derived for this paper. In addition, because the test product had never been in actual use, its interior was in brand-new condition. Therefore, total disassembly times given in this section are not representative of actual disassembly times of IV sets in any recycling plant. Actual disassembly of fully-wired and used products will undoubtedly take longer.

The major disassembly steps and their corresponding disassembly times according to both models are presented in Table I. At first glance, there seems to be a striking similarity between the results for some of the individual disassembly steps and especially for the total disassembly time. We shall explain the differences and what caused them below.

Table 1 Estimates In Seconds For Disassembly Operations According To Kroll And Philips ECC Models

#	Disassembly Steps	Kroll est.	Philips est.
1	Separate back cover	27.5	27
2	Separate speaker assemblies (x2)	15.8	14
3	Separate speakers from frame (x2)	32.4	30
4	Separate speaker grills from frame (x2)	74	70
5	Separate shield from back cover	10.1	11
6	Toss back cover aside	2.8	3.5
7	Separate CRT-print from CRT	2.8	1.5
8*	Separate main print from bottom plate	11.6	7
9*	Separate bottom plate from cabinet	3.9	8
10	Separate CRT from cabinet	24.1	23.5
11	Separate deflection unit from CRT	14	10.5
12	Separate degaussing coil from CRT	8.5	9
13	Separate earth cable	8.2	10
14	Separate switch/control print assy	10.9	12
15*	Separate switch print from frame	4.6	7.3
16*	Separate control print from frame	10.6	8.3
17*	Separate power button	2.8	7
18	Separate latch from cabinet	4.9	5
19	Toss cabinet away	2.8	3.5
TOTAL TIME ESTIMATE		273	268

* in these steps different operations were evaluated

As noted in Table I, some disassembly steps (namely, steps 8, 9, 15, 16 and 17) consisted of different operations, and their results are therefore impossible to compare. All of these steps involved parts joined by snap connections, and one of them also included a screw. Kroll's estimates were derived for undoing maps by pressing on the tabs and removing the screw by unscrewing it. Philips, on the other hand, observed that in practice, workers used hammers, pry bars, or excessive force to destructively remove the parts, and used these operations for their

estimates. For example, it was observed that workers performing step 8 always pulled the printed circuit board out of the snap connections securing it in place. This operation was easily done with a little force, and took shorter than undoing the snaps to release the print. On the other hand, the snap connections between the bottom plate and the cabinet (step 9) were almost always undone by striking them with a hammer. In this case, destructive disassembly took longer than just undoing the snaps.

Each of most of the other, comparable disassembly steps in Table I consisted of several operations or tasks. When these tasks were compared, it was noticed that the Philips ECC model tended to predict somewhat shorter times for the separation tasks, but longer times for removing the separated parts, than Kroll's model. It turned out that while the Philips ECC model makes a clear distinction between separation and removal tasks, Kroll's model does not always do that. For example, if a part is pulled until it is free and then tossed aside, Phillips would estimate the time for each of these two operations, while Kroll's "pull" operation already includes the tossing of the part in its standard task model.

This difference between the two models, while sometimes making it difficult to compare disassembly processes on an individual task basis, seems to almost disappear when the comparison is made between disassembly steps, as in Table I. The authors did notice, however, that handling times (i.e., the time it takes to place the separated part in a bin) are typically longer with the Philips ECC model. This was explained by realizing that Kroll's model assumes that bins for storing the retrieved parts are placed within reach of the worker. This means that the worker only moves his or her arms to toss parts into the bins. Philips, on the other hand, observed that workers often walk a few steps to reach the bins. Accordingly, the Philips ECC model predicts longer handling times than Kroll's.

V. Discussion and Conclusion

Two seemingly different approaches to disassembly modeling have been described. Kroll's disassembly evaluation method applies work-measurement analyses to disassembly operations, while the Philips ECC model uses times measured at a recycling facility. The two models were applied to the same test product, and their estimated disassembly times compared.

Generally speaking, the results of both models correspond very well. Perhaps this should not come as a big surprise, considering that Kroll's "theoretically-derived" data can be traced back to its origin in numerous motion-time studies of workers under real-life conditions. The Philips approach utilizes measured times more directly, but both methods still have common roots.

The comparative study presented in this paper allows us to make some helpful general observations. Both approaches to disassembly modeling resulted in very similar results, and are therefore equally valid. The Philips approach is suitable for a company that is large enough so it can afford conducting independent studies, has access to a recycling facility for gathering experimental data, and its products are somewhat standardized (e.g., all the products use similar joining techniques). Kroll's approach is more general in the sense that it is not product-specific, and can be applied equally well to a TV as to an electric drill or lawn mower.

On the other hand, the Philips approach facilitates incorporation in the model of company-specific practices such as breaking snap connections instead of undoing them nondestructively, or using special tools developed for specific tasks. This advantage also allowed the Philips ECC model applied to the test product to account for part handling times more realistically, as might be expected from a practical-type of disassembly model.

Kroll's model is more detailed because it covers a larger variety of conditions and circumstances for performing each task. This, in theory, should provide for better accuracy of the predictions. In contrast, the Philips time estimates are always based on an average value. For the case study of this paper, Philips' databases were very up-to-date and included data from very similar products. However, application of the same model to other products may lack the accuracy of Kroll's method.

The highest degree of detail and accuracy may not always be essential. Observations of actual disassembly processes show that the disassembly time for two identical products can vary considerably, even when done by the same persons, and under the same conditions. However, this is by no means a disqualification of the purpose of disassembly modeling, since very detailed information may still be necessary; for example, to further research in automated disassembly.

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Cities, I I**London, a jack of all trades**

London is the capital of an Empire. Maybe politically the Empire does not exist anymore, but its diversity makes it still feels like that.

For me it is a breeding ground, a city where you can experiment. For one reason or another during all the years I spent working on environmental issues I got a lot of invitations to speak in London: on a variety of subjects, for a variety of audiences. I always accepted even for subjects of which I was not completely in control. It is a real challenge to put together a story that will be attractive for the audience, but for which still something new has to be invented. It is a bit stressful, which helps to be creative. Through this mechanism, ideas on how to manage supply chains, how to do EcoDesign in small and medium sized enterprises, how to tackle chemical risk management and how to operate regional recycle systems were generated. Thank you, UK.

Walking the streets of London gives that special kind of inspiration, a lot of thoughts pass through your mind. After such a walk you begin writing back in the hotel and subsequently you get little sleep. However, the next morning bacon and eggs assist you to carry on. It is exhausting; but it is helpful. Many times, going back into the overcrowded and overheated Tube to Heathrow, I felt miserable and exhilarated.

London offers it all. By now the UK has turned its backlog in environment & electronic products into a pretty advanced position. The implementation style is pragmatic: better to go for better solutions later than for a messy quick one. Being a jack of all trades will help to ensure the cross-functionality of EcoDesign.

City walk: Start at the front side of Paddington Station, go into London street, straight to Sussex Place, L to Stanhope Terraces, cross Bayswater Road into Hyde Park, walk the Serpentine Road, end at Hyde Park Corner, cross over to Green Park, walk to Victoria Memorial in front of Buckingham Palace, enter St. James Park, go to the west side, go through Storey's Gate to Westminster Abbey. Enter Gr. College Street, walk along the Houses of Parliament, and go straight (Whitehall), end at Trafalgar Square.

Favorite Restaurant: Any pub where there is draft Boddingtons (food is less important).

Country walk: Go by train from Victoria Station to the Redhill North Station; walk the North Downs Way in a western direction up to Dorking.

7.3.2 The lasting advantage of disassembly analysis

Around the year 2000, disassembly as a go to treatment for recycling electronics came under pressure. There were three reasons for that:

- Traditional disassembly, which was done manually, turned out to be costly.
- Shredding and subsequent separation technologies became more sophisticated and therefore became much more competitive due to their low cost.
- The upgrading technology of secondary material fractions was improved. This includes the notion that 'integrated upgrading', for instance by copper smelters, makes disassembly superfluous for several subassemblies and components (mostly those containing copper).

The high cost of disassembly is demonstrated by the following table which gives the amount of material required to be disassembled in one minute, to stay cost neutral. In the case of cost neutrality, the proceeds of the recycled materials equal the disassembly and the upgrading cost.

Precious metals		Metals	
Gold	0.05 g	Copper	300 g
Palladium	0.15 g	Aluminum	700 g
Silver	5 g	Iron	50000 g
Plastics		Glass	6000 g
PPE	250 g		
PC, POM	350 g		
ABS	800 g		

Figure 7.4 Minimum amounts required to be liberated in one minute during disassembly to achieve cost neutral operation.

This figure shows that the minimum amount to be liberated in one minute time to achieve cost neutral operation amounts to at least several hundred grams for most common metals and plastics. At the time this table was calculated, material prices were low. However, even at the 2006 price level, which is 2-3 times higher than in 2000, the amounts are still substantial (approximately half of the 2000 situation).

The general conclusion from these calculations is that for most electronic products, with a weight less than 5000g, the value of the secondary materials does not warrant manual disassembly. Only in the case that products contain hazardous substances is disassembly necessary, but in that case the goal is to achieve toxic control.

This conclusion meant that several projects were begun to see whether the traditional design of different products could be modified in such a way that disassembly became competitive with shredding and separation treatments. Real cost neutrality was not a goal because of the very material composition of the products. A talented Delft student, Marielle, did the analysis and the design work for Audio products. She got very close to her goal but the product requirements prevented her from achieving her target. For audio systems (weight some 3000g) the gap was still a factor of two. For portable products (weight 100 – 300g) the gap stayed at the level of a factor of 6-8. The conclusion was clear: Design for Recycling cannot make manual disassembly competitive with shredding and separation techniques.

A parallel route which was followed was a foray into robot-assisted disassembly.

This was done through two avenues:

TU Delft did a Delphi inquiry among industry experts asking what they saw as the future of robot assisted disassembly. The outcome was moderately to fairly optimistic.

Philips CE supported a project about robot assisted disassembly in Germany. In principle it worked but there were problems as well. The robot had difficulties in removing rusted screws and could not handle

damaged products. This meant that manual disassembly still had to be done for at least 20% of the products. The system was complicated too, resulting in substantial down times and therefore a big supervision and repair effort was necessary to maintain it.

In this situation the conclusion was that big investments were still necessary to develop the process further. The projected final investment for the machine showed a marginal payback. As a result, no recycler dared to step in and the project was abandoned.

At Philips we turned our attention to design for non-disassembly, that is designing products in such a way that optimum results would be obtained when shredding and separating these products. As a result useful design rules were tracked down and implemented.

In spite of all this, disassembly and disassembly analysis of electronic products were not dead. When taking a wider perspective the traditional design for disassembly activities had yielded unexpectedly positive results:

- Lower disassembly times, in most cases, also yielded lower assembly times, which is something that directly brought in a lot of money for the company.
- Disassembly analysis can create a lot of awareness and produce free insights from your competitors.

This meant that in 2002 Casper Boks and I decided to write an article with the title: *“The Lasting Advantages of Disassembly Analysis: Benchmarking Applications in the Electronics Industry”*. It is to some extent a kind of rehabilitation for disassembly. It is reproduced here below.

The Lasting Advantages of Disassembly Analysis: Benchmarking Applications in the Electronics Industry

Ab Stevels and Casper Boks

I. Background

When Ecodesign in the electronics industry took off in the early to mid nineties, disassembly analysis was one of the cornerstones on which it was built. By both industry and academia, design for Disassembly was seen as the preferred way of redesigning products for better environmental performance during the end-of-life stage of the life cycle. Main reason for this was probably the fact that research in this field was mainly initiated in mechanical engineering and machine design environments – areas where traditionally manufacturing research took place, and where many started to focus on demanufacturing as a (at the time) logical step towards environmentally sound products [1].

Alternative (or supplementary) processing technologies such as shredding and separation for material recycling did not receive much attention until several years later when researchers realized that cost factors and stakeholder opinions played a role as well. Since this time, it has become clear to many people that from a total systems perspective, and without heavy subsidies, disassembly is often not a feasible option. In particular this applies to competitive, non-subsidized recycling markets. Because of these facts, in several Western European countries nowadays approximately half (on a weight basis) of all discarded electronic appliances are shredded and subsequently separated into various material streams. This has led to the approach that the determination of end-of-life scenarios requires primarily a perspective based on the *output* of the recycling process rather than on the *input* of the process. It has been pointed out in Ram et al. [2] that for shredding and separation, end-of-life processing is about material streams and about separating or joining them, rather than about individual products.

By the year 2000, industrial and academic attention for improvement of shredding and separation techniques have ensured a situation where for the majority of product categories, this is the preferred treatment option. On the other hand, disassembly is still a valid (pre)treatment option in those cases in which it always has been the preferred option (see Figure 1):

- For separating a relatively valuable part -- in which case the disassembly costs are (more than) balanced by the revenues of separating a valuable component or subassembly. This is for example the case for large monomaterial plastic parts, copper parts and high value electronics.
- For separating an environmentally harmful part -- in which case the remainder of the product can be treated in a regular way instead of a more expensive way. This is for example the case for potentially toxic components.

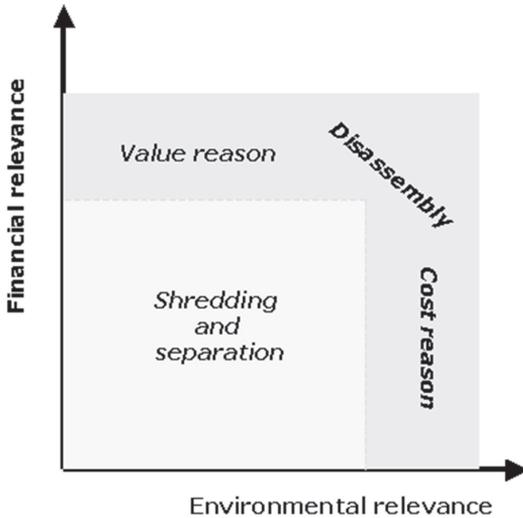


Figure 1: Applicability of disassembly vs. shredding and separation

For consumer electronics products, the expensive manual disassembly implies that products with picture tubes are in most cases the only feasible candidates for manual disassembly. The presence of the picture tubes makes that the cheaper alternative, shredding and separation, is not feasible for these products as conventional separation technology is not equipped to handle satisfactorily the recycling of glass from picture tubes, which accounts for approximately 50% of the total product weight. A positive side effect of having to remove picture tubes is the potential to separate large plastic parts that may be recycled as long as the presence of contaminants in the form of additives, stickers, etc. meets the (strict) specifications.

For metals dominated products, depending on the exact disassembly scenario and the size of the product itself, disassembly times for this product category are between 1.5 and 4.5 minutes. Usually, further processing and selling of the separated parts does not outweigh the cost for the disassembly process [3], even if the products are designed substantially more disassembly friendly [4], which makes disassembly an unfeasible option for this category. In plastics dominated products, usually more than half of the product weight consists of plastics, while the total weight of the magnetic materials can still add up to as much as 40%. The precious metals content is generally moderate or low since these products in general appear to include a relatively low weight of electronics. Since generally no valuable components are to be retrieved either, disassembly is usually too expensive for products from this category as well. Lastly, apart from the high associated costs making it unattractive, disassembly of miniaturized products is hardly of any use. The recovery of materials from disassembled components can only be done on a very small scale due to the size of the products and the fact that most parts are contaminated in one way or another due to the product configuration [5].

From the above it can be concluded that for most consumer electronics products, disassembly strategies are too expensive. Although research efforts are on their way to design flexible (partially) automated disassembly

cells (see Wiendahl et al. [6] for a good overview), their implementation is not to be expected in the next few years. Therefore, disassembly analysis based only on the objective of improving the suitability of disassembly is not meaningful.

However, additional reasons exist which continue to make disassembly analysis of – also – smaller products a useful activity.

At Philips Consumer Electronics, disassembly analysis has been integrated in the established Environmental Benchmark Method (EBM) as recorded in an official Philips document [7]. The EBM does not only comprise the benchmarking of products itself, but it positions this activity in an integral approach that facilitates the exploitation of the benchmark results (see for example also [8]). Using the method, products of Philips and competitors are chosen based on similar product generation, price and functionality, and assessed on the basis of five focal areas:

- Packaging
- Energy consumption
- Weight and material application
- Chemical content
- Recyclability

In the benchmark procedure, the disassembly analysis is made part of the focal area recyclability, though its benefits potentially extend beyond end-of-life issues only. Instead of only optimizing designs for reducing disassembly costs, benefits from including disassembly analysis are:

- It can bring good (and free) solutions for smart disassembly;
- It has the potential to teach about product architecture in general;
- Improvements will often work out positively for reducing assembly costs as well. This at the same time justifies disassembly analysis for small products that will never be disassembled in practice at their end-of-life;
- The phrase 'the competition is better' communicates better with management than 'our absolute environmental performance does not look good'. Also the relation with assembly costs strengthens communication with management.

In this paper, the above is clarified using a number of practical applications of disassembly analysis.

2. Current assessment procedure

The core calculations in the standard disassembly analysis procedure that is included in the Philips EBM is straightforward and does not differ much from the method already described in 1996 [9]. The total disassembly time T is calculated as

$$T = \sum_i N_i \cdot t_i,$$

where N_i is the number of joints i and t_i the standard disassembly time for joint i . Standard disassembly times are derived from several video taping sessions at a state-of-the-art recycling facility, to ensure that 'gross' disassembly times are used instead (including 'unproductive' operations and operations not related to actual disassembly).

In addition, T is calculated separately for subsystems like Housings, Printed Wiring Boards, Speakers, Remote Control Unit, etc. In the reports, also the number of connections per type of connection is given such as screw, click, solder, glue and other connections.

3. Applications

In this section, several applications of including disassembly analysis in the EBM are shown. It should be noted that an important aspect of comparison of the various brands is the fact that all brands in the same benchmark have approximately the same functionality. Hence, assuming otherwise similar conditions, in theory the optimal design solutions should not differ that much.

3.1 Application 1 (Competitor analysis)

One of the main advantages of environmental benchmarking is the creation of a large database of product data. By analyzing multiple instead of individual environmental benchmark studies, important benefits are [8, 10]:

- Identification of structural rather than occasional underperformance compared to competition;
- Identification of trends in product characteristics and environmental issues.
- Facilitation of communication with management and departments other than just product development.

Studying the disassembly performance in a series of environmental benchmark studies, initially by simple counting and comparing disassembly times for a range of products, Philips has learned for which product categories performance has been green (better than competition), yellow (on par) or red (worse than competition). For product categories where disassembly is a relevant strategy, this indicates if and where improvements in disassembly are required. For product categories where disassembly is not a relevant strategy, this indicates where improvements are likely to result in the reduction of assembly costs.

3.2 Application 2 (Differences in disassembly times)

In this example, the results of a disassembly analysis of a portable audio product are given.

Table 1: Disassembly times for four portable audio systems

	Brand 1	Brand 2	Brand 3	Brand 4
Screws	122	73	82	73
Connectors	7	14	7	5
Solder points	16	3	7	5
Click joints	14	0	0	29
Total disassembly time (sec)	1074	630	628	796

The results in Table 1 give rise to the following observations:

- Brand 1 uses too many screws, has too many solder points and click joints;
- Brand 2 makes smart use of connectors and thus reduces the amount of screws and solder points;
- Brand 3 appears to prefer solder points over connectors to reduce the type of screws;
- Brand 4 prefers to use click joints to reduce the amount of other types of joints.

Looking at the total disassembly times, it is clear that the solutions preferred by brands 2 and 3 result in the best performance. The solution chosen by brand 4 is an improvement compared to brand 1, but is far from optimal in comparison to brands 2 and 3.

A breakdown in connection types, such as done in this example, makes clear that a proper analysis of types of joints, in which the assembly costs of the various types of joints are included as well, can be used as a quick way to balance assembly and disassembly costs.

3.3 Application 3 (Similarity in disassembly times)

In the example presented in Table 2, all five brands exhibit total disassembly times that are in relatively close range (highest total is 14% higher than lowest total), in comparison for example with the previous example. However, considerable differences exist for the various separate disassembly operations. For end-of-life performance evaluation, most important are those related to separation and cleaning of the back and front cover and the CRT. Here we see that the highest total is 184%, 30% and 86% of the lowest total, respectively.

Table 2: Disassembly times for five TVs

Operation	Brand				
	#1	#2	#3	#4	#5
Getting ready	18	24	38	32	34
Mains cord	18	20	12	16	12
Unscrew Back cover	56	66	16	32	28
Clean/sort Back Cover	34	42	22	44	14
Take out/sort PWB	24	18	22	18	16
Take out/sort speaker	20	16	56	54	22
Take out/sort deflection unit	34	26	32	30	28
Take out CRT	72	50	74	70	90
Clean/sort CRT	74	62	68	46	46
Clean/sort front cover	74	58	74	44	82
Total	424	380	414	386	372

Although trade-offs will exist (low disassembly time for one operation may cause high disassembly time for another operation), it is also likely that this indicates improvement potential for individual operations. Moreover, differences and thus improvement potential are likely to exist in assembly times as well.

3.4 Application 4 (Link with shredding and separation)

In the light of recyclability targets as proposed in the draft EU directive on Waste of Electrical and Electronic Equipment, a useful application of disassembly analysis is the evaluation of recyclability scores. For manufacturers it is important to be able to determine to what extent recyclability targets can be reached by improved design, for example by using a disassembly strategy instead of shredding and separation (s&s).

In general, for consumer electronics products, the characteristics with respect to recyclability and end-of-life yield are as listed in Table 3 [3]. From this, it can be observed that for plastics dominated products the concerns for reaching recyclability targets at acceptable financial implications is to be considered relatively most problematic and deserves therefore special attention. As audio products are typical representatives of plastics dominated products, an example is given here on how to address this issue, by analysis of the improvement potential for four audio products. In Table 4 the data for these products are given before redesign.

Table 3: End-of-life characteristics per product category

Product category	Recyclability score	End-of-life yield
Metal dominated products	+	+
Plastics dominated products	0/-	-
Precious metals dominated products	0/+	++
CRT-based products	0	0

Table 4: Upfront recyclability scores for audio products

	Cost increase of disassembly over s&s strategy	Estimated rec% with s&s strategy	Est. rec% with disassembly strategy
Audio miniset	2 times as expensive	60%	62%
CD Radio Cassette Recorder	7 times as expensive	42%	77%
Radio Cassette recorder	9 times as expensive	46%	72%
Portable Radio	11 times as expensive	40%	72%

Observations from Table 4 can be summarised in the conclusion that combining environmental and financial considerations, the eco-efficiency of disassembly strategies for this type of products is indeed low. With the WEEE recyclability target for this category being 70%, it is clear that for audio mini sets, a disassembly strategy does not result in meeting the target. Considering the remaining three products, for the CDRCR the efficiency is relatively most favourable. Reasons for this include the fact that for this product, the housing parts and therefore the weight of the plastic that may be recycled is a relatively high percentage of the total product weight and will contribute to the recyclability percentage. This is of course under the assumption that plastics recycling will take place – something that is not to be expected in the near future but for which some favourable scenarios can be drawn [11]. As the specifications for this type of products are relatively high (for example in terms of sound quality), the parts that are released in a disassembly strategy are relatively sophisticated and will yield more in after material recycling. From a disassembly strategy perspective, the remaining, more miniaturised products in Table 3 are particularly unsuitable for eco-efficient disassembly and recycling because of the relatively low plastics weight and the high integration of the covers and the functional units resulting in high disassembly times.

In a TU Delft graduation project, for the above reasons a further analysis of the redesign options for the CDRCR was made. In this project, four different redesign avenues were considered for potentially improving the disassembly of a CDRCR aiming at relatively low disassembly costs and meeting the WEEE recyclability target. These avenues were:

- The use of already existing cover connections for tightening the functional units
- The use of disassembly friendly connections
- The use of a frame to concentrate all parts that are not disassembly targets
- The use of a disassembly-by-destruction strategy

For each avenue, not only the reduction in disassembly time was analysed, but also the effects on cost price for parts, assembly costs and repair time were assessed.

Based on a disassembly time of 640 seconds for the original product, analysis showed that the two latter avenues theoretically have the biggest improvement potential, as they reduce the disassembly time to about 170 seconds, which is almost a factor 4. In particular the disassembly-by-destruction strategy showed to also have benefits in terms of cost price and assembly costs. Also, by this strategy, the WEEE recyclability target would be met unambiguously. However, in order to be financially competitive with a shredding and separation scenario, it was shown that a further disassembly time reduction of 42 seconds would be required, representing a factor 5. In this project, further refining of the disassembly-by-destruction concept was done, both with respect to the required machinery (such as special punch machines) and the products themselves (incl. replacing wire connections with spring/connector connections, redesign of aerials and speakers).

Conclusions drawn in this disassembly analysis project included the following:

- Disassembly by destruction is probably the most feasible option for eco-efficient treatment of audio-waste, provided environmentally relevant substances can be retrieved this way.
- Using this strategy, recyclability targets will be met at relatively affordable costs per product.
- A positive effect is to be expected on assembly costs. Investments in machinery will have to be made by recycling companies.

- The effect on the Bill of Materials used in the products is uncertain. From a life-cycle perspective (both from an economical and an environmental perspective) this entails a considerable industrial risk.
- The method is widely applicable for most audio products.
- Good possibilities for automation.

The main conclusion from this project was that disassembly by destruction is the most obvious candidate for ensuring that recyclability targets for audio waste are met (something that is not the case with conventional disassembly nor shredding and separation strategies). However, the method is not ready for industrial implementation yet because of required investments by several stakeholders, and financial uncertainties depending on the exact nature of product redesign.

4. Conclusions

Although the sophistication of applied ecodesign has increased considerably since the days of counting screws in the early nineties, valid reasons for disassembly analysis continue to exist. These reasons go beyond counting disassembly times for reduction of end-of-life costs:

- With the inclusion of disassembly analysis as a part of Environmental Benchmarking, additional opportunities exist for the generation of environmental improvement options, and to improve products in comparison with those of competition.
- In the light of WEEE recyclability targets, disassembly analysis is essential for positioning various disassembly strategies as alternatives to shredding and separation – especially since the latter strategy may not satisfy WEEE recyclability requirements.
- As an additional benefit, disassembly analysis provides the opportunity to improve product architectures from a general perspective.
- The latter also provides options to reduce cost price and assembly costs.

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Eco-efficiency, the breakthrough

Eco-efficiency is defined as the ratio between environmental gains and the costs associated with achieving the gain. It had been applied to recycling before 2003 (see chapter 7.5) but since good and complete environmental metrics on recycling were lacking, this work had limited significance. This all changed with the QWERTY approach (see chapter 7.4).

But how to present results of Eco-efficiency calculations in a transparent way? Through figures and/or ratios alone? The problem of Eco-efficiency is a ratio; if either the numerator (the environmental effect) or the denominator (the cost) would be near zero, there is either no distinction at all or indefinitely high numbers come into play.

Maybe this is the reason why traditional environmentalists have avoided ratios and almost exclusively stick to absolute numbers.

Moreover, if the recycling does not represent a cost but brings a yield (or if the environmental effect of recycling is negative instead of positive), the ratio representation brings difficulties too. How to deal with such 'changes in sign'?

Jaco and I have been struggling with this issue for many hours. Finally we came to diagrams in which environmental effects were represented on the X-axis and money by the Y-axis diagram. The baseline situation (the situation before the recycling action, for instance landfill of electronic waste) which represents an certain environmental effect and a certain cost too is supposed to be located at the origin of the diagram. What is plotted is the relative change after the action, both in environmental and monetary terms. In this way there are four possible results: environmental gains combined with monetary gains, environmental gains at the cost of money, monetary gains at the cost of the environment and environmental losses combined with monetary losses.(see chapter 7.5)

Vector diagrams turned out to be very powerful in analyzing take-back and recycling. First of all it showed that for various product types (plastic dominated products, glass dominated products, metal dominated products, precious metal dominated products) the eco efficiency of recycling is very much different. This has important consequences in rule making (see chapter 8.3.1).

The Eco-efficiency diagrams turned out to be extremely useful in mapping the effects of all kinds of improvements agendas. In this way effects of design for recycling, applying different treatment technologies, effects of system organization (economy of scale) and changes in legislation can be quantified.

This quantification allows for the setting of priorities not just in one category of action but also between them. It turned out for instance that, generally speaking, achieving more economy of scale results in bigger Eco-efficiency improvements than design for recycling actions. Also recouping precious metals till the last part per million brings more for the environments than recycling kilograms of plastics.

Such considerations allowed for the creation of prioritized improvement agendas which include a mix of actions as collection, recycling and upgrading of materials allows to access impacts of design changes, technology investment and system organization.

In 2003 the first mature agendas (for short, medium and long term) were published (see chapter 8.2).

7.4 Quotes for Environmentally Weighted Recyclability (QWERTY)

Recycling performance is usually expressed as the ratio between the sum of the weight of materials recouped in some form, divided by the weight of the products subjected to the recycling treatment. Depending on how 'recouped' and 'form' are defined, a variety of definitions for recycling performance is possible. In 1998, when the first studies were done on the recycling effectiveness of shredding and separation of electronics, the first indications found that physical weight does not necessarily represent environmental relevance appropriately. In particular this became clear when the recycling behavior of cellular phones was considered. These products contain tiny amounts of gold and palladium, which determine not only to a large extent the economic value of the material streams after the recycling treatments, but their environmental value as well. The environmental values of materials (as determined by the Ecoindicator 95-method) are listed in the table below:

Table 7.4 Environmental value of materials

Material	Environmental 'value' (mPt/kg) according to Ecoindicator 95
Plastics	4-6
Iron/Steel	12-15
Aluminum	53
Copper	76
Nickel	380
Lead	580
Zinc	640
Silver	1500
Gold	100.000
Palladium	375.000
Platinum	560.000

This table shows that saving 1 kg of gold from being landfilled is, from an environmental perspective, 20.000 tons more important than saving 1 kg of plastics. For copper to iron the ratio is 5:1, for aluminum to plastics 15:1 etc.

For cellular phones these ratios mean that recycling 1 mg of gold is just as important as recycling of 20 g of plastics from an environmental perspective. Recycling of 1 mg Palladium is the equivalent of recycling 75 g of plastics.

Such findings made clear that it would be highly relevant to formulate a real environmental alternative for the weight based recycling performance criteria. It was realized however that several basic problems had to be solved in order to make it a real comprehensive approach. Such problems included:

- Including all environmental loads involved in end-of-life processing (collection, treatment, upgrading of secondary materials) in the performance calculation.
- Defining an appropriate scale on which the environmental performance is being measured. Should the scale be absolute, or should it be a relative system (comparison with a base line scenario like landfill or incineration)?
- How to deal with different levels of functionality in reapplication of the secondary materials ?

In 1999, there was the chance to hire Jaco Huisman as a Ph.D. candidate. He showed an eagerness to take on the subject and within a few months after his start in May 1999 came up with a remarkable concept that dealt with the problems listed above in an innovative way.

After this breakthrough, the QWERTY method was developed further. Additional methodology and data collection issues were successfully addressed.

- Differences in treatment behavior of plastics, glass, metal and precious-metal dominated products.
- Environmental characterization of streams of products of different type.
- Algorithms to transform product streams into secondary material streams
- Environmental performance of applying shredding/separation technology.
- Is the impact of end-of-life processing to be neglected?

The QWERTY theory and its applications were consolidated in a publication in 2002 called: "Quotes for environmentally weighted recyclability (QWERTY): concept of describing product recyclability in terms of environmental value". The paper is reproduced below. Its conclusion is that when the environmental performance of recycling is to be considered, QWERTY is far superior with respect to traditional methods based on physical weight. The application of QWERTY includes determination of design avenues, technology investments and environmentally appropriate recovery of materials. QWERTY can also be used to validate envisaged recycling legislation or to develop improvements of existing legislation like the European WEEE.

Quotes for environmentally weighted recyclability (QWERTY): a concept of describing product recyclability in terms of environmental value

J. Huisman, C. B. Boks and A. L. N. Stevels

Abstract

The quotes for environmentally weighted recyclability (QWERTY) approach focuses on the determination of environmentally weighted recycling scores rather than weight-based recycling scores. The concept describes the environmental performance of processing discarded products. It is very powerful in assessing the effectiveness of end-of-life processing, the consequences of design of products in relation to recyclability issues and the consequences of proposed legislation on take-back and recycling of consumer electronic products. QWERTY takes into account the 'environmental value' of secondary materials and the environmental burden of end-of-life treatment itself. The basic mathematical procedures for calculating QWERTY scores are presented as well as the application on the actual processing of different categories of consumer electronic products. For these categories, the complex decomposition behaviour into fractions has been modelled and integrated into the QWERTY calculations. Application of the QWERTY concept shows how well the primary environmental goals of takeback and end-of-life treatment, reduction of material depletion, controlling potential toxicity and reducing emissions can be achieved in practice. Applying the QWERTY concept on the end-of-life treatment of cathode ray tube containing appliances and cellular phones shows its value in assessing priorities in the field of policy, technology and design.

1. Introduction

Owing to increased attention for producer responsibility and take-back of products, the environmental performance of end-of-life processing of products has become important. Until now, product recyclability has mostly been calculated on a weight basis only, which is a poor yardstick from an environmental perspective and is scientifically very inaccurate. Moreover, calculations based on weight-based recyclability are likely to lead to incorrect decisions. At the Delft University of Technology, this notion has led to the development of the concept of quotes for environmentally weighted recyclability (QWERTY) for calculating product recyclability on a real environmental basis.

Proposed take-back and end-of-life processing legislation for the electronics industry, the so-called WEEE draft (Waste of Electric and Electronic Equipment), (Commission of the European Communities 2000), has primarily been set up out of environmental motives. The description of treatment performance and evaluation of recyclability targets should therefore also take place in environmental terms. Following this preposition, a number of items should be covered with an accurate measure of this performance:

- Measure should describe to what extent material loops can be closed, i.e. to describe on a material basis how much environmental resource value can be conserved.
- Measure should describe how much unwanted emissions to the environment are avoided on the short and long term. This applies, for instance, to leaching of heavy metals from landfill sites.
- Measure should indicate and prioritize from an environmental perspective the avenues for product (re)design for end-of-life treatment.
- Measure should give a proper description of the environmental performance of end-of-life treatment systems including the environmental load of logistics, processing and upgrading of materials.

The QWERTY concept, as explained here, can cover all these issues. In Huisman et al. (2000a, b), Huisman and Stevels (2001), and Huisman (2003) the concept was applied to several case studies, enabling, for example, comparison with the application of the traditional weight-based material recycling efficiency (MRE). Results show that the conventional MRE does not reflect the real environmental performance of a product's end-of-life treatment (Kalisvaart et al. 2000). In principle, this would mean that targets set in proposed take-back schemes, as stated in the draft WEEE Directive, should be revised. All underlying equations and basic assumptions of the QWERTY approach are comprehensively presented here for the first time.

A substantial amount of previous research has been conducted on mass balancing of disposed electronic equipment in end-of-life and the environmental consequences (Nordic Council of Ministers 1995a, b, European Trade

Organization for the Telecommunication and Professional Electronics Industry 1997, Zhang and Forssberg 1997, Ploos van Amstel Milieuconsulting BV 1997). Nevertheless, still limited overall environmental insights exist. Important aspects for analysis are detailed product compositions (trace amounts of toxic materials), specific behaviour of products in end-of-life processing (shredding and separation characteristics) and data from, for instance, primary and secondary metal smelters (recoveries of precious metals, heavy metal leakages). These data are rarely integrated in a detailed environmental evaluation of the end-of-life phase of consumer electronic products (Stevens 1999, Stevens and Ram 1999). With the QWERTY approach, all the elements mentioned above are integrated into one environmentally based recyclability concept. The literature also has some methods that are already available, describing recyclability or recoverability indicators, but, without exception, they all focus on single issues, themes or target groups, such as, for instance, the designer or the recycler (Mathieux et al. 2001, Stobbe 2001). In comparison with these 'performance indicators', the strength of the new and in itself unique QWERTY concept lies in its rethinking-character of recyclability in terms of real environmental value of materials instead of recovered weight.

Environmental value is defined here as the value or load calculated for a certain material or material processing using an environmental assessment model, such as life cycle assessment (LCA). End-of-life routes are defined as the additional processes after disassembly or shredding and separation as mentioned above. End-of-life treatment scenarios are defined as a set of (different) end-of-life routes for the material fractions resulting from shredding and separation and/or disassembly. The theoretical framework, including all equations to calculate QWERTY scores, is presented in Section 2. All requirements, and further assumptions and underlying data needed to conduct environmental assessment on discarded products are presented in Section 3. The practical application of QWERTY is explained further in Section 4 with a few examples. Conclusions are drawn in Section 5.

2. QWERTY concept, basic equations and assumptions

2.1. General idea behind QWERTY

The general idea behind the development of the QWERTY concept is to determine an environmentally justified alternative for MRE. Instead of measuring recyclability in terms of weight recovered per kilogram of product, the QWERTY score is based on the net 'environmental value' recovered over the 'total environmental value' of a product. To achieve this, the different material fractions of a product are weighed on an environmental basis, including the environmental impacts of end-of-life treatment itself.

In either case, MRE or QWERTY, the recyclability of a product cannot be determined 'as such', but depends on an assumed end-of-life scenario for a product. As every end-of-life scenario has an (positive or negative) environmental impact, the aim of the QWERTY concept is to relate the score to realistic best- and worst-case scenarios. To do this, a QWERTY score is always determined in relation to a well-defined theoretical minimum environmental impact, 'lower boundary', and maximum environmental impact, 'upper boundary'. For the determination of the environmental impact of a product within an end-of-life scenario, the recovery percentage of the processing techniques and the associated environmental scores for recycling or treatment of non-recovered material fractions are calculated. The starting point is a disposed product, economically or technically so old that higher levels of reuse options are not attractive. As illustrated in Rose and Stevens (2001), for the majority of consumer electronic products, opportunities for environmentally justified reuse or lifetime extension are very limited or even counterproductive. This is mainly due to much lower energy consumption levels of new products. Rose and Stevens present calculations, analysing the reuse potential for a certain product or product category. When a reuse potential is expected, such calculations should precede the application of QWERTY.

Figure 1 illustrates the starting point for the further explanation of the QWERTY context. It is shown here that material fractions leaving the pretreatment and shredding and separation stage, for instance, can end up as materials either to be landfilled, directly emitted, incinerated or used in the substitution of primary materials. The latter case is what is usually referred to as recycling. The conventional approach of calculating weight-based recyclability scores only addresses this route by taking the weight percentage of materials ending up in this fraction, without taking into account the environmental load of previous pretreatment, shredding, separation and upgrading steps. Furthermore, the remaining fractions can still cause potentially toxic materials to be emitted to the environment

while on a weight basis it is suggested that a good end-of-life performance is obtained.

The QWERTY concept also addresses, besides the amount of material ending up in each fraction, the 'environmental value' of each material fraction for every end-of-life route. Especially, the replacement of primary materials can vary substantially for different materials because of differences in the prevented environmental load.

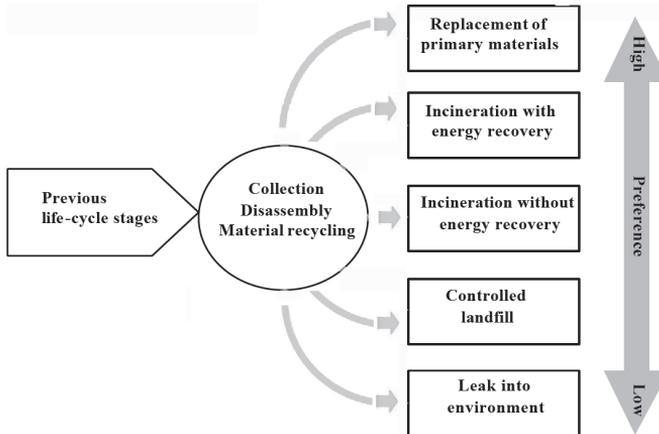


Figure 1. Simplified end-of-life treatment structure.

This is due to substituting for the environmental load of the corresponding primary material production. Note that the 'order of preferences' in figure 1 is a general order often given for products as a whole. For specific materials or material fractions, the environmentally preferred order can be different than depicted in figure 1 as will be explained further in Section 2.3.

To calculate QWERTY scores, first the lower boundary or minimum environmental impact is defined representing a 'best case' end-of-life scenario for the product or product stream under investigation. Second, also a 'worst-case' end-of-life scenario or upper boundary for the same product is determined. Then the relevant actual end-of-life treatment is determined and the distances between this scenario and the lower and upper boundaries is measured. As the upper boundary is set at the 0% level and the lower boundary at 100%, consequently the actual environmental impact is a percentage in between (figure 2).

The result is the QWERTY score. The individual contributions of every material to the final score can also be determined. The whole procedure can also be applied to product categories, single components, assemblies or even product streams.

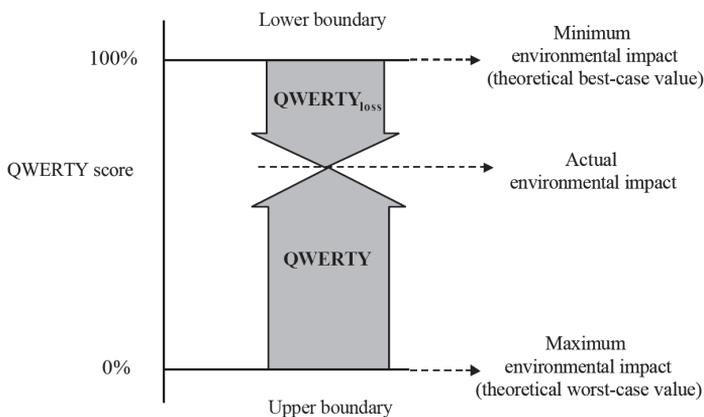


Figure 2. Calculating QWERTY scores.

2.2. Definition of the lower boundary

The lower boundary or minimum environmental impact as depicted in figure 2 is 'the best possible case' and defined as all materials recovered completely without any environmental burden to achieve this. More precisely, every material is recovered in its initial amount and grade without any environmental burden of treatment steps. Obviously, this is an unreachable, and therefore a fixed theoretical optimal situation.

Equations (1a) and (1b) describe this definition of the lower boundary:

$$EVW_{\min,i} = m_i \times EV_{\text{subst},i} \quad (1a)$$

$$EVW_{\min} = \sum_{i=1}^{\infty} (m_i \times EV_{\text{subst},i}), \quad (1b)$$

where $EVW_{\min,i}$ is the defined lower boundary/minimum environmental value for the weight of material i ; $EV_{\text{subst},i}$ is the environmental substitution value for the extraction of raw material for material i , measured with a relevant environmental impact assessment score; m_i is the weight of material i within the product; and EVW_{\min} is the total defined lower boundary minimum environmental value for the complete product.

The environmental substitution values in equation (1) can be measured with any suitable environmental assessment method (as further explained in Section 3). Equation (1) describes the avoided environmental impact associated with the recycling and subsequent reuse of all materials in a product. This part of the environmental impact is taken into account by determining the environmental value of primary material that is actually substituted and must therefore not be extracted from ores (metals) or to be manufactured (in case of plastics). It may be helpful to note that in all equations a positive environmental impact means environmental burden, whereas a negative one means an avoided environmental burden, which is referred to as an environmental gain. Therefore, the $EV_{\text{subst},i}$ and EV_{\min} are usually negative values.

The basis for the lower boundary is subject to choice, but there is substantial reason for choosing the situation sketched above. Any choice based on other scenarios requires additional arbitrary choices to be made regarding the level of environmental impact that must be assumed. The currently chosen boundary only depends on the product's material composition and is independent of the many possible treatment scenarios. Still, the QWERTY concept is not limited to the above choice for the lower boundary. If a strong preference exists for assuming other definitions, which is definitely not recommended, these can easily be implemented.

2.3. Definition of the upper boundary

The definition of the upper boundary or maximum environmental impact is the 'worst-case scenario' and is defined as every material ending up in the worst possible (realistic) end-of-life route, including the environmental burden of pretreatment: collection, transport, disassembly and shredding and separation into fractions. Important in this definition is that not one single end-of-life route for the product as a whole is selected, but the total set of, sometimes, different end-of-life routes for every material.

The reason for not choosing a single end-of-life route for the product as a whole is that some materials have very high environmental impacts on land-fill sites due to high leaching percentages and high toxicity values for emissions to soil and water (for instance known for lead, nickel and antimony). Whereas other materials, with high toxicity values for emissions to air (for instance mercury, cadmium and arsenic), can have high transferrals to the gas phase in incineration processes, combined with relatively low capturing percentages within the flue gas cleaning system and thus resulting in high environmental impacts. In other words, this definition is reflecting the fact that the order of end-of-life treatment preferences is different for every material (Vogtländer 2001).

Calculations have shown for this definition that the highest environmental impacts for most materials occur in two routes, or uncontrolled landfilling with maximum leaching to water and soil over a century (which is a common worst-case assumption in this field), or incineration, without energy recovery and limited traditional wet flue gas cleaning, including all leaching from slag from residues. In some cases, materials can have high environmental impacts in one of the other 'realistic' scenarios (like metal smelting, controlled landfill, plastic recycling or glass oven). As a mathematical consequence, in the formulas (2a) and (2b), the highest 'worst case'/maximum environmental

impact will be determined by taking the maximum environmental impact value for material i out of all the 'realistic' end-of-life routes.

Another practical benefit of this definition is that the total maximum environmental impact value can only be exceeded under 'unrealistic' conditions. In the calculation of the contribution of different materials to the total QWERTY score, no negative values occur. These negative values are not a mathematical problem within the concept, but can be difficult to interpret in practice (in examples like table 2, no negative QWERTY or QWERTY-loss values occur for any of the materials). Scenarios excluded in this definition are the 'unrealistic' scenarios, like, for instance, uncontrolled incineration without any gas cleaning (which can cause instantaneous health and safety problems and is obviously prohibited). Scenarios like this are in practice 'falling off' the scale. The definitions of the upper boundary are given in equations (2a) and (2b):

$$EVW_{\max,i} = m_i \times (EV_{\max\text{col},i} + EV_{\text{pretr},i}) \quad (2a)$$

$$EVW_{\max} = \sum_{i=1}^{\infty} (m_i \times (EV_{\max\text{col},i} + EV_{\text{pretr},i})), \quad (2b)$$

where $EVW_{\max,i}$ is the defined upper boundary/maximum environmental value for the weight of material i ; $EV_{\max\text{col},i}$ is the maximum environmental impact for material i in the end-of-life scenarios under investigation, e.g. the 'worst-case' scenario (usually or incineration without energy recovery, or uncontrolled landfilling); $EV_{\text{pretr},i}$ is the aggregated environmental value for material i undergoing pretreatment steps (transport and storage, complete shredding and separation); and EVW_{\max} is the total defined upper boundary or maximum environmental value for the complete product.

The reason for including the pretreatment part in the definition is the fact that the energy needed for pretreatment and the energy needed for shredding products is relatively high. For the current definition where the part of the upper boundary depending on certain processing steps, the assumed pretreatment is dominated by the energy to shred the disposed products into small pieces. This energy consumption is rather independent of the product composition and a relatively stable value. If a strong preference exists for assuming other definitions for the upper boundary, which is definitely not recommended, these can easily be implemented.

2.4. Determining the actual environmental impact

The actual environmental impact of a certain product (figure 2) in a certain end-of-life scenario is represented by equations (3a) and (3b). The actual impact for the total amount of material i , is the sum of all this material ending up at the end-of-life destinations as represented by figure 1, multiplied with the corresponding environmental value for this direction. Here, all pretreatment, shredding and separation and recovery steps are included. The environmental value of recovered material, as well as the 'environmental costs' for all necessary shredding and separation steps are represented this way:

$$EVW_{\text{actual},i} = m_i \times \left(EV_{\text{pretr},i} \times x_i + \text{rec}_i \times \text{grade}_i \times EV_{\text{subst},i} + \sum_{j=1}^{\infty} (EV_{\text{col},ij} \times y_{ij}) \right) \quad (3a)$$

$$EVW_{\text{actual}} = \sum_{i=1}^{\infty} \left(m_i \times \left(EV_{\text{pretr},i} \times x_i + \text{rec}_i \times \text{grade}_i \times EV_{\text{subst},i} + \sum_{j=1}^{\infty} (EV_{\text{col},ij} \times y_{ij}) \right) \right), \quad (3b)$$

where $EVW_{\text{actual},i}$ is the defined actual environmental value for the weight of material i for the EOL scenario under consideration; x_i is the percentage of material i undergoing the defined pretreatment steps; rec_i is the

percentage of material i being recovered and substituting its corresponding primary material; $grade_i$ is the grade in which material i is occurring after recovery (only relevant for recovered material with a different level of reapplication compared with the original material); $EVeol,ij$ is the environmental value for material i going into end-of-life route j ; y_{ij} is the percentage of material i ending up in end-of-life route j ; and EVW_{actual} is the defined actual environmental value for the complete product and the EOL scenario under consideration.

In equation (3), the pretreatment steps and the actual recovery of materials is described separately from possible end-of-life routes. Although in the end probably only a part of a material fraction is actually recovered, the product is likely to undergo the end-of-life treatment as a whole. Therefore, all environmental burden of pretreatment steps is allocated to the whole product on a weight basis. The $EVeol,ij$ represents the environmental value of the part of material i which ends up in a certain end-of-life route, for instance incineration. The total amount of material i ending up in each end-of-life route plus the actual amount of i that is recovered, must equal 100% as represented by equation (4). Usually, the $EV_{pretr,i}$ and the $EVeol,ij$ are positive values, the $EV_{subst,i}$ is a negative value:

$$\sum_{j=1}^{\infty} y_{ij} = 100\% - rec_i.$$

In equation (3), an important parameter representing the grade of secondary materials in comparison with the original grade is used. Except metals that are recovered in their original grade at their corresponding primary smelter, other secondary materials are usually not recovered in their original form. In particular plastics are usually not recovered with the same quality of the original material due to degradation. In addition, glass for instance, is not very often used in its original form, but in a lower quality or as a slag former in thermal processes. So for metals recovered at a corresponding smelter this value will be 1, for materials undergoing degradation or quality loss, it is the quotient of the environmental value of the secondary material over the environmental value of primary material.

2.5. Determination of the actual QWERTY score

With the determination of the actual environmental impact, a figure is calculated that represents an absolute value for the weighted environmental impacts of a particular product in the end-of-life stage. With this absolute figure, it is not yet transparent whether the results are good or bad from an environmental perspective. A normalization step is performed to obtain QWERTY scores that can easily be interpreted (and thus be compared with traditional weight-based recyclability scores). The product's actual end-of-life performance is always positioned in between the upper and lower boundaries and leads to the QWERTY value by applying equation (5). Similarly, the $QWERTY_{loss}$ is the distance of the actual environmental impact from the minimum environmental impact, as represented by equation (6).

$$QWERTY_i = \frac{(EVW_{actual,i} - EVW_{max,i})}{(EVW_{min} - EVW_{max})} \quad (5a)$$

$$QWERTY = \sum_{i=1}^{\infty} \left(\frac{(EVW_{actual,i} - EVW_{max,i})}{(EVW_{min} - EVW_{max})} \right) \quad (5b)$$

$$QWERTY_{loss,i} = \frac{(EVW_{min,i} - EVW_{actual,i})}{(EVW_{min} - EVW_{max})} \quad (6a)$$

$$QWERTY_{loss} = \sum_{i=1}^{\infty} \left(\frac{(EVW_{min,i} - EVW_{actual,i})}{(EVW_{min} - EVW_{max})} \right), \quad (6b)$$

where $QWERTY_i$ is the amount in which material i contributes to the total QWERTY score (%); $QWERTY$ is the QWERTY score for the complete product; $QWERTY_{loss,i}$ is the amount in which material i contributes to the total QWERTY loss score (%); and $QWERTY_{loss}$ is the QWERTY loss score for the complete product:

$$\text{QWERTY} + \text{QWERTY}_{\text{loss}} = 100\%. \quad (7)$$

In addition, equation (7) is always valid. The QWERTY score expresses the environmentally weighted recyclability of a product under a certain end-of-life scenario; the QWERTY_{loss} score expresses the distance to the best possible performance. Both scores can also be expressed per material present in the product, which is exactly one of the main strengths of this concept. (In practice, equation (7) also helps to check whether the assessments made with the QWERTY score were consistent.)

3. Requirements and assumptions

In Section 2 gives the generally applicable equations of the QWERTY concept. The practice of assessing the environmental aspects of disposed consumer electronic products leads to a number of requirements and assumptions necessary to evaluate the end-of-life of consumer electronic products. These requirements and associated assumptions deal with the following issues:

- Quantified environmental values based on environmental assessment models (Section 3.1).
- Product material compositions (Section 3.2).
- Description of end-of-life scenarios (Section 3.3).

These issues are highlighted below.

3.1. Quantified environmental values based on environmental assessment models

The basic QWERTY concept described in Section 2 uses 'environmental values' (equations 1–3). These values can be derived from any comprehensive method that produces these scores, but also methods focussing on a single environmental effect, like, for instance, eco toxicity or resource depletion, can be used. Recently, two life cycle assessment (LCA) methods and one method focusing on a single environmental theme were integrated in the QWERTY concept: The Eco-Indicator '95 (Goedkoop 1995), its successor, the Eco-Indicator '99 (Goedkoop and Spriensma 2000) and the EPS 2000 method (Steen 1999):

- Eco-Indicator '95 is a classical, so called problem-oriented approach, LCA method. The method addresses eleven environmental themes from, nine of which are included in the normalization and evaluation steps, leading to a single environmental score. This method has been widely used and is especially preferred by product designers and companies because of the resulting endpoint scores.
- Eco-Indicator '99 is a new, so-called damage-oriented LCA method. The approach is also called a top-down LCA method since all contributions to all environmental effects are translated to actual damage inflicted to eco-system quality, human health and resource depletion. Thus, this method is very different from its predecessor. It can also be regarded as more transparent, while at the same time different perspectives towards the environment are taken into account and quantified.
- EPS 2000 method, which stands for Environmental Priority Strategies in product design. It is adjusted for damage assessment and also a top-down approach. The EPS system is mainly aimed to be a tool for a company's internal product development process. In addition to these three methods, other alternative methods like the German TPI Toxic Potential Indicator (Nissen et al. 2000), the Swiss Ecopoints '97 (Braunschweig 1998), the Dutch CML method (Heijungs et al. 1992) and the Danish EDIP (Wenzel et al. 1997) can be integrated as well to check the consistency of QWERTY scores obtained. In the remainder of this paper, the Eco-Indicator '99 method will be used as a default as it is the most modern method available.

Further considerations with respect to the use of LCA methods and methodologies for providing environmental values are enumerated below:

- In LCA, there is always a 'subjective' evaluation step involved to weigh different environmental themes and to produce a single end-point score. This is inherent to aggregated environmental scores of any kind. One reason for choosing the Eco-Indicator '99 is that compared with other LCA methods, it is the most transparent one regarding influence of different environmental perspectives and opinions of all factors that influence the final

end-point score (and not only the final weighting step). It is also possible to integrate single themes used in LCA methods within the QWERTY calculations, which provides the final weighting step not to occur, but it limits the relevance of results to single environmental themes only.

- Starting point of the QWERTY concept is not the same compared to LCA. The focus of QWERTY is on the product's end-of-life, while LCA methods regard the full life cycle of products, hence different system boundaries and allocation rules apply. Owing to this different starting point, the QWERTY concept regards materials that are not recycled as causing extra environmental load by extra raw material extraction. Owing to this choice, many problems with allocation and the definition of system boundaries are prevented (Ekvall and Tillman 1997).
- An important requirement is an environmental database providing environmental values for all relevant end-of-life processing steps and materials. For all relevant processing of materials, the mass and energy balances must be transferred to corresponding environmental values. Especially for the end-of-life phase of products, there are usually many data gaps within current LCA databases. For QWERTY assessments, the Philips internal LCA database is used (Van der Wel 2000), as this database contains a sufficient amount of data on materials, components, end-of-life processing steps, energy consumption, emissions and contribution of related processes. In the examples of Section 4, the standard available databases within the LCA software tool SIMAPRO are used (Pre' Consultants 2002).

3.2. Product composition and levels of detail

To apply the theoretical outline of the QWERTY concept, a full and as accurate as possible chemical composition should be known, or at least be assumed in cases where only rough figures are available. To deal with this issue in practice three levels of detail are defined:

- Level 1: only the main materials are known, being the copper, ferro, aluminium, glass, plastic and rest content. Experience has shown that with these materials, per product category, good estimations can be made for both the actual product composition (Philips Consumer Electronics 2001) and the distribution of materials over the relevant end-of-life routes (Huisman and Stevels 2001). In practice, this means that rough QWERTY assessments can be made, based on the six aforementioned materials alone. Exceptions are single products with, in comparison to their product category, high amount of toxic materials or precious metals.
- Level 2: amount of all relevant materials and their average distribution over all occurring fractions are known. In this case, the processing applied to, for instance the copper fraction is allocated only to the materials recovered from this fraction. The copper lost to other fractions from which it is not recovered only adds to the corresponding value to the QWERTY loss value. In practice this means an extra loss due to materials ending up in the 'wrong' fraction, which can be quite substantial. The data behind this level of detail will be further explained in Section 3.3.
- Level 3: whenever a product composition is known in full detail and the specific distribution of all materials over all fractions and end-of-life destinations is known as well, the equations of Section 2 including all environmental values for every material can be applied in their fullest form for every possible material. This will in practice rarely be the case, as analysing product compositions on this level of detail requires substantial effort, which is very costly. Moreover, the decomposition behaviour and mixing of materials within various end-of-life processing steps is usually so complex, that only average distribution percentages of materials over fractions will be known.

Based on the above reasoning, the most accurate assessments in practice will be that of level 2.

3.3. Description of end-of-life scenarios and data

The distribution percentages, mass and energy balances of the end-of-life processing of disposed consumer electronic products that belong to the previously indicated level 2, have been described in literature. Many data is available from one of the subprojects of the Dutch SENTER—IOP Heavy Metals—Consumer Electronics research. This data, published in Ansems and Feenstra (2002) are obtained from many literature sources and from contacts

with Dutch and German recyclers. Out of these literature sources, three calculation modules were derived describing the distribution of all environmentally relevant materials over all fractions and end-of-life routes. Three types of treatments, with process-step sequences representing the European situation, are implemented in the QWERTY approach. The three modules are as follows:

- Shredding and separation of non-CRT browngoods.
- Disassembly of housings and CRTs, followed by shredding and separation of the remaining, for CRT-containing browngoods.
- Separate collection from the non-CRT stream of cellular phones by shredding and separation.

In Huisman et al. (2001), these three calculation modules have been introduced. In the next section these data and the implementation of them into the QWERTY concept will be highlighted using examples, which are representative for the issues mentioned in the introduction about the roles of policy, technology and design.

4. End-of-life scenarios and examples

4.1. Product composition versus fraction composition, CRT based appliances

To exemplify how the QWERTY approach works, the calculation module referring to the treatment of CRT-containing browngoods, will be used. In this case processing starts with a disassembly step. Housings are removed, resulting in a plastic fraction. Picture tubes are also treated in a separate process and are mainly converted to a glass fraction. The remaining parts, including PCBs, are converted to a copper, ferro, aluminium and a residue fraction. This process sequence is illustrated in figure 3.

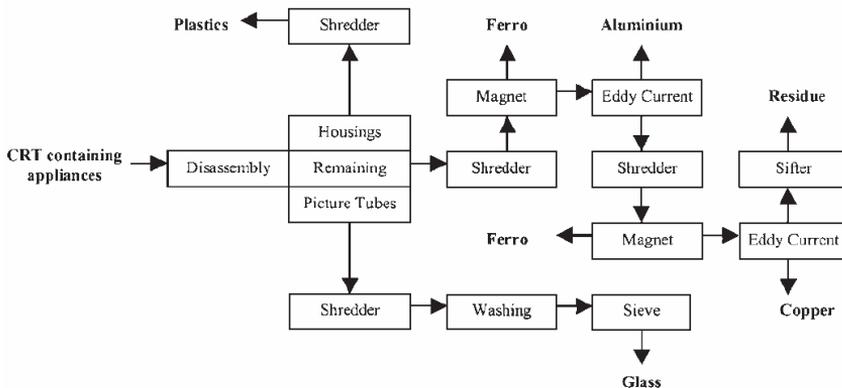


Figure 3. Disassembly, shredding and separation of CRT-containing appliances.

The calculation module corresponding with figure 3 estimates the average distribution percentages of the original materials over all fractions being created as well as for the further processing of these fractions. When a specific (ingoing) product composition is entered, the module calculates estimates for the amounts of all relevant materials for all (outgoing) fractions. In the connected LCA database, the corresponding environmental data for a number of subsequent end-of-life routes are known and the equations of Section 2 are applied. In table 1, the result for atypical material composition is given (a 1 kg CRT containing appliance).

Table 1 shows that, for instance, for the copper in the product, approximately 80% of the original copper ends up in the copper fraction, a little under 10% in the ferro fraction and almost all of the remainder in the residue fraction. Out of this 80% copper ending up in the copper fraction, approximately 95% is recovered at a copper smelter. The copper in the other fractions usually ends up in slag. Leaching from slag is included in the relevant environmental scores for (in this case) the ferro fraction and the residue fraction. The loss due to the copper not being recovered and the final copper emissions due to leaching from slag are both allocated to the total copper amount of the product. Note also that the disassembly of the CRT-glass and plastic housings aims at a better separation, not at collection parts for reuse.

Table 1. Product versus fraction composition for an average CRT-containing appliances.

	Weight (g)	Fraction out (g)	Percentage of original material in the 'right' fractions
Ferro	169.6	182.1	95.7
Aluminium	29.5	13.8	42.6
Copper	34.7	39.5	80.1
Plastic	210.6	155.4	73.7
Glass	548.7	539.6	95.7
Other	7.1	69.5	95.0

To make comparisons with the traditional way of addressing recyclability, the most common equation for material recycling efficiency is given in equations (8a) and (8b). As stated above, the definition of MRE in many legislative documents is not a very unambiguous one. For instance, the energy recovery from plastics is in some cases (very arbitrary) taken into account as 50% material recovery and in other cases even as a 100% material recovery (Kalisvaart et al. 2000):

$$\text{MRE}_i = m_i \times \text{rec}_i \quad (8a)$$

$$\text{MRE} = \sum_{i=1}^{\infty} (m_i \times \text{rec}_i), \quad (8b)$$

where MRE_i is the contribution of the weight of material i to the material recycling efficiency; and MRE is the total material recycling efficiency for the whole product weight and the corresponding EOL scenario under consideration. For the example of table 1, the resulting MRE and the QWERTY scores and losses (based on Eco-Indicator '99) are presented in table 2 and figure 4. They show the contribution of every material to the total QWERTY score plus the QWERTY loss value as can be calculated with the equations (5) and (6).

Table 2. QWERTY results for a CRT-containing appliance.

	MRE	QWERTY	QWERTYloss
Ferro	15.3	4.0	3.7
Aluminium	2.4	2.1	3.6
Copper	3.3	14.0	6.3
Plastic	0.0	3.3	31.6
Glass	43.9	12.7	15.7
Other	0.0	0.3	2.8
Total	64.8	36.4	63.6

Contribution to the QWERTY definition

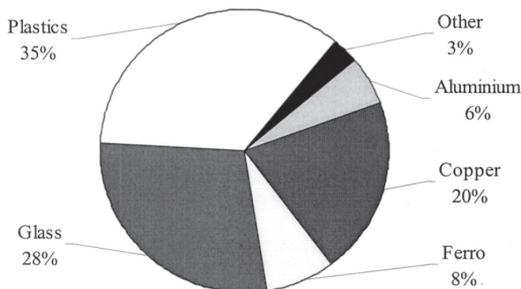


Figure 4. Average contribution of materials to the QWERTY definition (including loss) for an average CRT-containing appliance, based on the Eco-Indicator '99.

The contribution of materials to the total QWERTY score is completely different from the contribution to the total MRE score, as materials are not contributing according to their 'weight', but rather their 'environmental weight'. Moreover, for plastic dominated products this effect is even greater, because the relative importance of the copper content is much higher compared with the plastic content (under the assumption that the plastics do not contain flame-retardants). The relative contributions of materials, calculated with the QWERTY concept are therefore likely to lead to different priorities for design for end-of-life activities, while the conclusions from figures like figure 4 can lead to different priorities for primary material selection and can show, for instance, the relevance of addressing unlocking properties for copper containing components. The unlocking properties of those components can be altered by both appropriate design on one hand, and by optimizing shredding and separation process settings on the other hand.

4.2. Separate collection of cellular phones

An example of the influence of logistics is the optional treatment of cellular phones. They can be collected separately or as part of a stream of non-CRT containing appliances. For separate treatment, which is, if the numbers of disposed cellular phones are sufficient, in fact the best choice from both an environmental as an economic perspective, because in this way precious metals are recovered to the highest extend, a calculation module similar to that of figure 3 is used, with only two separation steps, using an eddy current process and a magnetic separation process. Subsequently, only two fractions are created, a relatively pure ferro fraction and a copper fraction containing all plastics and precious metals.

Figure 5 shows the difference in QWERTY scores for the same average cellular phone in the two end-of-life treatment scenarios. The results are shown for three different environmental assessment models already included in the QWERTY concept (see also Section 3.3). Assuming that a substantial amount of discarded cellular phones can be collected, it is shown that it is indeed better to treat them separately and not as part of the regular product stream with non-CRT containing appliances. The reason is that with more than one separation step, which means increasing the copper percentage of the copper fraction, too much of the precious metal content is lost (together with an amount of copper) to other fractions. In contrary to the QWERTY score, the MRE values would drop for the above example from 34% for treatment with non-CRT appliances to 31% for separate treatment. This is showing again that environmental policies should focus more on collection rates and optimized logistics than on the importance of weight based recyclability targets.

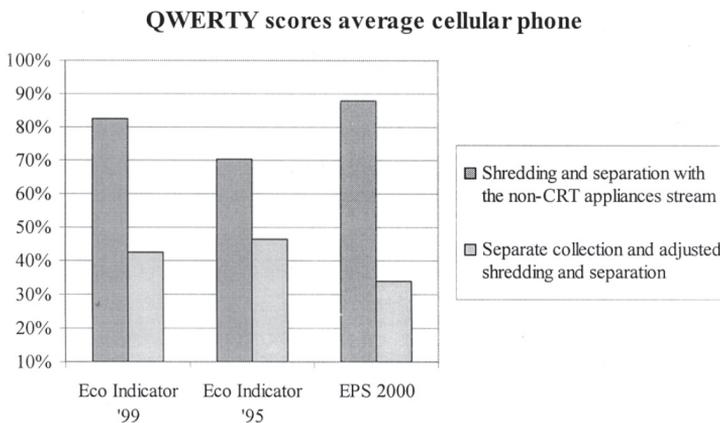


Figure 5. QWERTY results for an average cellular phone: separate treatment versus treatment as a part of the non-CRT appliances stream.

5. Conclusions

The QWERTY concept is a prime method to assess a product's end-of-life treatment from an environmental point of view. From both an environmental and a scientific perspective, it is to be preferred over conventional, weight-based approaches to assess recyclability scores. The main advantages of the QWERTY concept include weighing the different material contents with respect to their environmental impact and the potential to integrate the environmental losses, caused by a variety of treatment steps. Furthermore, the opportunity to include more than one environmental assessment model meets the wishes of a research community, in which still many different preferences regarding environmental assessment models exist. In that sense, the basic QWERTY equations are independent of personal preferences for assessing environmental impacts. Depending on the availability of data, QWERTY scores can explain in detail where the environmental impact of products in the end-of-life stage originates, and where the best potentials for improvements are. It has been explained that even with limited product and process data, very meaningful results can be generated.

The practical application of the QWERTY concept is manifold. In industrial applications, the concept supports priority setting as regards the environmental relevance of different materials. This in turn enables the determination of design avenues, technology investments and appropriate material recovery focusing in general. From a chain perspective, application of the QWERTY concept has been used to validate current draft legislation and the end-of-life processing practice. It has been shown, for example, in the cellular phone processing case study, that separate processing of products or product categories is to be preferred over combined processing. If such results were to be acknowledged, this would imply resetting targets for recyclability as done in WEEE (draft) legislation. This clearly shows that the QWERTY concept could also be useful as a tool for policy makers.

In the near future, the current research will be extended to include the following topics:

- Further development and implementation of new end-of-life scenario modules, for instance pyrolysis of disposed products and of specific fractions.
- Development of more case-specific environmental indicators.
- More accurate descriptions of the leakage of heavy metals and other environmentally relevant materials to the environment, resulting in more accurate environmental data on further process steps like incineration and landfill of remaining fractions.
- Quantification of the effects of initial design decisions, for instance the use of lead-free interconnection techniques rather than traditional techniques.
- Evaluation of the eco-efficiency of take-back and recycling policies.

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A Sleepless night in Taiwan

It all started well. We had gained credibility at the Monitors Business Group in Taiwan, particularly with the disassembly exercises (see chapter 7.3) and the benchmarking (see chapter 6.3) which contributed to the perception that environmentalists from Eindhoven could really help to move the business forward. The environmental benchmark had hit the jackpot; it demonstrated that products of Sony and Samsung were better – and not just from an environmental perspective. There was too much material being used in the Philips' products, the product architecture was too complicated and the cables and wires were an unorganized mess.

Therefore the proposal to do the environmental brainstorm for the next product generation had been accepted. Trusting that this would work out was still an issue. I had to promise to keep the business perspective, no environmental boy-scouting.

When I arrived in Taiwan, the taxi-driver who was to bring me to my hotel was arrested – he did not have a taxi license. Since I was supposed to be the principal, I was taken for questioning too. It was fortunate for me that I could provide a fax (yes, it was still the era of faxes) where I had asked the hotel to send a taxi to pick me up – I was released after two hours!

This left me still facing a problem which I had already been thinking about a lot during the flight without finding a real good solution. How to bring the business perspective into the environmental brainstorm on the next day. On one hand this is absolutely necessary for obvious reasons. On the other hand when money talk takes over 'green' is often lost within the first five minutes of the session.

The nice executive suite I got as compensation for the trouble during the day, did not put me at ease. I kept pondering what would be the best approach. Finally I arrived at the word 'benefit'. The word can mean material (money) or immaterial and emotional benefit, all of these count. Combine these with benefit for the environment, the company, the consumers and society and the EcoDesign matrix is born. Add feasibility (technical, financial society) and with help of the matrix a qualitative but decent priority list can be developed. But the question remained: how to kill money talk upfront? It cannot be done, so the best thing to do is to postpone it during the program. The schedule became environment in the morning, money in the afternoon with the Ecodesign-matrix as the bridge.

At that moment it was 3.30 in the morning and finally I could get to sleep.

The next day everything went smoothly and it was a big success. More than 50 'green' options were generated. With the help of the EcoDesign-matrix 12 options were selected to be included in the concept consolidation (combined with results from other brainstorms like the mechanical one, the electrical one, the software one, the marketing one, etc). Seven or eight of the survivors made it into the product specifications. A high hit rate due to the co-selection done based on business and consumer benefits and a proactive feasibility analysis.

The resulting product won the Philips Award for the best 'Green' product in 1998. The best news was that the product sold well. In bids from OEMs (computer companies) Sony and Samsung were beaten due to superior performance, including 'green'.

7.5 Eco-efficiency of take back and recycling

7.5.1 Cost Models

Of all the adventures in EcoDesign, making models to assess the end-of-life costs of electronic products has been the most challenging one. Many research groups in the world have addressed this problem. At DfS in Delft and at Philips Consumer Electronics there has been a lot of activity as well.

The table below gives a historical development of all this work. In subsequent years nine models in total have been studied. All of them have contributed in some way to the Eco-efficiency model (see 7.5.4) which has now been in use for six years.

Table 7.5 Cost models for end-of-life. An X indicates which items are addressed

Name of Model	Year	Design	Treatment	System organization	Environmental Performance	Business Performance
Design Evaluation	1995	X	-	-	-	X
Fee-differentiation	1995	-	-	X	-	X
From DOTTY	1996	X	-	X	-	X
Parametric estimation	1997-1999	-	-	X	-	X
Eco-efficiency old style	1999	X	-	X	X	X
PMRCM	1999-2002	X	-	-	-	X
QWERTY	1999-2002	-	-	-	X	-
Eco-efficiency	2001-present	X	X	X	X	X

From this table it can be seen that most of the drivers to make cost models (design/product-architecture, treatment, take back system organization and environmental and business performance) have been addressed from the very beginning. Until 2001 none of the models addressed all aspects in a comprehensive way. However, all of them represented 'bits and pieces', on the basis of which more advanced models could be built. This culminated in the Eco-efficiency model respect; due the depth of its assessment it is suitable for a broad range of applications (see 7.5.4).

The work on cost models started in 1995, at the very beginning, with a project called, "Design evaluation based on end-of-life cost". A student named Wendy addressed it. She was smart and solved the issue of how 'deep' disassembly should go by introducing a 'hierarchical' principle. This principle entails that cost and proceeds of further disassembly of a unit to be considered are compared with the costs/proceeds of no further disassembly. In this approach a product can be presented as a 'tree' consisting of a trunk, branches, sub branches and twigs. By making the comparisons at the different levels of the tree structure it can be identified what is the most economical way to cut the tree into pieces (the most economical way of disassembly). This is an example of a comparative (relative consideration) approach. This was revolutionary at a time when there was only 'absolute' thinking in the environmental world.

Parallel to this, there was work on 'Fee differentiation'. This was done to find out whether the core proposition of producer responsibility was applicable to recycling issues. In this case the proposition is that if producers are made responsible for recycling costs, they would redesign their products in such a way that recycling costs would become zero or even become proceeds. If this was true, design for recycling would give companies a competitive advantage. As a consequence take-back should preferably be organized on the basis of individual companies. If it was not true it would be better to organize collectively to benefit from economy of scale.

The outcome of this work (1995) was:

- Recycling costs will continue to exist for at least the first ten years to come. In 1998, it was found that even the best designed plastic and glass dominated products the recycling costs remained, the cost deficit is therefore structural, see chapter 8.2.
- In 1995 there was a difference of a factor of 2 in between the cost of recycling Philips TV sets (the lowest recycling cost) and the highest one identified. However, for competitors with a high market share as Sony and Panasonic the factor was about 1.3 at that time. This meant that initially Philips proposed to go for an individual take-back system.

Soon this changed to support for collective systems because of the conditions which were set by the Dutch Government to obtain a fee to cover the recycling costs (see 8.2).

In later years this decision was further supported by evidence that most Philips Consumer Electronics products had a structural recycling cost deficit. Moreover it was calculated that for reducing recycling costs it is important to achieve economy of scale.

Simultaneously it was observed that recycling cost differences between TV brands were diminishing.

'From DOTTY' was invented by a student (Nicoline) on a boring afternoon. She thought it was just funny crap, but this turned out not to be the case. What the method did was plot cost/proceeds of recycling as a function of disassembly time. Results showed S-shaped curves (cost come first, yields later). When the first derivative (which represents an efficiency) was taken of this curve (which is not really a curve but consists of discrete segments, but a curve can be drawn through it) it can be seen that for most products there is a maximum. This means that disassembly (or in general) treatment 'goes over the top'. At the inclination point the cost efficiency of further treatment drops, although there is still an increase in absolute terms of the costs and the proceeds. It was the start of the Eco-efficiency thinking.

An interesting approach was the 'Parametric estimation of recycling costs' introduced by Casper Boks. It turned out that for a certain product category (for instance TV sets), recycling costs could be estimated pretty accurately if only a few easily measured parameters (weight, screen size, volume etc.) are known. The method has not been followed-up further because it was feared that too many product categories had to be defined to ensure sufficient reliability of the predictions. It has however not been researched – in my opinion still very worthwhile to do.

The 'ELDA-method' aims at making recycling strategies rather than cost. It has been considered in cooperation with the Stanford Manufacturing Modeling Lab, and has been described in chapter 7.2. 'Eco-efficiency old style' will be presented in the Eco-efficiency chapter 7.5.3.

Pictures, I I

The green TV (1997): success and failure !



7.5.2 PMRCM, the Philips Materials Recycling Calculation Method)

PMRCM (Philips Materials Recycling Calculation Method) started at a moment when it was realized that mechanical shredding and separation would play a much bigger role in recycling of electronics in Western Europe. It has been developed at the Philips Center of Manufacturing Technology and has been applied at Philips Consumer Electronics. In PMRCM a crucial element is the economic value of material fractions. In order to determine them properly it is crucial to know the enhancers (gold, silver, palladium) in the copper fractions and the penalty elements (decreasing the value of metals).

The 'ensemble issue' (products never occur alone but in streams) could not be solved, but the method was good enough to do meaningful design exercises, such as the one given in the paper "*Recyclability of High Volume Electronics*" at the end of this chapter.

