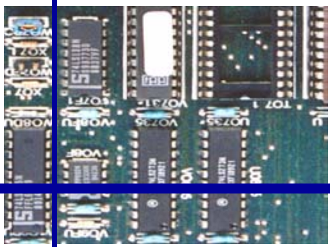
ECOLIFE Thematic Network



ECO-DESIGN GUIDE

ENVIRONMENTALLY IMPROVED PRODUCT DESIGN CASE STUDIES OF THE EUROPEAN ELECTRICAL AND ELECTRONICS INDUSTRY

Eco-design subgroup

July 2002

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The ECOLIFE Network

ECOLIFE NETWORK

ECOLIFE was a Thematic Network, supported by the European Commission under the Fourth Framework Programme (Brite-EuRam) between November 1998 and April 2002. Its mission was to close the loop of electronic products and domestic appliances by focussing on the product life cycle from eco-design to End-of-life technologies. It contributed to the elimination of, or at least mitigation of, major environmental problems by developing a series of solutions of wide ranging and general applicability to the electrical, electromechanical and electronics industry.

The aims of ECOLIFE were to strengthen European industry and to promote European leadership in environmental technologies by:

- Facilitating more efficient research and co-operation;
- Defining the "knowledge gaps";
- Co-ordinating work-related research to "fill the gaps", showing the interrelations between the various items addressed in the Thematic Network.

ECOLIFE originated from three networks that started in 1996/97:

- DFER - Design for Environmental Concerns and Materials Recovery: Application in the Electromechanical and Domestic Appliances Sector (1996);
- AREP - Advanced Recycling, Recovery and Reuse of Electronic Parts (1997);
- ENSURE - Environmental Impacts of Consumer Products During their Life Cycle. (1997).

The ECOLIFE Network consisted of 28 partners – including producers, SMEs, recyclers, and research, academic and scientific institutions from 10 European countries.

OBJECTIVES

- Main goal: to facilitate efficient research and co-operation among partners: each member conducted individual research work and at the same time participated in the Network;
- Follow up state of the art developments in order to identify opportunities and main gaps in this area;
- Improve the dissemination of data and pilot experiences within SMEs;
- Meet legislative targets relating to collection, recycling and reuse of products, components and materials, concerning the Electronic Waste and Hazardous Substances Directives that will come into force in the near future;
- Co-ordinate with other projects in this field, in particular with EU, EUREKA and national projects focused on eco-design, or investigating the possibilities of re-using and recycling components and materials from electrical and electronic products and domestic appliances;
- Development of a Best Practice Guide of the different stages during the life cycle of electrical and electronics goods. This "Eco-design Guide" focuses on reducing material use, avoiding the use of environmentally hazardous substances, facilitating maintenance, facilitating recycling and providing environmental data for marketing and recycling.

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Contents

Scope

This Guide tells the story of eco-design using case studies from the electrical and electronics industry. Successful eco-design needs information, as well as examples, to inspire those active in this area. Although there is already plenty of information available from academia as well as from industry (see bibliography), there is a shortage of well documented examples. To overcome this deficit, as part of the ECOLIFE Network, we have collected a number of case studies. While not all of them are success stories, and while not all of them are perfect examples, practical case studies, such as those presented here, are often more useful than theory and provide an invaluable learning experience.

It is frequently argued that the move towards sustainable design needs to be built on three pillars: ecology, economy and society. The companies involved in this Guide have made progress on the first two of these pillars and are beginning to address the third.

We hope that this Guide will give confidence to others to attempt eco-design in practice. All design activities, although presented here as the products of organisations, are in fact the work of individuals, usually working within an organisational framework. Eco-design has many cross-functional aspects which can be tackled best by involving other disciplines within an organisation, for instance by forming inter- and intra-departmental teams in which not all the members will be designers or engineers. Here, we give examples of new product development frameworks in an attempt to encourage individuals to promote eco-design further.

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Introduction

Environmental considerations in industrial activities have been growing continuously in importance since the first oil crisis of the early 70's. First attempts to find solutions to regional and global environmental damage consisted of developing environmental technologies ("end-of-pipe" treatments) to manage, control and treat waste from industrial activities in the environment. At the end of the 70's, the concept of pollution prevention[1] emerged as an economic alternative to end-of-pipe solutions. The focus of pollution prevention is on establishing a conservation-oriented technology, which not only involves raw-material supply and production, but also – in the first instance – consumption and disposal of products [ROYSTON 79]. Even with such efforts, threats to the environment have still grown. With the emphasis placed on sustainable development in 1987 [BRUNDTLAND 87] the concept of pollution prevention has been widened to cover all industrial activities, the complete product life cycle, and all other human activities affecting the economy, the environment, and society.

In the electronics industry the initial responses to these trends were mainly of a defensive nature, directed towards compliance with legislation and towards preventing a negative image developing in the press and with the public. Emphasis was therefore on issues such as eliminating banned substances, cleaner production, recycling of packaging, and power management for the standby mode [STEVELS and al. 2000].

Soon afterwards, it was realised that the pro-active approach of systems thinking in the form of eco-design could lead to direct cost reductions as well as to environmental improvements. This pro-active approach is gaining momentum. The basic idea behind it is to increase sales by bringing to the market products having both a good environmental performance ("social benefit") as well as a good performance for the individual customer ("customer benefit"). It is expected that this development will continue, from product improvement to productive system innovation (Figure 1).

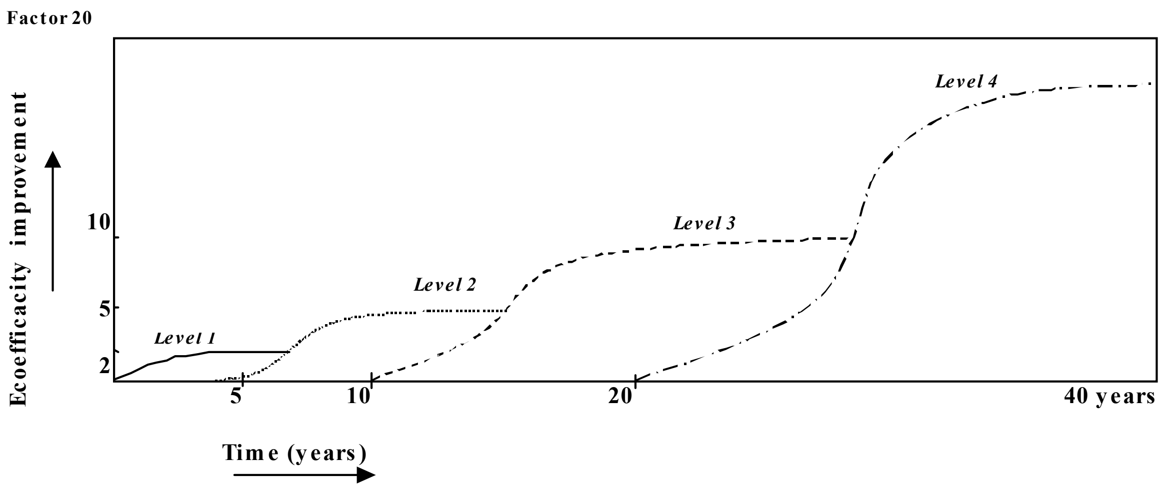


Figure 1: Four levels of eco-design [STEVELS 1996] and [BREZET et al. 1997]

Note 1: 🕮 This sign means that the term is explain in the Terminology section page 55.

Four levels of eco-design can be defined as follows:

- Level 1: product improvement: this is a progressive and incremental improvement of the product, a re-styling of the product; for example, it can consist of decreasing the use of materials or replacing one type of fastener by another;
- Level 2: product redesign: a new product is redesigned on the basis of an existing product;
- Level 3: new product concept definition: this is an innovation rupture as technical functions to fulfil product functionality are different.
- Level 4: new production system definition: this occurs when innovation in the productive system is necessary.

This is the background to this Eco-design Guide for the electrical and electronics industry. The Guide provides state-of-the-art examples of industrial practices in advanced companies, and seeks to motivate people in industry and academia to follow these examples and to explore the issues that they raise.

To reflect the most relevant aspects of eco-design, this Guide is structured into five sections, each of which focuses on a major principle of eco-design. Figure 2 shows these principles and their interrelations.

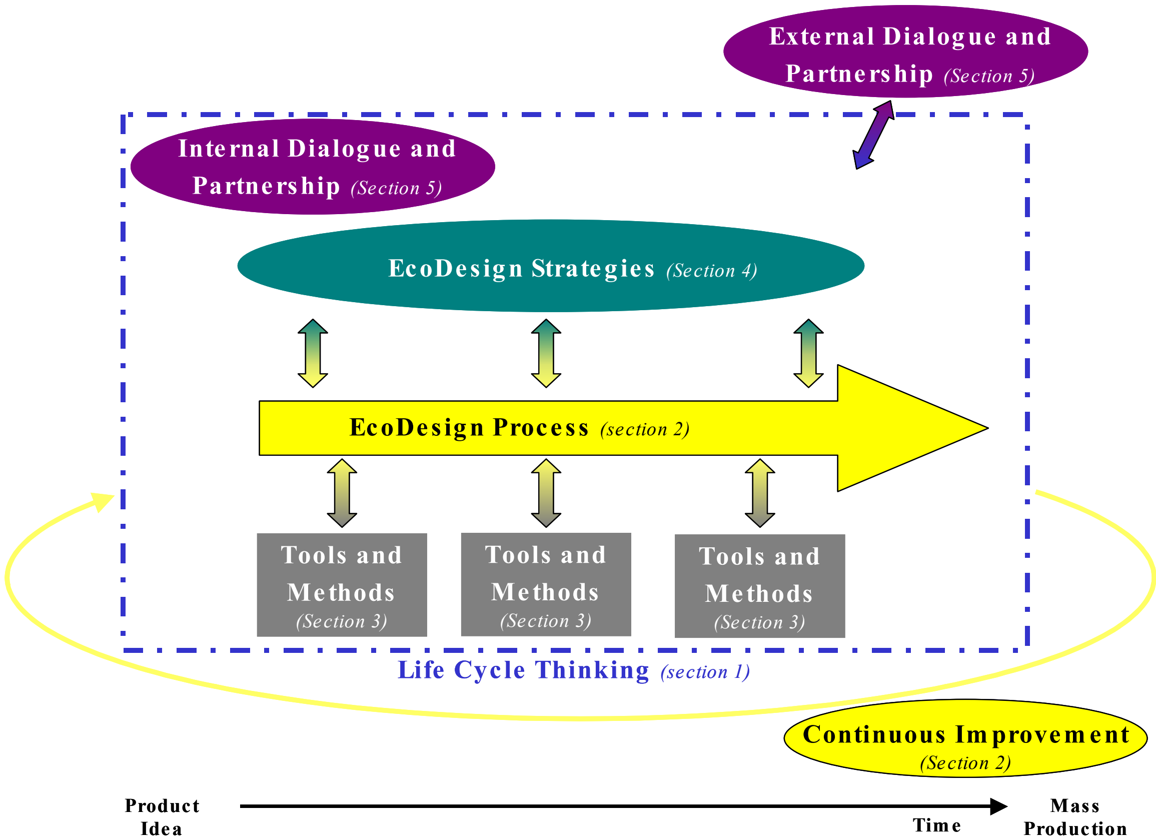


Figure 2: Schematic representation of the 5 eco-design principles described in this Guide [ECOLIFE 01]

In subsequent sections the five eco-design principles are described and illustrated with extracts from Case Studies. The full Case Study reports are presented in the Appendices.

1 - LIFE CYCLE THINKING

At the heart of eco-design is the concept of the product life cycle. It starts with resources taken from nature, goes on to the production of materials and product/component manufacturing processes, the use and maintenance of a product, and concludes at the end-of-life stage ("cradle to grave" approach).

In the past, industrial efficiency only dealt with labour productivity. Nowadays, the emphasis is on resource productivity: doing more with less. Many authors have described the Factor 4 or 10 concept, or even higher factors (see Figure 1), which focuses on the reduction of the resource input to products and services. In parallel the reduction of resource use leads to a reduction in emissions to air, water, and land (waste), because emissions can be understood, and subsequently managed, as unused resources.

'Life cycle thinking' takes into account all the environmental aspects that occur in the complete life cycle of a product. These include energy consumption, materials application, chemical substances, durability, reusability/recyclability, packaging, transport, etc. The complete life cycle includes mining and materials production, production of components and subassemblies, assembly of products, and the reuse and discarding of products. Finding eco-efficient solutions, on the basis of life cycle thinking, is encouraged nowadays by legislators, especially in the European Union (see, for example, the WEEE Directive, the EEE draft directive, and the discussion on the IPP proposal). One way to achieve eco-efficient solutions is by the “producers’ responsibility” principle, under which producers are made legally responsible for parts of the life cycle outside their traditional domain of manufacturing; for instance packaging waste, and products discarded by consumers.

Training designers in life cycle thinking is straightforward. The environmental impacts of products and services can be identified throughout the life cycle, and action can focus on reducing the relevant impacts (although these priorities are set not only by scientific considerations, but also by commercial and political goals).

Life cycle thinking is a holistic view. Design options should not have a reduced impact at one life-cycle stage at the expense of increasing the impact on the complete life cycle. Therefore trade-offs between design options, as well as between stages of the life cycle, have to be examined carefully.

Consideration of the entire life cycle can help ensure that [ISO 2001]:

- No materials are arbitrarily excluded;
- All the environmental and economic characteristics of a product are taken into account;
- Consideration is given to impacts generated by intermediate products, for example, emissions in manufacturing, which are not part of the composition of the finished product;
- Focus is not only on the environmental impact of the product itself, but also on the system in which the product will perform;
- Environmental impacts are not merely shifted from one life cycle phase to another or from one medium to another: for example by eliminating an air pollution problem a solid waste disposal problem may be created instead.