PMRCM allowed one to analyze in detail the effects of changes in parameters determining the cost of recycling. In his dissertation "The relative importance of uncertainty factors in product end-of-life scenario's", Casper Boks analyzes this in even much detail. His conclusions are as follows:

1. Most impact by far has the price of precious metals like gold, palladium and to some extent silver. The largest impact on the proceeds comes from the price of precious metals like gold, palladium and to some extent silver. This means that shredding and separation settings are to be set in such a way that the losses of precious metals are minimized. In practice this means maximizing the amount of precious metals in the copper fraction.
2. Second is achieving economy of scale in operations. This is particularly relevant for realizing the maximum efficiency of plastic recycling.
3. Legal obligations have the next highest impact. In many cases this obliges recyclers to go for higher recycling percentages than obtained by their standard treatments. There is however a higher price connected to this. The net result is that the yields often go up but the efficiency goes down.
4. Fourth is the copper price. Here the recommendation is to set the shredding and separation settings in such a way that the copper losses in iron, aluminum and mixed plastic fractions are minimized. The consequence is that more contamination in the copper fraction has to be accepted. In case this leads to financial penalties, high copper proceeds generally compensate for this.
5. Fifth is technology improvements: the efficiency of current shredding and separation technologies are already high; big increases are not expected anymore.
6. Design ranks sixth if lowering of disassembly times through design is excluded (see also chapter 7.6).

The sixth observation is a very interesting one because it goes completely against traditional EcoDesign beliefs. It is based however on the observation that in practice material compositions of products representing a certain functionality (TV, audio-system, VCR ...) show only small difference among brands. Apparently, once a certain functionality has been chosen (and cost issues have been addressed) the material composition is already fixed to a large extent. This demonstrates that the traditional EcoDesign belief that '85%' of the environmental load is determined in the early design phase is not true in the sense that through design this impact could be dramatically changed. It should be replaced by 'in electronics products 85% of the environmental load in the production stage is already fixed by physics when a certain functionality' has been chosen.

This observation underpins the fact that there are no companies replacing plastics by metal to increase recyclability. This recommendation was made by academics and others referring to future recycling obligations in the late nineties by– even Delft Earth Sciences once fell into this trap. Apart from cost considerations, such scenarios also backfire environmentally when the complete life cycle is considered. Recyclability goes up but the environmental load in the production phase goes up disproportionately as well (see also chapter 7.6).

PMRCM and also the dissertation of Casper Boks have contributed relevant developments connecting the cost models of the 1995-2000 area (see above) and the Eco-efficiency considerations from 2001. The time gap in thinking is related to the fact that around 1999-2001 there was a pressing need to produce a more tangible and detailed approach to the environmental performance of recycling. This gap was filled by QWERTY (see chapter 7.4).

Recyclability of High Volume Electronics

Design for Non Disassembly

Ing. A.A.P. Ram, Ir. J.M.H. Deckers & Prof. Dr. Ir. A.L.N. Stevels

I. Abstract

Philips Consumer Electronics recognises the need to pay attention to the recyclability of its products. Internal drivers for this need are the continuous improvement of the environmental quality, an increasing demand of customers to “take care of the environment” and a contribution to the brand image. A major external driver is take back regulation in several member states of the European Union. For television sets, a lot of research has already been done in the field of Design For Recycling. For the rest of High Volume Electronics far less is known, especially for small brown good products (< 10 kg) such as audio equipment, telecommunication products, VCR's and car stereo. The recycling of this type of products is expected to be less Eco Efficient compared to professional and picture tube containing products. In particular when dismantling is needed to meet the required material recycling efficiency at labour costs in Western Europe (see Table 1). A better insight in the recyclability of these small brown good products without picture tubes, is therefore needed.

The Eco Efficiency is in *this project* defined as the costs needed to recover the materials of a product. In case of take back regulation it can also be used to define meaningful criteria and as a decision support tool to evaluate take back schemes.

Table 1: Impression of the presently circulating material recycling efficiencies (march 1998)

Actor	Recyclability
European guideline DGXI (Draft Directive)	40-60%
Dutch take back directive (Draft)	60-65%
Philips Environmental Opportunity Program II (Draft)	80%

2. Why this effort?

Although the take back obligation in the Netherlands for white & brown good products will be based on a collective approach [2], the need to identify the consequences for individual products exists as well. A major argument is that Philips Consumer Electronics wants to position its products to competitors. The aim is to investigate whether advantage can be taken from its leading position or if design improvements are necessary to keep or extend a leading position. If the position of Consumer Electronics is favourite to its competitors, this can be exploited in negotiations with the authorities as well as to gain financial advantage by a collective recycling initiative. Another argument is that the knowledge can be used to improve the environmental brand image of the products to become world class on environmental issues, which in its turn can lead to business opportunities. This is an important issue since environment is more and more stressed as a matter of emotions and perceptions, which leads the way for green marketing possibilities [3]. In this context the recyclability must also be evaluated in life cycle and business perspective.

Since products will never be recycled individually, the contribution of individual products on the 'ensemble-matter' will be examined well. This means that factors will be identified by which an individual product can be distinguished in the brown good waste stream.

Added value of the “Design for Non Disassembly” approach compared to the “Design for Dismantling”, is more freedom in the product structure during the design and a higher recyclability compared to the dismantling approach. This freedom is coming from a lower number of rules to fulfil to meet recyclability requirements. Recyclability is defined here as the ease of attaining a required Material Recycling Efficiency at minimum recycling costs. The Material recycling efficiency is defined as the mass of materials which is not disposed as waste or incinerated divided by the total mass. The influence of environmental relevant substances is considered in the acceptance criteria of the outlets.

3. Design for Non Disassembly (DfND)

Recycling pilot projects such as Apparetour [1] indicated that for both small brown good products without picture tubes and small domestic appliances, dismantling did not lead to an increase of material recovery, compared to dismantling with higher recycling costs. Bearing this in mind, it is remarkable that most proposed design improvements for these type of products focus mostly on dismantling with respect to the product structure (e.g. joining techniques, use of mono materials, marking of plastics).

The “Design for Non Disassembly” approach exposes the consequences of recycling without dismantling and translates them into design rules, which can be used during the *product creation process* and at take back negotiations with authorities. The DfND approach is based upon the material composition of a product and is supported by a computer simulation model of a recycling process (Dutch recycling company MIREC). The structure of this approach is shown in Figure 1.

In many cases landfill is legally not allowed. Anymore the amount of metals is too high for incineration (>30%). On top of that, it is not attractive to sell directly to the raw materials industry, so recycling is necessary. In most cases the aim of recycling is to make the material content of the products attractive by means of material recovery (closing the loop) and economic valuable (meeting outlet specification).

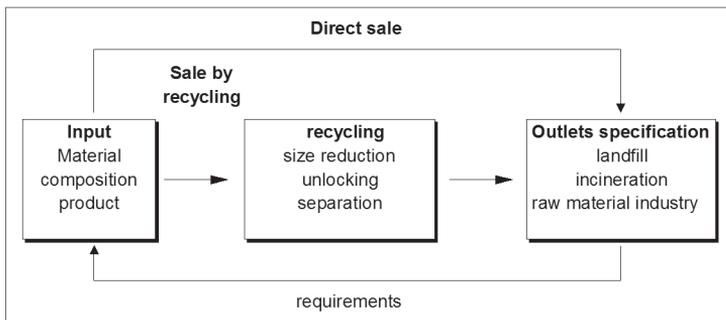


Figure 1: Material composition of a product in relation to the outlet market for materials.

The amount of materials coming from post consumer electronic products is too low to influence the specifications of the outlets. The best way to evaluate the recyclability is to compare the products' composition to the input of the material refinery industry such as a copper smelter (e.g. Union Minière in Hoboken, Belgium). Since products are generally not treated in separate categories, it is almost impossible to obtain practical recyclability information for specific products.

In the DfND project a computer program was developed which simulates the recyclability of individual products (Product Material Recycling Cost Model). Data sources for the computer model *PMRCM* are: Brite Euram Project DemRop [4], Recycling Project Apparetour [1], Recycling equipment of MIREC & Outlet Specifications. The input is the material content of the product and the results are described in terms of material recycling efficiency and recycling costs. In Figure 2 the recycling process is schematically presented. Another name for this type of process is mechanical or bulk recycling.

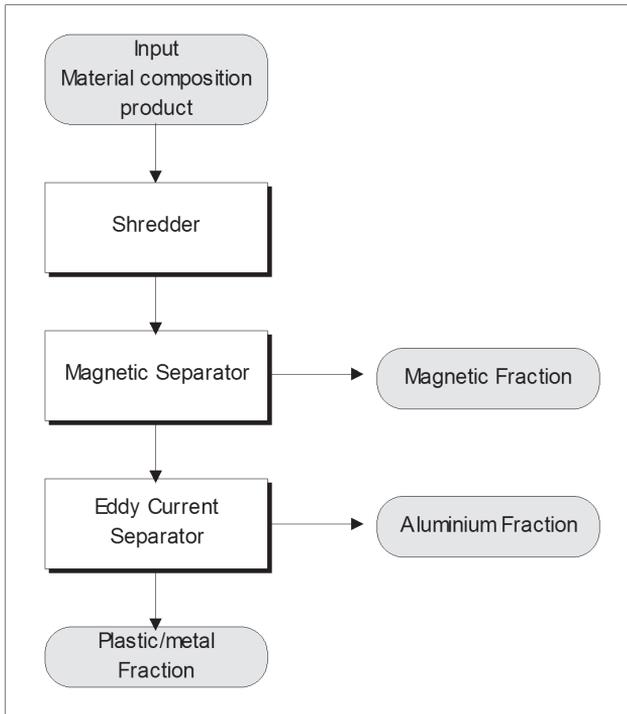


Figure 2: Mechanical Recycling Process which is simulated in PMRCM

To test the effect of redesign options upon the recyclability, a number of simulations were performed by means of the *PMRCM*.

4. Recyclability of HVE Products without CRT

Products of the pre Eco Design era were taken as reference [1]. For the current products the material content of a number of carriers are measured and the recycling is simulated with *PMRCM*. The material content of the redesign options are estimated and the consequences on the recyclability is again simulated with *PMRCM*.

Pre Eco Design Products

In Apparettour [1] small brown good products without cathode ray tubes (CRT's) were entirely processed in bulk (bulk recycling). The material fractions offered as outlet are presented in table 2. The metal/plastic fraction has a copper concentration of only 15.4 w/w % which is in principle too low for a copper smelter (20%). This fraction is added to a fraction with a larger content of copper and is sold to a copper smelter afterwards. It must be mentioned that the mercury content of 53 ppm is in the critical zone for acceptance by the copper smelter.

Current Products

The following carriers have been chosen; Sound Machine AZ1407, Magic CD mini HiFi System FW630 (Figure 3) and the car stereo 22DC396. It was quite some work to calculate the recyclability of the chosen products because the total material content of products is difficult to obtain by the set maker. The ecological validation based on the amount of *environmental relevant substances* (ERS) was not easy to determine, even when the Chemical Content method [5] was used.

For many components the exact amount and concentration of ERS is not precisely known. During the DfND project it was necessary to execute chemical analysis in order to determine the material content of the printed wire boards.



Figure 3.1: Sound Machine AZ1407



Figure 3.2: Mini set FW630



Figure 3.3: Car Stereo 22DC396

Table 2: Recyclability (carriers are simulated with PMRCM)

Material fraction	Pre Eco Design	AZ1407	carriers FW630	22DC396
Weight [kg]		3.77	6.59	1.18
Ferro fraction (incl. Speakers) [w/w %]	55	34	65	63
Aluminium fraction [w/w %]	5	0	5	1
Metal / plastic fraction (rest fraction) [w/w %]	40	64	30	36
Material Recycling Efficiency [w/w %]	63.1	30.6	69.7	67.1
Recycling costs [Dfl/kg] ³	- 0.40 ²	- 1.77 ¹	- 0.19 ¹	+ 0.78 ¹

¹: operational costs based on mechanical processing excluded logistics (not commercial prices for take back)

²: costs based on Apparettour conditions

³: negative values are costs and positive values are profits

It is remarkable that within the same product category there is a large difference in recyclability. The Sound Machine AZI407 has the biggest potential for improvement on both environmental gain (material recycling efficiency) and value for money (recycling costs). This is mainly caused by the relatively large amount of plastics (52%) which dilutes the concentration of copper and precious metals in the most valuable outlet of recycling (tail or copper fraction). The Car Stereo is an interesting product for the recycling industry if it can be recycled separately, because it will bring money. Conditions for a separate bulk recycling of specific products are economy of scale, a good technological infrastructure and the possibilities to collect products on recycling route in stead of function.

5. Design Drivers

Design drivers for bulk recycling without dismantling are parameters which have an effect on the recyclability and can be influenced by the designer. Evaluating the results from Table 2 with a group of experts, the following design drivers were defined:

Value of Materials: express Printed Wiring Boards (PWB) in the amount of copper, gold silver and palladium, be aware of the value of secondary materials (iron, aluminium and plastics)

Material Mix: use of preferred material combinations, minor differences in value between materials which can not be separated, minimal required material recycling efficiency

Separation Properties: use materials and design properties which make unlocking and mechanical separation of materials possible

Penalty elements: phase out those substances occurring in small concentrations which decrease the value, acceptance and re-use potential of secondary materials

The design drivers are translated into the following redesign starters:

1. Reduce Plastic in Copper Fraction: plastic decreases the value of the copper fraction and is incinerated during copper recycling. The recyclability can be increased by replacing the plastic by metal parts or to improve the unlocking of plastics.

2. Reduce Copper in Magnetic Fraction: copper in the magnetic fraction has no value. By 5% or more it turns even into a negative value. The copper is mainly coming from transformers, coils and motors. Because these type of components are always necessary in electronic products, the improvement must be found in a better unlocking and separation.

3. Optimise Elementary Composition of Copper Fraction: small elementary changes in composition (mg/kg) influences the value and the acceptance of the fraction. In table 3 an overview is given of a number of substances.

Table 3: Concentration limits of elementary composition in copper fraction (average)

Fraction	Penalty elements	Metal refinery limit [ppm]	Metal refinery limit [%]
Copper	Mercury	50	
	Bismuth	300	
	Fluorine	150 - 300	
	Bromine	???	
	Cadmium	1000	
	Chlorine	1000	
	Antimony	2000	
	Nickel	5000	
	Nickel + Cobalt	5000 - 10000	
	Zinc		5
	Aluminium + magnesium		5
	Aluminium		10
	Ferro		25
Magnetic iron	Zinc	2000	
	Copper	5000	
	Tin	5000	
Aluminium	Copper		5
	Magnesium	???	

¹ : on basis of cobalt.

The concentration limits of Table 3 are prioritised as follows:

1. Concentration near smelter specifications (danger zone)
2. Negotiable concentration (penalties)
3. Differences in concentration between outlet channels
4. Negative influence in level of application of material

Taken the priorities into account the following area's need design attention:

- Bromine and antimony containing flame retardant (first priority)
- Halogens in plastics (first and second priority)
- Bismuth and lead in solder (first and third priority)
- Cadmium and mercury in batteries or other components (first priority)
- Plated metals and other nickel, tin & zinc containing components (second priority)

6. Redesign

The designer diagram (Figure 4) and the redesign starters are used to find design improvements. The designer diagram helps the designer to structure the process of redesign as follows:

1. Input needed
2. Possible end of life treatments
3. Validation of current recyclability
4. Improvement of recyclability using redesign starters

The redesigns are focused on the improvement of the recyclability with respect to the non disassembly approach. Consequences for *Business* and *Life Cycle Perspective* are evaluated separately. The chosen product for redesign is the mini system FW630 because it has the biggest design potential for improvement. The following design options were found:

first starter

- Replacement of plastic front by extruded or moulded aluminium
- Plastic front attached to internal front PWB with easy to shred connections
- Replacement of plastic interior brackets by steel
- Attach all PWB's to the interior bracket and not to the housing

second starter

- Make power supplies recycling friendly
- select switching power supplies
- add hardened steel to core
- add ceramic 'knives' which break easily during shredding
- Use as much solid wiring as possible

third starter

- Increase components with a higher amount of value elements and less environmental relevant substances such as SMD's
- Eliminate the PVC coating on the encasing by epoxy powder coating
- Use plastics without halogens
- Replace zinc and nickel plated steel by powder coated steel
- Use printed circuits without halogenated flame retardant

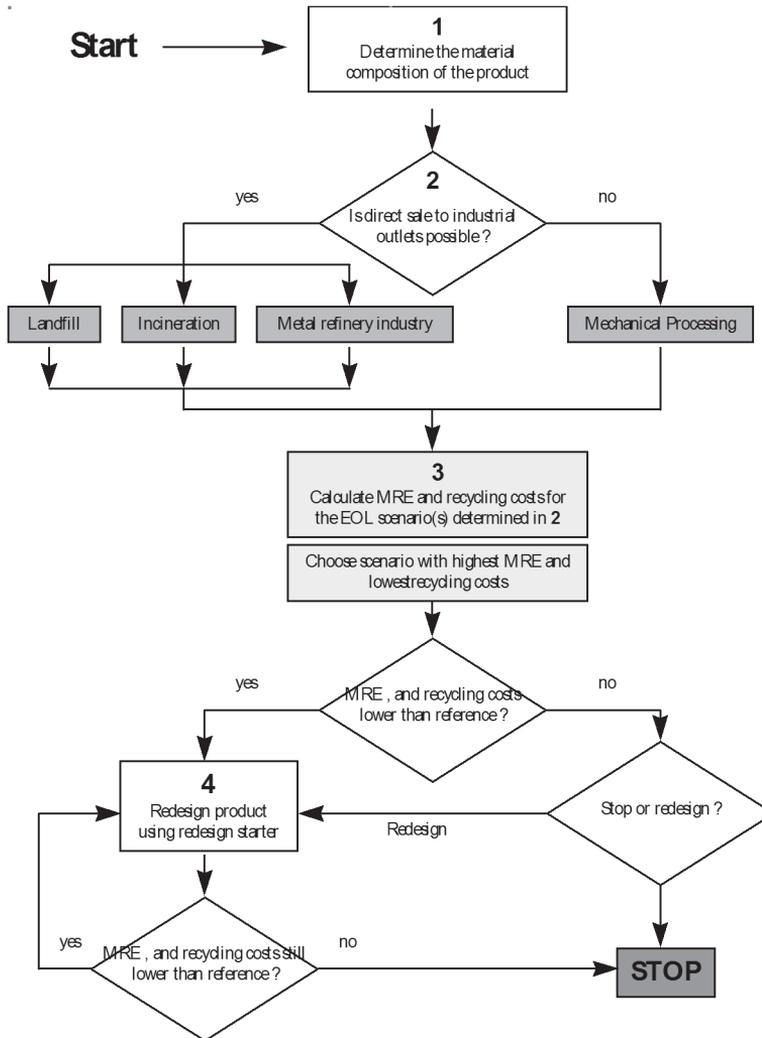


Figure 4: Designer diagram

To check the feasibility of the redesigns for a successful implementation within Consumer Electronics, the redesign options are also evaluated from a *life cycle* and a *business perspective* (see table 4). Life cycle perspective is hereby defined as the environmental consequences of recyclability improvements in other stages of the products' life cycle. Business conditions are aspects next to environmental aspects such as costs, brand image (consumers & societal) and feasibility (technical & financial). It must be mentioned that for all redesign there has to be a *take back system* in place which made it possible to isolate the products which are designed for non-disassembly. The improvement has a positive feasibility in business perspective when it does not lead to a financial burden in cost price and when it is technological available. The environmental feasibility in life cycle perspective is evaluated on other environmental aspects besides recyclability such as energy consumption during use, packaging & logistics, material weight and the environmental profile of manufacturing processes (emissions, use of chemicals).

Table 4: improvement potential of redesign options from a business and life cycle perspective

Improvement potential	Design option
Positive	<ul style="list-style-type: none"> • Switching power supply • Increased integration of custom boards, use of SMD technology • Green fluorescent display • Improvement on component level • Improved unlocking of plastic front
Neutral	<ul style="list-style-type: none"> • Internal steel brackets (replace plastic) • Integrated interior bracket
Negative	<ul style="list-style-type: none"> • Front made of cast aluminium • Front made of extruded aluminium • Power supply with hardened steel breaker sheets • Power supply with ceramic 'knives'

The *life cycle* and *business* evaluation is preferred because as this adds a check on the attractiveness to and fit in the business. For example, an encasing made of casted or extruded aluminium (Figure 5) is very attractive in terms of recyclability (Table 5), but is less preferred compared to plastic in the life cycle perspective (larger environmental impact manufacturing) and business policy (higher costs). This means that this design option would probably only be possible for high end "design specials".

Table 5: Recyclability redesign options (calculated with PMRCM)

Redesign	MRE ¹ [%]	Costs ² [Dfl]
FW630 (current product)	69.7	-0.19
Aluminium front	73.3	+1.05
Fe brackets	72.6	0
Separate plastic front	69.7	-0.19

¹: MRE = Material Recycling Efficiency

²: negative value is costs, positive value is profit

The redesign with an easy to separate plastic front does not improve the recyclability due to fact that there are no commercial outlet channels available for these type and amount of mechanically separated plastics. Also additional recycling steps are needed (see Figure 2) to separate and clean the plastic from the metal fraction or to separate the plastic before the mechanical recycling process. These options are not yet simulated in the *PMRCM*.

FRONT 2

ALUMINIUM CAST / MACHINED FRONT
 MORE EXPENSIVE MORE FORM FREEDOM
 DETAILS AS WITH PLASTIC PART
 ALTERNATIVE WITH SNAP FITS FOR
 EASY UNLOCKING

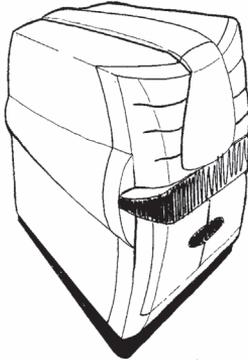


Figure 5: Redesign with aluminium front

7. Conclusions

For small brown good products such as audio equipment, telecommunication products, VCR's and car stereo, bulk recycling without dismantling seems to be the most Eco Efficient recycling strategy. Knowledge of bulk recycling in the *product creation process* is needed to identify the design consequences and opportunities. Simulation of bulk recyclability is necessary because in practice, bulk recycling is not performed on specific products, but will always be processed in ensemble with other products. The two chosen performance indicators to evaluate the recyclability of products are the material recovery efficiency (MRE) and the recycling. The indicators are calculated with the computer model Product Material Recycling Cost Model (PMRCM) which is developed by CFT and simulates the MIREC recycling process.

Conclusions of a number of simulations were:

1. With the current recycling processes, plastic dominated products (e.g. sound machine, corded phones) have a low material recycling efficiency (less than 40%) and the recycling costs¹ are higher to that of television sets (approximately Dfl. 0,40 / kg)
2. Metal dominated products (e.g. VCR's) have a high material recycling efficiency (approximately 70%) and low recycling costs¹ (approximately Dfl. 0,05 - 0,10 / kg).
3. Products with Printed Wiring Boards (e.g. car stereo, cellular telephones) containing components with a substantial amount of precious metals (gold, silver and palladium), can even have a positive recycling value¹ (approximately Dfl.0.50 / kg).
4. In case of plastic dominated products, the material recycling efficiency can be improved (to approximately 65%) by introducing manual disassembly. The recycling costs however go out of proportion (up to Dfl. 1,80 / kg). At the moment there is also no commercial outlet available for the dismantled plastic parts because of restrictions to meet the outlet specification requirements.

Most important lessons learned from the DfND approach are :

1. For determining the optimal recycling scenario of products, the Eco Efficiency of recycling needs to be considered. This means that not only the environmental gain of the recycling is to be considered, but the costs effectiveness as well.

¹ The recycling costs are without logistics, overhead and profit

2. The environmental gain of recycling needs to be considered from a life cycle perspective. The environmental impact of products is determined over the entire life cycle. Often product improvements determined from an end-of-life perspective are in contradiction to improvements from a life cycle perspective.

3. In order to improve the end-of-life performance by design, the following strategies are to be considered.

a) Improve the material mix, by minimise the use and number of plastic(parts)².

b) Increase the value of the extracted material fractions from the perspective of the recycling industry:

- Reduction of copper in de iron(magnetic) fraction (in particular with respect to the design of power supplies)
- Improve separation behaviour for material combinations (in particular by redesigning fixture connections with respect to the mechanical recycling possibilities).
- Decrease the amount of substances (mainly in electronic parts such as PWBs) which decrease the value and/or acceptance of the secondary material (this is in fact to improve the chemical content such as is defined by the ECC in relation to outlet specification).

The conclusions are drawn by the evaluation of carrier products and are summarised in a so-called designer diagram and design rules. The chosen carrier products are the sound machine AZ1407, the mini set FW630 and the car stereo 22DC396. For the FW630 several redesign recommendations are proposed to increase the end-of-life characteristics (design for non disassembly).

It is expected, that the design strategies to improve the recyclability of small brown good products without CRT's will only lead to marginal improvements. This means that in order to improve the recyclability of these products, the collection structure of take back systems, the economy of scale, the technological infrastructure of the recycling industry and the outlet channels need to be improved or optimised.

8. Recommendations

The scope of the DfND project was to find design options aiming on improving the recyclability. Results showed however that the recycling infrastructure is a more important aspect for improving the recyclability than the design of a product. Therefore it is recommended to evaluate and influence the developments in take back regulations, recycling technology and changes in outlet specifications. In order to get an impression of the recyclability of products the *PMRCM* seems to be a helpful tool. To decrease the needed time and to improve the quality of the results, it is required to have a better knowledge of the material content of especially the Printed Wire Board (PWB). The recyclability profile of products can be added to the *Product Creation Process* using the designer diagram and the *PMRCM*. The best place to apply these tools is the design stage during product development. Condition for a successful implementation is a management commitment with respect to recyclability targets.

9. Literature

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² Replacement of plastics by metal is not recommended both out of life cycle and cost perspective

Highlights of the year, 2004

An Agenda for the Future

The year 2004 was the year of my official retirement from Philips. In the 'old' pension system everybody had to go at the age of sixty, no discussion. Since I was born in 1944, I was one of the last people to benefit from this rule. As of 2005 the retirement age will be raised gradually to 65.

In 2004, I had worked for twelve years in Applied EcoDesign, a good time to look back, and an even better time to look to the future. The opportunity was there. I was invited to deliver a keynote speech at the Electronics Goes Green Conference. Simultaneously this could be the starter for writing a book – this book – something I had been already planning to do for some time.

In twelve years time the field had expanded enormously in width and depth. My estimate at that time was that for a book to cover it all it would come down to 30-35 chapters and subchapters and some 300 pages in total. For the conference I had to reduce substantially. Finally, it was decided (with Torsten Griese, see Personalities, 9) to come up with propositions and in short a few arguments to underpin them. All of them are still valid today, most likely a few have to be added – none of them have to be deleted.

The propositions were :

Subject I - EcoDesign

1. Energy in the use phase deserves much more attention
2. There is still a lot of potential in material and packaging reduction
3. EcoDesign performance is a much wider notion than just environmental performance
4. Integration of EcoDesign into current Product Creation Processes is a necessary condition for success.

Subject II – Management Issues

5. Green Supply Chain Management includes management systems, chemical content but also input-output analysis and joint exploitation of new technology
6. 'Green' as such does not sell; it has to be linked to other customer benefits
7. Management of the producers internal value chain is a key ingredient for success
8. Roadmaps and environmental key performance indicators are essential ingredients to ensure steady progress in 'green'

Subject III - Stakeholders

9. Stakeholder discussions can be largely improved by environmental and economic mapping of the issues at stake
10. Management of the external value chains requires convincing stakeholders of the benefits or the use of 'power'
11. The role of governments is best to be a stimulation and a referee
12. Money works faster than information; more attention for the demand side needed

Subject IV – Environmental Management Revisited

13. The role of an environmental manager has dramatically changed; from a technical expert to a communicator
14. The real significance of environmental management goes far beyond environmental improvement

These propositions are defensible. Evidence for them is in this book which has grown now to 90 chapters and subchapters and some 650 pages.

7.5.3 Eco-efficiency

As is shown in paragraph 7.5.1, the Eco-efficiency approach had its roots in the various cost models developed earlier. The first relevant cost model was the “From Dotty” model showing the efficiency of disassembly ‘going over the top’. The second one was the PMRCM model, bringing shredding and separation treatments onto the scene.

The impetus for more detailed Eco-efficiency considerations came from a completely different perspective. In 1999 discussions about legal obligations for take-back and recycling, in most countries where they were taking place, were in a stalemate position – only in the Netherlands a system had just started. Governments and NGOs had primarily had environmental gains in mind; industry was primarily concerned with cost. There were few links between these two ways of thinking.

Moreover, the primary goals which a recycling system had to fulfill were unclear. Was the goal reduction of volume going to landfill, was it chiefly material-recycling or was control of potential toxics the number one priority? Nobody knew at that time and unfortunately today this is still far from clear in many public discussions.

Eco-efficiency was thought to create a common platform in such stakeholder discussions. This was the chief reason that in 2001 the paper about “*Eco-efficiency of Take-back Systems of Electronic Products*” at the end of this chapter was published.

The paper did not work out the way it was intended to. Government felt pushed when asked to formulate real priorities and felt more comfortable with the goal of showing to be ‘green’ to the general public. People in some countries (particularly the Swedish Government officials and industrial managers alike) felt insulted by their low score (see table 4 in the paper) rather than seeing this as an incentive to improve. NGOs felt uncomfortable that a money component had been introduced in environmental considerations. Also the low Eco-efficiency scores for recycling of plastic dominated products was perceived as a trick of somebody with an industry background to exclude some electronic products from a recycling obligation. NGOs “want it all” and therefore had no problem with also pushing for priorities in the goals of a recycling system.

Also within industry there was little sympathy. It was suspected that I had also calculated Eco-efficiency for several products having different brands (which I did) and that Philips Consumer Electronics would do well (which was the case). Therefore my activity was primarily thought to be support for Philips to be rewarded for good EcoDesign within the collective recycling system in the Netherlands. If the outcome is inconvenient, the methodology is attacked. This was the reason that several companies qualified my approach as unscientific.

Such reactions demonstrate that take-back discussions are highly politicized and if science does not fit in the agenda they are not welcome. It is too bad for reality, but as a society you get what you deserve. The current mess in take-back and recycling of electronics has had its roots in politicking for many years, both from the EU – the Member States, the NGOs and the Industry Associations. There is no common goal, no common yardstick and limited will to change minds.

For me the study showed two things:

- Weight based recycling percentages as a yardstick for environmental performance is helpful but not good enough in the end;
- The classification of products into glass dominated, plastic dominated, metal dominated and precious metal dominated is a very useful one – classification of products per application may be suitable for stakeholder discussions (one industry association per application area) but it is a very bad idea from the perspective of treatment and monitoring.

Eco-efficiency of Take-back Systems of Electronic Products

Ab Stevels

Abstract

In order to describe the effectiveness of take-back systems the concept of eco-efficiency is proposed. Basically this is the ratio between environmental gain and cost of the system. The unit of environmental gain is dependent of the main goal to be realised: Preliminary results of eco-efficiency calculations (based on data collected from take-back projects) show that the eco-efficiency concept can create valuable insights. Effects of Design for Environment and Design for Recycling can be substantiated. Cost and yield of secondary material streams play a pivotal role in determining eco-efficiency. This opposes the traditional idea that material compositions of individual products should be considered first. Avenues for further work are indicated.

1. Introduction

In Europe there is now broad societal support for take-back and recycling of electronic products. However, there is a lot of discussion about responsibilities, organisation and financing of the take-back systems. The fact that end-of-life processing can serve several (partly interlinked) goals makes the situation even more complicated. Such goals are:

- A. reduction of the amount of materials and environmentally relevant substances going to landfill;
- B. recycling of materials so that they keep maximum value;
- C. control of environmentally relevant substances (inorganic) or annihilation of such substances (organic).

The concept of eco-efficiency of take-back will be helpful to objectivate the discussion and to set meaningful directions into which the actors jointly have to move.

In particular it will help:

Authorities

- A. to formulate criteria for collection, logistics and end-of-life processing;
- B. to differentiate the criteria for the various product categories;
- C. to monitor performance of take-back systems.

Producers

- A. to calculate end-of-life costs per product
- B. to evaluate results of eco-design
- C. to audit end-of-life processors / recyclers.

Processors/recyclers

- A. to calculate their tariffs
- B. to find the right avenues for technology improvement and investment

Consumer/society

- A. to get insight in the environmental value for the money spent. (directly or indirectly)

2. What is the definition of eco-efficiency?

The general definition of eco-efficiency of take-back systems is as follows:

$$\text{Eco-efficiency} = \frac{\text{Environmental Gain}}{\text{costs (ECU/kg)}}$$

The precise definition of Environmental Gain depends on the general goal set for the take-back systems. Four (partly independent) goals exist for a take-back system focused on materials reuse/control:

- A. Maximize the volume of materials not going to landfill.
- B. Maximize the amount of materials recycled either on a weight basis or on a LCA / eco-indicator basis.
- C. Minimize the weighted amount of environmentally relevant substances not going to landfill.

D. Maximize the weighted amount of environmentally relevant substances brought under control.

In formula form:

Related to goal 1.

$$\text{Environmental gain I} = \sum_M \frac{\text{Volume not to landfill}}{\text{Volume}} \times \text{VF}$$

Related to goal 2.

$$\text{Environmental gain II, I} = \sum_M \frac{\text{Weights recycled}}{\text{Weight}} \times \text{WF}$$

$$\text{Environmental gain II, 2*} = \sum_M \frac{-LCA_L - LCA_P + LCA_R}{LCA_{\text{product}}}$$

where L = logistics VF = Volume Fraction
 P = processing WF = Weight Fraction
 R = recycling
 M = materials

* This is the only definition taking into account the (negative) environmental impact of take-back logistics and of end-of-life processing

Note that LCA_{products} refers to LCA on an materials basis not to e.g. an component basis.

Related to goal 3.

$$\text{Environmental gain III} = \sum_{\text{ERS}} \frac{\text{Weight ERS not to landfill} \times T}{\text{Weight} \times T}$$

where ERS = Environmentally Relevant Substances

T = toxicity index for a material e.g. according to Nissen et al. (see presentation IEEE conference, San Francisco, 1997)

Related to goal 4.

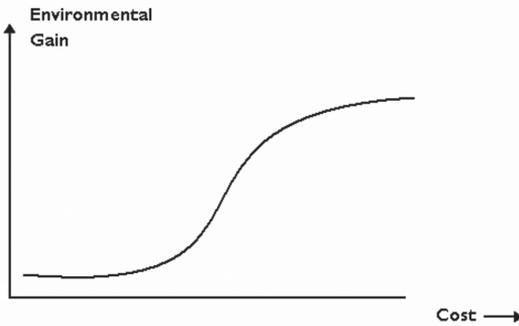
$$\text{Environmental gain IV} = \sum_{\text{ERS}} \frac{\text{Weight ERS controlled} \times T}{\text{Weight} \times T}$$

where controlled = (inorganic substances): recouped e.g. by pyrometallurgy (organic substances): annihilated e.g. by incineration.

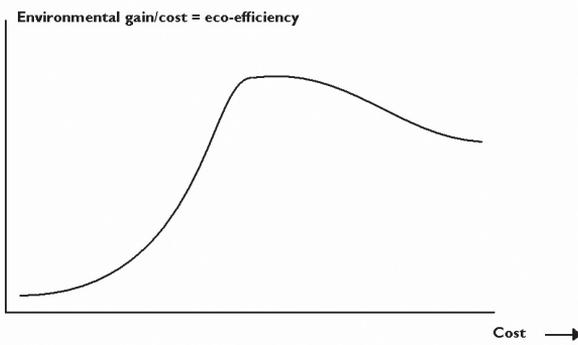
The end-of-life processor / recycler has at time T one technical performance (based on the know-how, investment and available secondary materials channels). This means that the parameters in the eco-efficiency definitions as above are not independent from each other. Therefore, when setting a target for one of the environmental gains as defined above, the other environmental gains follow as a result. This leads to an important conclusion when discussing targets for take-back systems: It should be agreed what is the PRIMARY YARDSTICK for environmental gain. (see annex I for a further explanation on interdependency of parameters in the eco-efficiency of end-of-life processing of electronic products)

3. General form of eco-efficiency curves

The general form of an environmental gain vs cost curve (not taking into account the "quantized form" in which materials in products looks as follows.



The first derivative of this curve represents the eco-efficiency and looks as follows.



This curve shows that there is an maximum in the eco-efficiency as function of cost. This is obvious: if too little is spent on end-of-life processing and recycling of the product, the environmental gain will be zero. On the contrary pushing up the money spent up to high levels will not substantially increase the environmental gain anymore (this is due to the physical nature of the functionality of the product). For different products or even for different design the maximum does not occur at the same cost.

These considerations lead to the second conclusion about take-back targets discussion. Parties involved should agree to what point on the eco-efficiency vs cost curve they go for (most obvious this is the maximum).

4. How to calculate eco-efficiency?

In order to do this properly a paradigms shift is necessary. Primarily one should look at the output side (what can be done / should be done with the secondary materials coming out of the processing) not to the input side (the individual products). The reasons for this that end-of-life technology is about materials streams and realizing optimum eco-efficiency results is a ball game about separating (and sometimes also joining materials) streams.

In order to do calculations it is to be accepted that the acceptance criteria for secondary materials are fixed. This is criteria set by:

- A. scrap dealers (Fe, Al, Cu, precious metals);
- B. plastic recyclers;
- C. incinerators.

Combined with the primary yard stick as defined / agreed in 2, this is setting the scene for the technology to be applied. Basic data needed to do useful calculations are:

Disassembly:

- A. hourly tariffs, disassembly time either from experience or by
- B. calculation (see Boks, Stevels, Kroll, Proc. IEE. Dallas, 1996)

Mechanical treatment:

A. machine / capacity tariffs

B. separation performance, either from experience or by calculation (PMCRM/ see e.g. Deckers / Ram, Philips internal report)

Incineration:

A. incineration tariffs

B. incineration performance, from experience (or theory, no literature known to author)

Yields, tariffs:

A. known by e.g. end-of-life processor / recycler. (Can also put into sensitivity models to check a future trends).

A qualitative overview of eco-efficiency of materials streams in terms of eco-efficiency as a function of take-back goal and technology applied is given in annex 2.

5. Preliminary results of eco-efficiency calculations

A. Introduction

In this paragraph preliminary results of eco-efficiency calculations are presented. These calculations refer to current take-back behaviour as evident from take-back pilot projects as Apparettour in Eindhoven, the Netherlands, to current level of technology at recyclers in various countries in Europe and on logistics cost resp. materials yield / waste costs as currently quoted. All calculations refer to scenarios where optimisation of recycling is the primary goal of take-back. The results have preliminary character, because not all figures needed could be tracked down in detail; in some cases approximations had to be made.

B. Results for old and new TV

In this paragraph old and new TVs are compared. Old TVs are TVs which are currently brought back in pilot projects in Europe; their average life time is approx. 15 years. New TVs represent TVs as currently sold in the market. Consideration of such products gives insight in the effect of Design for Environment (DfE) in particular in the progress in design for recycling. Average weight and end-of-life technologies, which can be applied to the material fractions, are given in Fig. 1.

	OLD (kg)	NEW (kg)
Housing and back cover	7.8 (I)	4.3 (I or R)
Glass	16.1 (R)	16.9 (R)
Electronics	3.5 (M)	2.2 (M)
Ferro	1.1 (M,R)	1.4 (M,R)
Cu containing	0.7 (M,R)	0.9 (M,R)
Aluminium	0.1 (M,R)	0.1 (M,R)
Other	0.4 (I)	1.2 (I)
	29.7 kg	27.0 kg

Fig. 1 Material composition of old and new TV

R = Recycling, I = Incineration, M = Mechanical processing

From this table the effect of DfE can be clearly seen:

A. An overall weight reduction of approx. 10 % when going from old to new. This gain gets more stature of it is realised that the average picture tube weight is increasing (+ 5 %). Housing material weight is reduced by some 45 %, electronics weight by some 40 %.

B. Technologies / yields which can be applied improve: more recycling, less incineration.

The improvement in yield, recycling efficiency is shown in more detail in Fig. 2.

	Material recycling efficiency (%)	Cost (US\$/kg)	Eco-efficiency (kg/US\$)
Old TV	68	0.47	1.45
New TV (incl. plastic recycling)	90	0.20	4.50
New TV (excl. plastic recycling)	75	0.30	2.50

Fig. 2 Old and new TV, Efficiencies and costs

Notes:

Material Recycling Efficiency = $\frac{\text{kg not to landfill}}{\text{weight product}} \times 100 \%$

Exchange rate 1 US\$ = 2 NLG

This table shows that the material recycling efficiency increases from 68 % (for old) to 90 % for new TV allowing full recycling of the housing. Cost drops dramatically, that is by more than a factor 2 (US\$ 0.47 / kg → US\$ 0.20 / kg). The combination of these results is a gain of a factor three in eco-efficiency. If the plastic of the new TV cannot be recycled (that is a situation where flame retardants have not been eliminated!), there are still substantial gain to be noted, in particular to an increase in the effectiveness of disassembly and of glass recycling.

C. Differences per product type (new products)

Differences in material recycling efficiency, cost and eco-efficiency for different consumer product types are given in Fig. 3.

	Material recycling efficiency (%)	Cost (US\$/kg)	Eco-efficiency (kg/US\$)
Glass dominated (TV)	90	0.20	4.50
Precious metal dominated (portable phones)	9	yield 2.50	N.A.
Metal dominated (VCR)	53	0.21	2.50
Plastic dominated (Audio machine)	30	0.46	0.65

Fig. 3 Differences per product type (new products)

This table is to show that material characteristics of products to be recycled have big impact on the eco-efficiency results. Material recycling efficiency ranges between 9 % for precious metal dominated products like portable phone up to 90 % for (glass dominated) TV of newest design. Metal dominated products have reasonable recycling efficiency but relatively low cost. Plastic dominated products combine low recycling efficiency with relatively high cost per kg. Eco-efficiencies develop correspondingly: highest for TV (glass), lowest for Audio sound machines (plastic).

Portable phones have an exceptional position since these represent - if brought together in one big stream - a yield.

It is concluded that this outcome supports the paradigm shift proposal in §4. In order to optimise recycling, end-of-life technology applied should refer to material characteristics rather than to characteristics of individual products.

D. Differences per country (Italy, the Netherlands, Sweden)

In table 4 differences per country on material recycling efficiency, cost / kg and eco-efficiency are presented for recycling of old TVs.

It is generally observed that there are big differences in all categories. This is due to differences in

- A. logistic costs
- B. outlet channels for secondary materials
- C. disassembly cost
- D. (mechanical) processing yields and costs

Fig. 4 indicates that for the time being it will be problematic to come to recycling targets which are uniform throughout Europe, at a similar recycling level these will result in big cost and eco-efficiencies; at similar cost level recycling efficiencies and eco-efficiencies will be strongly different as well.

	Material Recycling Efficiency (%)	Cost (US\$/kg)	Eco-efficiency (kg/NLG)
Italy	56	1.16	0.48
The Netherlands	68	0.47	1.44
Sweden (with screen glass recycling)	55	0.75	0.74
Sweden (without screen glass recycling)	20	0.75	0.26

Fig. 4 Differences per country (I, NL, S) - old TV

V. Conclusions

The results obtained so far have shown that the eco-efficiency concept can create valuable insights about take-back systems. The effects of Design for Environment and Design for Recycling can be substantiated. Eco-efficiency calculations also make clear that the costs / yield secondary material streams play a pivotal role in deciding about treatment options. This opposes that traditional idea that material compositions of individual products should be considered first.

Technology and industrial infrastructure are relevant as well. Currently big differences exist between European countries.

VI. Future work

Future work on the eco-efficiency concept will include:

- A. More precise calculation of eco-efficiencies (data acquisition program);
- B. Development of use friendly software for the calculations;
- C. Calculations on LCA basis, not only weight basis;
- D. Addressing general take-back / recycling issues like:
 - how does the ideal end-of-life factory look like
 - improvement avenues for various product categories, countries
 - improvement avenues for technology
 - inclusion of ecotoxicity

Appendix I

ELABORATION ON INTERDEPENDENCY OF PARAMETERS IN THE ECO-EFFICIENCY OF END-OF-LIFE PROCESSING OF ELECTRONIC PRODUCTS

Extreme situations are sketched here, in practice mixed situations will occur. This does not change the principle however.

Requirement:

Eco-efficiency of the preferred goal (the primary yardstick) should be high [see for individual material streams the eco-efficiency tables in appendix 2.

If the preferred goal is reduction of volume of materials not going to landfill, plastics are to a large extent the dominating factory due to their low specific weight.

Most eco-efficient technology to reduce volume is incineration. Metals and glass then end up in the incineration slag and thus can have only low recycling rate. Except from organic flame retardants, control of chemical content is poor as well.

If the preferred goal is optimizing the recycling, metals are the dominating factor due to their high specific weight and relatively high eco-indicator. The best eco-efficient technology to be applied is then mechanical treatment and separation.

Plastics can only contribute to this preferred goal by disassembling them, this is only eco-efficient for parts > 250 g (provided that no flame retardants are present). This results in a situation that the volume of material going to landfill will still be considerable. Control of chemical content will be dependent on the nature of the environmentally relevant substances. When metals recycling is done by pyrometallurgy heavy metals will be well controlled (this will also apply to flame retardant plastics in mixed copper / plastic fractions). If there is a lot of plastic material to be landfilled, control of chemical content is poor.

If the preferred goal is reducing the amount of environmentally relevant substances not going to landfill the most eco-efficient technology is incineration. This is only really eco-efficient for organic substances, not for heavy metals. This makes that slag has to be immobilised.

Recycling rates will be poor, reduction of volume going to landfill not optimal.

If the preferred goal is to bring the maximum of environmentally relevant substances under control, the most eco-efficient technology is a mix of disassembly and mechanical processing followed by separation. Reduction of volume going to landfill will be substantial, recycling will not be optimal.

Appendix 2

Schematic characterisation of materials streams in terms of eco-efficiency as a function of take-back goal and technology applied.

Table 1 Plastics

	Not to landfill	Recycling	Chemical content control
Monomaterial (no FR)			
• disassembly parts > 250 g	+	++	+
• disassembly parts < 250 g	-	0	-
• mechanical processing	0	--	-
• incineration	++	--	++
Flame retardant containing			
• disassembly parts > 250 g	++	-	++
• disassembly parts < 250 g	0	--	0
• mechanical processing	-	--	+
• incineration	++	--	++

Table 2 Metals

	Not to landfill	Recycling	Chemical content control
Iron			
• disassembly	--	-	
• mechanical processing	++	+	
Cu, Al			
• disassembly > 100 g	--	0	
• disassembly < 100 g	--	-	
• mechanical processing	++	+	
Heavy metal			
• disassembly	-	--	+
• mechanical processing	+	0	+

Table 3 Glass

	Not to landfill	Recycling	Chemical content control
Disassembly . 500 g	--	++	++
Mechanical processing	--	--	--

Soft as margarine

One of the most annoying things at breakfast in a hotel is dealing with butter and margarine. Either it is in a small paper-based package or it is in a plastic cup, which is difficult to open. It is either too much or not enough, in short: it is always a problem.

What about a small dispenser which would help by providing the exact quantity required? Simultaneously this eliminates the packaging; in short: it has provides all kinds of convenience.

That was the idea of Anne-Beth. She got Unilever interested and 'organized' that I be the graduation professor. She did a great design job. She went to canteens, carefully checking how people dealt with butter and margarine. In the Netherlands that is easy because the Dutch (together with the Norwegians) eat bread for lunch as well. The average use of butter or margarine is around 7-8 g, so irrespective of whether you pack 5, 10 or 15 g, at least some 20% is thrown away.

Apart from convenience this is the most powerful environmental argument for the design of a dispenser. Prevention of packaging seems to be another one, but it also must be realized that the material obtained from the dispenser needs to be put into a small cup (directly on a plate makes a mess), which reduces the environmental gains by eliminating packaging substantially.

Unilever veterans accepted these facts but their disbelief was held in check. They said, "Our margarine is no ketchup, so it will not work!". Against all odds, Anne-Beth made a thorough physical flow analysis, which showed that it could be done, provided that the temperature inside the dispenser could be kept constant.

There were two restrictions that showed that there is no one-size-fits-all solution:

- Butter is too stiff, most users cannot press a portion with a single hand so dispensing real butter had to be dropped.
- Margarine and margarine light have different flow characteristics. In each category the flow characteristics also differ greatly per brand. By adjusting the temperature in the dispenser this can be compensated for.

As a result, the final dispenser was a machine which was more complicated than anticipated. Nevertheless, the dispenser turned out to have a strong environmental and economical pay back time. It even convinced the conservatives in the organization.

So why don't see them in practice?

Caterers have to store blocks of margarine and need people to clean and refill emptied machines. It is perceived to be too much work to do this.

Or is it just that they don't want to try something new? Soft as margarine!

7.5.4 Eco-efficiency based on QWERTY

The issues mentioned in 7.5.3 paved the way to set up the QWERTY studies (see chapter 7.4). Jaco Huisman has been very successful with this work. For the first time complete environmental descriptions of the end-of-life chain could be produced. Subsequently it was a logical step to make similar descriptions in monetary terms and thus substantially upgrade the existing Eco-efficiency model.

This type of work was carried out between the years 2001-2004. Two important inventions were made to get Eco-efficiency functioning properly (see fig. 3 in the publication on the next page).

The first invention was the use of so-called Eco-efficiency diagrams instead of ratios. Earlier studies in which such ratios (environmental gain/cost) were used had the problem that when the cost is near zero, the Eco-efficiency becomes either indefinitely positive or negative. There is no rational way to rate such outcomes. Diagrams with money on one axis and environmental performance on the other one circumvent this problem.

The second invention has been the rating of results in a comparative rather than absolute way. For instance, the origin in the Eco-efficiency diagram represents the cost and the environmental burden of land filling electronics. This is the so called base line scenario. When products are recycled (an 'action') instead of land filled there is a recycling cost and an environmental performance of this recycling. The difference between these and the base line scenario are made visible in the diagram as a vector. This vector can point in four directions:

- to the upper right: this represent both environmental and economic gains; a win – win action
- to the lower left: this represents both environmental and economic losses; a loose – loose situation
- to the lower right: this represents an environmental gain at a cost (an action with a positive Eco-efficiency)
- to the upper left: this represents a monetary gain and an environmental loss (an action with a negative Eco-efficiency)

These diagrams are therefore suitable to evaluate the Eco-efficiency effects of all kinds of 'actions' like:

- Changes in treatment (of the same product)
- Design changes of products (treated in the same way)
- Organizational changes (logistics, economy of scale) of recycling
- Changes in legislation/implementation rules.

By now there are numerous examples that this Eco-efficiency approach is a powerful tool to improve take back and recycling systems for discarded of electronics. In the article below, the general Eco-efficiency approach is explained and some first results for cell phones and appliances containing cathode ray tubes are shown. Subsequently, results for the chief categories of electronics products are presented. The effect of different treatment options are described as well.

In chapter 7.6 the Eco-efficiency concept and product design are linked.

In chapter 8.3 it is explained how Eco-efficiency considerations can assist in improving WEEE-implementation (system organization).

In chapter 9.2.3 focus will be put on how Eco-efficiency concepts can contribute to review and improvement of legislation and rulemaking, with particular emphasis on the European WEEE.

Eco-Efficiency Considerations on the End-of-Life of Consumer Electronic Products

J. Huisman, A. L. N. Stevels, and I. Stobbe

Abstract

In order to improve the eco-efficiency at the end-of-life phase of consumer electronic products, comprehensive assessments should be made. The Quotes for environmentally Weighted Recyclability and Eco-Efficiency method (QW-ERTY/EE) developed at the Delft University of Technology is applied to aim at minimal end-of-life treatment costs against maximal environmental recovery. In this paper, the outcomes of this eco-efficiency concept are presented based on a range of improvement options like changing shredding and separation settings, plastic recycling, glass recycling, or separate sorting of certain products. The analysis of more than 75 different consumer electronic products clearly shows groups in state-of-the-art recycling performance in both environmental and economic terms and a substantial distinction between the various product categories. From there, the evaluation takes place of technical improvements in relation to current best-practice recycling. Even more, with the QWERTY/EE concept it is made possible to select and rank improvement options of current and future end-of-life processing and to determine which options bring substantial environmental gain in relation to financial investments made. For glass dominated products, an increase in glass recycling results in significant environmental improvements. The same counts for separate sorting and treatment of precious metal dominated products with a relatively high precious metal content like cellular phones. However, economies of scale are a major assumption that has to be fulfilled in this case. Other conclusions and outcomes are that plastic recycling seems only eco-efficient for large housings of appliances already undergoing disassembly due to the presence of a cathode ray tube (CRT) or liquid crystal display (LCD). For small and medium-sized housings, the extra costs of plastic recycling are high in relation to the environmental improvement realized. In most cases, dedicated shredding and separation of metal dominated products does not lead to substantial environmental or economic improvements. In general, it is shown that the various options to increase the eco-efficiency of end-of-life systems lead to very mixed environmental and economic results. As a consequence, end-of-life policy strategies should be evaluated, and in some cases revised, to support and enhance the most eco-efficient improvement options. Regarding the sensitivity of the results, it is shown that although the different environmental assessment models prioritize individual materials in a different order, the results for the improvement options on a system level are pointing in the same direction, except for plastic recycling scenarios.

Index Terms: Eco-efficiency, end-of-life, recyclability.

I. INTRODUCTION

Due to increased attention on producer responsibility and take-back of products, the environmental performance of end-of-life processing as well as economic considerations have become important. Until now, a very limited number of assessments are published on both the environmental part and techno-economical part of end-of-life processing of consumer electronic products [3], [9], [10], [17]

A comprehensive and quantified eco-efficiency approach would help support ongoing discussions about responsibilities, organization, and financing of the take-back systems [15]. But the fact that end-of-life processing can serve several (partly interlinked) goals has to be addressed as well. These goals are as follows.

- Reduction of materials going to landfill; minimizing land-fill-volumes.
- Recycling of materials in order to keep maximum economical and environmental value and to prevent new material extraction.
- Reduction of emissions of environmentally relevant substances; including leaching from landfill sites and incineration slags, etc.

The methodological backgrounds of the new eco-efficiency concept are presented in the next section, including environmental and economic backgrounds, data requirements, and assumptions regarding the end-of-life chains of disposed consumer electronics. The eco-efficiency concept will be applied to a typical glass dominated product in Section III: A 17-in CRT monitor (Cathode Ray Tube). Subsequently, the evaluation of multiple products and improvement options like glass and plastic recycling will be discussed.

In this paper, a scenario or improvement option is defined as a change in end-of-life processing in relation to state-of-the-art recycling or treatment. The latter is defined as the current average end-of-life processing including collection, disassembly, shredding and separation, final waste processing, and secondary material processing as applied in the Dutch take-back system for consumer electronic products.

II. METHODOLOGY: THE QWERTY/EE CONCEPT

A. Introduction: The End-of-Life Chain

Until now, product recyclability has mostly been calculated on a weight basis only, which is a poor yardstick from an environmental perspective and it is scientifically very inaccurate and can lead to incorrect conclusions regarding the initial environmental goals. Calculations based on weight-based recyclability are likely to lead to incorrect decisions, especially when materials are present in low amounts, but with high environmental and economic values like precious metals [11]. This notion has led to the development of the Quotes for environmentally Weighted Recyclability concept (QWERTY) for calculating product recyclability on a real environmental basis. European take-back legislation for the electronics industry, the so-called Waste of Electric and Electronic Equipment (WEEE) and Restrictions on the use of Hazardous Substances (RoHS) Directives [4], [5], are primarily set up out of environmental motives. The description of treatment performance and evaluation of recyclability targets, should therefore also take place in environmental terms. Currently, this is only the case in a very limited way [9].

Before discussing the methodology being developed in detail, the starting points, boundary conditions, and elements needed for the environmental and economic calculations, are presented. In Fig. 1, a general picture of a products life-cycle and the position of the end-of-life phase is given. The starting point of the QWERTY analysis is the point of disposal by consumers. From there, the product, its components, and materials can follow different directions. The main directions are re-use, refurbishment, and material recycling as well as disposal with municipal solid waste (MSW). Whereas the QWERTY approach is primarily mentioned for material recycling, the re-use and refurbishment option are regarded as out of scope of the calculations for consumer electronics. Environmental calculations on these forms of life-time extension should precede the material recycling calculations. The environmental calculations, as shown later on in this paper, are based on life-cycle assessment (LCA), but with one important difference: the calculations are starting at the point of disposal and therefore on the end-of-life phase only.

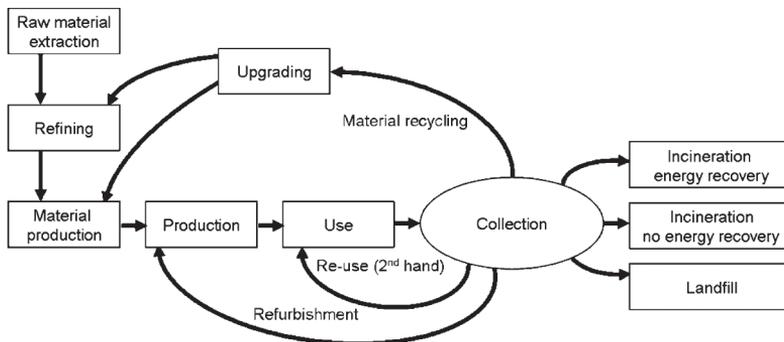


Fig. 1. Product life-cycle and end-of-life phase.

The most important elements required for environmental validation and integral costs calculations (which are needed for the eco-efficiency part) are as follows.

- The collection and transport characteristics after discarding (Section II–D4).
- The individual behavior of products in dismantling and, or shredding and separation operations (Section II–D2).
- Modeling of the secondary material processing and disposal routes like emissions at landfill and incineration.
- An environmental validation method producing environmental scores. (Section II–D3).

B. QWERTY

Based on the modeling of the end-of-life chain, environmental and economic calculations are based on three values as displayed in Fig. 2.

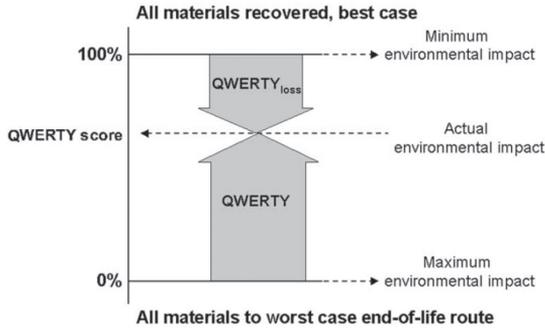


Fig. 2. Calculating QWERTY values.

1) *Minimum Environmental Impact and Minimum Costs*: These values are defined as all materials being recovered completely without any environmental impact or economic costs of end-of-life treatment steps, thus representing an environmental substitution value and the economic value for newly extracted and produced materials. (Usually, both are negative values, maximum environmental gain as negative environmental impacts and maximum revenues as negative costs). These values are theoretical values: in practice, there will always appear (environmental) costs connected to separation of materials, energy consumption, and transport.

2) *Maximum Environmental Impact and Maximum Costs*: These values for end-of-life treatment are defined as every material ending up in the worst possible (realistic) end-of-life route, including the environmental burden of pre-treatment: collection, transport, disassembly, and shredding and separation into fractions. The realistic end-of-life scenarios under consideration are controlled and uncontrolled landfill, incineration with or without energy recovery, and all subsequent treatment steps for material fractions, like copper, ferro, and aluminum smelting, glass oven, and plastic recycler. Also, this value cannot easily be exceeded: for instance, only under disposal conditions which are prohibited.

3) *Actual Environmental Impacts and Costs*: These values based on the actual environmental performance of the end-of-life scenario under consideration are compared with the two boundary conditions and expressed as percentages. This actual value is obtained by tracking the behavior of all materials over all end-of-life routes and by taking into account all costs and environmental effects connected to this. More information on this is presented in Section II-D2.

All detailed backgrounds and formulas to calculate QWERTY values can be found in [9] and [11]. In addition, data from the Fraunhofer IZM Recycling Potential Indicator (RPI) [16] is used to determine whether the scenarios assessed with the QWERTY concept are technically possible. In Section II-D3, more details follow on the environmental ingredients for the QWERTY part of the calculations; in Section II-D4, on the economic part of the calculations.

C. Eco-Efficiency

In order to enhance the eco-efficiency over the total end-of-life chain, the outcomes of the eco-efficiency calculations support authorities in formulating criteria for collection of disposed products and in monitoring end-of-life performance of take-back systems. It enables producers to calculate economical and environmental values on forehand. Furthermore, it supports recyclers in finding the right avenues for technology developments and investments. At last, from a consumer or society point of view, it helps getting insights in the environmental impacts per amount of money being spent, directly or indirectly.

In Fig. 3, the four main eco-efficiency directions are shown in a two-dimensional eco-efficiency graph. The Y -axis represents an economic index (this can be an absolute one, in euros or dollars, or a relative one, in percentages) for a single product. The X -axis represents an environmental index (this can also be absolute, in points or other environmental indicators or a relative one as well). The points in this graph are possible end-of-life scenarios for one and the same product. Apart from this, changes in technology, design or system organization can be displayed.

Examples of such changes are increasing plastic recycling and glass recycling, the effects of Design for Environment activities, or logistics changes. In order to achieve a higher eco-efficiency compared to current recycling scenarios, one should move into the direction of the upper right part of the graph (a plus for environment and a plus for economy). The opposite direction (minus, minus) should be avoided and the (minus, plus) and (plus, minus) should be balanced or ranked. In this paper, the choice is to use environmental points (mPts) and Euros for both axes (€ 1.00= \$ 1.13 at 8-8-2003)

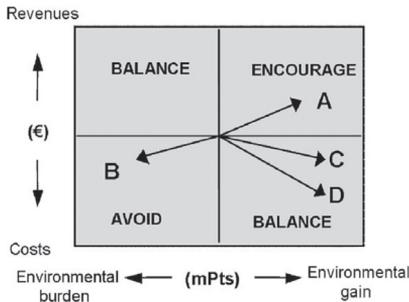


Fig. 3. Four eco-efficiency directions

The calculations for the economic axis are done similar to the environmental calculations. The integral costs connected to the treatment of a certain product or material fraction over the end-of-life chain are determined. All elements needed for this are discussed in Section II-D.

D. Modeling End-of-Life Chains: Assumptions and Data

1) *Assumptions:* All data, results, and graphs presented in the next sections are based on the following important assumptions and starting points.

- State-of-the-art recycling is based on best available shredding and separation techniques. Shredding and separation behavior is described with distribution tables derived from [1],[2],and [9].
- Data are representing the Dutch take-back system for typically short transport distances.
- Economies of scale are realized for all examples and improvement options.
- Costs to consumers for handing in products are excluded from the integral costs.
- All graphs and results are based on the occurrence of plastics within the other fractions, mainly the residue fraction to be treated in an MSW-incineration plant.
- For all example products, chemical analysis of the printed wiring boards (PWBs) is performed. Data for all other components are obtained from environmental benchmarks [12]. The two combined result in full product compositions.
- For the other products without chemical analysis of PWBs, good estimates are available based on the types of PWB materials, the level of integration of components, and the amounts and types of components attached to the boards [12].
- The Eco-Indicator'99, Philips Best-Estimate, Hierarchic Perspective, Average Weighting set, weighting factor Resource Depletion—Minerals adjusted to 5%, is used as a default environmental assessment model [9]. More details on the application of single environmental scores, the weighting set, and other LCA characteristics follow in Section II-D3.
- All fractions sent to a subsequent process fall under the acceptance criteria applicable for this process or operation.

2) *The Double Ensemble Issue:* In many cases, the environmental performance of individual products in end-of-life processing, as illustrated in Fig. 2, cannot be determined as such. The reason is that no individual products are treated as such, but rather as material streams as a result of shredding and separation or disassembly operations

(not for reuse of remanufacturing purposes). This is referred to as an ensemble issue. The product streams are transformed into fractions to be treated in a subsequent process, a secondary material processor, or final waste processor. In fact, another ensemble issue occurs here. A copper smelter, for instance, does not treat single fractions but fractions of multiple sources. A combined copper smelter, for instance, takes in both fractions from secondary origin as well as primary materials from ore. This double ensemble issue is displayed in Fig. 4.

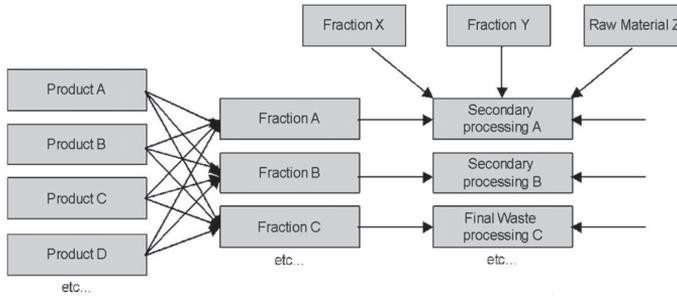


Fig. 4. Double ensemble issue

Fig. 4 is important for the quantification of environmental and economic performance of individual products in end-of-life treatment. The aim of this paper is not only to determine system performance of large product streams and multiple environmental processing steps as origin for the environmental and economic calculations, but also the performance of individual products and materials in given product and material streams and in take-back systems as a whole. This product perspective helps evaluate take-back systems. In practice, it is impossible to track each individual product and material in the steps drawn in Fig. 3. As a consequence, it is not possible to describe the behavior of single products or materials in a complex end-of-life system based on actual behavior.

It is, however, possible to make a first-order estimate on the double ensemble issue. This is presented in Fig. 5. (In fact, there are multiple materials in one product, multiple products in one product stream, multiple product streams are converted to multiple fractions, and multiple fractions are treated by multiple processing options). The solution or first-order estimate for the double ensemble issue is to use average distribution tables for certain settings in shredding and separation for a certain product stream. This includes the description of the distribution of materials over the end-of-life chain. In detail, this distribution of all materials over the various fractions results in contributions to fractions which on their turn are assumed to be treated as real fractions in subsequent secondary material or final waste processing (see, for instance, Table II). The distribution tables are a first-order estimate of the chance of appearance of a certain material in a certain fraction. When calculated for all materials within a product, the contribution of the product as a whole to the resulting fractions is obtained. These imaginary contributions or fractions are treated as real fractions again in subsequent processing steps. In this secondary or final waste processing, again, average distribution tables are used to describe the amounts of materials respectively recovered, ending up in other new fractions sent toward other processing (like slags), or emitted to air, water, or soil. Mass balancing of all materials present in the product under consideration is applied, describing the estimated routes of all materials in all processing steps involved.

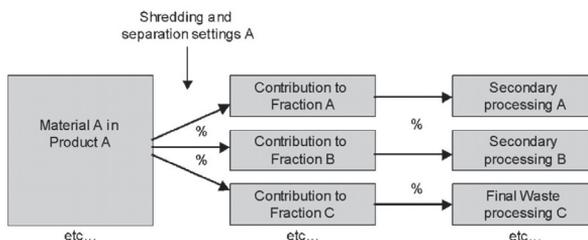


Fig. 5. Solution to the double ensemble issue

Due to the focus on the performance of individual products in this paper, calculations are starting with the behavior of single products and not with product streams. As a consequence, both environmental as economic performance for all materials in a certain product under investigation over all relevant end-of-life processing steps can be related to this individual product. Subsequently, the contribution of many individual products to a total system can be determined. This choice and solution with respect to the double ensemble issue is crucial and is resulting in better understanding of the behavior of products in complex end-of-life systems and the aimed alignment of technology, design, and policy. Due to the importance of the tables, the subsequent distribution tables are checked by other experts in [1] and [2] and published in [9].

3) *Environmental Assessment Models and Data*: The QWERTY calculations require environmental values. These values can be derived from any comprehensive environmental assessment model that produces these scores, but also methods focusing on a single environmental effect, like for instance, eco toxicity or resource depletion, can be used. The default method applied in this paper is the Eco-Indicator'99 method, a damage-oriented LCA method. The approach is also called a top-down LCA method since all contributions to all environmental effects are translated to actual damage inflicted on eco-system quality, human health, and resource depletion [7],[8]. In addition to the default choice, other methods are integrated in the QWERTY/EE calculations to evaluate the environmental outcomes. It is possible to evaluate based on single environmental themes, like for instance on greenhouse effect alone. With this, the disadvantages of applying a final weighting step as enumerated below are reduced, but it limits the relevance of results to single environmental themes only.

Further considerations with respect to the use of LCA methods and methodologies for providing environmental values are that in LCA, there is always a subjective evaluation step involved to weigh different environmental themes and to produce a single end-point score. This is inherent to aggregated environmental scores of any kind. One reason for choosing the Eco-Indicator'99 method is that, compared to other LCA methods, it is the most transparent one regarding influence of different environmental perspectives and opinions of all factors that influence the final end-point score (and not only the final weighting step). Furthermore, the starting point of the QWERTY concept is not the same compared to LCA. The QWERTY analysis starts at the point of disposal until the end of the end-of-life phase, while LCA methods regard the full life-cycle of products, hence, different system boundaries and allocation rules apply. Due to this different starting point, the QWERTY concept regards materials that are recycled as preventing extra environmental load (so negative values appear for recycled materials) due to avoidance of new raw material extraction. As a result of this choice, many problems with allocation and the definition of system boundaries are prevented [9].

An important requirement is an environmental database [12] providing environmental values for all relevant end-of-life processing steps and materials. For all relevant processing of materials, the mass and energy balances must be transferred to corresponding environmental values. Especially for the end-of-life phase of products, there are usually many data gaps within current LCA-databases. Therefore, additional data on all processes relevant for end-of-life treatment of consumer electronics is gathered and included in the database. These environmental data can be found in [9] and are summarized here.

- Transport distances, way of transport and destinations, energy needed for collection, and sorting.
- Energy needed for shredding and separation.
- Environmental impacts of incineration, including energy recovery effects.
- Environmental impacts of controlled and uncontrolled landfill.
- Environmental impacts at metal smelter operations, including emissions, energy needed, and recovery percentages.
- Environmental impacts of other secondary material processing like plastic recycling, CRT glass recycling, ceramic industry, building industry, cement kiln, etc.

Under the default method applied, the Eco-Indicator '99, different perspectives exist for the environmental validation in general. This is represented by different weighting sets for the various environmental effect categories (like greenhouse effect, ozone layer depletion, and resource depletion) in the LCA calculations. As mentioned in

Section II-D2, the Eco-Indicator'99, Philips Best-Estimate, Hierarchic Perspective, Average Weighting set, weighting factor Resource Depletion—Minerals adjusted to 5%, is used as a default. The Philips Best-Estimate refers to an update of the characterization factors connected to a few metals relevant for electronic products (solder materials). These values are updated by new research regarding the fate and exposure of the metals concerned in the environment [9]. The Hierarchic Perspective—Average Weighting set refers to the commonly used set for weighting different environmental themes. More information on the application of different weighting sets can be found in [7]. The adjustment of the specific characterization factors for the environmental theme Resource Depletion—Minerals is due to the use of the so-called Surplus Energy approach in the Eco-Indicator'99 method to estimate the extra energy needed for new material extraction in relation to decreasing average ore concentrations. This Eco-Indicator'99 approach is different from more traditional approaches based on the quotient of global metal consumption versus reserve base. The determination of the reserve base of minerals is subject to many different interpretations. From a methodological point of view, with the surplus energy method, the discussion on how much metal reserves are still available is avoided. The extraction and connected speed of increasing energy needed to acquire the same amount of metal over time is regarded as a better reflection of environmental damage. However, in practice, for some metals the uncertainty in average ore concentrations versus time/amounts extracted is very high. This has led to overestimates of the mineral depletion values in particular for gold and nickel, which are of relevance for electronics. The above effect is one of the reasons to lower the weighting factor for resource depletion of minerals to 5% as. The uncertainty in resource depletion factors in the Eco-Indicator'99 methodology is confirmed by [13]. The decrease in weighting factor is applied to keep the resource depletion aspect included in the methodology on one hand, and to avoid overestimation on the other hand. Furthermore, the adjustment results in a similar ranking of materials as compared with traditional consumption versus reserve base methods [14]. The sensitivity of the results as a result of this choice is checked in [9]. In the conclusions and discussion presented in Section V-A and V-B of this paper, a sensitivity analysis is also performed by showing the influence of using a different LCA method.

4) *Economic Data*: Many of the data to determine the Y -axis of Fig. 2 are derived from the Fraunhofer RPI tool [16] and the TU Delft/Philips Product Material Recycling Cost Model (PMRCM) [3]. Further data is made available by Dutch and German recyclers and waste processing installations [9]. Included are:

- Sorting, registering, transportation, and buffer storage costs.
- Integral costs for shredding and separation.
- Costs at primary copper smelting including treatment charges, analysis and administration costs, as well as price adjustments percentages for recovered metals. Also included are refining charges and unit deductions for copper, silver, gold, and palladium (including concentration dependencies) and costs for penalty elements like arsenic, chlorine, mercury, lead, antimony, and bismuth (concentration dependent).
- Costs at ferro and aluminum smelter processes.
- Costs at incineration sites, both MSW incineration and special waste incineration, also including charges for all environmentally relevant materials (concentration dependent).
- Costs at landfill sites, also including charges for all environmental relevant elements occurring in disposed consumer electronics (concentration dependent).
- Costs for plastic recycling including cleaning and upgrading, color sorting.
- Disassembly costs based on disassembly times for standard operations.
- Revenues paid for all recovered materials.

With the environmental and economic modeling of the end-of-life chain as presented in Fig. 1, the values for both axes in Fig. 3 are calculated. In the next section, an example will be given on how this is performed in practice.

III. EXAMPLE: A GLASS DOMINATED PRODUCT

A. Product Data, Pre-Treatment, Shredding, and Separation

The following steps are taken to conduct the eco-efficiency analysis.

- Product data are gathered and shredding and separation behavior is modeled.
- Contributions of materials to the QWERTY values are determined.
- Different environmental scenarios are calculated such as recycling, incineration, landfill, etc.
- Integral costs per stage of the end-of-life chain are calculated.
- Different cost scenarios are calculated such as recycling, incineration, landfill, etc.
- The eco-efficiency graphs similar to Fig. 3 are determined
- The eco-efficiency outcomes for improvement options like plastic recycling and glass recycling are calculated.

In this section, a 17-in CRT monitor from 2002 will be discussed as a typical example of a glass dominated product. In addition, the PWB compositions of this product are chemically analyzed. In Table I, the resulting product composition is given. The most important characteristic is obviously the high glass content, which is 9.4 kg on a total product weight of 14.7 kg. The precious metal content in this well-developed product is 8 ppm for gold, 133 ppm for silver and 5 ppm for palladium over the total amount of the electronic fraction (PWBs and wiring). On the total product weight, this is 11 ppm for Silver, 0.7 ppm for gold and 0.25 ppm for palladium.

Table I Product Composition 17-in Crt Monitor

Material	Weight (g)	Weight %
Aluminum	48,55	0,33
Copper	892,15	6,09%
Ferro	1324,08	9,04%
Glass	9392,50	64,1%
Plastics	2606,62	178%
Ag	0,16	11 ppm
Au	0,01	0,7ppm
Pd	0,00	0,3ppm
Other	385,22	2,63%
Total	14649,30	100%

For CRT-containing products, disassembly of the CRT and the plastic front and back covers is applied. The remainder is shredded after removing the electron gun, the deflection coil, the degaussing coil, and the cabling and wiring. This results in six fractions. In Fig. 6, these steps are displayed.

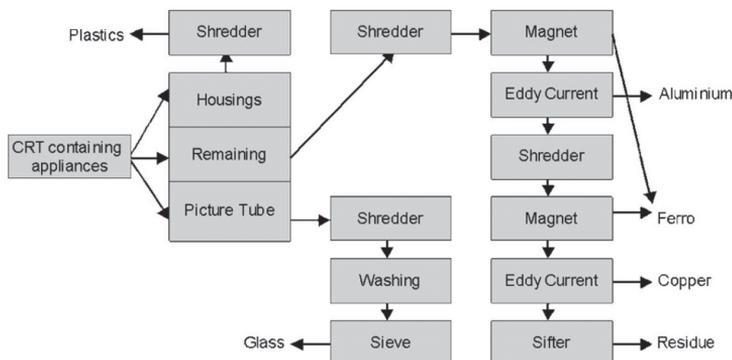


Fig. 6. Shredding and separation of CRT-containing appliances

The resulting compositions are displayed in Table II.

The default destinations of the fractions are respectively ferro smelting, aluminum smelting, copper smelting, and incineration with energy recovery of the plastic and residue fraction. For the glass fraction, this table represents the 2001 average situation for the Netherlands with only 15% recycling of old to new CRT glass, 40% to uncontrolled landfill, 35% to the building industry, and 10% to the ceramic industry. The environmental performance of the current settings will be discussed in the next section.