1.1 THE CONCEPT OF 'LIFE CYCLE THINKING' - OVERVIEW

A life cycle approach should be able to define the best design strategy in order to reduce the environmental life cycle impact of a product. This can affect the life cycle stages of a product as follows:

- Extraction of raw materials;
- Production of materials;
- Manufacturing of parts;
- Manufacturing of semi-finished products and components;
- Assembly of the end product;
- Distribution;

- Use and maintenance;
- End-of-life treatment (reuse, disassembly, material and chemical recycling, energy recovery, ultimate disposal).

Although it may be useful to define the relative importance of the different life cycle phases for a specific project (based on past studies or experience), it is advisable not to focus on a single phase beforehand in order to avoid an adverse shift in environmental impacts from one phase to another. Minor shifts, however, might even be a useful strategy if the environmental performance of the complete life cycle is improved.

The Flymo Lawn Mower Case Study illustrates the importance of designers understanding the environmental impact at all stages of the life cycle of their product.

Case Study 1 a – Flymo Lawn Mower
LCA study post launch

the MANCHESTER METROPOLITAN UNIVERSITY

See APPENDIX 6

Written with the contribution of ***Matthew SIMON*** *and* ***Stephen POOLE***

Designers have always given much attention to the use phase of their products. The ergonomics will have been studied carefully in order to make the product easy and comfortable to use. However, few designers will have fully analysed the environmental implications of the choices open to the user. This Case Study shows that a lawn mower's environmental impact can be totally changed by how the user chooses to operate it.

The life cycle assessment on a new design of mower produced two results that were not surprising: energy consumed during use is a concern and there are burdens associated with material acquisition (in this case primarily copper). However, if the scope of the LCA is broad, it can be argued that the implications of grass cutting disposal should be incorporated – it is the lawn mower that makes it practical for the user to cut, collect, compact and dispose of the grass. If the user chooses to dispose of the cuttings in the municipal waste stream, there are obvious ramifications in the landfill site. To give a scale to the potential problem, organic waste is estimated to account for 22% of the UK's domestic waste stream. No estimation has been made regarding what proportion might be grass cuttings, but it clearly has the potential to be very significant from properties with lawns.

Given this knowledge, there is one important feature that the designer of lawn mowers should include to minimise the total product's impact. Probably the environmentally preferred choice regarding cutting disposal is to simply leave the cuttings where they are – on the grass – where they will mulch and decompose benignly (with the extra benefit of thus fertilising the lawn). This is only possible if the design is such that the user has the choice of removing the grass collecting equipment: if grass collection is enforced, dispersal *in situ* is not an option.

The other preferred option for cutting disposal is for the user to compost them. This could be encouraged by providing free or discounted composting bins with the mowers, but this requires a company-wide and retailer commitment and is well beyond the remit of the designer. Clearly, both the preferred options require knowledge and commitment from the user.

A final point is worth making on this Case Study. It illustrates the difficulty of incorporating qualitative issues in life cycle assessment. Marketing studies by the manufacturer indicated that in the public's perception, the greatest environmental impact of lawn mowers is noise.

Thus, the environmental impact of a product has to be taken into account considering its life cycle and its function.

1.2 TRADE-OFF CONSIDERATIONS THROUGH LIFE CYCLE THINKING (MULTI-CRITERIA APPROACH)

As much as possible the designer has to take into account the potential impacts in terms of the use of resources and discharge of pollutants in every part of the environment (water, air, and soil). Other criteria such as odours, land use and damage, noise, radiation, etc. might also be considered. The complete range of different potential impacts has to be taken into consideration through a multi-criteria approach [ISO 2001].

This multi-criteria approach helps to avoid displacing one type of environmental impact by another. In this context any arbitrary exclusion of an environmental criterion has to be justified.

Some examples of "displaced impacts" are:

- A recycling process that consumes more energy, possibly in transport as well as in processing, than is saved by recovering material;
- A miniaturised product, using fewer resources than its precursor, that is impossible to deal with at its end-of-life stage because of its complex design and use of mixed materials;
- A car with a white aluminium body and with a low mileage during its use phase: it is lighter and therefore uses less fuel, but there may be more energy and emissions embodied in its manufacture than can be saved in the use phase;
- A product whose lifetime is over-extended by being much more robust and consuming more materials. New technology would permit its replacement with a product having much less environmental impact in use through enhanced energy efficiency.

It was explained in section 1.1. that shifts from one phase to another should be avoided. Minor shifts, however, might be a useful strategy if the environmental performance of the complete life cycle is improved.

For example, the Alcatel Case Study shows that, even if environmental impacts in the manufacturing phase are increased, the redesign of a product can lead to a lower environmental impact for the complete life cycle. Displacement from one environmental impact to another should also be considered.

Case Study 1 b – Alcatel Cooling Sub-assemblies for Telecom Equipment
Single phase environmental impact compared to combined phases environmental impact

ALCATEL

See

APPENDIX 1

Written with the contribution of ***Marc HEUDE***

The redesign on cooling sub-assemblies has been initiated with the aim of reducing manufacturing costs for Alcatel. A parallel environmental study has been carried out to determine to what extent gains in manufacturing efficiency could be coupled with environmental gains.

The environmental evaluation showed that the new generation sub-assembly (N-COSUB) had a higher environmental impact in the manufacturing phase than the old one (O-COSUB).

However, it was shown that an assessment of a larger picture (manufacturing + use phase) resulted in N-COSUB having a significantly lower impact.

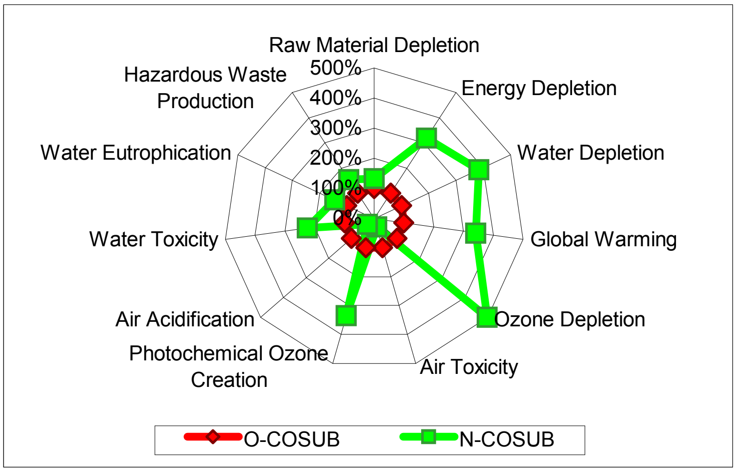


Figure 3: Manufacturing impact

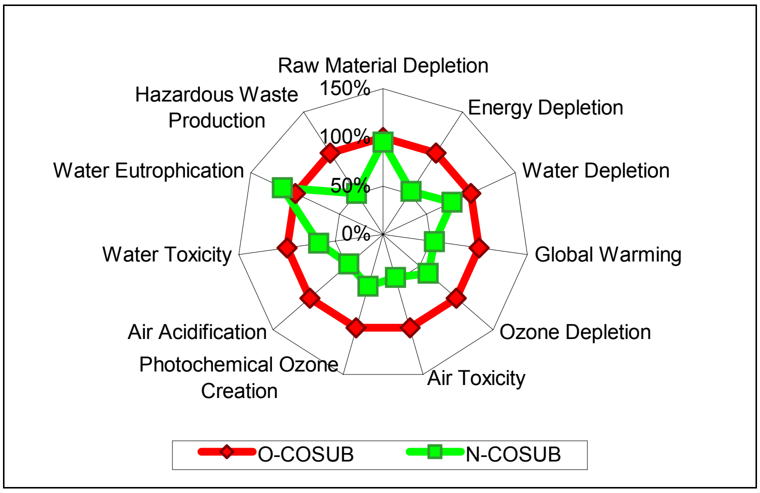


Figure 4: Manufacturing + Use impact

The total decrease of environmental impacts is due to the reduced electricity consumption in the use phase, which offsets the additional impacts in manufacturing.

The reduction of energy consumption is also profitable to the customer from an economic point of view and, therefore, improves the competitiveness of the product.

1.3 CONCLUSION

Life cycle thinking is the essential basis of eco-design. Only if the complete life cycle of a product is taken into account can an assessment of the environmental performance of a product be made. This approach helps to identify trade-offs in the life cycle, and, therefore, to avoid the displacement of impacts from one life cycle stage to another which may lead to an overall negative change in the product. On the other hand, life cycle thinking aids identification of the relevant “hot spots” in the life cycle of a product, therefore enabling the designer to focus on the most relevant issues. Consequently, the resources (time and money) used in design can be used efficiently in order to improve the environmental performance of a product. In addition, if the complete life cycle is considered, potentials for economic savings can also be determined, going far beyond traditional accounting procedures because the costs of the customer during use and end-of-life are also taken into account.

2 - ECO-DESIGN PROCESS

The product development process varies enormously between products and organisations. In practice, companies use an individual combination of approaches and tools for their development processes. Accordingly, a standard approach to integrate environmental aspects into product development is not feasible. In large companies the product development process might be a formalised approach with fixed milestones and gateway management, whereas in small companies one or a few persons in an informal and more intuitive process may carry out product development. Some "trial and error" should be expected as each organisation follows its own learning curve. Many different participants may be involved (e.g. engineers, scientists, suppliers, marketing departments, and customers) [ISO 2001].

In the following section important aspects of the eco-design process are explained in more detail. These aspects are not conclusive, but are meant to demonstrate issues that have to be tackled in order to make eco-design work and to exploit its benefits.

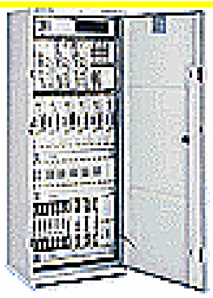
2.1 INTEGRATION OF ENVIRONMENTAL ISSUES DURING PRODUCT DEVELOPMENT

In product development, the environment cannot be added as an afterthought. Generally eco-design cannot be added-on but must be built into all the stages of the design procedures of a company. This can be done by raising awareness, training, setting of clear specifications and targets, and by incorporating environmental issues in design reviews.

Companies normally have a distinctive and customised product development process. Therefore, it is necessary to customise the integration of the environment into the process according to the company's culture, and the characteristics of its products and processes.

Technical choices (materials, manufacturing processes, assembly methods) made by designers condition the impact of a product on the environment during its life cycle (see Chapter 1). As the environmental impact is mainly defined at the design phase, eco-design has to be taken into account at each stage of the design process, from idea generation to the embodiment of design.

To integrate fully environmental concerns in the design process, companies develop design methods (standards). For instance, Siemens has developed such a method, based on ISO 9000. This method is demonstrated by Case Study 2 a, which shows at which step of the design process environmental criteria are incorporated.

Case Study 2 a - Siemens Base Station Siemens Standard SN 36350 SIEMENS	See APPENDIX 18	

Written with the contribution of ***Friedrich KOCH*** *and* ***Dr. Ferdinand QUELLA***

Siemens' environmental policy focuses on process-integrated environmental protection. The principle of eco-design was introduced early (1993) into product planning, the development of processes and purchasing with the "Environmentally Compatible Product" internal standard, SN 36350. This standard covers all aspects of the IEC Guide 109, which deals with the inclusion of environmental aspects in electro-technical product standards.

The SN 36350 standard is applied in all Siemens groups and affiliated companies. Product planners, developers, and quality managers are trained continually in seminars and workshops in the application of the standard that is accessible via the intranet.

Siemens Standard SN 36350 consists of 6 parts [KOCH 00]. It is supplemented by a guidance document in the intranet “Solutions and examples on the Siemens Standard SN 36350”, which gives more information such as technical options regarding a specific requirement.

The first part, which is linked to product development, is described below. The others parts are outlined in Appendix 4.

Product development guidelines:

- principles of environmentally compatible product design;
- guidelines on environmentally compatible product design;
- integration of the environmentally compatible design into the product planning and development process.

The guidelines consist of 40 rules addressing all life cycle phases. (Figure 5). Focal points are:

- energy consumption in the use phase, especially in the case of a product with a long life-span;
- reduction and recovery of end-of-life waste;
- substitution of hazardous substances.

This set of rules has to be integrated into the design process: Figure 5 gives some example of such integration.

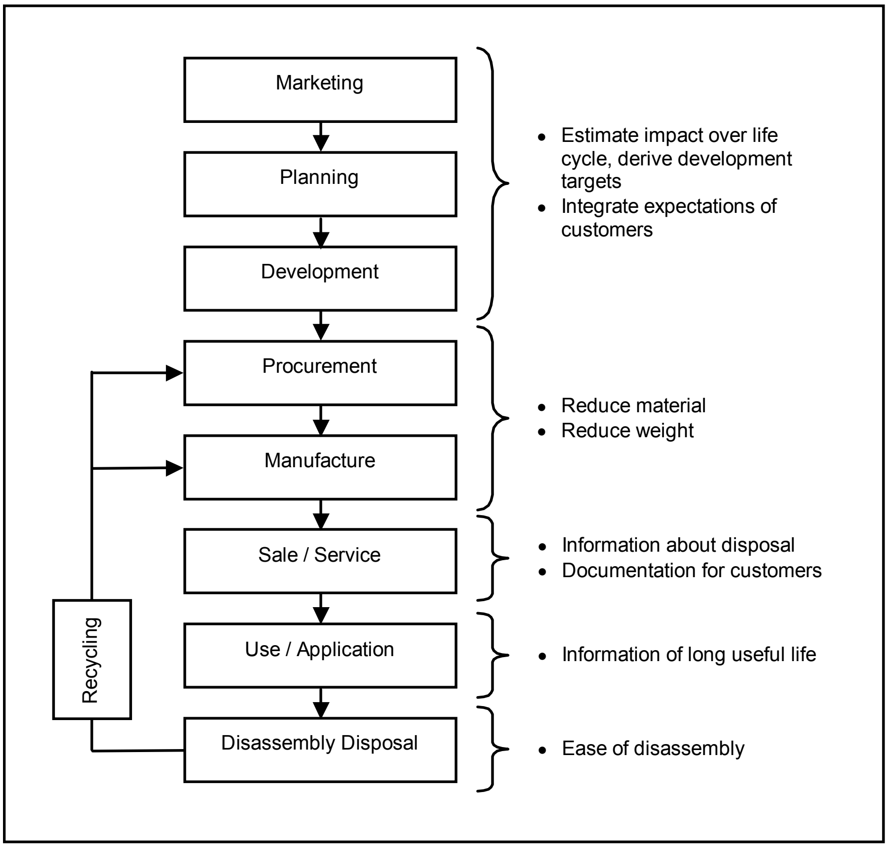


Figure 5: Examples of input of rules into development phase

The Base Station BS 240/241 has been developed in accordance with these guidelines. Table 1 shows the improvements and the resultant design process step.