Table II Fraction Compositions from State-of-the-Art Shredding and Separation

Fraction	Ferro (g)	Aluminum (g)	Copper (g)	Glass (g)	Plastics (g)	Residue (g)
Aluminum	0,25	40,09	7,28	0,00	0,00	0,93
Copper	8,39	44,61	697,75	0,00	0,00	141,4
Ferro	1258	26,48	26,48	0,00	0,00	13,24
Glass	46,96	46,96	93,93	9158	0,00	46,96
Plastics	31,54	13,03	260,7	0,00	1895	406,4
Ag	0,000	0,000	0,138	0,000	0,000	0,025
Au	0,000	0,000	0,0088	0,000	0,000	0,0010
Pd	0,000	0,000	0,0033	0,000	0,000	0,0004
Other	1,34	1,47	125,1	123,1	58,03	76,26
Fraction Weight	1346	1726	1211	9281	1953	685,2
Fraction%	9,2%	1,2%	8,3%	63,4%	13,3	4,7%

B. Environmental Performance

Fig. 7 displays the QWERTY scores of the 17-in Monitor. Note that this “environmental recyclability graph” is completely different compared to the material composition on a weight basis as represented by Table I. The two pies together represent the QWERTY definition. In this graph, copper plays a more important role compared to its weight (Table I), both to the QWERTY loss and QWERTY gained percentages. The contribution of glass is much smaller compared to the weight percentage of 64% in Table I. The QWERTY value under state-of-the-art recycling is 43, 4%.

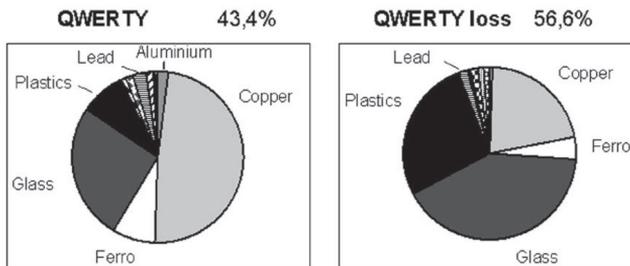


Fig. 7. Contribution of materials to the QWERTY values recovered/lost

Besides the state-of-art recycling scenario as displayed in Fig. 7, the environmental behavior of the product within other scenarios also can be displayed. In Fig. 8, the environmental performance of the 17-in CRT monitor within all end-of-life scenarios (the product as a whole goes into one scenario) is shown. The third recycling bar is the average Dutch state-of-the-art recycling scenario. Note that recovery of copper adds the most to the recovered

environmental value. Also, an important conclusion is that although state-of-the-art recycling is applied, the environmental recovery is far from the best-case scenario (first bar) primarily due to the glass and plastics content not being recycled. To some extent, energy required for end-of-life treatment and environmental impacts of transport play a role as well.

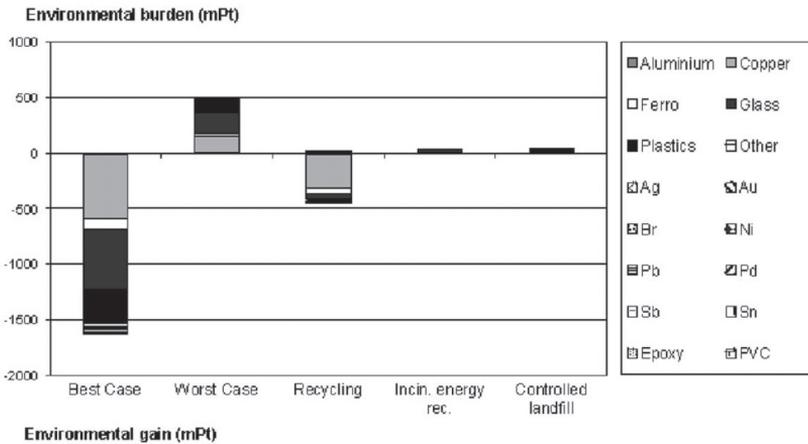


Fig. 8. Environmental scenarios

C. Costs and Revenues

In this section, the economic performance of the 17-in CRT monitor is discussed. The costs per end-of-life stage are represented in Table III. In contrast to the environmental impacts per stage, the highest costs are caused by, respectively: disassembly, sorting and handling, collection, shredding, and separation. The total disassembly time is calculated at 285 seconds. The costs presented are excluding the costs for consumers to hand in their products. In total, some material value (€1.47) is regained at the secondary material processors, but this is substantially lower than the total costs for all operations (€ 7.41) to which the costs for collection and recycler are the highest (€ 5.17). Again, the costs to consumers for handing in products at municipalities or retailers are excluded. These additional costs are estimated at € 3.03 per 17-in CRT monitor.

Table III Integral Cost Per End-Of-Life Stage

End-of-life stage	Integral costs	Costs	Revenues
Transport and collection	€ 0,81	€ 0,81	€ 0,00
Disassembly	€ 2,85	€ 2,85	€ 0,00
Shredding and separation	€ 0,48	€ 0,48	€ 0,00
Sorting and handling	€ 1,03	€ 1,03	€ 0,00
Incineration, energy recovery	€ 0,13	€ 0,13	€ 0,00
Landfill uncontrolled	€ 0,24	€ 0,24	€ 0,00
Building industry	€ 0,34	€ 0,34	€ 0,00
Ceramic industry	€ 0,08	€ 0,12	- € 0,04
Copper smelter	- € 0,26	€ 0,74	- € 1,00
Aluminum smelter	€ 0,06	€ 0,11	- € 0,05
Ferro smelter	- € 0,07	€ 0,06	- € 0,12
Glass furnace	€ 0,27	€ 0,52	- € 0,25
Total	€ 5,96	€ 7,41	- € 1,45

Fig. 9 shows the economic equivalent of Fig. 8. (A minus means a revenue or negative cost). Besides the state-of-art recycling scenario (third bar), the economic behavior of the product within other scenarios can also be displayed. An important conclusion is that although state-of-the-art recycling is applied, the economic recovery (in fact, only net costs are realized) is far from the best-case scenario, in this case, mainly due to the disassembly and collection costs.

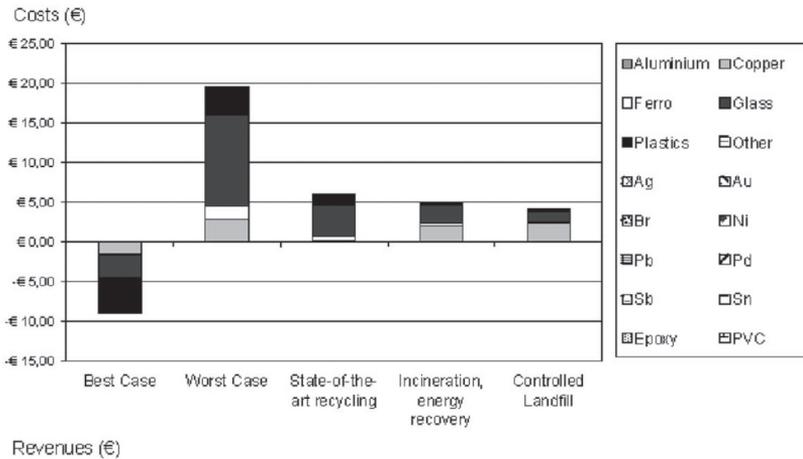


Fig. 9. Cost scenarios

D. Eco-Efficiency Graphs

1) *Current Treatment Within the Dutch Take-Back System:* In this section, the economic and environmental data are brought together in the eco-efficiency graph of Fig. 10. With this graph, the effect of increasing collection rates is visualized. The arrow nr. 1 in Fig. 10 shows that with the change from 0% collection toward 60% collection (and 31% incineration and 9% landfill) results in higher environmental gains against slightly lower costs for the take-back system as a whole. If it would be possible to collect 100% of the discarded products (arrow nr. 2), then a significant increase in environmental gain is realized against higher costs. The total costs for the system are then increasing from € 5.42 per 17-in CRT monitor to (14.7 kg) to € 5.95.

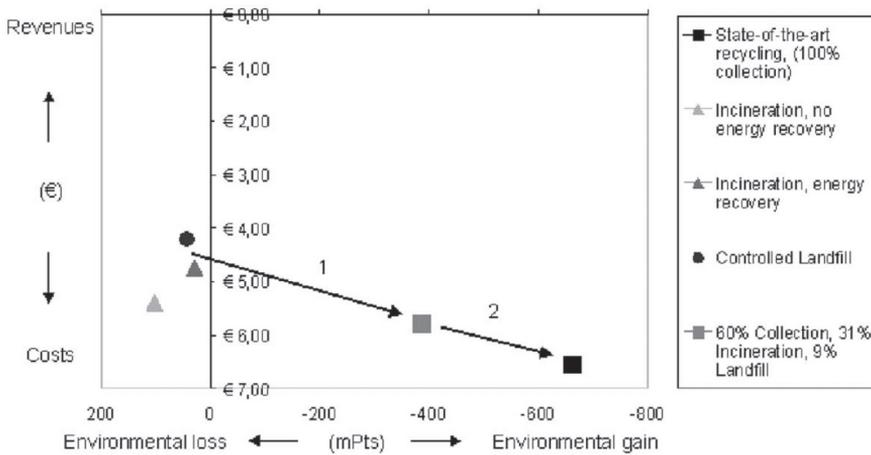


Figure 10. Eco-efficiency of all relevant end-of-life options

2) *Increasing Glass and Plastic Recycling*: One option to increase both the environmental and economic recovery from metal dominated products is to increase CRT glass recycling. The maximum percentages that can technologically be achieved are estimated at 70% recovery of glass back to CRT glass (screen-to-screen and cone-to-cone glass), 20% to the ceramic industry (replacement of Feldspar), and 10% to the building industry (replacement of sand). The resulting eco-efficiency direction is displayed with the fourth arrow in Fig. 11. An assumption here is that there is a demand at the glass producers for secondary material, which is often not the case due to technical constraints, immature markets, and varying compositions of secondary glass.

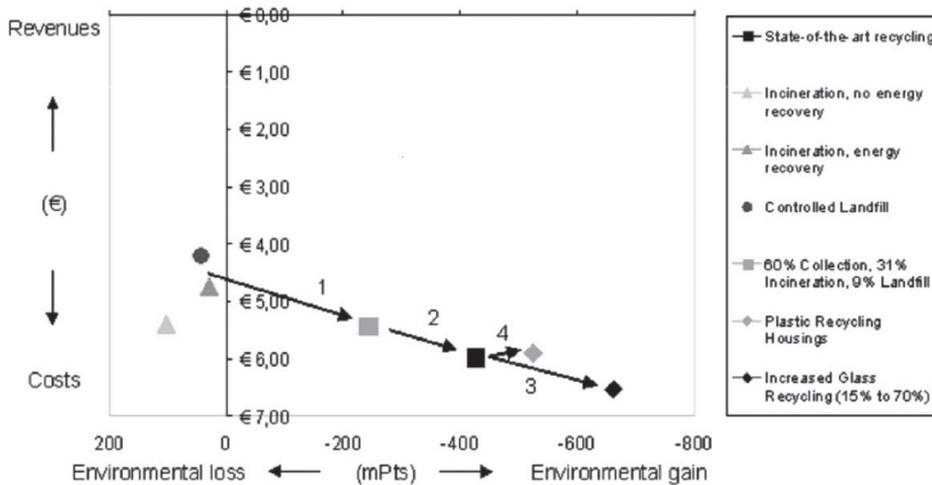


Figure 11. Eco-efficiency of increased glass and plastic recycling

Fig. 11 shows a substantial improvement in environmental performance for increased glass recycling (see arrow nr. 3 in Fig. 11: from -425 to -661 mPts). From a cost perspective, there is an increase from € 5.95 to € 6.54 per product.

Another option is to increase plastic recycling. Instead of incineration with energy recovery of the plastic fraction, the recycling of 1.9 kg of the front and back covers is taken into account. The resulting eco-efficiency direction is also displayed in Fig. 11 with arrow nr. 4. The result of this plastics recycling is an environmental improvement of -425 to -525 mPts against almost the same costs (from 5.95 to € 5.88) as the original scenario with incineration plus energy recovery.

IV. EVALUATION OF MULTIPLE PRODUCTS AND SCENARIOS

A. Eco-Efficiency of Multiple Products

Besides the example product discussed in the previous section, the eco-efficiency of other products and product categories also can be calculated. Around 75 different product compositions from the Philips Environmental Benchmark reports [12] are evaluated. In this paragraph, the following eco-efficiency graphs are presented for the next four product categories.

- Glass dominated products that are all products containing a picture tube (this also means exclusion of LCD screens (Section IV-B))
- Plastic dominated products, which are all products with a plastic content above 50% (Section IV-C), but excluding the precious metal dominated products.
- Metal dominated products, which are in general all products with a metal housing, but no picture tube and also excluding the precious metal dominated products. The metal content (copper, aluminum, and ferro) must be greater than 50%.

- Precious metal dominated products: all products without a picture tube for which the total gold plus palladium content exceeds 50 ppm (parts per million, 50 ppm=0,005%).

In Fig. 12, the QWERTY/EE results for all these products are summarized in one graph. Despite the relatively low amount of products per type/year, clear groups of similar products are formed. The economic and environmental performance of the larger products appears in this graph. Not displayed are cellular phones, which have a relatively high yield per product and high environmental recovery values until € 4.00 and 1000 mPts per kg treated. Other categories are: LCD-projectors ranging from 60 to 120 mPts recovered environmental value and costs around € 0.35 per product; CRT Monitors (around € 0.50, 40 mPts per kg); Audio systems (around € 0.35, and 40 mPts per kg); and TVs (around € 0.30, and 25mPts recovered environmental value); DVD players and VCRs around € 0.15 and 90 mPts per kg.

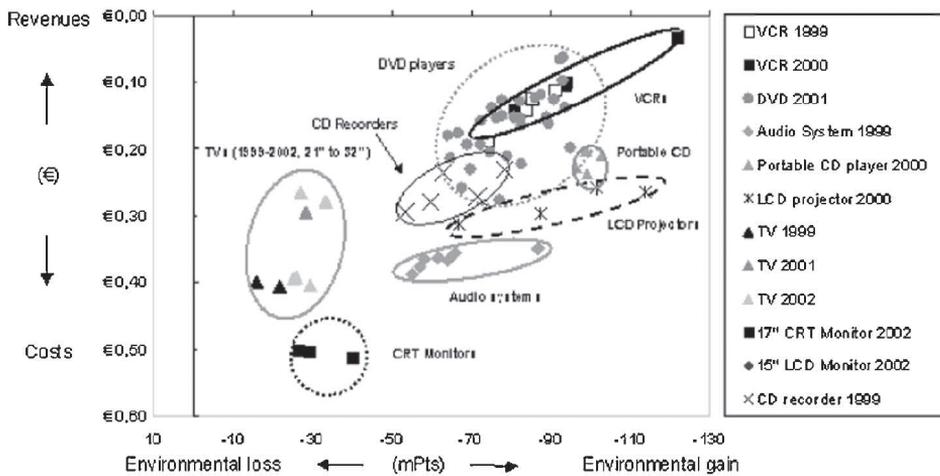


Figure 12. Eco-efficiency of state-of-the-art recycling of various (large) products

B. Eco-Efficiency of Glass Dominated Products

The first product category to be evaluated is that of the glass dominated products. From this category, 15 different TVs and CRT monitors are taken with production years between 1999 and 2002 and with screen sizes between 15-in and 28-in. Disassembly times are measured and included in all scenarios and are known from the Philips Consumer Electronics Environmental Benchmark reports [12]. The corresponding costs are also included for the default state-of-the-art recycling scenario, while also without plastic recycling, the CRTs must be disassembled. LCD monitors form a different group compared to the CRT containing products and are not evaluated here. In fact, they are not in the glass dominated area of Fig. 11, but around the middle of the metal dominated area and the plastic dominated area.

A key question for the glass-dominated products is what the results of plastic and glass recycling are in relation to the state-of-the-art recycling scenario. Both options are assumed to be best case scenarios and are calculated under the assumptions and conditions of Section II-D1. The calculations for both the increased glass and plastic recycling are presented in Fig. 13. In Fig. 13, a clear result is generated. The plastic recycling of large housings which are already disassembled (no extra disassembly costs accounted to the plastics), leads in all cases to a small environmental improvement of around 8 mPts per kg of product weight and to a decrease in integral costs of around € 0.02 per kg. The increased glass recycling leads in all cases to a relatively large environmental improvement of around 14 mPts/kg compared to the plastic recycling scenario against a cost increase of € 0.08 per kg. Although the results per kg are relatively small, they appear for all products under consideration and they are in line with the

results of the example 17-in CRT monitor in Section III. It has to be noted that the results presented are valid for best case plastic recycling and glass recycling with allocating all disassembly costs to the glass. In practice, however, plastic recycling is often not possible due to the presence of flame-retardants or other contaminations or due to a lack of markets for secondary plastics.

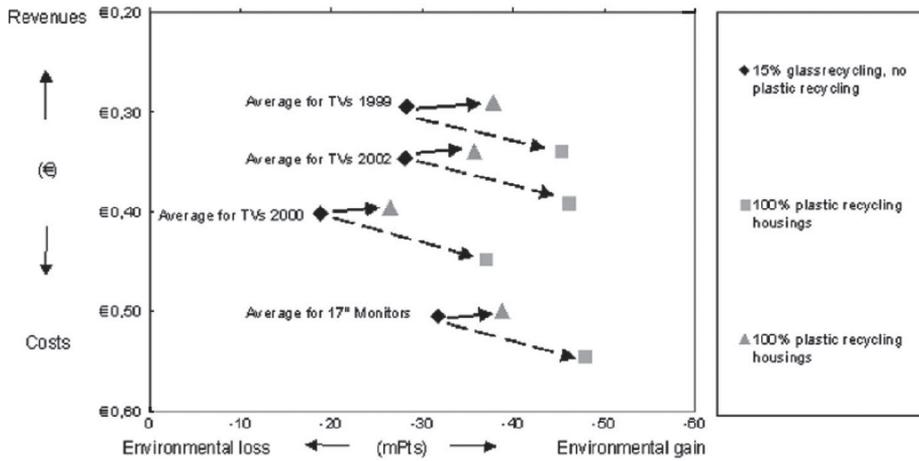


Figure 13. Eco-efficiency per kg of glass and plastic recycling of CRT containing products

C. Eco-Efficiency of Plastic Dominated Products

The second product category to be evaluated is that of plastic dominated products. As examples, 16 different audio systems, portable CD players, and fax machines are used. These products chosen have a large variety in product weight. The audio systems (7 pieces) are from the year 1999 and weigh around 20 kg; the fax machines (4 pieces) are from the year 1999 and weigh around 5 kg; the portable CD players (4 pieces) from the year 2000 and weigh around 0.5 kg [12]. The portable CD players have very similar product compositions. The fax machines, however, are very different. In two of them, a scanner and phone is also included. The audio systems also have rather different product compositions, especially in PWB weight and sophistication.

A key question for the plastic dominated products is about the relation between the weight of the plastic housings of the above products and the eco-efficiency of the corresponding improvement avenue: plastic recycling. A best case scenario is assumed for the plastic recycling of housings of the three product types. This means plastic recycling under economies of scale and under the assumptions that the plastic housings can be gathered without any contaminations, which is not the case for most of the products. The portable CD player and the audio systems have many contaminations, such as metal inserts, stickers, different plastic types connected to the housings (such as buttons), etc.

Despite these aspects, it is assumed that the plastic housings are collected as such without contaminations. The following average disassembly times are measured: 120 seconds for the portable CD players (many small screws) and around 200 seconds for both the faxes and audio systems. The weight of the plastic housings recycled are on average: 130 g for the portable CD players (ranging from 80 to 160 g); 1.3 kg for the fax machines (ranging from 1.0 to 1.9 kg) and 4.1 kg for the audio systems (front and back covers ranging from 2.3 to 5.1 kg).

The results for the plastic recycling scenarios are visualized in the eco-efficiency graph of Fig. 14. In this graph the economic and environmental performance is displayed per kg of product in order to exclude the big differences in weight between the plastic dominated products. It shows that a distinction should be made in the results.

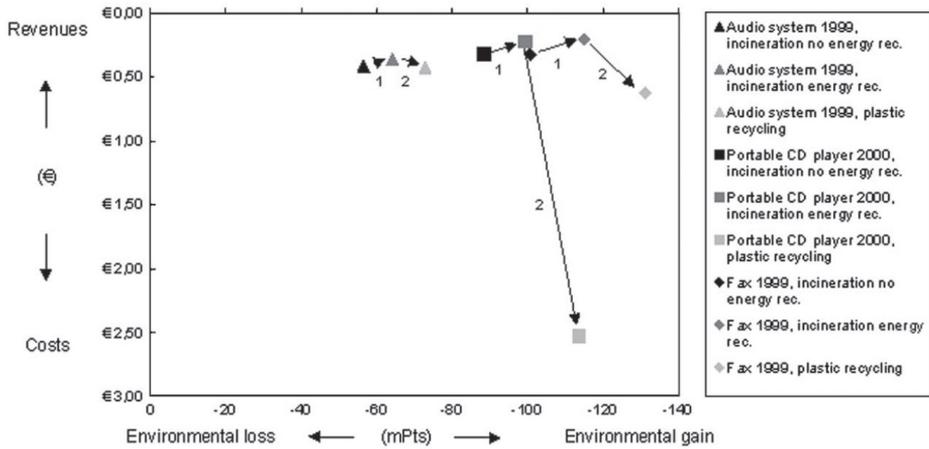


Fig. 14. Eco-efficiency per kg of plastic recycling different plastic dominated products

1) *Large Plastic Housings*: The first group of points (on the left) in this Fig. 14 reflects the scenarios for the average audio system. The first arrow represents the change in environmental and economic performance of incineration without energy recovery toward incineration including energy recovery of the residue fraction (including almost all of the plastics within the products). The third point is the difference between incineration with energy recovery and the exclusion of the plastic housings of this operation by applying plastic recycling. This change is visualized with the second arrow. The two arrows on the left show that for the large housings some environmental improvement is realized against small extra costs per kg (there is a move to the right). In this, the disassembly costs are taken into account for the plastic recycling. For most of the CRT or LCD-containing appliances, disassembly is required to remove the picture tubes and the plastic housings acquired separately at (allocated) zero costs. To be more precise: plastic recycling of large encasings including disassembly costs, under best case conditions, leads to an invested. (From 56 mPts, € 0.37 per kg; 1227 mPts, € 7.10 per product to 64 mPts, € 0.43 per kg; 1447 mPts, € 8.57 per product). Plastic recycling, without taking into account disassembly costs, leads in almost all cases to vectors in the first quadrant of Fig. 2, and thus to a positive eco-efficiency.

2) *Medium Sized Plastic Housings*: The right group of three points in Fig. 14 reflects the scenarios for the average fax machine. The first arrow, again, represents the change in environmental and economic performance of incineration without energy recovery toward incineration including energy recovery of all plastics. The second arrow represents the difference between incineration with energy recovery of all plastics and the plastic recycling of the housings. The two arrows together on the right show that, for the medium sized housings, environmental improvement is realized against relatively higher costs per kg compared to the audio systems. This means that plastic recycling of medium sized encasings (1.3 kg) under best case conditions leads to an environmental gain of 40 mPts/€ invested (an increase from 115 mPts/kg to 131 mPts/kg and from € 0.21 to € 0.63 per kg).

3) *Small Plastic Housings*: The middle group of three points in Fig. 14 reflects scenarios for the average portable CD player. The second arrow represents the difference between incineration with energy recovery of all plastics and the plastic recycling of the housings. The two arrows together on the right show that for the small plastic housings, environmental improvement is realized against high costs per kg. This means that plastic recycling of small encasings (0.13 kg) under best case conditions leads to an environmental gain per amount of money invested of 6 mPts/€ invested (an increase from 99 mPts/kg to 113 mPts/kg and from € 0.22 to € 2.52 per kg).

D. Eco-Efficiency of Metal Dominated Products

The third product category to be evaluated is that of the metal dominated products. As examples, 38 different LCD projectors, CD recorders, VCRs, DVD players, and DVD recorders are used. The differences in functional-

ity are very small inside the individual product groups. However, there are main differences in weight: The LCD projectors are from the year 2000 and weigh in between 5.0 kg and 8.9 kg (4 pieces). The VCRs are from the years 1999 (4 pieces) and 2000 (5 pieces) and are between 2.1 kg and 4.8 kg. The DVD players are from the years 2001 (15 pieces) and 2002 (3 pieces) and are in the range of 2.0 to 3.8 kg. The last groups are the DVD recorders from the year 2002 (7 pieces). In this case, the difference in product composition and degree of product development is large, which results in differences in weight of 2.6 kg toward 6.6 kg. The differences in plastic content are relatively large: The plastic content in the CD recorder and VCRs is much higher than in the DVD, DVDR, and LCD projectors. The amount of high-integrated PWBs is the highest for the DVDR and LCD projectors resulting in higher precious metal contents.

A central question for the metal dominated products is whether dedicated shredding and separation of these products would lead to increased eco-efficiency performance. This improvement option is based on applying dedicated settings for shredding and separation in order to get more PWB materials in the copper fraction. Due to the lower plastic content of metal dominated products, no plastic fraction or residue fraction is obtained, only an aluminum, ferro, and copper fraction. Only some larger plastic pieces are separated by handpicking. The resulting more contaminated copper fraction should lead to higher amounts of materials recovered without too much dilution of these most valuable materials. The eco-efficiency of this technical improvement option is determined in relation to the default state-of-the-art recycling scenario.

The results for the dedicated shredding and separation scenarios on all products mentioned above are displayed in the eco-efficiency graph of Fig. 15. In this graph, the economic and environmental performance is displayed per kg of product in order to exclude the big differences in weight.

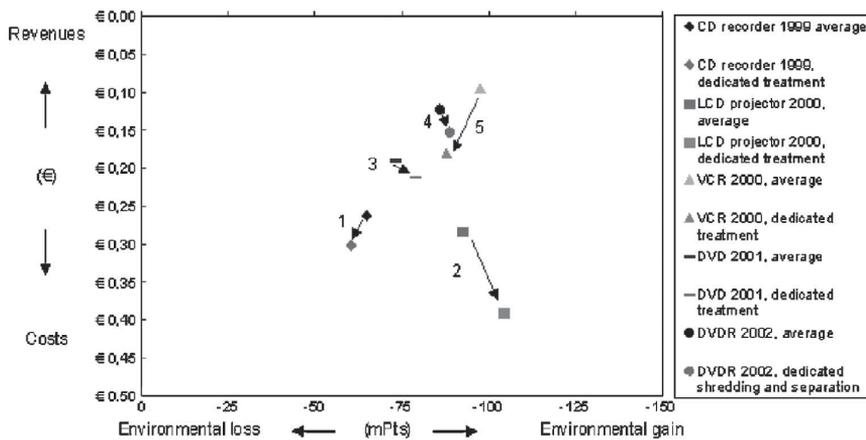


Figure 15. Eco-efficiency per kg of dedicated shredding and separating of metal dominated products.

1) *CD Recorders*: The first two points (arrow nr. 1) represent the result for the average CD recorders. The dedicated shredding and separation does not result in higher environmental recoveries and less costs, but to the opposite effect. In this case, by sending more plastics and other environmentally relevant materials to the copper smelter with a relatively bad flue gas cleaning, it results in lower environmental gains, whereas in the original scenario more plastics are incinerated in a MSW incineration plant with a more extended and more modern flue gas cleaning system and energy recovery. The net effect is relatively small (only 5 mPts less environmental gain and € 0.04 extra costs per kg), although more valuable metals are recovered in this scenario.

2) *LCD Projectors*: The second group of two points visualizes the change of state-of-the-art recycling toward dedicated shredding and separation for the LCD projectors (arrow nr. 2). In this case, the metal and precious metal content is relatively high and the plastic content is low compared to the previous VCR example. For the

LCD projector, the resulting eco-efficiency direction is presented with the second arrow. There is a cost increase from € 0.28 to € 0.39 per kg, but in this case some environmental improvement is realized as well (around 140 mPts/ €).

The reason is that the environmental effect of recovering more valuable materials is higher than the changing impacts of incineration of plastics in a copper smelter. 3) *DVD Players*: The third two points in Fig. 15 represent the DVD players (arrow nr. 3). In this case, however, there is a small environmental improvement of 6 mPts/kg against a small cost increase of € 0.02 (300 mPts/ €). However, the arrow in Fig. 15 is relatively small. Due to the low plastic content in comparison with the CD recorder, the effect of increased recovery is more or less in balance with the lower revenues due to dilution of valuable materials.

4) *DVD Recorders*: The same counts for the DVD recorders (arrow nr. 4). Although in this case the increase in integral costs is higher due to the higher precious metal and ferro content: The environmental gain is increased with only 3 mPts/kg against increased costs of € 0.03 (around 100 mPts/ €). The direction is quite similar, but the vector is much smaller compared to the LCD projectors.

5) *VCRs*: The fifth set of points is showing the results for the VCRs (arrow nr. 5). Like the CD recorders, a relatively high plastic content is also present in this case. This also leads to the same negative eco-efficiency direction as derived before for the CD recorders: 9 mPts/kg less environmental recovery and € 0.09/kg higher costs.

From the results above it can be concluded that the improvements in environmental terms are not very large compared to the effects measured for plastic recycling of large housings in the previous section. At most, in some cases a fourth quadrant result is appearing. In Section 5.2 the result of the improvement options for all product categories are compared.

E. Eco-Efficiency of Precious Metal Dominated Products

In this section, the last product category to be evaluated is that of the precious metal dominated products. For this category, two groups of products are evaluated: The cordless DECT phones from 1999 (4 pieces) and the cellular phones from 1999 (5 pieces). Chemical analysis of all PWB of all phones is individually available while the precious metal content can be very different for phones with the same age and functionality. For the cellular phones, the precious metal contents are between 320 ppm and 385 ppm for gold and between 187 and 222 ppm for palladium. This is much lower compared to the 500 ppm gold and 800 ppm palladium for the other cellular phones (high-end cellular phones from 2001 at the right in Fig. 16). The precious metal content of the cordless phones varies even more: from 8 ppm to 183 ppm for gold and from 23 ppm to 135 ppm for palladium.

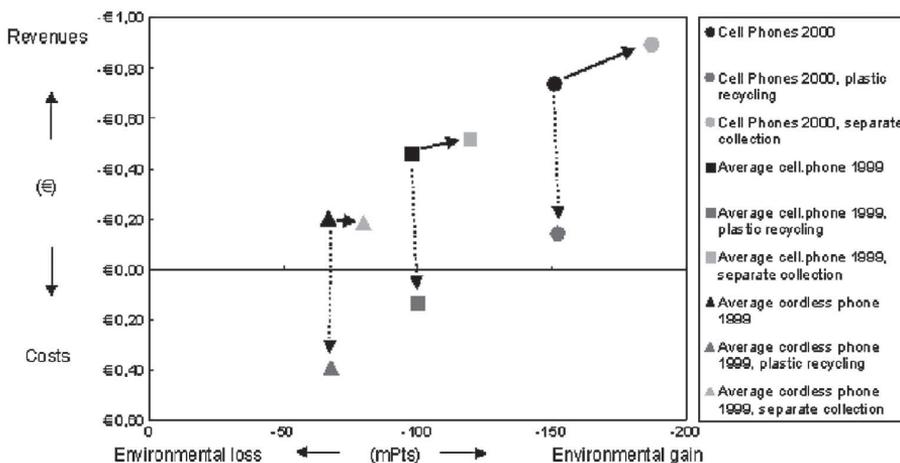


Figure 16. Eco-efficiency per piece for precious metal dominated products

This graph shows similar trends for all product types. The plastic recycling leads in all cases to almost no extra environmental gain but relatively high extra costs. The separate sorting and treatment scenario leads in all cases to an increased environmental performance. But for the products with lower precious metal contents (the cordless phones), it leads to slightly increased integral costs. This is due to the much higher logistic costs, which were included. In the cellular phone cases, an increase in economic performance is also realized. As discussed earlier, the increase in revenues for products with a relatively high precious metal content is quite substantial (from € 8.87 to € 10.72 per kg for the high-end 2000 phones and from to € 3.69 to € 4.17 per kg for the 1999 low-end cellular phones). It should be noted that the underlying assumptions have a significant influence on the results. For the plastic recycling scenario, one of the main assumptions is an optimized product design to make plastic recycling technically possible. For the separate sorting and treatment scenario, it means that economies of scale must be realized. In simple words: enough precious metal dominated products must be collected (batches of a few tons) to make it attractive to treat them separately and to make it efficient to be shipped to a copper smelter.

V. DISCUSSION AND CONCLUSIONS

A. Discussion

In order to check the results generated with the Eco-Indicator'99 method, as mentioned in Section II-D3, the eco-efficiency results for the example products are also calculated under the EDIP'96 method [14] as a completely different LCA method. In Fig. 17, the comparison is made with the eco-efficiency results for the 17-in monitor under the Eco-Indicator'99, as previously illustrated in Fig. 10. Both graphs show similar results for the scenarios: increase of collection rates and glass recycling, but different results for plastic recycling.

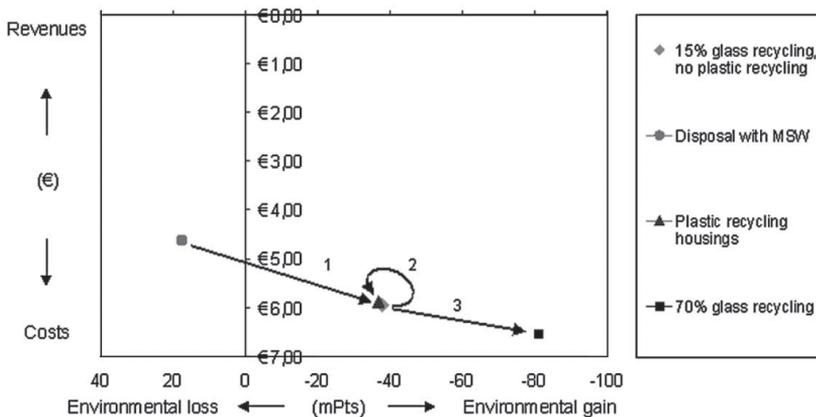


Figure 17. Eco-efficiency of a glass dominated products (EDIP'96)

All scenarios work out in a similar way compared to the Eco-Indicator'99 method, except for plastic recycling. This is explained by the lack of resource depletion factors for plastics in the EDIP'96 method compared to the Eco Indicator'99. This leads to almost no bonuses for preventing new primary material extraction for plastics and, as a result, to a lower evaluation of plastic recycling. It is known from [9] that the choice of the environmental assessment model does not significantly influence the results for the other product examples. Only plastics and plastic recycling are valued very differently under various LCA methods [6], [14]. Under five other environmental assessment models, it appears that plastics recycling results in less environmentally beneficial outcomes compared to the Eco Indicator'99 method.

In addition to this, other parameters having substantial influence on the results are as follows.

1) *Economies of Scale*: This plays an important role for glass and especially for the plastic recycling scenarios. Costs for plastic recycling can be significantly higher when applied on relatively small streams.

2) *Disassembly Times*: There is a large variety in disassembly times measured. In the cases of plastic recycling of small and medium sized housings, which are comparable in terms of functionality, this has the highest contribution to the cost increases.

3) *Technical Constraints*: Many of the plastic recycling cases are not possible in practice due to technical boundaries: the presence of flame-retardants, attachments with other plastic types, stickers, buttons etc., that are jeopardizing the operations.

4) *Sorting and Separation Costs*: In the case of separate sorting and treatment of precious metal dominated products, this aspect is highly uncertain and also dependent on return behavior of consumers, bottom-of-the-drawer effects, and refurbishment in other markets.

5) *Precious Metal Contents*: These can vary significantly. Further research on this matter for more modern products with a higher degree of miniaturization is recommended.

B. Conclusion

1) *Eco-Efficiency Directions*: Summarized, the eco-efficiency directions obtained in Sections 3 and 4 can be divided into directions to be *avoided*, to be *balanced*, and to be *encouraged*, representing, respectively, the first quadrant, the second plus fourth quadrant, and the third quadrant of Fig. 2. These results are independent, except for plastic recycling, of the environmental assessment model chosen. Based on the results in Section 4, including a few results of similar analyses in [9], the following eco-efficiency can be divided in the four quadrants of Fig. 3.

Eco-efficiency directions to be encouraged (first quadrant) are as follows.

- The increase in collection rates of precious metal dominated products. Collection and treatment is costing less than the environmental and economic value being recovered.
- Separate sorting of precious metal dominated products with relatively high precious metal contents under the assumptions that economies of scale can be realized.
- Increase collection rates of metal dominated products with relatively high precious metal and low plastic content.
- Plastic recycling of large sized housings already disassembled (only under Eco Indicator'99 method, see the discussion in Section V-A).

Eco-efficiency directions to be balanced (second and fourth quadrant) are presented in Table IV. In this table, the results under the EDIP'96 method are also presented.

Table IV Fourth Quadrant Strategies: balance

Strategy	EI '99 mPts/€	EDIP'96 MPts/€
1. Increase collection metal dominated products	>800	>100
2. Separate collection precious metal dominated products with relatively low precious metal content	600 – 800	80 – 100
3. Increase glass recycling 15% to 70%	380 – 420	65 – 75
4. Increase collection rates glass dominated products	200 – 400	30 – 60
5. Dedicated shredding and separation metal dominated products with low plastic content	50 – 250	8 – 4
6. Plastic recycling medium sized housings	50 – 150	N.A.: 3 rd quadrant
7. Plastic recycling small sized housings	2 - 20	N.A.: 3 rd quadrant

Eco-efficiency directions to be avoided (third quadrant) are as follows.

- Dedicated shredding and separation of metal dominated products with a relatively high plastic content. This result is also independent of which environmental assessment model is chosen and only caused by a worsening in balance between recovering more material versus diluting the most valuable materials.

- Incineration of plastic and residue fractions without energy recovery.

2) *Methodology: QWERTY*: The QWERTY concept takes into account the environmental value of the treated secondary materials, including the level of re-application and the connected environmental burden of end-of-life treatment. The double ensemble issue of Section II-D2 and all other descriptions of end-of-life processing involved are addressed. Application of the concept shows how well the primary environmental goals of take-back and end-of-life treatment, reduction of material depletion, controlling potential toxicity, and reducing emissions are achieved in actual environmental terms. In some cases, the environmental results are not in line with the intended regulations. The example of the 17-in CRT monitor shows its added value by quantifying the influence of changes in technology in order to increase environmental performance of end-of-life treatment of consumer electronics. The main characteristics of this concept are as follows (not all are shown in this paper [9]):

- The contribution of individual materials and material fractions to the total environmental performance of products.
- The consequences for individual stakeholders to the overall system performance are described, as well as the avenues through which they can increase end-of-life system performance.
- The consequences of system organization by visualizing the impact in the result of logistics, collective versus individual systems, collection rates, etc.
- The relation between certain policy or legislative actions and the resulting environmental performance and economic effects.
- It is based on current best available insights in science and LCA on environmental accounting and it enables fast and streamlined assessments, based on precooked environmental and economic data sets to avoid time-consuming activities for evaluation of individual products. Therefore, data on all relevant processes are integrated.

3) *Methodology: QWERTY/EE*: Generally, it can be concluded that addressing costs and revenues in relation to environmental costs and revenues on a quantitative way is a powerful approach for rethinking on the eco-efficiency of the end-of-life of consumer electronic products. Furthermore, better insights into the system performance and the demands and constraints of secondary material processors are obtained. Despite the uncertainties in economic data, due to the use of very specific and actual data, a good view on the current performance of the Dutch take-back system and the consequences of the enactment of the WEEE Directive is obtained. The QWERTY/EE methodology is proven to be very useful in evaluating the environmental and economic performance of products in end-of-life processing and in determining the most promising technical improvement options. With the example product, the relevance for economy and environment is also shown for all relevant end-of-life scenarios possible. With the QWERTY/EE methodology the following aspects can be addressed in a quantitative way:

- monitoring of the environmental and economic performance of individual materials, single products, and product groups within certain take-back systems;
- the environmental and economic performance of single products in different end-of-life scenarios;
- the determination of priorities regarding different materials and end-of-life options. In addition to this, the following issues can also be addressed [9]:
- monitoring of the eco-efficiency of take-back systems as a whole;
- the quantification of the contribution of different actors and stakeholders.

C. Consequences for Waste Policies and Stakeholder Debates

The application of the QWERTY/EE approach in stakeholder debates can be very useful, and when followed and implemented, it is expected to lead to better end-of-life system performance in general. In most cases, consensus on which environmental assessment model to use or which priorities to assign to the different environmental themes is not required while all arrows point in the same direction. However, upfront agreement on which environmental assessment method to start with for evaluation purposes is recommended. The use of weight-based recyclability targets in the WEEE Directive [4] and the treatment rules (which currently can be fulfilled with manual disassembly only) of its Annex II leads to an overemphasis on aspects of the end-of-life chain that are

of relatively less importance. Generally speaking, most environmental attention should be given to the relation between recyclers creating the right fractions for the right secondary processors who are closing material loops with these fractions. Also, attention should be given to the realization of economies of scale and efficient collection infrastructures. The exact policy measures or steps to take, especially for the options displayed with the fourth quadrant, need special attention. These can be supported by calculations as made in this paper. For instance, when an evaluation round is performed—scheduled a few years after implementation of the WEEE Directive—the QW-ERTY/EE methodology, the underlying calculation schemes, and the background data presented in this paper would be the appropriate means to do this.

Generally, it can be concluded that addressing economical costs and revenues in relation to environmental costs and revenues on a quantitative way is a powerful concept in rethinking about the eco-efficiency of the end-of-life of consumer electronic products.

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Dick Pijselman: it is all chemistry

Times have changed. Today, I dare to write Mr. Pijselman's first name. Twenty years ago he was the boss, THE BOSS of the Philips Glass Division, and with big bosses you rarely knew their first name.

He hired me because he wanted to bring more chemistry into the 'art of glass-production' at the Philips glass factories. This was done in a highly empiric way. Experience and memory of best practice played a major role in the past.

When he hired me he said, "Stevens, I believe that you are a good chemical engineer and scientist, but before I give you any responsibility in this organization I want you to work for a year in our factories first. You will have to learn the practicalities of production and what is even more important is that you have to get rid of the mindset of a researcher. You should become a much more practical guy."

This was tough. I started at Philips at age 21, now as a 36 year old I had to restart in a completely different world. I worked as an operator, a shift leader, a technologist and did the start up of glass furnaces. Most of all, I learned that getting rid of old habits is more difficult than learning something new.

Just before the year was over, the phone rang. I became a group leader and later on the head of the 'Glass laboratory', which was to a large extent a production supporting organization.

There I could do what I was hired for: chemistry of glass production. Mr. Pijselman's intuition was right: there is a lot of chemistry involved in this process. This is a very useful basis for developing action plans and remediation efforts for production problems. It is important to realise that diffusion of glass constituents in molten silica is slow, so you have to make sure that all constituents have been perfectly mixed beforehand. The melting mix has to go through a precise temperature profile in the glass tank which allows for the completion of all chemical reactions. I calculated such profiles and presented these to the production crew in the best tradition of scientific precision.

After the presentation Mr. Pijselman called me to a side room and gave me a tough time. Instead of being praised for my contribution I was 'gepijseld' as it was called at that time. It is a nice expression for a very unpleasant experience. What was wrong? Nothing was wrong, in fact, there was too much right. If you are scientifically precise there is no room to maneuver in operations anymore, if new circumstances or considerations require that. He told me that for the crew it will be very hard to accept later orders to put the temperatures in the tank at different values. The result could be that the old lack of discipline creeps in again.

This was something I had not realized in my scientific zeal. However, soon after Mr. Pijselman's vision turned out to be true. Wear in the furnace did not allow the ideal temperature profile to be maintained anymore and the managerial decision was taken to deviate from what science dictated. Decide base operations on a scientific basis, but take managerial decisions from a much wider perspective!

Thank you BOSS for all you taught me.

The 'Pijselman' Walk: Start at the Inner Ring Road of Eindhoven, opposite the back entrance of the Technical University (the Javalaan). Follow the Javalaan, go L at the Johan de Wittlaan, go L at the end and directly right to the Aalberspad. Go L to Wandelbos Eckart and continue the walk according to the length of your choice. Go back the same way.

7.6 Design and Ecoefficiency at End of Life**7.6.1 Design Rules**

In chapter 2.2 it has been explained how design for end-of-life/design for recycling is subordinate to 'holistic EcoDesign' which stands for minimization of the environmental impact over the complete life cycle. Design for end-of-life can therefore only really work if there is synergy within Life Cycle Design.

Design Rules for End-of-Life therefore have real significance in brainstorming. They can be used as starters for creativity. Later on it must be checked whether results obtained do not violate the life cycle principle. Keeping this in mind, the following design rules work well:

Design Rules for End-of-Life, General

- Extend technical life of products (less waste)
- Decrease weight of products (less waste)
- Decrease weight of those subassemblies which are giving rise to high end-of-life cost (lower cost of recycling)
- Decrease volume of products (transport of discarded product to recycling facilities)
- Modular construction (ease of disassembly)
- Decrease the amount of parts (ease of disassembly, better yields on mechanical treatment)

Design Rules for End-of-Life, Prevention, Reuse

- Make product repair-friendly (accessibility)
- Make trendy parts exchangeable (front cover)
- Make products in such a way that new features can be introduced later on (upgrading)
- Fix subassemblies and components which have reuse potential in such a way that they can be taken out without damage (increase of reuse potential)

Design Rules for End-of-Life, Materials application

- Avoid composites materials like laminates, glass fiber, reinforced materials, metal composites (increase of recycling yield)
- Limit application of materials with surface coatings (avoid contamination of secondary fractions)
- Make materials with recycle potential easily accessible (lower recycling cost)
- Make parts with unavoidable hazardous substances easily accessible (lower cost of final disposal)
- Use iron screws (allow magnetic separation of screws)

Design Rules for End-of-Life, Materials Compatibility

- Apply the compatibility rules for:
 - metals
 - plastics
 - glass(avoid materials combinations which are unfavourable for recycling)
- Use mono-materials plastics, preferably only one type per product (make plastics recycling more effective)
- Mark all plastic parts (easy recognition of type)
- Limit of stickers, wire fixtures, etc. (avoid contamination of fractions)
- Ensure that glass can be easily separated from other materials (increase recycling yields)

Design Rules for End-of-Life, Fixtures

- Limit number of joint/fixtures (lower disassembly time)
- Use click joints > screws > glue joints > soldering (lower disassembly time)
- Make it possible that fixtures can be separated with simple tools (lower disassembly time)
- Limit the number of tools needed, use preferably one type of screws (lower disassembly times)
- Limit the number of tool changes needed (lower disassembly time)
- Construct the product in such a way that there is no need to turn it when disassembling (lower disassembly time)

Design Rules for End-of-Life, Non disassembly

- Product material composition: avoid penalty (see 5.3) elements (increase yield of secondary materials)
- Minimize amounts of flame retardants (increase recyclability)
- Avoid halogens in plastics (lower costs of incineration of left over fractions)
- Special attention for bismuth in (lead-free) solder
- Avoid cadmium and mercury containing batteries (lower costs of final disposal)
- Avoid plating with nickel, tin, zinc (increase value of secondary fractions)

Professors deliberation

It was an invention that came out of necessity. In the sociological seventies decisions taken by the faculty (professors only) were considered to be 'mandarin policies' or conspiracies against the will of students and staff. At that time, plenary discussion and 'democratic voting' (whatever that means) were seen as the only way forward for the university. Such ideas were not just a transient experiment for fun; they were meant to be serious. In practice however they led to stagnation, mediocrity and lack of responsiveness and flexibility in Dutch universities. Several leading scientists left out of frustration and even more importantly high-level people were no longer interested in a university career.

At Delft University such diseases arrived later than elsewhere, but it also took longer to cure them. In my opinion the effects of the bad times in the seventies and eighties are still felt today.

The professors deliberation at Industrial Design Engineering was an informal meeting of the faculty at somebody's private home. Initially it offered the opportunity to discuss issues in an atmosphere without the demagogy and politicking of the plenary meetings. It was an effort to maintain at least some academic level.

Over the years it has developed into a gathering where informality gained more and more importance. With the return of a more normal situation at the university it was not really necessary anymore. When I came to Delft in 1995, it was still flourishing – for me it was a gateway to getting acquainted and becoming part of the faculty community.

The end of the professors deliberations did not come through a new red wave. On the contrary, it was the new Dutch law on universities which dealt the deadly blow. It introduced a clear hierarchical order by giving more power to the Board of Management and the Deans. The 'collegial principle' was abolished, some professors became more equal than others. Faculty 'management teams' were set up. The so-called business-like approach prevailed, there is little room for informality today. Deliberations have been replaced by 'strategy meetings'. Subjects like 'care for students' and 'the cultural function of the university' are not on the agenda anymore. It is all about acquiring funds, realizing output and competition with other institutions. Yes, there is still something left of this practice. At the end of the Academic Year there is an informal meeting in the best spirit of the 'old deliberations'. This is one of the highlights of the year.

Gaudeamus igitur, vivat Academia! (Lets rejoice, long live the University!)

7.6.2 Design and Eco-efficiency at End-of-Life

All these design rules given in 7.6.1 are of qualitative nature. In spite of this, these have provided a lot of support for design activities over the years, and still do today. Their character has changed however; from dogmas into valuable contributors for developing design action agendas.

Today, the QWERTY/Eco-efficiency approach (see chapter 7.5) makes it possible to evaluate what design for end-of-life actions are to be preferred on a quantitative basis. Examples for a 17" monitor and a DVD-player have been worked out in the publication "An Operational Eco-efficiency Concept Linking Design and Recycling of Consumer Electronic Products".

This paper concludes that design for end-of-life can contribute to better Eco-efficiency in the recycling stage. However, the limitations set by the (overall) life cycle impact minimization principle limit its contribution. In many cases achieving economy of scale, investment in better treatment technology and upgrading secondary materials streams in such a way that high levels of reapplication can be realized, are often more effective than design actions.

Nevertheless, design for end-of-life can still make a positive contribution; however, it does not maintain the prominent position it once had (and sometimes still has) in the mindset of practitioners and legislators (WEEE !)

An Operational Eco-efficiency Concept Linking Design and Recycling of Consumer Electronic Products

Jaco Huisman, Nicole Eikelenberg and Ab Stevels

Abstract

Producers of consumer electronic products need to take into account the environmental and economic consequences of the end-of-life phase of their products. The most important driver behind this are the recent EU Directives on Waste of Electric and Electronic Equipment (WEEE) and Restrictions on the use of Hazardous Substances (RoHS). This paper discusses a concept for addressing environmental and economic values for electronics recycling. This concept is applied on the issue of balancing early design strategies with expected end-of-life treatment processes. From this, three general design strategies are defined for improving environmental and economic end-of-life performance of products: reduce parts and materials that are burdening, reallocate materials or components and improve connections. The environmental and economic feasibility of the suggested improvements are determined based on actual redesigns. Finally, evaluation of the redesigns is performed in order to check whether or not an environmental and/or economic improvement is realized. The concept presented in this paper show how producer responsibilities on end-of-life treatment can be better fulfilled in practice. The paper also addresses the boundary conditions and limits for improvement of consumer electronic products by applying Design for End-of-Life.

1. Introduction

Due to increased attention on Extended Producer Responsibility (EPR) and take-back and recycling of products, the environmental performance of end-of-life processing of products as well as economical considerations have become important. Recently enacted European regulations on take-back system operation, the so-called WEEE and RoHS Directives (Commission of the European Communities 2003 I, 2003b) form the legislative framework for electronics recycling in general. This paper mainly focuses on consumer electronic products in particular and not on other categories like cooling, freezing or domestic (kitchen) appliances. Also outside the EU, EOL (end-of-life) legislation is initiated. The EU regulations on electronic waste serve several (partly interlinked) goals.

The intended goals of electronic waste policies are:

1. Reduction of materials going to landfill; minimizing landfill-volumes.
2. Recycling of materials in order to keep maximum economical and environmental value.
3. Reduction of emissions of environmentally relevant substances; including leaching

The Directives apply the four main policy strategies of: setting (weight based) minimum recycling and recovery percentages, minimum collection amounts per inhabitant as well as prescribing certain treatment rules for recyclers and restricting the use of materials (certain heavy metals and Brominated flame retardants). It should be noted that the main focus in the current policy balance is on using weight based criteria. Another strategy of prescribing minimum outlet destinations like for instance a minimum percentage of CRT (Cathode Ray Tube) glass to be used again as CRT glass is not applied at all.

Transposition into national law and implementation is left over to the individual EU member states. They are responsible for operationalization and the way of monitoring, reporting and financing. The finance system can be based on visible fees for consumers to be paid at purchasing a new product or directly being paid by producers on basis of market shares. Producers can choose to join a (semi-)collective system with multiple producers or organize, operate and finance an individual system themselves. The choice for a collective versus an individual system has consequences for the economies of scale for secondary material processing. The way of collecting disposed products, transport distances, the volumes and variety of discarded products as well as the chosen recyclers and secondary processors are to a large extent determining environmental and economic performance (Boks 2002; Huisman 2003).

Directly and indirectly, the new policy framework is also (intentionally) influencing design aspects of products in order to easier comply with the legislation and to reduce costs connected to this. An example could be an extended application of the use of metal housings instead of plastic housings in order to achieve recycling targets easier. As a result, the environmental and economic question is what the influence is on the total environmental

impacts and total costs of a product. To provide answers on questions like this, the relation between environmental impacts and costs over both the production as well as the end-of-life phase must be clear. However, until now, a very limited number of assessments are published on both the environmental part and techno-economical part of end-of-life processing of consumer electronic products in order to obtain a proper balance between environmental results and costs (Huisman 2003; Mathieux 2001; Zhang 2000). In addition, addressing and predicting the way products are recycled many years after their selling is difficult.

In this paper, the relation between and alignment of end-of-life processing and 'design' in general, is discussed. The use of the Quotes for environmentally Weighted Recyclability and Eco-Efficiency concept (QWERTY/EE), developed at TU Delft and its application on Design for End-of-Life (DFEOL) activities is explained. Although the concept as such is not primarily developed for design purposes, it will be proven in this article that this methodology for calculating environmental performance of products at end-of-life is very useful. It supports determining the relevance of design for end-of-life activities on forehand and to relate them to a wider perspective: the total environmental impacts and costs of a products life-cycle. Detailed insights can be generated with this concept on where environmental losses in recycling occur, on what the contribution of the various processes in end-of-life treatment is, on which material to focus on and finally how to evaluate (re)designs (Eikelenberg 2003; Huisman 2003). In addition, the original principle of extended producer responsibility is re-assessed based on the actual outcomes of the redesign cases highlighted in this paper.

In the next section the QWERTY/EE concept will be introduced. In Section 3, the main design strategies as well as a proposal for a DFEOL approach will be discussed. In Section 4, results of two very detailed redesign cases will be discussed: a DVD player and a 17" CRT monitor. In Section 5, conclusions will be drawn on the redesign cases and methodology applied.

2. QWERTY/EE Analysis and Principles

2.1 Starting points

Before introducing the instruments for environmental and economic evaluation, a few additional remarks and boundary conditions are mentioned regarding the place of DFEOL in ecodesign strategies in general:

Redesign activities should not lead to an increase of the environmental burden over the life cycle as a whole. This means that for material selection the combined environmental burden over raw material extraction, manufacturing and production and end-of-life may not increase and for the use phase it means that energy consumption may not be increased due to for instance changing component selection. Furthermore, options and solutions must not lead to exceptional extra costs in the production phase. Product lifetime is not influenced in a negative way due to the redesign activities. Optimal product lifetime considerations like in (van Nes 2003; Rose 2000) are out of the scope of this article. Redesign options also should not jeopardize reliability of products nor decrease functionality requirements.

In this article, the term 'design' must be regarded as (incremental) product design and not as system design or radical changing functionality. Normally, these broader aspects are not end-of-life or environmentally driven, but the result of changing functionalities and technological developments.

Based on comprehensive modeling of the end-of-life chain, environmental and economic calculations are based on three main values as displayed in Figure 1.

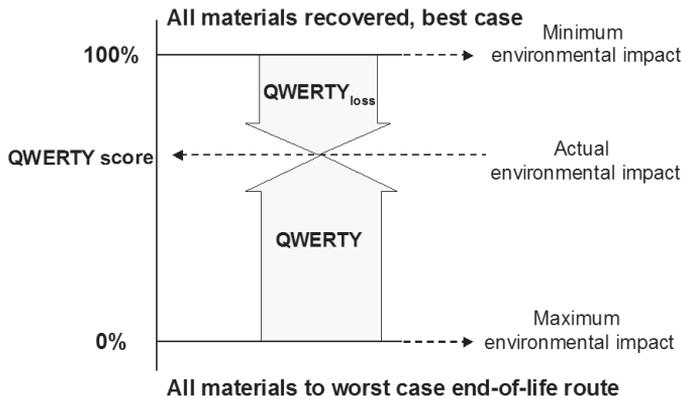


Figure 1 Calculating QWERTY values

1. The minimum environmental impact and minimum costs are defined as all materials being recovered completely without any environmental impact or economic costs of end-of-life treatment steps, thus representing an environmental substitution value and the economic value for newly extracted and produced materials. (Usually both are negative values, maximum environmental gain as negative environmental impacts and maximum revenues as negative costs). This value is a theoretical value: in practice there will always appear (environmental) costs connected to separation of materials, energy consumption and transport.

2. The maximum environmental impact and maximum costs for end-of-life treatment are defined as every material ending up in the worst possible (realistic) end-of-life route, including the environmental burden of pre-treatment: collection, transport, disassembly and shredding and separation into fractions. The 'realistic' end-of-life scenarios under consideration are controlled and uncontrolled landfill, incineration with or without energy recovery and all subsequent treatment steps for material fractions, like copper, ferro and aluminum smelting, glass oven and plastic recycler. Also this value cannot easily be exceeded: only under disposal conditions which are prohibited for instance.

3. The actual impacts/ costs based on the actual environmental performance of the end-of-life scenario under consideration are compared with the two boundary conditions and expressed as percentages. This actual value is obtained by tracking the behavior of all materials over all end-of-life routes and by taking into account of all costs and environmental effects connected to this.

All detailed backgrounds, data included and formulas to calculate QWERTY values can be found in (Huisman 2003; Huisman *et al.*, 2003). With the QWERTY/EE approach, products to be considered are not classified according to their product group (like DVD players or TV's) but are classified according to their material content as plastic, metal, precious metal and glass-dominated products. This is because it is found that improvement avenues in design, technology and policies and take-back system operation are different for these four categories on a material basis. Similar to the environmental calculations in Figure 1, also all costs per end-of-life stage are addressed. An important outcome in Figure 1 is also the amount of environmental value lost, for which also the contribution of materials can be displayed. Hence, the difference between the actual scenario and the 100% shows where room for design improvements is.

For consumer electronic products specifically, the following aspects can be assessed. First of all the performance of single products in different end-of-life options, like incineration and landfill as well as the effects of adaptations in material processing like applying plastic recycling or modifying the destinations of CRT glass fractions between various processing options. Secondly, the contribution of individual materials and material fractions in this performance can be determined. The comparison between WEEE recycling targets and QWERTY values ('weight composition' versus an 'environmental weight composition') can thus be made, hence generating improvement avenues

in design, policy, technology development and system organization. Next, the position and contributions of single stakeholders or stages to the total end-of-life chain can be calculated. For instance for the influence of transport, copper smelting, cement kiln and other stages to the total environmental and economic outcomes. Furthermore, the consequences for system organization can be visualized: This includes the role of logistics, economies of scale for collective versus individual systems, increasing collection rates, etc. Finally, optimizing the technical correlation between recyclers and secondary material processors and final waste processors is made possible.

2.2 QWERTY/EE: Ingredients

In order to perform the environmental calculations and to determine costs made over the end-of-life chain, many other elements are needed in order to deliver a comprehensive and accurate description for recycling of consumer electronics. Included are therefore (Huisman, 2003):

1. An environmental validation method. Although multiple environmental assessment models are incorporated (Steen, 1999; Heijungs *et al.*, 1992), the Eco-Indicator'99 method (Goedkoop and Spriensma, 2000) is chosen as a default method. A further elaboration on the consequences of different environmental assessment methods can be found in (Huisman *et al.*, 2004).
2. Detailed product compositions and amounts of relevant substances, like heavy metals and precious metals, must be known. Many data are derived from environmental benchmarks of products from (Philips Consumer Electronics, 1999, 2001a, 2001b, 2002, Stevels and Ram 1999).
3. Furthermore, shredding and separation behavior and disassembly characteristics of products. Data are derived from (Ansems and Van Gijlswijk 2002).
4. Accurate Life Cycle Inventories for metals are obtained from TU Delft, Department of Applied Earth Sciences (Scholte 2003; Verhoef *et al.*, 2004).
5. Technical data on further treatment of certain fractions, like acceptance criteria, input requirements and recoveries at aluminum, ferro and copper smelters are available from individual contacts with German and Dutch recyclers and waste processors.
6. Collection data, transport distances and energy consumption numbers are gathered for the Dutch E&EE take-back system (NVMP, 2004).
7. Landfill and incineration data is also obtained from (Ansems and Van Gijlswijk, 2002). Included are leaching behavior and treatment efficiencies at controlled and uncontrolled landfill sites, incineration data including final emissions to air, water and soil as well as energy recovery.

In addition to the environmental data described, the following economic parameters are included (Huisman, 2003):

1. Sorting, registering, transportation and buffer storage costs.
2. Disassembly costs based on disassembly times for standard operations.
3. Integral costs for shredding and separation.
4. Costs and revenues at primary copper smelting
5. Costs at ferro and aluminum smelter processes.
6. Costs at incineration sites, both Municipal Solid Waste (MSW) incineration and special waste incineration, also including charges for all environmentally relevant materials (concentration dependent).
7. Costs at landfill sites, also including charges for all environmental relevant elements occurring in disposed consumer electronics (concentration dependency).
8. Costs for plastic recycling including cleaning, upgrading and color sorting.
9. Revenues paid for all recovered materials. Including changes in metal prices over time.

The examples of Section 4 are based on the following assumptions and boundary conditions: Firstly, state-of-the-art recycling is based on current shredding and separation technologies as presented in (Huisman 2003) and updated in 2004 by (Mirec, 2004). Secondly, data are representing the Dutch take-back system for consumer electronics. The third issue is that there economies of scale for glass and plastic recycling as well as well-established

markets for secondary materials leading to representative market prices are assumed to be in place. Furthermore, costs for consumers for handing in products at a municipality, retailer or other collection point are excluded from the integral costs. Finally, results are based on treatment of residue fractions in MSW-incineration plants with energy recovery.

2.3 QWERTY analysis: 'Weight' versus 'Environmental Weight'

The results of the QWERTY part of the analysis are illustrated with Figure 2. The contribution of materials to the MRE (Material Recycling Definition which represents nothing more than the weight based composition of the product) versus the environmental equivalent (QWERTY) is presented for a DVD player. The left figure is representing the chemical content of the product. The right figure is displaying the contribution of the same materials to the distance between the best and worst case boundaries of Figure 2. The mathematics behind this right graph are explained in (Huisman 2003).

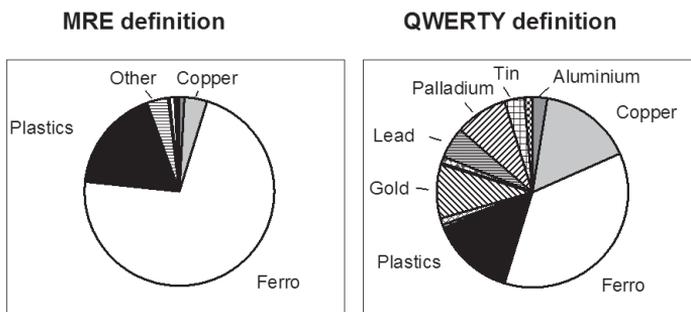


Figure 2 Example Weight versus Environmental Weight

From a weight perspective, the conclusion would be from the left graph that the ferro and plastic content are the most important to look at. In the environmental alternative other materials are appearing. The copper and precious metal content have a higher contribution, the ferro and plastic content has a lower contribution compared to the 'weight based' graph. This leads already to the preliminary conclusion that the QWERTY concept gives a different priority setting in DFEOl compared to looking at the weight of products only.

2.4 EE: Eco-efficiency, the relation between environment and economics

In Figure 3 the basic idea behind the eco-efficiency (EE) part of the calculations of the QWERTY/EE approach is visualized. The Y-axis represents an economic indicator (in this case €'s). The X-axis represents the environmental indicator (in this article LCA scores in mPts, millipoints, from the Eco-Indicator'99 methodology (Goedkoop and Spriensma, 2000). This value corresponds with the absolute value(s) displayed in the middle of Figure 3, which are representing one or more actual end-of-life scenarios.

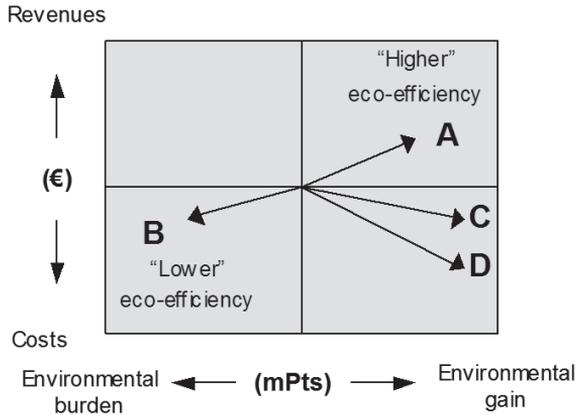


Figure 3 Example 2D Eco-efficiency graphs

Different end-of-life scenarios for one and the same product are displayed as points in Figure 3. Such options represent changes in end-of life treatment or applying certain technological improvements like for instance increasing plastic- or glass recycling. In order to achieve higher eco-efficiencies, improvement options should lead to a change from the reference or starting point (the zero) into the direction of the upper right part of Figure 3 (point A). However, options with a direction towards the down-left part of Figure 1 should be avoided (higher costs and higher environmental impacts), because from the point of reference a lower eco-efficiency is realized (point B). The other two points C and D are leading to the same environmental improvement but also higher costs compared to the reference point. When point C and D are to be compared, one could say that in general direction C is more eco-efficient than direction D, because the same environmental improvement is realized with lower integral costs.

3. Resulting design principles

3.1 The place of DFEOL in general ecodesign

In Figure 4, the environmental impacts of 'the production value (best case)', 'worst case' and 'actual practice' recycling scenario are displayed for treatment of the same DVD player. The first bar shows the total environmental value connected to the materials present in the product under consideration, i.e., the environmental value of the materials if they would replace new materials when fully recovered without any environmental burden of end-of-life processing itself, which is also equal to the production value. The second bar represents the worst-case disposal scenario, i.e. the highest environmental impacts of all realistic end-of-life directions like for instance uncontrolled landfill or incineration with MSW (Municipal Solid Waste) without energy recovery. The third bar displays the environmental value generated by treating the product under consideration in an actual recycling scenario, like for instance average treatment in the Dutch take-back system. The Y-axis shows environmental burden above and environmental gain below due to prevention of new material extraction.

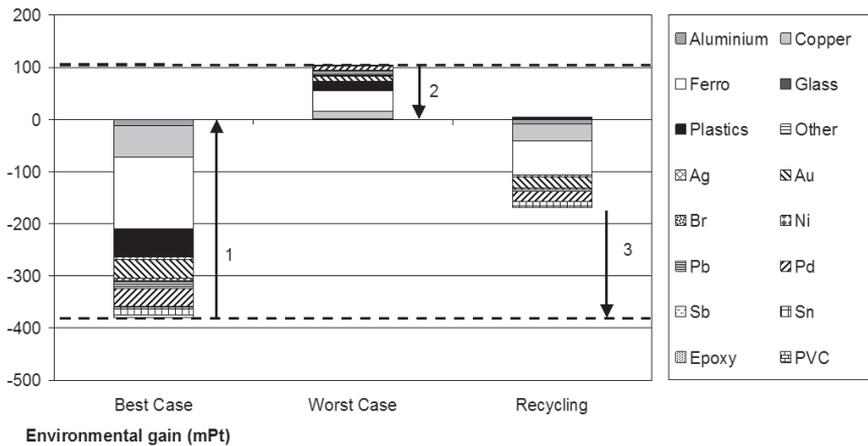


Figure 4 The place of DFEOL in ecodesign in general

With Figure 4 for design for end-of-life should not only focus on the environmental value of a certain recycling scenario (the third bar) but also take into account the 'best-case' and 'worst-case' environmental impacts, while the final destination of a product is always uncertain. This leads to formulating the general life-cycle perspective into three principles for Design for End-of-Life activities:

1. The environmental value of materials within the product in the manufacturing stage should be decreased. This is an important principle, while it should be prevented that recycling percentages, either on a weight basis, or on environmentally weighted QWERTY basis are increased by 'adding more environmental load' into products at the beginning of their life cycle. Such an activity would lead to overall increases of environmental impacts. Therefore the first arrow in Figure 1 is directed downwards: The total environmental value of the materials compositions should be decreased.

2. The second arrow represents the second important principle for redesign. When the product under consideration is not recycled at all and for instance ending up in a landfill, the environmental impacts must not increase as well for example as a result of leaching of toxic materials. Therefore, the environmental value connected to the 'worst case scenario' should be decreased as well. This can be achieved by for instance avoiding potentially toxic materials.

3. The third arrow shows that a redesign activity should lead to minimizing the gap between maximum environmental value to be recovered (the 'manufacturing value' of the first bar) and the actual performance of product in the recycling scenario under consideration (third bar). In other words, the environmental value of the materials present in the product must be recovered as much as possible.

The result of a successful redesign activity should comply with all three principles at the same time and not only with one or two of them, in order to prevent higher overall environmental impacts. Diagrams like Figure 5 are also crucial for the evaluation of (re)design cases. Besides these three general principles, with the QWERTY/EE concept also the role of individual materials present in the product as well as the role of the different end-of-life processing steps can be quantified in detail. This way, detailed information on the environmental role of the different end-of-life processes and stages can be obtained. The role of the various processes to the total environmental gain and losses of end-of-life treatment shows which processes contribute the most.

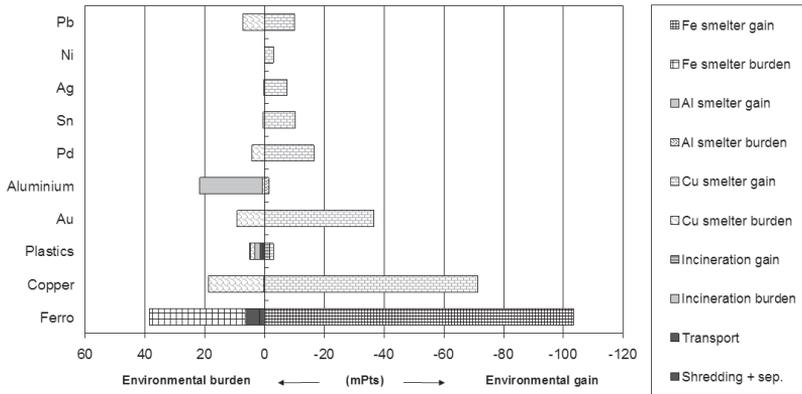


Figure 5 Environmental contributions of processes for a DVD player

Design for End-of-Life activities should in particular focus on creating optimal fractions for the most relevant processes. In Figure 5, the contribution of the various processes involved are displayed for a DVD player. It shows for instance, that the copper smelter is the most relevant process in the state-of-the-art recycling scenario being displayed. The ferro smelter is less important as expected for this product consisting for, two-thirds out of steel from the housings. It should be noted here, that also technical capabilities of for instance a copper smelter in the above example should be taken into account.

3.2 Example: replacing plastic with steel or aluminum housings

Due to the weight based recycling targets in the WEEE Directive, designers may tend to replace plastic housings with metal housings (metals lead in general to higher recycling percentages) in order to comply easier with the targets set. The effect is shown in Figure 6.

As mentioned above, the first principle of Figure 4 should put as less as 'environmental value' in the product as possible in the first place. However, Figure 6, shows that the end-of-life performance of products with a metal housing is improved, but at the 'environmental expense' of the production stage. By adding more environmental value in the product at manufacturing, also more environmental value can be recovered in end-of-life, but the net effect is negative from an environmental point of view. This will be even worse when the product with metal housing is not recycled but disposed off as MSW. In this case, the higher environmental value is thrown away completely.

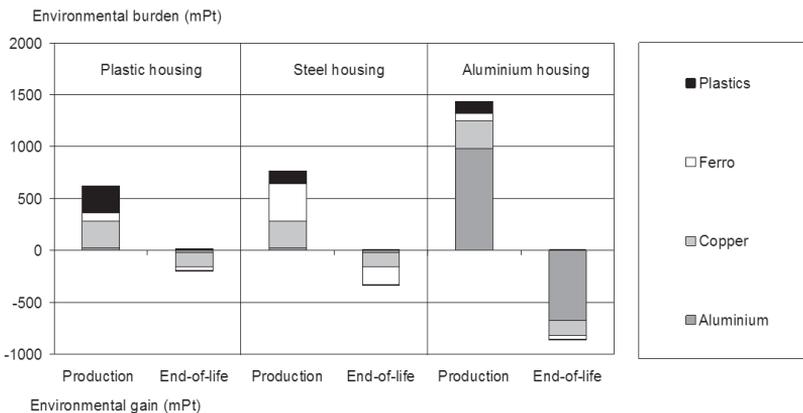


Figure 6, Replacing plastic with steel or aluminum housings

3.3 Strategies for improvement

Based on the QWERTY analysis mentioned above, there are three main strategies to be applied in practice to increase the amount of materials in the right fractions and to reduce environmental impacts (Eikelenberg 2003):

1. Reduce or replace the amount of critical and undesired materials like penalty elements and hazardous substances. This strategy incorporates volume and weight reduction where possible. Furthermore the use of heavy metals should be avoided when components with less toxic substances are available. Also alloys containing toxic or disturbing elements for further treatment like upgrading should be prevented where possible.
2. Reallocate materials. With proper reallocation of materials cleaner fractions can be obtained. Based on analysis of problem areas within the product under investigations, in some cases reconfiguring of components or assemblies might be an option.
3. Improve unlocking properties of parts and components. Both for shredding and separation as for disassembly, the unlocking properties of materials and components play an important role. The changes of materials ending up in the 'wrong' fractions can be decreased by changing product architecture in general and by changing types, sizes or form of the connections between components or assemblies involved

Based on these directions, the redesign results for a 17" Monitor (14,6 kg) CRT monitor (Philips Environmental Benchmark, 2002) and a DVD player (2,7 kg) (Philips Environmental Benchmark, 2001) are presented in the next Section. From both products, a full chemical analysis is available, including Printed Circuit Board compositions. But first, the main problems in design for end-of-life and the approach used for redesigning is discussed.

3.4 DFEOL and recovery of materials

In the recycling practice for electronic products, the fundamental problem is to obtain pure and valuable fractions out of very mixed compositions. This problem can be divided in two sub-issues:

1. Contamination of valuable materials with other valuable materials which results in losses of both.
2. Contamination of valuable materials with undesired elements or environmentally burdening materials (e.g. heavy metals).

Table 1 demonstrates some examples of contaminations in fractions that should be avoided by taken these aspects into account in the design process when decisions on material combinations are made.

Table 1 Knock-out and penalty elements at metal smelting

Fraction	Knock-out element (no processing above a certain limit)	Penalty element (reduces value)
Copper (Cu)	Hg, Be, PCB	As, Sb, Ni, Al, Bi, Mg
Aluminum (Al)	Cu, Fe, polymers	Si
Ferro (Fe)	Cu	Sn, Zn

For the four main product categories in terms of material content (glass-, plastic-, metal- and precious metal dominated products), there are large differences in the priority setting for each of the valuable fractions. For each of the four categories Figure 7 is applicable:

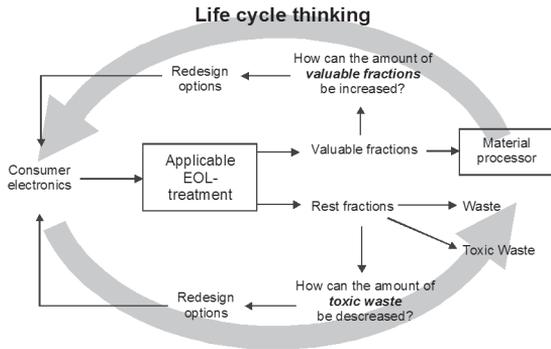


Figure 7 The fundamental DFEOL problem

Besides this figure, the general and material related environmental and economic problems are translated to the following main focal areas for consumer electronics, based on (Eikelenberg, 2003; Huisman, 2003):

1. Plastics are highly ranked in the list of main environmental bottlenecks. Generally speaking, plastic recycling is not very eco-efficient, except for large and medium sized housings consisting of one and the same material and without contaminations and flame-retardants. In all other cases, the recyclable quantity and grade is not sufficient to obtain a good market price and high level re-applications. For the design process this means that plastic fractions should be as clean as possible.
2. Copper is always an important QWERTY-loss bottleneck. Copper/aluminum or copper/ferro combinations are to be separated in order to obtain valuable fractions. For design this means improving unlocking properties of combined copper/aluminum and copper/steel parts and to maximize appearance of copper in the copper fraction as well as to keep precious metals and flame retardants in the same copper fraction.
3. Precious metals (gold (Au), silver (Ag) and palladium (Pd)) are also high on the priority list for all products. The main issue here is loss of these materials towards fraction where they are not recovered. For design (again Figure 4) this means that the amount of precious metals used in products should be decreased and that precious metals appearance in the copper fraction should be maximized.
4. Glass separation and recycling is an important issue for TV's and monitors. Currently, glass recycling (back to CRT glass) is not widely applied. For the glass fractions the level of re-application is highly relevant (Huisman 2003, Huisman 2004b). The environmental gain connected to replacing primary CRT glass is much higher than old glass replacing Feldspar in the ceramic industry which on its turn is to be preferred over CRT glass replacing sand in the building industry.

3.5 The DFEOL approach

The focus areas identified have to be internalized in the design process. To be able to generate useful redesign options, the designer needs to know what valuable fractions and toxic fractions arise from the current product design when treated in a specific EOL-scenario and how to improve fraction compositions.

The knowledge gaps for the product developer are regarding chemical content of parts and components of products; the EOL-scenario to be expected; details of recycling processes in terms of (desired) input and output; requirements from material processors on desired compositions of fractions. For a useful DFEOL-approach it is necessary that these knowledge gaps are filled. However, it cannot be expected that product developers become recycling experts. Therefore, an integral approach is presented and illustrated with two elaborate redesign cases: a DVD-player and a monitor. This includes tools like rules of thumb, checklists and advice when it is really necessary to consult an expert. In addition redesign options need to be evaluated for their life cycle impact and end-of-life costs. End of life improvements do not always result in total life cycle improvements! This sub optimization should therefore be recognized and prevented. Finally, the approach needs to fit into the regular design work and (tight) time schedules of product designers. The procedure is illustrated in Figure 8.

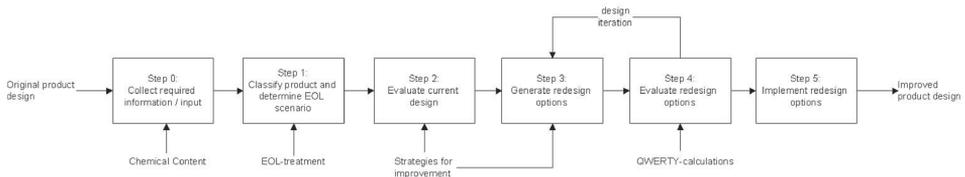


Figure 8 DFEOL process

4. Examples

4.1 Introduction

Based on the above approach, the DFEOL case studies are explored with existing products in four main categories of consumer electronics. In each of these categories a representative product is chosen as a case study: a 17" Monitor (glass dominated product), a DVD-Player (metal dominated product), a portable audio set (plastics dominated product) and a mobile phone (precious metals dominated product). For each of the cases QWERTY-priorities are calculated based on losses of critical elements in the end-of-life chain. These priorities are translated in the main problem areas to be addressed. The results are presented in Table 2.

Table 2. QWERTY main problem areas results for different CE products

Product	Characterization EOL-treatment	QWERTY-loss	QWERTY-loss focus	Main problem areas
DVD player	Mechanical processing & material processing	55.6%	Plastics 14.6%; Ferro (Fe) 13.9%; Copper (Cu) 7.5%; Lead (Pb) 5.9%; Palladium (Pd) 4.0%; Silver (Ag) 2.9%	<ol style="list-style-type: none"> 1. Recovery of plastics 2. Unlocking properties of Cu/Fe parts 3. Recovery of precious metals
CRT Monitor	Disassembly, mechanical processing & material processing	67.7%	Plastics 22.6%; Glass 16.8%; Palladium (Pd) 9.2%; Copper (Cu) 6.7%; Gold (Au) 4.87%	<ol style="list-style-type: none"> 1. Recovery of plastics 2. Recovery of glass 3. Unlocking properties of Cu/Al 4. Recovery of precious metals
Mobile phone	Removal battery; Mechanical & Material processing	71.7%	Palladium (Pd) 40.9%; Gold (Au) 13.4%; Zinc (Zn) 8.7%; Copper (Cu) 2.6%	<ol style="list-style-type: none"> 1. Recovery of precious metals 2. Unlocking properties of steel 3. Disassembly of battery
Portable Audio	Mechanical processing & material processing	57.2%	Plastics 30.5%; Copper (Cu) 11.5%; Lead (Pb) 5.5%; Ferro (Fe) 3.9%	<ol style="list-style-type: none"> 1. Unlocking properties of Copper parts and ferro parts 2. Recovery of plastics

From the case studies it can be deduced that each product category has its own specific EOL-scenario and in combination with its specific material composition this results in a fraction composition. This fraction composition then determines the share of material, which can be recycled by material processors or has to be treated as waste. In most cases it is clear to which category a product belongs, based on archetypes of the product categories. For each category there are specific valuable materials, the preferred EOL-treatment is known and general bottlenecks can be identified

4.2 Results Detailed redesign case: CRT Monitor

From the above table two products are selected for redesign. The design priorities and avenues for the detailed redesign case of a 17-inch CRT monitor are derived from (Eikelenberg, 2003). It has to be noted that the monitor under consideration is a product which is already for a long time on the market and well optimized from a general design perspective. Technically it is possible to recycle screen glass to screen glass and cone glass to cone glass. However, the material cycles for this glass are not closed for 100% due to necessary cleaning and separation of materials. The rapid growth in sales of flat panels will make it even more difficult in the future to deal with a bulk of 'historic glass' towards a probably decreasing demand. With the QWERTY-analysis of Table 1, the following critical components are identified:

1. The front and the back panels of the plastic housing contain flame-retardants for safety reasons and regulations. The separation of the two types of plastic is required for plastic recycling in order to prevent relatively high costs when recycled.
2. A high amount of copper is appearing in the residue fraction and the aluminum fraction after shredding and separation. Copper in the residue fraction will be lost. Unlocking properties of copper (and aluminum) parts are general bottlenecks in recycling.
3. In steel recycling, copper is a penalty element. Critical components are motors and transformers, which are often removed by hand-picking after shredding.

In addition to the identification of these critical parts and components it is very important to make an inventory of connections in the product. Especially connections between materials that need to be directed to different fractions are important. These connections need to break to assure that materials are separated as desired. In current practice however, this often is not the case and particles consisting of several materials end up in the residue fraction or in another fraction. Furthermore, the disassembly time has a significant influence on the costs of the treatment of glass dominated products. The numbers and types of connections present in the monitor can be found in (Eikelenberg, 2003).

For the generation of redesign options, the QWERTY priorities and resulting critical parts and components and the analysis of connections are used for the redesign. The following redesign options are examples as proposed for this type of products:

1. Reduce or substitute critical materials: Make flame retardant and non flame retardant plastics easier to identify: As discussed in the QWERTY analysis (Table 1) plastic recycling is one of the main problems. Especially flame retardant plastics cause difficulties in recycling. The use of these flame retardant plastics, however, cannot be prevented because of safety regulations.

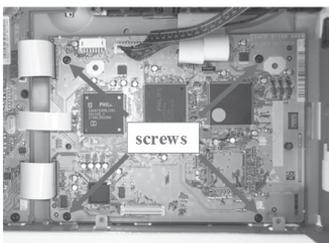
Use plastic screws or form closures to attach PWB's to steel carriers or housings: PWB's contain precious metals that have a relative high value for recycling. However, PWB's are often attached to steel carriers or housings with screws that do not easily release in mechanical processing. By using plastics screws and / or form closures to attach the PWB to steel parts the PWB will have a much bigger chance to break apart from the steel parts and thus be able to be separated to the right fraction.

2. Reallocate materials or components: Move the monitor control or other small PWB's to central PWB instead of fixing it to the plastic housing. In the case of no PWB's attached to plastic housing parts this leads to a cleaner plastics fraction (no pollution by PWB-materials) and to a higher recovery of materials of the PWB.

3. Optimize connections:

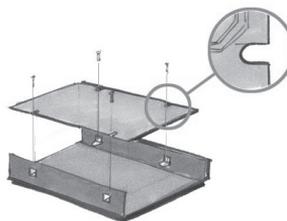
Replace metal brackets of CRT by widgets in plastic housing in order to make disassembly easier and support with icons on the product where to hit. Since disassembly time is one of the dominant cost factors of a monitor every simplification of the disassembly process will have a significant effect on the costs, regardless of the possibilities of better separation.

Problem: PWB is connected to steel carrier with many screws



'old' design

PCB is connected to the steel carrier by form closures for easy release when shredded



'new' design

Figure 9 Critical DFEOL aspects

Based on the previous technical explanation, a complete redesign has also been made of the monitor. This redesign is evaluated in Figure 10.

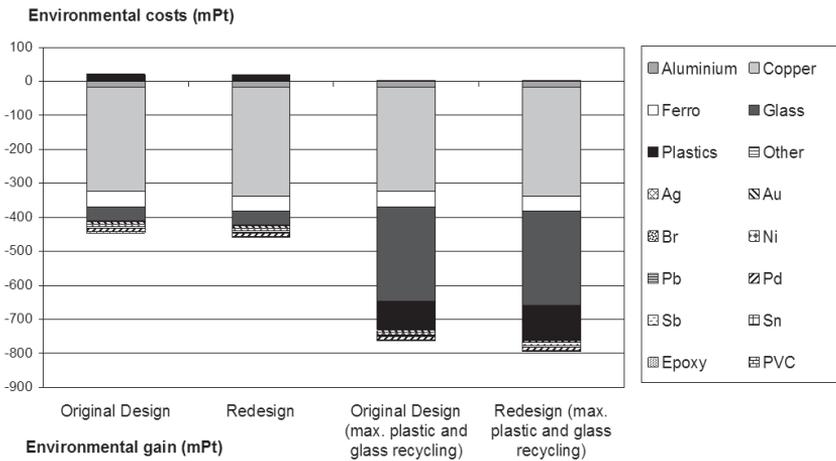


Figure 10 Evaluation redesign 17" Monitor

The environmental improvements of the detailed redesign of a glass dominated product like a CRT-monitor are relatively small. The main reason for this is the fact that the product under consideration is already a highly optimized product for which functionality leaves little room for improvement. Application of all feasible redesign options in practice leads not to a significant improvement in the best-case – worst-case environmental bandwidth of the product. However, especially by improving the disassembly characteristics (from 285 to 176 seconds/ piece), a significant change in end-of-life costs is obtained: Under state-of-the-art recycling operations as described in (Huisman, 2003), the original design is estimated to have an integral end-of-life cost of € 5,95 per 17" Monitor, whereas the redesign is estimated at € 4,86. This is including all costs for transport, disassembly, shredding and separation, final waste treatment and revenues for secondary materials.

4.3 Results Detailed redesign case: DVD player

In Figure 2, 4 and 5, already some information from the QWERTY analysis for this DVD player is presented. The main conclusions from this analysis are:

1. The main environmental losses related to the ferro content are caused by end-of-life processing and transport and not from losing materials in processing.
2. The copper and the ferro smelter are the most important processes for treating this product.

The design priorities and avenues for the DVD player are derived from (Eikelenberg 2003). New fraction compositions for the redesign are calculated and evaluated based on preferred and non-preferred materials in the various material fractions. From this evaluation the following main redesign priorities are identified:

1. As a result of the presence of aluminum heat-sinks, significant amounts of both steel and copper are lost to the aluminum fraction.
2. Connections between steel housing, PWB and plastic parts should be avoided or optimized for shredding and separation.

For the generation of redesign options, the QWERTY priorities and resulting critical parts and components and the analysis of connections are used for the redesign. Similar to the 17" Monitor, a number of redesign options are proposed and discussed in (Eikelenberg, 2003).

The new embodiment of the relevant options resulting in new redesign is used as input for the QWERTY-evalu-

ation. Included is also are the improved separation characteristics for the various components resulting in new fraction compositions of this redesign in end-of-life treatment. The effect on the weight and the product composition in general is significant. Thus also the effect on the environmental bandwidth ('best case' and 'worst case' conditions) as earlier discussed with Figure 4 is appearing in this evaluation. The evaluation of the new design is presented in Figure 11. For the state-of-the-art recycling scenario there is a decrease in recovered environmental value compared to the original design (the third set of two bars in Figure 11). With this example the relevance of Figure 4 and its three principles is made clear. The decrease is due to the fact that less material value is 'put into the redesigned product'. The change in absolute values is from 164 mPts to 161 mPts recovered environmental value. The reduction in bandwidth (as the distance between first and second bar) is from 485 mPts to 443 mPts environmental burden for production and is more than ten times as high compared to the decrease in absolute environmental values of the considered recycling scenario (third arrow).

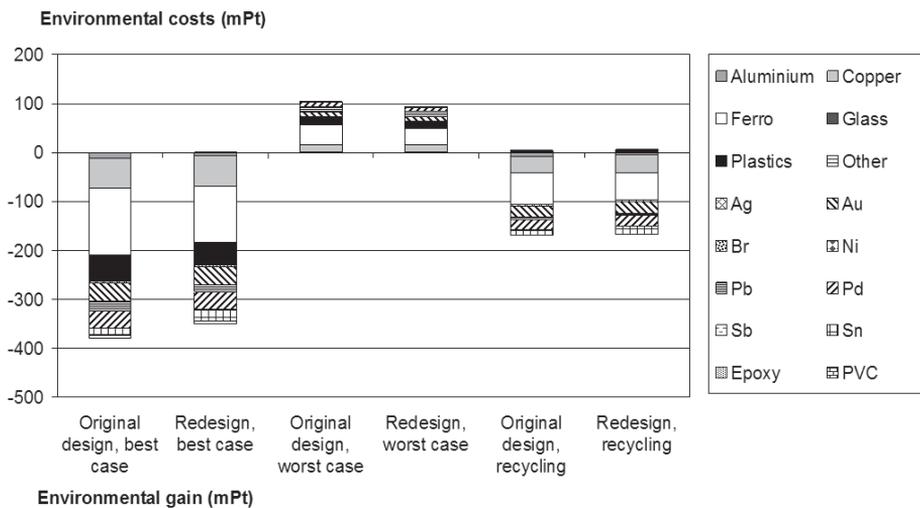


Figure 11 Evaluation redesign DVD player

Not only is the environmental bandwidth significantly decreased. Also in this case a significant decrease in total integral end-of-life costs is obtained from € 0,46 to € 0,33 per DVD player. Furthermore, a much lower material value put into the product in the manufacturing stage has been obtained. The total material value (equal to the maximum value of the materials in the disposed product when no other costs are considered), as such is decreased from € 1,80 to € 1,61 indicating that the material costs in production are decreased as well. In this redesign case, both an environmental improvement and a significant economic improvement is realized, but the compliance with the weight based recycling percentages prescribed in the WEEE Directive is more off target.

4.4 Evaluation of redesign options: restrictions

Redesign options have to be evaluated on their effect on improving the closing of material cycles and reducing the environmental impact of CE-products. It goes without saying that apart from these environmental issues functional requirements (dimensions for specific products like audio-goods), impact of change of components that are also used in other products (e.g. CD-unit, power PCB), cost aspects of design changes, effects on total life cycle impacts, etc. are most important when deciding on the redesign. In general, some restrictions which can limit limiting the freedom for Design for End-of-Life are of environmental, 'practical' or managerial origin:

1. Functionality and looks: Design changes that affect the looks or functionality in a negative way in the eyes of the designers or marketing department will not be accepted. Often length and depth of products are fixed for fitting products into one product line.

2. Cost aspects. Design solutions that cost significantly more have obviously little chance to be implemented.
3. Reliability and safety, legal requirements: For instance the obligation to use flame-retardants in covers of TVs makes plastic recycling currently technically difficult and economically not attractive.
4. Development time. The development cycle of many consumer electronics products is so short that a time consuming and tailor-made Design for End-of-Life evaluation can't be included in the design process. Therefore, experience on this probably has to be collected in 'pilot projects' and implemented in a stream-lined manner.
5. Supply chain aspects. Lasting contracts with certain suppliers can limit the selection of preferable 'end-of-life friendly' product modules or components.

5. Conclusions

5.1 Redesign cases

The main conclusions from the two redesign cases are and from the QWERTY results for the other two product categories are that optimizing design and end-of-life processing has to be done tailor-made: The environmental improvements of the detailed redesign of a glass dominated product like a CRT-monitor are relatively small. The main reason for this is the fact that the product under consideration is already a highly optimized product from a functionality perspective. Applying feasible redesigns options only leads not to a significant change in the best-case – worst-case environmental bandwidth of the product, but the disassembly time of the product can be decreased significantly.

The detailed redesign of the metal dominated product like a DVD player leads to a small lowered recovery of environmental value. However, the reduction in environmental 'bandwidth', which corresponds to the first two principles of Figure 4, is much more significant than the third principle: recovering of environmental value in end-of-life treatment. The evaluation of the DVD redesign leads to the interesting and apparently contradictory conclusion that a good 'Design for End-of-Life' effort can finally lead to a lower end-of-life performance of a product in the state-of-the-art recycling scenario. In fact the intended Design for End-of-Life has become a proper Design for Material Application on a life cycle basis. For the above example, also the weight based recyclability targets would drop for the redesigned products. **The redesigned product is less compliant with the WEEE recyclability targets** (Commission of the European Communities 2003b) compared to the old product, **but is in fact a better ecodesign from an environmental life cycle perspective.**

Two other screening studies not further discussed in detail in this paper. Also redesign are made for a plastic dominated product like an Audio set, shows that the main improvement areas are increasing the possibilities for plastic recycling of the housings and decreasing the disassembly times. Without these improvements plastic recycling of medium sized housing like these would be even more expensive or even impossible. In addition, also a redesign case of a precious metal dominated product like a cellular phone is done (Eikelenberg *et al.*). This shows the domination of the precious metals to the environmental and economic outcomes. All design efforts should be focused on recovery of these materials by decreasing their presence in other fractions than the copper fraction. If separate collection of cellular phones would be more common, then a few design aspects have to be addressed in order to make this stream more optimized for secondary processing.

5.2 Methodology

The QWERTY/EE approach as such is not primarily developed from a design perspective. The calculation sequences are for instance not including the products architecture, assembly and disassembly structures and which components and subassemblies are used in a product. Nevertheless, the detailed manual analysis in this paper proves that the QWERTY methodology for assessing environmental performance is very useful in determining redesign strategies. The main 'features' are the calculation of the influence and relevance of the various processes involved and which materials to prioritize. The way of working can be applied on products and components being available on the market and is regarded most useful after a first design cycle like a first and new type of product on the market. When done appropriately, improvements are realized in all further product types on the market for future years.

Also the evaluation of the redesign results is very valuable. The implementation of streamlined environmental calculations for various end-of-life scenarios is recommended for the development of design tools. In such tools, it is not possible or desired to apply a traditional and time consuming LCA with very limited room to compare alternatives very quickly. Due to the comprehensive methodology and the environmental descriptions of all relevant end-of-life options, the QWERTY/EE concept can be incorporated result in dynamic and very fast obtainable outcomes. In simple words, by starting to model the end-of-life system first, followed by tracking individual behavior of products within such end-of-life systems is on the long term much more efficient than applying data collection and environmental validation on the end-of-life impacts of products one by one. Another recommendation is to further develop the life-cycle check on the redesign results. In the case of a substantial changing material selection, also the full production values of materials including deformation processes etc. should be incorporated. The Figure 4 (left bar) should be extended with the environmental value of deformation and shaping processes for materials.

5.3 Extended producer responsibility and design

The actual redesign results illustrate that despite the very limited degree a designer has for improving end-of-life aspects from an environmental perspective, still significant improvements can be realized from an economic perspective and thus in costs for society. This is clearly a valuable result with societal relevance, while in the end consumers will pay for take-back and recycling of electronic products. However, despite the design improvements made, improving end-of-life environmental performance of recycling chains is to a large extent bound by applying proper waste stream management, by the availability of markets for secondary materials and most importantly by realizing economies of scale in collection logistics and treatment, rather than by trying to make producers responsible for Design for Recycling as the only environmental solution for electronic waste. Further examples of this can be found in (Huisman 2004a) and (Huisman 2004b) for treatment of cellular phones, CRT glass and printed circuit boards.

In simple words: Proper ecodesign can make an eco-efficient contribution, but is not solving the environmental issue connected with electronic waste altogether.

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Stockholm, justice and injustice

Stockholm has been built as the capital of the North, for an empire which does not exist anymore. It is still the capital of Sweden and the centre of environmental activities (although some Gothenborgians and others might protest) in Sweden for industry, government and research institutes.

Stockholm is a great city, I like its spirit, it impresses me again and again. When there is a chance I always go to the Suomen Kirkko/Finska Kyrken, a humble building opposite the Royal Palace. Behind it, there is a small garden with a monument for the volunteers who fell in the Finnish-Russian war of 1939-1940. It was a lost case for the Finns, but the volunteers joined because they could not stand the injustice. It is an idea solidly entrenched in the Nordic spirit. Even if it is known beforehand that defeat is likely, you go for it because your soul cannot stand to back down. It is called 'sisu' in Finnish.

A completely different thing is available near by in Yttre Borggården. It is the change of the guards of the Royal Palace. It happens at 12:00, with pomp and music a band plays. However at the side a tramp, a person like Findus of the well-known TV series, is imitating the ceremony in parallel. He is tolerated with a smile. Serious with sense of humor, that is the way to do it!

There are in my mind strong parallels here with environmentalism and EcoDesign. Never give up when even if it seems to be lost, go on to the very (sometimes bitter) end. It is serious, but always being serious can sometimes be ridiculous too. Relativism comes with time.

City walk : Start at Central Station, go through Vattugatan, right to Malmotorsgatan, L to Fredsgatan, go through Kungsträdgården to Wahrendorffsgatan and to Nybroplan. Back through Arsenalsgatan, and cross the Norrström bridge. In Gamla Stan walk through as many small streets as you like between Skeppsbron and sterlanggatan and end up at Jäsontorget. Proceed to Prästgatan via the stairs and go to Stortorget. Visit from there Suomen Kyrkko and the change of the guard.

Favorite Restaurant: Blå Dörren, Södermalms Torg 6, 11645 Stockholm (Sjöborgsplan, Slussen).

Country walk: Take the green line of Tunnelbanan (Metro, train) to Hässelby Strand. Walk along the shores of Lövatafjarden as far as you like. Maybe you can make it even to Kungsängen (return with the (dark) blue line).

Chapter 8: Organizing Take Back and Recycling

8.1 System Organization

8.1.1 Product characteristics and take back

In Chapter 7.5.1 it was explained that by the end of the nineties Philips Consumer Electronics had effective tools to calculate the end-of-life costs of their products. On one hand this has been used to evaluate PCE's competitive position in the field (see highlight of the year 1998) and to support decisions on take back and recycling system organization. On the other hand the calculations have been used to make an 'improvement agenda'. This agenda specifies how recycling costs of future products can be brought down and also indicates the conditions for successfully realizing this goal. The study on the next page with the title "*Take-back of discarded consumer electronic products from the perspective of the producer - conditions for success*" is an example of this approach. It was written in 1999 but still relevant for today. In view of PCE's competitive position few numbers were given – in fact they are known but are proprietary. The studies brought up several interesting issues:

- The importance of achieving plastic recycling at low prices (in fact the housings of Philips products had the potential to do this, however later PCE was forced to use flame retardants which drove the recyclability of products down (see Tidbits, 7).
- The importance of economy of scale – in fact this turned out to be much more important than EcoDesign (see also chapter 9.2.1).
- The observation that in the year 2010, logistics costs would become higher than treatment (recycling) costs.
- The relevance of the copper fraction in shredding/separation as an 'universal acceptor' for valuables (precious metals) and 'penalty' elements (flame retardants, solder, ...).
- The importance of having semi-automated disassembly (and corresponding economy of scale) in order to drastically reduce disassembly times.

The final conclusion was that if plastic recycling could be realized and semi-automated disassembly could be introduced. The result would be that the recycling cost of TVs would be reduced to somewhere near € 0.10/kg (excluding logistics). It was even calculated that if PCE realized these items and the competitors did not, Philips could abandon collective systems requiring fees paid by consumers after the year 2006/2007. Neither of the two items materialized. PCE was forced to put flame-retardants into housings again (see Tidbits, 7). The investment in robot assisted disassembly did not work out (see chapter 7.3.1).

It is also relevant to observe that the paper below calls for the close cooperation of producers, recyclers, scientists and authorities in order to really move forward. In view of the broad diversity of opinions about take back and recycling, there is no doubt that this would be difficult to achieve. However, traditional dialectics suggest that even in the case of big differences of opinion fruitful cooperation is possible, if for instance simple rules of trade and business are followed (if I do something for you, you should do something for me) and proper negotiation agendas have been formulated. This turned out not apply to the environmental field; it is a world which seems to be full of absolutism, Eco-belief and all the emotion connected with it. Stakeholder dialogue does exist but is often not very well structured; it seems rather to take place for justification purposes more concerned with home rank and file than with producing balanced compromises.

Take-back of discarded consumer electronic products from the perspective of the producer - conditions for success

A. L. N. Stevels, A. A. P. Ram and E. Deckers

Abstract

Take-back and recycling costs of discarded television sets can be brought down substantially by a combination of design improvements, technology improvements and by achieving economy of scale in the processing. Authorities can enhance the eco-efficiency further by appropriate supporting policies. It is estimated that, compared with the present situation, the total environmental gain over cost ratio can be pushed up by a factor 4 to 8. Prospects to improve end-of-life performance of smaller consumer electronic products (audio, VCR, etc.) are much less. In view of the fact, however, that television sets make approximately 60% by weight of the total waste stream, the improvement potential of the total stream is large.

Keywords: Recycling; Take-back costs; Ecoefficiency; Design for recycling

1. Introduction

In a growing number of countries around the world, laws are in preparation to make producers and importers of electronic consumer products responsible for their products at the end of life stage. Plans are being prepared to oblige industry to take-back its products and set up an end-of-life processing industry for consumer electronics. The ultimate objective of this is to reduce the environmental burden caused by discarded consumer electronic products and to encourage industry to conserve resources.

The aim of this article is to present the point of view of Philips Consumer Electronics — Sound & Vision, on how the take-back regulation and the end-of-life industry of electronics should be built up in a gradual way, without imposing an unnecessary financial burden on society.

All actors involved in the take-back of discarded electronic products agree upon the issue of taking back end-of-life consumer equipment. In principle they all want:

- better conservation of resources and value (cascade principle);
- more recycling/re-use;
- less waste;
- eco-design.

Up to now, the major points of debate about the organisation and operation of take-back and recycling of these products have been:

- who is responsible for which of the relevant issues?
- how should the take-back system be financed (waste taxes, internalisation in prices of new products, etc.)?
- how should the take-back system be organised (public or private, pool systems or individual brands)?

The debate between the actors is now so intense that it tends to overshadow the common ground which is already in place. Moreover, resolution of the differences of opinion will take much time, while the final outcome

can be a situation in which our society pays too much for a sub-optimal solution.

The present paper considers take-back primarily from the perspective of product characteristics. It will be shown that the costs of take-back and recycling can be lowered substantially and that the recycling performance can still be substantially increased if technical, organisational and regulatory conditions ('the conditions for success') are fulfilled.

We first focus on the cost effectiveness of the end-of-life treatment of consumer electronics. From this perspective a distinction is made between the take-back of television sets, and the take-back of the remainder of the consumer electronic products waste stream. The main reason for this is the cost effectiveness of recycling and the level up to which this can be influenced. The cost effectiveness of recycling can, for example, be influenced by dismantling criteria and an acceptable economic material content during recycling.

It is suggested that for products that contain picture tubes, dismantling leads to the most eco-efficient recycling process. For products without picture tubes it is pleaded that integral mechanical processing leads to the most eco-efficient recycling process. Eco-efficiency is defined herein as the environmental gain over cost ratio of the recycling process.

Moreover, it will be shown that recycling of television sets can be improved and that a reduction in costs can be achieved by means of improved design and an appropriate organisational structure. The end-of-life aspects of television sets are treated, but in principle the same matters apply to picture-tube-containing products in general (e.g. computer monitors). For the remainder of the consumer electronics waste stream, like VCRs, audio equipment, and car stereo products, it will be shown that improvement of the recycling efficiency of these products is much more difficult to achieve. Subsequently, the conditions for success and the effect of these conditions on the recycling efficiency for both these categories of electronic products will be presented.

2. Costs of take-back

Televisions and computer monitors form 55–60% of the weight of the total waste stream of consumer electronic products. It is expected that this figure will shift towards 60% or even higher in the future due to the increasing part of monitors.

The costs of take-back of television sets over time are shown in Fig. 1. The present recycling costs are approximately 10–15 € per television set (0.35 €/kg), as found in the Dutch national pilot project concerning the take-back and recycling of consumer electronic products, Apparettour [1 and 2]. Logistic costs are assumed to be constant. Costs of end-of-life processing of television sets show a change over time. Fig. 1 shows clearly that a large cost reduction in the take-back costs of television sets can be achieved when the conditions for success are fulfilled (see Section 3). It is expected that by approximately 2010, the recycling costs of television sets will have dropped to the level of current landfill/incineration costs (\pm NLG 0.25/kg).

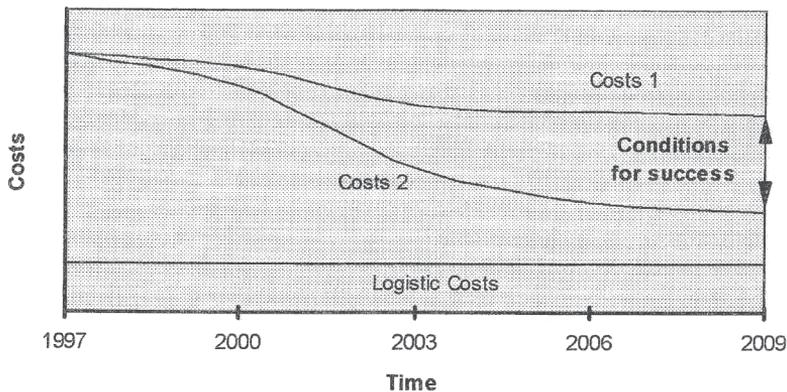


Fig. 1. Take-back costs of television sets over time.

Fig. 1 also demonstrates that until approximately 2003 hardly any cost reduction of end-of-life processing of television sets can be achieved. This is due to the fact that the television sets to be taken back in this period have been developed and manufactured in the pre-eco-design period and thus are not appropriate for efficient recycling. Since the late 1980s, the first eco-design activities in this field have been started. Together with an average lifetime of television sets of 15 years, this leads to an expected improvement of recycling results after approximately 2003. The difference in materials composition and thus recycling potential will be explained in Section 3.

At present, far less is known about the costs of take-back of the remainder of the consumer electronics waste stream. Apparettour [1 and 2] showed that the present costs are approximately 0.75–1 €/kg. From research done in this area so far [3], we believe that the change over time in the take-back costs of these products should be something like that presented in Fig. 2. The similarity between Fig. 1 and Fig. 2 is that, also for this category of products, it is expected that until 2003 hardly any change in costs can be achieved. The reasoning here is similar to that used for television sets. The striking difference is that after 2003 the reduction of end-of-life costs will be smaller (see Section 4). It should be noted that the cost axes in Fig. 1 and Fig. 2 are not on the same scale.

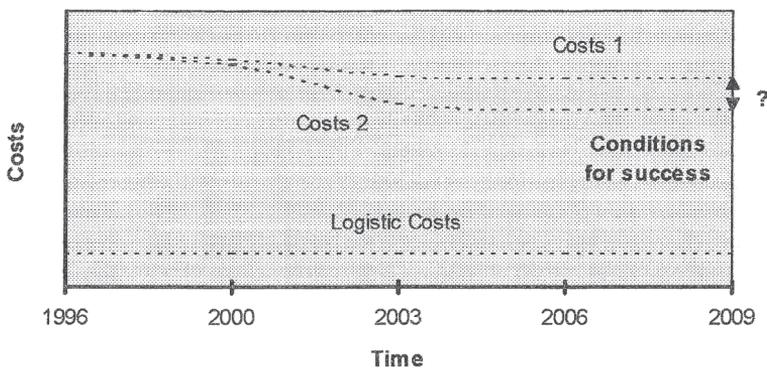


Fig. 2. Estimated take-back costs of the remainder of consumer electronics waste stream over time.

Following from Fig. 1 and Fig. 2, it is obvious from the financial perspective that take-back obligation should start to be applied to television sets. Even here it can be seen from Fig. 1 that costs of take-back can vary substantially, depending on economies of scale, organisational conditions, and legislation. Due to the little knowledge existing so far related to the take-back of the remainder of the consumer electronic waste stream, it is suggested that take-back legislation regarding these products should be implemented at a later time.

It should be noted that low costs for taking back and recycling of television sets can only be achieved in the case that the responsibility for the various end-of-life stages (logistics, disassembly, mechanical processing, reapplication of secondary materials) are attributed to those actors in the life cycle chain who can influence these costs. This means that society only gets a cost-effective and ecologically efficient take-back system when the costs are based on the operational responsibility (shared responsibility). The responsibility is thus attributed to the actor that can achieve the best environmental gain/cost ratio for the particular part, and is able to close the material chain. At present, common governmental policy however, puts the responsibility with the actor that is responsible for product manufacture or even only for product sales! From the analysis it is also shown that both from an environmental, and a cost point of view, the responsibility for take-back *logistics* should stay where it is, i.e. with the local authorities. The main reason for this is that currently local authorities already collect other waste streams and have the necessary infrastructure.

3. Recycling of materials in television sets

Recycling of television sets means recycling of the materials present in a television set. Because of the rapid technical evolution, the re-use potential of components or sub-assemblies is at present only very limited or non-existent.

On the other hand, a market driven by second-hand products is already in place. In practice a large number of old sets are simply discarded. The second-hand use of television sets may diminish or delay the recycling problem, but as such is not at all a solution to this problem. Moreover, from a life cycle perspective the use of old (second-hand) television sets is no solution to environmental problems either, due to the higher energy use. The higher energy use of old television sets contributes significantly to the higher integral environmental impact, as can be calculated using Life Cycle Assessment [4 and 5].

In order to recover single materials, electronic products need to be disassembled to reach a sufficient yield. The main reason for doing so is to ensure that the quality of the materials obtained is such that they have the potential to be upgraded to their original level of application. This is crucial for an optimal conservation of resources and value, and the only way to really achieve a high environmental gain/costs ratio. Disassembly of products has to be done manually and is therefore rather costly in Western Europe.

The most important criteria for applying disassembly are:

- To reduce the recycling costs, which can be achieved by:
 - disassembly of mono-material parts (parts of one kind of material, e.g. ABS) which leads to improvement of the recycling yield (criteria described in Table 1);
 - disassembly of parts made of materials containing 'penalty elements', which leads to a higher value of the waste. Penalty elements are elements that lead to (financial) penalties when the material fraction containing those elements is sold to the metal refinery industry (e.g. Pb, Zn).
- To reach a certain efficiency in material re-use.

In Table 1, the approximate amounts of materials (in grams) that have to be disassembled per minute to balance the labour and reprocessing costs are shown. The labour costs are based upon the current tariffs of a Dutch recycler, and amount to 7.0 NLG/min. The results are obtained by dividing the current average prices for virgin material by the labour costs, and multiplying this by a factor (0.9) to include the processing costs. In this case, disassembly is aimed at regaining the materials.

Table 1. Approximate amounts of material that have to be disassembled per minute to balance labour and processing costs with value of materials recovered

Metals	Amount (g)	Plastics	Amount (g)
<i>Precious metals</i>			
Gold	0.05	PPE	250
Silver	5.0	PC, POM	350
Palladium	0.14	ABS	800
		PS	1000
<i>Metals</i>			
Copper	300	PVC	4000
Aluminium	700	Glass	6000
Iron	6000		

For the main construction materials of television sets (PS and ABS), this table leads to the conclusion that it is useful to disassemble those parts of PS and ABS whose weight exceeds 800 g and 1000 g, respectively. For Philips television sets, where PS is the main construction material, this means that the cabinet (weight approximately 3 kg), the backcover (weight approximately 2.7 kg) and the speaker box (weight approximately 1 kg) are candidates for disassembly. Restrictions are that no contamination of other materials (such as metal inserts) and that no flame retardants are present.

Fig. 3 shows the recycling efficiency of old and new television sets, recycled according to the current industrial practice.

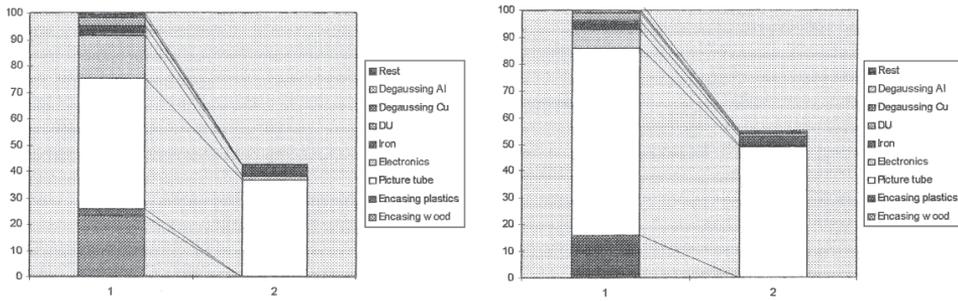


Fig. 3. Material composition and recycling efficiency of old and new television sets.

As can be seen, current Philips television sets already have a higher recycling efficiency than older ones (55% vs. 43%). Reasons for this are as follows.

- Design for assembly and design for serviceability have been improved. This has automatically led to fewer parts and thus to an improvement of the disassembly of the television set as well.
- Environmentally relevant substances have been eliminated. This has led to less contamination in material fractions, which make them more suitable for recycling (smelter specifications).
- Plastic encasing without flame retardants.
- Electronics have been reduced. This has led to a smaller fraction with a complex material mix, and therefore to a smaller waste fraction.
- Miniaturisation. Because of miniaturisation, the weight of television sets has been reduced significantly. Since less raw materials are used, less waste is generated at the product's end-of-life stage. This automatically implies a better conservation of resources and value.

Recycling of current television sets, however, can still be improved. This can be achieved by a better eco-design of these products and by fulfilment of some additional conditions for success. The main deficits for recycling of current television sets are as follows.

- The encasing is currently landfilled or incinerated because it is made of plywood. New television sets have a higher recycling potential with respect to this matter since the encasing consists of plastics, provided that these do not contain flame retardants.
- Currently, picture tube glass is not recycled at equal level of application. At best, apart from low level applications in ceramics and road pavement, Philips has shown that 70% of the picture tube glass can be recycled into cone glass production. However, if sufficiently large streams of materials are recovered, this recycling capacity will no longer be sufficient and new technology has to be developed to recycle screen glass.
- From printed wiring boards (PWB), mainly copper and precious metals are recovered (also iron and aluminium but these do not have a high value), which leaves a considerable remaining fraction (laminates and other elements) which are landfilled or incinerated.

For efficient material recycling of the parts that can be disassembled from television sets (at the original level of application) therefore, complementary conditions have to be fulfilled. These conditions for success are listed in Table 2.

Table 2. Conditions for success to improve the recycling efficiency of television sets

TV component/ fraction	Technological condition	Economical condition	Organisational condition
Housing - plastics	<ul style="list-style-type: none"> • No flame retardants • Identification of different types of plastics 	Economy of scale, 5000 t/year (300 000 television sets/year)	Consuming market needed (no television set production in NL)
Picture tube - glass	Separation of screen and cone	Economy of scale	Consuming market needed (no glass production in NL)
Electronics (PWB) - Cu, plastics	<ul style="list-style-type: none"> • Reduce penalty elements • Recycling of plastic mixtures • Recycling of main other elements as well (Fe, Al,...) 	Economy of scale (easy to achieve by integrating electronic waste fraction in existing Cu waste stream)	Consuming market needed (currently existing, but efficiency can be better)
Metal - Fe, Al	Treatment of surface coatings (e.g. zinc)	Prices secondary materials vs. virgin materials	NA
Rest - waste landfill	Specification of waste	Fair tariffs	Landfill still possible

In Table 3, the current situation, and the expected situation until the year 2005–2010 when the conditions for success are fulfilled, regarding end-of-life processing of discarded television sets is presented. It is assumed that the functionality, the imaging principle (CRT), the materials applied and the end-of-life processing technologies are comparable to the ones of today. Table 3 refers to the average performance of recyclers in Western Europe. The current situation is represented in two columns, current industrial practices, and the maximum level of recycling without downgrading.

Table 3. Current and expected situation in television set recycling

Item	Current industrial practice	Maximum level	Year 2005–2010
Logistics	Present municipal systems	Present municipal systems	Present municipal systems
Average disassembly time	15 min	20 min	5–7 min
Recycling on equal level	15%	50%	85%
Downgrading (rec./inc.)	70%	35%	8%
Waste (landfill)	15%	15%	7%
Economy of scale	NA	100 000 sets/year	250 000–400 000 sets/year
Costs/set	±20 €	±35 €	±10 €
Env. gain/costs ratio ^a	1	1.5	8.5–4

^aThe environmental gain/cost ratio is defined here as the amount of material re-used in its original application divided by the end-of-life costs.

Clearly, it can be seen that the recycling efficiency is projected to have increased by 2005–2010, with respect to both material recovery, as well as cost effectiveness. In Fig. 4 the material composition and the recycling effectiveness that can be achieved in 2010 is presented.

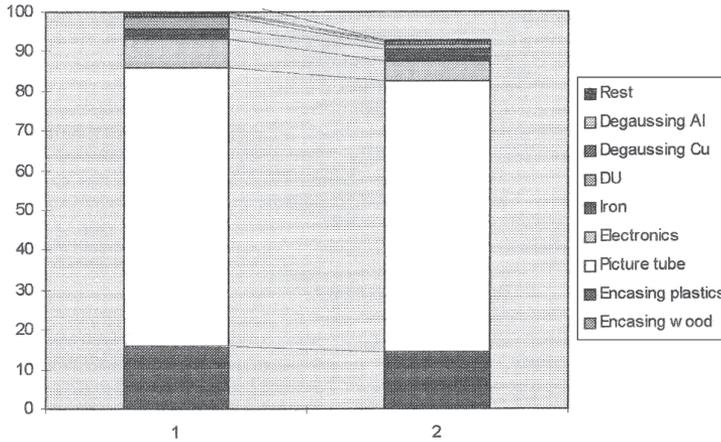


Fig. 4. Expected recycling efficiency of television sets in 2010.

In order to fulfil the conditions for success, much has to be done by all the actors. Below, roadmaps are presented for the four main categories of activities.

3.1. Roadmap EcoDesign

Activity	Responsible actor
Weight reduction (min. 10%)	Producer
Miniaturisation of electronics	Producer
Elimination of flame retardants	Producer
Standardisation of glass compositions	Producer
Reduction of environmentally relevant substances	Producer
Design for recycling (disassembly/non-disassembly)	Producer
Application of secondary material	Producer

3.2. Roadmap for the development of end-of-life processing technology

Activity	Responsible actor
Activity	Responsible actor
Recycling technology for plastics	Producer, recycler
Improvement of separation technologies	Recycler, scientists
Picture tube glass recycling technology	Recycler
Optimisation of disassembly	Recycler, scientists

3.3. Roadmap for the development of an economy of scale

Activity	Responsible actor
Certification of recyclers (technical, performance)	Authorities, producer
Supranational approach (e.g. adaptation of Basel convention)	Authorities
Environmental validation	Producer, Authorities

3.4. Roadmap for the development of supporting policies

Activity	Responsible actor
Handling pre-eco-design products	Authorities
Differentiated fee system	Authorities
Supporting legislation/regulation	Authorities
Monitoring and control	Authorities

This list obviously shows that much still has to be done. From this list it follows that:

- the authorities need to support research and development activities in this field to overcome the gap between current practice and what is needed in 2010;
- recyclers should be certified according to their recycling achievements in order to create an economy of scale;
- the authorities must stay involved as an actor in the consumer electronics' recycling and act on a transnational level (economy of scale).

4. Recycling materials in VCRs, and audio and car stereo products

Based upon the present technology, the recycling of all other consumer electronic wastes is less favorable than the situation for television sets. The two main reasons for this are as follows.

- The weight and size of these products is such that they do not fulfil the disassembly criteria presented in Table 1.
- The use of monomaterial for the heaviest and/or biggest parts is much more difficult because of functionality requirements. The front cover of e.g. a miniset or soundmachine incorporates far more functions than e.g. the front cover of a television set. Consequently, at the back of the front cover several different engineering plastics and metal parts are present. This means that even in the bigger parts, many different materials are present.

The above considerations have led to the conclusion that the end-of-life processing for these types of products for the time being basically should consist of an integral recycling process.

In Fig. 5, Fig. 6 and Fig. 7, the average material's composition and the recycling efficiency of respectively a VCR, a midset (audio), and a soundmachine (portable audio) are given. These figures show that the recycling efficiency of these products presently varies from moderate to very low. The main material that can be recycled is the iron fraction from the housing parts. Although this fraction may maximally be approximately 50 weight percent of the product (VCR, see Fig. 5), its intrinsic value is very low, which makes the recycling of these products cost-inefficient. Moreover, the waste fraction of the product consists of a considerable proportion of mixed plastics, which are difficult to recycle.

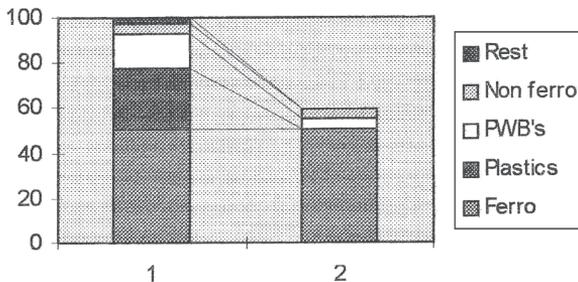


Fig. 5. Average material composition and recycling efficiency of a VCR.

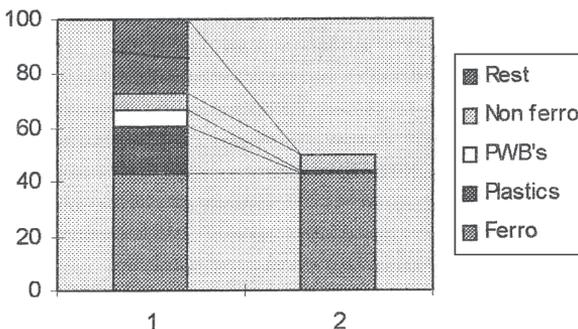


Fig. 6. Average material composition and recycling efficiency of a miniset.

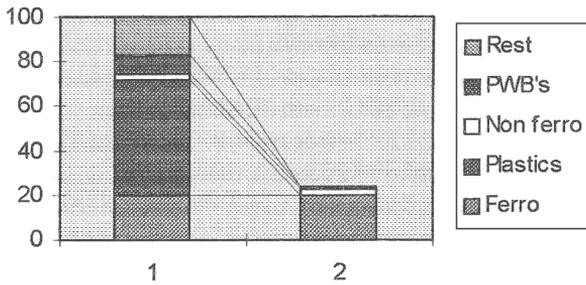


Fig. 7. Average material composition and recycling efficiency of a soundmachine.

At this moment far less is known about the problems related to end-of-life processing of these products, compared with the knowledge related to the take-back of picture-tube-containing products. The main problems are as follows.

- Mainly the ferro materials are regained. This is not a valuable fraction (0.05 USD/kg), which makes the recycling of these products very cost-ineffective because the material benefits do not equal the processing costs.
- Substantial waste fraction (mixed plastics).
- More contamination in useable material fractions (low grade application only).

In principle the conditions for success for television sets recycling also apply to the remainder of the consumer electronics waste stream (with the obvious exception of picture tube glass). An additional condition is given below.

- Combination of these products with the television set material fraction that shows the largest similarity in composition. This is most probably the electronic fraction. For the products that have a high plastic content (e.g. soundmachine, walkmans, minisets, etc.) this means that an additional separation technique has to be used to prevent contamination of the valuable television set fractions with the plastics from the remainder of the electronic waste stream. When it is not possible to carry out the above-mentioned condition, incineration should be considered as the best eco-efficient solution for the recycling of these products.

At the moment, it is difficult to predict the improvement of the recycling efficiency and end-of-life costs when the conditions for success are fulfilled. Before including audio, VCR, and car stereo products in take-back legislation, the following issues should be investigated.

- A well-operating take-back and recycling system for television sets. The other products can be added to this system at a later stage.
- An in-depth technological and design programme, tailored to these types of products.
- A cost effective incineration capacity for the (large) material fraction which cannot be recycled at equal level of application (not even after carrying out the above programme) or for the products as a whole.

5. Conclusions

The present outstanding issues about take-back and recycling of consumer electronic products, like producer responsibility, financing, and system organisation, can only be achieved if all actors involved (producers, recyclers, local/national European authorities) work together on the basis of a common agenda and of shared responsibility. For take-back and recycling of discarded television sets, impressive environmental and economic gains are expected to be achieved, if the conditions for success elaborated in this paper are met.

The very nature of other consumer electronic products (audio, VCR, car stereo) makes it much more difficult to get similar results as for television sets, but, again, when compared with the current situation, progress can be made.

In all cases, conditions for success include:

- a technological programme;
- appropriate organisation and certification of the end-of-life industry;
- legislation and supporting measures, including continuous involvement in this matter by authorities.

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Highlights of the year, 2005

Ecovalue

It has been quite a struggle to develop the Ecovalue concept. It originated out of a sense of unease with the traditional EcoDesign concept. This is due to the so called rebound effect which can be explained as follows:

EcoDesign actions aim at lowering the environmental load but may result in lower cost as well. This means that successful Ecodesign implies a substantial rebound effect. If EcoDesign products get cheaper, a consumer can buy more goods so that the environmental gain for one product is offset by more consumption. One-sided supply side (EcoDesign in industry) thinking has therefore less environmental effect than anticipated at first sight.

So far little attention has been paid to the demand side (how do consumers spend their money). A useful approach is to stimulate consumers to spend their money on goods and services where the ratio between price and environmental load over the life cycle is high. Generally speaking this ratio (the EcoValue) is higher when the added value of the product is higher. High labor content scores best, followed by high tech content; material intensity ranks third whereas energy intensity products have the lowest EcoValue.

Consumption of products and services with higher EcoValue have a benign effect simply because consumers can spend their money only once. If more money is being spent on products with high EcoValue, less money is left to buy more goods and through this mechanism a reverse rebound effect is achieved. People are prepared to pay higher prices if the goods on offer are more attractive, this is not just from a physical functionality point of view but particularly from an immaterial or emotional value point of view (see also chapter 2.3)

Shifts to consumption of goods with higher Ecovalue can be stimulated through external means as well. For instance by a tax system which taxes consumption instead of income; or differentiated taxes on consumption according to environmental load (see chapter 9.3). Whatever happens, more efforts to design products with high EcoValue seem to be needed. It has been analyzed in chapter 2.3 that, under appropriate conditions, there can even be products with an environmental load which is higher than the one of a standard product.

This paradigm shift was supported by earlier work on communicating 'green' through design (chapter 5.5).

In 2005 the ideas got more operational. Students determined EcoValue of products in the Philips Consumer Electronics catalogues from 1998 to 2005 and on basis of this, Uri Pascual and I started to define the new avenues for EcoDesign (see chapter 2.3). This work has not yet come to fruition, but this is a real new opportunity!

8.1.2 Compliance with the law and company strategy

8.1.2.1 The intent of the European Directive on Waste of Electronics and Electric Equipment (WEEE)

At this moment (2007) all the Member States have transposed the European WEEE Directive into national laws and as a result in all those countries take-back systems are in place or are in the process of being in place. This very process has created a lot of problems for which there is a common basis: lack of harmonization between the Member States both as regards administrative procedures and financing, and most of all interpretation of the Directive which is basically a juridical document which by its nature is incapable to deliver a detailed set of implementation rules (see chapter 9.3).

It means that companies wanting to comply need to take action in 27 States and in each country adaptations have to be made to local requirements. Today, Pan-European solutions are only possible in theory, not in practice. A further problem is the complexity of the technicalities of take-back and recycling systems. The lawmakers, with their ideas from the year 1995 (see chapter 9.2) and lack of 2007 knowledge and insight have largely underestimated this complexity. Current WEEE laws have serious environmental and Eco-efficiency shortcomings as specified in the chapters 7.4, 7.5, 9.2 and 9.3. The chief environmental shortcomings are specified below:

Environmental shortcomings of WEEE

1. Product categories per application, not per material composition (no "resource focus")
 2. Unfocussed collection targets (no 'input rules')
 3. Weight based recycling targets (not really serving the environment)
 4. Ignoring the level of material reapplication (no 'output rules')
-

The Eco-efficiency shortcomings are summarized below:

Ecoefficiency shortcomings of WEEE

1. Ignores ensemble issue (products come in as streams not as individual items, sorting is costly)
 2. Focus on EcoDesign not on system organization (economy of scale)
 3. Unclear recycling definitions for what is counted as recycled/recovered (how much gain for how much money)
 4. Removal requirements as prescribed in Annex II
-

Moreover basic system requirements are poorly defined for example the collection quote:

Poor definition of the collection quote

1. Absolute number, no relation with previous sales
 2. No split per category
 - Plastic dominated products
 - Glass dominated products
 - Metal dominated products
 - Precious metal dominated products
-

And the lack of clarity with what is precisely meant with recovery and recycling quote:

Recycling quote can be defined in different ways:

- Either: everything not incinerated or going into a landfill is supposed to be recycled (NL)
 Or: only material recycled counts (most likely WEEE intended definition)
 Or: only recycled material in the right fraction counts (Cu in Cu stream: Yes, Cu in Fe stream: No)
 Or: as above but glass and plastics only counted when reapplied at same level
-

Recovery quote

- Either: only plastics fractions going to metal smelters is included
 Or: also material going to incineration with energy recovery is included
-

Particularly the last two items makes it very difficult, if not impossible to comply 100% with WEEE.

What is however clear is the ENVIRONMENTAL INTENT OF WEEE: ensure environmental protection through a high degree of recycling and a high level or reapplication of secondary materials whilst keeping potential toxic substances under control. This is to be achieved through applying the best technologies and organizing systems in such a way that overall costs are as low as possible.

What is also clear is that when this environmental intent of WEEE is being served, this a substantial step forward with respect to simply land filling or incinerating discarded electronics.

Companies should therefore start to work on the subject, develop working definitions and procedures which help to develop the systems, instead of waiting and complaining about complexity, lack of transparency, bureaucracy and unfair implementation rules. If it is demonstrated that the intent of WEEE as defined above is well served, there should be confidence that monitoring authorities will acknowledge this positively, even if the outcomes are not precisely according to their precise formulation.

- One example where this applies is the recycling of cell phones. When treated through direct input into a copper smelter, the maximum environmental result is obtained (precious metals are recouped up to the last ppm) at minimum cost (it is even at a profit); however the weight based recycling-target as required by WEEE is not realized.
- Another example is the treatment of small plastic dominated products. Here control of potential toxics prevails over recycling; therefore putting material into an incinerator with well-controlled flue gas control is serving the intent of WEEE best, although this results in the recycling quotes required by WEEE not being attained.

Therefore two principles are recommended when organizing recycling systems to choose treatments and find outlets for secondary materials.

- The environmental equivalency principle: if the environmental result of an action is better or equal compared the (perceived) WEEE requirement, it should be applied (and allowed by authorities).
- The cost equivalency principle: if the cost of an action is lower and its environmental result is at least equal, it should be applied (and allowed by authorities, even if it is not allowed by WEEE).

Recognition of these principles will solve a lot of the technical issues of the WEEE implementation, particularly regarding, recycling quotes and the Annex II treatment requirements.

8.1.2.2 Company Strategy

For making an appropriate company strategy regarding WEEE, it is needed assess the business consequences of its implementation should be addressed. A very relevant issue in this respect is the material composition of the product line up. Are the products plastic dominated, glass dominated, metal dominated or precious metal dominated? This determines to a large extent the take-back and recycling costs as can be seen in the box below.

Actual take-back costs per product type (price level 2003)					
Issue	Type of product				
	Plastic dominated (audio, etc.)	Glass dominated (TV, monitors)	Metal dominated (Printer, PC)		Precious metal dominated (communication)
Recycling cost (€/kg)	0.70	0.50	0.30	0.10	0.00
Recycling cost as % of sales (100% return)	4	2	0.50	0.10	0.00
Current sales margin (%)	2	2	?	?	?

This box shows that costs/kg and costs as percentages of sales vary greatly per product category. For plastic and glass dominated products both costs are high and sometimes even exceed the sales margin for the producer. A first conclusion is therefore that producers with a product line up which consists to a large extent of plastic and glass dominated products will support recycling systems requiring fees for recycling, whereas producers with a package of mostly metal and precious metal dominated products will not.

A second analysis is: can EcoDesign assist in bringing costs down? As the table above shows, the general answer to this question is 'only limited' for plastic dominated products and not anymore for glass dominated products. There is reasonable potential for most metal dominated products and almost none for precious metal dominated products.

Another aspect to be considered is: what is the absolute amount of the recycling costs? If the weight of the products is for instance less than 2 kg the recycling cost will be €1.40 in the worst case. Since such products have sizes which fit into a waste bin, the return rates are also low (for most consumers convenience prevails over environmental consciousness) and therefore actual recycling costs will be much lower than calculated on a 100% return basis. In current practice, return rates for small household appliances and consumer electronics products are some 20% of the amounts sold. This would reduce the effective recycling cost to some € 0.30 /piece. In such a case, even for plastic dominated products collecting a fee is not very worthwhile in view of all the transaction costs.

The evolution of market share as a function of time is also very relevant. If a company is a newcomer to the market recycling costs (per piece sold) in the foreseeable future are low; for the time being few products will be discarded. This contrasts to companies which had a high market share in the past, so this brand will be overrepresented in the return streams. This can create awkward situations: As from 1975 till 1995 the Philips market share in Consumer Electronics in the Dutch market has been dropping: although the recycling costs/piece were analyzed to be lower than those of the competition, the ratio total recycling cost/total of number of pieces **currently** sold was much more than the competition. This is due to the higher sales in the past. This made Philips conclude that a payment based on present market share (either through fees paid by consumers or by the companies themselves) is the only method to keep the market playing field at equal level.

After 1995 the Philips market share stabilized and even went up: however not enough to warrant reconsideration of its position.

Also reuse (and lifetime) aspects of products are to be considered as well. If a company brings high end products (or products with a long lifetime) to the market, the amount of reuse (extended use) will be larger than that of the competition. Per unit of time their recycling costs will be lower.

With respect to developing a company strategy based on its product portfolio a final question to be asked is, where is the company making money, in hardware or in something else (consumables, software)? If consumables (for instance ink cartridges for printers) or software (games for game boxes) are the main source of income/profit, the chief strategy should be to maximize the size of the fleet of hardware in the market. Requesting recycling fees will not fit into this strategy.

Last but not least, how the market is structured should be considered.

- Are there many newcomers or many brands which have disappeared from the market (how to let them contribute responsibly and how to avoid to paying for others)
- Are there many a lot of e-sales in the market (how to deal with this phenomenon not foreseen in WEEE)
- Are competitors willing (or not willing) to cooperate and if so to what extent and under what conditions?

8.1.2.3 External factors to be taken in strategy making

External factors influencing the company strategy on organizing take-back and recycle systems includes issues such as: achieving economy of scale, leverage to recyclers, managing relations with trade/municipalities with regards to collection, and administrative requirements for registration and reporting.

Of these aspects achieving economy of scale has turned out to be a dominant factor in the technical domain. It has been calculated on the basis of data presented in chapter 7.5.1 (and other sections) that recy-

clinging activities on electronics have the highest environmental performance and the lowest cost for handling 50.000- 100.000 tons of electronic waste a year. Becoming a member of the consortia which handle this kind of volume, is therefore highly relevant to ensure the lowest cost.

There are four drivers for this economy of scale:

- Disassembly efficiency
- Investment in mechanical treatment technology
- Investment in material upgrading technology
- Securing the highest value in secondary material outlets.

Applying the economy of scale principle to the Member States of the EU leads to the conclusion that only six countries (Germany, UK, France, Italy, Poland, Spain) can support at least one Eco-efficient recycling system, all others basically have inefficient systems due to the size of their population. The Netherlands and Sweden (high return rates) are candidates for Eco-efficiency as well but it needs to be taken into account that competition among recyclers at a national level requires at least two. Experiences have shown that organizing competition among recyclers (approx. 50% of total take-back costs) and in logistics (approx. 40%) is more important than among systems (approx. 10% of total cost). In practice achieving economy of scale is THE important driver to carry out individual responsibility in practice by **consortia** of producers or even by a collectivity of a product sector (in all 'small' Member States). The only chance this situation can come to an end is if the national regulations for WEEE implementation in the varying Member States become much more harmonized and pan European recycling systems become possible. Conversely, the present fragmentation in Europe has led to a situation where costs are unnecessarily high in many countries – the original idea of individualized systems is far away – even its strongest proponents in industry operate semi or quasi collective systems.

A second important issue is to organize competition amongst recyclers. The effect of this is demonstrated by the observation that when NVMP (the Dutch recycling organizer of (amongst others) household appliances and consumer electronics sector) started public bidding, prices to be paid dropped by some 30-35%.

The original ideas about take-back and recycling had the perception that most discarded electronics would come back through the trade. Costs of take-back logistics were thought to be low because the (naïve) idea was that goods could be returned to producers with the same trucks that were delivering the goods to be sold.

Practice is different however. The majority of discarded goods are returned through municipalities. Almost none of the goods returned have any reuse value. Any product having such value is either given away by the first owner, sold to somebody else or traded in when buying a new product. Reselling such goods, after trade in, is an additional source of income for retailers.

Many shops resist taking back discarded goods other than the ones that are traded in. This is because of the storage space required for such goods and because of the administrative costs involved. They are only prepared to cooperate if they are paid. Only a minority of trade channels are interested – these are shops active in second hand trade or in selling at the back door for export to Eastern Europe or Africa (at least this is the situation in the Netherlands).

Municipalities are a case in point. Basically they want to be paid for their assistance in take-back. In the Netherlands the industry association has done a good job by stating that if industry is to bear the costs of collection, the waste fees for household waste (in which electronics waste was included) should be lowered proportionally, which municipalities were not prepared to do. The industry won the argument. The national government realized that municipalities should not get this 'license to print money' and ordered the municipalities to do the collection job without sending their bills to industry.

Sorting of discarded goods is costly and should therefore be done only once. Calculations show that maximum collection rates at minimum costs are achieved if both municipalities and retailers are (obliged to be) involved. All goods should be brought to regional collection centers where the goods are grouped and sent to recycling sites.

If individual companies or groups of companies like to 'opt-out', that is benefit from the joint collection, but have their goods individually recycled, the regional sorting center is the place where the split is to be made. From a cost and a paper work point of view this is a situation which is preferred over the situation in Germany for instance, where a combination of 'competition mania' and a wrong perception of the cartel authorities (take-back and recycling is to a large extent a societal activity not a business one) has lead to a so called 'clearing house model'. This involves the assignment of take-back orders for WEEE on a nationwide scale, based on a random allocation mechanism. Given the size of Germany this leads to much longer transport distances on average and correspondingly higher environmental loads and costs (and a lot of extra paper work). Four regional collection systems (North, East, Center and South) with an opt-out mechanism for the various consortia would be by far more Eco-efficient!

8.1.2.3 Individual or collective systems?

From the final text of WEEE (and from the developments in the draft texts over the years) it is clear that deep in their mind the EU and most Member States prefer individual systems. It has taken great effort by industry to add to the final text of WEEE the option that implementing individual responsibility through a collective system is at least a tolerated option.

Implementation of WEEE through individual or collective systems has been the subject of a lengthy discussions which continues today. Instead of leaving the choice up to practicalities such as product type and business conditions (see above) and thus allowing pluriformity, the idea that there should be a 'one size fits all' system has resulted instead in a lengthy and, in most cases, inconclusive 'beauty contests'. Such discussions take attention away from the real issue: how can WEEE complied with in the best environmental way at the lowest cost. The unfortunate circumstance has been (and is) that companies have been promoting the best solution from their individual perspective as the one which should be implemented industry wide. Also, Industry Associations made their contribution to the confusion. On one hand the Associations championed the freedom to choose any system, on the other hand individual members promoting different ideas were not corrected.

Companies choosing for collective systems with recycling fees do not do that out of an inclination towards communism or out of fear for competition, but out of necessity. On a weight basis, more than 80-90% of the electronic goods have a structural recycling cost deficit (see also chapter 7.5) which cannot be influenced. Therefore, in a large number of cases fees are simply a must. As long as this is still allowed (after 2011 the present WEEE will not longer allow this anymore). On top of that, collective systems make reporting easier as well as dealing with orphan products (with brands no longer on the market), also financial guarantees can be easier dealt with.

Even the strongest proponents of 'individual' responsibility have realized this and have begun to form 'loose consortia' which try to combine the benefits of the collective approach with individualized elements. So in fact the two system approaches are in practice becoming more similar.

In fact it is my opinion that when appropriate opt-out clauses are built in systems can be developed in which on one hand the intent of WEEE can be optimally served and on the other hand the particular interests of individual companies can be safeguarded as well.

The other option would be to organize different take back and recycling systems which compete with each other. This requires a pan European scale and therefore requires pan European rules, pan European monitoring, and pan European collection etc.

This is still far away; the agendas to achieve this have still to be developed. At this moment the opposite development seems to be taking place; individual Member States are digging in deeper and deeper with their own ideas. It is hoped that the Review of WEEE, which the EU has announced for 2008, will be the start of the reversal of this trend.

Hong Kong, the Jewish Cemetery, may the righteous go before thee into the glory of God



8.2 How to improve performance of take-back systems

In Applied EcoDesign at TUDelft, the way of working is a mix of scientific insight (what are the environmental basics), engineering (what are the metrics), priority setting (what has the most environmental gains for the least of money) and pragmatism (what can be realized easiest). The approach of the 'outside world' is consistently positive, well documented alternatives have to be developed before criticizing other proposals. Simultaneously focus is kept primarily on environment and improving environmental performance. This means that we also have to get involved in discussions about system organization (for instance collective or individual systems) and financing (visible recycling fee or no fee). The position of TUDelft in such debate results from its scientific work. The underlying research has therefore not been set up to justify any stakeholder opinion.

A typical example of this approach is the work which has been done on proposing roadmaps to improve WEEE implementation. As usual, Jaco Huisman has been the big driver behind this project, exploiting the power of his Eco-efficiency calculations to the full. Several papers have been published on this subject. A representative example is given in the publication "*Eco-efficiency as a roadmapping instrument for WEEE implementation*". The general conclusion of this paper is that relating environmental gains (and losses) to costs and revenues is a powerful concept to rethink the current rules for the implementation of the European WEEE Directive (see chapter 9.2). The Eco-efficiency concept can also be used to improve the organization of take back and recycling systems.

The original idea behind these studies was that the work described here would particularly serve recycling systems which were already in operation before the start of WEEE. Implicitly it was assumed that the same issues would come into play when other Member States were setting up their systems. It now has become clear (see chapter 9.2.3) that apart from the technical and organizational issues, administrative and EU harmonization issues are a huge set of items to be addressed as well.

Eco-efficiency as a roadmapping instrument for WEEE implementation

Jaco Huisman, Ab Stevels

Summary

A comprehensive and quantitative Eco-efficiency concept for end-of-life consumer electronics is developed at the TU Delft. It addresses the key question in setting up take-back systems for discarded consumer electronics: How much environmental improvement can be realized per amount of money invested? This paper highlights the latest results of applying the concept in practice on the implementation the European WEEE Directive (Waste Electric and Electronic Equipment). The aim is to show how short, medium and long term developments in applying electronic waste policies should look like, based on this Eco-efficiency thinking. In this paper, the outcomes of the QWERTY/EE concept, (Quotes for environmentally WEighted Recyclability and Eco-Efficiency) on the current European waste policy situation are discussed. Based on this, generic rules and strategies are presented which are applicable for the start and further development of take-back and recycling systems for electronic products.

Introduction

With the QWERTY/EE concept, detailed insights are generated on where environmental losses in recycling occur, on what the contribution of the various processes in end-of-life treatment is, on which material to focus on, how to evaluate (re)designs and finally how to develop Eco-efficiency waste policy strategies. In general, there are 5 main strategies to improve environmental performance of end-of-life products:

1. Weight based recycling and recovery targets (obviously present in WEEE)
2. Restriction on hazardous substances (RoHS Directive, this is mainly out of scope in this article)
3. Treatment rules for recyclers (WEEE Annex II)
4. Minimum collection amounts (4 kg per inhabitant per year)
5. Outlet rules for recyclers (almost not addressed in WEEE)

For the European situation, from these five strategies, the main focus is on the first three items: weight based recycling targets for various products categories, restrictions on the use of specific hazardous materials and specific treatment rules for recyclers like mandatory and selective treatment of certain components (printed wiring boards (PWB's), capacitors, LCD (Liquid Crystal Display) screens and plastics with brominated flame retardants). In the WEEE Directive, there is only limited attention paid to the minimum collection amount strategy (currently 4 kg per inhabitant to be collected per year together for all categories covered, which is relatively easy to obtain) and no attention paid to the strategy of prescribing in more detail the outlets of recycling operations. This last strategy means prescribing what the processing destinations and characteristics of the various fractions created should be as a minimum. The RoHS Directive (Restriction on the use of Hazardous Substance), which addresses the strategy of restricting hazardous substances, is out of the scope of the present article. In this article the QWERTY/EE concept will be introduced and various results and examples are presented to illustrate its application, followed by the conclusions from the Eco-efficiency calculations performed on the implementation process of the WEEE Directive in the form of a roadmap.

The QWERTY/EE concept

A comprehensive approach

Until now, recyclability of products has mostly been calculated on a weight basis only, which is a poor yardstick from an environmental perspective and basically very inaccurate. The general focus on 'weight' can lead to incorrect conclusions regarding the initial 'environmental' goals of waste policies. Calculations based on weight-based recyclability are likely to lead to incorrect decisions, especially when materials are present in low amounts but with high environmental and economic values like precious metals. This notion has led to the development of the QWERTY concept for calculating product recyclability on a real environmental basis instead of on a weight basis only. Before discussing the methodology development in detail, the starting points, boundary conditions and elements needed, are discussed shortly. The starting point of the QWERTY analysis is the point of disposal by

consumers. From there, the product, its components and materials can follow different directions. The general directions are re-use, refurbishment and material recycling as well as disposal with MSW (Municipal Solid Waste). Whereas the QWERTY approach is primarily focused on material recycling, the re-use and refurbishment options are regarded as out of the scope of this article. The environmental calculations, as shown later on in this paper, are based on LCA (Life-Cycle Assessment), but with one important difference; the calculations begin with the end-of-life phase followed by the destinations of materials into new products or to disposal options only. The most important elements required for environmental validation and integral costs connected to this (which are needed for the Eco-efficiency part) are included in the calculations. These are: collection and transport characteristics after discarding, the individual behavior of products in dismantling and or shredding and separation operations, modeling of the secondary material processing and disposal routes like emissions at landfill incineration and an environmental validation method producing environmental scores. The resulting modeling is very comprehensive and covers all main environmental and cost aspects.

QWERTY

Based on the modeling of the end-of-life chain, environmental and economic calculations are based on three values as displayed in Figure 1.

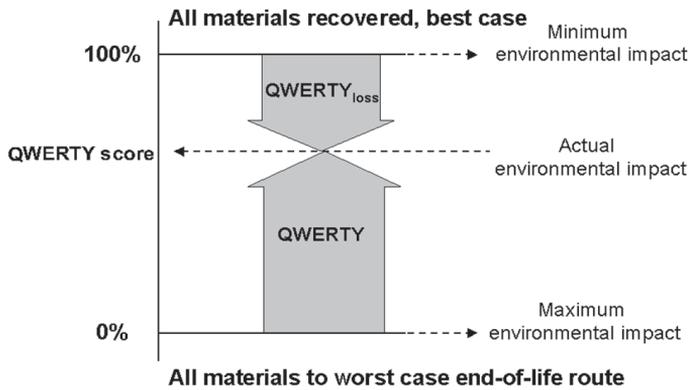


Figure 1 Calculating QWERTY values

Minimum environmental impact and minimum costs

These two values (environmental and economic) correspond with the theoretical scenario of all materials being recovered completely without any environmental impact or economic costs of end-of-life treatment steps. As such, they represent the environmental value for substitution of primary materials and the economic value for newly extracted and produced materials. Usually both are negative and theoretical values: in practice there will always be (environmental) costs connected to separation of materials, energy consumption and transport.

Maximum environmental impact and maximum costs

These two values are defined as the theoretical scenario of every material ending up in the worst possible (realistic) end-of-life route, including the environmental burden plus costs of pre-treatment: collection, transport, disassembly, shredding and separation into fractions. The 'realistic' end-of-life scenarios under consideration are controlled and uncontrolled landfill, incineration with or without energy recovery and all subsequent treatment steps for material fractions, like copper, ferro and aluminum smelting, glass oven and plastic recycler. Also this theoretical value cannot easily be exceeded: only under extreme disposal conditions like incineration in the open, which are forbidden by law.

Actual environmental impacts and costs

These values are based on the actual environmental and economic performance of the end-of-life scenario under consideration and are compared with the two boundary conditions above and finally expressed as percentages. These actual values are obtained by tracking the behavior of all materials over all end-of-life routes and by taking into account all costs and environmental effects connected to this. The environmental values can be calculated with different LCA methods. As a default method however, the Eco-Indicator'99 method is used.

Eco-efficiency

In order to enhance the 'Eco-efficiency over the total end-of-life chain', the outcomes of the Eco-efficiency calculations support the stakeholder and others involved in take-back and recycling. These stakeholders include authorities for helping formulate criteria for collection of disposed products and monitoring end-of-life performance of take-back systems. It enables producers to calculate economic and environmental values beforehand. Furthermore it supports recyclers in finding the right avenues of future technology application and investments. At last, from a consumer or society point of view it helps provide insights regarding the environmental impacts per amount of money being spent, directly or indirectly, whereas the consumers pay the environmental and economic bill in the end. In Figure 2, the four main Eco-efficiency directions are shown in a two-dimensional Eco-efficiency graph. The Y-axis represents the absolute environmental outcomes of the QWERTY calculations (in environmental millipoints), the X-axis represents the economic outcomes. The points in the graph represent various end-of-life scenarios for one and the same product (or an individual component, assembly, fraction or product stream). The scenarios are based on changes in technology, design or system organization. Examples of such changes are for instance saving products from the landfill (increasing collection rates), increasing plastic recycling and glass recycling and the effects of Design for Environment activities or logistics changes. In order to achieve a higher Eco-efficiency compared to an existing recycling scenario, one should move into the direction of the upper right part of the graph (a 'plus' for environment and a 'plus' for economy). Besides this direction, the opposite direction (minus, minus) should be avoided and the (minus, plus) and (plus, minus) should be balanced or ranked. Based on Figure 2, application of the Eco-efficiency method to analyze take-back and recycling includes two important steps: Step 1 is the application of a 'vector approach' as sketched above. This means that in the first instance four quadrants are selected. A 'positive Eco-efficiency' is realized when, for example, the resulting vector is directed to the first quadrant (e.g. point A) of Figure 2 compared to the original situation (reference point). The opposite counts for the third quadrant. Options and directions in this case should be avoided from both an environmental and economic point of view. Step 2 includes calculation of environmental gain over cost ratios and ranking of the 'quotient' for the second and fourth quadrant. This is applied when an environmental improvement is realized and financial investments are needed to obtain this or in reverse. In general, when multiple options are appearing in the fourth quadrant, the 'quotient approach' can be applied to determine how much absolute environmental improvement (mPts) is realized per amount of money invested (€).

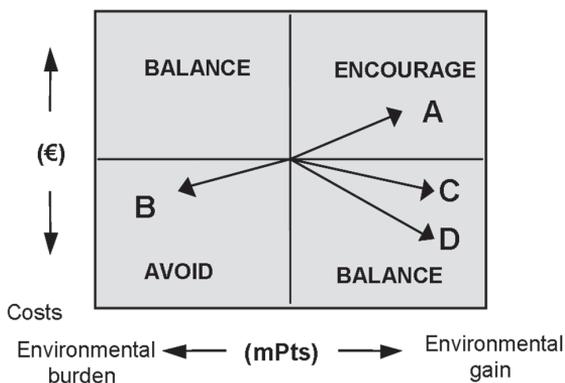


Figure 2 The four Eco-efficiency quadrants

Assumptions and data

All data, results and graphs presented in the next sections are based on the following important assumptions and starting points:

- State-of-the-art recycling is based on best available shredding and separation techniques.
- Data represent the Dutch take-back system with relatively short transport distances.
- Economies of scale are realized for all examples and improvement options.
- Costs for consumers for handing in products are excluded from the integral costs unless stated otherwise.
- For all example products, chemical analysis of the PWBs is performed. Data for all other components are obtained from environmental benchmarks. A combination of the two results in full product compositions. For the other products without chemical analysis of PWBs, good estimates are available based on the types of PWB materials, the level of integration of components and the amounts and types of components attached to the boards.
- The Eco-Indicator '99, Philips Best-Estimate, Hierarchic Perspective, Average Weighting set, weighting factor Resource Depletion – Minerals adjusted to 5%, is used as a default environmental assessment model. All fractions sent to a subsequent process fall under the acceptance criteria applicable for this process or operation.