Part of the product	Guideline part	Improvement
Base station	MPD	volume reduction: 8 transmission units instead of 6,
Cooling system	MPD	volume reduction: 38%,
Base station	MPD/PM	no more outdoor air conditioning system
Cooling system	PM	weight reduction 50%
Subrack	PM	reduction of the number of material: 1 pure instead of 4
Base station	PM	manufacturing cost reduction
Subrack	PM	cost reduction: 22% instead of 100%;
Cooling system	PM	cost reduction: 33%.
Cooling system	UA	energy consumption reduction: -180W
Cooling system	UA	better heat balance: +7 K
Cooling system	UA	MTBF improvement: 31%
Subrack	DD	reduction of the number of parts (17 instead of 66),

MPD: Marketing, Planning, Development PM: Procurement, Manufacture
UA: Use, Application DD: Disassembly, Disposal

Table 1: Improved Base Station

2.2 EARLY INTERVENTION IN DESIGN

Early intervention in design and product development is important. Design is only one part of product development: before technical design even starts, decisions may have been made in business planning, marketing and industrial design. It is, therefore, vital to have senior management commitment and an extended design team which considers eco-design from the very start of a project, in the same way as any other technical or economic requirement.

Such an approach is extremely relevant, because in most cases more than 70% - and often as much as 90% - of the costs, as well as the environmental inputs are fixed during the research and development stage. Therefore, the earlier the complete life cycle is taken into account, the higher the potential for improvements and for cost savings.

2.3 CONTINUOUS IMPROVEMENT

The integration of the environmental dimension into design should be a continuous improvement process where impacts are being reduced while innovation builds upon experience.

All technical or market developments should be taken into account, both upstream (e.g. the development of new materials) and downstream (e.g. the drawing up of new recovery processes) of the product's life cycle.

Ideally, the information acquired from the different experiences should be organised to constantly feed into a knowledge base so that all data required for conducting an environmental assessment or set of design rules is gathered.

Case Study 2 b - THOMSON multimedia
TVs eco-design integration

See

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Figure 6: TV 21''- 4/3 launched in 1997

Figure 7: TV 28''- 4/3 launched in 1999

Written with the contribution of ***Alain CLEMENT***

The integration of the environmental dimension into design is a continuous improvement process, but also a goal, and a strategy, on which THOMSON multimedia has based its efforts. Every opportunity was sought to apply the results achieved on the TV sets above to new products launched. This integration process was implemented in different stages.

Building upon the experience and the positive results obtained on the more environmentally friendly and easily recyclable 21'' TV-set (Figure 6) launched on the European market by THOMSON multimedia from September 1997 onwards, a second project was launched in 1999 (Figure 7) to evaluate the possibility to extend the new design concepts to the whole range of TV sets.

The main aim of this project was to guarantee the technical and economical feasibility of the recycling of the TV-sets as follows:

- Design options were compared in regard to easier dismantling;
- Selection, adjustment and use of recyclable materials were all essential issues when planning a recycling process for the mechanical parts;
- The environment was also considered when developing new concepts of packaging, when devising an easy, quick, and economically sound disassembling process, and when removing toxic substances from products and processes.

These projects all aimed at studying new concepts of TV-sets, using materials and technologies, which directly contributed to the reduction of waste, but also to a significant reduction of the global impact of products on the environment (including the reduction of energy consumption and the quantity of materials used in products and processes, and the removal of toxic substances or paint).

Today, the following rules are applied for all of THOMSON multimedia European TV production:

- Guarantee the technical & economical recycling of the main plastic parts (use of polystyrene and compatible plastics only);
- Use an increasing share of recycled materials;
- No use of hazardous substances;
- Use of as-moulded technology as often as it is aesthetically acceptable;
- If paint is necessary, use of water-based paint in production;
- Limit energy consumption during different life cycle stages of the product;
- Reduce the weight of materials for the product itself & for packaging elements;

while providing optimal safety, quality and services to consumers.

This is the result of a continuous and progressive process feeding on new developments in materials and processes as well as on an enhanced knowledge of existing recovery practices. This process is by definition never-ending and THOMSON multimedia is committed to keep minimising, as far as is feasible, the environmental impacts of its products throughout their whole life cycle.

2.4 CONCLUSION

As shown by the above examples, the integration of environmental considerations into the product development process is vital for the success of eco-design and even for product development in general. Eco-design must not be viewed as an additional requirement, but rather as a broadening element which can enhance production, use, and the end-of-life stages of electrical and electronic products.

As product development processes and organisations differ from company to company, depending on their specific needs and requirements, the integration of eco-design also differs. In this and other sections of this Guide, the product developer can find many suggestions, experiences and ideas, which should help to stimulate the creation of the best suitable eco-design process for a given application and/or company.

3 - ECO-DESIGN TOOLS AND METHOD

Many eco-design tools and methods exist: some are extremely simple and qualitative, while others are complex and quantitative. The selection of the best tool for a given application depends on the individual situation of the user as explained in Chapter 2.

Eco-design methods are often computer-based: a simple example would be an intranet Web page, and a complex example, a programme for life cycle assessment within eco-design. Tools and methods may be developed in-house, but more often they are available commercially and customised for the particular company.

The simplest classification of tools is into those which perform analysis, and those, which are aimed at improvement. Analysis tools provide a measurement, however basic, of the potential environmental impact of a product. They may be used before design starts, by analysing a previous product or that of a competitor. Alternatively, they maybe used at the end of a design project to verify the result. Improvement tools, on the other hand, are used during the design process to direct activity and provide information on the process.

For more information on eco-design tools, see the "Eco-design Navigator" [Simon at al, 1998] and other references in the Bibliography.

3.1 ENVIRONMENTAL ANALYSIS METHODS AND TOOLS

3.1.1 Life Cycle Assessment

Before establishing and systemising improvement rules, methods and tools, it is strongly recommended that a company gathers information and acquires knowledge of the environmental performance of its products throughout their whole life cycle. Such an approach does not only represent a strategic vision for the implementation of eco-design practices, but it is also the only means of assessing if a measure is effective and efficient. In addition, it could also become a legal obligation: "manufacturers of electrical and electronic equipment shall perform an assessment of the environmental impact of a product throughout its life cycle, based upon the assumption that it is used under the conditions and for the purposes intended" [EEE, 2001].

Life cycle Assessment (LCA) is a framework for assessing the environmental impact of the complete life cycle of a product. It is an extremely powerful method for the implementation of life cycle thinking as explained in Chapter 1. LCA is defined as the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" [ISO 1997].

It is evident that this is a very complex and comprehensive method, which cannot be easily applied in product development. However, to facilitate the application of LCA, there are several commercial software tools available, which provide data, calculation procedures, and presentation of the results. The most relevant LCA tools are listed in the Eco-design Navigator [SIMON et al. 1998]. On the other hand, it must be noted that these are expert tools and, in most cases, only feasible for large projects in multinational companies. A full LCA study is not a suitable tool for "ad hoc" decision support in product development due to the time, effort, and know-how needed for its application. To learn more about LCA and its application in industry, the reader is strongly encouraged to read publications such as [ISO 1997], [Frankl and Rubik 2000] or *The International Journal of LCA*.

Due to reasons of commercial confidentiality, full LCA studies of electronic and electric equipment cannot be presented in this Guide.

3.1.2 Other analysis methods and tools

Since detailed LCA studies are usually time consuming and expensive, they are little used during the design of products. In fact, simpler approaches are used for the evaluation of environmental performances of design options. These approaches generally take into account some life cycle stages and some specific environmental criteria. Of course, for these simpler evaluation methods, the reproducibility and reliability of the results are critical issues, which need to be addressed. However, LCAs can be used to validate simpler methods, so that the latter can be applied correctly if certain specifications are met. Also, simplified LCA methodologies are being developed, which will enhance the future of the methodology (see [de BEAUFORT 1997], [HUNT et al. 1998], [REBITZER 1999], [REBITZER and FLEISCHER 2000]).

One successful simplified LCA method, developed in the Netherlands and extensively used by Philips, is the Ecoindicator measure, published in 1995 and revised in 1999. This combines different environmental impacts into a common unit, based on the mean impact of a single citizen; this valuation approach is not supported by the ISO1404x series of LCA standards but is attractive to industry as it provides simple benchmarks. For design projects, it is often sufficient to use such a method to reinforce life cycle thinking by designers and to evaluate alternative designs.

The Product Improvement Matrix [GRAEDEL 1996] is also an example of a simplified approach. It assists in assessing the environmental impact of the five life cycle stages of a product (Resources extraction; Manufacturing; Packaging and Distribution; Use; End-of-life) according to five criteria: Choice of materials; Energy use; Solid residues; Liquid residues; Gaseous residues.

Another example is given in the Alstom T&D Case Study. It shows the use of EIME® Software for the product environmental evaluation of electric devices, and describes the methodology used to determine the reliability of these evaluations.

Case Study 3 a – Alstom T&D Environmental performances evaluation of circuit breakers ALSTOM	See APPENDIX 2	

Written with the contribution of ***Jean-Luc BESSEDE***

In Alstom T&D, as a prerequisite to eco-design practices implementation, a good knowledge of the environmental performances of products has been established. Since 1998, Alstom T&D has initiated the capitalisation of products' environmental performance analysis.

These analyses are carried out using EIME® software (based on LCA studies and other criteria, see Chapter 3.2) using 11 environmental indicators (Raw Materials Depletion, Energy Depletion, Water Depletion, Global Warming, Ozone Depletion, Air Toxicity, Water Toxicity, Photochemical Ozone Creation, Hazardous Waste, Air Acidification and Water Eutrophication). The impact of design and constituent materials is also evaluated, and the impacts of manufacturing and use are compared for each switchgear.

Then, in order to obtain maximum advantage from the environmental analysis, the reliability of these evaluations is determined. Alstom T&D developed a "Relevance of Data" indicator (RD), which allows it to assess the reliability of the data and its influence on the complete product environmental analysis. The Relevance of Data indicator is defined as the Data Reliability (DR) multiplied by Consumption Reliability (CR) and by the Sensitivity of environmental impact to the Data (SD):

$$RD = DR * CR * SD$$

This environmental analysis reliability assessment for Alstom T&D products leads to the identification of missing and/or insufficient elements in the database for materials and processes, and allows environmental experts to determine which data modules should be developed as a priority.

Alstom T&D is continuing to develop information on the real environmental performances of its products. It makes the set-up of some eco-design rules more effective.

3.2 INTEGRATED SOFTWARE AS AN IMPROVEMENT TOOL

The sophisticated tools described in this section should be used within the context of a trained design team. Laying the foundations by training courses, team activities and workshops with external specialists is important for the successful use of specialised eco-design tools. In large organisations, there are often environmental specialists available who can join design teams and advise on tools or assist in their use.

Case Study 3 b – TUB
Design for Environment (DfE) tool: euroMat

Written with the contribution of ***Gerald REBITZER***

euroMat is a method and software prototype (including a database) that supports the engineering or industrial designer in the materials selection process in product development [FLEISCHER at al, 2000]. Its goal is to find innovative materials for a given product, therefore enhancing business competitiveness. Besides the conventional requirements (production costs, technical specifications, etc.), criteria of the sustainability paradigm are integrated.

The euroMat methodology was applied by the Technical University of Berlin (Germany) to several case studies in order to validate the capabilities and practicality of the method. Co-operating companies included Ford Motor Company and MAN Technology.

The euroMat methodology consists of several steps:

- **First step: profile of technological requirements**
  These requirements correspond to the specifications for the product or components. Table 2 gives an example of requirements for a product.

Product performance	Representing material specifications	Requirements
Mechanical strength (> 700 N) and stiffness (> 45 N)	Modulus in flexure	> 1.1 GPa
Resistance against hood slam impact	Impact strength	> 16.0 kJ/m2
Weight of subframe system < 4.9 kg	Density	< 10.2 kg/dm³

Table 2: Profile of requirements of a product (example)

- **Second step: selection of technically feasible materials**

The selection is based on a material's technological feasibility (functionality) and the identification of suitable manufacturing and recycling processes (see Figure 8).

- All the materials, which respond to the requirements, are identified;
- Materials are then assigned manufacturing processes that meet the specific requirements of the component or product;
- Analogously, the availability and feasibility of recycling options are determined

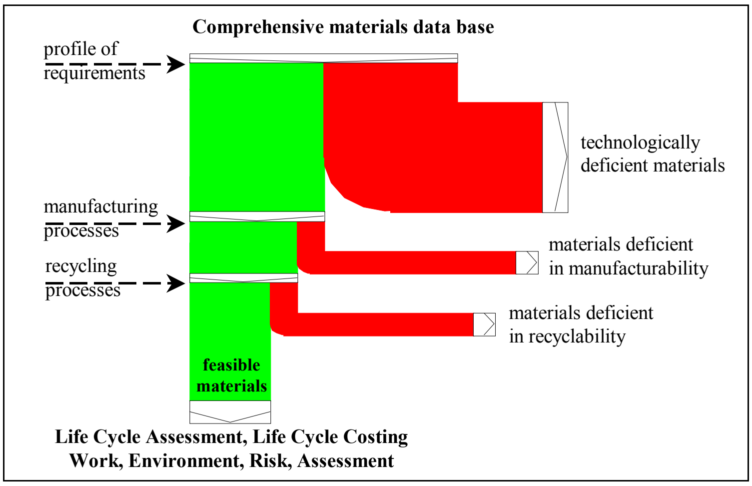


Figure 8 - euroMat procedures
t3i top-down approach (all materials and combinations), Iterative, Integrative, Interactive

Table 3 shows the examples of materials, which correspond to the specifications listed in Table 2.

Material for subframe system	Wall thickness	Weight
Steel	0.9 mm	6.8 kg
Magnesium	1.6 mm	2.6 kg
PA, glass fibre-reinforced	3.0 mm	4.3 kg
PP, hemp fibre-reinforced	3.0mm	3.5 kg

Table 3 - Identified materials (feasible materials) for the product's part

- Third step: LCA and LCC

After the selection process, the remaining materials are assessed for life cycle impacts using specific simplified life cycle assessment - LCA (impacts from raw material extraction, processing of materials, manufacturing, consumption, and end-of-life - reuse, recycling, and disposal - as well as energy consumption and transports), life cycle costing (LCC), and risk- and work environment assessment procedures.

The results for PA, glass fibre-reinforced, PP, hemp fibre-reinforced, steel, and magnesium of an example from the automotive sector are detailed below (see Figure 9).

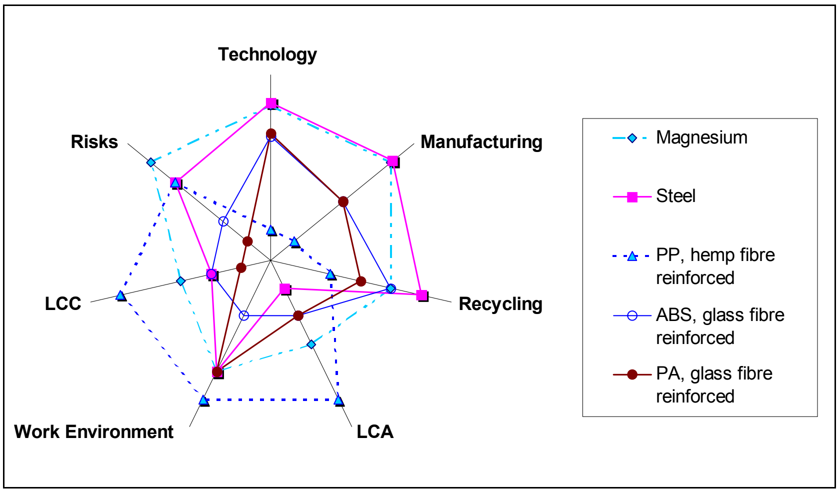


Figure 9 - Comprehensive multi-criteria assessment, ranking of material options (also including results for ABS, glass fiber reinforced)

euroMat has not yet been applied to specific products or components from the electrical or electronics sector. However, the tool and methodology is not restricted to specific branches, but can give decision support in all areas of industry.

Tools also exist which not only assist material selection but focus on joining modes and general architectures (assembly/disassembly sequence). The Green Design Advisor (GdA) is such a tool used in the electric and electronics industry.

Case Study 3 c – Motorola WARIS phone
Use Green Design Advisor (GDA) software

MOTOROLA

See

APPENDIX 7

Written with the contribution of ***Katrin MÜLLER*** *and* ***Markus STUTZ***

The Green Design Advisor (GDA) software is the corporate DfE tool of Motorola, which is used by several people within the company, such as DfE experts working in some design departments and responsible for the whole process. Other departments split the responsibility into material, EOL, and packaging.

The software is mainly used as a product analysis, evaluation and reporting tool.

- Analysis means, for example, information about material balance, product structure (components, materials, weight, number, type and arrangement of fasteners/connections).

The screenshot below (Figure 10), presents some elements of the WARIS 2-way-Radio.

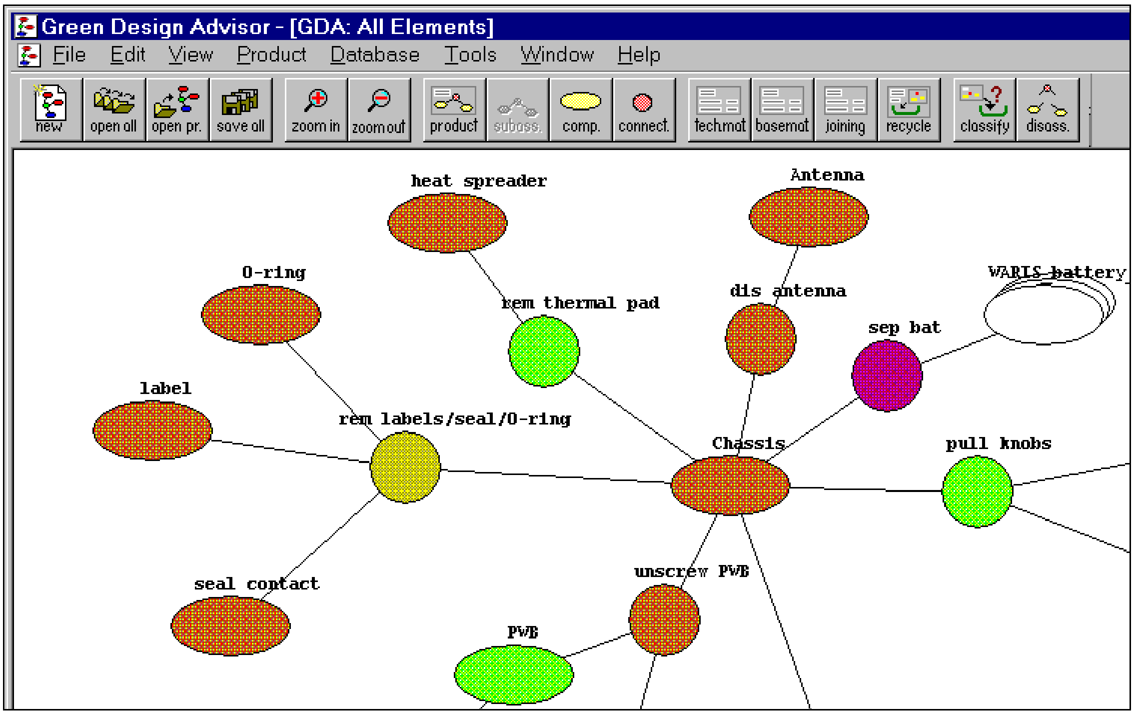


Figure 10: GDA software – Elements of the WARIS 2-way-Radio

- Evaluation of design options is based on eight criteria:
  - number of materials;
  - mass;
  - recycled content;
  - recyclability;
  - toxicity;
  - energy use;
  - time for disassembly;
  - disposal cost.

For example, designers are able to use two end-of-life metrics to evaluate their products: time for disassembly and cost at optimum disassembly depth.

- Reports include the analysis and evaluation of results.
- The GDA tool is integrated into each phase of the design process:
- product planning phase: the environmental requirements and material restrictions are considered or checked within the methodology of the tool;
- product concept phase: a first evaluation is made using average material composition – in the subsequent phases the best concepts can be chosen;
- detail phase: these models can be detailed;
- prototype phase: the final evaluation is carried out, and it is possible to make last changes to the product.

All the reports are generated before mass production begins

The GDA tool:

- provides a direction of improvement, as well as the design features with the highest improvement potential;
- shows the weak points, as well as good design features.

Regarding the results (Figure 11), the designer knows, where to invest to improve the product, what to improve by reducing, increasing, substitution, etc. In comparison with the former product generation the GDA indicates the relative improvement ratio.

Additional design guidelines exist; however, there are no automatically generated design alternatives. The designer should know the general set of guidelines. The technical solution depends on the designer's own creativity and is product specific, so it is not really possible to create online help.

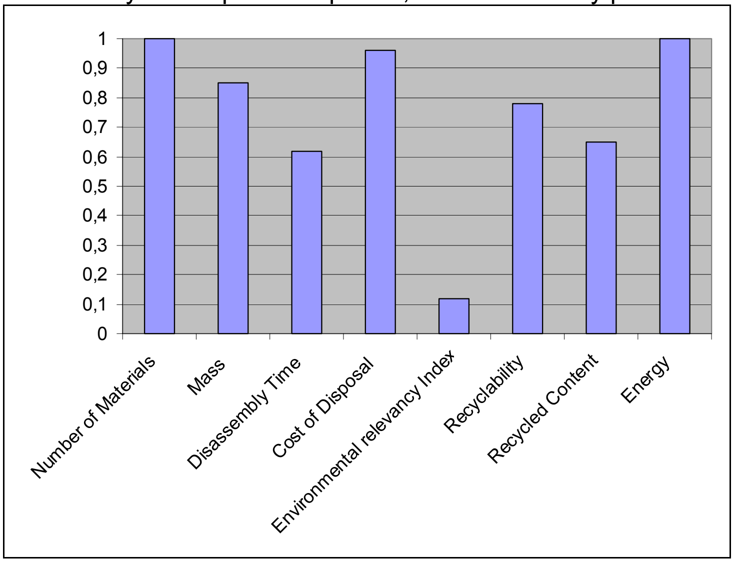


Figure 11: Normalized GDA scores compare to the baseline of 1,0 (reduction and improvement means lower score) - WARIS 2-way-Radio

Within the same range of tools, the EIME® software has been developed by several electrical and electronics companies: its main feature is its architecture which is designed to interact with the company design process and organisation, tools (environmental indicators, guidelines, checklists), and actors (designers, product managers, environmental experts).

Case Study 3 d – Schneider MasterPact circuit-breaker Use of EIME® Schneider Electric	See APPENDIX 14	

Written with the contribution of ***Isabelle FERNANDEZ***

The EIME® software is a design for environment tool. The product is defined along its life cycle (raw material extraction, manufacturing, use and end-of-life phases).

The product itself is defined by:

- Materials and additives which define the parts;
- Components (which contain materials and substances);
- Subassemblies (parts/components) which are linked together by specific joining modes;
- Product, which is the union of subassemblies linked together by joining modes.

The EIME® evaluation is based on the LCA multi-criteria approach (Raw Materials Depletion; Energy Depletion; Water Depletion; Global Warming; Ozone Depletion; Photochemical Ozone Creation; Air Toxicity; Air Acidification; Water Toxicity; Water Eutrophication; Hazardous Wastes Production).

Other design criteria are also evaluated, for example physical criteria (weight, volume), use criteria (energy consumption, life span), and end-of-life criteria.

The product improvement focus is based on:

- Designer improvement initiative based on evaluation criteria
- *Warning/To Do* messages which appear when the designer uses a specific component/material/additive. These checklists/guidelines can be defined for the whole company (e.g. plastics marking) or for a specific product.

The EIME® tool results from a joint industry effort to develop a methodology compatible with both specific environmental evaluation requirements and industrial design process constraints [GABILLET 00]. EIME® software is organised as shown in Figure 12.

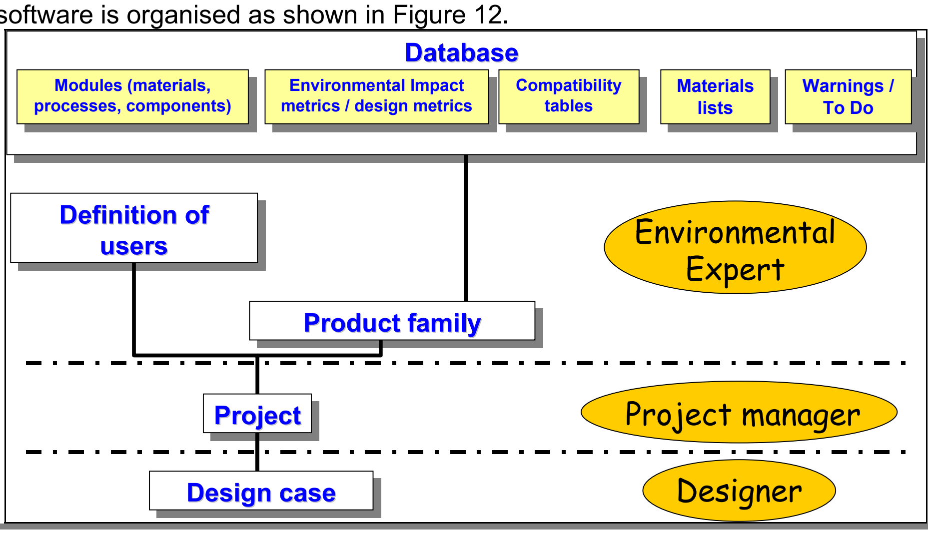


Figure 12: Management of databases in the EIME® software

In particular, environmental experts in the company maintain the databases, e.g. creating checklists or guidelines, which are to be used by designers. Product managers and environmental experts then have the responsibility to choose the right databases for the product, which is developed.

For the MasterPact, a specific warning message (Figure 13) was created in order to alert designers when:

- a battery was incorporated (Figure 14);
- lead was used (Figure 15);
- a plastic with halogen fire retardant was selected (Figure 16).