Results

The environmental level of re-application for CRT glass

The environmental level of re-application for CRT glass

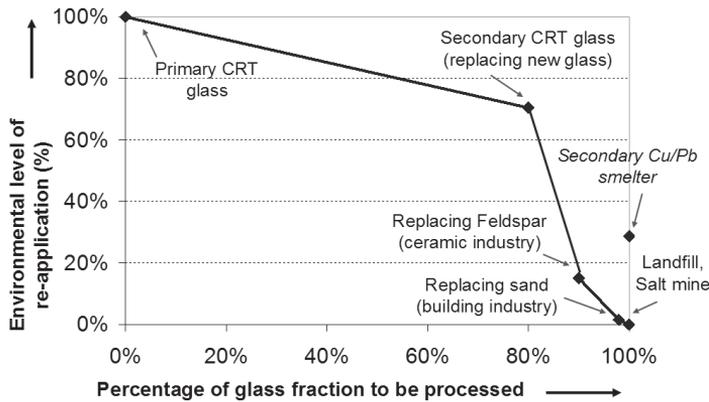


Figure 3 The environmental level of re-application of CRT glass

Currently, glass fractions from CRT containing appliances can be sent to different outlets such as landfills, replacement of sand in the building industry, replacement of Feldspar in the ceramic industry or as secondary material for new screen and cone glass. In the WEEE Directive, all of these applications (except the landfill of course) are counted as a useful re-application and therefore as 'recycled'. Recyclers are likely to send their fractions to the cheapest outlet with the highest recovery rate. Figure 3 shows the environmental level of re-application versus the recovery percentage of the glass replacement options under consideration. The points in the graph represent the environmental level of re-application (Y-axis) versus the 'recovery' percentage (this is not the WEEE definition but the amount of material really re-applied in a 'new product'). The initial value for primary CRT glass (100%) can not be reached due to transport, cleaning operations and energy needed for processing secondary glass. The graph shows that the lower levels of re-application result in higher WEEE recycling percentages. An important outcome from this graph is that all secondary options contribute equally to the WEEE recycling targets and that they do not contribute equally to the environmental results. The conclusion on this issue is that lack of prescriptive 'output'

rules results in the effect that the environmental intent of the WEEE Directive is not served. In the above picture only the environmental results are displayed. In Figure 4 the economic effects are also displayed. The scenarios 1 (building industry), 2 (ceramic industry), 3 (secondary copper-lead-tin smelter) and 5 (CRT glass recycling) consist of full disassembly of the CRT for complete and average monitors of 14,5 kg. Scenario 4 is the partial dismantling (removal of the plastic housings) and 'direct treatment' without further split of electronic and glass fractions in the secondary smelter. In this option, the glass itself is used as necessary flux and thus replacement of sand in the smelter. The Aluminum and Ferro content is utilized as a necessary reductant for the oxidation of Cu, precious metals and other valuable metals (Sn, Ni, Zn, etc.). Also a high percentage (approx. 96%) of the lead present in the glass is recovered as well as immobilization and/or capture of other environmentally burdensome metals, like small traces of Cd and rare earth metals in the fluorescent powder.

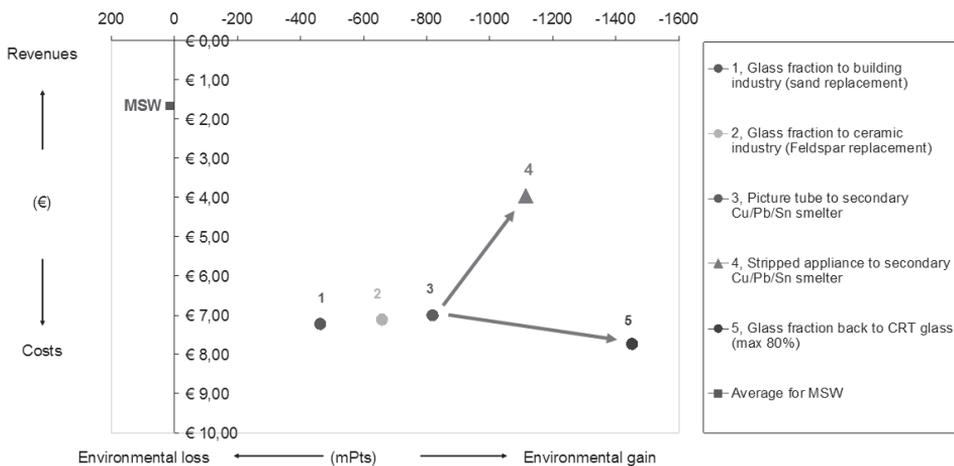


Figure 4 Eco-efficiency of different CRT glass recycling options

As a result, this treatment option is economically attractive, as less handling, shredding and transportation is needed. From an environmental perspective CRT glass recycling is still the most attractive option, as the energy and material consumption prevented prevail in this case. Drawing a vector from scenario 4 to 5 would result in an Eco-efficiency of approximately 50 mPts/€ invested which is a moderate to low Eco-efficiency in comparison to other improvement options. It should be noted that this outcome (under average 2004 material prices) is improving with rising raw material prices and is also highly dependent on the disassembly time and thus costs needed for full dismantling which may vary considerably per treatment facility per country. Another important conclusion is that the direct treatment option here performs well in terms of Eco-efficiency but completely contradicts the 'selective removal' requirements detailed in Annex II of WEEE.

Plastic recycling and compliance with recycling targets

Another example, related to recycling targets being prescribed, is the recycling of plastic housings from various products. In Figure 5, the Eco-efficiencies (in mPts/€) are presented on the Y-axis. The size of housings are displayed on the X-axis. The points in this graph represent the Eco-efficiency of plastics recycling of the housings from various electronic products. The distinction between large, medium and small sized housings is due to the disassembly time needed for obtaining recyclable plastics. Spending 500 seconds for 5 kg of plastics is significant compared to 50 seconds for 50 grams (factor 10). In the WEEE Directive, no real distinction is made in the recycling targets for small, medium and large sized products. Especially for small plastic dominated products, the recycling targets can only be achieved by applying plastics recycling. In this respect, the actual costs for take-back

and recycling will be dependent on how strict monitoring (and this will be different per individual EU member state) will take place by authorities.

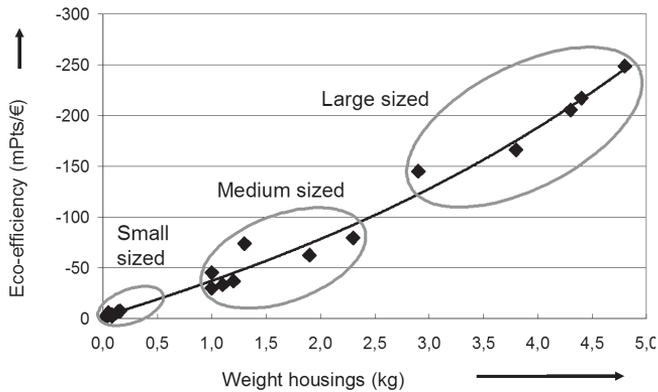


Figure 5 Plastic recycling versus size of housings

Roadmap for Eco-efficient implementation of WEEE

The consequences of the above examples on the short term development process of implementation of the WEEE Directive in Europe will be discussed in this section. This includes a roadmap towards a more Eco-efficient and long term revision of the European Directive and also learning material for those countries still without electronic waste regulations. However, before starting with the roadmap, three important and key-elements which are required for Eco-efficient take-back systems for the present situation are discussed. These are important to consider and needed to start with take-back system 'construction' or further development on the basis of current best practices.

Start on the basis of available technology: key elements

These elements are presented in order of importance: Economies of scale contribute the most, followed by 'outlet management' and Design for End-of-life last.

Economies of scale

Achieving economies of scale is the number one element for cost efficient take-back systems. Relatively high costs occur when product streams collected or recycled are too small. As a consequence, recyclers might process multiple product streams from the 10 WEEE categories within the same process at the same time. As a result, certain monitoring problems could occur for instance on determining whether the recycling and recovery targets are achieved per WEEE category or not. This is due to mixing multiple categories (like treating TVs and Monitors from two individual categories on the same disassembly line).

Manage outlets and markets for secondary materials

For recyclers, despite all prerequisites of the WEEE Directive, it is recommended to search for those outlet options first which results in the highest level of re-application. This applies specifically for glass, residue and plastic fractions. (For metal fractions, the obvious destination is the corresponding available and preferably modern metal smelter). This issue is further discussed in the next part of this section on short term implementation and effective and efficient monitoring.

Design for end-of-life

Besides the strategies which increase environmental performance of products in end-of-life, as a starting principle, the environmental life-cycle perspective should be taken into account. In other words, sound EcoDesign in general should focus on reducing the environmental burden of products throughout the life-cycle, in the production, use and disposal phase. In this respect, it is shown that replacing the plastic housings of products by metal housings enables better compliance and environmental performance of electronic products in end-of-life. But, this is achieved at the 'environmental cost' of putting more environmental value in the products considered in the production phase and leads to worse overall environmental results. Within the existing limits of the above life-cycle perspective and other practical limits like functionality demands, health and safety, appearance and looks, the degree of freedom to apply design for end-of-life activities is limited to the following options:

1. Improve connections, better unlocking properties
2. Avoid certain materials and materials combinations
3. Reduce disassembly times

Short term: effective and efficient monitoring

Within the EU there are large differences in the development of take-back systems for electronic waste. As a result of the previous analysis on where the most Eco-efficient and the most Eco-inefficient lie, it is recommended to be flexible in the development of take-back system on the short term. The key element enabling higher Eco-efficiencies is monitoring by authorities. Within the different protocols that have to be developed by EU member states individually, the measuring and reporting of the inputs and outputs of recyclers (instead of their treatment activities themselves!) enables control over the system's performance. In this respect, the various and in most cases, undeveloped monitoring protocols should encourage, avoid or balance the following three directions:

Encourage 'WIN – WIN' situations

Encourage those changes or configurations that have a positive Eco-efficiency for the system as a whole. This includes increasing collection rates (inputs) of those products with a relatively high value (precious metal dominated products). For these products, separate sorting out of the larger waste streams, followed by direct treatment in a copper smelter appears in the WIN-WIN quadrant of Figure 2. The same counts for plastic recycling of large sized housings which are already disassembled due to the presence of a CRT (encourage or prescribe that the output of those fractions is plastic recycling!). However, this direction is only possible for well-defined plastics, without contaminations, flame-retardants, stickers metal inserts and in the case that an outlet or market is available for the recycled content.

Avoid 'LOSS – LOSS' situations

Changes or configurations that lead to LOSS-LOSS outcomes should be avoided. Examples of this are the incineration of plastic or residue fractions without energy recovery compared to incineration with energy recovery (output). In simple words: Always get the energy back. However, fractions that have a relatively low plastic content, but a high metal content should not be incinerated in a cement kiln without sophisticated flue gas cleaning, due to the emissions of metals to air.

Balance 'WIN-LOSS' situations

Take into account the Eco-efficiency of those options that appear in the fourth quadrant of Figure 2. In this case, there is a cost to obtain a certain environmental improvement.

(Obviously, this direction appears most frequently). In Figure 6, all main options investigated are presented.

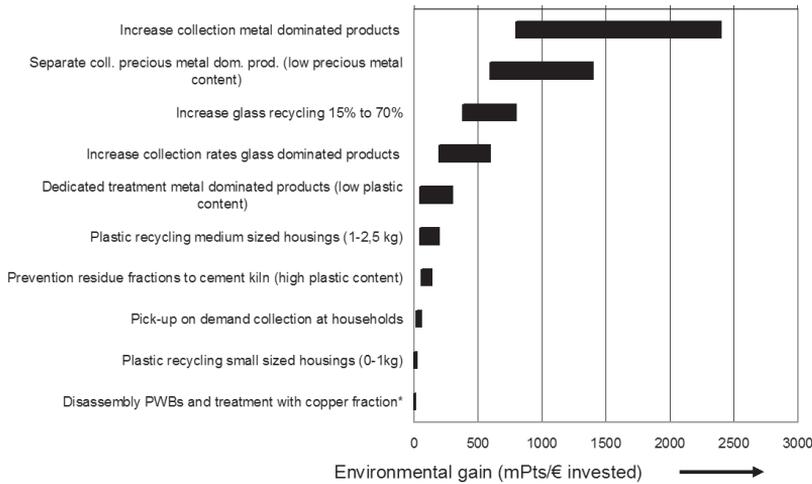


Figure 6 Ranking of several Eco-efficient improvement options

In Figure 6, the results of analyzing many different improvement options and configurations in end-of-life processing are presented. These options are presented on the vertical axis. On the horizontal axis, the Eco-efficiency in mPts/€ are displayed. The ranking shows that certain options contribute more to the development of Eco-efficient take-back system than others. The conclusion out of this is that ideally, waste legislators or authorities should draw a line for the 'WIN'– 'LOSS' directions and prioritize in order to explore the most Eco-efficient options first and to avoid inefficiency. It should be noticed that plastic recycling of small sized housings and a mandatory disassembly of PWBs (treatment) are the most inefficient options. Increasing collection rates of metal dominated products and enabling CRT glass recycling (prescribe a minimum amount to be recycled, output) result in the highest environmental returns on investments.

Generally speaking, the main available avenue for increasing Eco-efficient take-back system performance within the boundaries of the already enacted WEEE Directive is by monitoring and steering the inputs and outputs of recyclers. This could be combined with auditing recyclers on basis of their inputs and outputs by the methodology presented in the second section of this article.

Long term review

In the long term legislative development of WEEE, but also for waste policies in general, the following revision is proposed, based on the insights obtained with Eco-efficiency analysis:

Collect more data and insights

In order to come to a more Eco-efficient and practical legislation at the same time, it is necessary that more information on the end-of-life chain of products as a whole becomes available. Recycling is a very complex field with many stakeholders (legislators, industry, consumers, recyclers, secondary material processors, final waste processors, take-back system organizers) and connected with many different stages of product life-cycles (design, production, disposal, transport, collection, shredding and dismantling, treatment and secondary material processing). Information on the Eco-efficiency 'behavior' of products should be treated in a comprehensive way in order to optimize product life-cycles in general and the end-of-life phase in particular. Based on such future and developing insights, waste policies should be evaluated and rebalanced:

Rebalance policy strategies

Already now, general directions on how to alter policy strategies on the long term become clear:

1. Weight based recycling targets should either be discarded completely, or be replaced by more accurate (and streamlined) environmental equivalents.

2. Treatment rules, except those necessary for Health and Safety reasons, can also be discarded, whereas in most cases environmental and economic optimization of recycling operations is directed similarly and thus can be left to the recyclers themselves. This also avoids many monitoring problems in practice, which can be done more effectively by following and measuring the inputs and outputs of recyclers. In particular the rules for printed circuit boards, CRTs plus fluorescent powders, electrolytic capacitors and for brominated flame-retardants need to be reviewed.

3. Differentiate in collection targets. Some products are more worth being recycled from both an environmental and economic perspective. One general collection minimum per inhabitant should maybe be differentiated. More focus should be given to (precious) metal dominated products, medium priority to glass dominated products and a lower priority to small plastic dominated products. In summary, it is suggested to differentiate and control the inputs of the systems better.

4. Focus on 'outlet rules'. The example of the re-application of glass (and others) shows that by monitoring the outputs of recyclers, much higher Eco-efficiencies can be achieved than the current set of rules used in the WEEE Directive. Prescribing which fractions should follow which secondary treatment routes as a minimum is also very practical because the take-back systems are controlled better this way (in particular this applies on the destinations of plastic, glass and residue fractions).

5. Support industry, system organizers and recyclers. It is recommended for system organizers and authorities to enable the exploration of the most Eco-efficient options first. This is also needed to stimulate further technological developments in the long term. This issue specifically applies to the fields of automated disassembly, efficient identification and sorting techniques for different materials and components (plastics) and the development of secondary outlets or markets for secondary materials, for instance in finding useful thermal applications for shredder residue fractions. In contrast with wide-spread belief, for producers there are (limited) Eco-efficiency improvement options possible in Design for End-of-Life related to expected end-of-life treatment configurations.

Conclusions

Generally it can be concluded that addressing costs and revenues in relation to environmental costs and revenues in a quantitative way is a powerful concept for rethinking the Eco-efficiency of the end-of-life of consumer electronic products. Furthermore, better insights in the system performance and the demands and constraints of secondary material processors are obtained. The concept places the best possible and state-of-the-art environmental quantifications in an economic context, addressing the environmental effectiveness of, for instance, the WEEE Directive in relation to actual costs efficiencies.

With this concept, the following aspects can be addressed:

1. Performance of a single product in different end-of-life scenarios.
2. Contribution of individual materials and material fractions to this performance.
3. The consequences and contributions of single stakeholders.
4. The Eco-efficiency effects of possible changes in design, policy, technology, logistics and system organization.
5. Optimizing the relation between recyclers (fractions) and secondary material processors or final waste processors.

The Eco-efficiency results derived with the QWERTY/EE method appear to be very consistent and not very sensitive to the choice of the underlying environmental assessment method, except for plastic recycling. This is less preferable under other environmental assessment methods not addressing resource depletion of fossil fuels.

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Spaghetti blues

One of the great things about EcoDesign is that it often looks at old problems from a new perspective. There are no holy cows and if one is crossing your path it is often butchered in the name of 'green'.

On the contrary, in traditional companies making high-tech products, there are a lot of holy cows ranging from tradition (this is the way we design products) and lack of flexibility in the supply chain (these are our key suppliers) to fragmentation into all kinds of specialist jobs – few people have an integral view on product architecture and performance.

The best demonstration of how departments inside companies work together is the organization of cable and wiring (C&W) in products. Mechanical people will say C&W is electrical, therefore not for us. Electrical people will say we are electronic rather than electrical and as a result they do not feel responsible either. If there is not good communication between the two groups, nobody will feel responsible for C&W in the end. The result is obvious: excessive material use and more dissipation of energy.

In such a situation, an upfront reduction of 20% is possible. However people do not believe it, for instance with packaging reduction potential (see Tidbits, 2). Therefore I made bets about C&W reductions with a bottle of whiskey (Irish!) at stake. I won many bottles – and consumed the spoils with the losers after work. A good environmental strategy!

There are also positive examples where a tradition of cooperation has brought impressive results:

Philips Consumer Electronics has worked a lot with the Philips components division. The result has been low energy consumption. Japanese companies have traditionally put a lot of focus on resources (weight reduction) and began very early to ship overseas (reduction of packaging volume), East Europeans are good in metal (plastics came later here), west Europeans are good in plastics.

8.3 The NVMP take-back and recycling system in the Netherlands

Take-back and recycling of discarded electronic goods began in 1999 in the Netherlands – many years before the European WEEE Directive came into force. Many years of discussions preceded its introduction. A brief description of these discussions appear in § 2 of the article “*Take back and Recycling of Consumer Electronics at work in the Netherlands*” below. Although these started in a similar way as elsewhere in Europe, in the end the practicalities of making a system work have dominated the principles of how it should be in theory.

The scope of the NVMP system discussed here is one for ‘white goods’ (household appliances) and ‘brown goods’ (consumer electronics). It is a collective system, financed by fees paid by consumers when they buy new products. In the Netherlands there is a separate system for IT (the ICT system). It doesn’t require fees to be paid by consumers. It can be best characterized as ‘quasi-individual’.

The prices in the article no longer represent the reality of today. Nevertheless it is demonstrated that the system works well, both from an ecological and an economic point of view.

Today, the system as described below (situation in 1999/2001) is still in place. The collection rates are generally up, particularly for small products. On the other hand, the collection of washing machines has dropped; apparently the high metal prices of today mean that alternative routes are attractive.

Recycling percentages have changed very little; increases due to better treatment technologies are balanced through changes in material composition (lower weight/piece treated, relatively more plastics).

The recycling fees, in Euros, have not changed either.

In system operations, the cost break down is (for all categories) approximately 40% for transport and sorting, 50% for recycling and some 10% for overhead and promotion. From the very beginning costs in the various product categories have been kept separate so that cross subsidising was avoided. The costs of recycling of electronics, not belonging to the scope of the NVMP system (for instance IT products), is some 2-4% of the total cost and therefore does not warrant special action.

This is not the case for the ‘quasi-individual’ system for IT (the Dutch ICT system). Here the goods for non-members of ICT forms 35-40% of total costs. The ICT system used to make ‘collective’ contracts with recyclers but billed its members on the basis of quantities per brand processed.

Since this favors newcomers to the market, this has now been replaced by payment on the basis of current market-share, which makes the system quasi-individual rather than truly individual. However, the problem of how to make non-members pay has however remained in place.

Take back and Recycling of Consumer Electronics at work in the Netherlands

Ab Stevels

Abstract

The current performance of take-back and recycling of consumer electronics in the Netherlands are reviewed. Both the organization of this collective system as well as its performance will be described. The operational data show that for most categories pretty high collection rates and recycling quotes are achieved at low cost.

I Introduction

Systems to take-back and recycle consumer electronics products (‘brown goods’), household appliances (‘white goods’) and IT equipment began to operating in the Netherlands on January 01, 1999. This means that by now there is lots of practical experience to report. This is particularly relevant because at a EU level the Directive on Waste of Electronic and Electrical equipment has been finalized and the transposition into national law is to be done in the Member States. WEEE has been formulated primarily in juridical terms.

For this reason and because it is a so-called “article 175” Directive leaves room for individual Member States to formulate their specific national requirements, provided that these exceed the ones of the EU as a whole. Such pro-

cesses have the danger being operationalized in a variety of ways with a corresponding distortion of the common market. The common element however in what all Member States and stakeholders have is that they all want to serve the environmental intent of WEEE as well as possible while keeping the overall costs as low as possible.

2 Starting the Dutch take-back and recycle scheme for electronics

In The Netherlands the take-back and recycling debate has been a tedious one for a long time. Started in 1991, progress was very limited up to 1996. In that year a dramatic change in mindset took place among stakeholders: let's not talk in terms of principles and targets anymore, but let us talk in terms of solutions, that is see what can be achieved in practice on the basis of technology and infrastructure. On the basis of the outcome of this inventory, a take-back and recycling system will be started. In later stages it will be developed further in the directions of better environmental performance and lower cost.

In order to create a basis for this pragmatic approach a pilot was supported and financed by the Environmental Ministry, local authorities (in charge of collection), producers/importers of the products and the retailers. The pilot was carried out in the year 1996. The results of it have been published in ref.1. On the basis of the outcome of the pilot responsibilities for the future take back-system were attributed to the stakeholders and the targets for the system were defined.

The law creating the legal basis for take-back and recycling was passed in both Houses of Parliament in 1998 and the system could be started as of 01/01/99 for big appliances – the smaller appliances were included as of 01/01/00. The present paper describes the experiences with the take-back and recycling system in the years 1999-2002.

3 The goods flow and the collection rates in the Dutch system

The goods flow in the Dutch take-back system for white and brown goods is given in the figure below:

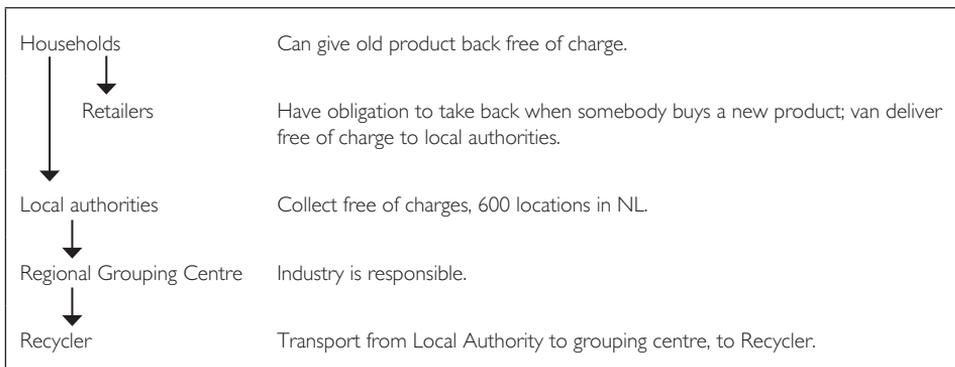


Fig 1: The goods flow in the Dutch take-back system

Households can give discarded products back free of charge through two channels: retailers (who can give them in turn back to municipal recycling yards) and directly to the municipal recycling yards. This way of organizing leaves room for trading in old products for new ones at retailers that maintains their sources for a pre-owned and repair business.

After being collected by local authorities, products are moved to regional grouping centres which are operated by the Dutch Association for Recycling of Metal/Electronic Products NVMP (the Management Organisation established for this purpose by the industry). Individual companies can become a member of NVMP on application. Almost all producers/importers bringing products to the market have become a member of NVMP although they are free to choose to discharge from the responsibilities of the take-back and recycling law through an individual approach. At the Regional Grouping Centres, products are sorted according to category and sent to the recyclers contracted by NVMP.

The table shows the collection rates as achieved in the years 1999-2002.

Table 1: Collection rates in the Dutch NVMP system in 1999-2002

	1999		2000		2001		2002	
	Tonnes	Index	Tonnes	Index	Tonnes	Index	Tonnes	Index
Freezer	19.800	76	24.600	94	20.000	100	25.560	98
Washing machines etc.	8.200	40	17.100	83	20.600	100	20.900	102
TV's	5.500	64	8.600	100	8.600	100	8.000	93
Small white & brown goods	N.A.	N.A.	5.500	58	9.400	100	11.300	120

In all categories the return quantities increase in the second year after start up and go on to stabilize afterwards. Compared to the quantities sold ten years before, the tonnage of freezers and fridges collected in 2001 is approximately 95% of previous sales. This shows that the export ban for discarded products (because of CFC content) in this category works well.

For washing machines a similar percentage is only 30%. Processors operating outside the NVMP system are the main explanation for this.

For TVs the ratio with respect to sales a decade ago is 73%. Export to Eastern Europe is the main reason for this relatively low figure.

For small white and brown goods take-back was started one year later. In 2002 numbers and weights collected are still on the increase. Return rates are still low compared to earlier sales. A main factor here is "convenience" from the side of the consumer: the small products are put into the garbage bin rather than to return through the official channels.

4 The money flow, experiences with the visible fee system

The money flow of system is given in fig. 2:

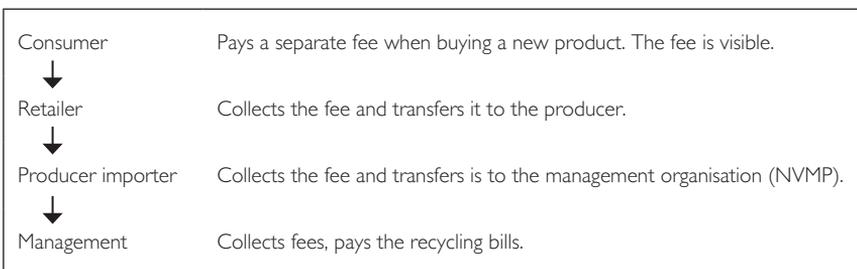


Fig 2: The money flow in the Dutch take-back system

The basis for financing the system is that the consumer pays a visible fee when buying a new product. The amount to be paid (see §5) is independent of the brand, the weight, the value or the price of the product in a certain category. This choice has been made for simplicity and transparency.

Payment made when buying a new product, rather than payment at discarding, is preferred because this is expected to boost returns and prevent 'wild' discarding/ illegal dumping. Internalisation of the cost will in practice destroy the margins of trade. Additional advantages of the visible fee system described above is that 'historical

waste' can be taken care of easily and the interests of traditional brands (higher market share in the past) are balanced. Also 'orphan products' (products where the producers or importer is no longer active in the market) can be taken care of easily.

Experiences so far have shown that a visible fee system creates awareness among consumers in a positive way. Few cases have been reported where buyers in shops refused to pay the fee.

After the retailer collects the fee the money is transferred to the producers through the usual payment procedures and subsequently transferred to the management organisation NVMP.

Here the money is used:

- to pay recyclers.
- to pay transportation cost from the local collection centres.
- to reimburse retailers for their costs for participating in the system.
- to cover overheads and to promote the system.
- to cover the costs of the regional centres.
- to create a buffer for financial fluctuations.

5 The recycling performance

The recycling performance of the Dutch take-back system for white and brown goods is given in the table 2.

Table 2: Recycling performance

Category	Target in the Netherlands *	Realized * (%)	EU Target * (current) %
Freezer/fridges	75	79	75
Washing machines	73	73	75
Small white goods	75	76	50
TV	69	76	65
Small brown goods	63	71	50

* The Dutch definition of recycling quotes count everything not going into a landfill and incineration as being recycled; a EU definition is not yet in place.

The targets for the recycling performance have been based on the pilot experiment in 1996 and have been approved by the Dutch ministry for Environment. The recycling rate in The Netherlands is defined as:

Weight % of material not going to landfill or incineration
Weight of material processed

This definition is a practical one. It is easy to establish and gives a solution for the discussion over how to count energy recovery in recycling targets; for instance mixed plastics going with copper to a copper smelter are counted as 100% recycled in the Dutch system. Mixed plastics going to an incinerator with energy recovery are counted as zero % recycled. For the current WEEE targets in the European Union a distinction is made between recycling and recovery. Although not explicitly mentioned the definitions are most likely recognized as material % 'physically' recycled and materials % incinerated respectively.

Care should be taken therefore to compare directly recycling percentages in the Netherlands and the EU.

From table 2 it can be seen that the recycling quotes realised in the regular take-back scheme are higher than in the pilot – this is due to increased economy of scale. The quotes seem to be higher in The Netherlands than for the current EU targets. When corrected for the difference in definition (see above), the quotes actually realized are slightly below the current EU targets; for brown goods they are approximately on par with TVs. For small white and brown goods the figures seem higher; however due to the so-called 'ensemble issue' (see ref. 2) it is difficult to attribute exact figures here. Basically this ensemble issue comes down to the fact that in shredding and mechanical treatment products are not treated individually but in streams where a large variety of goods (also IT products, electrical equipment, etc.) are combined in order to achieve economy of scale. 'Individual' recycling scores therefore are difficult to disentangle.

6 The actual fees and the operational cost

The fees for take-back and recycling in the Dutch System are given below. These fees cover all operations including the processing of orphan products that is of products where the producer or importer is no longer active on the market.

Table 3. The system fees. Old (at start) and new (as of 01/07/01)

Category	Old (incl. VAT), € as of 01/07/01	New (incl. VAT, € as of 01/07/01)
Freezers / Fridges	18	17
Washing machine, dryer	9	5
Small white goods	1-2	0
TV	12	8
VCR, Video camera, DVD	7	3
Decoder etc.	7	3
Small brown goods (audio etc.)	1-2	0
Magnetron	7	3
Grill, furnace	7	0

The old fees of the system have been set according to the expectations for the various categories in 1998. The old fees vary between €0.30/kg for the bigger products up to €1/kg for the smaller. Due to the fact that lower amounts of products than expected were returned initially the economy of scale and leverage of NVMP permitted lower prices from recyclers than were budgeted. Therefore there was a financial surplus in the first years of operation. This allowed lowering of the fees as indicated above. As can be seen in this table the fee reductions vary greatly per category; all costs were from the very beginning administrated separately per product category.

In the table below the treatment costs per category are given. The costs given here are the average of the seven systems currently operating in Europe with similar set-up as the NVMP one collective systems (in 6 of 7 cases also visible fee), for proprietary reasons no specific breakdown for the Netherlands can be given. **However, due to its economy of scale and its efficient organization and the high population density of the Netherlands the costs in the NVMP system are lower than the European average.**

Table 4. Costs of treatment in the Dutch NVMP system (all amounts in €/kg)

Category	Collection * and sorting	Treatment	Overhead / Promotion	Total	Collected in NL (kg)
Freezers / Fridges	0.25	0.45	0.16	0.86	1.6
Washing machine / dryer	0.14	0.06	0.11	0.31	1.3
Small white goods	0.18	0.22	0.12	0.52	0.4
TV	0.19	0.40	0.10	0.69	0.6
Small brown goods	0.17	0.36	0.10	0.63	0.2

* from municipalities onwards

With the exception of the washing machine/dryer category (which has a high metal content and therefore low treatment art) collection and sorting is some 30% of total cost, treatment is some 50-55% whereas overhead represents only 15-20%.

So far the collective system operating in The Netherlands is not giving a reward for good EcoDesign (Design for Environment). This is often cited as an important draw-back of collective systems. It is however possible to develop technology which – while keeping the advantages of economy of scale and coverage of historical waste and orphans – allows for the set up of a reward/penalty system. Currently a project guided by the research institute TNO, and supported by well known industrial companies called EcoScan-Dare, is going on in The Netherlands. It is designed to deliver the software driving a system that identifies individual products entering recycling, calculates their individual recycling cost and refers this cost to the average values. In this way amounts can be calculated which are to be paid to or by individual producers or importers.

7 Conclusions

In the present paper it is concluded that

- The current collective Dutch system for take back and recycling of consumer electronics and household appliances works well both from an ecological and economic point of view.
- Further improvements to the system should be sought in introducing environmentally weighted recycling quotes that include the environmental load of treatment and the level of reapplication of the re-melting of secondary materials as well.
- Making sure that through the treatment all precious metal present in the discarded product has high priority.
- Reapplying glass from Cathode Ray Tubes for producing new CRT has a high Eco-efficiency whereas the mechanical recycling of plastics has a much lower one.
- Several of the current treatment rules of the European Electric Waste Directive WEEE are counterproductive in terms of Eco-efficiency and should be replaced by “output rules”.

References

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2. The QWERTY/EE concept, Quantifying Recyclability and Eco-Efficiency for End-of-Life Treatment of Consumer Electronic Products Thesis, Jaco Huisman, Delft University of Technology, obtainable through J.Huisman@io.tudelft.nl.

Re-appointment

One of the great things about Dutch universities is that they maintain the institution of part-time professorships. These are people recruited from the professional world to teach for one or two days a week at the university. The big advantage, particularly for engineering students, is that in this way they get first hand information about what is going on in the world. This is highly relevant because the recruitment of full-timers from industry is getting to be more and more difficult, due to reasons ranging from bureaucracy and pay to available research facilities and overstretched teaching duties.

Part-timers are also helpful for industry and business contacts (data, case studies and application of theories developed, sponsoring, etc.). Moreover, many of them are made available for free in a gesture of goodwill. In spite of all this part-timers are considered to be relative outsiders. In terms of academic level they seem to work best in the corridors of real science. The Temple's Inner Shrine is exclusively for the full timers and all time saints, not for you. In contrast to the full timers, quality and performance is to be checked regularly – and as such there is nothing against that.

Every three years you are up for re-appointment which involves the completion of a pretty humiliating form. It has to be sent back, not directly to the Board of Appointments, but via the section leader, the department head and the Dean. It covers how your time at the university was spent, how much you have published in (leading scientific) journals, and what are the plans for the coming years etc. It is a far cry from seeing professorship as an office. Instead, it feels like a tokenistic position granted as a favor rather than as recognition of valued contributions. It is a one-sided form. The idea that persons subject to this kind of distrust could have wishes or suggestions for how things could be done better, by the university, is not acknowledged by the makers of this form. Feedback on the progress of the procedure is scarce and anecdotal, but this is apparently good enough for mortals living below Olympus. The final nod can take many months.

'One day at the gate is better than thousand days in the huts of pagans which (not who!) are not circumcised as far as mind is concerned!'

Chapter 9: Legislation

9.1 On the effectiveness of Legislation

It is very well possible that the events in the Netherlands in the late nineties (see 8.3) made me too optimistic about the upcoming environmental Directives for electronics in the EU. The basic law on Producer Responsibility in the Netherlands was a very strict one focusing on environment exclusively - costs consequences had not been considered in the first instance. All possibilities were in place for a one sided and therefore Eco-inefficient, inflexible implementation. What worked out in practice (see 8.3) was realistic, balanced and pretty satisfactory. As far there is dissatisfaction, it seems presently to be shared equally among the stakeholders.

If a similar system was to be worked out for Europe, the Netherlands could become the trailblazer.

I have presented many times in the Industry Associations on behalf of Philips with the following sentiment: "Most likely the environmental soup as being served by the EU will not have to be eaten as hot as being served". If we as industry do not like certain proposals, then we should come up with alternatives instead of only voicing our concerns. I have confidence that if industry is reasonable, the Member States will be reasonable as well. Good practices are already in place in several Member States and this will show the way forward if the fundamental debate gets stuck. The present examples show that it is not forbidden to develop systems which serve the intent of the European Directives well!

At Philips Consumer Electronics we try to contribute in this way. Philips' actions include:

- for the WEEE Directive (recycling), support for the Dutch NVMP Recycling System, sponsoring of research at Delft University.
- for the RoHS Directive (substances), the development of the Philips Chemical Content System which is open for other companies.
- for the EuP - previously named EEE Directive (EcoDesign of products) - contributions to the ISO 14062 technical report, public environmental benchmarking and business integration practices

Looking back, this type of argument had only limited effect. Industry Associations work on a consensus basis. However there is a diversity of interest, also in environmental matters. As shown in this book there are no 'one size fits all' solutions for environmental issues. This combination of factors made it very difficult for the Associations to agree. Moreover, many compromises, that were ultimately worked out, had to be referred by the company representatives in Brussels to their headquarters elsewhere in the world.

These processes meant that industry was slow and cautious and led to the perception that there was no creativity nor positive engagement involved and even that it was trying to delay. With all the criticism on the EU Directives (see chapter 9) – and there is a lot- it should not be forgotten that, in my opinion, the electronic industry has failed to contribute properly and in time to the development of better alternatives. The fronts became rigid. Roughly speaking the EU was focusing only on environment, industry was focusing on cost and financing issues. It was like two separate planets circling around each other. The planets never met. On the contrary, negative sentiment about the opposite party started to prevail and particularly in the European Parliament the prevailing attitude was to push industry harder to get something achieved.

In this situation, a real positive appraisal of the proposed EU Directives was virtually impossible. When analyzing these Directives in detail in 2002, several things were quite apparent:

- The intent of all Directives was clear, however clear goals for each Directive (may be with exception of RoHS) were missing.
- The Directives did not include the three dimensions of dimensions of 'green', see chapter 6.1. They missed, in the case of WEEE and RoHS, clear life cycle thinking.
- Implementation issues were not referred to (these can better **not** be put into a Directive, but need to be stipulated as an special issue for the Member States to ensure Europe wide coherence).
- EcoDesign is overestimated as a tool for environmental improvement. Other ways and means (technology, system organization, supply chain management) were not considered.
- Eco-efficiency (how much environmental gain for how much money) was not addressed at all.

These fundamental problems of the European Directives were addressed in 2002 in the publication on the next page. Its title is: "*On the effectiveness of currently proposed EU Environmental Directives and Policies for Electronic products*". Partly it overlaps with what has been said in chapter 6.1 but in order to avoid this the whole text has been reproduced here.

The paper demonstrates that it was, and still is, highly necessary to further align the different Directives. Proper definitions also need to be provided and targets must be formulated in such a way that they represent major environmental improvements. Simultaneously there should be room for differentiation depending on the product category considered.

In general, guidance for Eco-efficient implementation is missing. This is in fact the major weakness of the Directives.

My hope that Industry Associations would use these ideas as the environmental basis for coming up with proposals for improvement of the Directives was soon dashed. Some representatives did not grasp the ideas, others preferred delay tactics and only a few could appreciate them. The net result was that this opportunity to get out of the corner where industry was placed – unwilling, negative, money driven only – was lost.

The EU was not doing better. They talked to a lot of stakeholders but did not listen very well. A lot of potential beneficiaries (at least that is how they saw themselves) were knocking on their doors: recyclers, consultants, university professors. Many of them were uncritical in their advice and told what was thought to please 'Brussels'. Combined with a basically negative attitude of industry this was a dismal show. Europe deserves better than that.

A next attempt from our Delft crew was to take on the principles of the past on which the Directives were based. Leave them as they are, but go for more practical implementation. Just do it and practice will show the way!

On the effectiveness of currently proposed EU Environmental Directives and Policies for Electronic products

Ab Stevels and Casper Boks

Abstract

Current proposed EU Directives and Policies are reviewed as regards their environmental effectiveness. It is concluded that a better integration of the emissions, the resources and the potential toxicity aspects of 'green' is needed. This will also permit a better approach to integrating life cycle principles and better reflection of stakeholders' interest. A formula is proposed which allows measuring environmental performance from this holistic perspective. As regards operationalization, having proper definitions for the basic parameters will need more attention. Including the Eco efficiency principle (environmental gain /cost) will allow to better-set priorities and to make more appropriate trade-offs. Furthermore in this paper the role of EcoDesign is highlighted. It is concluded that in the current drafts there is ample room for further improvement.

1. Introduction

In the European Union Environment ranks high on the political agenda. Particularly for electronic products. Several initiatives have been established to arrive at Directives and Policies which should stimulate strong environmental performance. The following proposals have been made:

WEEE: The Directive on Waste of Electronic and Electric Equipment

ROHS: The Directive on Restriction of Hazardous substances (in Electronic and Electric Equipment)

EEE: The Directive on Environmental Conformity of Electronic and Electric Equipment (Later renamed to Design Directive of Energy using Products, EuP)

IPP: A proposal on Integrated Product Policy (which will also refer to electronic products)

The purpose of all these (draft) Directives and Policies is to create a common basis for law making of the Member States. Therefore the language used is primarily a legal one – operationalization details are not addressed as such. On one hand this situation creates flexibility; it is left to the stakeholders in the Member States to agree on implementation forms, which reflect the intent of the legislation.

However, this flexibility could also lead to a variety of interpretations and operationalization agreements, which could jeopardize the principle of a common market with "common rules of the game".

The shared goal of all environmental regulations is that they aim at minimizing the environmental impact over the life cycle of the products. Therefore in this paper the first question is "what is green?" What is really beneficial?, will be discussed (§2). This will show that "environmentally friendliness" can be seen and rated from several perspectives.

This will lead to the conclusion (§3) that life cycle thinking should take place on the basis of an agreed broad perspective. The current basis of life cycle analysis is chiefly emission based and therefore in fact a one-dimensional way of looking at environmental items. In order to get an overall picture, a formula is proposed to measure environmental performance from a very holistic perspective.

As regards operationalization of the European Directives and Policies, first of all the issue of proper definitions is addressed (§5.1), subsequently balancing environment and economy ("Eco-efficiency") is addressed (§5.2) followed by the role of EcoDesign (explained in (§5.3).

In all paragraphs examples will be given which relate to the proposed regulation/policies. These will be summarized and discussed further in §6.

2. What is Green, What is Environmentally Beneficial?

The answer to the question "What is 'green?'" has several environmental dimensions, but they are dependent on stakeholder perspectives.

This is depicted schematically in the diagram below:

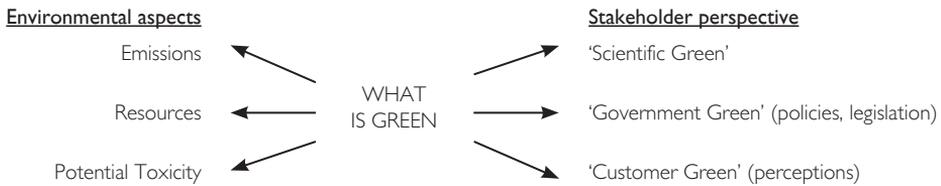


Fig. 1 Aspects of 'What is 'green?'

The environmental aspects include emissions, resource aspects and potential toxicity aspects. For all three, descriptive models exist; the most well known is Lifecycle Assessment (LCA), which concentrates chiefly on emissions. For electronic products a typical Life Cycle Analysis based on single scores according to the Dutch Ecoindicator 95 method, would read as follows:

Life Cycle Item	Life Cycle impact (% of total)
Energy consumption	50-80%
Materials and parts	10-40%
Packaging and Transport	approx. 10%
End-of-Life / Recycling	max. 5%
Substances, potential toxicity	N.A.

This scientific / emission based analysis shows that environmental priorities in the EU should be completely different from the current situation (energy first); in this approach resources aspects are not and potential toxicity aspects cannot be incorporated.

Moreover stakeholder needs (see §3) are not addressed. These items mean that performing a LCA exclusively to base environmental decisions on can be misleading and even can be counterproductive. Both EEE and IPP have in their wording a strong inclination to rely on life cycle analysis (written with small letters, so this refers to the approach and not on the methodology which is written in capitals).

As shown above great care should be taken when applying results of such analysis without checking on the holistic environmental (including resource and potential toxicity analysis) and stakeholders analysis. In view of this it is recommended to change the wording in EEE and IPP to life cycle thinking or to "lifecycle and stakeholder perspective" to avoid confusion.

Resource aspects can in principle be incorporated into a LCA (for instance by including future extra emissions which will arise due to mining of resources with low concentrations) but this is opening a new debate and uncertainty about what depletion rates should be taken into account.

Even potential toxicity can be incorporated as well but here the debate will be what emissions are to be incorporated on top of actual emissions in the future and to what extent 'natural' absorption levels have to be deducted.

It is concluded therefore that real comprehensive models are far and away and the best to consider the three aspects on separate entities.

A lot of environmental issues have dilemmas inherently linked to the three environmental dimensions. A few of them are listed below:

Table 1. Example of Environmental dilemmas

Environmental dimension	Emissions	Resources	Potential Toxicity
Using natural gas instead of coal to generate energy	+	-	+
	(less CO ₂)	(high energy resource sacrificed)	(no fly ash)
Replacing metal by plastics	+	-	-
	(less energy needed for production)	(recycling becomes a problem)	(additives in plastic)
Lead-free solder	-	-	+
	(more energy needed for process)	(use more source resources)	(lead eliminated)
Use of flame retardants	-	+	-
	(less production energy)	(less material needed)	(more potential toxicity)

- Future Kyoto requirements (these are a case in point, but will not be discussed here further) will put pressure to use more high quality resources.
- Replacing plastics to better fulfill ROHS and WEEE will result in more emissions in the production phase.
- Lead-free solder application is environmentally doubtful, particularly when it is realized that a lot of the solder in lead-free alternatives is produced as by product from lead mining. Also increased demand for tin could pose a resources problem.
- Eliminating flame-retardants will result in use of more primary materials and this in use of more production energy.

So far, the draft European Policies and Directives have been one dimensional in the sense of concentrating on single environmental aspect. RoHS has the potential toxicity perspective, WEEE the resource perspective, both EEE and IPP claim a holistic perspective, but are in practice strongly emission/LCA oriented in their environmental analysis approach. Although in both cases recommendations and design rules also address the two other dimensions, no balancing mechanisms are proposed. The way in which this can be done in §4.

3. The Stakeholder Perspective

The stakeholder perspective basically has three dimensions: a scientific one, a governmental one and a customer one. Each of these contributes to the outcome of the debate, which environmental issues need to be prioritized. 'Scientific green' is best represented by LCA (although this is a methodology rather than a science, in the end a subjective recycling step has to be taken to produce conclusions). For resources a variety of depletion models exist for which there is no consensus in the form of, for instance, ISO 14000 standards.

Potential toxicity models start to appear but here consensus is even more far away.

In practice therefore, 'scientific green' approaches will prioritize emission related environmental issues.

'Governmental green' strongly depends on a variety of factors like population density, the availability of energy sources, the geographical position (near the sea, mountains), availability of landfill sites and/or incineration capacity and the status of the economy. Such circumstances determine the priority of items on the agenda.

'Green' perceptions of the general public are strongly linked to emotions. Particularly environmental issues related to Health and Safety (therefore potential toxicity) score high, resources are long-term and score low, emissions generally score medium. There is also a relation with events, for instance when energy taxes are raised, energy issues score high, when incidents occur with toxicity/food safety, the toxic diversion flag up. When shortages of materials or of fuels occur, the resource aspect takes over.

In view of what has been said above, it is concluded that it is unlikely that the stakeholders debate will result in clear “fundamental” setting of environmental priorities. This is however badly needed to align environmental policies and directives and to allow stability in time, so that investments in technology and product design can be appropriately prioritized.

4. How to Balance Environmental Dimensions and Stakeholder Perspectives in Environmental Legislation/Regulation

In order to balance the environmental dimensions as discussed in §2 and the stakeholder perspective (§3) in environmental legislation/regulation the following formulas are proposed for a product or product category:

1. Environmental impact = $A * B * \text{energy consumption over the lifecycle} + C * D * \text{weight of the product concerned} + E * F * \text{weight of electronics and flame retardant plastics}$.

2. Environmental effect of legislation = $\frac{\text{Environmental impact after legislation}}{\text{Environmental impact before legislation}}$

In formula 1 energy is to be expressed in kWh; this parameter includes the production phase, (including production of components of subassemblies the transportation, the user phase and the end of life phase). Since for the majority of electronic products the energy consumption in the user phase is dominant, evaluating only this phase will do in many cases.

The weight of the product represents in very crude way resource consumption. Material recycled in the future can be deducted from the amount. The weight of packaging materials can be added. The resource term can be made more sophisticated if weighting according to resource scarcity indices or to Eco indicators is applied.

Potential toxicity in electronic products is to a large extent found in the electronics (incl. connectors, wiring) and flame retardant housing. Again sophistication of this term can be increased by introducing weighting on basis of toxicity indices and deducting potential toxicity, which in the end will be brought under control by appropriate end of life treatment.

The coefficients A, C and E are normalization constants A is in 1/kWh and refers to the way energy is generated in a certain country (for instance A is relatively low in Norway – hydro power – and high in countries where coal is used as a fuel for electricity generation).

B reflects the materials mix; it is higher when sophisticated or high impact materials are used (for instance cell phones) and relatively low when a lot of standard materials are applied (for instance TV).

C represents the toxicity in a certain product category.

B, D and F represent social priority factors ('government' and 'customer green', see §3) Basically these factors can fluctuate as a function of time; currently D ranks relatively high (recycling, WEEE) as well as F (toxicity, RoHS). With the Kyoto targets for energy gaining momentum B will increase at the expense of D and F, indicating basically a change of priority in environmental legislation/regulation. It is the personal opinion of the author that both from a societal and scientific environmental perspective it is currently better to push for energy reduction than to insist on higher recycling quotes. Technically speaking, for instance, miniaturization of electronics contributes more to the improvement of the overall environmental impacts (in spite of reducing recyclability!) than sticking with the current electronics and high recycling targets. On a similar basis it can be argued that saving energy through increased materialization is better than going for dematerialization. A well-known example in this field are the energy saving lamps compared to incandescent lamps.

Formulas such as the ones described above, cannot only be used to evaluate the effect of environmental regulation initiatives (WEEE, RoHS) and prioritize also options, to simplify environmental information (an important issue in IPP) and balancing a variety of recommendable design avenues (EEE). It should be stressed here that A, C and E are basically linked to design (and limited by physics) once a certain functionality is chosen to be realized. B, D and F are basically subject to political decisions. If their coefficients were to be used for a certain period of time this would create an environmental policy stability from which product design and technology investment will greatly benefit.

5. The Operationalization of European Directives and Policies

5.1. The necessity of making clear definitions

In the introduction it has been pointed out that European Directives and Policies primarily focus on principles and intent (sometimes giving explicit targets).

However, key parameters are often not well defined. This is necessary to enact swift operationalization (and to make calculations as proposed in §4) and to avoid lengthy discussions and even legal procedures.

Below some examples are given showing that stakeholders consensus “operationalization agreements” are badly needed to make it work.

Example 1: Recyclability (WEEE)

Material can be considered to be recycled if it is not going to a landfill or being incinerated (definition A). A stricter definition implies that from the percentage calculated according to A, the amounts being incinerated in the upgrading smelting process (for instance plastics in streams treated by a copper smelter) are deducted (the “gross metal” definition, definition B). An even stricter definition implies that only metals that are in their own main stream are considered to contribute to recyclability (for instance iron in the iron stream counts, iron as a contamination in the copper stream does not count). Definition A is applied for recycling systems in the Netherlands. The results of this system, amongst other inputs, have been used to set the targets of WEEE. However although not explicitly stated, the definition for recyclability implied in the WEEE text is of the B type, although an interpretation according to definition C is possible as well. As things stand now, this ambiguity in the recycling targets of WEEE needs clarification including adaptation of the numerical values.

Example 2: Banning of substances (RoHS)

The important problem from an operational perspective is what does banned really mean? A very strict interpretation would mean total elimination or the figure zero. Zero is however a concentration of which cannot be proven scientifically. Another interpretation could be: eliminated to a level that can be detected by current standards of analytical chemistry and acceptable costs. Under circumstances this is not yet a practical solution. The scope to which this detection-limit-at-acceptable-cost is to be applied needs to be defined as well. This means answering the question, “Will this rule be applied to total products, to subassemblies or to individual, components and parts?” It is the opinion of the author that in case of RoHS agreement on a set of thresholds from concentrations and for product/subassembly weights to which these thresholds are to be applied to are urgently needed.

Example 3: Essential requirements (EEE)

Essential requirements can be interpreted as physical targets to be realized, as environmental issues to be addressed or as procedures, which at least should be followed. Currently there is lots of confusion about what is meant here; the envisaged standardization procedures cannot make up for this lack of transparency.

Example 4: Life Cycle Analysis (EEE)

This has deliberately been written in small letters in the text, suggesting that this should not be interpreted as a necessity to apply LCA methodology exclusively. In practice this assessment can be done in a large variety of forms:

- Environmental benchmarking based on physical qualities (e.g. kg, sec, kWh)
- LCA as described in ISO 14040
- Simplified LCA methods
- Hazard and risk assessment
- Decision matrices, checklists, ‘spider diagrams’
- Life Cycle Costing

In all cases apart from the methods to be used the relative importance of the various environmental perspectives (see §2) have to be agreed upon. This is a major effort – with an uncertain outcome if agreement among stakeholders can be achieved at all.

5.2. Eco-efficiency

Reducing environmental load will not come for free in many cases. Society will have to realize that 'green' issues cannot be realized "ceteris paribus" (leaving anything unchanged) and that it will have to pay either directly or indirectly. It is therefore of utmost importance to analyse, for instance for investment purposes for design changes but also for legislation and regulation what, environmental gains are to be realized at what cost.

It is therefore surprising that so far Eco-efficiency has played a minor role in European development of environmental policies. The EEE draft has come the nearest because it states that environmental gain should be balanced with economic, technological and societal factors. The economic part could here be using an environmental gain / cost ratio. The economic part could here be using an environmental gain / cost ratio, where environmental gain could be assessed according to the formulae of §4. A similar approach could also be used to establish practical thresholds for RoHS (see example 2 of §5.1). For IPP the cost of the envisaged programs/instruments compared to the expected results could be an appropriate yardstick.

Eco-efficiency in WEEE is a case in point. To get insight on this matter, Eco-efficiency defined as above can be listed together with money spent.

For end of life treatment of TVs for instance the following data apply to 25 inch TVs (weight approx 27kg) produced in 2000 (and most likely to be discarded in 2010-2015)

Table 2. Eco-efficiency of treatment of modern (EcoDesigned) TVs.

Money spent on end of life treatment (€/kg) (prices in the Netherlands)	Recovery % scored (WEEE definition)	Eco-efficiency kg/€	Comment
0.18	0	0	Logistics only
0.35	26	0.74	Only metals recycled
0.50	62	1.24	Approx. current disassembly practice
0.70	78	1.11	More disassembly
0.70	88	0.98	Detailed disassembly done

These data show that initially the Eco-efficiency of the end of life treatment increases with the amount of money spent. The maximum in Eco-efficiency is when approximately € 10 is spent; when the WEEE requirement of 75% recovery is fulfilled the Eco-efficiency is already clearly over its top.

A compromise between maximum Eco-efficiency and high recovery would be spending € 12 resulting in a recovery of 70%.

The situation is more complex for portable audio products like "boomboxes". There the Eco-efficiency table looks as follows for a product with a weight of 5 kg.

Table 3. Eco-efficiency of treatment of big Audio products

Money spent on end of life (€) (prices in the Netherlands)	Recovery % scored (WEEE definition)	Eco-efficiency kg/€	Comment
0.18	0	0	Logistic only
0.35	32	0.91	Shredding and separation
0.75	51	0.68	
1.35	77	0.75	Includes disassembly

First of all the Eco-efficiency of this audio product is lower than for TVs in the high recovery region (0.6 – 0.7 kg/€ versus 1.1 – 1.3kg/€); just spending money on shredding and separations is most Eco-efficient but results in less than 1kg of material per Euro spent.

Even by spending twice as much money (additional disassembly compared to standard shredding and separation) the current WEEE target is not yet attained and the Eco-efficiency is already for over its top (approx 0.7 €/kg)

In our paper on disassembly in chapter 7.2 it is concluded that improving the design of the products can only marginally improve the situation.

From these examples it is concluded that using Eco-efficiency principles can contribute to balancing the requirements in various product categories as set by WEEE (a comparison between what is required in the Car Directives and the Electronics Directives would be interesting as well).

Further insight in Eco-efficiency could also be helpful when after a couple of years from now the current WEEE is reviewed.

5.3. The role of EcoDesign

EcoDesign aims to fulfill a certain functionality in the form of an embodiment (an artifact) which entails a minimum of environmental impact.

This definition also includes the EcoDesign of so-called 'services' since these always include the use of physical embodiments or at least the use of physical infrastructures.

This need for embodiment makes that EcoDesign can reduce the environmental impact but simultaneously is limited by the physics that have to be applied to get the functionality. For instance, TV pictures cannot be watched without a display, music cannot be listened to without speakers, PCs do not operate without a memory.

The role of EcoDesign is widely recognized in EEE, IPP and WEEE, it even seems that the role that it can play is overestimated. This is most apparent in WEEE; for instance for the 25 inch TV discussed in §5.2 the sales (functionality) value is approx. 600 € whereas the end of life cost is 10-15 €.

From these numbers it is clear that economically speaking the functionality value dominates in design decisions and lowering end of life costs by design will only happen if it does not polarize sales value.

Within the limitations sketched above, EcoDesign will deliver fast if there is a financial reward for it. This either by enhancing sales in the market; IPP is for instance strongly relying on enhancing green marketing. On the other hand, it has been recognized that products which are presented as explicitly 'green' do appeal to a minority of the buying public only. It would be therefore better that the reward for EcoDesign would be reaped through a system of tax breaks. In the opinion of the author this is an area which is still underdeveloped.

Within the field of EcoDesign several recommended design rules as for instance given in EEE are conflicting; it is to be realized that "you cannot have it all", apart from the requirements to do an environmental analysis which EEE does – it should also require that there are clear mechanisms in place to set priorities. There the formula presented in §4 could be of help.

A few examples of trade offs to be made in EcoDesign are:

Example 1: PVC is a low-impact material and therefore advantageous in terms of materials application, however it could be a problem in the end of life phase.

Example 2: Modular designs are advantageous for reuse and recycling but generally require more material.

Example 3: Integrated functionalities make that material is saved; however energy consumption generally goes up (TVCR versus separate TV and VCR).

Example 4: Miniaturization of electronics will lower energy consumption but generally implies the use of more high impact materials particularly when precious metals are used (SMD electronics versus traditional electronics)

Many more of such examples can be given. The general conclusion from it is: design rules as given in EEE (and to be promoted under IPP) are at best generics, design solutions are to be tailor-made.

6. EEE, IPP, WEEE, AND ROHS EVALUATED IN ONE GLANCE

Based on what has been discussed in the previous sections, EEE, IPP, WEEE and RoHS can be evaluated in the following way:

Table 4: Evaluation EEE, IPP, WEEE and RoHS

	EEE	IPP	WEEE	RoHS
Taking the life cycle perspective properly into account	++	+	--	-
Addressing the three dimensions of 'green'.	-/+	?	?	-
Adequate definitions	--	+	-	-/+
Taking Eco-efficiency aspects into account	+	-	-	-
Setting priorities / targets	-	--	++	+
Highlighting the role of EcoDesign	++	+	?	-
Having proper evaluation / validation mechanisms	+	-	+	-

Overall this evaluation shows a very mixed picture of plusses and minuses (and still some question marks) indicating that there is plenty of room for improvement.

WEEE and RoHS both address specific departments of the environmental issues; in both cases the alignment with the overall perspective needs to be improved. Currently there is the danger of single-minded implementation which could even be environmentally counterproductive.

As shown in this paper, there is still plenty room for discussion and plenty of inaccuracy in data (and ways to handle such data) in the environmental field as a whole.

Irrespective of this it is reasonable to require that the proposed Directives and Policies formulate adequate definitions of key parameters. It is also logical that environmental issues are placed in a general, economical, technological (Eco-efficiency) and societal perspective. This integration aspect (the wording integration in IPP refers different environmental issues only) to develop this further has in the opinion of the author currently the highest priority to be tackled.

If the integration mentioned above is realized, other aspects of operationalization (setting priorities and targets, proper application of EcoDesign) are much easier.

Currently the situation in this field is a mixed up one. There are clear priorities and targets for the specific Directives (WEEE and RoHS) but there is a lack of emphasis on the role of EcoDesign.

For EEE and IPP the opposite holds, EcoDesign is strongly addressed but mechanisms achieve priorities and targets are absent. In total this makes it difficult to evaluate whether the intent of the Directives and Policies has been properly fulfilled. Here EEE and IPP seem to rely strongly on LCA type of approaches which are cumbersome to implement and only describe one dimension of the environmental landscape (see §2) WEEE and RoHS are into comparison to this typically "single issue" regulation. Here the basic definitions need to be made more precise to allow ambiguous evaluation and validation.

7. CONCLUSION

The current spate of draft environmental legislation / regulation on electronic products in the EU covers a wide range of issues to be tackled by industry. Further alignment of the current four main initiatives (EEE, IPP, WEEE and RoHS) according to the life cycle perspective 'could substantially improve environmental effectiveness.

This becomes even more urgent if a Directive on energy consumption is to be added.

The “Kyoto” issue will also further sharpen the discussions about how to balance the three dimensions of ‘green’ (emissions, resources and potential toxicity)

In this paper it has also been shown that for operationalization of the proposed Directives clear, unambiguous definitions are needed, to allow proper integration with economical, technological (eco-efficiency) and societal items; lack of Eco-efficiency considerations in the current drafts could lead to wrong priorities and even to anti-environmental action.

Also proper definition of the role of EcoDesign deserves more attention; moving it from the current rather philosophical concept for universal cure of environmental sins to a strong tool which can be tailored to specific solutions for the challenges, which current Directives and Policies are posing to industry, will require quite some effort.

Personalities, 13

Klaas Herman Jan (‘Klaas’) Robers: riding the frequency waves

Klaas and I have known each other already for more than fifty years. His parents were friends of my uncle and aunt, who lived some 250 meters from my parents’ house. I often used to play with my nephew Leen Kees and thus I met Klaas when his parents were visiting or when he was staying there for a longer time.

I lost sight of him until the moment we both started at Philips Research in the Nat. Lab. (the physics lab). He was in electronics, which I detested as a field. I was in chemistry. Our communality was that we lived close to each other, Klaas and Henny, on 50 St. Jorislaan, Annet and I on 54. Most of all we shared that inquisitive, self-willed and analytic mindset, which was so common for young promising researchers in the end of the sixties. Science and technology should prevail where possible. This represented quite a difference from the social engagement of researchers, which took over as a fad in the early seventies. We remained traditional, even in our outfit: grey trousers, white shirt, red necktie, blue blazer. Both of us were seen in that period as being potential right wing suspects.

The four of us became friends for life but our career paths went in completely different directions until we met again at Delft University. Klaas became a professor in Industrial Design Engineering in 1991 and I in 1995 – we were even in the same department, and often we shared the same 07.09 AM train from Eindhoven to Delft.

Klaas will never become fan of the environment and I still have little affinity for electronics. What I learned from him is to put emphasis on the self-motivation of students, let them find out their own field, let them formulate their graduation assignment themselves and let them develop their designs based on physics. His method is a combination of making the students struggle (mostly with good results, if not, apply some non-humiliating support) and stimulating their self-confidence.

Most of all Klaas is a teacher, a real one, a real presenter selling his field and motivating the students. Dutch taxpayers pay 80% of the Delft University budget. Their expectation is primarily that good engineers are educated; Klaas is their best buy both in terms of content and style.

‘Care for students’ also means for Klaas that that you have to be firm and demanding – being popular and soft is not the right idea.

The ‘Robers’ Walk: there is none. Klaas does not like to walk at all. Rather than doing that I suggest to rent a bike at Delft Central Station and make the following tour:

Leave the station, go Left on the Westvest, go to the end of the Canal Left on Bolwerk, continue on Buitenwatersloot, 5th Right to Krakenpolder, Westplantsoen (all the way) at the end slightly L, cross two streets into Laan van Altena, cycle around the Agnetapark, leave through J.C. van Markenweg, go L under the tracks, L on Wateringse Vest, R on Nieuwe Plantage, R to Oostplantsoen continue to Oranje Plantage, at Oostpoort cross the bridge and go R to Kanaalweg, go L Kanaalpad, continue south to Mekelweg, go 6th R Balthazar van der Polweg, go R Rotterdamseweg, all the way north, go R Kanaalweg, cross the bridge, go through the tunnel, cross another bridge, L, R (Lange Geer); L over bridge (Breestraat), R Oude Delft, L Binnenwatersloot and L through Westvest back to the station.

9.2 The European Directives

9.2.1 Waste of Electric and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS)

One of the big problems of European Environmental Directives is that it took them ages to come into operation. Both WEEE and RoHS are clear examples that there has been such a long time between the first debates and the final decisions by the Commission and the European Parliament. As a result the WEEE and RoHS Directives are based on principles, ideas and knowledge from 1995. Implementation has to take place from 2005 respectively 2007 onwards. In the meanwhile valuable insights have been gained like:

- There is need for implementation agreements next to legal texts (interpretation of requirements, definitions, system organization, monitoring,...)
- Apart from environment also cost should be considered for instance in the form of Eco-efficiency (how much environmental gain for how much cost).
- There is no one size fits all for products, system organization and the application of treatment technology. This suggests an environmental equivalency principle clause; if there is an alternative to the law which is equal to or more 'green' than the rule, it should be allowed.
- There is need for organizational suggestions and administrative formats by EU (Member States are legally responsible for the implementation of the Directives, but in the current situation this had lead to a wide disparity in the national implementations).

On top of that, many of the ideas originating from 1995 are outdated and some of them turned out to be wrong. Since a clear mechanism to incorporate the latest insights and knowledge into the Directives has been missing; this has led to a big gap between the starting points in 1995 and the reality of today.

Specifically for WEEE this gap can be summarized as follows:

Table 9.1 New and old ideas about WEEE

Item	1996 idea	2006 idea
Starting point	Doing good for environment	Create value (including green value) for society
Principle	Extended producer responsibility will reduce recycling cost to zero	95% of electronic products have a structural recycling cost deficit
Environmental issue	The primary issue problems are discarded products	The primary issue is to do sensible things with the material streams resulting from treatment
Design	Design for recycling is priority number 1	Design for recycling can contribute but is at best priority number 3
Technology	Manual disassembly will do the job	Shredding and separation technology have become very effective
System organization	'One size fits all'	Diversity of solutions depending on product material composition

In a similar way times have changed for RoHS:

Table 9.2 New and old ideas about RoHS.

Item	1996 idea	2006 idea
Starting point	Electronic products are 'hazardous'	Electronic products have potential toxicity
Principle	Upfront elimination of substances	Control of potential toxicity
Environmental issue	Prevent dispersion	Balance substances use, functionality requirements and the three dimensions of 'green'
Solution	Design substances out	Technology & supply chain management

In the article on the next page "An Industry Vision on the implementation of WEEE and RoHS" it is described how a flexible approach to monitoring the implementation of WEEE and RoHS is the avenue to go for in

the years to come. The reason for doing so is that the present WEEE and to a lesser extent RoHS show substantial environmental and economic flaws. In the publication, ways and means are described for how these can be remediated. Since time will be needed to take such actions, real enforcement should take place at the moment that both Directives have been overhauled.

This article was published in 2003. Together with similar publications it has been an eye opener for a lot of people in the EU, in the industry and elsewhere. However as scientists it is difficult to have an impact on vast audiences. They often have vested economic and political interests (or simply fixed opinions and positions) as well. Moreover, TU Delft became involved at a late point in time; the research underlying the ideas was started in 1999 and most results were available in 2002-2003, at a time when the Directives were already in the European Parliament.

For this reason, we never had the illusion that we could have a big impact on the content of the Directives adopted by the European Parliament and the Member States. It was hoped however that in the implementation phase there could be an impact, particularly if the Industry Associations would take some of the issues on board and subsequently would promote them in the various countries. This did not materialize and this is one of the reasons that particularly WEEE worked out so disastrously in practice, see also chapter 9.2.3.

By now, the EU has realized that an Eco-efficient implementation of WEEE as envisaged has become a failure. Complexity, lack of coherence between Member States, administrative and organizational problems and technical imperfections have led to environmental effectiveness which is far from the maximum attainable and at a high cost. As a result of all this confusion there will be a Review of WEEE in 2008. TU Delft is one of the members of the consortium which is currently involved in the technical review of WEEE. The proposals for simplification and for increasing the environmental effectiveness will be handed in to the Commission in September 2007. Subsequently the decision making process on the proposals will start. Lets hope for the best!

An Industry Vision on the implementation of WEEE and RoHS

Ab Stevels and Jaco Huisman

Abstract

In this paper the implementation of the European WEEE and RoHS directives will be considered from the perspective of an Eco-efficient implementation. The basis for the environmental considerations of take back and recycling is the Quotes for Environmentally Weighted Recyclability (QWERTY) method as developed at Delft University of Technology.

Combined with economic (cost) calculations a comprehensive approach on the Eco-efficiency of electronic goods will be presented. In this way, it can be assessed how the intent of the WEEE can be best served.

Moreover, meaningful avenues can be indicated for further improvement of take back and recycling system both through EcoDesign and through technology investment but also through systems organization and improvement of rule making. The QWERTY / Eco-Efficiency approach also delivers a clear priority setting in this respect.

For RoHS implementation adequate thresholds, appropriate system boundaries and an agreed set of chemical analysis methods are key ingredients for success. It will be discussed in a separate section.

1. Introduction

In the spring of 2003, the European Directives on Waste of Electric and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) have been accepted by the European Parliament and by the Council of the Member States. Both Directives are clear in their intent and leave sufficient flexibility to come to optional solutions for the various product categories concerned. However, the complexity of the various electric and electronic products as well as the limited experience in setting up efficient take-back and recycle systems mean that a lot of issues still have to be settled.

In this paper WEEE and RoHS will be considered from the perspective of Eco-efficient implementation, which is how maximum environmental gains at minimum cost can be achieved when still acting within the spirit and the intent of WEEE and RoHS. This sentence has been formulated deliberately in this way. Elsewhere (see [1] and [2]) it has been explained that a strict, juridical and literal enforcement of WEEE and RoHS could under certain circumstances lead to far from optimal results and could in some cases be even anti-environmental effects while costs are unnecessarily high. Concluding that this situation is not serving the initial goals of the Directives, alternatives to do things in a better way should be offered. It will be shown here that looking from an implementation perspective and by acting within the spirit and intent of WEEE and RoHS, will lead to the most Eco-efficient implementation of the Directive (including its transposition into National laws). Moreover the approach presented here will indicate the avenues through which current 'state of the art' can be improved. This will not just be through 'Design for Recycling' and appropriate treatments, it will be shown that management of input ('collection'), output (reapplication of materials) and system management in general, will contribute much more to ecological and economical improvement of the systems than design and treatment as such.

The basis for these considerations is the Quotes for environmentally Weighted Recyclability and Eco-Efficiency approach (QWERTY/EE) developed at Delft University. In this paper, first the basic ideas behind this approach are discussed (§2). Subsequently, results of calculations of traditional, recycling quotes, QWERTY percentages and Eco-Efficiency directions are presented for consumer electronics products (§3). A next section (§4) will be devoted to analysis of a variety of improvement options with respect to the current situation. This analysis will lead to a prioritized set of recommendations for successful WEEE implementation. The potential contribution of EcoDesign to improvement of recycling systems will be discussed in §5. It will be shown in §6 that achieving economy of scale is of much more importance than just applying Design for Recycling. Finally, the issue of how to handle RoHS will be discussed in a separate paragraph (§6).

2. Eco-efficiency as a starter to consider WEEE

The general idea of QWERTY is to replace in end-of-life considerations (physical) weight – this is done for instance in WEEE – by “environmental weight” of the materials in the recycling streams. This “environmental value” consists of two components.

- A positive one: the environmental value of the materials which are replaced by the recycled materials in their second life (in this way the 'level of reapplication' issue is addressed as well).
- A negative one: all environmental loads due to collection (transport), treatment (process energy) and materials upgrading including the material losses (waste to be discarded) in all these processes.

In fact QWERTY takes into account all environmental effects in the recycling chain. QWERTY scores in percentages are calculated on a scale comparing recovering all materials (with zero environmental load due to processing, the ideal situation) and the 'worst- case' (for instance for WEEE dumping on a landfill). This is illustrated in the Figure 1:

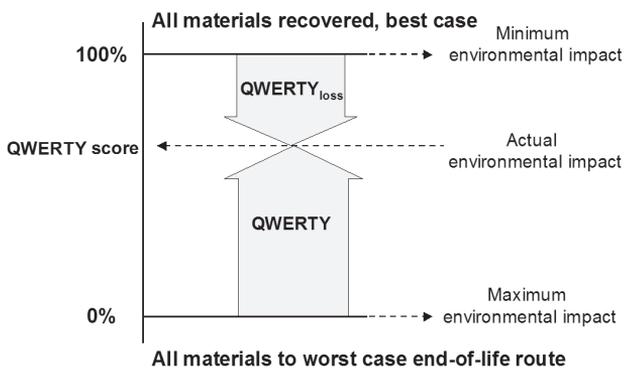


Figure 1 The basics of QWERTY score calculation

On the basis of QWERTY scores improvements of individual treatment steps can be quantified, including improving transport, improving upgrading and last but not least addressing higher levels of reapplication. The fact that QWERTY compares with a minimum of worse-case scenario allows to come to environmental considerations. In this sense QWERTY gives a real environmental GAIN (for instance of recycling WEEE instead of dumping it on a landfill).

If all costs involved are known it can be calculated how much environmental gain is generated at what cost. The resulting Eco-efficiency (EE) component of the work presented here makes that possible! The important consequence of the ability to make such environmental gain / cost calculations is that now also the effectiveness of the various 'rules' laid down in the WEEE Directive can be tested and -even more important- the PRIORITY of improvement avenues can be assessed. A further possibility is that this approach can be used for instance for auditing different technologies or multiple recyclers as well as for rewarding good EcoDesign.

3. Results of QWERTY/ EE calculations

In this section the results of QWERTY and Eco-efficiency calculations will be presented for consumer electronics products. The geographic setting for the calculations has been the Netherlands; this is relevant for logistics (transport distance) and baseline ("worst-case") scenario, which has been discarding through municipal solid waste (in the Netherlands this goes partly to landfill, partly to incineration.)

Data from the following sources were used:

- Materials composition of products: Philips Consumer electronics
- Products concerned were products produced in the last three years; as such results allow conclusions about the future performance of recycling systems.
- Disassembly and shredding / separation characteristics: data from Mirec Electronic Recycling NV.
- Take back system characteristics / costs: NVMP (the Dutch recycling system for consumer electronics)
- Outlets for secondary materials / reapplication: as existing in the Netherlands
- The environmental calculations were carried out on basis of the Eco-Indicator 99 method [3]. For more details about the calculations see [4].

In the table below the results of the QWERTY / EE are presented.

Table 1: Results of QWERTY / EE calculations

	WEEE Recycling (%)	QWERTY (%)	Eco-efficiency mPt; € revenue/cost
<i>Precious metal dominated products</i>			
High end cell phone	17	65	151 mPt; € 0,75 revenue
Average cell phone	26	69	98 mPt; € 0,48 revenue
<i>Metal dominated products</i>			
DVD Player	77	55	250 mPt; € 0,05 revenue
DVD Recorder	72	54	367 mPt; € 0,37 revenue
<i>Glass dominated products</i>			
32 inch TV	53	53	1576 mPt; € 4,57 cost = 345 mPt/€
20 inch TV	51	42	543 mPt; € 2,53 cost = 215 mPt/€
17 inch Monitor	56	43	492 mPt; € 2,88 cost = 170 mPt/€
<i>Plastic dominated products</i>			
Audio system	44	51	1264 mPt; € 1,46 cost = 855 mPt/€
Sound system	45	46	316 mPt; € 1,50 cost = 210 mPt/€
MP3 player	30	53	41 mPt; € 0,02 revenue

From this table it is concluded that:

- Precious metal dominated products like cell phones will not comply with the WEEE requirements for recycling, but on an environmental basis (QWERTY) they score well compared to other products (75-80%) and precious metal dominated products produce revenue!
- Metal dominated products score well in WEEE as well as (corrected) QWERTY. There is a small revenue for the products investigated.
- Glass dominated products score well in WEEE but score low in QWERTY (mainly through low level of reapplication of the glass), the Eco-efficiency is moderate (100 – 400 mPt/€).
- Plastic dominated products that do not comply in with WEEE, have acceptable QWERTY scores, but have low Eco-efficiency scores. An exception is that when precious metals are present, the Eco-efficiency can be high (portable MP3 player).

The Eco-efficiency is low with exception of small products where the presence of precious metals lead to a revenue (and makes that the QWERTY score much higher that the WEEE recycling one). Generally it is concluded that the outcomes based on (complete) environmental considerations (QWERTY) differs substantially from the current WEEE approach, which is based on weight. Care should be taken therefore to enforce WEEE on it current basis. It is recommended to instead take "how well is the environmental intent of WEEE served" as a basis.

4. Improvement of WEEE on an Eco-efficiency basis

With the data of §3 and the conclusions following from that, a new basis is laid for exploring the improvement options. Apart from expressing numbers, this can be visualized in the following diagram:

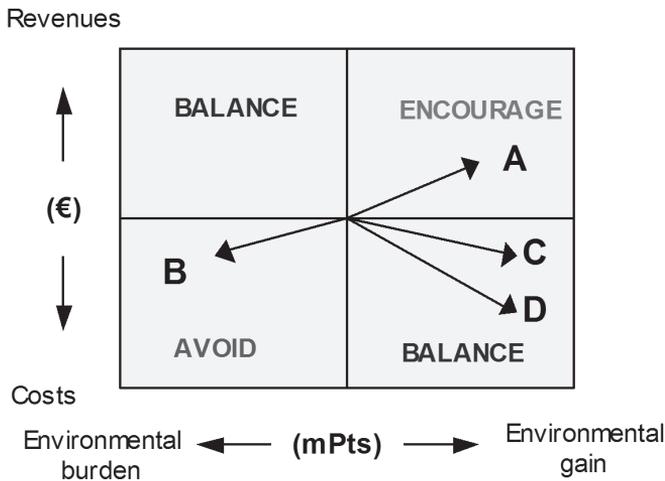


Figure 2 Visualizing Eco-Efficiency Directions

On the X-axis of this diagram the environmental aspects are represented; the money part of Eco-efficiency is on the Y-axis. In the center (X-Y intersection, the 'zero') is the reference or baseline scenario).

Compared with this scenario, actions which lead to an improvement direction A (environmental and monetary gain) should be encouraged. Developments in the direction C (a lot of environmental gain at little cost) and D (still substantial environmental gain but also high costs) should be subject to balancing: how much gain is wanted or still allowed for how much cost. These are items for discussions to take place among stakeholders. Direction B is not part of the agenda: nobody will want to enter an avenue where both environmental and financial losses occur.

A direction not mentioned in the diagram (which in practice rarely occurs for electronic products) produces

another dilemma: what to do with options which bring financial gain but lead to environmental losses? In this case the quotient of extra environmental burden versus financial gain can be calculated and be directly compared with the options in the 'C and D' quadrant, but in here as the reverse effect. (What is the Eco-efficiency of avoiding this options?)

In this section Eco-efficiency data about the following improvement options will be presented:

1. Further improvement of cellular phone recycling
2. Increased collection of metal dominated products
3. What do higher levels of CRT glass bring in terms of Eco-efficiency
4. Increase of collection rates in general
5. Recycling of plastic housings (instead of incineration / landfill)
6. Implementation of treatment rule in Annex II of WEEE (separate disassembly of Printed Wiring Boards (PWB)).

Option 1 Cell phones

The results of Eco-efficiency calculations are summarized in the Eco-efficiency figure below.

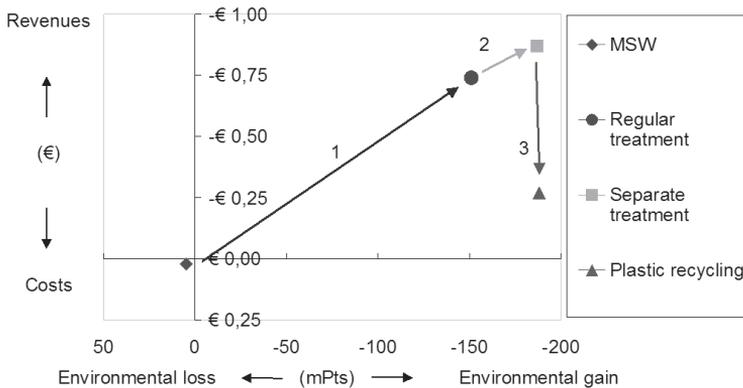


Figure 3 Eco-efficiency of Cell phone scenarios

This figure shows that the current recycling scenario of cell phone treatment together with other electronic goods shows pretty good results. Separate collection and treatment would create even a greater win-win, see the point in the upper right corner. Separate disassembly of PWB (even when plastic recycling is included) as mandated by WEEE Annex II, will bring almost no environmental gain but instead shows a dramatic drop in revenues (even results in a loss), see the point at the bottom of the right hand side.

Option 2 Increased collection of metal dominated options

Increasing of the collection rates of such products through immaterial means, for instance by increasing awareness of consumers, has been calculated to bring an additional Eco-efficiency of more than 800 mPt/€ which is very high (For some product even end-of-life revenues are created, see Table 1). This is because of the fact that the environmental gains are achieved with little additional treatment costs.

Option 3 Higher levels of reapplication of CRT glass

The results of Eco-efficiency calculations of increasing the amount of CRT glass back into its original level of application in the glass tank from 15% (the current level in the Netherlands) to 70% are summarized in the table below.

Table 2. Effect of increasing reapplication level of recycled TV glass (from 15 to 70% of total)

Type of product	Eco-efficiency (mPt/€)	Type of product	Eco-efficiency (mPt/€)
32" TV	410	22" monitor	390
28" TV	390	17" monitor	400
21" TV	400		
20" TV	400		

The conclusion of this table is that irrespective of the screen size and type of product (TV / Monitor) environmental gain is consistent and which is higher than of plastic recycling. This is due to the fact that the higher level of reapplication implies only limited extra costs. This is because TVs and monitors are disassembled anyway.

Option 4 Increase of collection rates specifically by pick up on demand.

The Eco-efficiency of such actions are generally low: 20-40 mPt/€. This is due to the fact that environmental gains are limited due to extra transport and additional costs are high.

Option 5 Recycling of plastic housings

The results of the Eco-efficiency are shown in Figure 4. This figure shows that plastic recycling instead of incineration has still a reasonable Eco-efficiency (150-240 mPt/kg) for large size products (housing weight 3-5 kg). For medium size (1-2.5 kg) this drops to 40-100 mPt/€, whereas for housings less than 500 g the Eco-efficiency is very low (less than 10 mPt/kg).

The explanation of these results is that disassembly costs, which are at first approximation constant irrespective of the size / weight of the housings drag down the Eco-efficiency ratio.

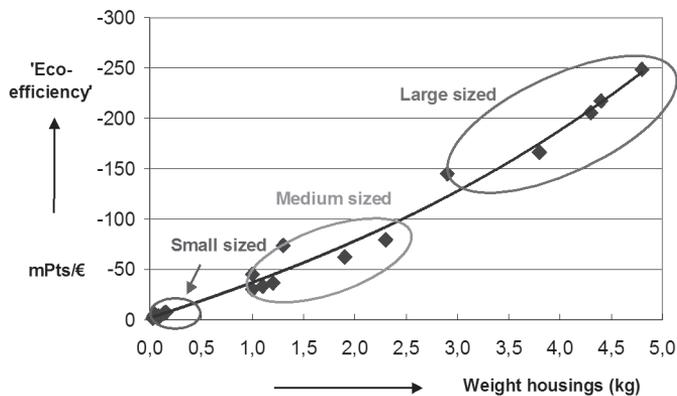


Figure 4 Eco-efficiency of plastic housing recycling

Option 6 Separate disassembly of PWBs

Table 3 Eco-efficiency of separate disassembly of Printed Wiring Board (PWB)

Product	Eco-efficiency (mPt/€)	Product	Eco-efficiency (mPt/€)
High end cell phones	76	Audio System	12
Average cell phone	40	Sound Machine	1
DVD player	3	MP3 Player	11
DVD recorder	6	TV	Already included in disassembly
		Monitor	

From the data in Table 3 it is concluded that separate disassembly of PWBs has a very low Eco-efficiency. This is due to the fact that the environmental gains are limited (gain due to 'concentrations' of (precious) metals in PWBs however losses to more metal 'leakage' in the remaining fraction without PWB) whereas costs increase dramatically.

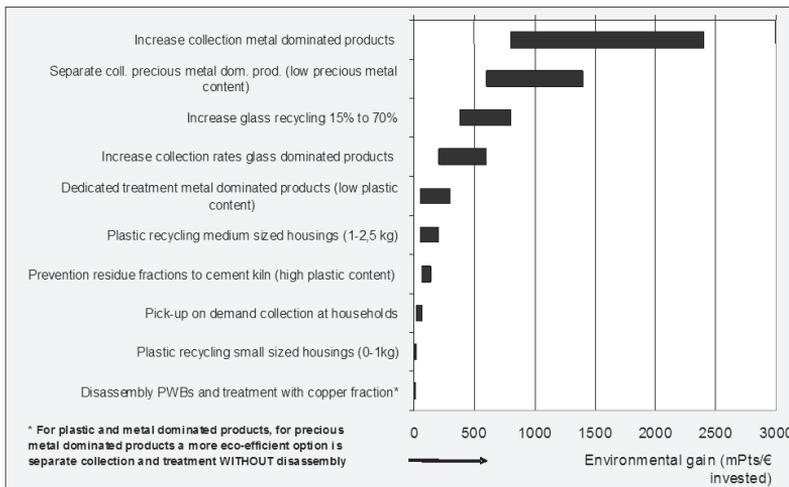


Figure 5. Prioritization of improvements options according to eco-efficiency

In the Figure 5 below we have listed the options discussed above according to their Eco-efficiency and included some other ones, which are not discussed. It is concluded from this figure that different improvement options of recycling systems can be classified in priority according the Eco-efficiency. From a policy perspective an important application could be that a 'cut-off' is introduced for instance all options bringing more than X mPt/€ are to be implemented the ones below that ratio not. The stakeholder discussion left will be about the level of X, which is acceptable.

5. The role of EcoDesign

So far Eco-efficiency has been discussed in terms of input (collection), treatment and output (reapplication).

What EcoDesign can contribute respectively will be discussed below.

For this purpose a distinction is being made between products which are to be disassembled (glass dominated products like TVs and monitors) and ones that are not (precious metal, metal and plastic, dominated products).

For the latter, shredding / separation techniques are applied as the main treatment process. The low weights in

these product categories (less than 5kg) result in low Eco-efficiencies when these products are disassembled; lower environmental value is combined here with relatively high cost. For glass-dominated products the main handle, which can be turned through EcoDesign, is disassembly costs. Material composition is almost impossible to act on; the CRT is dominating in this respect, and cannot be designed out because of the very functionality requirement. Also improvement in material value on recycling leads to higher environmental loads in the production stage (this is for instance the case when plastics are replaced by metal) [2].

What has been achieved by EcoDesign in terms of Eco-efficiency as a function of time for instance for TV's is illustrated in the next diagram:

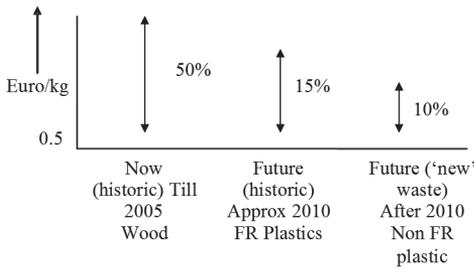


Figure 6 Average treatment cost TVs versus time

This figure shows that for historic waste till 2005 average treatment costs are on average some 0,90 €/kg with a large spread (50%) among brands. For newer products – as a result of EcoDesign – the costs have been lowered to some 0.70 €/kg whereas the spread among brands has been reduced to 15%. Current products which will come back after 2010 have a cost of some 0.60 €/kg, the spread between brands is further reduced to some 10%. These facts allow various conclusions:

- Design for disassembly has already been successful. A level of saturation has been more or less reached, therefore future potential is limited.
- Spread in costs among brands has been substantially reduced; rewarding good EcoDesign will have a limited time frame (till 2010).
- For TVs there is a high likelihood that a structural deficit of 0.5 €/kg will remain which cannot be bridged by good EcoDesign. This is a strong argument to have (visible) fees for recycling to be paid by the consumer, in the phase of 'historic waste' but also in the period of future waste (after 2011).

For products which currently go through a shredding/ separation treatment attempts to redesign them in such a way that the higher cost of disassembly is compensated by higher environmental gains, has failed (see [5]); the Eco-efficiency of disassembly treatments of such products remains low. Design strategies, which remain relevant, are:

- Reduce and replace undesired materials. An example of this is avoiding metals giving rise to penalties put in the value of secondary material streams given by metal smelters.
- Reallocate materials so that cleaner fractions are obtained through increased separately.
- Improve unlocking properties of parts and components (less cross contamination of fractions).

It has been shown in chapter 6 of [2] that application of such design rules to consumer products will lead to improvements in Eco-efficiency of only a few percent. EcoDesign efforts for such kind of products can therefore better directed towards other parts of the life cycle for instance the production phase.

6. The effects of achieving economy of scale

Positive effects of increased economy of scale will be evident in almost all parts of the recycling value chain. It will be quite obvious that:

- For collection, more volume will lead to lower cost of operation in collection producing better loading factors of transportation.

- If secondary materials like Fe, Au, Co volumes are offered to the market in volumes exceeding a certain threshold, the full market value will be paid. If the volumes are below this threshold, lower prices will be paid.
- Upgrading of materials before they are offered to the market. Upgrading processes require a certain minimum volume to be Eco-efficient; for plastics as used in electronics such a minimum is estimated to be 100-1500 tonnes a year, for TV glass this minimum is 15.000-20.000 tonnes a year.
- Bargaining power of recycling systems organizers increases with the volume they handle. Contrary to what many people think, recyclers gaining leverage and becoming competitive is more important than having competition between various system organizers.
- Overheads costs of recycling systems / organizations will decrease on a tonnage basis with increasing economy of scale.
- Investments in technology, for instance, for improved shredding separation will lead to lower depreciation cost per unit volume of the occupation rate will be high.

In this section the effect of economy of scale effects on disassembly will be discussed in more detail. As an example the recycling (disassembly) cost of 28" TVs is considered. A formula derived from practice for the recycling costs reads (based on price levels in 2003):

$$\text{Recycling cost (€)} = 3E + 3 * \sqrt{\frac{100.000}{X}} + 1.5F$$

In this formula:

E = The EcoDesign factors, currently ranging between 0.85 (best) and 1.15 (worst) EcoDesign

X = The number of pieces processed by one recycler (for the formula to apply, volume should exceed 50k)

F = the flame retardant factor: it equals 1 if flame retardants are present in the housing and 0 if absent. From this formula the following can be concluded.

- Increasing the volume for disassembly at one recycler, for instance from 50k to 200k, brings a substantial cost and Eco-efficiency gain (€ 2,10 /piece).
- This volume strategy permits more improvement through EcoDesign (for instance going from average to best will bring € 0,45 /piece). Moreover, going for volume will manifest itself directly whereas effects of good EcoDesign only manifest themselves many years later.
- The presence of flame retardants in an important cost factor. The Eco-efficiency effects of their presence is bigger than the effects of good EcoDesign and can be even dominate volume effects if these are not put very high on the priority list.

In general it is concluded that going for economy of scale will have a very big effect on the Eco-efficiency of take back and recycling systems. The implication of this conclusion is that Member States of the EU with less than 15M inhabitants will have to cooperate to increase the Eco-efficiency of their take back and recycling systems compared to the bigger states. In order to promote Eco-efficiency and to prevent market distortion cross nationality of systems (tendering, processing, upgrading and reapplication of materials will be necessary).

7. RoHS

Whereas WEEE chiefly considers conservation of resources, RoHS addresses control of potentially toxic substances. The term 'potentially toxic' is used deliberately because RoHS substances in electronics are not hazardous as long as the products maintain their integrity. There is however a toxic potential when they lose this integrity (for instance by irresponsible end of life treatment or uncontrolled land filling). This distinction is relevant for the interpretation of RoHS because real hazardous substances need to be 'banned' whereas potential toxic risks should be controlled. This is done by reducing their concentration to levels where the likelihood that they still can do harm is very low.

From this it is concluded that RoHS substances like lead, hexavalent chromium, Cadmium and the organic bromine compounds as mentioned in RoHS need a threshold concentration below which their potential toxic risk is to be sufficiently minimized.

Defining such thresholds would require toxicological data and a risk assessment of all end of life scenarios which could exist for discarded electronics. Currently this is no realistic requirement, therefore a practical implementation approach is proposed where other factors are taken into account such as:

- Possibilities of current analytical chemistry (for instance 'zero' is the preferred threshold, however zero is a concentration level which cannot be proven to exist)
- Costs of applying chemical analysts (sometimes checking on very low concentrations will require analytical chemistry of a type which is very costly)
- Systems boundaries (electronics products contain up to 10.000 different parts or components with weights ranging between a kilogram (there are maximally a few of them) to numerous parts with weights below 1g or even 0.1 gram).
- Implementation level in producer / supplier relationships
- Consequences for recycling. This issue plays a particular role in the recycling of tin. This is a key constituent in solder and it will be used in higher amounts due to lead free soldering. A lot of tin is already recycled from lead containing solder; this situation is to continue in the coming 20 years. If in the future tin originating from recycling is required to be lead-free at too low a threshold level (for instance 0.1%), the Eco-efficiency of tin recycling will drop dramatically. Pressure on mining more tin will increase (tin is already a scarce resource and the prices will go up).

Based on such considerations the following thresholds are proposed:

- Lead, hexavalent chromium: 0.1% for articles with a weight of more than 1 gram and 1% for articles with a weight less than 1g.
- Lead in lead free solder 0.5%
- Cadmium: 0.01% for articles with a weight more than one gram and 0.001g for articles with a weight of less than 1g.
- Brominated organics as addressed by RoHS 0.1% for articles with a weight of more than 25 grams and less than 0.025 grams for articles with a weight less than 25 grams. In relation to this proposal, the following should be noted:
- No distinction has been made between intentionally and non-intentionally added substances. This is done for two reasons:
 - There is no difference between the two categories in terms of the RoHS intent to control potential toxicity.
 - The distinction between the two categories could be a heavy burden in producer - supplier relationships.
- Disputes can arise about compliance because different analytical chemistry methods have been applied, therefore it is recommended to make an 'approved chemical methods list' in combination with a list of approved chemistry labs (certification).
- 'Homogeneous' articles are not allowed to be split up artificially into units of less than 1g (this trick would allow cheating the system).
- Implementation of RoHS could also be considered to be analyzed in terms of Eco-efficiency. The environmental gain is in this case the (toxicity weighted?) amount of substances eliminated in comparison with the situation before introduction of RoHS. Cost in this case is associated with this elimination. However, since insufficient data will be available in the near future it will be very difficult for the time being to formulate improvement / modification options which will lead to a more Eco-efficient implementation of RoHS.

8. Conclusions

From the present paper the following conclusions can be made:

1. Implementation of WEEE should be enforced according to the spirit of the law rather than on the strict descriptions of the law. The last approach mentioned could under circumstances lead to Eco-inefficient and even

anti-environmental effects.

2. Considering recycling systems on the basis of environmental weight, or rather than on the basis of material weight, serves the goal of implementing the spirit of WEEE very well. This approach also allows for the formulation of meaningful improvement avenues and also permits their prioritization.

3. Achieving economy of scale in recycling systems is next to appropriately balancing 'input' (collection), treatment and output (reapplication of materials) issues regarding their importance. Compared to these effects those of applying good EcoDesign (Design for Recycling) rank third place.

4. Currently the knowledge of the effects of RoHS implementation is very limited. It has therefore been chosen to be taken on a practical rather than a scientific basis to make recommendations for the implementation of RoHS.

9. References

[1] Ab Stevels, is the WEEE Directive Eco-efficient? Proc. CARE Conference on 'Green Electronics', Vienna, November 2002 and Proc. Of the International Electronic Recycling Conference, Basel, January, 2003

[2] Jaco Huisman, The QWERT/EE Concept, Quantifying Recyclability and Eco-efficiency for End-of-Life Treatment of Consumer Electronic Products, Ph.D. thesis, Delft, June 2003.

[3] M. Goedkoop, M., The Eco-Indicator '99 – a damage oriented method for Life Cycle Impact Assessment, Pre Consultants, Amersfoort, the Netherlands, 2000.

[4] Ab Stevels and Casper Boks, the lasting advantages of disassembly analysis: benchmarking applications in the electronics industry. Proc. CARE conference on 'Green Electronics', Vienna, November, 2002.

Tokyo, it is busy, very busy

Tokyo gives you the impression of being busy, very busy. It seems that crowds of people are on the streets twenty-four hours a day. They walk and it looks as though they all move with a special purpose in mind or as though they are after a specific goal.

Sometimes the crowds merge into well-disciplined streams. This is particularly apparent at Shinjuku Station. Streams go in and out without colliding, all in an orderly fashion, hundreds of thousands or maybe even a million a day.

This is also my perception of environmental activities in Japan. Many people work on the subject in academia, maybe more than in the rest of the world, but very intensively inside companies too. A lot of what has been published is in Japanese and is therefore poorly accessible to non-Japanese. This is unfortunate because there is a lot of learning to be done out there!

City walk: Go with the Yamanote Line (ring) to Hammamutscho Station and walk to Hinada Pier. Take the boat to Asakusa and visit the Asakusa Kannon Temple. Walk through small streets to Ueno Park, get around the Station at the southern part and walk around Shinobazu Pond. Go north to Toshogu Shrine and try to find the onsen (hot bath with spring water) at the backside of the Park (street opposite the backside of the Biological Garden). Take a soak and proceed north to Yanaka Cemetery. Return through Nippon Station.

Favorite Restaurant: Small Japanese - 'tapas' style - as they are found for instance in Ochanomizu.

Country walk: Climb Mount Takao. Travel from platform 3 at Shinyuku Keio Station (this is a relatively small station in the Shinyuku complex of stations) and go to Takaosanguchi. Make sure that you sit in the backside of the train (sometimes they are split). Walk from the station to the Cable Car (which goes up but not to the top) and follow trail nr. 6 up to Mount Takao. Go back following trail nr. 1 but branch off at Yakuo Temple. Descend there the path with 108 steps (one for each earthly sin) and join trail nr. 1 again.

9.2.2 The Directive on Energy using Products (EuP)

EuP (EcoDesign of Energy using Products) is a renamed version of the old EEE (EcoDesign of Electronic Equipment) draft Directive. In the EuP clear attention is being paid to life cycle design. In practice this means that the main emphasis is on the energy consumption of electronics products since this is a dominating feature of the lifecycle impact, see also chapter 3.1. In the earlier EEE versions materials application and recycling were emphasized so the latest versions are an important step forward. EuP is now much better balanced with respect to a holistic life cycle perspective. This contrasts with WEEE and RoHS which refer to very specific and mostly less insignificant parts of the life cycle impact. As such, fulfilling the targets of these Directives should be subordinate to the ones of EuP.

Another big step forward is that EuP mentions that environmental improvement should be balanced with economic, technological and societal issues. This is putting environmental improvement into a broader societal perspective and is as such to be welcomed.

Simultaneously however, EuP is not yet balanced with respect to the dimensions of 'green' (see chapter 6.1). Emissions clearly get most of the attention whereas the resource dimension and the potential toxicity dimension are – if at all- addressed through a peculiar set of design rules.

In terms of environmental analysis, EuP is stressing the making of so called "ecological impact profiles" but simultaneously it also uses language which suggests that an analysis in terms of physical quantities could be acceptable as well.

Recently, the option to make the life cycle analysis in physical terms has been losing its equivalency through the promoting of the so called 'VHK' method for making ecological profiles by the EU. VHK suffers from the same problems as Life Cycle Analysis however (see chapter 6.2.1). Its biggest drawback is that it is only a profile and does not allow to derive prioritized actions agendas, which can be used in industry.

Altogether, EuP is much closer to current ideas about EcoDesign than WEEE and RoHS. This is demonstrated by the table below:

Table 9.3 New and old ideas about EcoDesign

Item	1996 idea	2006 idea
Starting point	Do good for the environment	Enhance EcoValue of products
Principle	Improvement of Ecological profile	Development of prioritized action agenda for producers
Environmental issue	Materials, applications, recycling is most important	Energy consumption / CO ₂ is most important
Solution	EcoDesign	EcoDesign and/or technology, system organization or regulation

Taking the EcoDesign ideas in 1996 and 2006 and the remarks above together, it is clear that the European EuP Directive has moved more closely to the 2006 ideas, with exception of the Ecoprofile issue.

In the publication on the next page with the title: "Towards an optimization of the proposed framework Directive for the setting of EcoDesign requirements for energy-using products (EuP)" it is stated that – in spite of potential criticism of the EuP wording –in practice it is very well possible to fulfil the intent of the EuP. This is particularly true if the application of environmental benchmarks (see chapter 6.3) is accepted as a way to make Ecoprofiles.

Towards an optimization of the proposed framework Directive for the setting of EcoDesign requirements for energy-using products (EuP)

Theo Schoenmakers, Ab Stevels

Abstract

This paper discusses how the European Directive on electronic end use products (EuP) as it is currently proposed can best be implemented into EcoDesign practice. First it is explained that the environmental analysis (Life Cycle thinking) to be made under EuP can be done most effectively on the basis of Environmental Benchmarking using physical metrics as the best instrument to do the analysis (section 4). Integration of EcoDesign into Product Creation Processes is a key condition for successful application of EuP principles. This process, including road mapping and performance measurement as explained in section 3. The opportunities and limitations of EuP are discussed in section 4. In section 5 the strength and weaknesses of the current EuP versions are analysed based on the operational perspective sketched in this paper. Prospects for EuP in this respect are good, be it that some revisions are necessary to increase practicality and Eco-efficiency. This judgment supposes that the current differences of opinion between the European Council, Parliament and Commission are sorted out in a way that is satisfactory for industry.

Introduction

In the European Union, environment ranks high on the political agenda, particularly for electronic products. Several initiatives have been taken including Directives and Policies/Strategies that should stimulate good environmental performance of electronic equipment. The main proposals made so far are:

- WEEE: The Directive on Waste of Electronic and Electric (EE) Equipment.
- ROHS: The Directive on Restriction of Hazardous Substances in EE equipment.
- IPP: A proposal on Integrated Product Policy (which will also refer to EE products).
- EuP: The proposed framework Directive on setting EcoDesign requirements for energy-using products.

Of all these initiatives EuP currently is the most comprehensive and concrete because it refers specifically to a holistic perspective; in the design the total life cycle should be taken into account. Annex I specifies that all technology areas (energy consumption, material application, packaging and transport, potential toxic substances, recyclability/durability, and many others) are to be taken into account. Since the purpose of EuP is to create a common basis for law making of the EU Member States, the language that it is using is primarily a legal one – operationalization details are not addressed as such. On one hand this creates the flexibility needed for the different product categories. On the other hand this could lead to a variety of interpretations among Member States, which could create confusion. It is the purpose of the present paper to describe a platform on the basis of which the implementation of EuP could take place.

The draft EuP Directive basically requires that energy-using products are designed and manufactured taking environmental considerations into account. A careful design analysis should lead to 'green' design improvement proposals which are to be balanced with economical, technological and user aspects. The final design is to be assessed regarding its conformity with EuP requirements before it can be put on the market.

Where our paper refers to EuP, we typically refer to the Council's Common Position (first reading result), which was the latest paper available at the time of writing. In the annexes of the EuP draft following items are addressed:

- Annex 1: Methods for setting generic EcoDesign requirements.
- Annex 2: Method for setting specific EcoDesign requirements.
- Annex 3: Conformity mark.
- Annex 4: Documentation for Internal Design Control.
- Annex 5: Management System for assessing conformity.
- Annex 6: Declaration of conformity.
- Annex 7: Contents of implementation measures.

Generally speaking, the Commission's proposal for an EuP directive received a pretty positive reception among stakeholders, particularly from industry. Although a lot of the basic principles have been acknowledged there are serious doubts however, whether the intent of EuP can be well implemented in practice. This intent is jeopardized by various amendments proposed during the first reading in the legislative process, particularly in the European Parliament. Our paper is to show that such fears are to a large extent unjustified if the very intent of EuP is put into pole position.

2 Environmental benchmarks a basis for the environmental analysis in EuP

Introduction

Since some versions of EuP advocate to do environmental analysis in terms of physical quantities, the environmental benchmark procedure as developed by Delft University of Technology and put into practice by Philips Consumer Electronics [1,2] becomes a solid tool to assist in the implementation of EuP.

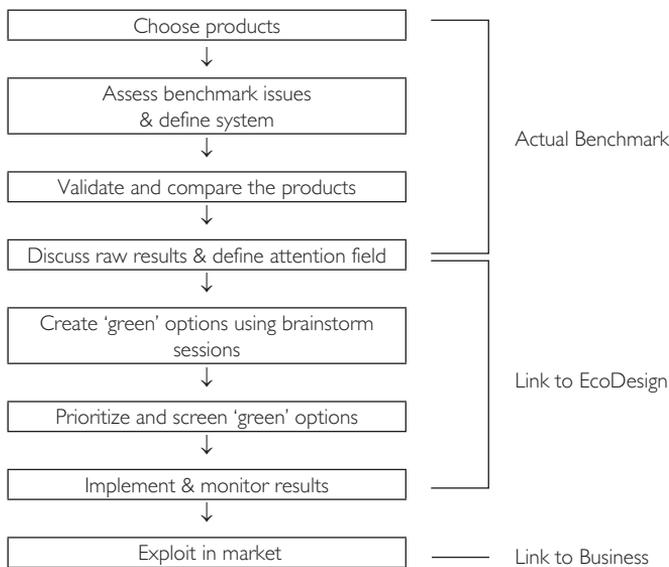


Figure 1: The Environmental Benchmark method

The environmental benchmark method does not only comprise the benchmarking of products themselves, but it positions this activity within an integrated approach that facilitates the exploitation of the benchmark results. The flowchart explains that there are three main elements: the actual benchmark procedure itself, the link to EcoDesign and the exploitation of the results in the market.

The actual benchmark

The actual benchmark procedure consists of four elements: the choice of products, the system definition, comparing and validation of products, and the review of results.

Choice of products

The first element of the actual benchmark procedure is to decide on the products to be benchmarked. In a commercial context, one of the reasons to perform benchmark studies is competitors. This brings in a challenge to do better, offers a lot of learning (for free) and in the end will facilitate acceptance of the proposed improvements by the organization. This product is then compared with 3 to 4 products from the competition that are selected as

follows: first of all, the best commercial competitor should be included. The additional products should preferably be chosen based on good known or expected performance on environmental criteria. In addition, all products in the same benchmark study should display similar characteristics in the following areas:

- functionality
- commercial availability
- price/performance ratio
- size
- product generation

Assess benchmark issues and define system

This step includes two elements. First, it is important to consider which are the important criteria to include in the benchmark. The five focal issues are: packaging, energy, materials, potentially toxic substances and recyclability. Additional issues can be relevant as well for particular products or product groups. Environmental perceptions of the consumer market (including consumer test organizations) as well as legislative bodies should be considered an important indication of the system boundaries and functional units (which are for example required for the energy analysis).

Comparison and validation of products

In this step the actual comparison of products is done, according to the five focal areas and possibly including additional criteria identified in the previous step. A full set of parameters to be checked in the benchmark procedure is given in [2].

In addition to checking the five focal areas, it is recommended to use some LCA method (Ecolindicator for instance) for the validation of the environmental performance of the benchmarked product. At Philips Consumer Electronics, this is always done. The main idea behind this is to include the life cycle perspective in the final assessment of the product, and also to enable the determination of the environmental feasibility, which is one of the steps preceding the prioritization of the 'green' (re) design options as explained in §2.5.

Review of results

In the benchmark procedure executed so far in practice, fact sheets are made on which the measurements derived in the preceding step are compiled. From these fact sheets, per focal area all measurements for all benchmarked products can be seen at a glance, which makes them easily interpretable.

The link to EcoDesign

The second main part of the Environmental Benchmark Method comprises the creation, prioritization and implementation of 'green' (re) design options.

This is done through brainstorm and screening sessions. These sessions are useful methods to create opportunities for environmental improvements. Two major sources exist for doing so:

- learn from competition: experience tells that in practice, no single product outscores – on all criteria – all other products against which it is benchmarked. This means that from benchmarking always options for improvement can be generated, based on design solutions found in competitors' products.
- smart technological alternatives: these can include alternative plastics applications, alternative fixing solutions, alternative energy sources, alternative finishes, etcetera.

Balancing environment with economical, technological and user aspects

In the balancing phase, the main emphasis is on fact finding, creation of 'green' options and their prioritization. The link to economic, technological and user aspects can be made by applying the 'green' options of the so-called EcoDesign Matrix, see the figure below.

Green Options	Benefit				Feasibility	
	Environmental	Business	Customer	Societal	Technical	Financial
First option						
Second option						
Third option						

Figure 2: The EcoDesign Matrix

The environmental benefits are in fact a (qualitative) assessment whether the 'green' option indeed reduces the impact on the environment on a full life cycle basis (see section 2.2).

The business, customer and societal benefits are to be specified also in the table.

	Company	Customer	Society
Material	Cost reduction	Lower cost of ownership	Use of fewer resources
Immaterial	Simpler to produce Simpler to sell	Easier Convenience More fun	Better compliance
Emotional	Better image	Feel good Quality of life	We make progress in green

Figure 3: Specification of the benefits for the EcoDesign Matrix Evaluation

As is evident from this figure there is primarily a "material" line of evaluation. This is to be done on a monetary basis. With respect to the calculations proposed in Annex II of the draft EuP this approach has four chief advantages.

- It works per 'green' option, so it gives detailed direction to design (an overall calculation as in Annex I is more a validation);
- It works on a relative basis (comparison with previous generation) and creates therefore more insight, understanding and acceptance than the "absolute" Annex I calculation;
- It takes into account monetary effects in all focal areas, the approach proposed by Parliament only considers environment;
- It identifies value chain issues (specifies per stakeholder).

The immaterial and emotional items generally speaking cannot be identified qualitatively. They have however an important role to play, for instance in many rich societies. Ease, convenience and fun prevail for many customers over environment (and even money). Also many goods are purchased on an emotional basis: it makes one feel good; it makes one enjoy quality of life.

Feasibility issues address the question of whether the proposed 'green' options can be easily implemented.

Technical issues include:

- Do physics/chemistry/... allow to impede the implementation of the idea?
- Can we implement overnight or do we need additional R&D to ensure that it really works?
- If we implement will quality and durability be equal or better?

Financial issues include:

- Are investments needed to implement the option?
- What are the consequences of implementation for our suppliers?
- Are there shifts in the value chain supporting or blocking the 'green' option?

Generally speaking the experience with operating the EcoDesign and Benefit matrices is that contrary to earlier expectations environmental, company, consumer and societal benefits run parallel to a large extent (little contradiction in the design direction to go) – be it that the priority in the various categories varies greatly.

3 EcoDesign procedures

Investigation into Product Creation Processes

EuP focuses on EcoDesign itself, as such and rightly so it does not touch on the integration of EcoDesign into the business (organizational aspects). It is to be realized however that this is an essential condition for success. To realize products with superior performance – EuP only ensures that EcoDesign is properly taken into account, but it is in principle not prescriptive about an outcome (that it is impossible to do this in a generic way, see also section 5). A basic scheme to integrate EcoDesign into the Product Creation Process (PCP) is given in **figure 4**. Such PCPs exist either in a written form or an informal way in all industrial organizations irrespective of their scope, size and location. A basic scheme to do this is:

	Stages of Product	Environmental actions within stages
Feedback / continuous improvement	→ Stage 1: Planning	Get facts, prioritize according to benefits and feasibility, align with company strategy, consider environmental aspects, life cycle thinking
	→ Stage 2: Conceptual design	Brainstorming, life cycle screening, consolidate into specification
	→ Stage 3: Detailed design	Applying design approaches
	→ Stage 4: Testing / Prototype	Evaluation of results against targets and specification
	→ Stage 5: Market launch	Release, communication plans
	← Stage 6: Product review	Consider environmental aspects and effects

Figure 4: Integration of EcoDesign into the product creation process

A common practice in environmentally proactive industry is to formulate requirements for products on the basis of fact finding for that particular product category (benchmark, section 2) but also on the basis of so-called environmental roadmaps. These basically describe where a company is currently situated with regards to a certain issue and describe how progress should develop, for instance over 5 years time. From this perspective it contains issues, owners (the persons responsible to move the subject forward) and targets, for instance formulated on a year-to-year basis.

Progress in the environmental part of the PCP can be measured with the help of an Environmental Key Performance Indicator. The EKPIs used at Philips Consumer Electronics are described in [3]. In this paper an example is also given how this EKPI is applied in practice.

4 What can EcoDesign really deliver?

EcoDesign aims to fulfill a certain functionality in the form of an embodiment (an artifact) which entails a minimum of environmental impact. This definition also includes the EcoDesign of so-called ‘services’ since these always include the use of physical embodiments or at least the use of physical infrastructures. This need for embodiment means that EcoDesign can reduce the environmental impact but simultaneously is limited by the physics that have to be applied to get the functionality. For instance, TV pictures cannot be watched without a display, music cannot be listened to without speakers; PCs do not operate without a memory.

It is often said in literature that 85% of the environmental load is determined by choices made in the early design stage. This suggests that design can have a very strong influence on the final environmental load of a product. The authors of this article have a clearly different opinion. As soon as a certain physical embodiment has been chosen (for instance to have a cathode ray tube to realize TV pictures) a very substantial part of the environmental load is already fixed. For instance for a TV with a certain screen size design impact is 15% rather than 85%. At TU Delft currently a project is underway to determine the actual design “bandwidth” of consumer electronics products.

In EuP (and in a wide design community) it is suggested that design action is the most important way to improve environmental aspects. An extreme example of this kind of thinking is also in the European Electronic Waste Directive WEEE (which has had a strong echo in EuP). This directive is explicitly said to be set up to foster better design through internalization of the recycle costs.

However ranking of EcoDesign for its capability to bring end-of-life costs down is in fact low, see the table below (see also ref4).

Table 1. Ranking of effects on end of life costs

Rank 1 (highest effect)	System organization (economy of scale)
Rank 2	Organizing appropriate outlets for secondary materials
Rank 3	Improving treatment technology
Rank 4 (lowest effect)	EcoDesign

(This table excludes a rank 0, appropriate rule making)

It is also to be realized that electronic products are products with a high added value. Making the parts, components and assembling them are generally labor intensive; there are also pretty substantial costs in terms of tools and machines.

This means that cost items closely related to environment are modest compared with the functionality value. In such a situation design for functionality value will dominate design specific for EcoDesign. Also in the cost of ownership structure the functionality cost dominates; for instance for a TV the ratio between shop price to be paid by the consumer and cost of electricity for the use (in the whole lifecycle!) is approximately 4:1.

The situation sketched above will mean that in practice the market will have limited financial reward for good EcoDesign. It is therefore to be seriously considered that rewarding EcoDesign be done in a different way, for instance through a system of tax breaks or alternately through taxing consumption with rates correlated to the environmental load over the life cycle. To address such issues will require political courage – however introducing such systems will be far more effective than relying on EcoDesign alone.

5 A judgment of the current status of EuP

With the background of the material presented in the previous paragraphs, it is now possible to give a judgment on the current status of EuP. Three documents are relevant; in chronological order they are:

- The original Commission proposal
- The Parliament's first reading opinion
- The Council's political agreement on a common position

A number of items are treated very differently in these documents; the effectiveness of eventual implementation will be greatly affected by the choices made.

For the legal basis the Commission and Council propose Article 95 of the EC Treaty for a single harmonized internal market, whereas the Parliament proposes a dual legal base together with the Treaty's Article 175 for environmental protection. A legal basis for Article 175 allows Member States to set stricter requirements than those specified in an implementing measure.

It should be clear that a global industry like the consumer electronics industry cannot support the barriers to trade introduced by Article 175. Furthermore, the product variety and/or strictest requirements implementation could jeopardize an appropriate balance of environmental, economic, technical and social aspects.

For obtaining the CE mark, both Commission and Council propose manufacturer self-declaration. Such proposal is based on mutual stakeholder trust and seems to be appropriate as long as no abuse is evident. The Parliament starts from up-front distrust and proposes set levels of random third-party pre-distribution verification. Such a concept risks severely delaying product introductions, making the EU less competitive, apart from the practical point

that “pre-distribution” of a product is rarely ever truly final. It further burdens industry financially with a third-party scheme that is not proportionate to the risk involved.

A third clear distinction is the manner in which stakeholders are involved in the preparation of implementing measures. Whereas the Commission’s proposal had little to show for stakeholder consultation, the Parliament introduced a dazzling array of boards and committees. The Council appears to have found a reasonable answer by creating a Consultation forum of stakeholders that operates upstream of the normal Regulatory Committee.

Finally it is unfortunate to see that Parliament appears to have very little trust in industry regarding voluntary agreements. Although several sectors (white goods, consumer electronics) have shown considerable progress under these unilateral commitments, very severe restrictions were introduced. Commission and Council appear to take a more pragmatic approach where industry initiatives are first given a chance to prove their value before regulation is considered as an alternative.

Taking a holistic view of these three EuP variants, the generally positive items are:

- Obligation to make an environmental analysis of the product or product families.
- Addressing the complete lifecycle
- Promotion of physical quantities to characterize products
- Balancing of environmental, economic, technical, functional and other aspects
- Promotion of systematic review of new technology and new physics for functionality realization

General drawbacks are:

- Emphasis on just EcoDesign could weaken focus on other conditions for success (EcoDesign integration, Roadmaps, Performance measurement, Smart management & organization).
- Complicated and thus expensive manufacturer requirements, e.g. documentation of design choices, and documentation required for internal design control or under the management system of Annex V.

When reviewing the text in detail critical remarks are to be made on Article 13 and several of the annexes (referring to the Council’s common position).

Article 13: Although this article in principle sets out a good stakeholder consultation, its part 2 in principle gives a two-year license to the Commission to introduce energy implementing measures without any life-cycle check.

Annex I: Part 1: Too much emphasis on end of life aspects; and use of some “environmental” language about emissions that contrasts with the “physical” language on product properties in the rest of part 1. Part 2: Refers to sales and later events in the value chain, does not belong in a Directive where EcoDesign is the focus. Part 3: Sensible mix of requirements that leaves it unfortunately rather vague how the Commission will identify benchmark products.

Annex II: Specific EcoDesign requirements may lose sight of the overall life-cycle of a product. As such, the focus on energy sets a dangerous precedent. The proposed minimum life-cycle cost analysis should be coupled to the life-cycle analysis (for instance on benchmark as explained in §2). Due to the fact that low energy products have generally higher sales margins it is not guaranteed that such A-class products have the lowest cost of ownership. Also, setting of specific EcoDesign levels is inappropriate because EcoDesign is not exclusively determining Eco-performance (see §4). For the same reason promoting a generic set of design rules does not make sense even within one product category.

Annex IV: Involves a lot of paperwork that unfortunately is necessary for correct enforcement.

Annex V: Having an Environmental Management System like EMAS has little to do with performance in EcoDesign. It is therefore good that a general management system description was introduced, with specific and checkable documentation requirements.

Finally, it is disappointing to note that only one recital text (nr. 18) and one article (nr. 3) specifically note the need for rigorous enforcement. Political bodies should take their responsibility seriously and should police their regulations strictly. History has shown that free riders will undermine the potential environmental gains of regulations and that the market will suffer from unfair competition, unless regulation is well enforced.

6 Conclusion

In this paper the current EuP Common Position is acknowledged as a good step forward to anchor EcoDesign in the creation of electronic products. Several items, which will enhance life cycle thinking and address the various dimensions of 'green' (emissions, resources and potential toxicity) are introduced. These include environmental benchmarking, an EcoDesign Matrix and an Eco Benefits Matrix (methods to balance environmental, economical, technical and societal aspects are addressed).

Also organizational issues like integration of EcoDesign in current Product Creation, Environmental Roadmaps (as reference) and Environmental Performance Indicators are presented as key ingredients to enhance EuP.

In §4 and 5 EcoDesign is put into a wider perspective; what can it deliver and what does it not deliver. It turns out that proper organization; technology and communication can be apart from EcoDesign big contributors to lowering environmental load over the lifecycle.

The original EuP proposal and the Council's common position are to be appreciated positively, but some paragraphs or parts of it still have room for improvement.

7 Literature

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Pictures, 13

Jyväskylän Yliopisto, candidate, supervisor and opponent march into the Auditorium



9.2.3 What went wrong with WEEE, how to do better?

What friends and enemies of WEEE have underestimated are the organizational aspects of WEEE. For many years, I had the simplistic idea that if other Member States would follow one of the models of countries where recycling systems are already in place (Belgium, the Netherlands, Norway, Sweden, Switzerland), the recycling systems in Europe would fall in line, to a large extent. This did not materialize. Member States have interpreted the Directive in a variety of ways, and this was possible since it is a so called article 175 Directive. This article allows Member States to deviate from a Directive, for instance by having stricter requirements than the European minimum, as regards collection and recycling targets in WEEE.

However, the 175 charter has led to big differences among the Member States all over the place. This holds both for organizational and administrative requirements, for definitions and technical requirements as well as for financial issues.

Efforts of the EU to contain the damage through TAC (the Technical Adaptation Committee, making 'implementation rules') have been in vain. TAC has turned out to be too slow in many cases or could achieve no agreement at all. As a result Member States were even more inclined to go their own way. Moreover, the biggest disparities turned out to be of an organizational and financial nature rather than over technicalities (the scope of TAC).

The good news is that WEEE is up for Review in 2008. (see 9.2.1). This study will deliver options which will assist the EU to simplify WEEE. Moreover, more transparent and more realistic requirements will be proposed. A clear boundary condition to get more effective systems will be to create more alignment among Member States in administrative and organizational requirements.

For the time being however, the implementation of WEEE is a nightmare for producers, see the publication "Where did WEEE go wrong in Europe? Practical and academic lessons for the US". It is to be realized that in the end society will have to pay for all these inefficiencies, either directly or indirectly. The good news is that, starting from the current mess, detailed and prioritized improvement agendas can be developed, both for short, medium as well as long term. The article has been written for an US audience, but is fully applicable to Europe as well.

Where did WEEE go wrong in Europe? Practical and academic lessons for the US

Jaco Huisman, Ab Stevels, Thomas Marinelli and Federico Magalini

Abstract

This paper links lessons drawn from the WEEE Directive implementation process going on in Europe with academic lessons obtained from the TU Delft Eco-efficiency studies on electronics recycling. The combination of Eco-efficiency and organizational analysis is proven to be very useful for enhancing stakeholder interactions on improving end-of-life chains. From this, a roadmap is proposed for US developments, in order to prevent similar chaos as with the current EU WEEE introduction process. The key issues for setting up take-back systems for discarded consumer electronics are addressed: How to organize take-back and recycling in an Eco-efficient way plus how to align all stakeholder interests and positions in a practical way at the same time for the short, medium and long term?

Keywords: Electronic waste, WEEE Directive, eco-efficiency, organization take-back and recycling, electronics recycling

I. INTRODUCTION

An important development in Europe becomes clear: the transposition and implementation of the WEEE Directive [5] by EU Member States results in substantial problems for all parties involved so far and the first signals calling for a radical change of the current principles, framework and redefinition of the roles of responsible parties are noticed.

The research described in this paper was carried out for the Dutch Ministry of Environment, Philips Consumer Electronics Sustainability Center and NVMP – The Dutch take-back system for electronic products. For these three stakeholders (a producer, government and take-back system), the aim was to analyze ways to obtain higher environmental performance against lower costs. In other words: what are avenues towards a higher Eco-efficiency? Based on the QWERTY/EE concept (Quotes for environmentally Weighted Recyclability and Eco-Efficiency) [1,2,3,4], insights are obtained on how to support stakeholder discussion and the development of end-of-life chains

and recycling infrastructure in general by quantifying (in a very comprehensive way) the environmental and economic effects of specific scenarios. The different avenues or scenarios investigated include '**policy**': environmental goals and regulatory measures, '**design**': guidelines and activities, '**technology**': recycling configurations and '**system organization**'. The most important lessons from the Eco-efficiency scenario analyses are described in Chapter IV. In addition, a full overview has been made for Philips Consumer Electronics on the implementation status of the WEEE Directive in all 25 EU Member States [13]. The overview contains the relevant details on the national laws (± 60 individual aspects), the financial consequences (± 70 aspects) and the compliance schemes (to be joined (± 40 aspects)). The results are discussed in Chapter III. First some summarizing remarks are made on the change in thinking about electronics recycling in the last ten years to explain the changing opinions in the field:

II. FROM 1996 TO 2006: MORE PRACTICAL EXPERIENCE

"An old-fashioned Directive"

Large parts of the EU WEEE Directive were written during a time (around '96) when thinking was dominated by looking at ways to: 'do good for the environment' with the EPR (Extended Producer Responsibility) principle as a starter. At the time, one was primarily focusing on control over toxic substances by means of smart Design for Recycling (DfR) and manual disassembly of hazardous components in the recycling phase itself. As a result the WEEE Directive prime environmental strategies are:

- Weight based recycling targets
- A single collection amount of 4 kg per inhabitant
- An origin oriented categorization of products (Annex I)
- Selective treatment rules (by manual dismantling) for recyclers (Annex II)

However, 10 years later, both academic research and practical treatment experiences show that electronic waste policies should serve multiple broader environmental goals. Significant developments in shredding and separation technologies lead to the realization that dismantling does not deliver the desired control necessary for toxic substances as it depends much more on the destinations of disassembled components and/or shredder fractions, plus there are relatively high costs involved. In addition, the recovery of valuable materials (prevention of new material extraction also decreases emissions) and energy preservation became much more important. At last, a more practical categorization of material streams with similar content in (precious) metal-, glass and plastic dominated products occurred naturally. A definition on the basis of application, as in Annex I of the WEEE Directive, has been ignored in practice.

Why DfR does not bring the solution

Besides the change in environmental priorities the intended role of DfR turned out to be a different one. From an economic perspective it was realized that for some categories a structural deficit (negative recycling costs) occurs that simply cannot be phased out by smart design. Two other practical boundary conditions have further limited the room for effectively applying DfR: The environmental life-cycle principle as well as functionality demands. Proper EcoDesign aims at limiting the environmental impacts over the total lifecycle and keeps the functionality demand intact. Furthermore, the prevailing 'collective' character of the collection stream (products do not come back nicely sorted by producer) results in a limited role of DfR. See for further proof and backgrounds: [7].

The above doesn't mean that there is no room for improvement. For example at the moment for LCD panels no adequate recycling solutions exist for the mercury containing backlights. Both manual dismantling and shredding (too risky for workers as lamps will break even when removed carefully) and separation (direct and indirect uncontrolled Hg emissions) are not an option. What could be done with design is to improve the 'remove-ability' of the backlights and decrease the disassembly times. Basically, the example demonstrates that DfR has a different role in practice than was expected 10 years ago. However, for products that need to be sorted out, for instance due to components requiring selective treatment (Hg backlighting, batteries), or otherwise have to be disassembled (CRT Monitors and TVs), certain design characteristics could be improved. With that observation, DfR basically turns into 'DtARA': Design to Avoid Recycling Accidents.

III. WHERE DID WEEE GO WRONG IN EUROPE

Why WEEE is used for other purposes

In addition to the 1996 ideas, the required framework for transposition of the WEEE Directive was rather simple at the time and one thought the practical details could easily be left over to the (then 15) EU Member States. Therefore, the Directive contained the so-called '175 character': which means that the requirements are minimum ones and individual MS have the option to formulate additional ones. Practice showed that the different stakeholders involved, faced large difficulties in coming to agreements **per Member State**. Simply said, the net result is a complete chaos having 25 completely different transpositions plus inaccessible rules and agreement due to language problems. Subsequently there were substantial delays in transposition and building up of infrastructure in many EU Member States plus 'inappropriate use' (for other means than the original environmental one) of the Directive by different stakeholders.

Examples are:

- Retail and municipalities demanding disproportional compensation for usage of collection space and their services, retailers charging producers/ compliance schemes extra for service/ high fees to make a profit on collection or even earning twice: receiving part of the ARF (Advance Recycling Fee) on one hand and selling waste to brokers instead of to the compliance scheme on the other hand. The opposite also occurs: retail and municipalities are refusing to collect discarded appliances
- Individual or collective Compliance Schemes having 'substantial' overhead costs or using the ARF for building up funds for after the ARF period, which is not in line with the Directive's legal text or having 'heavy management boards' in place steering single or even multiple compliance schemes with sometimes also overlapping treatment categories.
- Governments (especially those without own producers) asking high penalties on all kind of compliance details, plus sometimes having contradicting obligation dates.
- This can lead to the creation of competitive differences between producers. For instance this can be due to different accounting standards, which apply to producers in the EU, Asia and US, on long term accruals for future recycling costs. Depending on the location of their headquarters, different rules apply. For recyclers these differences can be due to different environmental standards per Member State, for instance, in some states landfilling of mixed plastic fractions is still allowed, in other ones it has been prohibited.
- Producer Lobbying Organizations with different types of producers and business models, lobbying against each other over all kinds of individual aspects and losing view of the total sustainability picture.
- Recyclers not complying with all strict environmental rules or even causing illegal waste exports (through brokers) to non-OECD countries thus lowering the costs of recycling and treatment.

Probably, the most negative effect is the loss of focus on the original environmental intent and societal goal of the Directive.

Why producers have implementation problems

Of particular concern for producers, as the first responsible stakeholder group, currently is:

- The need to set up financial guarantees for B2C (in almost all cases the amount is not yet defined), even for producers joining compliance schemes. It also seems that different bookkeeping standards have different consequences for US, EU and Asian producers. In contrast with the Directive legal statements, in some countries it is also necessary to set up financial guarantees for B2B appliances.
- The use of an ARF is restricted, only for some categories, mandatory or not allowed in some countries. This leads to an asymmetry in the compliance cost across industry sectors and potential competition distortion.
- Financing can be paid once as a fixed amount or as a percentage of operating costs. Separate collection activities are to be carried out by municipalities or through other channels as well.

A more detailed overview of other main issues to be taken into account by legislators, system organizers and producers when putting electronic equipment on the EU market is presented in Table I. It clearly demonstrates the complexity of the WEEE transposition process in Europe.

Table I. Producer Compliance Aspects

Items in Legislation	Definitions, scope and frameworks
Producer/ distributor	Who and when 'puts appliances on market'
Type of compliance scheme allowed	Clearing house, individual, mandatory
Financing mechanism	ARF, Compliance Costs, based on min. amount, market share, weight, return share, pieces
Financing collection	Reimbursement to retail, municipalities, supply of containers
Register of Producers	Who: Hold by Min. of Environment./ independent party/ registration deadline, legal entity in MS?
ARF for financing Historical WEEE	Mandatory, Prohibited, Choice producers or compliance schemes
Scope ARF, Compliance Costs	Definition historic waste, allowed till., also for B2B? Setting height fees in law?
Financial guarantee for new appliances	B2C/ B2B, back account, insurance, membership CC, Bond, 3rd party contracts
B2B/B2C definition	What's the split when put on market? And at the End of Life? Dual Use?
B2B Compliance Requirements	Reporting B2B contracts, reporting performance, financing by.
Deadline and height of recycling / recovery percentages	Scope and definition of rec. %
Penalties	F.i. for not providing financial guarantee, info to final users/ recycling facilities, inadequate marking, not registering, info on quantities, not achieving rec.%'s, not fulfilling take-back obligation
Decisions on role in Compliance Schemes	Type and scope of schemes
Realizing economies of scale versus competition	Both for contracted logistic partners, retail, municipalities, as for recyclers per treatment category
ARF or CC for financing	Min. amount, market share, weight, return share, pieces, split historic/ new waste
Also open for B2B?	Financing (see cell above), how to split B2B coming back as B2C?
Refund to retail/ municipalities	Yes, No, fixed amount, percentage, per year, containers? # of separate containers
Treatment categories	Scope category, # of recyclers available/ desired per cat.
Overhead and PR	How much can/ should be spent on education, PR and overhead
Decisions/facts on financing	Financial and liability impacts
Producer/ distributor	Definition producer and 'put on market
Register of Producers + costs	Per year, entering fee, clearing house, other
Scope of use	ARF How to account funds for historic waste
Use of ARF	For which products/ how long/ breakdown of costs
Financial Guarantee New Waste, for B2B and B2C?	Provisions for new waste, how much? Based on weight/percentage/ units/ return share. Means: back account, insurance, membership CC, Bond, 3rd party contracts
Determination Compliance Costs	Weight/percentage/ units/ return share per MS, per category, breakdown of costs?
Marking	Marking requirements and costs, where to mark (product, packaging, user manuals)
Reporting and costs	What to report, performance, market shares, units, accessories, definition products weight, definition when put on market, sales organizations dealing with multiple MS, product info to recyclers
Which schemes to join in which countries?	Financing and role in organization in each scheme

IV. ACADEMIC LESSONS

Weight versus environmental weight

In the process of setting-up and implementing the WEEE Directive, so far little notice has been given to the question of whether current developments are indeed serving the environmental goals. This notion has led to the development of the QWERTY concept for calculating product recyclability on a real environmental basis instead of on a weight basis only. All important elements required for environmental validation and integral costs connected to this are discussed in [1,2]. An example of evaluating a product with environmental weight instead of traditional weight based thinking is given in Figure 1 for a precious metal dominated cellular phone. The graph shows that from a weight based perspective, maybe recycling of the plastics is the first priority, whereas the environmental equivalent shows that avoiding the loss of precious metal value is the most important aspect to focus on [8].

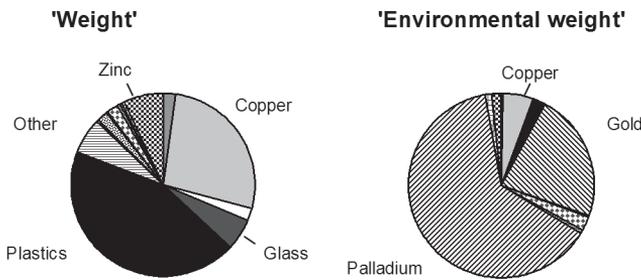


Figure 1. Weight versus environmental weight, cellular phone

Eco-efficiency

As a second step of the Eco-efficiency approach developed, calculations of environmental gain over costs ratios are made. This is applied for all those cases where an environmental improvement is realized and financial investments are needed to obtain this, or in reverse. By this it can be determined how much absolute environmental improvement (mPts) is realized per amount of money invested (in €; € 1, 00 = \$ 1,20 at 2006- 02-20) Obviously, this direction appears the most. In the next graph, all main options investigated in the QWERTY research are presented.

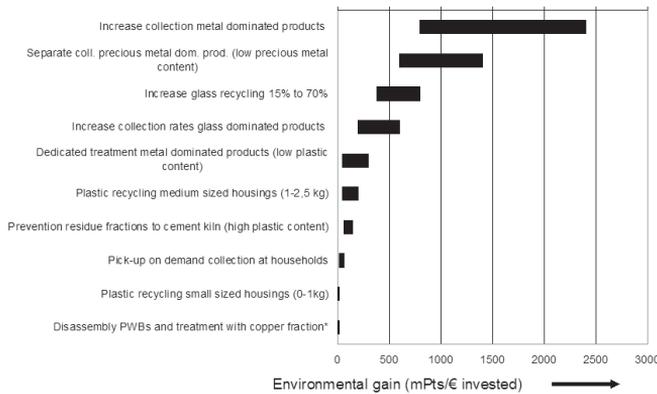


Figure 2. Eco-efficiency of various recycling scenarios

The graph shows which options have the highest environmental effect per one € or \$ invested. To go into detail on one of the options above: currently, glass fractions from CRT containing appliances can be sent to different outlets such as landfills, as replacement material for sand in the building industry, as a replacement of feldspar in

the ceramic industry or as application as secondary material for new screen and cone glass. In the WEEE Directive [5], all of these applications (except the landfill) are counted as a 'useful re-application' and therefore as 'recycled'. Recyclers are likely to send their fractions to the cheapest or easiest outlet with the highest recovery rate. Figure 4 shows the environmental level of reapplication versus the recovery percentage of the glass replacement options under consideration [9,10].

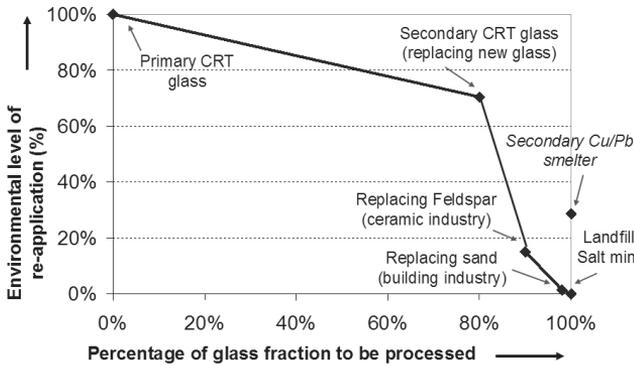


Figure 3. The environmental level of re-application of CRT glass

The points in the graph represent the environmental level of re-application (vertical axis) versus the 'recovery' percentage (this is not the WEEE definition but the amount of the material fraction actually re-applied in a 'new product'). The initial value for primary CRT glass (original material value is set at 100%) can not be reached due to transport, cleaning operations and energy needed for processing secondary glass. The graph shows that the lower levels of re-application result in higher WEEE recycling percentages, but in contradiction with environmental performance! An important conclusion from this graph is that all secondary options contribute equally to the WEEE recycling targets but are not equally contributing to the environmental results. The conclusion on this issue is that lack of prescriptive 'output' rules results in the effect that the environmental intent of the WEEE Directive is not served when there is no economic driver to do so. The lessons drawn from the quantifications of environmental and economic performance are summarized in the Table II.

Table II. Lessons from the Eco-efficiency Research

WEEE:	QWERTY and example of a new priority setting:
All materials are equal	Some materials are more equal than other: avoid loss of precious metals for cellular phone recycling
All products are equal	Some products are more equal than others: promote higher collection amounts or differentiate in collection targets
All processing options are equal	Some processing options are more equal than others: promote highest environmental level of reapplication: more CRT glass recycling when CRT production market still allows this
Efficiency thinking irrelevant	Efficiency thinking is highly relevant

The main contribution of the QWERTY/EE concept is that environmental priorities regarding individual materials, products and recycling processes can be quantified from an environmental point of view. Also the relation between various environmental improvement strategies and the costs connected to them are quantified. Based on the above analysis of many technical, design and organizational aspects of take-back and recycling, certain lessons can be drawn. Moreover, these lessons are translated into a 'technical and Eco-efficiency roadmap' in Chapter V plus an 'organizational' one in Chapter VI.

V. TECHNICAL AND ECO-EFFICIENCY ROADMAP

When weight based recycling targets and DiR are not the core of the solution, how should one set-up the right framework? The answer plus the necessary practical steps to take are summarized in the following roadmap for the short, medium and long term on how to deal with all relevant Eco-efficiency and technical aspects (a much more extended version is available in [4]).

A. Short term: Realize take-back systems a.s.a.p.

Both for EU Member States or US states without a take back system in place, one should try to build up collection and recycling infrastructure as soon as possible. From the EU, one can observe that for those Member States having take-back system in place the use of an ARF or direct Compliance Costs for new appliances put on the market increases the development pace as money becomes available upfront. Furthermore, realizing economies of scale is the number one element for achieving cost efficient take-back systems. Relatively high costs occur when product streams collected and/ or recycled are too small. As a consequence, one should categorize products according to their material compositions and subsequent treatment categories instead of streams based on the 10 WEEE categories as already discussed in Chapter 2.

B. Medium term: Less treatment rules, more monitoring

Many of the current WEEE Annex II treatment rules have an adverse effect on the environment due to technical progress and too strict a focus on toxics only. In Europe, the QWERTY/EE concept has been used by the TAC (Technical Adaptation Committee) to provide a guidance document on the removal entries which gives more room to recyclers to achieve good overall environmental performance for new or other treatment solutions [11]. The discussions on the EU monitoring framework are still going on and it is expected that take-back system (organizations) for instance will come up with their own standards. Monitoring of treatment performance should not be a bureaucratic burden and used for more active steering of material fractions to the 'right end-processing'. When recyclers can prove their performance is lower on a weight basis but better environmentally, they should be given room to divert from the prescribed recycling and recovery percentages.

C. Long term: Better balance in legislation, setting the framework in advance

Regarding waste policy strategies used/ available the following is concluded:

- Weight based targets seem to be a good and easily understandable target. However, both toxicity issues and highly valuable materials (due to environmental effects of mining new ones) are to be taken into account as well. Furthermore, the exact definition of recycling percentages is controversial as the split in technical operations is rather black or white: whether an operation is accounted for is not displaying the true environmental performance. CRT glass recycling vs. replacement of sand could both be recycling operations, but are completely different operations environmentally.
- Differentiate in collection targets. Some products have more value/ toxic components
- Treatment rules should only be applied when labor conditions are at stake or direct toxic effects or emissions are to be prevented (for instance. Removal CFC from fridges)
- Create room for system optimization through the recycling field itself. This can be done by explicitly stating that deviation from rules and standards is allowed when recyclers can demonstrate equal or better environmental performance for new or alternative processing options.
- Create incentives for Design to Avoid Recycling Accidents, f.i. by setting-up a rewarding mechanism for products with substantially lower treatment costs than the average products in the corresponding 'collective' stream. This would maintain the desired collective character of take-back systems and rewards better product design in those cases where it actually matters.

VI. ORGANIZATIONAL ROADMAP

In the next table the main technical and Eco-efficiency lessons are linked with the organizational aspects of Chapter III. Key issue here is the notice that placing the sole responsibility (or EPR) on one stakeholder is proven not to

be sufficient in the EU. Basically, one has to realize that recycling of electronic products requires multi-stakeholder cooperation to actually meet the societal goals of electronics recycling:

Simply said, the responsibility should be given to the stakeholder that has the capability to contribute to the solution.

Table III. Lessons for stakeholders

Stakeholder responsibilities	Lessons from Eco-efficiency studies + Lessons from practical implementation problems in the EU
Equal sharing of WEEE responsibility	From a societal perspective one should try to maximize collection performance. Research shows a clear link between # of collection points and kgs collected. Especially in the start-up phase of take-back, the availability of collection points is crucial.
Legislators	25 Different transposition and interpretations of the WEEE Directive were leading to high costs, disorder, delays and lost focus on the original environmental intent
Producers	Extended Producer Responsibility (ERP) includes the legislator's thinking that the producer is able to adapt the design in such a way that the recycling cost will be zero. 1. The major part of product design is fixed & 2. Collection is the major cost. From an Eco-efficiency perspective, design is not the first priority but should rather be focused on avoiding specific recycling 'accidents'
Producer Organizations	Develop a joint strategy and positioning towards a pan-EU / US federal 'Ideal WEEE Framework' based on 'give and take' instead of fighting over all individual issues separately in all 50 US States or 25 EU Members. Keep also in mind that there is no 'one size fits all' solution. Solutions need to be tailor made for different sub-sectors (IT, CE, White Goods, Lighting equipment)
Municipalities	Maximize collection: avoiding illegal trading and 'cherry picking', provide easily accessible, free of charge collection points for consumers
Retailers	Maximize collection: Better retail involvement means more service to consumers with more easily accessible collection points and a direct fulfilment of 'producer' obligations for their 'own-branded products'. An 'all for all' take-back mechanism should be considered: selling a category means take-back of any type of equipment free of charge + obligatory forwarding collected waste to compliance schemes
Compliance Schemes	Realize economies of scale, PR: Educate consumers to hand in old products, Make the logistic phase efficient, aggregation and active steering of treatment performances and auditing recyclers
Recyclers	Avoid the use of different standards, give room for technical developments, promote highest levels of re-application of materials
Consumers	Maximize collection: Hand in old products!!!
Academia	Provide proof for overall objectives and framework, before setting rules

A. Short term: One US federal/ pan-EU framework

One general lesson is obvious: in Europe too much room for interpretation is given to the individual Member States, resulting in chaos. **A clear federal/ pan-EU framework addressing all individual responsibilities of stakeholders plus definitions, standards and targets should be developed prior to setting rules.** For the US situation, it is recommended to develop such a framework to avoid similar 'lobbying battlefields' and the subsequent 50 different types of laws, take-back systems, financing mechanisms, environmental standards, etc...in each individual state. Having the producer as the only responsible player, results in inefficiency or **even a malfunctioning chain.** Therefore, the role of retail and municipalities, take-back systems, recyclers and academia should clearly be addressed. A federal (or pan-EU) legislative framework should be surrounded with standards and formats that address all stakeholder responsibilities and at least the most critical items like:

- Definitions: what is 'put on market', who is a 'producer'.
- One choice for either an ARF or Compliance Cost (per (limited number of) product types), guarantees arranged collectively, etc.
- No distinction between B2B and B2C or when divided, a clear definition for 'grey area products'.
- A central register plus enforcement to avoid 'free riders'.
- Environmental standards for recyclers (US certification).

Such an approach would avoid many of the critical bottlenecks and enhance the speed of setting up take-back and recycling and thus Eco-efficiency as could be seen from the Eco-efficiency roadmap.

B. Medium term: treatment and monitoring standards

On the medium term one should develop US wide standards and formats of environmental quality for treatment and monitoring formats for outgoing material fractions to maximize environmental levels of re-application of materials. A mechanism of self-declaration when treatment facilities can prove equal or better performance for new or alternative processing options than the targets should be present as well. Such a mechanism helps to avoid constant updating of waste treatment rules to the latest developments and leaves incentives to the recycling field to improve. One should create competition only on those components where it adds value: so for logistic partners and recyclers.

C. Long term: Incentives for better performance

On the long term one should develop mechanisms for rewarding good Design to Avoid Recycling Accidents, for instance by determining individual producers recycling costs for critical recycling parameters like toxic materials, high dismantling times, improved remove-ability of components or materials that need to be separated. In addition, auditing schemes could be developed to keep track of environmental performance of compliance schemes and recyclers systems and to avoid illegal 2nd trading with adverse environmental effects. Finally, describe 'Best Available Technologies' for the recycling sector.

The two proposed 'Eco-efficiency' and 'organizational roadmaps result in a more practical and scientifically based approaching to take-back and recycling: develop a clear framework, well defined and shared responsibilities, the right incentives for improvement and avoidance of 'inappropriate' behavior from a societal point of view.

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Highlights of the year, 2006

Legislation

Debates about environmental legislation for the electronics industry have been taking place throughout the period between 1993-2007.

As a function of time they intensified. The year 2005 was a milestone; the first EU-wide implementation of a Directive took place; the WEEE Directive on Recycling had to be kicked off in all the Member States.

It has become a drama. What was intended as a harmonized approach for Europe turned out into 25 sets of different rules, different administrative procedures, different fee and cost systems, different physical execution and different monitoring. What a mess! Understanding that The Directive was made 'article 175', this means that every Member State could set higher environmental standards than the minimum required. This has been interpreted as the liberty to set their own standards all over the place.

Environmental zeal has been prevailing over common sense, emotion over science, political infighting over creating a real common basis. The EU, the European Parliament and the Member States have talked to many people, but have been listening to few of them!

The effect: too little environmental gain for too much money. The painful process of backtracking on the WEEE has now started – a lot of effort needs to be made to do dramatically better. It is also important to prevent that the next Directives (RoHS on substances, EuP on EcoDesign, REACH on chemicals) will go down the same road.

Universities also have societal tasks. This belief has meant that in the Applied EcoDesign group in Delft a lot of time has been invested in creating a better scientific basis for development and implementation of the Directives as above (see also chapters 7 and 8 of this book).

There is no reward for such activities in the University budget system, which is surprising in view of the fact that some 80% of the Delft University budget is coming from taxpayers money. Nevertheless we have been very active in this field, particularly in 2006 and more work is planned for the years ahead. Will it help? It remains to be seen but we will do it anyway.

9.3 The Role of Governments

9.3.1 General Issues

9.3.1.1 Goal and action

Today, many (national) governments have taken initiative in the field of environment, addressing reduction of emissions, better use of resources and potential toxicity risk.

A lot of these programs lack comprehensiveness and do not take into account - in a balanced way - the three dimensions of 'green' (see chapter 6.1). Moreover, a lot of external circumstances (geographic location, availability of resources and space, income per head, status of national budget and the status of economy in general) strongly influence short and long-term goals. In few countries there is a real focused and prioritized agenda from which action plans can be derived in a consistent way. Even in these cases there is mostly a weak link with economic issues.

In my opinion defining the real challenge in developing environmental policies is to define an overarching goal which is appealing to all stakeholders. Such a goal could be: lower the environmental impact per unit of Gross Domestic Product (GDP). This definition creates a clear basis for analysis and allows developing quantitative targets. Moreover it clearly links environment and economy and thus avoids absolute environmental language. Simultaneously it is a baseline. Every change in the current system (national economy, industry sector, company level, product category level, or individual products) can be measured in this way. In this approach rebound effects also (see chapter 2.3) have to be included. Apart from effects inside the national economy, these can be caused by moving production from the developed economies elsewhere. In most cases such a shift leads to extra transport and more inefficiency in production, and higher environmental loads, for instance, in generation of energy needed in the production phase.

Presently in the Western world (Europe, USA) a decrease in the environmental load per unit of GDP is already observed. Some people ascribe this to successful environmental policies, a shift from products to services and to more innovative products in general. This is however measured on a **supply side** basis. On a **consumption** basis (see chapter 2.3), which is a much more representative for real environmental performance in a region or state, progress would be much less, if any.

An example of this is that in the last decade aluminum factories in Western Europe were closed because aluminum from Russia was cheaper (a.o. lower environmental costs and lower energy costs). When Russia subsequently improves environmental efficiency from its present low level, Western Europe can buy carbon emission rights there!

9.3.1.2 The value-chain

Many environmental activities – at least in the field of electronic products - are 'profitable' or 'win-win', at least on a chain basis. There are however situations (for instance for energy saving in electronics) where in spite of the overall gain, there are also losers in the value chain, for instance producers who have to do investments which they cannot recoup from higher prices – the financial winner is in this case the consumer. Good examples of this are reducing standby energy and introducing more efficient transformers in products. There are even win-winners who do not believe that it is really win-win for them. The well-known example is the replacement of incandescent lamps by energy saving lamps (see Tidbits, 4).

In both situations the market is unable to deliver the overall societal, environmental and monetary gain which is in the value chain. In such cases regulation is justified. Therefore in my opinion 1W standby for electronics should be mandatory. Also incandescent lamps should be replaced by energy saving lamps, at least for standard applications. Also transformers in electronic products and chargers for batteries of portable products should satisfy minimum efficiency standards.

9.3.1.3 Enablers

As explained elsewhere in this book, technology and supply chain management are important enablers for more Eco-efficiency. Many governments support them through funding of environmental research programs. There is a strong preference for projects promising 'breakthroughs', that is doing 'inventions' which (instantaneously) solve the problems in a radical way. Reality is much tougher however. Physics does

not allow many of them and therefore the hit rate of the programs is generally low. Moreover, it takes a lot of effort before the new breakthroughs are implemented into the economy. A lot of money has to be invested in product development and or building the infrastructures needed to exploit the new idea to the full. This is often high risk and as a result investors operating on a commercial basis shy away from it.

Therefore it is recommended to spend more public money on exploiting breakthroughs which are already in place. This can be done for instance by doing more pilot projects to find out how research results can be implemented best. If funds available are limited, it is preferred to do more pilots and to reduce amounts for more fundamental research including 'modeling'.

Parallel to this, applicants for funding in 'traditional' technology and research projects should be obliged to have an environmental paragraph describing effects on the environment if the program will be successful. Environmental criteria should be included in the evaluation criteria for such projects as well.

Having been an evaluator for environmental projects for many years it is worthwhile to mention that consortia submitting proposals are not necessarily the best in the field. They are available and also prepared to spend all the time needed to submit a proposal – the best experts however are too busy to go through all the procedures necessary. Particularly at European level the efforts to be done to submit a proposal is a grueling one requiring a lot of effort. Often a chance of funding is low because the scientific level, nationality and size of the institutions involved rather than practical merit determine the outcome. Excellent potential contributors therefore sometimes refrain from participating. Philips Consumer Electronics for instance has refrained in the last ten years for this reason to participate in European Consortia bidding for environmental projects. Their contribution – compared to the organizations which got funding in the end– could have been superior. The administrative effort to be done (and the low hit rate, amongst others due to the fact that a Product Division is not seen as to have enough scientific level and moreover belongs to a Dutch multinational) is judged to be a killer. The end result of all this is that European citizens do not get the best environmental 'bang' for the research Euros spent. The only way to circumvent this is to have a kind of active invitation policy for high level experts and organizations. This is at odds with the general principles of making public policies, but it is to be realized that science and technology are driven through meritocracy, not through democracy.