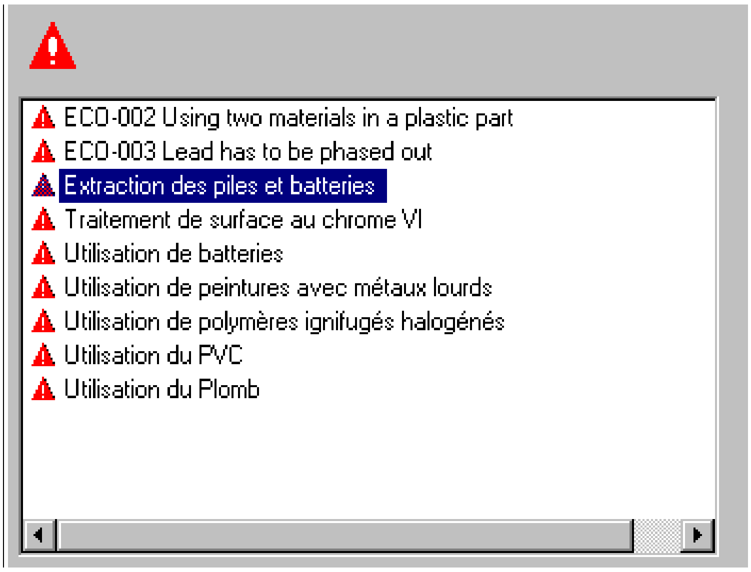


Figure 13: Warning messages

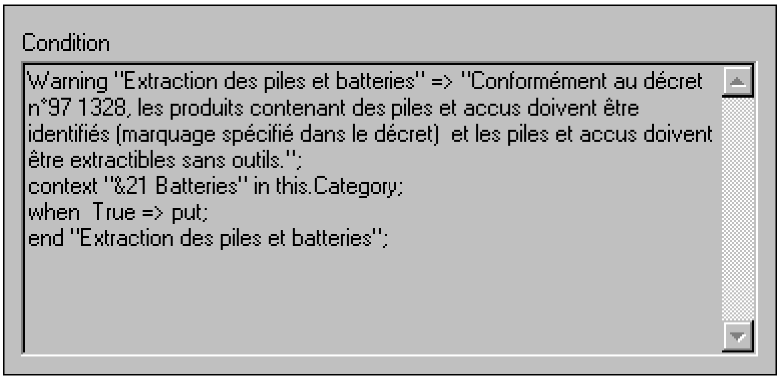


Figure 14: Warning message for the MasterPact batteries

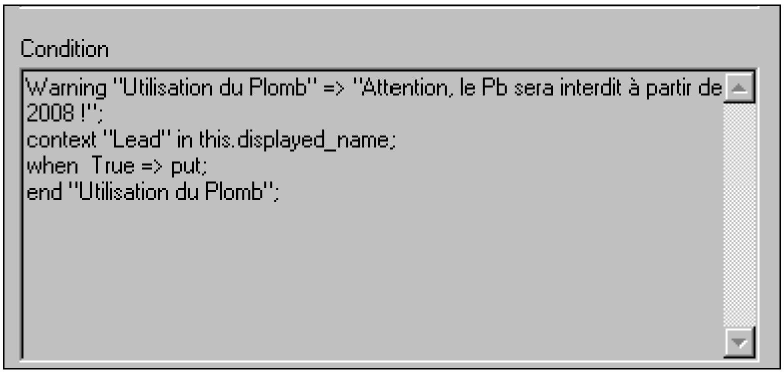


Figure 15: Warning message for the MasterPact lead use

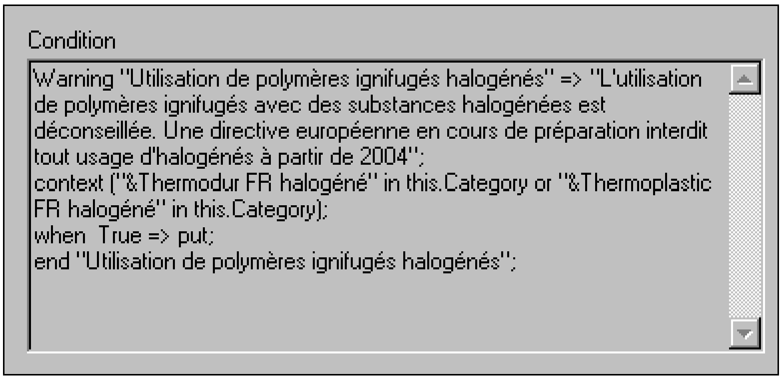


Figure 16: Warning message for the MasterPact plastics to not be filled up with halogenous fire retardants

Moreover, the Schneider product databases contain a plastics marking guideline (Figure 17).

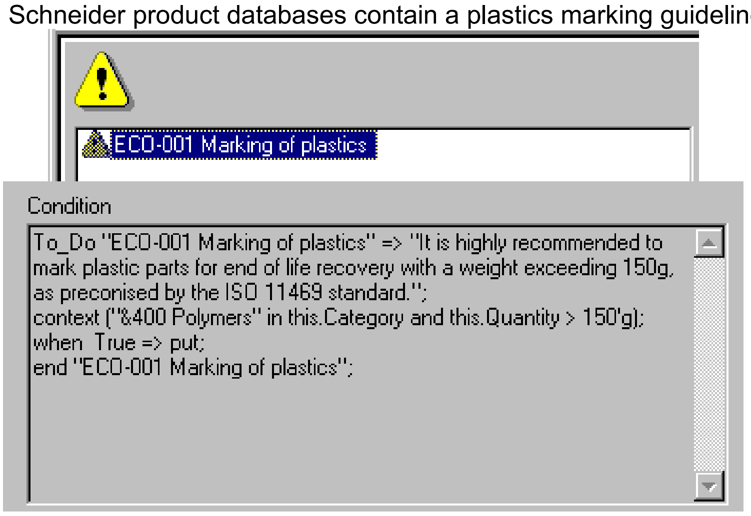


Figure 17: Guideline message for the MasterPact plastics to be marked for end-of-life recovery with a weigh exceeding 150g

One of the main advantages of the EIME® tool is that it contains evaluation and improvement criteria. The software structure is such that environmental experts who maintain the databases can define simple rules for designers to use.

3.3 SPECIFIC TOOLS

Most companies have developed their own indicators or methods corresponding to physical (e.g. mass, volume) or technical parameters (e.g. percentage of recycled material, dismantling time), supplemented by well-known environmental assessment methods. Thus each tool is adapted to the product and its context.

The range of specific eco-design tools available includes many published sets of guidelines, simple metrics or measurement systems and techniques for optimising the design with regards to a particular environmental issue such as end-of-life impact. In particular, a number of tools have been developed to advise on end-of-life issues in the light of new EU legislation. The principles of life-cycle thinking imply that the use of these tools is unlikely to be the only environmental intervention in a design project: but if a project strategy highlights end-of-life as important, then there are a variety of tools to deal with this new and growing area of producer responsibility.

Case Study 3 e – Manufacturing Modelling Lab of Stanford University End-of-life Design Adviser tool (ELDA)	See APPENDIX 21	

Written with the contribution of ***Catherine ROSE***

Since 1997, ELDA has been under development to determine product end-of-life strategies early in design, as well as to provide the technical basis for decisions made by product planners regarding end-of-life treatment technology. Also the development of end-of-life technologies and communication with third parties is addressed (e.g. authorities, NGOs).

Through the collection of extensive case studies on product end-of-life strategies, the following technical product characteristics have been identified as influencing most strongly the end-of-life strategy: wear-out life (0-20 years), technology cycle (0-10 years), level of integration (high, medium, low), number of parts (0-1000), design cycle (0-7 years), reason for redesign: original, minor/major and function/aesthetic.

- ELDA leads to a product classification as presented in Figure 18:

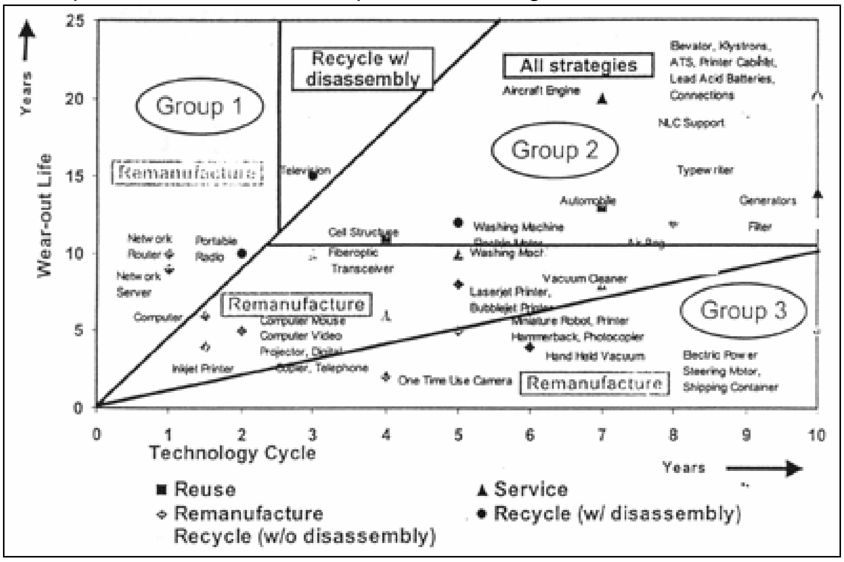


Figure 18: Results of ELDA [STEVELS et al. 2000])

Products	Current best end-of-life treatment implemented in industry	End-of-Life strategy recommended by ELDA	Action needed
TV	Recycle (with disassembly)	Recycle (with disassembly)	Match
Stereo System	Recycle (without disassembly)	Remanufacture	Mismatch
Monitors	Recycle (with disassembly)	Remanufacture	Mismatch
Cell phone	Recycle (with disassembly)	Remanufacture	Mismatch
VCR	Recycle (without disassembly)	Recycle (without disassembly)	Match

Table 4: ELDA and actual practice [STEVELS et al. 2000]

When two classifications match (Table 4), it means that the end-of-life strategy is validated. It means also that technical modifications of the product can be made to improve the product's overall end-of-life performance. For example, for a TV set Life Cycle calculations show that it is preferred to reduce energy consumption rather than trying to achieve a higher level of end-of-life strategy.

When two classifications mismatch, it means that more work has to be carried out on non-technical aspects.

For the cell phone, ELDA shows that a high-level end-of-life strategy (remanufacturing) is technically feasible (currently discarded phones are shredded and metals are removed through separation). In such a case primarily non-technical items have to be addressed (how to get products back, how to organise industrially, how to sell the remanufactured products) to make the strategy happen in reality.

As life cycle and multi-criteria approaches are difficult to apply directly in the design process, simplified tools, which evaluate products according to several parameters, are available ("Benchmark" approach).

Case Study 3 f – Philips Green TV
Benchmark approach

PHILIPS

See

APPENDIX 13

Written with the contribution of ***Maarten TEN HOUTEN*** *and* ***Ab STEVELS***

In order to design products with higher levels of sustainability, Philips developed an Environmental Benchmark Approach (EBM) based on:

- The Ecovison programme (see Case Study 4j);
- Life cycle performance approach
  - eco indicator score of production phase,
  - eco indicator score of use phase,
  - eco indicator score over the whole life cycle.

The EBM consists of 4 steps (Figure 19):

- Choose products:
- A product should be chosen in a way that extension to a green range is highly possible. The chosen product is then compared with 3-4 important competitor ones). More or less comparable functionality must be described.
-
- Assess benchmark issues and define system:
- Marketing perception and environmental impact are two important aspects for the assessment of benchmark issues.
- The product is also defined in terms of: market (target groups, competition), and position (consumer demand, legal requirements).
-
- Validate and compare the products:
- It is the most important step as environmental performance is determined following the green focal areas of the Ecovision strategy and a Life Cycle Assessment approach.
- It is also the most time consuming part because the products have to be analysed.
-
- Discuss raw results and define attention field:
- The results are discussed in a team from the following departments: product management, purchasing, marketing, product development, manufacturing and the Environmental Competence Centre.

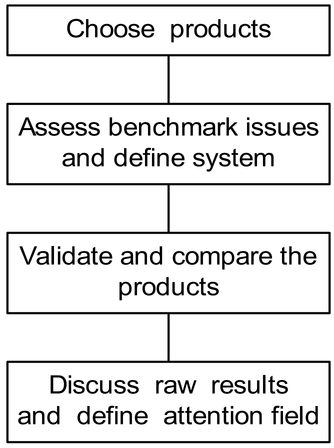


Figure 19: EBM

This method has been followed to develop an environmental friendly TV, the Green TV, for which, the improvement potentials are shown in Table 5.

Achievements for Green TV	%
Reduction of energy consumption	39
Reduction of plastic weight	32
Reduction of hazardous substances	100
Use of recycled material	69
Recycle potential	93
Reduction of life cycle impact	30

Table 5: Environmental improvements for Green TV

As can be the seen, the Green TV was a success in developing novel and environmentally sound technologies for a TV set on the basis of the entire product life cycle. The project's results yielded invaluable insights and solutions which are still used in many Philip's products. Moreover, this EBM procedure, which was one of the results of the project, is applied now for all Philip's products.

Although this study was a success, the product has never been brought to the market because of:

- a lack of a clear value proposition to the potential customer and unclear position of a product line-up;
- an insufficient analysis and management of the internal value chain: environmental communication and competition, production technology, cost, investment and time to market were not mapped very well;
- no involvement of suppliers and logistics.

Use of environmental indicators (like LCA, eco-indicators, benchmarking) helps the design team to broaden its knowledge on the environmental performance of a product. However, specific tools, which help designers to find directly design solutions, are also available.

For example, companies set up some lists of design guidelines or lists of controlled substances to be used by designers and/or by suppliers. End-of-life options and design attributes checklists developed by the Centre for Sustainable Design are presented in Case Study 3g.

Case Study 3 g – CfSD
Eco-design guidelines

The Centre for Sustainable Design

Written with the contribution of ***Martin CHARTER***

Checklists have been developed by the Centre for Sustainable Design for a range of user types and levels of previous knowledge, considering:

- Use by general electronic and electrical suppliers;
- Use by small and medium-sized enterprises (SMEs);
- Accommodation of a range of previous environmental and eco-design knowledge;
- Use by a range of functions, management as well as technical;
- Inclusion of specification as well as design considerations;
- Inclusion of management as well as technical considerations.

Some examples of guidelines are given below.