9.3.1.4 Infrastructures

In regards to infrastructures, including ones which could foster lower environmental impacts on society, it can be observed that governments leave more and more to the private sector, both in terms of investment and in exploitation. In practice this means more emphasis on short term - often only financial - effects. Investment in 'quality', including environmental quality, is often kept at a minimum. The great thing about a market economy is that this type of economy can deliver fast. In my opinion this is a great asset to be kept. However appropriate boundary conditions and control should be in place to guarantee that intangibles like environmental quality are appropriately considered.

On the other hand governments themselves have done huge investment projects in the belief that they are Eco- and energy-efficient. Examples of this are investment in high-speed trains between Cologne and Frankfurt and between Paris and Amsterdam. In neither of the cases an ecological payback was calculated or environmental gain over cost ratios were estimated (compared to alternatives). Such analysis would be very helpful, because it will lead to better qualified priorities in the (environmental) investment agenda.

Similar issues play a role in the utility sector. For instance in the Netherlands a lot of natural gas is being used amongst others to fulfill the Kyoto targets. Natural gas is clean so from an emission perspective it is great to use it as a fuel to generate electricity. However, natural gas is a first class resource too, fit for many high level applications. It is simply too good to be brought in one stroke into its lowest state of entropy, like is happening in electricity generation (see chapter 6.1). From a resource perspective using natural gas to generate electricity is a first class environmental crime.

High-tech and affluent countries like those in Western Europe should concentrate on generating electricity from low-grade fuels; they are the best positioned countries to abate the negative emission effects of such use. A similar thing holds for producing petrol from coal. Revival of the good old 'coal-chemistry' to produce energy and/or fluent hydrocarbons is a far-reaching initiative, which will be essential for the future but

will not be picked up by private investors because of the risks and the time horizon. Again, where 'markets' fail, governments should step in!

The issue of time horizon of investments plays a prominent place in developing 'capacity' in the resource field. When the more easily accessible oil sources start to run out (as currently is the case, there is pumped more than there is still found in this category), massive investment is needed in building capacity in alternative energy sources, ranging from solar to wind, tar sand oil, biofuel and nuclear energy. Only higher energy prices will warrant this. Price changes will however not be gradual. If there is a shortage these will go up disproportionately. The lead time of investment projects to abate the shortage will be much longer. This kind of instability (on the supply side) is, in my opinion, a threat to mankind which will materialize on a much shorter term than the effects on the output side like the CO₂ issue. A 'liquid carbon crises' has been hidden so far because its price effects have been largely compensated by moving production of a lot of goods, like electronics and clothing in particular to China. If this mechanism does not work anymore through saturation and increasing costs in China, the time gained through it will be of no use. Due to the fact that no alternatives have been developed in this time window, the real problems will start.

In my opinion these kind of issues get too little attention from governments; instead of the supply side ('sustainable energy') too much attention is being paid to the output side (CO₂). The reason might be that financial and social investment in the supply side will require much more than buying off the CO₂ effects.

9.3.1.4 Consumers

By now, it has become clear that giving information about environment to consumers in the hope that these will change their behavior has only limited effect. This is largely due to the fact that environment is seen as a collective good, whereas consumers primarily act from an individual (self interest) perspective. A well-known illustration is that most people know very well the environmental effects of car driving and have the opinion that governments should do something about it, but few draw the personal consequence: no private car anymore...

In practice informing consumers is therefore an uphill battle, which helps but is not good enough. In my opinion it is better therefore to use financial instruments such as taxing consumption rather than income. Consumption involving a high environmental load should be taxed more than the one with a lower load. From this perspective, the present 'greening of the tax system' as for instance is taking place in the Netherlands is too weak and not directly coupled to reduction of taxes elsewhere. Because of this, many 'green' contributions are often perceived as a sneaky way in to increase taxes without giving anything back.

More over it is politically 'easier' to let industry (the supply side) pay instead of consumers (the demand side); consumers are voters too. The best example about this issue is in Germany where some ten years ago the green political party pleaded (completely in line with their principles) for doubling the petrol price through taxes. In the next elections their share of the votes was halved and the proposal was dropped. In the end however, environmental load is decided through the way people spend their money, see also chapter 2.3. Making holiday trips to Spain and the Caribbean involve a higher load than spending the same amount of money on buying rare stamps. Conversely, from an environmental perspective it is unimportant whether somebody's income is € 10.000, € 100.000, or € 1.000.000. The environmental loads occur only when the money is spent. From the same perspective saving is better than lending money. Taxing 'wealth' and estate tax are therefore just as bad from an environmental perspective as allowing tax deductions for interest paid on loans. The inconvenient truth for the 'green left' is that consistent green taxing is in fact conservative. Taxing consumption according to environmental load leaves people freedom of choice about what to do with their money but also will help 'green'. Simultaneously this can be conflicting with the kind of social agenda the left parties wants to promulgate.

Like tax, subsidies can also stimulate 'greener' behavior. Through such subsidies prices of goods which are more energy efficient can be lowered. Programs in the Netherlands to subsidize high efficient stoves for space heating were very successful – it was a program with high environmental and economic payback. Savings were however expressed in absolute terms, not in relative ones (ton CO₂ per € spent). This was followed by a similar program for energy efficient washing machines. In this case, savings in absolute terms were impressive but poor in relative terms. Most likely, better alternatives (in which more tons of CO₂/€

were gained) were available, however the options were not analyzed from their **relative** merit. The flip side of subsidies for 'green' is scrapping of subsidies for environmental inefficiency. The notorious example is subsidizing overproduction in agriculture. Europe still has to do a big task in this respect. Finally there is a big opportunity for governments in their capacity as consumers themselves. Purchasing by government and government related agencies is up to 10-15% of GDP, so why not be the trailblazer and buy consistently 'green' only. The best example of a successful 'green' purchasing action by governments is surprisingly the USA. President George W. Bush signed an Executive Order stating that electronic equipment bought by government and its agencies should have an energy-standby to the max of 1W. Since the leverage of public purchasing in the market is so big, soon such equipment was available and the rest of the market followed. It is now even difficult to buy products with more than 1W standby energy in the USA. Europe is still deliberating for many years ...

Personalities, 14

Johannes Marinus ('Jo') Stevels (1913-2000): 78 glass

He is my father. He has deeply influenced my research work (he was a researcher all of his life) and the 12 years I spent at Delft University (he was a part time professor at the Technical University of Eindhoven for 17 years).

Pa was born in Nederlandsch-Indie (Dutch East Indies, now Indonesia). As a boy he returned to the Netherlands, where he had to grow up in an orphanage. Instead of being put into a vocational school, as was the norm, his intelligence brought him to middle school, high school and finally to University.

He had this 'scientific modesty' which many researchers in the Netherlands in the forties, fifties and sixties had. Research was intended to serve the Truth - engineering pragmatism is to be tolerated at best. When I got my PhD, cum laude, and became a researcher at Philips Research he was delighted. When I left that department to work in the Philips factories he considered this a regression in academic level. Subsequently becoming a businessman was even more doubtful. Working in the field of environment was clearly the worst thing you could do. He perceived it with suspicion, and thought that it could be a way to introduce socialism within companies through the back-door. Moreover, his strong opinion was that environment is not a science or a discipline but rather an awkward mix of 'quasi-sciences'.

When I became a professor in Delft he did not congratulate me; in the real scientific world there is no room for applause. Instead he said, "The most important thing you have to do now is to take care of your students, do not listen to the Dean, do not listen to all these university managers that are around today – they only create confusion. The university exists because there are the students and not vice versa."

Pa often had very pronounced opinions, in this case I agreed.

This was not enough. Until the last moment of his life he wanted to check whether my care for the students was done in the way, and at the intensity, that he had wanted.

I passed most of my exams but sometimes things went wrong. In the end the only thing to do in such a case was to admit your defeat and go to the local pub to enjoy mussels and beer.

Sometimes I could sidestep questioning about my university activities, we discussed glass, the science of glass compositions (his field) and glass properties versus manufacturability - with '78' glass as the pronounced example of this dilemma. Glass compositions had kept him busy all of his professional life – glass production was much less of a concern for him.

'78' glass, which he invented in 1943 (I was born 9 months later), was the result of creative thinking and systematic scientific analysis of the properties of glass. It had an extremely low electrical conductivity and was therefore very well suited to be used in the necks of Cathode Ray Tubes in TVs. Such tubes operate of high voltage but should have zero electrical leakage. Unfortunately, the composition of the '78' glass is such that it is very difficult to manufacture. Philips had lost the skills and the experience to do this during the decades and as a glass technologist my fate in 1984 was to get the assignment to reinvent '78' glass production - the management was not aware of the "family history".

The 'Stevels' Walk: Go from Eindhoven with a bus to Achel, Belgium. Get out at 'Achel Statie' and walk along the Beverdijk. At the pub 'De Bever' go for one of the marked walks starting here.

9.3.2 Research programs

9.3.2.1 Introduction

In the last five years I was challenged to formulate research programs in three environmental areas of electronics:

- Energy
- Materials application and linked to it recycling
- Control of potential toxics ('hazardous') materials

The chief driver to do so was that criticism on existing programs requires that alternatives are formulated as well. Focus of the proposals below will be on Design for X (Chapter 3); some more general research items will be addressed in Chapter 12.

Proposed activities on Applied EcoDesign within the proposed research framework should be focusing empiric research and on pilot projects. Style should be "just do it", and "practice will show the way". The chief reason to propose such projects is that particularly in Europe far too much time has been spent on conceptual debates, to drivers instead of enablers, to validation instead of idea generation and creativity (see elsewhere in this book). In many cases the style has been rather self-chosen environmental "apartheid" instead of considering environmental issues in a technological, economical and societal context as well.

When this practical approach turns out to be successful a very meaningful spin-off could be the restructuring of the current environmental R & D portfolio in the EU and improved funding structures in the future, including the procedures and criteria to get funding.

The empiric projects should address three fundamental questions:

1. What does physics, chemistry, technologies allow in terms of reducing energy/material/ substances/ increasing functionality? (Feasibility analysis)
2. How much does this bring in energy/ ecology (keeping in mind the 3 dimensions of 'green'), economy and society? (Benefits analysis)
3. What value chain and infrastructure transformations will be needed to make it happen in full scale and what supporting policies will be needed? (Implementation analysis)

Exploring the limits of physical feasibility will ensure that the most far reaching results will be obtained. The benefits analysis will be particularly relevant in addressing the priority in implementation. The implementation analysis itself will give insight in the efforts to be done to make it happen in practice.

In order to facilitate discussions, to prioritize projects and programs, to evaluate results and to decide on implementation it will be necessary to develop a common language for the Eco-efficiency program. This language should contain environmental (emissions, resource, potential toxicity) elements as well as Eco-efficiency (how much environmental gain for how much money). Existing Life Cycle Inventories^{1*} allow separate calculations, in principle, in the three environmental dimensions; the real decision to be made is how to link the three to one single score (see chapter 6.1). For resources the debate will focus on what resource depletion model is to be used. For potential toxicity it will be about release models (including the application of thresholds) and how to introduce toxicity risk in the calculations. It is proposed not to wait for the outcome of this debate with operationalization. A combination of engineering guesses and sensitivity analysis will do to make decisions. In this respect it should be noted that energy-efficiency is about management of product and production systems where the direction into which to go is much more important than precise indications about what final gains are to be made. Eco-efficiency assessment so far got surprisingly little attention in the environmental community (including the environmental regulation community). In fact this is a lack of maturity of the field and of societal integration in general.

The debate whether real costs or 'virtual Eco-costs' have to be included in eco-efficiency calculation has been a blocking factor as well. Since Eco-efficient technology is to be implemented in a market economy, it

^{1*} In the Life Cycle Assessment Community the debate whether environmental profiles are allowed to be merged in to single indicators scores is still continuing. This is the reason that ISO standards (14040 series) offer no guidance in this respect. In practice, application of EcoIndicators (like the Dutch EcoIndicator '95 and '99) are therefore playing a prominent role in environmental analysis and in validation of design choices.

is proposed to base Eco-efficiency on 'real costs' and not on virtual costs (in fact most of the virtual costs approaches are monetized LCA scores; in such a case not a real Eco-efficiency is calculated).

The projects formulated below are 'background research' projects. All of them are of a general nature; due to this very character public funding will be needed. This does not necessarily mean that the work should be of general scientific nature as well. It is rather the opposite; due to the complexity only empiric and engineering approaches will produce results. This is justified because the outcomes will be used to make decisions in the fields of policymaking, technology investment and design. For such purposes knowing the avenues to go is much more important than a 100% proven truth.

9.3.2.2 Projects proposed

I Energy

I.1 General 'language' Projects

*A project aiming at formulating a common language to evaluate eco-efficiency technology and energy efficiency proposals. This language should include:

- the 3 environmental dimensions
- a baseline for comparison

*A project aiming at comparing 'supply' (product related) and 'demand' (customer, basically electricity generation) driven solutions for Eco-efficient technologies/energy efficiency.

I.2 Usage patterns of electronic products

*A project allowing consumers to assess themselves their energy saving potential based on their user habits. For various types of products, checklists are to be developed (and tested in practical application) to allow users to do this. If successful, such forms should be included with customer information provided when buying a product. The form should preferably also include the assessment of a functionality alternative.

*A project aiming at the feasibility of establishing in an objective way an energy consumption name and shame list; who is performing good/bad for a certain functionality in energy consumption of product.

I.3. Modes of operation

A project aiming at increasing the Eco-efficiency of various types of electronic equipment aims to further reduce the standby energy they require. A similar project can be formulated for energy consumption during operation. In both cases a clear baseline needs to be formulated.

The outcome should serve as an objective basis for rule making in this field (this includes balancing of rules to be made for various product categories on an environmental and Eco-efficiency basis).

I.4. Energy efficiency of power supplies, transformers, other subassemblies

A project systematically exploring the Eco-efficiency and payback of ecological and economic investment in power supplies, transformers, other subassemblies with 'better' performance in this respect. The outcome is to be used in (mandatory?) design and application rules.

I.5. Battery efficiency

A project similar to the one formulated in I.4, including alternatives like human power, solar energy, fuel cells. Comparison with these 'alternative sources' should also include 'context' research (stakeholder perceptions, in particular user oriented/applicability/acceptance investigations).

I.6. New energy sources

Projects aiming at producing products demonstrating that it can be done. Many companies have done feasibility studies in this field. These demonstrated that there are a lot of opportunities. However due to internal and external value chain problems (see chapters 5.1 and 2.3) only a very limited number of such products reached the market.

Successful demonstration products (for instance designed at Industrial Design Engineering faculties at universities and produced in small contracting companies) will create market pull to overcome the value chain problems.

I.7. Eco/energy efficiency of IC's

A project investigating the role Eco-efficient ICs can play in large information structures (see II.1). Such a structure could lead to substantial energy savings in hardware and system operations ('IT on demand').

I.8. Customer information

See the project formulated under I.2.

I.9. CO₂ and CO₂ benchmarking

A project concerned with life cycle CO₂ emissions calculations. For this purpose CO₂ emissions data can be used from existing life cycle inventories (the owners of these should of course agree to make these available). On top of making a CO₂ 'data bank' a procedure should be designed and tested to do CO₂ benchmarks (comparison of different products and processes). Outcome should be a tool that can be used in EcoDesign and Product Management.

I.10. Energy use in the lifecycle

A project similar to the one defined at I.9. but now working on the basis of kWh of kJ. The link with LCA is now that for instance Eco-indicator data for the various forms of energy generation are to be taken into account. The outcome should be delivered to encourage a more transparent discussion on how different fuels are to be used in the EU.

I.11. Measurement procedures

A project aiming to come to a standardized procedure for measurement of energy consumption of electronic products that are agreed on by all stakeholders. This would facilitate agreements on reducing energy consumption.

I.12. 'Low energy' materials and components

A project aiming at mapping the 'energy content' over the life cycle of functional units of materials, components and treatments (there is a relation with I.9 and I.10). The outcome would allow to set better priorities in EcoDesign and would allow to develop better legislation/regulation.

I.13. The three environmental dimensions of energy

A project exploring application of the holistic impact/performance formula proposed in chapter 6.5 in EcoDesign of products and in electricity generation. The outcome will allow to position 'scientific results' in a societal/stakeholder context.

I.14. Communication of energy efficiency to users

A project aiming at substantial improvement of communication of energy efficiency to users so that they move to a more rational approach to these issues. In fact this project can involve a variety of subprojects.

I.15. Managing Eco-efficient technology and energy efficiency transitions

Pilot projects aiming to develop tools to do this better (based on a practical perspective). The outcome should show that it can be done and show how it could be done (which boundary conditions are to be fulfilled/have to be set).

I.16. Emission trading as a baseline for energy efficiency

A project assessing the effectiveness of current governmental initiatives on fostering energy-efficient technology and energy efficiency with the price of CO₂ emission trading units as a baseline. Also the formulation of a portfolio with policies with an efficiency, which is above this baseline should be formulated. The outcome would allow to set clear priorities in European energy policies and in EcoDesign.

II. Materials application and recycling

II.1. A general 'language' project

A project for description of material as 'frozen environmental load' and thus considers material as 'environmental investment in products'. Products have in this type of language 'environmental profit and loss accounts' and appear on 'environmental balance sheets' (see also chapter 6.5). In such description energy is due to its dissipative character expenditure, materials are investments for which expenditures have been made and potential toxicity is a liability for which provisions have to be taken on the balance sheet.

II.2. Keeping materials in the cycle.

A project aiming at a more detailed study of discarding behavior of first users and strategies to optimize product transition (replacement) 'Development of prevention strategies' (see chapters 4.5.2 and 4.5.3)

II.3. Environmental modeling of life cycle load including first, second, etc. owners.

A project aiming at giving clues for how to optimize the cascade given discarding behavior and reuse patterns as they occur in practice. Assessment on how much of the functionality for which materials have been invested is used in practice.

II.4. Business models for pre-owned products of quality brands.

The title of this project speaks for itself.

II.5. How to ensure high collection rates.

A project aiming to study in particular the effect of return premiums.

II.6. Producer responsibility extended to suppliers of materials.

A project making models for take-back in turn.

II.7. Quantification of 'environmental difference' between Reuse, Remanufacturing, Component reuse and materials recycling for selected products.

This is an analysis of absolute and relative gains which can be made.

II.8. Methods to measure remaining functional potential of products, subassemblies and components.

This will facilitate the use of preowned products.

II.9 Quality assurance of preused items.

This is a "facilitator project" as well.

II.10 Optimizing the 'garbage can function' of secondary material streams in particular of materials fed to copper smelters.

A project aiming to find out what contaminants can be tolerated in secondary materials fractions without jeopardizing secondary application at high level

II.11. Optimizing materials flows of new smart material applications

This project specifically refers to materials in LCD's, GaAs-based semiconductors, Mg-parts, halogen-free flame retardants ...).

II.12. What potential toxic flows can be accommodated using 'garbage cans' as secondary copper streams.

A project answering the question, "Which materials really have to be designed out of the flow?"

II.13. Rewarding good design for end-of-life in collective take-back and recycling systems.

A project specifically on the issue how to reward good EcoDesign performance in collective recycling systems.

II.14. Development of curricula for teaching optimizing material cycles.

III Potential toxic/'hazardous' substances'

III.1 Metrics for hazardous substances

A project to come to metrics which adequately position such substances in the three environmental dimensions (see chapter 6.5)

III.2 Environmental risk and environmental load.

A project to integrate environmental risk into environmental load calculations (including the outcome of project III.1)

III.3 Application of the 'TPI' and 'BASF' methods to a wide range of electronic products (see chapter 6.5).

A project to classify products according to their scores and their score/ price ratio.

III.4 Standardized substance inventories, parametric estimations.

A project to come to parametric estimations of products of their 'hazardous' content based on weight of for instance housing, electronics, (standard) subassemblies, cable/wiring etc. (for this purpose first the composition of a number of products in certain category needs to be known).

III.5 Positioning of 'hazardous' from a holistic perspective.

A project to develop formula further based on application to various product categories, political setting (Europe, USA) and consumer preferences / feelings (see chapter 6.5.)

III.6 'Hazardous' substances and Eco-efficiency.

A project to build a system allowing for Eco-efficiency calculations of 'hazardous' substances

III.7 Evaluation system to evaluate the effect of legislation/ regulation of substances

A project to test the effectiveness of the formula given for this in chapter 6.5

III.8 Evaluation of substitute materials

The aims of this project are discussed further in the chapters 3.2 and 3.4.

III.9 Pilot projects on 'hazardous' substance elimination

A project to find out the right balance between upfront elimination and treatment after discarding.

III.10 Creating levels for 'hazardous' elimination from a cost perspective

A project to make a calculation tool for this based on analysis made in main product categories.

III.11 As 10 but now for end-of-life costs

III.12 'Input', output and treatment rules for discarded electronics – including the 'hazardous' perspective

A project aiming to give more appropriate attention to "hazardous" in WEEE requirements

III.13 (Re) positioning of RoHS

A project to come to a repositioning of RoHS based on results in projects III.1 - III.12

III.14 Positioning of "hazardous" in EuP.

A project be able to include "hazardous" in EuP based on results of the projects III.1-III.12.

108 Screws

Design for disassembly was a popular subject in the Nineties. In order to do it properly a disassembly analysis is necessary. Methods to do this are available (see chapter 7.3), but the biggest problem has not been solved yet. After identification of opportunities for simplifying the product structure, acceptance of the proposed changes by the product creation team is still necessary.

The answer is simple: involve the team, make a sport out of it.

A good trick is to ask team members at the kick off of a disassembly session how many screws they think are in the present product. In the case of a monitor, disassembly session guesstimates ranged between 30 and 50. After disassembly it turned out that there were 108!

The same question was asked to the general manager who came to review the results of the session. So far he had been suspicious about environmental activities, but nevertheless had approved the session to take place.

All the screws had been put into a coffee cup. His bet was on the safe side (60) and then he started counting ... 108! The result caused him to revise his opinions and to put full authority behind a screw reduction effort. The effect was impressive:

- *Initial proposals for screw reduction were generated the same night. The next product generation had only 30 screws.*
- *The result paved the way for the monitors group to be prepared to be the 'test rabbit' for a much wider environmental benchmarking that went beyond just the screw analysis.*

9.4 Will China show the way?

In China legislation of the type of WEEE, RoHS and EuP is underway. For WEEE and RoHS drafts have been published. A draft for EuP has not yet been made public.

A basis for this legislation has been laid by studies in China itself. Moreover, Chinese delegations have been visiting Japan, Europe and the USA to assess the developments in those regions of the world. The Chinese strategy to develop environmental legislation for electronic products will consist of three elements:

- Take on board elements of legislation elsewhere in the world that are appropriate (and do not take on board what is inappropriate).
- Introduce specific Chinese elements.
- Look at cost consequences/economic impact from the very beginning.

The debate in China about the draft legislations is in full swing. What the outcome will be is at the time of writing still unsure.

Nevertheless there are four elements in the Chinese debate which are useful to consider when reviewing WEEE. These elements will also be helpful to come to a better implementation strategy for ROHS in Europe and will avoid WEEE type disasters on implementation of EuP. These are:

1. Make laws to formulate the environmental intent/goals, but make standards to specify the implementation. Advantage: the law can stay in place, standards can be modified according to growing experience, technological developments, and changing prices respectively cost.
2. Formulate organizing principles and formats for procedures, before implementation. Advantage: more uniformity among regions/provinces.
3. Use catalogs of products to be considered instead of product categories. Advantage: priority setting, no scope discussion.
4. For overall improvement purposes put EcoDesign, technology development and system organization on equal footing with functionality optimization. Advantage: the life cycle principle is in the lead – all technicalities are equally subordinate.

It is by no means sure that in the debate in China, all these ideas will prevail and appear in one form or another in the legislation. Irrespective of what happens in China, it is valuable inspiration to (re)visit the development of legislation elsewhere in the world, in particular in Europe. In the publication below, the four 'China dimensions' as described above are presented in a much more detailed form. It has provocative title: "How China can beat Europe in Environmental Legislation for Electronics". There is a lot to learn from China!

How China can beat Europe in Environmental Legislation for Electronics

Li Ying, Ab Stevels

Abstract

China will develop environmental legislation like for recycling (Chinese WEEE) and substances (Chinese RoHS) in its own style. Elements of for instance European and Japanese Directives will be taken on board as well but this will happen on basis of proven merit. The current confusion in Europe about European WEEE and RoHS implementation will also give clear indications what to avoid.

Possible developments in the legislations in China will offer towards the European Union the opportunity for review and modification and thus to pull their present Directives out of their crisis.

There are five issues which could make that China will beat Europe in effectiveness of Environmental Legislation for Electronics:

- 1. Clear separation between national laws (which are difficult to change) and implementation standards (which can be updated regularly)*
- 2. Stronger upfront guidance on national level as regards organization principles and administrative procedures/formats*
- 3. Use of product catalogs instead of (application based) categories definitions.*
- 4. Determine room to maneuver on basis of 'packages' which eco-design, new technology and system organization can deliver for specific products or product groups in the product catalog. Taking this into account in target setting will be very effective.*
- 5. No distinction between B2C (Business to Consumer) and B2B (Business to Business), no distinction between "historical" and future" waste and only one collection system out of which several dedicated streams can be separated.*

In a more detailed analysis it will be made clear that especially the product catalog concept will be helpful to realize in practice the intent of the Chinese and European legislation. For WEEE the product catalog is to be based on a material composition of the product. Recycling of precious metal dominated products will result in the best environmental gains, followed by metal dominated products and glass dominated products. Plastic dominated products rank last in priority.

For RoHS product and parts catalog can be built based on potential toxic analysis.

1. Introduction

In quite some regions in the world, specific environmental legislation for the electronics industry is in the process of implementation or is being considered. Three fields are in the focus of attention:

- Recycling of discarded products (resource conservation)
- Restrictions on potentially toxic (hazardous) substances (control of toxic risks)
- Eco-design of products (reduction of energy and material consumption)

In all three cases, market forces have been unable so far to deliver the level of environmental protection which is wished for by a broad variety of stakeholders in society. From a technical point of view it can be demonstrated that this wish and therefore the intent of the three legislative items can be executed in such a way that a lot of environmental gains are obtained for little (extra) cost. However, current legislation and current drafts have been based on principles and ideas of the nineties of last century, and take a one-sided environmental perspective as well. Due to the slowness of political processes it does not reflect scientific insights and technology progress of later years. Moreover eco-efficiency (maximizing the ratio between environmental gains and cost) has been not considered so far. Legislation uses primarily juridical wording and addresses in general terms what items are to be complied with. However, the complexity and variety of electronic goods makes that it is almost impossible in general to cover all situations and to derive in a precise way from the text of the law what is to be done in practice in organizational and technical terms. Separately implementation standards have therefore to be made. In the EU these have been partly incorporated in the Directives and partly this is left to the Member States. This is another reason why Europe has so much difficulty in getting its act together (see refs 1-6).

2. The Opportunity for China

China has been later in developing environmental legislation than Europe and Japan. This gives the opportunity to come up with more up-to-date approaches and to learn from mistakes elsewhere. Currently there are five items which have brought up in China which could make that it could beat Europe in effectiveness:

I. Legislation and implementation are seen by most stakeholders in China as a development process. Basic legislation and its intent are formulated in a Law, implementation (including targets) are to be put into which can be regularly reviewed. Following developments (data from practice, new technologies, more detailed insights in costs), standards can be adapted and made more ambitious without the necessity to go through lengthy procedures to change the law.

II. Organization principles and formats for the administrative procedure will be formulated before implementation and can be updated as the procedure goes. The fact that China is an unitary state will be of help here. The advantage is obvious.

III. The scope of the laws will be determined on basis of catalogs of products which are relevant for the subject. For instance qualifying parameters are/ can be:

Recycling: Weight of product, number of products and the content, value of materials to be recycled.

Control of Substances: toxic risk, number of the products in the market.

Design/Energy: energy consumption, number of products in the market.

An appropriately chosen product catalog will allow focus on the start-up and allows for extensions when operations have become successful. Simultaneously it avoids lengthy discussions about scope (what is included or not included) and avoids collection of rare "stamps" (addresses products with low environmental value, costs a lot of money, contributes little to the envisaged goal).

IV & V. It is clearly realized in China that Eco-design alone will not do the trick, but that functionality requirements technology development and system organization to determine to a large extent the room to maneuver. This makes that the Producer Responsibility Principle is not adhered to or applied in a flexible way and the question who pays what can be addressed more pragmatically.

For instance it has been planned in China to make no distinction between 'historical' and 'future' waste and there will be no distinction between B2C (Consumer goods) and B2B either. Collections will be through one system avoiding for instance allocation procedures as in Germany. The advantage is obvious.

Discussion about all these items is still going on in China. It is by no means sure that all of them will prevail.

3. Discussion of the opportunities for China

3.1 Separation between law and standards for implementation

This idea will allow to "develop" take back and recycling systems step by step to more maturity. Given the law and "guestimated" standards, a first stage of implementation could be used to collect data which will allow to improve the standards based of real facts. In this way collection targets, recycling targets, treatment rules and rules for reapplication of materials can be developed. Parallel to this, research projects, technology investment and administrative measures can be defined to support these processes.

3.2 Upfront guidance to organization and reporting

Under this heading there is a step by step process suggested for administration (producer registration), financing (fees will be necessary, also in China), technical definitions (collection, recycling quota), removal of substances and monitoring. It is to be realized that this is the heart of the problems in Europe: it is organization; it is not technology of lack of eco-design.

3.3 The product catalog approach

A product catalog approach as currently introduced in China will allow to classify products according to the very basis of recycling that is according to material composition. In contrast to Europe where it is based on application (10 categories) these are in this schematics only four:

- Plastic dominated products ($\geq 50\%$ plastic), P
- Glass dominated products ($\geq 50\%$ glass), G
- Metal dominated products ($\geq 50\%$ metal), M
- Precious metal dominated products (precious metal dominating in value), PM

The classification is very relevant in view of the differences in the chief characteristics of these waste streams (see the table below).

Table 1: Recycle system parameters are material composition of products.

Property	P Plastic dominated	G Glass dominated	M Metal dominated	PM Precious metal dominated	Remarks
Tons discarded	Medium	High	High	Low	Most of the material value is in M, PM
Weight/price	Medium/low	High	Medium	Low	Relevant for collection, fees
Priority in collection target	Nr 4	Nr 3	Nr 2	Nr 1	PM represents highest values (environmental and economic)
Priority in recycling target (weight)	Nr 3	Nr 2	Nr 1	Nr 4	M>G>P PM: recoup only PM is good enough
Rule for Annex 2 treatment	Limited	Most	Few	Few	Metal shelters requires few treatment rules
Rules for reapplication of material	No	Yes	No	No	M, PM: reapplication OK G should go back to glass tank
Rules for incineration, landfill	Yes	No	No	No	P has potential toxics to be controlled
Disassembly relevant	No	Yes	No	No	P, M, PM shredding dominated
Recycling cost/kg	High	High	Low/cost neutral	Yield	Cost is excluding logistics
Fees needed?	Yes	Yes	No	No	P and G have a structural recycling deficit not to be covered by Eco-Design
Economy of scale required	Yes/no	Yes	Yes/no	No	Issue: can recycling of electronics be added to other recycling streams
Re-use potential	Low	Low	Medium/high	High	Depends on ratio technology cycle/wear and tear cycle.

This table shows that among the 4 categories there are big differences in the chief recycle parameters. It makes clear that there are no “one size fits all solutions”. This insight - after a lot of hesitation - is gaining ground in Europe. However it should not apply to application categories of products but to the very heart of what recycling is all about – material composition.

3.4 & 3.5 Room to maneuver, simplification

What has been said in chapter 2 speaks for itself. In Europe the Eco-design fixation has done a lot of harm. Also distinction between historical and future waste is a consequence of this – 10 years ago the realization that plastic and glass dominated products have a structural recycling cost deficit (see ref. 1) was not yet in place. In China recycling costs (and therefore the deficit) will be lower due to a lower labor cost, but a return premium will have to be offered to get sufficient amounts collected (see ref. 6)

4. RoHS

The basic issue of RoHS is already embedded in the name of the directive. The RoHS Substances in Electronics are not hazardous-as long as they the products keep its integrity they are potentially toxic. They are in the products because they bring functionality and eco-efficiency. Only when the products are treated irresponsibly after discarding the potential toxicity of the RoHS substances can materialize. The list of RoHS exceptions shows that for reasons of physics the potential toxic substances cannot be completely eliminated; also the concentration thresholds are a sign that RoHS has rather to do with risk management than with absolute control.

For the implementation standards of RoHS, a similar five item approach as for Chinese WEEE can be followed. In view of the status of implementation of European RoHS, Europe could follow a similar path.

From the perspective of development of implementation (item 1) it is therefore recommended to start data acquisition for parts/ subassemblies with weights over 100g, than move to a limit of 10g, and 1g respectively. If the results warrant this even lower system boundary limits this could be addressed in a later stage.

Parallel to this general approach it is to be realized that some components and subassemblies pose more RoHS risk than others. Part with flame retardant plastics(encasing/printed with boards) connectors, brackets), switches, cables/ wiring, pigmented plastics, electromotor, springs and electrolytic capacitors pose more risk then other.

Although full implementation of RoHS is supposed to be in place by 2007/2008, it is realistic (and avoids) arbitrariness, if a systematic risk reduction agenda is agreed. For the organizational aspects, formats could be provided allowing to 'do it yourself risk assessment'. As regards assessing risk factors in electronics the situation is not blank, the Environmental Protection Agency in the USA and the Fraunhofer (IZM) Institute in Berlin (the TPI indicator) have developed useful indicators. (See ref. 7,8). Such methods could be applied to a wider scope that just the RoHS substances and rightly so: RoHS is to be considered as a 'stop gap' for elements which traditionally are perceived to be most potentially toxic. Looking to chemical form in which they occur and their concentrations, TPI analysis have shown that ROMS designated substances score sometimes relatively low whereas other elements score higher than popular opinion says.

Broader studies than just about RoHS substances will in the end lead to catalogs of products and sub assemblies to which 'chemical risk management' should be applied (item 3).

An exception to the ideas proposed above is lead-free soldering. Whether it has an overall environmental effectiveness depends on what environmental dimension is seen as the priority. (See ref 9) Lead free scores well in the dimension of potential toxicity, however not good in the dimensions resources and emission (energy consumption). A final judgment whether lead-free is better depends therefore on a subjective judgment which of the three is most important. Science is not a position to give clues to this (see also ref 9) It makes therefore the impression that the EU decision to go for lead free solder has been rather an emotional one than a rational one. As such emotion in environmental issues is a legitimate component provided that the maximum of scientific analysis has been applied. For lead-free soldering this has not been the case; for the future Deubzer (ref 10) indicates how substances bans can be developed ensuring maximum of scientific content in decisions which are in the end 'political'. Introduction of lead free soldering is unsuitable to a product catalog approach. The change over is digital whether it is done or not. This is due to the complex nature of the change over; finishes of components to be soldered have to be adapted as well; this is a big deal particularly from the logistics perspective.

5 Conclusions

In the discussions about Chinese WEEE and RoHS, valuable new ideas have come up which – when implemented – will lead to an eco-effective and low cost implementation. These ideas will also be of great help to Europe where currently confusion and (potential) high costs dominate stake holders attitudes.

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Rituals and Habits, 14

St.-Nicholas and the Dutch Christmas party

For the Dutch, December 5 is a holy day. It is St.Nicholas Eve, the moment at which the Saint finally distributes his gifts. Weeks before this day he has arrived by steamboat from Spain with his white horse and his black assistant Peter.

Children receive his special attention, but they only get presents if they have behaved well. How you behaved during the past year is written in the big book is continuously updated. Punishment can consist of getting no gifts, but it can be even worse: being put into a bag and subsequently sent to Spain.

Kids in Holland do not sleep well in November!

Adults have to be creative; buying something for somebody else is not good enough. You are required to make a poem accompanying your gift, which can be either sweet, funny or mocking. All presents are supposed to come from St. Nicholas and are therefore anonymous. This is the day to address your boss about hot inter-personal issues in a quasi-serious way. Wherever Dutch are outside the Netherlands, there is no escape – St. Nicholas is where two Dutch are together.

When my wife Annet and I were at Stanford University in the fall of 1999, it was announced that St. Nicholas, after visiting the Netherlands, would fly to California to visit the Mechanical Modeling Lab on December 8th. Presents were to be distributed, provided that the big book contained good news. I bought a robe in a second hand shop and with some improvisation managed to have a long white beard and a moustache as well. Annet's outfit as black Peter offered more problems, but it was resolved in the end.

There we went, at 4.00 PM into the conference room. All the staff was sitting there. My host, Kos Ishii (see Personalities, 10) turned out to be a resentful sinner. Kurt and Brad were very well behaving American boys. For the Japanese PhD students this game was difficult to play but they were happy with the gifts. Mark was clearly the guy to be sent to Spain. Catherine tried to turn the table by offering St. Nicholas a gift. Rashida from South Africa did very well too. And so it went on until everybody had had their turn. After the session, the door was opened and it turned out that during the session the Lab had been changed by an invisible hand into a party center with food and drinks, all in honor of St. Nicholas and Peter! Real great fun!

Next day I overheard somebody saying: "Yesterday, we had a wonderful Dutch Christmas party..."

Publications

In the 1993-2007 period hundred ninety papers have been published, either in the form of conference contributions (148) or in scientific journals or contributions as chapters of books (42).

In 71 cases EcoDesign as such has been adressed; 53 papers are about Environment and Business and 66 are about Recycling and Recycling systems.

For 98 papers, I have been the first author, the other 92 have been mostly written by Ph.D. or graduation students. Most of them had difficulties in writing their first paper (see also Personalities, 1) but almost all of them learned quickly. The later papers gained substantially

in structure and quality and needed therefore less guidance from my side.

For all my writing, I owe much to my secretaries. I still work on basis on paper and pencil; my speed of writing with my hand is substantially higher than the one on a keyboard. Once the structure of a paper is on my mind, I can write it with few corrections during the writing process itself or with substantial changes afterwards; my typing cannot match this.

A critical condition for sucess of the process is that secretaries can read my handwriting. They learned it all, sooner or later. Ladies, thanks a lot !

Chapter 10: Teaching

10.1 The teaching modules for Applied EcoDesign

From the very beginning teaching Applied EcoDesign has been high on my agenda. As a person who believes in 'action' and that 'practice will show the way', my courses and classes have been primarily based on practical experiences. From this perspective the science behind it has been built up.

The teaching materials that I have used developed as a function of time in a way similar to the development of Applied EcoDesign in general, see chapter 2.1.

It took many years of trial and before there was a comprehensive and consistent system in place. In the year 2000 I had a set of some 300 overhead sheets addressing EcoDesign, Environment and business, Benchmarking and Tools, Green Supply Chain Management, Recycling and Recycling Systems and General Items.

After the year 2000 the number of teaching modules and their extensions were expanded substantially. Particularly in the fields of Environment and Business and Recycling and Recycling Systems (chapters 7 and 8), a lot of material has been added.

In the year 2002 all materials were consolidated on one CD (which is still available on request from ranta@xs4all.nl). For this purpose it was necessary to put all presentations in an electronic version; until that moment overhead sheets were primarily used.

In 2006-2007 a completely new update of the teaching modules was developed. The most important additions include here: EcoDesign/Ecovalue (chapter 2), Organizing Take Back and Recycling (chapter 8), Legislation (chapter 9) and China (chapter 11).

Digitization of all the teaching material makes further extensions easier. More importantly it allows tailoring the teaching to specific needs. For preparing any training course, seminar or presentation today the procedure is as follows :

1. Presentation materials are continuously updated and extended according to latest research results and publications/presentations.
2. The organizer specifies subjects, time schedule of the training and learning goals.
3. Presentations are put together from the database including specific additions for the training.
4. Materials (presentations, reading material) are sent to the organizer.
5. The training/seminar is executed.

This approach has proven very satisfactory for preparing technically and business oriented training sessions. Completely new training modules had to be set up to include legal aspects. These include today:

- Recycling (the European and Chinese WEEE Directives):
 - The technical/scientific perspective
 - The system organization and compliance perspective
 - The rule interpretation/rule improvement perspective
- Potential toxic ('hazardous') substances (the European and Chinese RoHS Directives/laws):
 - The technical perspective
 - Lead free soldering
 - Chemical analysis
- EcoDesign in general (the European EuP Directive):
 - Positioning of EuP in design for functionality/EcoDesign
 - Making of environmental profiles and environmental validation
 - Interpretation of EuP
 - Best ways to implement EuP

Orientation of these seminars is to serve the intent of the Directives and Laws in the best possible (Eco-efficient) way. Focus is therefore on compliance in this case and not on pro-activeness. From a perspective of need this is understandable, from a perspective of moving forward environment really, it is far from the best. It is however the reality of life!

General teaching experiences involving EcoDesign, and in particular EcoDesign for competitive advantage, are described in the publication "*Teaching Modules On EcoDesign For Competitive Advantage*". It was written in 2001, but most conclusions – both from the learning and the teaching perspective - are still very much relevant today. In the article it is demonstrated that with a practice oriented approach high 'take home value' for the participants can be produced.

Teaching Modules On EcoDesign For Competitive Advantage

Ab Stevels

Abstract

With Design for Environment having become a business issue affecting all parts of the value chain, the need for teaching and training of industrial as well as academic and other audiences is clear. At Philips Consumer Electronics and Delft University of Technology a comprehensive set of teaching modules has been developed addressing all relevant aspects of EcoDesign, including technicalities as well practicalities, ways to improve, experiences with implementation, how to deal with stakeholders, et cetera. The present paper gives a broad overview of available teaching material. Also, the importance of how to address the various audiences (designers, managers, students etc.) is stressed. Based on experiences with teaching applied EcoDesign, conditions for successful implementation of EcoDesign strategies are formulated.

Keywords: *Design for Environment, Design Education, Environmental Benchmarking, Take-back and recycling, Environmental validation*

1. Introduction

The concept of EcoDesign (or Design for Environment) has grown substantially in the last ten years. Once seen as a technical activity concerning materials, energy and end-of-life aspects it has moved now upstream (supplier relationships), downstream (green marketing and sales) to a strategic level (competitive advantage through 'green') and into the wider context of societal responsibility. EcoDesign has therefore become a business issue that affects all parts of the value chain. A successful EcoDesign program therefore requires therefore a cross functional approach. Being a business issue also mandates that the drivers for it need to be carefully examined. This means that apart from environment as such, customers' attitudes, legislation/regulation and cost, quality issues must also be addressed. Scoring well in 'green' is therefore not only scoring well in 'scientific green' but also in 'government

green', 'customer green' (perceptions) and Eco-efficiency. The multitude of activities that nowadays are included in EcoDesign need to be supported by all kinds of tools. They are now available in abundance and careful selection seems more urgent than increasing their numbers further.

The underlying idea of EcoDesign is a paradigm shift: think in terms of functionality rather than in embodiments. Present technological developments (digitalisation, miniaturisation, more powerful ICs) enhance this functionality thinking further. The natural result of this is that creativity in EcoDesign is gaining more importance. This also holds for moving into higher levels of EcoDesign. Practical efforts should take place mainly at an improvement level. The best is to start on the basis of proven technology but to exploit it more successfully than it was before. In a later stage - by considering latest technological developments in more depth - radical redesigns and product alternatives (both exploiting other physical principles and by replacing products by services) can be much better addressed. The developments in the field of EcoDesign as described above have far reaching consequences for teaching and training, both in terms of content and in terms of audiences.

2. Development of the teaching modules

As soon as EcoDesign activities were initiated at Philips Consumer Electronics the need to include training and teaching in the program was felt. In the very beginning it was decided that these activities should be focussed on implementation in an industrial organisation in the electronics business. As starting points the mandatory design rules and the Environmental Design Manual already in place were taken. To this the more conceptual approach of the Design for Environment Class 211 at Delft University of Technology and the PROMISE (a promising approach to sustainable production and consumption) EcoDesign handbook [1] were added. The teaching material has been organised in modules, which take 50-80 minutes to present. To each module (see §3) extension modules were added which elaborate on items in the module. Apart from the modular structure a principle was established that each year the modules should be updated and revised. Content wise the teaching modules embody four chief elements:

1. Teaching material should be primarily derived from experiences in the company itself (in this case Philips Consumer Electronics). Teaching material that originates from work in academic institutes is only incorporated when it has been tested with respect to robustness and practicality.

2. Wording and language used should be the one of the user. Therefore, teaching material should be primarily concentrated at the five environmental focal areas which constitute easily understandable items: energy, material application, packaging and transport, substances and end-of-life/recyclability. The life cycle principle should be introduced later, rather as a check for overall performance than as a starting point. This approach also includes a primary focus on internal environmental effects, that is on items which can be influenced by the company. Subsequently, it should include the external effects, addressing items which contribute to the overall environmental effect over a product life cycle but that cannot be directly influenced by the company. For instance electronics companies can influence the electricity consumption of their products through design, however not influence the environmental load of generating electricity.

3. Chief targets of the training are to assist participants in:

- Becoming better than the competition in their environmental performance
- Combining environmental improvement and cost reduction and/or quality increase
- Achieving proactivity in compliance with regulation/legislation

4. The training should also contribute to the strategic and commercial dimensions of 'green':

- Assist in making appropriate strategies and roadmaps
- Foster creativity and test 'green' options so that they can be incorporated into product concepts and product specifications
- Prepare for green marketing and sales campaigns

The basis of all this should be self empowerment; employees should become self propelled on environmental issues without the need to be continuously supported by environmental specialists from inside or outside the company.

3. Survey of teaching modules

Below an overview of the main and extended teaching modules is given, followed by a short description of the content of each of the main modules. For each item, the year in which the module was first developed and used is given. This clearly illustrates the developments in EcoDesign that took place in the past decennium:

- From 'technical' to 'business'
- From 'defensive' to 'proactive'
- From 'standalone' to 'integrated'
- From 'absolute scores' to 'being better than the competition'.

The present list of teaching modules is given in Table 1.

Table 1: Overview of teaching modules for EcoDesign.

Teaching Modules	First year of use	Module extensions	First year of use
1. Introduction to EcoDesign	1995	- Levels in EcoDesign	1997
2. Environment and Business			
2.1 Vision, Strategy, Roadmap	1998	- How to make money with 'green'	1999
		- Roadmap details	2000
		- Stakeholder issues	1999
		- Environmental Performance Indicators	2001
		- Environmental Value	2001
2.2 Environmental Programs	1998	- Green Flagships	1999
		- Environmental Value Chains	1999
		- Score Cards	2000
		- Product Environmental Care	2001
		- Five ways to make money with green	2000
2.3 Experiences in Environment and Business	2000	- Green at department level	1997
		- How to operate design manuals	1996
		- Green projects	1996
		- Moving towards Sustainability	1998
		- Modern EcoDesign	2000
3. Benchmarking, validation and creativity			
3.1 Environmental Benchmarking	1998	- Benchmark Audio Systems	1998
		- Benchmark Monitors	1997
		- Benchmarking Communication Equipment	1999
		- Benchmark TV sets	2000
		- LCD vs. CRT monitors	2000
		- Benchmark DVDs	2001
3.2 Environmental Validation	1997	- Environmental Weight	1996
		- LCA Applications	1998
		- Life Cycle Cost	1997
		- Industrial Applications of the EcoIndicator	1999
3.3 STRETCH	1997	- Durability	1997
		- Replacement behaviour	1998
		- Human power applications	1999
		- How to prepare for green 2010	2000
		- TV refurbishment	2001

4. Disassembly Session	1996	- Disassembly times	2000
5. How to Improve			
5.1 Energy Consumption	1995		
5.2 Material Application	1996	- Material Science and EcoDesign	1998
5.3 Packaging and Transport			
5.4 Chemical Content	1994	- Potential Toxicity	2001
6. Suppliers			
6.1 Supplier Requirements	1996	- EcoQuest	1998
6.2 Supply cost and green	1999	- Supplier benchmarking	2001
6.3 Suppliers and EcoDesign	1998	- Reverse supply chains	1999
7. Green Marketing and Sales			
	1997	- Eco labels	1996
		- Green marketing II	2001
8. Take-back and recycling			
8.1 Generalities of Take-back			
	1998	- Eco-efficiency of take-back	1998
		- Producer responsibility	1996
		- Roadmap for take-back	1997
		- Recyclability definitions	2000
		- Experiences with take-back in NL	2001
8.2 Technicalities of End-of-life			
	1997	- Design for non-disassembly	1998
		- Plastics recycling	1996
		- Glass recycling	1996
		- Design for End-of-life	2000
		- Lessons learned from 10 years of take-back and recycling	2000
8.3 How to make product-specific EOL strategies			
	1997	- Take-back and product characteristics	1996
		- Business case recycling	1998
		- Env. uncertainty in EOL scenarios	2001
		- Weighted Recyclability Quotes	1998
		- ELDA	2000
		- ELSEIM	2001
8.4 End-of-life design rules			
	1996	- Design evaluation based on end-of-life cost	1996
9. What is happening in the world			
9.1 Europe			
	1998	- Learning from EOL discussions in Europe	1999
		- WEEE	2000
		- EEE and IPP	2001
		- Effectiveness of Regulation	2001
9.2 Japan			
	1999	- Lead-free soldering	2000
9.3 USA			
	1999	- USA 2000	2000

- Module I, **Introduction to EcoDesign** explains first of all the differences between environmental care for products and environmental care for processes. Furthermore the interrelationships of EcoDesign with other stakeholders (customers, society) are shown with help from the 'green circle'. The drivers to EcoDesign and the various type of 'green' (scientific, governmental, perceptions) are examined. Also the different levels of EcoDesign (improvement, radical redesign, product alternatives and sustainable systems) are explained.

- Module 2, **Environment and Business** considers the managerial aspects of making money while being 'green'. This includes both the avenues of vision, policy, strategy and roadmaps (module 2.1) as well as organising the processes of idea generation, product creation and validation and green marketing and sales.
- Module 2.2, **Environmental Programs** describes how to move from defensive to proactive actions, while developing parallel programs to reduce costs.
- Module 2.3, **Experiences in Environment and Business** analyses the conditions under which environmental programs will be successful or will fail. Internal factors, business conditions, external pressure, room to manoeuvre have turned out to be the chief determinants.
- Module 3.1, **Environmental Benchmarking** teaches the approach to be taken in this field. Five focal areas: Energy, Material application, Packaging and Transport, Chemical Content and recyclability need to be addressed as well as the Life Cycle perspective.
- Module 3.2, **Environmental Validation** explains how validation methods work from a business perspective. Methods include common sense, factor methods, Life Cycle Analysis, Life Cycle Cost and various methods tailored to specific areas. The applicability of the methods is reviewed from a practical perspective as well as from the different 'green' perspectives (scientific, governmental and perception).
- Module 3.3, **STRETCH** (selection of strategic environmental challenges), is a brainstorming technique to systematically generate ideas for radical environmental improvement. It is shown how this technique works and how ideas generated in this way can fit be aligned with business objectives.
- Module 4 consists of a **disassembly session** which is a way to organise do-it-yourself disassembly by participant groups. In three hours time a quick environmental analysis is done for the chosen products and the first set improvement options are generated.
- Module 5.1, **How to improve Energy Consumption** teaches from a practical perspective how to make this work. Chief approaches are roadmaps with suppliers, internal energy analysis, intelligent catalogue work, and specifically addressing battery issues.
- Module 5.2 shows that for improving **Material Application** similar paths can be followed. Main elements here include: design review, specification tightening, materials substitution and detailed examination of surface treatments.
- Module 5.3, **How to improve Packaging and Transport** looks primarily at the different functions of packaging and transport; through parallel environmental and economical analysis priorities are set. These are subsequently related to eight main strategies for improvement.
- Module 5.4, **How to improve chemical content**, digs deep into the different definitions of hazardousness and environmental relevance. In relation to this a two-tier approach is presented for chemical content improvement. The first part deals with how to eliminate of "banned" substances. The second part is about reducing environmentally relevant substances.
- Module 6 is about improving the environment through **Supplier Relationships**. For the different types of suppliers, effective approaches are presented ranging from checklists for jobbers, best practice process management for component suppliers to joint roadmaps and EcoDesign for key suppliers.
- Module 7 addresses **Green Marketing and Sales**. On the basis of seven archetypes of consumer orientation it is shown that 'green' as such does not sell. However by linking to other benefits (material, immaterial and emotional) 'green' can become a strong business asset. 'Green' communication strategies are taught to be strongly dependent on the type of audience. Generally speaking image items are more important than technical achievements.
- Module 8.1 describes the **generalities of take back** and recycling systems. Subsequently political, industrial, financial and environmental perspectives are discussed. On the basis of the stakeholder communalities an item agenda is developed. Ways and means to bridge the gaps between the various stakeholders are demonstrated.
- Module 8.2 reviews **the technicalities of end of life**. After presenting the various treatments possibilities, these are discussed in more detail, particularly disassembly and mechanical treatments. An overview of material compatibilities in recycling forms the basis for the cost and yield tables presented.

- Module 8.3 shows **how to make optimal end of life strategies** for individual products. This can be done by taking into account product characteristics, form of ownership, reasons for discarding, supplier relations, age of products coming back and the legislation and regulation currently in place.
- Module 8.4 gives an overview of **end-of-life design rules** and their applicability.
- In module 9, actual developments in “greening” of the electronics industry in Europe (module 9.1), Japan (module 9.2) and the USA (module 9.3) are reviewed.

The audiences for which the teaching modules are intended are summarised in Table 2.

Table 2: Relevance of teaching modules for various audiences.

Audiences	Teaching module number								
	1	2	3	4	5	6	7	8	9
Academia									
- Design	√	√	√	√	√	√		√	
- Engineering	√	√	√	√	√			√	
- Business	√	√					√	√	√
Industry									
- Strategic management	√	√					√	√	√
- Product management	√	√	√	√			√	√	√
- Purchasing	√	√			√	√			
- Development	√	√	√	√	√	√		√	
- Production	√	√		√		√			
- Sales	√	√	√					√	√
- Quality	√	√	√				√		√
- Environment	√	√	√	√	√	√	√	√	√

This table shows that the teaching modules aim at a very wide audience, both in academia and industry and to a wide variety of professional backgrounds. Module 1 and 2 form the common platform for all participants. All other modules have been set up in such a way that they are of interest to at least half of the group they were intended for.

4. Experiences from teaching EcoDesign for Competitive Advantage

The modules and their extensions as described in sections 3 and 4 have been used to do a variety of training, seminars and brainstorms inside Philips Consumer Electronics: programs lasted from 1 hour up to 3 days depending on demand and on opportunity. The material has also been used for similar activities at the corporate level of Royal Philips Electronics.

An important part of its application has also been in academia. Classes and courses have been held at Delft University of Technology in the Netherlands (where the author has the part-time chair of Applied EcoDesign), Stanford University, USA (where the author has been a visiting professor in 1999), TU Berlin (Germany), TU Vienna (Austria), Georgia Tech (Atlanta, Georgia, USA), Hong Kong Polytechnic and National University of Mexico.

Part of the material has also been presented at international conferences like ISEE (USA), CIRP Life Cycle Engineering conferences (international), CARE conferences (Europe) and EcoDesign conferences of various backgrounds. Sizes of groups addressed varied between 5 and 200 persons. When evaluating feedback, the practical approach is highly rated; particularly the learning-by-doing-it-yourself method of the disassembly session (module 4), which consistently gets very high marks.

4.1 Experiences from the course participants' perspective

Based on the feedback received from the various participants that have attended the courses outlined above, it has become clear that learning experiences consist of two specific types, namely the practical and conceptual learning. For the various modules they are as explained in Table 3.

Table 3: Chief learning's from the teaching modules.

Teaching Module	Chief practical learning	Chief conceptual learning
1. Introduction to EcoDesign	EcoDesign can bring money, synergistic effects are abundant. It is also cross-functional, it relates to various disciplines other than design or engineering, including for example finance, marketing, social sciences	The ability to analyse drivers for EcoDesign, and to understand and analyse different types of 'green' (industrial, scientific, political)
2.1 Vision, Strategy, Roadmap	Processes to operate and implement EcoDesign in industry	The need for vision and strategy, and for cross-functionality
2.2 Environmental Programs	Learning to think and act, changing from a defensive attitude to a proactive one	Separate idea generation and validation to enhance creativity
2.3 Experiences in Environment and Business	Addressing the internal value chain within companies is imperative to getting things accomplished	The understanding that generic processes apply, but that tailor-made solutions are strongly preferred
3.1 Environmental Benchmarking	Evidence proves that big design differences exist for the same functionality. No product ever scores best on all criteria.	Fact-finding and metrics for fact interpretation are the basis of many EcoDesign activities
3.2 Environmental Validation	The importance of separating internal and external effects, the importance of properly addressing various audiences using appropriate languages	There are much more tools than LCA. LCA is to be used for scientific validation rather than creating environmental improvement options
3.3 STRETCH	Thinking out of the box	Functionality should be the driver for design instead of embodiment
4. Disassembly Session	Reveals low hanging fruit, enables the instant generation of ideas for environmental performance improvement, creates commitment with participants	Practice shows the way, knowing about your products enables you to substantiate your own claims and respond to hostile claims
5.1 Energy Consumption	The need for roadmaps becomes apparent	The importance of energy analysis as this is often a main contributor to environmental impacts
5.2 Material Application	Like with the disassembly session it becomes evident that potential for improvement is large	The revealing of opportunities for alternative solutions, the elimination of narrow-minded design histories within companies
5.3 Packaging and Transport	This creates almost always a win-win situation for environment and general business activities	Straightforward approaches exist to accomplish these improvements
5.4 Chemical Content	How to make and implement substance lists	The issue is very complex, affects many stakeholders, but needs to be dealt with

6. Suppliers	How to cooperate creatively, how to vertically integrate in the supply chain, how to know better about your products	The importance of implementing environmental care systems that stretch beyond the OEM
7. Green Marketing and Sales	How to link 'green' and other benefits for communication with customers	'Green' as such does not automatically sell
8.1 Generalities of Take-back	The importance of negotiation agendas	The understanding that this is mainly a political issue, but that it is affected by a considerable amount of emotion
8.2 Technicalities of End-of-life	To be able to assess yields and costs of products in the end-of-life stage	Different value chains, the interests of OEMs, recyclers and legislations are often different
8.3 How to make product-specific EOL strategies	The importance of linking end-of-life issues with product characteristics	Only tailor-made solutions will survive in the end

4.2 Experiences from the teaching perspective

From the teaching perspective the most important lesson I learned was to keep it as simple as possible. Environmental items, irrespective of their nature, are easily taken on board by a variety of audiences when presented in an honest and straightforward manner with an emphasis on "what to do when back home". It is of particular importance to show practical examples from 'real life' in which it is shown that people with whom the audience can identify itself have done a great job.

Since most of the participants of the training course are not environmental specialists and never will be, it is also important to avoid esoteric environmental language. For the teacher it is important to put him or herself 'in the shoes' of the recipient of the messages including mindset, cultural background and profession. This experience allows for the conclusion that the content of teaching EcoDesign for Competitive Advantage is of a generic nature, but that the way this content is taught should be very specific ('tailor-made').

A further observation is that although audiences on the courses are generally highly motivated and eager to learn and get results, there are also a lot of preset ideas when entering the course. These include:

- "Environment is something technical"
- "Environment will always cost money in the end"
- "Environment should be a kind of corporate activity, not for us here"
- "Environment is nice but does not rank high on the business agenda etc"

It is therefore crucial to address such issues at the very beginning of the classes and to ensure that the participants are convinced that the reservations they (or their classmates) might have are dealt with either earlier or later in the training course.

What turned out to be very important were "the learning by doing" or "self-discovery" experiences. Disassembly sessions on products developed, manufactured and sold by the organisation hosting the course were highly instrumental towards achieving this effect. Also having participants fill out forms and do some simple calculations themselves turned out to be very beneficial for meeting the learning targets. By doing so the overall picture emerges before them and for drawing conclusions they can easily refer to details, which have been jotted down earlier. Such processes turn out to yield far more creativity than feeding data into software programmes – this will produce fast and accurate results but creates less insight.

A further teaching experience is drawn from the issue "what to do back home, how to set priorities in the environmental field". Most of the time participants leave the training courses with a wealth of ideas and insights – when they are back at their jobs the usual day to day worries take over and little time is left to address the lessons learned. It is of crucial importance to help in prioritising the actions to be taken – in this way the scarce time available is used efficiently. When this produces results, the effect will be that of a multiplier: more time will arise

or be made available and the standing of environmental issues in the department where the course participant is working will increase.

5. Achieving the desired learning; the future of EcoDesign teaching

The modular set-up of the training curriculum, its regular updates, and the addition of new modules has ensured that in ten years the dynamic development of EcoDesign [2] has been able to achieve the desired learning goals in each of the stages (see §3). Although the basic structure of the course has not changed substantially as a function of time, the centre of gravity of EcoDesign teaching has gradually moved.

In the start up period, in the early nineties, modules 1 (what is EcoDesign) and 5 (how to do it) were the most important. When more structured approaches were introduced in the mid nineties modules 3 (benchmark, brainstorm, validation) and 4 (exercises) gained in importance. Business integration of EcoDesign, starting in 1997 – 1998 meant that module 2 (environmental business) and 7 (green marketing and sales) became very relevant for the internal value chain, whereas 6 (suppliers) and 8 (take back and recycling) did so for the external value chain. Currently, EcoDesign is seen more and more in a wider societal context. This means that module 9 (what is happening in the regions of the world) has gained substantial priority.

A further evolution will be that the EcoDesign will go beyond the limits of individual companies. Product design will be a part of system design as a whole. This will require more intensive interplay of companies (business coalition building) and stakeholders in general. The first experiences in “system design” are now trickling in and this will add new chapters to the teaching module kit, for instance on:

- EcoDesign coalition building.
- Infrastructure and EcoDesign.
- Cultural impacts of EcoDesign systems.
- Corporate governance (triple bottom line) and EcoDesign.

6. Conditions for success for EcoDesign teaching

The conditions for successful teaching of EcoDesign depend not only on the content (see §3) and the way it is taught (see §4) but also of a number of internal and external circumstances related to the company. These include:

- Internal company culture. This is chiefly the way environment is perceived by the various participants in the internal value chain (management, development, production, marketing and sales, purchasing, logistics). Generally speaking people have a positive perception towards environmental topics but business perception varies widely; from threat to opportunity; from a cost factor to a potential source of profit; from a business enhancement to a complication etc. Attitudes can be improved by bottom-up processes, for instance by environmental management, but in the end top-down action is needed as well, particularly when different corporate (sub)cultures exist.
- Business conditions. Depending on whether business is profitable (or loss making), is expanding (or restructuring) has ethical drivers (or not), interest in EcoDesign and EcoDesign teaching will be greater or smaller. In the last ten years it has been observed to fluctuate widely both as a function of time but also per decision or with each business unit within one company.
- Presence of outside pressures for instance from customers, governments of NGOs.
- Competitors. In the electronic industry EcoDesign performance of competitors has been a strong driver in the last decade.

7. Conclusions

On the basis of practical experiences is Philips Consumer Electronics and conceptual inputs from the Design for Sustainability Group of the Faculty of Industrial Design Engineering at Delft University of Technology a comprehensive set of EcoDesign teaching modules has been developed. These teaching modules have been used for teaching a variety of audiences in industry, academia and at international conferences.

The evaluation of the learning results, throughout training, shows substantial self-empowerment of participants,

both in terms of practicalities and conceptual items. Important learning experiences have also been obtained from the teaching perspective. Simplicity, tailoring to participants values and learning by doing are key ideas here. The modular set up of the EcoDesign training courses has ensured that its flexible content and emphasis could be easily adapted to changing circumstances. Conditions for the success of EcoDesign training include corporate culture, business conditions, external pressures, competition behaviour and perceived benefits of the participant.

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Trondheim, the inspiration of nature

Trondheim is 600 km north of Oslo at 62° latitude. It is the centre of research in Norway and the town is full of scholars and students. Although it has approximately 150,000 inhabitants it is quiet; the population is spread over a large area. This means that nature is close by wherever you live in town. The workday starts early (08:00) and ends early (16:00, in summer 15:00). This means that you have plenty of opportunity to do outdoor activities. In spite of its latitude, the weather in Trondheim is mild with relatively little rain.

When we were living in Trondheim (Aug-Nov 2003), such opportunities were taken advantage of as much as possible, such as walking every day and being out on weekend trips to the countryside.

The atmosphere at the Institute of Industrial Ecology (Indecol) was inspiring, a lot of new ideas were generated through all kinds of in-depth discussions. This institute is doing excellent work, which deserves to be known better in the world. It is a great environment to rethink Ecodesign and other environmental activities.

Nature contributes too, through long walks to little villages tucked away in marshy woodlands, hills, mountains but most of all the fjells. You can roam for hours, and be impressed by the variety of colors in green, grey and black. You can struggle with the wind and rain, and see new horizons.

An exceptional highlight was a 2-hour spell of Northern Lights over Trondheim in November, 2003. I described it as follows in the Indecol newsletter: standing, and after some time sitting, in the early snow on the lawn in front of the university building (which is on a hill above town), looking to the skies over town where this wild 'game of green' was on display for almost two hours. People next to us told me, "the best in twenty years." That was really what it was in a broader sense for us too!

Trondheim, jeg vil komme tilbake!

City walk: Start at Trondheim Central Station; cross the Jernbanebua and go right to Fjordgata to Ravinkloa. Proceed through Munkegata all the way to the Nidarosdom. Go through the Erkebispegarden and cross the Nidelva river through Elgeseter bridge. Go left to Klostergata and climb up to the building of the NTN University. Go the same way back, but now walk through Vollaakken and Øvre Bakkelandet. Cross the Nidelva through the Bybrua and go right on Kjøpmannsgata, go L to Dronningsgata and go R through Søndre Gata and back to the Station.

Favorite Restaurant: Bakkelandets Skyddshuset, Øvre Bakkelandet.

Favorite Pub: Den Gode Nabo, near Bakkebru.

Country walk: Take the tramway from the city centre to Lian. Walk from there to Grønlia and Elgesethytta. Go back from there to Skistua, follow the paved road from there and go R at the second parking, back to Lian again.

10.2 Teaching Applied EcoDesign in Academia

10.2.1 Organizational and financial issues

It has been a hard fight to get Applied EcoDesign appropriately positioned in the teaching curriculum and in the research programs. This is because it is CROSSFUNCTIONAL and therefore it is at odds with the traditional university structure.

At TUDelft, Faculties (this is the continental European name for 'Schools') are not only organizationally separate, but also mentally separate. Faculty members usually consider themselves to be (vastly) different from the other faculties. Faculties are split into departments, departments have sections and finally sections have individual chairs. The idea that each chair should represent a 'discipline' is widespread and working together with other 'disciplines' is an issue. At Industrial Design Engineering in Delft (IDE) it is a big issue, although it is imperative today it should be natural that such territorial instincts are over. Simultaneously it is to be realized that the universities of today the time for brilliant individuals is over: it is all group work and groups need a certain minimum size to ensure continuity and to have a chance to become world class. Fragmentation is the best guarantee of mediocrity.

At TUDelft time for individuals is also over in a different way; the 'collegial' principle among professors has been abolished by law. Collegiality meant that each of the chairs were responsible for all of its affairs. The great thing about this is that each professor can manage their activities very efficiently. However, if this is not done in a proper way, there were few possibilities for correction.

Instead of enhancing mechanisms for such corrections a completely new hierarchical system has been introduced. Currently a professor in Delft has to deal with a section leader, a department head and a Dean which are supposed to be his bosses. Management teams assist these persons to deal with the numerous plans that must be submitted, procedures followed and approvals to be obtained. Instead of a lean and mean system in which the performance of professors can be checked with regards to output and finances a huge bureaucracy has been developed. Professors at universities are no saints, but this institutionalized distrust worries me as a Dutch taxpayer. This applies not only for Delft, at other Dutch universities the same problem exist.

The situation is aggravated by the financial system which is in place in the Netherlands. Universities still get money from the State (at TUDelft some 80% of the University's budget; at IDE more than 90% is coming from this money stream). It is distributed over the Faculties according to a certain formula (which is regularly 'updated', in my opinion to consolidate status quo rather than to reward success). Faculties distribute money to the departments in a similar way. Both inside a Faculty and a department a policy to invest more in successful activities and to reduce budgets for other ones does not exist. In practice the opposite happens, the surpluses generated by successes are used to cover deficits elsewhere.

The Design for Sustainability Group (DfS) has existed now in its present form for eight years in a Faculty (a School) which has been in place for some forty years. The tradition of the University as a whole goes back some hundred and sixty years. In practice this simply means that the IDE Faculty, including DfS, is simply on the wrong side of the equation. The only chance for financial survival is therefore to go for money provided by third parties; in this respect DfS has been pretty successful. In practice this circumstance is very stimulating. However it means that the more fundamental research questions cannot be addressed.

A part-time chair representing cross functional engineering activities, has to fight even harder. It would be most obvious to integrate applied EcoDesign into the existing programs and courses inside and outside the Faculty like Design Engineering, Mechanical & Electrical Engineering, Materials Science, Economics, Social Sciences, etc. This did not happen, the mental and administrative barriers simply prevent this.

It was even difficult to get a place in the mandatory sophomore class on Design for Sustainability. It took an assistant professor with very specific 'Ecobelief' to retire to get Applied EcoDesign appropriately on board.

Altogether the conclusion is that the most satisfactory way to operate is to run separate research programs and to give specific elective courses. As a part-time professor this is not preferred, but in practice it is the best means of survival; run your own show without being bothered by all kinds of 'blood group thinking' and endless fights about money.

**Nisse, Zeeland, NL, the tower of the Dutch Reformed Church.
 “They will rest from their labor, their deeds will follow them” (Revelations 14:13)**



10.2.2 The Applied EcoDesign Classes

For IDE, two courses have been developed, each with seven sessions:

Applied EcoDesign (AE)

Introduction to Applied EcoDesign
 Basics of AE and how it can be organized
 AE and energy reduction
 AE and Material application
 AE and Packaging/Transport
 AE and Take-back/Recycling

Environment and business (EB)

Introduction into Environment & Business
 Strategy, roadmap, and measurement of performance
 Integration of green into Product Creation Processes
 Green supply chain management
 Green marketing and communication
 How to organize for legal compliance

Both classes are internet based which makes it more flexible for the participants and allows interaction between the participants themselves and the lecturers.

Apart from participation in the sessions, students should also take an active part in the proceedings.

For Applied EcoDesign this is a disassembly session. Groups of students (3-4) should take apart an electronic product and do a functionality/user friendliness analysis and measure basic technical and 'green' parameters (benchmark, see chapter 6.3). On top of the group report, each individual should come up with a report with suggestions for improvement including a prioritization according to the EcoDesign matrix. Apart from this the final exam includes an essay about a subject chosen by themselves (but related to the course material), and five questions.

For Environment and Business the approach is different. Here the Sustainability Report of four electronic companies is the material to be studied. Before each session students review reports for discussion, for instance what is mentioned (or not mentioned) about it, how companies are doing in respect to each other etc. At least one proposition has to be formulated and put on the electronic blackboard. From these, two opposing propositions are selected and the submitters have to defend them in class. After 20 minutes discussions are stopped (which is often difficult to do because it is great, so you let it go) and I try to put the

discussion into the broader perspective of the subject with the help of the class material. The exam consists of three items. The questions to be answered, the essay and a report on how one of the companies can improve their sustainability report.

How does this work out in practice? First of all, students love these subjects. The maximum number allowed for an elective is 25 (more is difficult to handle) and mostly it is fully booked. Only few 'vote with their feet', that is do not turn up anymore in later sessions because of lack of interest.

It is fun, particularly the disassembly sessions and the group discussions about the propositions are the best. It is interactive, with improvisation and strong arguments. It is great to do, every year, again and again.

On top of the two classes a third one called 'Recycling and Recycling Systems' has been developed. It has the following subjects:

- Material recycling
- Legislation on recycling, particularly the European WEEE Directive
- Making End-of-Life Strategies
- Experiences in the Netherlands and the EU with take-back and recycling
- Design and end-of-life
- Materials and chemical content issues in products to be recycled
- Eco-efficiency of recycling
- Implementation issues of the WEEE Directive
- How can we do better than the current WEEE Directive.

Coupled with this course is a disassembly session with particular emphasis on recycling issues. This course, or part of it, received great attention at the Universities where I was a visiting professor, in particular at Tsinghua University in Beijing.

Both students and I will remember it all of our life (see Tidbits, 15).

Recycling and recycling systems have been taught at IDE. This is understandable because the main focus is design. My hope to have an outreach version of this class elsewhere at TUDelft did not materialize. At Earth Sciences for instance recycling and recycling technology is an important subject. The approach involves a different technology -metallurgy – but design is supposed to adapt to that. Why not incorporate design in a more balanced way? Real science has little to do with superiority feelings.

(Applied) EcoDesign can also be considered to be part of an Industrial Ecology curriculum. My visiting professorship at NTNU in Trondheim (see Cities, 14) shows that this could be a good match; there can be a lot of synergy. Together with Delft, Leiden University and Erasmus University Rotterdam an Industrial Ecology program has been set up. Several Delft Faculties were involved, but not the Faculty IDE. I became aware of this through Philips! I contacted them to offer my support and help and they said, "We will call you". I am still waiting.

What happens in Delft is not unique. Almost all universities struggle with how to integrate EcoDesign, environment and products.

Many institutions have only one chair for it. This forces specialization and does not permit cross-functionality, there is just not enough body.

In Delft Design for Sustainability is located in one Faculty only – may be it is too 'heavy' for that one Faculty, but the very limited outreach beyond that makes this the only way to survive. If all experience and know-how in environmental design, technology and management available in Delft could be brought together, it would be a powerhouse on a world-level.

At NTNU in Trondheim there is a joint Master Course in Industrial Ecology. Different Faculties work together here – with success. A big problem however is the big spread in influx of bachelors. It ranges from sociologists to engineers and from knowledge of the mathematics to economists.

The University of Brandenburg on the contrary has a problem with its outflow. There is an integrated Faculty solely devoted to 'green', which is great. The stumbling block is outside: the status of the graduates in the labor market is weak. Prospective employees have little idea how to value the diploma.

Wanting to teach Applied EcoDesign makes you collide with traditional university organizational structures. This is here to stay. The only way forward is to keep on going for it and try to integrate it!

Times have changed

This flurry of adventures in Ecodesign did not offer much time to become philosophical. The ambition was to develop the field, drive to make it happen, and to debate with other practitioners. A simple curiosity made me run. For many years I have been working relentlessly and sometimes I came close to the limit of my physical abilities.

Looking back occasionally it has been too much, but I did it and I feel good about it.

My official retirement from Phillips in 2004 brought some relief in my workload, but my mind kept turning. In the EcoDesign field I currently observe a kind of stagnation and something really new needs to be done. Putting much more effort into 'low energy design' must be one of those efforts. The Ecovalue approach (chapter 2.3) and some other new items popping up are very promising as well.

In Europe the implementation of the environmental Directives in the Member States resulted in a mess; dogmatism and 'green' window dressing prevailed over practicality and common sense. Now all energies have to be devoted to the prevention of further disasters – for me this is very important because the ramifications of failure could be significant and very negative.

In spite of all this personally I am slowly winding down. Often I still feel challenged. It is still difficult to say no to various invitations, but I am making progress in this field also. What has helped me a lot has been the writing of this book. When you write things down you realize what has happened. Particularly chapter 1.2 (times have changed) is relevant in this respect. I had never anticipated that the field would expand so much and that today ideas about it would be so different from 10 or 15 years ago.

I also realized that 15 years is also only a small window in time. There are a lot of new and interesting aspects which are not for me to explore anymore. Young people have to take over; it has to be accepted that they will do it their own way. I love seeing them picking it up.

My window of opportunity is over. Hora est!

Facts and Figures, 5

Writing, coordinates and weather

Of the 98 papers of which I am the first author it is known in 48 cases where I have been writing. In a few cases there are even some more details as well.

Twelve out of forty-eight have been written at the office, either at Philips or at Delft University. Fifteen have been written at home, either inside (nine) or outside in the garden (six). For the inside papers two periods stand out: between Christmas and Dec 31 and in the summer when the weather is so hot that it is better to stay inside. For the outside papers, sunshine (put your desk on the lawn!) and crisp cold spring or fall weather (put a sweater on) are clear favorites.

The train to or from Delft is responsible for another six publications.

Most interesting are the other locations of writing. Vienna dominates with five: on the tramway or S-Bahn (see chapters 6.2.2 and 10.1), in an apartment shortly after my father had died (see chapter 5.4.1), on a hotel room (see chapter 5.3.1) and on the train to St.Anton (see chapter 4.2.1). Georgia Tech ("hot and sticky outside") is responsible for two: one of them is in chapter 9.1.

Other institutions where I had visiting professorships contributed as well. First Stanford University under a patio, chapter 5.1.1. At NTNU in Trondheim, Norway it was raining all day although the weather in the period there was in general quite good, see chapter 9.2.1. In Berlin the weather when writing was "clear after clouds", see chapter 7.1. Finally, in Beijing, I wrote at the old Summer Palace location on chapter 11.3.

A Toronto paper ("cold") and a Phoenix one ("at the pool"), see chapter 4.6.3, confirm prejudice about the climate. A paper at Gatwick Airport is an exception, I never wrote papers at airports, reports at best.