ATTRIBUTES	Scrap	Recycle	Resale	Upgrade	Remanufacture
1. Design for second market Must work with range of voltages and operating conditions.			x	x	
2. Durable, high value sub-assemblies Design assemblies containing precious metals, high tolerance components or ICs for reuse. Standardisation helps.		x		x	x
5. Easy access to replaceable parts Design sub-assemblies so they can be dismantled easily without specialist tools. Minimise number of operations to replace these parts; serviceable parts easily accessible.			x	x	x
6. Easy separation of contaminated materials Confine contaminated or hazardous material to a section of the product so easy to identify and remove; avoid such material where possible.	x	x			x
7. Easy disassembly to constituent parts Reduce parts count, variations in size, type and head of fixing screws; use self-threading screws rather than bolts and inserts, alternative fixing types (e.g. snap fits, clips, slots); avoid need for special tools for assembly; make it quick to dismantle.	x	x			x
10. Avoid use of glue and fixing tape Unless destined for disposal, as difficult to remove and contaminate material.		x		x	x
12. Design key pad for disassembly The button array should be easy to remove but remain intact. Silicone button pads should be combined into a single assembly.		x			x
15. Materials identified and marked Mark all materials using internationally recognised codes, especially polymers and other recyclable materials; identify hazardous and other toxic materials; avoid method which will impair reuse or recycling.	x	x	x	x	x
16. Maximise density Ensure no wasted space on the circuit board; put assemblies and loose components in a housing.	x				
20. Minimise material mixtures Avoid laminated or compounded materials as difficult to recycle; where possible use materials of a single type or blend.	x	x			
25. Use recycled materials where possible Adapt designs to encourage use.	x	x	x	x	x

ATTRIBUTES	Scrap	Recycle	Resale	Upgrade	Remanufacture
26. Customer friendly upgrade User not required to dismantle much or use special tools; ability to upgrade made clear.				x	

3.4 CONCLUSION

Many environmental evaluation and improvement tools already exist. They differ widely in the:

- environmental impacts they consider;
- design phases during which they can be used;
- input data which are needed to use them;
- results which can be obtained (nature, quality, uncertainties, usefulness, etc.);
- persons able to use them.

Moreover, each company - as well as separate parts of each company – may use the tools differently.

Case study 3 h – ENSAM Downlight Europa

Building coherence between tools and design process – Validation in a Downlight design team

ENSAM

Ecole Nationale Supérieure d'Arts et Métiers

Institut de Chambéry

See

APPENDIX 4

Written with the contribution of ***Marc JANIN*** *and* ***Fabrice MATHIEUX***

It was shown that qualitative and simple tools, e.g. a benchmarking tool, seem to be more efficient. Even if it focuses on a few specific environmental issues, the design team more easily achieves technical improvements.

Qualitative tools (e.g., benchmarking) seem to be more useful for designers in the operational phase.

- Researches identify the main benefits and problems of the integration of eco-design tools into product development process. Eco-design tools are classified according to their degree of evaluation and improvement;
- It then appears that tools should be chosen carefully in order to be as efficient as possible during the design process. For that purpose, tools can be classified according to three levels: the type of tool (inventory, assessment or improvement), product life cycle stage (raw materials extraction, manufacturing, use and end-of-life) being considered, and product design process stage (see Figure 20);

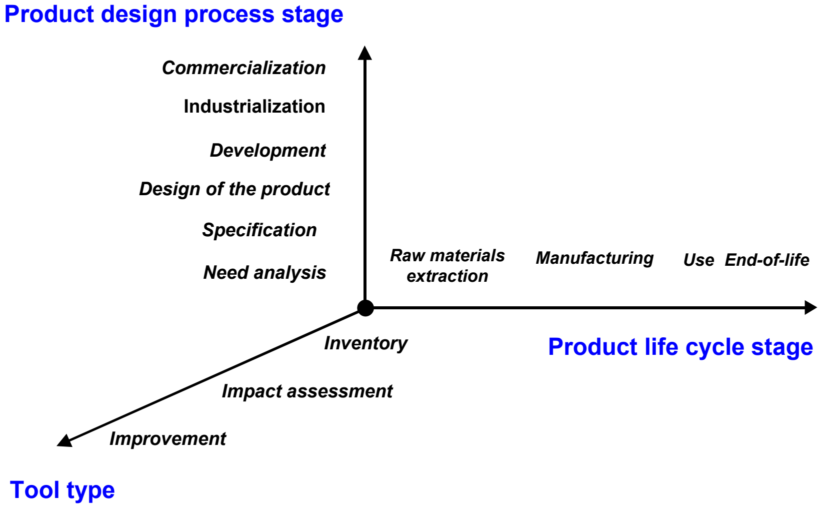


Figure 20: Three levels of classifications for eco-design tools (adapted from [EHRENFELD 1999])

- In this specific Philips Lighting context, the validation phase at Philips Lighting showed that the use of an LCA tool (e.g. easy to use EcoScan software) brought added value to the design team from an eco-design point of view.

This case study shows how the success of a design project depends on the integration of various tools (e.g. benchmark and LCA) in the design process. Highly sophisticated tools, such as those based on LCA, cannot be efficiently applied if they are not embedded into the company structure and organisation.

It appears that design teams need structured approaches to properly implement eco-design in their practices. Some researches focus on the development of tools, while other on eco-design organisation in companies, specifically SMEs. However, insufficient research connects tools with organisations [JANIN 2000].

The choice of the right tool and/or method, for the right purpose, by the right person and at the right moment, is a critical issue, which should be fully 'incorporated' in a company's eco-design practices. It is essential to articulate design and design processes and to test them in real life to assess their robustness.

4 - ECO-DESIGN STRATEGIES

This Chapter is based on the ECO-DESIGN manual [BREZET et al. 97].

Environmental design strategies are environmental improvement strategies tailored to a specific product's context and particular environmental impacts. Both strategies attempt to minimise environmental impacts and enhance design characteristics. Among these strategies one can find a selection of low-impact materials, reduction of materials usage, optimisation of production techniques, optimisation of distribution systems, reduction of impacts during use, optimisation of initial lifetime, and optimisation of end-of-life systems.

The selection and combination of the strategies in this section is a method in its own right (the “Ecowheel”) and an eco-design team activity [BREZET et al. 1997].

4.1 SELECTION OF LOW-IMPACT MATERIALS

Decreasing hazardousness in the resources used can minimise the environmental impact at the product disposal stage. Selection of low-impact materials can be done either for the product or for the packaging, or for both.

Case Study 4 a – Motorola/Swisscom V2288 WAP- enabled phone Lead and Bromium free product MOTOROLA swisscom	See APPENDIX 8	

Written with the contribution of ***Markus STUTZ*** *and* ***Katrin MÜLLER***

To put its environmental policy into practise, Motorola used an LCA approach which focused on material toxicity and energy, combined with an EPP (Environmentally Preferred Product) Design tool, which emphasised hazardous material reduction, increased recyclability, use of recycled contents of plastic housings, and reduction of energy consumption.

From these, Motorola developed a phone with the following characteristics (Tables 6&7):

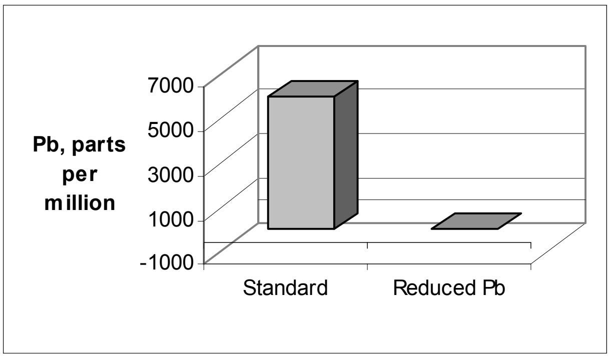


Table 6: Motorola Lead-free phone

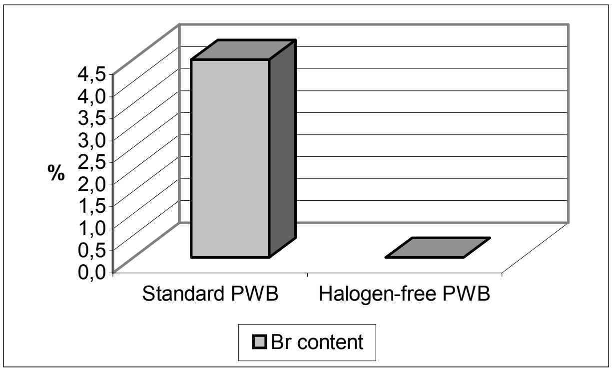


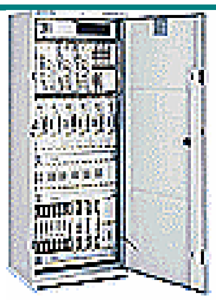
Table 7: Motorola Bromium-free wiring boards

The housing was made of recycled plastics and Motorola developed an energy-efficient charger, which was able to reduce energy consumption between 41% and 83 % depending on the input voltage.

- Customer reaction was tested at specific Fairs but the phone has never been released to the mass market. Customers regarded the SAR (specific absorption rate) value as an important property for environmentally preferred products.

4.2 REDUCTION IN MATERIALS USAGE

Reduction of materials usage is based on a product's dimensions, weight and number of parts. It can also lead to the development of new techniques to avoid the use of some components like ventilation or cooling systems.

Case Study 4 b – Siemens Base Station	See APPENDIX 18	

Written with the contribution of ***Friedrich KOCH*** *and* ***Dr. Ferdinand QUELLA***

The Base Station BS 240/241 has been developed in accordance with the Siemens Standards SN 36350, described in Chapter 2.1. This lead to the development of an environmentally friendly product as outlined earlier.

- Dimension reduction
  - the new structure allows for the installation of 8 transmission units instead of 6,
  - the volume of the cooling system is reduced by 38% ;
- Weight reduction
  - the new subrack contains 17 parts instead of 66,
  - the new cooling system is half the weight of its precursor;
- Component reduction
  - a new air conditioning system has been developed so there is no need to use an outdoor system.

These improvements resulted in a 50% reduction of the manufacturing costs.

4.3 OPTIMISATION OF PRODUCTION TECHNIQUES

The production process should be investigated in order to improve environmental performance. Improvements can be obtained with material substitution, good housekeeping, on-site recycling and modification of technologies. An audit of the manufacturing plant can indicate where changes should be made in the production process.

Case Study 4 c – Shipley PCB Improved production process SHIPLEY A ROHM AND HAAS COMPANY	See APPENDIX 16	

Written with the contribution of ***Martin GOOSEY***

In order to reduce the harmful environmental effects of production process of the PCBs, Shipley decided to improve its processes. One of the improvements was the reduction of water consumption. Shipley also worked on the reduction of tin-lead etch resists by creating an internal recovering and recycling system, by optimising the processes and developing new techniques to reduce tin-lead thickness, the amount of lead plated and stripped. Shipley is now using pure tin etches and has replaced electroless copper with an alternative conducting film.

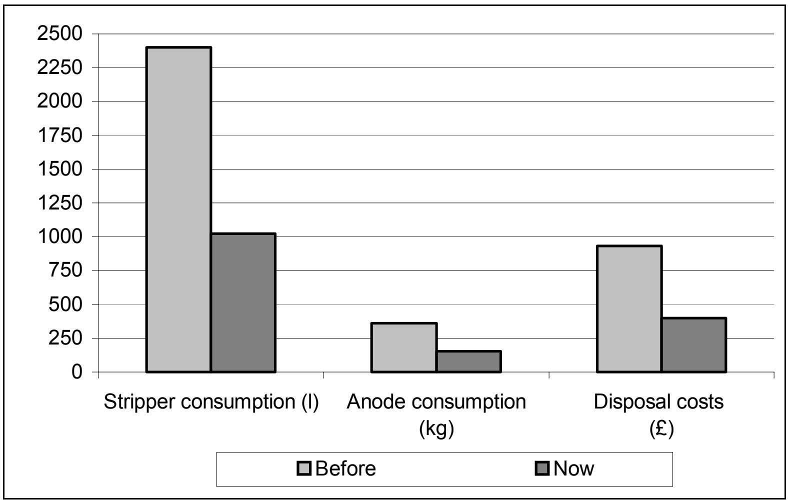


Figure 21: Tin-Lead etch resist savings

The major effort concerns the reduced amount of waste solution generated in the process. This is described below in Case Study 4g.

4.4 OPTIMISATION OF LOGISTICS SYSTEM

Logistics during the whole life cycle of a product (raw materials transport, product distribution, and reverse logistics) has a significant impact on the environment. Companies should minimise the environmental impacts and associated economic costs of their logistics.

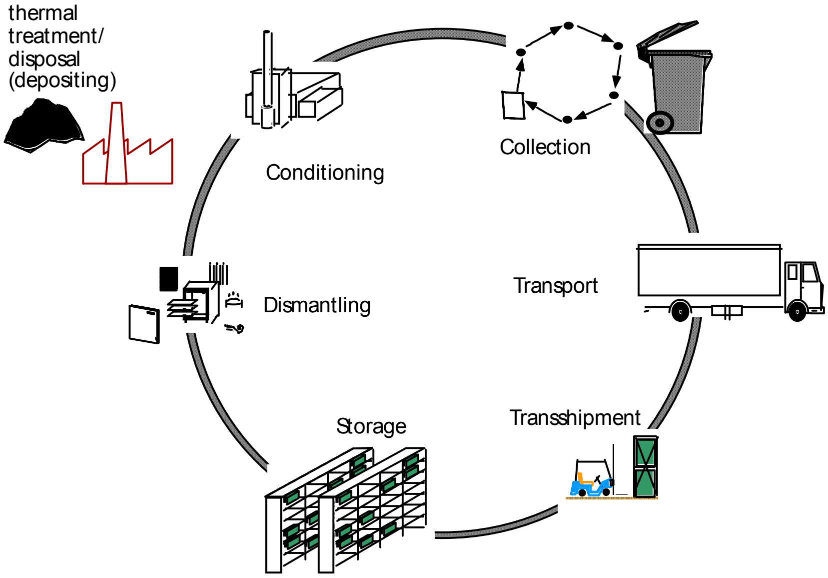


Figure 22: Logistical processes in closed loop economy

Case Study 4.d. outlines a methodology that deals with reverse logistics.

Case Study 4 d – Fraunhofer Institute Logistics account IML Institut Materialfluß und Logistik	See APPENDIX 5	

Written with the contribution of ***Gregor ECKERTH***

A crucial aspect of new legislation is the comprehensive responsibility of the manufacturer for the entire life cycle of his products, which also includes re-acceptance, return and recycling of used products. To carry out these tasks it is necessary to plan and realise appropriate redistribution systems.

In order to address these issues, Fraunhofer-IML developed both:

- a system analysis methodology to identify logistic system's elementary processes and their interactions in a structured way, and
- a corresponding software tool called EDS-RLog (see Figure 23) to support the planning of integrated and cost-optimised take-back and recovery systems.