And finally there is, last but not least the Minneapolis, MI paper, shortly after 9-11, waiting to get home, see chapter 5.3.2 and also Cities, 1.

Chapter 11: China

11.1 Introduction

China is fascinating. The speed of its development is phenomenal. Since I visited for the first time in 1990 many things have changed dramatically. However, some things have barely changed.

I cannot recognize some cities anymore – historic sites have been preserved – but otherwise the change is dramatic. In a few years time things have been achieved which took the Western world a hundred years or more.

People have changed and not changed as well.

Self-confidence and self-pride have grown tremendously: we as China will do it, China will make it, and China will do it our way!

However, culture, traditions and values are basically the same as before.

It is a country of contrasts too. In a country with 8-10% economic growth per year there are still some 800-1,000 million poor people. Developments go so fast that infrastructure cannot keep up. On one hand there is a centralized state with detailed laws and rules (for the environment as well), on the other hand due to its vast territory and its current status of development, implementation and enforcement of the laws is often a problem. People want to advance and fight their way towards new personal lifestyles but are refrained by the enormous competition for the opportunities available. Simultaneously they want their own values and lifestyles to stay.

China has enormous environmental problems:

- Emissions: breathtaking smog 90% of the time, for instance in Beijing.
- Resources: oil and materials savings and reduction are still in their infancy
- Water: shortages in Northern and Western China and in cities, water pollution
- Waste: 'End of pipe' can barely keep up; little prevention

They are faced with the dilemma of all countries in development: how to balance speed of development and environment. How can China escape from the devil and the deep blue sea through technology, design, systems organization (supply chains, recycling) and legislation?

For several years I had been looking for ways to get involved in the environmental developments in China. Finally, I was lucky enough that my drive to get involved in this interesting world and my interest to contribute, materialized through two channels:

- Philips Electronics, having invested billions in China, wanted to develop a network of subcontractors and suppliers, intending to apply its global standards for Environment and Sustainability in China as well.
- Interest from China (Tsinghua University and Chinese authorities, see *Cities*, 2; *Personalities*, 11 and *Tidbits*, 15). The particular focus of their interest was on recycling and recycling systems on the developments in environmental legislation in Europe.

The business plan I made for enhancing sustainability for Philips in China had a strong emphasis on environmental benchmarking, 'green' supply chain management and establishing good relations with the Chinese Government. Its core goal was to transfer best practices from elsewhere in the world to China. However this is not good enough. Specific circumstances in the country like industrial infrastructure, stakeholder value chains and cultural perceptions have to be addressed as well.

The cooperation with Tsinghua University resulted in a visiting professorship in Feb-April 2005 where I presented a full class on recycling and did seminars as well. The scientific aspects of recycling were addressed in a seminar in November 2004. Industrial aspects were addressed in April 2005 and legislation issues were addressed in Nov. 2005.

The work on the environment in China is great. The Chinese are quick learners and very practical. Just do it. The tendency to intellectualize environmental subjects like we have in Europe, or drive to make numerical models first like in the USA, is almost absent. First action, then learning by doing. That is what it comes down to in China. What also helps is to include a human touch in your approach as well. All people in China are friendly and willing to help, even if their English is poor. Western arrogance and feelings of superiority are deadly. There is no reason for it as well. It should also be realized that for instance the one hundred years ago the Dutch country side was in the same stage of development as the country side in China today. For instance my grandfather (see *Personalities*, 5) grew up in a village where there was no paved road to town.

Smoke stack industries, which exist in some parts of China today, existed in Europe and the USA in the fifties and sixties of last century. The upgrading of old parts of cities in taking place today in China was started elsewhere in the world just twenty years ago in the eighties. In industrial supply chains, the level of small and medium sized suppliers in China is almost on par with what is presently found in the western world.

Blaming China for poor performance in 'green' does not solve environmental problems. It is unreasonable to require items to be realized in short notice which took many years in the developed countries. On the other hand, being in a phase of economic development is not an indefinite excuse. If the ambition is to be a member of the world community, China has to live up to its standards.

Most important for the Western world however, is to put its own house in order first. If it is incapable of managing its own energy and material intensive society at sustainable levels, what right does it have to teach the rest of the world a lesson?

Ten minutes past seven

Beijing, Tsinghua University, March 2005. It is cold outside. It's freezing. The wind is blowing directly from Siberia. I cycle through the dark streets to my class, which will start at 7.10 pm sharp – Chinese universities use their buildings very well. The first class starts at 8.00 AM and classes continue until 10.00 PM. Every 50 minutes the hooter goes, followed by a 5 minute break, and then the hooter goes again. The next class is on.

This night my class is a special one: the disassembly session. Products will be taken apart and studied. Everything is in place, the discarded products, the tools, utensils and the notebooks. The students are ready as well. It took me quite some effort to convince everybody that this session was a useful exercise for their intellectual education.

The hooter sounds, time to attack the products, there they go at an incredible speed. I let it go for one minute, it is great to see this engagement and concentration, then I shouted: STOP!! Everybody was amazed or puzzled. Some students showed fear when they heard this penetrating Dutch voice. What is wrong?

No there is nothing wrong, this is a learning moment. "All of you have started very eager, but what is the goal for this evening? What could be learned from this disassembly session? Please, give each of your favorite learning targets; all of them will be listed on the blackboard here and at the end of the evening we will see what has been achieved."

There is relief and at the same time a moment of anxiety. What should I say? The first students have the disadvantage of being first, but have the best choice of possible learning objectives. The last ones have the most time to think but have the more difficult job of saying something new.

In record time 18 subjects were raised. When grouped together, they were reduced to 12. Still one hour and a half time to collect information and scribble it on pieces of paper. Go ahead, folks. 9.20 PM. I start collecting the notes, sometimes I have to rip it out of their hands. Yes, I can read most of the handwriting and understand what has been meant. Summarize the findings, two lines per item; all of them are covered well. 9.45 PM. Ready, the hooter goes. We made it, and enjoy the success. Great stuff!

11.2 EcoDesign and China

The development of EcoDesign in China has been slow so far. This is in line with what happened in Europe and the USA a few decades ago. Environmental concerns and their remediation start in the process industry. It took the western world almost 30 years to realize that products have to be addressed as well. If the time lag in China is something like 15 years, it is expected that EcoDesign will take off before 2010. EcoDesign in China will be more than just catching up in regards to design. Ecotechnology implementation, systems organization (supply chain, recycling) and regulation will have to be promulgated as well. In order to become proactive and to build upon specific Chinese circumstances, following mainstream practice in the world will not be good enough.

The basis for this conclusion was laid by a benchmark-study of two Delft students in Suzhou (China), 2003. In this work, the EcoDesign characteristics of products from international companies sold on the Chinese market while those of local brands were compared. The study resulted in a manifold of interesting observations.

As an example of this, measurement results of the energy consumption of comparable 28" inch TVs are presented:

Table 11.1 Comparison of energy consumption of 28"TVs sold in the Chinese market (2003)

Energy	Unit	Philips	Competitor 1	Competitor 2	Competitor 3
On mode (factory settings)	[W]	77.4	85.6	83.3	82.5
On mode (no sound)	[W]	77.1	79.5	74.6	79.6
Standby mode	[W]	2.3	6	10.4	6.6
Off mode	[W]	0	0	0	0

It is concluded from this table that both in the operational mode (+/- 10%) but particularly in the stand-by mode (up to a factor 5) there is substantial room for improvement of local brands.

For material application a similar conclusion also applies – as is apparent from the following table:

Table 11.2 Material application of 28" TVs; sold on the Chinese market (2003).

Weight	Unit	Philips	Competitor 1	Competitor 2	Competitor 3
Weight – product	[g]	45374	46889	46290	50105
Percentage	[%]	100	103	102	110
Weight - accessories	[g]	198	186	166	209
CRT	[g]	36200	36100	35610	37400
Encasing	[g]	6445	7830	6134	6634
Speakers	[g]	342	683	1666	3206
Wiring	[g]	703	473	619	731
PWB's	[g]	1626	1559	2021	1899
Screws	[g]	32	181	159	97
Rest	[g]	27	62	83	139

At first sight the improvement potential in this category seems to be limited (max 10%). However, CRTs form some 75-80% of the total product weight and since they have pretty much identical weights (range up to 5% differences only), other categories of functionality have a substantial spread:

Encasing 25%

Speakers almost a factor 10

Wiring up to 75%

Printing Wiring Boards some 30%

Screws almost a factor 6.

For the weight of the remaining parts there is a difference of a factor of 6.

Again for all these categories the conclusion is that there is substantial room for further improvement.

For packaging the opposite is true; Chinese local brands do better than Philips:

Table 11.3 Packaging benchmark of 28" TVs sold on the Chinese market (2003).

Packaging	Philips	Competitor 1	Competitor 2	Competitor 3
Packaging weight	100%	-29%	-28%	-24%
Box volume	100%	-26%	-35%	-32%
Volume ratio (volume of packed product / volume of product)	2.38	1.76 (-26%)	1.69 (-29%)	1.69 (-29%)
Weight ratio (packaging weight/product weight)	0.15	0.11	0.11	0.11
Use of PVC	In binder	In binder	-	In binder
EPS buffer density	16.12	18.56	22.69	24.75

This table shows that the results for the local brands in all departments are substantially (up to 25-30%) better than the Philips one. Most likely this is due to the fact that Philips packaging designs have their origin in Europe, where packaging materials are relatively cheap and transport costs are relatively low. As a result of this 'overshoot' in packaging, damage by transport is very low. Since such figures for the local brands are not available some caution should be taken in making conclusions about their realistic potential.

Much of the material in the report mentioned above is proprietary. Nevertheless, it has been a very useful basis for my keynote presentation at the first China EcoDesign Conference which took place at Shanghai in March 2004 (see the article below: *"An Industry Vision how to move EcoDesign (Design for Environment) forward in China"*).

Four chief recommendations are made to move Applied EcoDesign in China forward:

- * Develop an University Curriculum for Applied EcoDesign in China.
- * Introduce Environmental Benchmarking as a basis for Applied EcoDesign.
- * Set up a standardized system for Green Supply Chain Management
- * Base Environmental Legislation in China on experiences elsewhere, take the good elements on board, avoid the mistakes made and add specific Chinese elements if necessary.

An Industry Vision how to move EcoDesign (Design for Environment) forward in China

Ab Stevels

Abstract

This paper demonstrates that EcoDesign (Design for Environment) in China can be moved forward through four avenues:

1. *Developing and implementing a university and industry teaching curriculum. The fundamentals are already in place through experiences elsewhere in the world.*
2. *Performing pilot projects on Environmental Benchmarking of products. This Benchmarking is the basis for design creativity.*
3. *Working on green supply chain management. Suppliers can have a substantial impact on decreasing the environmental load of products over the life cycle in general.*
4. *Supporting EcoDesign by appropriate legislation. Compared to the situation in Europe, China can substantially improve by paying more and well-integrated attention to*

** different environmental dimensions (emissions, resources, potential toxicity)*

** proper definitions and target setting*

** operationalization and enforcement aspects.*

I. Introduction

In 1987 the Brundtland report (ref. 1) made the world clearly aware that the production and use of products had serious environmental impact. Such impact was identified to be in a variety of fields: energy consumption (emissions and resource depletion), consumption of materials (resource depletion but also energy needed to refine materials, as well as the waste from the discarding of products) and (potential) toxicity of substances used to make products or embedded within them.

As a result of societal concerns raised by the report, industry, in particular the electronic industry began with EcoDesign (Design for Environment) of its products. The aim of this activity is to minimize the environmental load of products ('functionalities') over their whole life cycle ('from cradle to grave').

By now, leading companies in the field have the experience of more than 10 years in developing EcoDesign and implementing it in the business. A main characteristic of this industrial approach is its practical, action-oriented basis – see for instance ref. 2 where a review is given on how EcoDesign has been developed at Philips Consumer Electronics.

An important issue is to integrate EcoDesign into day-to-day business operations. This requires that apart from technical and analytical/scientific skills, management and communication skills are also needed to make EcoDesign

really happen. The absence of managerial and communication roles in EcoDesign has led to the fact that part more academic approaches (often with a holistic Life Cycle Analysis as a starter) have had a limited impact in industrial practice thus far.

There are four basic reasons why China in its current stage of economic development should put EcoDesign high on the agenda in academia, industry and government:

- The rapid increase of standards of living of China's citizens will result in a vast increase of emissions, resource consumption and exposures to potential toxicity, amongst other measures. EcoDesign can contribute to control this development.
- Countries in the developing world already struggle with increased environmental loads as mentioned. For this purpose environmental requirements on products have been put in place. Goods exported from China will have to comply with these or otherwise will be discriminated against on this ground.
- Apart from its environmental merits, application of EcoDesign also generally leads to cost reduction and therefore will contribute to competitiveness.
- Practical experiences in EcoDesign can also contribute to the development of realistic and enforceable legislation and regulation. China would be the first country in the world following such an approach. In this report, valuable lessons can also be learned from developments in the European Union, where a much more conceptual approach has been used so far. In the opinion of the author this will lead to numerous difficulties in implementation.

In this paper four proposals are made to move EcoDesign forward in China. It is preferable that these four activities are to be carried out concurrently, within is in similar time frames. This will allow a maximum of mutual learning and will create a diverse community of opinion-leaders in the field.

These proposals include:

- Development and teaching of a university curriculum for (Applied) EcoDesign
- Pilot projects in the industry on Applied EcoDesign, with particular emphasis on how to simultaneously improve environmental and economic performance. This is to be done through the so-called benchmarking approach.
- Similar pilot projects on Supply Chain Management with particular emphasis on potential toxic substance control, cost reduction at the supplier through environmental action and joint EcoDesign in the value chain.
- Support of the development of environmental legislation.

In the chapter below, these items will be specified in much more detail. It is important to note that all elements of the programs and projects have already been tested as regards their practicality. For the educational aspect this has been through activities at Delft University of Technology (and courses at Stanford University, Georgia Institute of Technology, UNAM Mexico, TU Berlin, TU Vienna, and NTNU Trondheim, as well as in industry). For the practical aspect, this has been mainly through activities at Philips Consumer Electronics.

2. Development of a university curriculum for Applied EcoDesign in China

A successful university curriculum for Applied EcoDesign requires a cross-functional approach. This means that on one hand different Schools/Faculties will be involved (Design Engineering, Mechanical Engineering, Electrical Engineering, Production Engineering, Economics, Managements School, Marketing & Communication, Public Administration). On the other hand, the set-up of an organization is needed to charge this inter-school curriculum. As a model for the content of the curriculum to be developed further for China, the Teaching Modules on 'EcoDesign for Competitive Advantage' as developed by Delft University of Technology and Philips Consumer Electronics can be taken. Starting points for these have been practical experiences in design projects and in the management of environmental issues in the business. Wording and language in the courses are primarily focused on the user and five 'focal areas' which each constitute easily understandable topics: energy, material application, packaging and transport, substances and end-of-life/ recyclability. The life cycle principle is introduced later on as a check for overall good performance rather than as a starting point. The approach also includes a primary focus

on the internal environmental effect of these topics, which can be influenced by the members of the audience. Subsequently external effects, that are those topics, which contribute to the overall environmental load over the product life cycle, but which cannot be influenced directly, will be included. For instance electronics companies can influence the electricity consumption of their products through design. However they can not influence the environmental load of generating electricity.

Chief targets of the training are to assist participants in:

- Becoming better than the competition in their environmental performance.
- Combining environmental improvement and cost reduction and/or quality increase.
- Achieving pro-active behavior in compliance with regulation/legislation.

Training should also contribute to the strategic and commercial dimensions of 'green':

- Assist in making appropriate strategies and roadmaps
- Foster creativity and test green options so that they can be incorporated into product concepts and product specifications
- Prepare for green marketing and sales campaigns.

Basis of all this should be self-empowerment: that is employees should become proponents of 'green' without the need to be continuously supported by environmental specialists from inside or outside the company.

The training modules have the following chapters:

1. Introduction to EcoDesign

- 1.1 How to improve
- 1.2. Energy Consumption
- 1.3. Material application
- 1.4. Packaging and Transport
- 1.5. Chemical content.

2.1. Environmental and Business, Vision, Strategy Roadmap

- 2.2. How to make company environmental programs and how to implement them.
- 2.3. Product Environmental cares systems
- 2.4. Experiences in Green and Business
- 2.5. Value Chain Considerations
- 2.6. Green marketing and sales.

3.1. Benchmarking and Validation

- 3.2. Environmental Benchmarking
- 3.3. Environmental Validation in Industry Practice
- 3.4. Managing EcoDesign Creativity.

4.1. Green Supply Chain Management

- 4.2. Defensive and Pro-active actions, ISO 14001, chemical content
- 4.3. Measuring green performance of suppliers
- 4.4. Suppliers and EcoDesign.

5. Take back and Recycling

Introduction; how to organize systems.
End of life strategies, management of the take back systems.
Materials recycling
Eco-Efficiency and recycling.
Experiences with take-back and recycling in practice.

6. What is going on in the world: legislation, company's strategies

Europe, USA, and Japan.

7. Teaching EcoDesign at Universities.

Each module of the course takes 60-90 minutes to present with the help of additional material. Apart from the basic course this can be extended to 120-180 minutes per subject. In the course (part of) these subjects can be supported by a practical disassembly session 'where participants can apply their acquired knowledge. In such a session they receive assignments to work out specific problems.

Experiences so far with the training modules are characterized by high amounts of practical learning due to the bottom-up approach: practical learning precedes conceptual learning. It turns out that it is very important to take away in a very early stage all kind of prejudice which still exist about EcoDesign, such as:

'Environment and EcoDesign is just a bundle of 'technical tricks'

'Environment and EcoDesign will only cost money'

'Environment is not for us, a practical folk'

'Environment is nice but does not belong to the business agenda'

On the basis of such experiences it is concluded that a university curriculum for Applied EcoDesign in China can be swiftly developed, provided that:

- The right content and the right teaching approach are available.
- Companies are prepared to put Environmental and EcoDesign on their business agenda.
- Participants in the courses can be given the self-empowerment they need to achieve success in practice.

3. Environmental Benchmarking as a basis for Applied EcoDesign

The environmental benchmark method proposed here has been developed through a co-operation between the Applied EcoDesign/Design for sustainability group at Delft University and Philips Consumer Electronics.

It is depicted in the figure below:

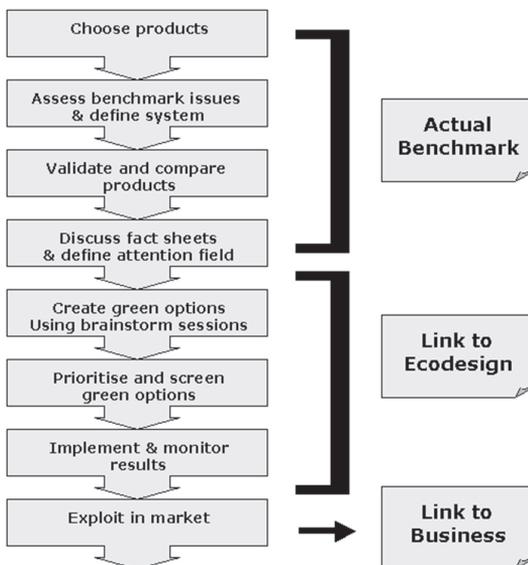


Figure 1: The Environmental Benchmark Method and its links to the EcoDesign and the Business

The actual benchmark precedes the actual EcoDesign. In fact it collects all the data needed to form a solid basis for brainstorms and other green creativity activities.

In the 'choose products' step, products of different brands with similar functionality are bought and/or collected. Price/performance, size and product generation/year of production should be similar.

The 'Assess benchmark issues and defines system' step includes two elements. First, it is important to consider which are the important criteria to include in the benchmark. The five focal issues: packaging, energy, materials,

potentially toxic substances and recyclability are always included, but additional issues can be relevant for particular products or product groups as well. Environmental perception from the consumer market (including consumer test organizations) as well as legislative bodies should be considered an important indication for relevant issues. Secondly, these considerations should be used within the definition of the system boundaries and functional units (which are for example required for the energy analysis).

In the step 'Comparison and validation of products', the actual comparison of products is done according to the five focal areas, with the possibility of the inclusion of additional criteria identified in the previous step. The analysis should include product characteristics as given in Table I.

Table 1: Issues to be checked in the Environmental Benchmark Method.

FOCAL AREA	ISSUES CHECKED IN THE BENCHMARK PROCEDURE
Energy	<ul style="list-style-type: none"> • Consumer behaviour (usage scenarios) • Power consumption <ul style="list-style-type: none"> ○ On-mode ○ Stand-by mode(s) ○ Off-mode • Battery and adapter applications • Alternative energy sources
Materials/Weight	<ul style="list-style-type: none"> • Per (sub)assembly <ul style="list-style-type: none"> ○ Embodiment ○ Picture tube (if present) ○ Drives (if present) ○ Electronics subassembly ○ Electrical components ○ Accessories ○ Directions for use ○ Remote control (if present) ○ Functional parts (antenna, speakers) ○ Wiring and connectors (mains cord etc.)
Packaging	<ul style="list-style-type: none"> • Packaging materials (documentation, box, buffer, bags) • Product weight and volume • Box volume • Number of materials • Presence of recycled cardboard
Potentially toxic substances	<ul style="list-style-type: none"> • Type of plastics and metals • Use of recycled materials • Presence of PVC • Chemical content <ul style="list-style-type: none"> ○ Check for released components ○ Check for banned components
Recyclability	<ul style="list-style-type: none"> • Plastics application <ul style="list-style-type: none"> ○ Mono-materials ○ Halogenated flame retardants ○ Markings • Type of connections • Disassembly time for selected components • Check for valuable electronics • Material recycling efficiency • Processing yield

In addition to checking the five focal areas, it is recommended to use some Life Cycle Analysis method, such as the so-called Edo-indicator method, for the validation of the environmental performance of the benchmarked product. The main idea behind this is to include the life cycle perspective in the final assessment of the product, and also to enable the determination of the environmental feasibility, which is one of the steps preceding the

prioritization of the green (re)-design options as explained below.

In the 'Review of results' step fact sheets are made on which the measurements derived in the preceding step are compiled. From these fact sheets, all measurements for all benchmarked products per focal area can be seen at a glance, which makes them easily interpretable.

The Link to EcoDesign

The second main part of the Environmental Benchmark Method comprises the creation, prioritization and implementation of green (re)-design options.

Creation of green options

Brainstorms and screening sessions are useful methods to create opportunities for environmental improvements. Two major sources exist for doing so:

- *Learn from competition*: experience tells that in practice, no single product outscores – on all criteria – all other products against which it is benchmarked. This means that from benchmarking options for improvement can always be generated, based on design solutions found in competitors' products.
- *Smart technological alternatives*: these can include alternative plastics applications, alternative fixing solutions, alternative energy sources, alternative finishes, et cetera.

Prioritization of 'green' options, implementation

Apart from environmental considerations, a multitude of other considerations are to be taken into account in product design. Whereas in the first instance the generation of improvement options should not be hampered by financial restrictions, for example, in the second instance the thus generated improvement options are to be assessed in regards their feasibility. For each option, at least the following aspects should be verified:

- *Environmental feasibility*: a (qualitative) assessment whether the improvement option indeed reduces the impact on the environment, also when the full life cycle is considered.
- *Consumer feasibility*: an assessment of whether the consumer is likely to accept the option as a benefit to him or her.
- *Societal feasibility*: an assessment of to what extent society as a whole will benefit from the proposed improvement.
- *Company feasibility*:
 - *Technical feasibility*: an assessment of whether the improvement options are technically feasible in a way that timely implementation can be ensured.
 - *Financial feasibility*: because of the implementation of the improvement options, that no unwanted costs or investments should be incurred.

For each type of feasibility it is generally possible to indicate a score per improvement option. Depending on the weight factors that can be appointed to the various types of feasibility, an overall score can thus be derived. Based on these scores the improvement options can be ranked.

After improvement options have been generated, ranked and validated, the results of this process need to be deployed in the actual core business.

More than one hundred benchmark studies have been performed at Philips Consumer Electronics. One of them has been carried out at the Philips Consumer Electronics factory in Suzhou, China. In this study, products from the factory were compared with competitive products at the Chinese market.

The main conclusions of this study have been:

- Benchmarking showed great differences in environmental performance between brands.
- For Philips products there is a potential for further improvement.
- Awareness for environmental issues in the whole organization has been substantially raised.

4. 'Green' supply chain management

A 'green supply chain management' activity generally addresses suppliers of materials components and sub-assemblies for better performance.

A first subject in the category is making sure that environmental management systems are introduced at suppliers.

This is to make sure that they are well organized in the environmental field. Although continuous improvement in one of the elements of ISO 14001, certification is no guarantee that such improvements are really delivered. Therefore proper organization is a necessity, but not a sufficient condition to achieve environmental success. Activities to introduce the use of ISO 14001 are already exist in China, but this still should be part of the teaching (see modules 4.1. and 4.2.) and pilot projects proposed above.

A second activity is to make sure that supplied articles do not contain 'banned' substances. Often substance checklists and the requirement of supplier certification to be free of banned substances has to do with legal requirements and as such can be characterized as a defensive strategy rather than a contribution to environmental progress.

This type of action is on one hand inspired by the fact that producers want to be socially responsible in the sense that they want to reduce the use of environmentally relevant substances like solvents, heavy metals and bromine or chlorine containing substances such as those found in flame retardants. Based on this philosophy, leading electronic goods companies like Philips, Sony and Panasonic have put chemical content programs into place.

On the other hand the European Directive on the Restriction of Hazardous Substances (RoHS) will basically limit to zero the use of lead, hexavalent chromium, cadmium and certain brominated flame-retardants. The deadline for this is by the year 2006. All electronic companies selling in or exporting to the European Union will have to follow this Directive. Therefore they must check their supply chain to make sure that none of these substances is present in purchased materials, components and subassemblies. It will require quite a bit of organization to achieve this – there is little more than two years to get this completely into place.

Another activity to be done in cooperation with supplies is to apply the benchmarking idea outlined in § 2 to the supply chain. The basic idea is to measure the incoming and outgoing materials and energy streams at the supply source and to come to a mutual comparison.

The idea behind this is that through comparison awareness is created and subsequently by adequately analyzing the data proposals can be made for reduction of the environmental loads and costs.

The following fields are to be considered:

1. Material use ('substances' which are potentially toxic)
2. Use of auxiliary materials
3. Water use
4. Energy use
5. Emission to air, water
6. Waste
7. Packaging

In all cases scores are related to the output (weight or number of products produced). Where relevant, ratios are multiplied by 'quality ratio', which represents specific elements (for instance use of lead, bromides, nickel, and organic solvents in lacquers in 1, use of ozone depleting chemical, organic solvents, water purification chemicals in 2 etc.).

Two examples of supplier benchmarking are the following.

The first one compares the four top-ranking suppliers of finished printed wiring board materials.

In the table below their scores in the seven departments are given.

Table 2: Relative Environmental performance of four suppliers of finished printing wiring board materials (100=best)

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
1. Material use	37	24	100	39
2. Use of auxiliary material	30	35	82	100
3. Water use	25	18	100	4
4. Energy use	10	100	10	100
5. Emissions to air	100	67	<1	100
6. Waste	6	2	<1	100
7. Packaging	14	4	16	100

This table immediately shows big differences among the suppliers – the application of the quality constants make this very visible. No supplier scores best consistently well in any one area which indicates to each of them what the most urgent areas of improvement from a competition should be.

The underlying effects of collecting data to calculate performance was in all four cases that enormous awareness was created. In addition the principle of 'what is measured is better managed' fully applied – even without data on the competition improvement actions were initiated. Since in all seven categories, environmental improvements almost correspond to cost reductions, the other managerial effect turned out to be that suppliers discovered a new and effective tool for cost reduction.

The second example involves the application of environmental benchmarking to a broader range of suppliers of printed wiring board materials. Here valuable lessons were learned about the way 'input' and 'output' were generally managed.

Out of 25 suppliers invited to respond 4 were not prepared or incapable of providing the required information, which was a requisite to review the supply relationship in its totality. In 7 cases the materials balances constructed from the answers was way off balance showing serious flows in data control.

Remediation of this has resulted (or will result) in substantial improvements including environmental ones.

In a further 5 cases some surprisingly high and low answers (when compared with average scores) were obtained. In this category the same aspects apply to the 'mass-balance' category.

Completely satisfactory answers were obtained in only 9 of the cases. Similar processes could be started, as in the case of the four printed wiring board materials suppliers selected earlier.

This example of the printed boards suppliers shows that an approach primarily aimed at environmental improvement can have a much wider significance.

5. Environmental Legislation in China

5.1. Introduction: basic dilemmas

In order to ensure that the entire industry fulfills certain minimum environmental requirements and in order to encourage positive environmental approaches which contribute to increased competitiveness, China is also currently in the process of developing environmental legislation and regulation. For this purpose it orients itself towards what is happening elsewhere in the world so that a process of mutual global learning starts. In this respect developments in the European Union are highly relevant. Environment ranks high on the political agenda. Particularly for electronic products, several initiatives have been taken to arrive at Directives and Policies which should stimulate good environmental performance. The following proposals have been made:

- WEEE: The Directive on Waste of Electronic and Electric Equipment
- ROHS: The Directive on Restriction of Hazardous Substances (in Electronic and Electric Equipment)
- EuP : The (Design) Directive on Energy Using Products
- IPP : A proposal on Integrated Product Policy (which will also refer to electronic products.)

The purpose of all these (draft) Directives and Policies is to create a common basis for law making of the Member States. Therefore the language used is primarily a legal one – operationalization details are not addressed as

such. On one hand this situation creates flexibility; it is left to the stakeholders in the Member States to agree on implementation forms which reflect the intent of the legislation. However, this flexibility could also lead to a variety in interpretations and operationalization agreements, which could jeopardize the principle of a common market with “common rules of the game”.

The shared goal of all environmental regulations is that they aim at minimizing the environmental impact over the life cycle of the products. ‘Impact’ can be seen from a perspective of emissions but also from a resources or a potential toxicity perspective. Life Cycle Analysis is the dominating tool in looking at environmental aspects: it is also recognized by the European Union as such.

The table below shows that there are several – currently very pressing environmental issues which ask for a wider approach. A few of them are listed below:

Table 3: Example of Environmental dilemmas

Env. dimension	Emissions	Resources	Potential Toxicity
Issue			
Using natural gas instead of coal to generate energy	+ (less CO ₂)	- (high energy resource sacrificed)	+ (no fly ash)
Replacing metal with plastics	+ (less energy needed for production)	- (recycling becomes a problem)	- (additives in plastic)
Lead-free solder	- (more energy needed for process)	- (use more source resources)	+ (lead eliminated)
Use of flame retardants	- (less production energy)	+ (less material needed)	- (more potential toxicity)

- Future Kyoto requirements for CO₂-reduction (these are point in case, but will not be discussed here further) will put pressure to use more high quality resources.
- Replacing plastics to better fulfill ROHS and WEEE will result in more emissions in the production phase.
- Lead-free solder application is environmentally doubtful, particularly when it is realized that a lot of the solder in lead-free alternatives is produced as by product from lead mining. Also increased demand for tin could pose a resources problem.
- Eliminating flame-retardants will result in the use of more primary materials, which in turn results in the use of more production energy.

So far, the draft European Policies and Directives have been “one dimensional” in the sense of concentrating on single environmental aspects. RoHS takes a potential toxicity perspective, WEEE the resource perspective, both EEE and IPP claim a holistic perspective, but are in practice strongly emission/LCA oriented in their environmental analysis approach. Although in both cases recommendations and design rules also address the two other dimensions, no balancing mechanisms are proposed. The way in which this can be done is discussed in for instance in ref. 3. China could leapfrog the world if it would directly step towards such an approach.

5.2. Operationalization of the law

In the introduction it has been pointed out that European Directives and Policies primarily focus on principles and intent of the laws (sometimes giving explicit targets). However, in order to be implemented swiftly and eco-efficiently key parameters need to be defined in operationalization-decrees. Such an action is necessary as well to avoid lengthy discussions and even legal procedures. In the European Union such a task is attributed to a Technical Advisory Committee (TAC). It is however recommended that such a TAC starts operating and has its main decisions in place **before** legislation is formulated. In this way the industry can prepare itself properly, and the

current period of great uncertainty is avoided. Below examples are given showing that upfront agreement among stakeholders in China about major issues is badly needed:

Example 1: Recyclability (WEEE)

Material can be considered to be recycled if it is not going to landfill or incineration (definition A). A stricter definition implies that from the percentage calculated according to A, the amounts being incinerated in the upgrading smelting process (for instance plastics in streams treated by a copper smelter) are deducted (the “gross metal” definition, definition B). An even stricter definition implies that only these metals contributed to recyclability that is in their own stream. (That is Fe in the Fe stream counts, Fe in a copper stream does not, vice versa Cu in the Cu stream counts, Cu in the Fe stream does not)

Definition A is applied for recycling systems in the Netherlands. The results of this system, amongst other inputs, have been used to set the targets of WEEE. However although not explicitly stated, the definition for recyclability implied in the WEEE text is of the B type, although an interpretation according to definition C is possible as well. As things stand now, this ambiguity in the recycling targets of WEEE needs clarification including adaptation of the numerical values.

Example 2: Banning of substances (RoHS)

The important problem from an operational perspective is what does banned really mean? A very strict interpretation would mean total elimination to zero; zero is however a concentration of which cannot be proven scientifically. Another interpretation could be: eliminated to a level that can be detected by current standards of analytical chemistry and acceptable costs. Under the circumstances this is not yet a practical solution: the scope at which this detection-limit-at-acceptable-cost is to be applied needs to be defined as well. This means answering the question: Will this rule be applied to total products, to subassemblies or to individual components and parts? It is the opinion of the author that in the case of the RoHS, an agreement on a set of thresholds for concentrations as well as a set of ‘system boundaries’ product/subassembly weights to which these thresholds are to be applied to is urgently needed.

Example 3: EcoDesign, requirements and parameters (EuP)

Essential requirements can be interpreted as physical targets to be realized, such as environmental issues to be addressed. They can also be interpreted as procedures to be followed. Currently there is a lot of confusion about what is meant here; the envisaged standardization procedures cannot make up for this lack of transparency.

Example 4: Life Cycle Analysis (EuP)

This has been deliberately written in small letters in the text suggesting that this should not be interpreted as necessary for the use of a LCA methodology. The life cycle assessment can therefore be done in a variety of forms. One is an Environmental benchmark based on physical quantities (e.g. kg, sec, kWh) as used by Philips (see chapter 6.3). Other methods include:

- LCA as described in ISO 14040
- Simplified LCA methods
- Hazard and risk assessment
- Decision matrices checklists, ‘spider diagrams’
- Life Cycle Costing

5.3. The role of EcoDesign

EcoDesign aims to fulfill certain functionality in the form of an embodiment (an artifact), which entails a minimum of environmental impact.

This definition also includes the EcoDesign of so-called ‘services’ which always include the use of physical embodiments or at least the use of physical infrastructures.

This need for embodiment leads to the fact that EcoDesign can reduce environmental impact but is simultaneously limited by the physics that must be applied to achieve functionality. For instance, TV pictures cannot be watched without a display, music cannot be listened to without speakers and PCs do not operate without memory.

The role of EcoDesign is widely recognized in EuP, IPP and WEEE; it even seems that the role that it can play is

overestimated. This is most apparent in WEEE, for instance for the 25 inch TV discussed in §5.2 the sales (functionality) value is approximately 600 €, while the 'value' which can be influenced by EcoDesign is something near 100 €, whereas the end of life cost is 10-15 € (design for recycling only).

From these numbers it is clear that economically speaking the functionality value is dominating in design decisions and lowering end of life cost by design will only happen if it does not jeopardize sales value.

Within the limitations sketched above, EcoDesign will deliver fast if there is a financial reward for it. This is either done through cost reduction or by enhancing sales in the market. On the other hand, it has been recognized that products which are presented as explicitly 'green' only appeal to a minority of the buying public. It would therefore be better that the reward for EcoDesign could be reaped through a system of tax breaks. In the opinion of the author this is an area which is still underdeveloped.

Within the field of EcoDesign several recommended design rules such as those given in EuP are conflicting. It should be realized that "you cannot have it all". Apart from the requirements to perform an environmental analysis which EEE does – it should also require that there are clear mechanisms in place to set priorities. The formula presented in §4 could be of help.

A few examples of trade offs to be made in EcoDesign are:

Example 1: PVC is a low-impact material and therefore advantageous in terms of materials application, however it could be a problem in the end of life phase.

Example 2: Modular designs are advantageous for reuse and recycling but generally require more material.

Example 3: Integrated functionalities make that material is saved; however energy consumption generally goes up (TVCR versus separate TV and VCR).

Example 4: Miniaturization of electronics will lower energy consumption but generally implies the use of more high impact materials particularly when precious metals are used (SMD electronics versus traditional electronics)

Many more of such examples can be given. The general conclusion from it is: design rules as given in EuP (and to be promoted under IPP) are at best generic; design solutions should be tailor-made.

5.4. Recommendation for Environmental Legislation on EcoDesign in China

From the § 5.1. – 5.3, it can be concluded that legislation could consider both the general scope of EcoDesign and more detailed fields like recycling and/or potential toxic substances.

A necessity, which is valid UNDER ALL CIRCUMSTANCES, is that laws addressing various aspects of the environmental impact of products are kept properly ALIGNED.

A further necessity, in the opinion of the author, is to address up front the operationalization and enforcement of the laws. This will allow proper integration with economical, technological, financial and societal items.

Also the task of establishing a proper definition of the role of EcoDesign deserves more attention - moving from the current, and rather philosophical, concept for universal cure of environmental problems to a strong tool that can be tailored to specific challenges. This will require quite some effort.

6. Conclusion

In this paper it has been demonstrated that Eco-Design can be moved forward by relatively simple means. The strategy comes down to introducing a lot of basics developed elsewhere, adapting them to specific Chinese situations, learning from the implementation experiences of others and improving where necessary.

It is expected that through this approach China can leapfrog and advance to the forefront of the way EcoDesign is operationalized.

7. References

- 1) The Brundtland Commission "Our Common Future", Report of the World Commission on Environment and Development, Oxford University Press, Oxford, UK, 1987.
- 2) Ab Stevels, Application of EcoDesign, Ten years of dynamic development, Proc. EcoDesign Conference, Tokyo, Dec. 2001.

Royichi Yamamoto: conceptual and practical

Royichi Yamamoto is the most prominent of the godfathers of Ecodesign in Japan. His vision, concepts, zeal and attention for practicalities, like the organization of the yearly eco-products exhibition, has had a big impact. You can only look at the whole of his efforts as a humble scholar.

When I had the honor to present the Environmental Award to Royichi at the 'Electronics goes Green' conference in Berlin, I took the liberty to say that he reflects many of the characteristics of a preacher in the Dutch Reformed Church. This is because he is able to teach the distinction between sin and salvation in the environmental world and between 'green' fates and predestination too. Most of all this is true because of his hard work - a Calvinistic diligence to pursuing his goals.

His environmental work has deeply influenced me and I am thankful for that. In the discussions we had, he always challenged me; please give me comments about the programs we are running and the policies we are pursuing in Japan. He is always eager to learn more, always driving to do better. This sharpens your mind as well, it forces you to come up with in-depth arguments.

The greatest learning is done when you are back home in Europe again. Apply the same type of analysis to your own activities ... and be honest!

The 'Yamamoto' Walk: Go with Yamanote (ring) line to Yoyogi station, enter the Meiji Shrine Inner Garden through an entrance at the northern side, have your thoughts at the Shrine (which is difficult and emotional for Dutch). Go to the Harajuku exit and cross the bridge over the railway and walk through the opposite shopping street to Omotesando station (Ginza & Chiyoda lines).

11.3 Electronics Recycling in China

Recycling is one of the top 15 priorities in the national economic strategy for China for the year 2020. The reasons are obvious:

- Lack of domestic resources, increasing world prices of commodities
- Control of potential toxics in products
- Development of a new type of industry which can be competitive in the world
- Employment, jobs.

Recycling issues in China are under guidance of the National Development and Reform Commission (NDRC). This is one of the highest-ranking bodies in the Chinese Government. It is directly linked to the Peoples Congress.

Currently a lot of recycling and reuse is already taking place. This activity has a bad image however both at home and abroad. A lot of initiatives have been taken to improve such operations, both from the perspective of labour conditions as well as from the perspective of increasing yields and controlling secondary waste. The most obvious strategy is to upgrade existing facilities and to invest in more advanced technologies. This is a sensible strategy in which leading universities, entrepreneurs, local, provincial and national governments are involved. The availability of low cost labor in addition to today's high resource prices will assist in speeding the development of a more effective sector. This will not be enough to bring electronics recycling activities to a level which will make treatment of electronic waste generated elsewhere in China acceptable for the stakeholders involved.

In the paper "An agenda to move forward electronics recycling in China" an agenda is presented that demonstrates how electronics recycling in China can be moved forward. It is concluded that to achieve economy of scale in operations it will be necessary to allow for and encourage further investments.

An agenda to move forward electronics recycling in China

Ab Stevels and Jin Hui Li

1. Introduction

Take back and recycling of discarded electronic products is receiving more and more attention worldwide. The reason for this is that is twofold. First materials are kept in the application loop so that resource depletion is slowed down. Second, the potential toxicity of materials can be controlled and the volume going into landfills can be reduced.

Take back and recycling activities also result in employment and will contribute to the reduction of the environmental load per unit of GDP.

It has been shown in ref. 1 that take back and recycling of discarded electronics can bring – when properly executed – substantial environmental gains for the money invested.

For China electronics recycling can have even more dramatic implications than in the fully developed economies. Already now the number of TVs and cell-phones sold in China supersedes the number sold in the USA, with PCs, washing machines and fridges soon to follow.

On the other hand a specialized Eco-efficient industry infrastructure for recycling is still under development. This offers the opportunity to leapfrog intermediate technologies and adopt the best available technology with investment.

Also driving take back through legislation is still under development in China. This will allow for the inclusion of improvements with respect to, for instance, the European Directive on Waste of Electric and Electronic Equipment (WEEE).

The competitive labor cost of China will allow them, when their high tech recycling systems are up and running, to attract electronic waste from other countries and treat such waste as well.

This paper will formulate a clear agenda for how to develop a powerful Chinese recycling industry.

In chapter 2 the basic legislative framework underlying the building of this new industry will be reviewed.

The baseline will be recycling systems for electronics already running in Europe and the European Directive WEEE. Departing from this, avenues to be followed will be sketched.

In chapter 3, the transformation of the current recycling industry in China into a specialized high tech industry and economy of scale are discussed.

Chapter 4 addresses collection issues – which in China are even more prominent than in the EU – and emphasizes the importance of achieving economy of scale in operations.

Chapter 5 goes in more detail about the recycling treatment.

Chapter 6 focuses on the importance and relevance of doing Pilot Projects in take back and recycling and therefore on the necessity to base take-back legislation on practical experiences as well.

The role of Design for Recycling is discussed in Chapter 7. It is stressed here that for the majority of electric products, the structural deficit in recycling cost will necessitate fees.

2. The basic legislative framework

Discussions about take back and recycling began in the early nineties. At that time there was still little practical experience with end-of-life treatment of big amounts of electronics. This has meant that the framework for - for instance WEEE – has been strongly based on the application of principles rather than being solution oriented.

At that time, making producers individually and totally responsible was thought to be the best approach. This was supposed to result in the producers adapting their product designs so that operations would be cost neutral (by now its obvious that this mechanism is not the right approach, see below).

Later it turned out that high volume treatment of electronic waste is a high-tech operation, which requires economy of scale. This means that the issue of collectively carrying out recycling while keeping competition in recycling operations needs much more attention.

Due to the very fact that the functionality to be realized in the production phase is being done very Eco-efficiently

during the production phase, the far majority of electronics have a 'structural' deficit in recycling costs, which cannot be eliminated by design. Particularly for plastic and glass dominated products this gap is enormous (between 0.50 and 1.00 €/kg in Europe) requiring fees needed for 'historical' waste but also for 'future waste' (see also ref 2). Of such costs up to 50% are related to transportation; recycling costs represent the balance (overhead costs generally are less than 10%). This means that in the opinion of the authors much more attention is needed for collection and transport.

The WEEE-Directive is also strongly based on the idea that 'treatment will do the trick'. This is ignoring the total life cycle concept that is only after reapplication of the material streams resulting from the treatment, the final environmental gains of recycling and the final level of toxic control achieved can be established. Output management (and monitoring of it) should therefore rank very high on the 'recycling agenda'.

In the early days manual disassembly was thought to be by far the best way to realize high recycling quotas, and to control substances. However, due to the complexity of electronic products (many of them have 1000 or more parts) the cost of such operations are unacceptably high, for instance in Europe. Even in countries with substantially lower labor costs, treatments like shredding followed by separation and direct smelting or thermal treatments need to be considered (and accepted when appropriate in environmental terms).

Even more adding to the diversity of approaches to be allowed is the observation (see ref. 1), that what can be achieved in take back and recycling strongly depends on the material composition of the product concerned. Products with a lot of precious metals (cell-phones, DVD's) produce the best environmental gains per amount of money invested (some products even have a positive yield). Metal dominated products (e.g. computers) are second best. Eco-efficiency is pretty low for glass-dominated products (TV, monitors) whereas plastic dominated products (many small electronic products score lowest).

Material composition (not application as the current WEEE does) is therefore an important basis for differentiated rule making.

Overall it can be concluded that take-back and recycling of electronics is a very complex issue: its underlying principles might be generic but solutions are certain to be tailor-made. Currently the Member States in the European Union are struggling to transform the WEEE basics into practical implementation rules for instance through the Technical Adaptation Committee (TAC) of the EU.

The draft Chinese recycling is currently a framework rather than a document providing detailed requirements. This leaves room for addressing much more directly the implementation issues as discussed above. These include

- a. attributing responsibilities
- b. fees, financial items
- c. reapplication of secondary material fractions
- d. monitoring
- e. diversity of treatment technologies
- f. differentiated rule making based on material composition

3. Transformation of the Chinese Recycling Industry for Electronics

Recycling of electronics waste has a long tradition in China. In ref. 3 the development of this industry has been described. There are several reasons why this industry currently has a bad image:

- a. Low-tech, resulting in substantial health and safety risks for workers amongst others
- b. Low yield/huge amounts of waste: there are no good outlets for fractions like secondary glass and plastics. As a result of this a lot of such materials are dumped as waste.
- c. Deficits in reprocessing and upgrading of secondary materials. As a result of this there is now a kind of stalemate situation in Chinese Electronics recycling: The Chinese Government has forbidden import of discarded electronics

However, importing are continues through informal channels with unknown, most likely insufficient, volume to develop the industry further.

As a result practices which result in poor health and safety conditions for workers and the generation of uncontrolled waste continue.

Since collection volumes of electronic waste from China itself are to stay low in foreseeable future (see also chapter 4), the only way to break the stalemate sketched above is to build high-tech recycling facilities in China, which are fed by strictly controlled imports of discarded goods.

Such an approach will benefit both China and the exporting countries (for instance of the EU) where legally mandated take back and recycling exists. Benefits for both worlds are specified below.

Table 1: Benefits of sharing recycling efforts

Benefits for China	Benefits for Exporting country
<ul style="list-style-type: none"> • Get extra resources for low prices • Employment, jobs • Leapfrogging to high volume • Do it right from the start with latest technology • If volume collected in China starts to increase, it can be easily accommodated 	<ul style="list-style-type: none"> • Stimulus for more collection • Lower cost of fulfilling legal obligation • More in depth disassembly (higher recycling rates for same cost) • Possibility to get back fractions for which there is Eco-efficient upgrading

Particularly in terms of material knowledge and qualified dismantling, humans can do a better job than machines. Basically this means that in China the financially optimal mix of disassembly and mechanical treatment can achieve, in total, a higher level of separation and thus do a better environmental job (as a result losses in the upgrading will be reductions as well).

Currently, Tsinghua University in Beijing and Delft University of Technology in the Netherlands are studying the environmental and economic effects of take-back in the EU countries, recycling treatment in China and upgrading of secondary streams in China and/or Europe.

This should form the basis of a joint effort between Chinese and European authorities, Investors, Recycling System Operators and Recyclers to develop a joint action plan to balance trans-regional take-back and recycling efforts.

4. Collection and economy of scale

Whereas in Europe current practice shows that in the 'old' EU Member States the target of collecting 4 kg electronic/inhabitant will be realized or will be realized soon, the picture in China is still quite unclear in this respect. This is mainly due to the following factors:

Sales of electronic products in China really started to take off after the years 2000-2005, particularly for private PCs.

The lifetime of products is expected to be longer than in Europe due to the fact that in China secondary and tertiary markets for products are very well developed.

Most of the collection of products discarded in China is done through private persons/organizations, which pay for discarded products.

To underpin these conclusions a number of statistics are given.

Table 2: Sales (in million) of electronic products in China.

Sales in Million	TVs	Fridges	Washing Machines	Private PCs
1995	12	7	8	<1
2000	25	10	11	2
2005	40	14	14	7
2010	50	15	16	20
2015	60	16	18	100

It is concluded from this table that sales of electronic products have increased substantially in recent years, with strong growth to continue in the nearby future, particularly for private PCs, where sales will really explode.

Simultaneously 'obsolesce' rates are low. With the obsolescence rate defined as the ratio between (obsolesce in year x /sales in year $x-20$) \times 100% a Tsinghua University study (see ref. 4) found that the ration is some 10-15% for TV's, Fridges as well as washing machines; for PCs so far no accurate figures are known.

This points to a much longer lifetime before products are discarded in China than in Europe. In the European region of the world products normally are discarded before less than half of their theoretical technical lifetime has passed. Reasons for this range from high repair costs to increased functionality demands to simple distaste for the product.

Reuse rates of products discarded by their first owner are high in China. It is estimated that some 90% of products of this kind currently bought by organizations/persons involved in repair/second hand trade – only 10% goes to public waste systems.

Of the 90% mentioned above 2/3 (60%) has been actively collected by individuals who go 'door to door'. The rest are sold to repair shops or traded in.

The difference in use (real technical end-of-life life versus prohibitive repair cost/unfit functionality) does not explain to the full extent the very low obsolesce rates in China. In order to do so it has to be assumed that large numbers of dysfunctional products are still kept by their last owners, traders etc. to harvest parts to repair other devices. Although no real numbers are known the empirical proof of this assumption can be seen when visiting 'second-hand electronic trade' markets for instance (which are held in the open air). In Beijing only there are some twenty-five of them.

Experience in Europe has shown that in order to set up a dedicated, high-tech recycling factory with sufficient economy-of-scale to justify full technology investment, achieve maximum value for secondary material streams and to ensure specific development of material reapplication, an input of some 50.000 – 100.000 tons of discarded electronics is necessary (see ref. 2).

In order to make China's, high-tech recycling 'self-propelling' (that is make it independent of imports after a start-up period) the issue of substantially increasing collection of discarded goods around the country is of utmost relevance. Using a return premium most likely is the best way to achieve this, provided that the premium is set (per product category) at the right level. On one hand it should be high enough to encourage the delivery of products, which no longer function. On the other hand it should not compete with reuse activities on complete devices. This will require a careful balance, as transportation has a substantial impact on recycling costs.

When working with return premiums it is therefore also necessary to consider, in detail, where and what premiums are offered.

It must also be realized that offering return premium will increase the recycling fees required (see also chapter 7) on new purchases.

5. Treatment

A general scheme for processing of discarded electronic products is given below:

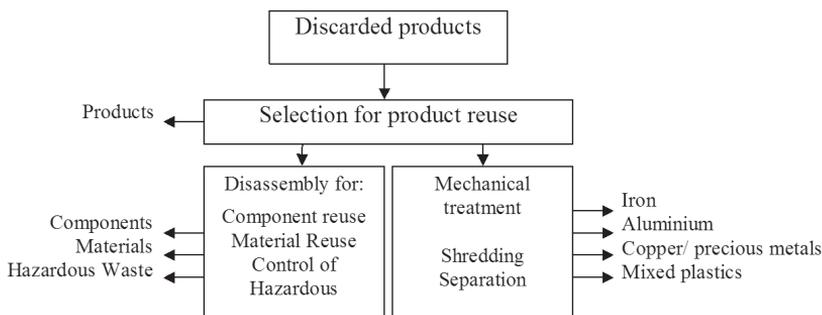


Fig. 1. Processing of discarded electronics.

In this figure it can be seen that the first step in processing is selection for reuse. The amounts in public recycling systems which are suitable for reuse are low in Europe, pointed out in chapter 4. Private reuse activities are on a much smaller scale as is the case in China. Subsequently products go in two directions:

- Disassembly; this mostly concerns products with a weight of 5 kg or more (see below);
- Mechanical shredding and separation. Most products with a weight lower than 5 kg go directly into this treatment – after removal of real potential toxic parts like batteries. To this stream fractions from the disassembly process (like printed wiring boards) are added to the process as well.

In Europe input to these two types of treatment relate to roughly 50:50 on a weight basis. Since manual disassembly is cheaper in China, it is expected that a much higher percentage of products will go into disassembly. This is demonstrated by the table below in which the amount of - materials to be disassembled in one minute - to be 'cost neutral' are compared. Costs of disassembly are labor costs^{1*} (which are in China a factor 20-30 lower) and upgrading cost of materials (including process losses) yield is the value of the material produced.^{2**}

Such a calculation leads to following results:

Table 3: Amounts in EU/China to be disassembled to be cost neutral.

Material	Cost neutral amount (price level 2003)	
	EU	China
Gold	0.05g	0.005g
Palladium	0.15g	0.015g
Silver	5g	0.5g
Copper	300g	30g
Aluminum	700g	70g
Iron	5000g	500g
ABS	250g	50g
PC	350g	70g
PDM	350g	70g
PS	800g	160g
PPE	800g	160g
Glass	6000g	600g

This table shows that the amounts of metals, which can be disassembled in China with neutral expenditure are a factor of 10 lower. For plastics this is a factor of 5. It is therefore demonstrated that in China for the same cost a higher environmental quality can be obtained (disassembly fractions are 'more pure' than the ones from the mechanical treatment) or alternatively, that the same environmental quality can be obtained at lower cost. On the other hand it should be acknowledged that electronic products are very complex and that disassembly of bigger parts cannot support all the deficits incurred with parts with a weight below the cost neutrality level of the table. Therefore investment in shredding and separation equipment (which precludes economy of scale) will be a necessity in China as well.

Another type of treatment required under the European WEEE is the one in Annex II, which involves removal of components containing Hg, brominated flame retardants (used for instance in Printed Wiring Boards), LCDs and batteries. In the early days of WEEE 'removal' was perceived by many to be the equivalent of disassembly. It has now been realized that such mechanical removal as such is an essential but not sufficient condition to achieve

^{1*} is 'full' labor cost including overheads, not including subsidies etc.

^{2**} assuming identical scrap prices on a global level.

big environmental gains. It all depends on what happens to the fractions removed. It has been demonstrated for instance in ref. 4 that the basic idea of Annex II, that control of potential toxics can be better fulfilled by 'integrated treatment', for instance putting cell-phones as a whole in a copper smelting process or controlled incineration of selected plastic fractions.

Currently, it is discussed how the removal definition in Annex II can be addressed in such a way that on one hand its essential goal is being fulfilled whereas on the other hand the purpose of Annex II will be allowed to be achieved by technologies, which are more Eco-efficient than manual disassembly.

In order to make this happen, such integrated treatments should be available in China and this should be price competitive as well. Investigation into this issue (and subsequent investment to fill gaps) will be an essential point on the agenda to make China competitive in recycling.

6. The eminent role of Pilot Projects

The previous chapters have shown that making rules for take back and recycling of electronics, organizing systems to make that happen, applying Eco-efficient technology and securing the best outlets for secondary materials is a very complex matter altogether. Even with all the insights, which have developed in the last years, it is almost impossible in practice to define the systems upfront. These systems should be well balanced with regards to their environmental ambition, economic aspects (cost), geography (logistics), product characteristics and industrial infrastructure.

Practical experience gained through pilot projects can be of great help. A good example of this has been the take-back pilot in the Netherlands, which took place in 1996/1997. The outcome of the pilot* has been that it brought to an end a huge debate and substantial disagreement among stakeholders on, amongst other things, principles of the take-back systems and its targets. On the basis of data from practice allowed to attribute in a natural way, the responsibilities of each stakeholder in the future system soon after the recycling law was approved by Parliament and (as of 01-01-1999) operations could be started.

The pilot also formed the basis for an assessment of costs, technology available and collection infrastructures. This provided valuable insights for its implementation and allowed for the formulation of improvement plans as well.

It is strongly recommended that in China the results of pilot projects have an important impact of the formulation of the implementation rules (the standards) for take-back and recycling law.

In contrast to the WEEE Directive, the current draft of Chinese Recycling Law leaves ample opportunity for this.

7. The Role of Design for Recycling, the necessity of recycling fees

Investigations of Delft University (see for instance refs.2 and 5) have shown that in order to achieve the best Eco-efficiencies** in take-back and recycling priorities are as follows:

Priority nr.1: Organize economy of scale of operations (and of competition between recyclers and between transportation companies)

Priority nr.2: Achieve higher environmental gains by special attention in high-level reapplication of materials generated.

Priority nr.3: Focus collection efforts on precious metal and metal dominated products (both in terms of environmental and economic value).

Priority nr.4: Design for recycling.

Contrary to the expectations in the early days of electronics recycling, it is now understood that design for recycling can only have a limited contribution relatively speaking. This is due to two reasons:

- In order to realize a certain functionality, (for instance TV pictures), certain physics (CRT, LCD displays) are required, which necessitates materials (glass in this case) which have high recycling costs.
- Use of plastics (with or without flame retardants) is widespread in electronics, because these are functional (and Eco-efficient) in the **production phase**. In a life cycle balance this phase generally prevails over the end-of-life phase. Such factors mean that for almost all plastic and glass dominated electronic products there is a **structural deficit** in recycling cost (in Europe it is estimated to be Euro 0.50/kg of which Euro 0.25 is transport and overhead) which cannot be bridged by good design for recycling.

There is a strong argument to have (visible) recycling fees paid by the consumer in the period of 'historic waste' but also for waste of products, which still have to hit the market.

In the last decade substantial progress has been achieved among leading brands in reducing disassembly times of products. For instance for TVs this time has been reduced by a factor of 2 (when comparing products from 2005 and 1995). This result was chiefly driven by the desire to reduce assembly costs. The drive has meant that the difference in recycling costs for comparable TVs of leading brands are now within a range of 15% only with a further reduction potential to some 10%. Therefore the issue of rewarding strong EcoDesign – which was still very relevant 10 years ago – has virtually vanished. In conclusion, the clear point on the agenda for China should be 'how recycling fees charged to the buyer of new products can be best introduced into the market.

In spite of all this Design for Recycling is still an issue. However it is one for the laggards rather than for proactive companies, which have already successfully dealt with it.

8. Conclusions

It has been shown how take-back and recycling of electronic products has developed in the last decade from a seemingly simple issue to a very complex one. The good news is that it has become clear that if there is a good interplay between four items (listed below), very good results can be obtained:

- Legislation
- System organization:
 - Collection
 - Treatment
 - Output management
- Technology
- Design

Europe is gradually but increasingly moving forward – replacing on the rigid principles of the past with a flexible approach focusing on results.

China has the opportunity to leapfrog a lot of this. However, it must adapt to its own specific situation while introducing high-tech and worldwide competition.

The challenge, the agenda to do this is huge, but the rewards will be great!

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* The Report on this project is available through ranta@xs4all.nl.

** Eco-efficiency is defined here as the ratio between environmental gain and cost.

“This never would have happened in Sweden”

The way in which many PhD candidates in the field of environment operate is often an awkward mix of science, opinions and emotion. There is a good reason for this. It is basically impossible in this field to develop your deliberations into 100% scientifically proven conclusions. This is due to the fact that ‘green’ has at least three dimensions (see chapter 6.1). So, what is finally determined to be most important or to be prioritized is partially subject to some degree of personal judgment.

The environment is a societal issue as well and has to be seen in that context. A scientific basis is helpful to more effectively analyze the issues, but in the end, belief regarding what is best for society is the real deciding factor.

This is a basic problem in assessing PhD dissertations as well. Are these supposed to contain only ‘proven scientific truth’ or should it also demonstrate that the PhD candidate is capable of ‘conducting research independently and successfully’? The rules of Delft University have addressed this issue and give clear guidance: proof of independent research is the ultimate yardstick (which also includes that the promoter/supervisor should not necessarily agree with the results). However, regulations at other universities do leave the issue more unresolved, which can create uncertainties.

Location: NTN University, Trondheim/Norway. The PhD candidate had written a dissertation on improving the environmental performance of industrial products through product service systems. It was a mix of a great analysis, detailed synthesis (with recommendations) and opinions (regarding how things should change) however, there was little evidence of testing regarding whether their concept of the ‘big leap forward’ could be realized in practice. It was a stimulating dissertation. It was holistic, with a gold mine of ideas yet it lacked empirical evidence that it could be done in practice. So, how this should be judged? The supervisor and promotor realized this problem long before the defense was due. Long before that moment all committee members had long discussions with the candidate and as a result many changes were made. The content of the work became better and better, but the basic problem as described above had not been resolved. After two years of debates the conclusion was finally: this stuff has PhD potential, let’s go for the defense.

There we sat as a committee. It was a problematic afternoon; there were questions and answers on different wavelengths. Anyway, challenging questions were met with a stiff defense. What was missing were the sparks that ignite real debate and it dragged on until the end.

In contrast to the Netherlands, in Norway writing of a letter of approval before the defense does not necessarily mean that you support the doctorate to be awarded, so in the committee meeting after the defense there was plenty at stake.

The opening salvo came from the Swedish committee member who said, “In Sweden, a doctorate would not be awarded in this case.” He had a point, where is the scientific proof, where is the convincing defense? The Norwegians countered by pointing to the originality, creativity and the ambition of the candidate. As a Dutchman I stayed out of the discussion because I felt an undertone of Norwegian-Swedish rivalry similar to the one that exists between Belgium and the Netherlands. Discussion carefully moved in circles and was not conclusive. It kept going on, 15 minutes, 30 minutes, 40 minutes. In the corridor next to our room, where family and friends were waiting, it became more and more noisy...They asked, “What is going on?” After 45 minutes, I decided to step in. The Delft PhD regulation rescued the candidate: there has been proof of independent research capabilities. This was the deciding factor. The doctorate had to be awarded by a vote, majority against minority.

We had scratched at the essentials of environmental research. Is it a truly academic discipline, is it science supported creativity or is it a kind of applied engineering management?

Who knows?

Chapter 12: The Future of Applied EcoDesign

In general, for a bright future of (Applied) EcoDesign a lot will depend on the capability of its practitioners to take the functionality value concept - as explained in chapter 2 - on board. There is a real paradigm shift in modern Applied EcoDesign thinking: one must contribute to value first and through this to eco, rather than the reverse. This will help to overcome feelings of 'saturation' in industry, where it is often asked, "What can we do more than we already are doing?" It will also help to overcome the feelings of crisis in academia: Why does the industry not take our concepts on board? In addition, it is also hoped that the implementation of the functional value concepts will prevent EcoDesign from shrinking to merely a compliance issue.

In the field of Applied EcoDesign quite a few opportunities will emerge, either within or outside of existing fields. My expectations and suggestions for the future are summarized below.

Chapter 1. Introduction / Times have changed.

A lot of people in the field are still stuck on ideas, beliefs and concepts which now belong to the past. This results in confusion, fruitless discussions and sometimes disasters (like for instance the implementation of European Directives). In particular, academia has a role to play in bringing interested stakeholders up to speed. This also means that Universities need to accept that EcoDesign activities are much more than just 'nice to have' in their programs and need to organize and to commit budgets accordingly.

In the industry there is currently a strong tendency to a 'compliance only' attitude. In principle this is an opportunity for those wanting to take a productive attitude. In practice it is difficult to row against the tide.

Chapter 2. EcoDesign.

Apart from more emphasis on functionality thinking (see above), it is expected that the EcoValue concept will get a bigger role. It can assist in making much more focused product strategies. However, a lot of work will have to be done to make this concept operational.

Governments will realize more and more that lowering the Eco-impact per unit of GDP (in fact this is a societal EcoValue approach) will be the only holistic concept on which to base a comprehensive set of environmental policies. All other starting points will lead to suboptimization or unbalances.

A new subject to be researched in this respect is SocioValue, which is a ratio between environment load and monetized social effects. This parameter could also play a role in assessing progress in a wider sustainability context.

Chapter 3, Design for X

Lowering energy consumption in general and design of low energy products will dominate the environmental scene in the near future. For research supporting activities in this field an extensive agenda has been formulated in chapter 9.3.2.1.

Issues regarding inorganic materials get a revival at the moment it is recognized that resource issues deserve a position on the agenda which is equivalent to the one for emissions. A research agenda for this subject is proposed in chapter 9.3.2.2.

Potentially toxic or hazardous substances have a highly emotional perception. It remains to be seen whether through carrying out a research agenda as formulated in 9.3.3.3 these issues can be transformed into forms of risk management.

For packaging and transport issues no research agenda has been proposed. In this field commercial issues, like the sales and the experience function of packaging, will supersede the environmental items. Nevertheless, in the field of packaging and transport, the traditional landscape has dramatically changed. From an environmental perspective, this makes it worthwhile to revisit this seemingly uninteresting field.

A general issue which would be worthwhile to address, is how the physics underlying the realization of functionality poses a limit to EcoDesign. In particular it would be interesting to find metrics which can describe the environmental gap between a current design status and what physics allows.

Chapter 4, Environment and Business.

Real business integration of environment has only been realized in a few electronics companies. Many of such companies still see EcoDesign as an effort and a cost to be spent on defensive and compliance-oriented issues. The opportunity dimension is clearly missing, which means for all that a lot of work can and needs to be done.

Chapter 5, The Value Chain.

Value Chain issues got so far little attention in Applied EcoDesign. It is still seen as a chiefly technical item. As shown in this book, the proper management of internal and external value chains is at least a condition for success. It is recommended that Business Schools engage themselves more into this subject.

The future of green supply chain management is in fact go 'back to the past'. Many supplier relations have impoverished to goods for money transactions only. Enriching these relations to address common immaterial issues will lead to mutual enhancement and will be fruitful in many respects. For EcoDesign it is even a necessity to make steps forward. How to make road maps is a very practical but also an interesting research subject.

Chapter 6, EcoDesign tools.

With the passage of time realism will also make progress in the EcoDesign tool discussion. The perception that there are no 'one size fits all' tools is making headway. Also the insight that there is a relationship between the nature of the tool and the goals of its application. Tools for enhancing creativity are different from validation, tools to support managerial decisions are different from the ones aiming to find the real environmental truth. There are absolute and relative tools, there are tool to prove to be right and there are ones to help to get it right. Focus of tools can be on emissions, on resources or on environmental risk.

In the future, tools will be judged more and more on their ability to generate agendas for action and for their ability to link environmental with economic issues.

Chapter 7, Take back and Recycling.

Take back and recycling of electronic products will take place in more and more regions in the world. It will be either in an Eco-efficient or in an Eco-inefficient way, either in systems with a wise balance between collection, treatment and upgrading targets or in systems with unbalanced requirements. The reason for the occurrence of an awkward mix of systems is the high amount of politicking around take back and recycling. In order to improve systems it will be necessary to go back to basic environmental issues and also to include economic considerations. A common basis for understanding these items is still lacking. Research items relevant for this purpose are listed in chapter 9.3.2.

On top of that, applying the QWERTY concept (chapter 7.4) for an analysis of remanufacturing/ reuse/ material recycling issues will be highly interesting. Also a split into QWERTY positive (recycling part) and QWERTY negative (amount of toxic control achieved) may be very relevant for practice.

Chapter 8, Organizing take back and recycling.

It is expected that the fad of having 'beauty contests' and other discussions about the merits of various types of system organization (individual, collective, semi-individual/collective) will gradually stop. Realism will supersede ideology and pragmatic approaches will prevail. Also here, the idea that there is no one size fits all is gaining ground.

Tension is to stay between minimizing costs of treatment and maximizing their environmental value. Eco-efficiency concepts will show the way here.

An issue to stay is the question who pays what. It will take a lot of wisdom and a lot of value chain management to balance this properly.

Chapter 9, Legislation.

For European WEEE it has already been recognized. For other environmental legislation it will soon turn out to be necessary. Regular review of environmental legislation of electronics is a must. This is because of the complexity of electronic product systems and because of the rapid developments in scientific insight, in technology and the ideas of the various stakeholders.

Governments have so far addressed the supply side (the industry) for environmental issues. It will turn out that in order to make further progress the demand side (how are consumers spending their money) will be just as important. This will pose challenging dilemmas with regards to setting boundary conditions for free markets and as regards tax systems (taxing consumption instead of income).

Challenging dilemmas also exist for legislators in the environmental domain itself:

- resource conservation (liquid hydrocarbons, natural gas) versus emission control (CO₂)
- resource conservation versus potential toxic control (lead free soldering, Light Emitting Diodes)
- emission control versus potential toxics control (LCD TVs, energy saving lamps)

Such dilemmas are a subset of more general input versus output dilemmas:

- supply side action versus demand side action
- reducing consumption versus maximizing recycling/ hazardous control
- maximizing recycling versus maximizing toxic control.

Chapter 10, Teaching.

Integration of 'Eco' into existing university curricula is still in its infancy. In fact most of the dedicated eco classes, for instance at the Industrial Design Engineering Faculty at Delft University, will become superfluous if integration would have been realized. Through such integration, 'Eco' may also give valuable perspectives to general courses like: Design for Value Creation, Design and Supply Chain Management, Design and Quality Management and Design for Managing Experiences. In Delft, EcoDesign can also play a role in other faculties/schools like Mechanical Engineering, Earth Science (Recycling) Technical Management, etc. It is hoped that in the future the administrative and psychological barriers for doing so will be taken away.

For universities elsewhere in the world similar remarks are highly relevant, see also chapter 10.2.

Chapter 11, China.

China is and will be fascinating. Also in the field of environment there are a lot of challenges to be dealt with. China can be a source of inspiration and learning for the Western world. Go there with an open mind and there will be plenty of rewards.

Chapter 12, The future of the Profession.

From the developments in the field of Applied EcoDesign in electronics, it can be concluded that also the profession of environmental designers/ engineers in industry has dramatically changed in the last fifteen years. It has developed from a technical expert in the environmental department, trying to implement generic solutions, to a process manager with the whole company as his/ her territory. In the future this will evolve further into the role of a communicator addressing the complete value chain while having sustainable solutions for society in mind.

Parallel to this, in Academia, EcoDesigners will be less and less focused on design itself. More attention will be paid to mobilizing enabling-technology and generating system solutions which have societal Ecovalue. In consultancy there will be a shift from design supporting to planning and road mapping to audit and review.

For all categories, focus of environmental activities will also shift from the supply side to the demand side. Also the 'old' issues are there to stay, but are gradually losing priority to new items.

How do I feel now?

Applied EcoDesign helped me initially to survive the bloodletting reorganization at Philips Consumer Electronics in the early nineties. Contrary to my expectations, it soon became a fascinating field. Next to technical items, managerial and communication issues were to be addressed. Philips Consumer Electronics generously supported my development in the field and even allowed me to accept the part-time professorship at the Faculty of Design Engineering at Delft University. There I was back at the roots of my career: scientific curiosity. Soon graduation students and Ph.D. candidates challenged and inspired me as well; I worked (too) hard and traveled (too) much.

Delft turned out to be a springboard for all kinds of international activities. Amongst other things six visiting professorships were a result of this.

Philips Consumer Electronics has benefited a lot from all this. Delft could have done better in this respect. Inward looking attitudes and organizational weakness have prevented better use of the results.

And now? Time for a new generation to take over. They will do it, in their style, like I had mine. I retired officially from Philips CE at September 1, 2004, but stayed as an advisor. This stopped September 1, 2006, at the moment I had been associated for 40 years with "The Company".

On December 1, 2007, I am up for reappointment at Delft, but have decided not to be eligible anymore. Time to stop after 12 years; my farewell address has been planned on November 30, 2007.

For me "Applied EcoDesign" has been a wonderful window of opportunity. I started from scratch, a lot has been realized.

Time to wind down.

Vienna, old and new, but nostalgia prevails

Austria is an environmentally friendly country. After Denmark it ranks at the top in the world. Vienna is clean too. It has excellent public transport and has many beautiful, well kept parks.

Partly this is due to the fact that industrial activities have moved elsewhere: to nearby Hungary, to Eastern Europe (more generally) and to Asia. One of the most dramatic restructurings of Philips Consumer Electronics took place in Vienna. Video-recorders used to be produced there – a high tech product with a lot of know-how. Production has been discontinued, and the production of DVDs had been relocated; thousands of jobs disappeared. Audio production had been moved already earlier.

A lot of fine work in the field of environment has been pioneered in Vienna as well. The first radical waste reduction, 'green' investment in machines (a great concept which has found limited application elsewhere) and Ecodesign efforts were done there. Implementation has been one of the best efforts ever seen inside Philips Consumer Electronics. The annual local environmental seminar, where I was a guest, had always been stimulating and creative. Then there is this typical Viennese atmosphere, the always pleasant 'Schmäh' and the bitter but great humor ('keine Welle') and the sense of fatality in the end: 'Ana hat immer dass Bummerl, Ana wird immer verlieren' ('somebody always gets the bangs, somebody will always loose'). That is what happened in Vienna in the end. The Philips factories at the Guthell Schödergasse do not exist anymore. It was sad. It was inevitable. It was a great waste of talent as well.

Vienna is also the centre of interesting 'green' initiatives; the Ecolife programs, the CARE conference on 'green' electronics every four years, and challenging programs at the university. It was always a pleasure to be there, to have an exchange with others, to learn and to contribute.

In the city, I love the trams of Vienna most of all. Just step in and be moved around. Enjoy the sounds, enjoy the announcement of the transfer possibilities. I used the trams for transport but also to write publications. While being moved between the two terminuses a lot of work can be done, just go up and down until you have finished. Occasionally you look out of the window. What you see is old or new but all of it has some nostalgia. Maybe because it is Vienna, maybe because you sit in a tram (or maybe both). Chapter 6.2.1 is a tram publication made on line D. Line 60 and 38 work well for shorter reports.

City walk: Start at the Karlsplatz, in front of the University of Technology, go L Treitlstrasse, go L Rechte Weinzeile, go R walk across the Naschmarkt or Linke Weinzeile, go straight to Friedrichstrasse, Operngasse, go L Opem Ring, Burg Ring, go R to Heldenplatz under the palaces to Kohlmarkt, R on Hoher Markt, L on Rotenturmstrasse; R to Griechengasse, R to Postgasse R and L Rievergrasse, R Singerstrasse, L to Kärtnerstrasse and back to Karlsplatz.

Favorite restaurants: Wiener Heurige, anyone is good! Best is 10erMarie (in the suburb of Ottakring).

Country walks: In spring, summer: go by tram 66 to the terminus (Rodaun); do walk VI, Zugberg, Maurer Wald. In autumn, winter: go with tram D to the terminus (Nussdorf); do walk I, Kahlenberg.

Stanford University: Scoring is running the Flag!



Curriculum Vitae

Albert Leendert Nicolaas ("Ab"). Stevels was born in Eindhoven (The Netherlands) on Aug. 31, 1944. After Grammar School he studied Chemical Engineering at the Technical University of Eindhoven and took a Ph. D. degree (cum laude) in Physics and Chemistry at Groningen University.

As of Sept. 1969 Ab has worked for Royal Philips Electronics in a manyfold of capacities in research on materials, production technology of glass, as a business manager in electro optics and as a project manager for jointventures and licenses in Asia.

On Jan, 1, 1993 he became a senior advisor in Environment at the Environmental Competence Center of Philips Consumer Electronics.

In December 1995 Ab was appointed as a part-time professor in Environmental Design at Delft University of Technology. In the fall 1999 he was visiting professor in the Mechanical Engineering Department of Stanford University, in the fall of 2001 he was visiting professor at the Faculty of Electrical Engineering of the TU Berlin, in 2002 he was visiting the School of Industrial Systems Engineering at Georgia Institute of Technology (Atlanta) , in 2003 the Industrial Ecology Program at NTNUniversity in Trondheim, Norway and in 2005 at Tsinghua University in Beijing.

This was followed by shorter stays at Hong Kong Polytechnic in 2006 and TU Ostrava in 2007.

Ab Stevels has done trailblazing work in how to make Eco-design into day-to-day business really happen and has researched in detail the setting up of take-back and recycling systems for electronics For these purposes tools and management procedures have been developed which have proven their strength through their practical success.

Ab is the author of some 180 journal articles and conference contributions. This training courses on applied Eco design have been held at various universities (Delft, Stanford, TU Berlin, TU Vienna, TU Ostrava, the University of Arts and Design , Mexico City, Hong Kong Poly,NTNU), Tsinghua Univ Philips departments and divisions around globe and at other companies.

Ab is married to Annet Stevels-Ekering as of 1968. They have three children : Wim, Jolien and Lenno and six grandchildren : Vera, Jorin, Mathijs, Mick, Marit and Tess.