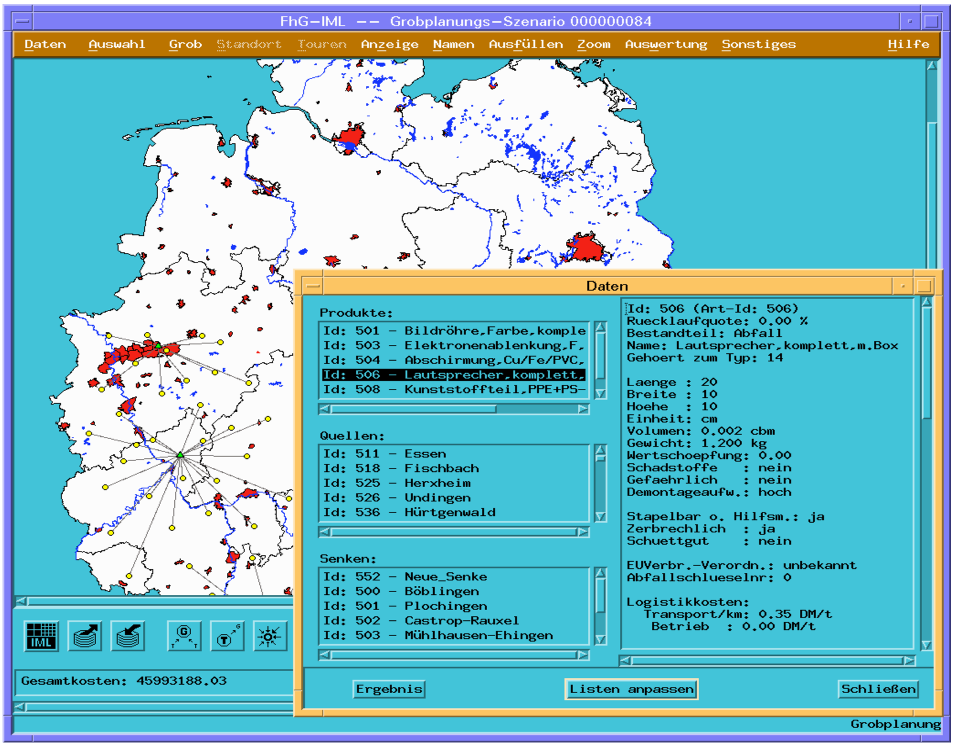


Figure 23: Screenshot of software tool EDS-Rlog

- The system analysis is based on a multi-criteria approach with an economical, ecological, technological and social (H&S) evaluation, also taking into account logistics, recycling and disposal processes.

The flow analysis methodology references seven main processes divided into two well-differentiated groups: transfer (collection, transport, transhipment, storage) and transformation (disassembly, recovery, and disposal) processes.

- The EDS-RLog software tool can be applied for planning suitable redistribution systems, comparing them and showing them on a graph (Figure 24).

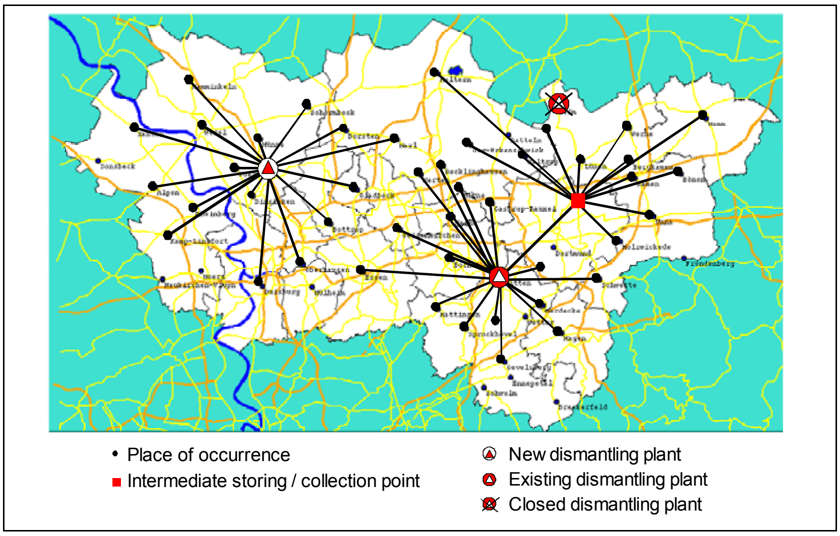


Figure 24: Suitable redistribution systems

Planning of reverse logistic systems are based on:
- Strategic planning: quantity, location and assignment;
- Tactical planning: operating equipment at single locations;
- Operative planning: application of operating means and processes.

The allocation and route-planning tool permits the determination of the theoretical minimum average transportation distance (see Figure 25), which can then serve as a reliable data base for modelling and assessing transfer processes in the context of ecological and/or economical analyses.

Some examples of distribution systems studied with Fraunhofer-IML methodology are :

– Collection system of refrigerators in Germany

The flow analysis showed that a refrigerator:
- is hauled for approximately 165 km before being delivered to a recycling plant;
- is shipped twice on its way (see Figure I, Appendix 5).

Economic evaluation showed that:
- collection and transportation represents nearly 25% of the recovery cost;
- the recovery costs can increase by 75% when transportation distance is up to 750 km.

The theoretical minimum average transportation distance has been determined as 95 km and represents a 40% reduction in the real transportation expenditure.

- Collection and recycling system of cooling appliances in Germany (see Figure 25).

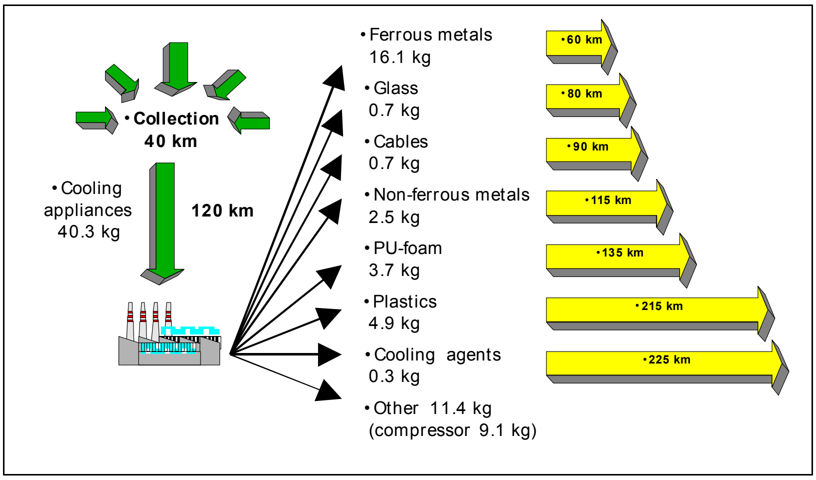


Figure 25: Average transport distance for the recycling of used cooling appliances

- World-wide collection of cameras

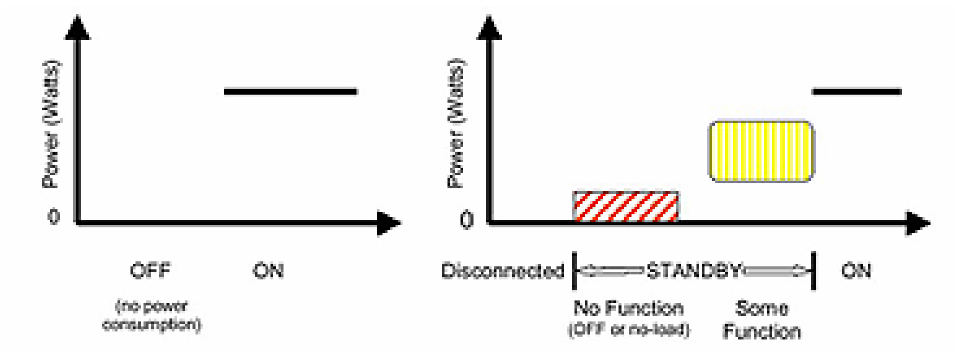
In 1996 AGFA-Gevaert AG put a single-use camera on the market with the intention of reintegrating used components into the production of new cameras for a second life cycle. Concerning the camera version with flashlight, 93% of the weight can be reused, after detailed quality tests. (The version without flash enables 89% of weight being reused). Almost all of the rest of the weight can be recycled.

With EDS-RLog software, different scenarios for a world-wide collection system were elaborated and assessed. The chosen one was certified as decreasing cumulated energy consumption by 30% in comparison to the existing decentralised recycling system carried out by German authorities.

4.5 REDUCTION OF IMPACT DURING USE

Substantial environmental gains can be made for many products by reducing the environmental impact during the use phase. Two key areas that should be addressed are water and energy consumption.

Appliances and other electrical equipment increasingly draw power when they are switched off or are not performing their primary function. This "standby power" provides remote control capability, network sensing, digital display and other features. Often, standby power is consumed simply because power supplies remain "on" while their appliances are switched "off" (Figure 26).



Conditions of product with no standby power consumption | **Relationship between standby and other product conditions**

Figure 26: Product conditions [IEA 98]

Standby power consumption can be reduced by an average of 75 % with cost-effective design changes and technological improvements. Savings as high as 90 % can be achieved in many appliances without any reduction in services. Some products have already achieved very low standby power consumption at little or no cost like the Sony CMD-series phone.

Case Study 4 e – Sony Reduced energy during standby SONY	See APPENDIX 20	 CMD-J5

Written with the contribution of ***Thomas FISCHER***

In order to reduce the environmental impact of its products, Sony has established a list of indicators that enables the quantitative monitoring of each product's environmental impact and suggests concrete steps to be taken to reduce that impact. One of the most important of these indicators is the reduction of products' power consumption in standby mode.

Figure 27: Specific requirements of the Green Management 2002 action plan

Each mobile phone made by Sony since 1996 has been designed so that the power supply is equipped with a supplementary transformer, relay, regulator and microprocessor. When the system is in standby mode, this additional circuitry ensures that power is sent only where it is needed. During this time, a relay cuts off power to the main power supply transformer to prevent the waste of electricity.

The benefit is substantial:

- in the spring of 1998 standby power consumption was less than 3 watts;
- in 1999, it was 1 Watt or less ;
- the challenge for year 2000 was 0 Watt.

A reduction in energy consumption can also be achieved by reducing the power consumption of a product, replacing conventional batteries with solar energy systems or even using human power.

Case Study 4 f – Philips Free powered radio
Human power

PHILIPS

See

APPENDIX 12

Written with the contribution of ***Maarten TEN HOUTEN*** *and* ***Ab STEVELS***

The free powered radio has been developed in order to primarily eliminate batteries. Its current supply is provided with a directly integrated generator, such that 1 minute crank time provides the radio with enough current for approximately 30 minutes play time.

Table 8 compares the characteristics of the Philips wind-up radio to competitors' products.

	Philips	Comp1	Comp2	Comp3
Energy battery mode (mA)	18,6	N.A.	28,3	16,3
Human power mode (min)	30	20	20	20

Table 8: Characteristics of newly developed Philips wind-up radio AE1000

4.6 OPTIMISATION OF THE INITIAL LIFE STAGE - DESIGN FOR UPGRADE AND REUSE

The objective here is to increase the initial lifetime of a product so that it can be used for a longer period before being replaced. The main issue in this field is to focus not only on products themselves, but on the product within the system and the constraints in this system. Optimisation for upgrade and reuse can be reached by:

- designing for easy maintenance by, for example, incorporating simple and quickly detachable parts;
- designing for upgradability, which is easier if the product is modular.

The extension of the original lifetime can lead to the establishment of a repair and maintenance service to supply spare parts and labour.

A product can become obsolete for the user for many reasons [VAN NES et al. 1998].

- Technical: the product is worn out and no longer functions properly;
- Economic: new products have a lower level of 'costs of ownership' (maintenance, energy, etc.);
- Ecological: new products have less harmful impact in the use phase (maintenance, energy, etc.);
- Aesthetical: new products have a nicer look, a more fashionable design, a better image;
- Functional: new products fulfil functions better;
- Psychological: old products have a negative emotional factor (unpleasant history); new products have a positive emotional factor.

Taking these into account, a design team can design a product that overcomes these obstacles. In particular, if one of the above reasons only concerns a part of the product, it can be designed to be easily upgraded, using modular design principles.

In the following Siemens Case Study, the functional obsolescence of a part of the product demands this part should be easily removed and replaced at the end of the product's initial lifetime.

Case Study 4 g – Siemens Control Module
Retrofit solution

SIEMENS

Written with the contribution of ***Siegfried WISSER***

The use-time of systems is influenced by many different factors. Defects are rarely the only reason for refurbishment and replacement. Additional functions, better-controlled processes, faster and cheaper production or excellent quality are the main features preferred by customers.

How can these requirements be performed?

- On one hand the total system can be replaced by a new one. An often-preferred solution is to achieve state-of-the-art, which needs much effort, resources and cost.
- On the other hand an environmentally sound solution can be obtained by the upgrading of specially selected components and reuse of the remaining ones. The second way to deal with this is used if there are very specific conditions. For example: high electrical power or special voltage is needed, or for cost reasons total replacement is not economical.

Cross-cutter drives in the steel industry, main drives for printing machines, applications in paper manufacturing or rolling mill drives are examples of these complex and extremely expensive plants/equipment. The investigation showed that wear-out and damage of motors, power sections and mechanical systems is less than expected. Therefore, these components can be used and reused for longer periods.

Control units are linked to other innovation cycles, for example to personal computers (integration, communication and network capabilities), which quickly become unfashionable or inefficient. For this reason, the SIMOREG DC-Master Control Module was developed and produced.

The compact and modular structure of the product allows the integration of the Control Module in every control section of all existing plants /equipment:

- Systems that have already been 5 -15 years in use can be upgraded with the Control Module to state-of-the-art / higher performance and efficient use for an additional 5 -15 years;
- At the same time, the functionality of the whole system leads to high working speed, or with predictive process control the problems can be solved before they affect production;
- RE-start can be obtained quicker and easier, thanks to a fully electronic parameterisation of all settings;

- Disassembly, new installation and two way transportation of the main components is not required.

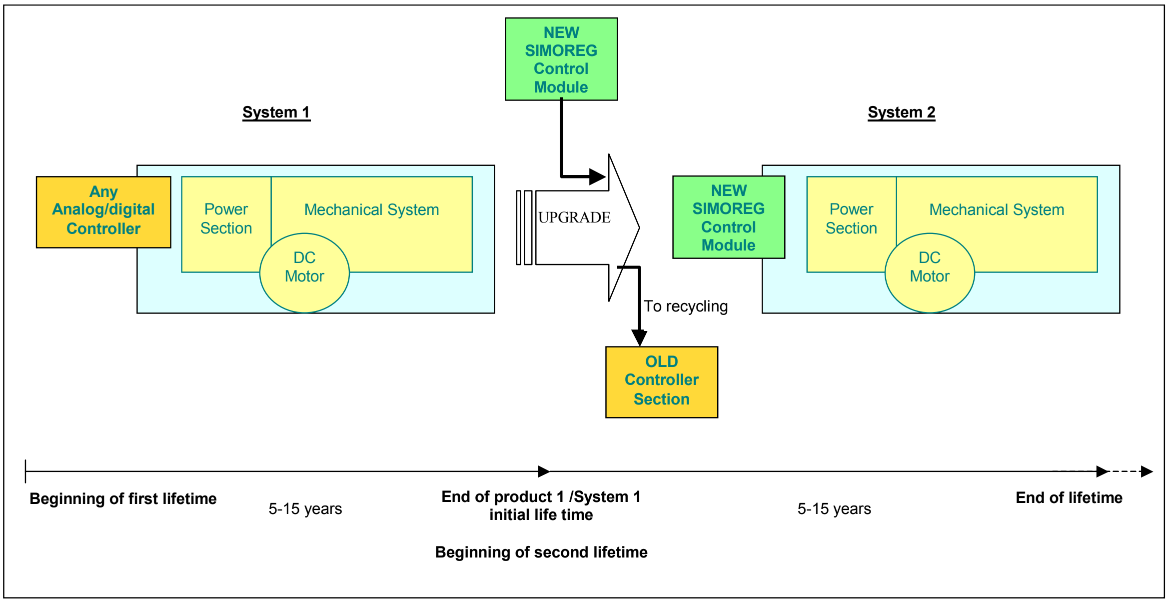


Figure 28: Schematisation of an upgrade process which increases the initial life time of a product

With the Control Module as a new product, reuse of most of the system components of existing plants is possible, and their usage can be extended.

4.7 OPTIMISATION OF END-OF-LIFE SYSTEM

This section deals with reuse, remanufacturing, refurbishing, and recycling options.

Case Study 4 h – Shipley Tin and Lead recovery SHIPLEY A ROHM AND HAAS COMPANY	See APPENDIX 17	

Written with the contribution of ***Martin GOOSEY***

The Printed Circuit Board industry employs tin-lead alloys as etch resists in the manufacture of PCBs and subsequent processing resulting in the generation of large quantities of spent solutions containing high concentrations of both tin and lead. These solutions are increasingly undesirable from an environmental/disposal perspective and in terms of waste treatment costs.

Shipley with two others companies, Vero Electronics Ltd and Finishing Technology Ltd, decided to undertake a project to evaluate waste treatment methods for these tin-lead stripper solutions. It involved practical evaluation of recently identified electrochemical techniques for the reclamation of tin and lead so that they can be recycled rather than consigned to landfill. As a result, an optimised treatment methodology has been identified and a prototype piece of equipment manufactured, which is currently undergoing Beta site testing at Vero Electronics.

The equipment is capable of taking typical spent tin-lead stripper solutions and converting them into reusable tin oxide and lead deposits, whilst producing a metal free liquid component that can be treated with other PCB effluent.

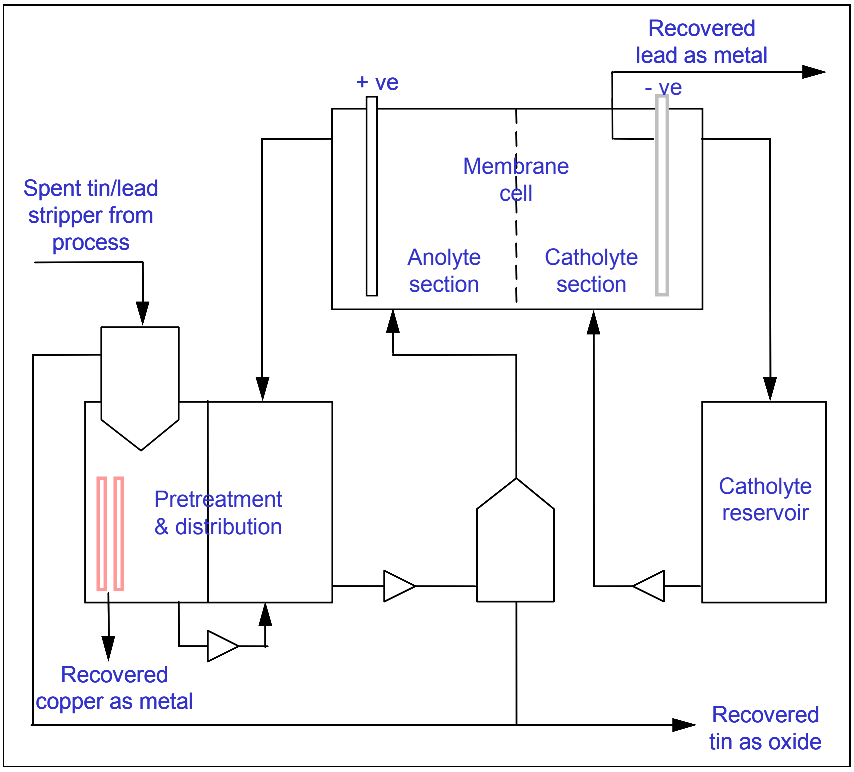


Figure 29: Tin-Lead recovery module

- The tin is recovered as tin oxide - widely used as a polishing medium, which is more valuable than tin metal - by use of a specially designed filtration technique.
- The lead is electrochemically recovered using a divided cell approach and ion permeable membrane technology. It can be recovered onto either stainless steel sheets or, alternatively, copper clad laminate.

It is estimated that the capital payback period for this new equipment, based on the value of metal recovered and savings in the cost of offsite disposal, will be approximately two years. Additionally, the continually increasing costs of disposal (landfill tax etc) mean that this technique will become even more attractive over the next few years.

Case Study 4 i – Xerox
Refurbishment

THE DOCUMENT COMPANY
XEROX®

Xerox copier

Written with the contribution of ***Malcolm HEMMING***

As a result of a strict environmental policy the end-of-life potential of products, components and supplies has been maximised by building the concepts of easy disassembly, durability, reuse and recycling into equipment design. Xerox document systems are designed in such a way that a large proportion can be reused or recycled in a new product from the same family (Figure 30). Xerox offers the same guarantee for products regardless of the reprocessed content.

Used copiers are dismantled at a special factory.	Parts are tested and selected for reuse.	Worn out parts are turned into scrap. The scrap is used as raw material for producing new parts.	A new copier is assembled from reused parts, (partly) recycled parts and new parts.

Figure 30: Reprocessing stages

The reuse and recycling rate is enhanced by situations where Xerox remains in contact with the customer throughout the product Life Cycle. Examples of such customer relationships include the servicing and maintenance of equipment, and arrangements whereby the customer purchases a document service rather than the equipment.

This policy yields important results: up to three quarters of the components are reused and for some parts up to 98% are recycled.

Optimisation of the end-of-life system implies that the collected products are undamaged before reuse and are of a high standard. Product components must be available or remanufactured for a long time.

4.8 NEW CONCEPT DEVELOPMENT

This eco-design strategy differs from the previous ones in this chapter because it requires innovative thinking. A "Factor 4" or greater reduction in environmental impact is hard to achieve by modifications to existing products. The idea behind new concept development is to integrate and optimise product functions or to replace the product with a service. This potentially leads to the development of new products with new functions or new business patterns to meet the same market needs. One example is the replacement of individual telephone answering machines with voicemail services operated by the telecom company: this eliminates many products, and substitutes a computer at the telephone exchange, providing new services at the same time. Another example is the convergence of portable electronic products - combining mobile phone, PDA and MP3 player into one product reduces materials use.

When eco-design strategies are considered by the design team, “new concept development” promotes thinking towards a sustainable future beyond the existing product.

4.9 COMBINATION OF STRATEGIES

The use of several different impact reduction strategies can produce better results than the application of a single one. In the process of product development, these strategies may include optimisation of the service provided by the product, conservation of resources, and reduction of pollution, waste and nuisances.

Eco-design strategy can be a corporate decision (and not only a specific product decision), as is the case with the Philips Ecovison programme.

Case Study 4 j – Philips
Eco Vision programme

PHILIPS

See

APPENDIX 11

Written with the contribution of ***Ab STEVELS***

Product development (Eco-design), marketing and sales are focused on one or more of the following Green Focal Areas:

- Energy consumption (operational, stand-by, sleep- and off mode) and energy cost during use of the product; 
- Weight reduction: weight and cost of materials applied (plastic, ferrous metals, non ferrous metals); 
- Environmentally relevant "hazardous substances": flame retardants in housing, area, weight, and number of wiring boards, length of cable and wiring; 
- Packaging and transport: weight (plastic bags, manual/user books) and cost (packaging, recycling); 
- Recycling and disposal: calculated disassembly time, cost/yield with respect to reference disposal cost (mix of landfill and incineration); 

These five focal areas are used for benchmarking studies (see APPENDIX 10), and enable analysis in a single measurement unit (kWh, kg and percentage).

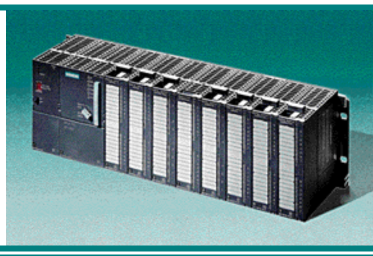
The programme has yielded very positive results: market share increased by 2% and profit margins by 3%.

Case Study 4 k – Siemens Simatic S7-300
Reduced energy, materials

SIEMENS

See

APPENDIX 19



Written with the contribution of ***Friedrich KOCH*** *and* ***Dr. Ferdinand QUELLA***

The SIMATIC S7-300 has been redesigned in order to improve recyclability of the former programmable controller. Ecological, economic and technical aspects have been taken into account along the entire product life cycle so that environmental performance of the product was optimised at the end of the project.

The main benefits related to energy consumption and weight, which were reduced by 40% and 46%, respectively.

It appears that design choices should be determined by a combination of environmental strategies. The ecological aspects should also be included with other design criteria, and "the choice of a specific design solution shall achieve a reasonable balance between environmental factors and other relevant considerations, such as safety and health, technical requirements for functionality, quality, and performance, and economic aspects, including manufacturing costs and marketability." [EEE 2001].

4.10 CONCLUSION

It has been shown that a combination of eco-design strategies can be defined for a specific product or a company. The strategy or strategies chosen are mainly based on environmental criteria. The choice of an environmental impact reduction strategy should be based on internal environmental criteria weighting. However, it can also be based on “organisational/strategic” reasons: for example, in an SME there is less need for specific tools or for management of the eco-design process, as long as there is a senior manager who is committed to eco-design and innovation, and who can see the strategic benefits and cost savings.

Besides being easily understood by most of the users, it appears that legislation (in particular the WEEE Directive) is perceived as a very strong driving force.

5 - DIALOGUE AND PARTNERSHIP

As was shown earlier, eco-design is comprised of complex concepts and actions. Therefore, co-operation represents a key element in the eco-design process; it can be internal (between product manager, environmental expert, designer, marketer, etc) or external (collaboration with customers, recyclers, research centres, etc), or both.

Case Study 5 a – Motorola Green phone	See APPENDIX 9	
MOTOROLA swisscom		

Written with the contribution of ***Markus STUTZ*** *and* ***Katrin MÜLLER***

The objective of Swisscom is to develop, implement and market environmentally friendly services. The company decided to promote "green products" by working closely with its suppliers and researching the ecological interests of its customers.

Co-operation with suppliers (see also Chapter 4.1)

The main co-operation was established with Motorola to determine the improvement opportunities for telecommunication equipment. Swisscom asked Motorola to deliver life cycle assessment data relating to a pager and a mobile phone to quantify the environmental performance of the products and to detect product-oriented weak points. Based on the supplied data, Swisscom decided to focus on material toxicity and energy use. For this purpose, Motorola developed a lead free and a bromium free wiring phone which also reduced energy consumption by between 41 and 83 % depending on the input voltage.

Collaboration with customers

A customer enquiry was made via hotline to evaluate:

- the ecological interest of customers (Figure 31);

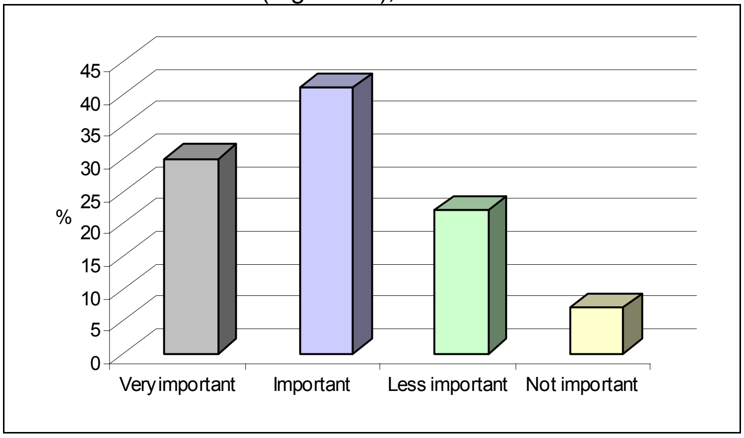


Figure 31: Importance of EPP to consumers

- the major issues (Figure 32);

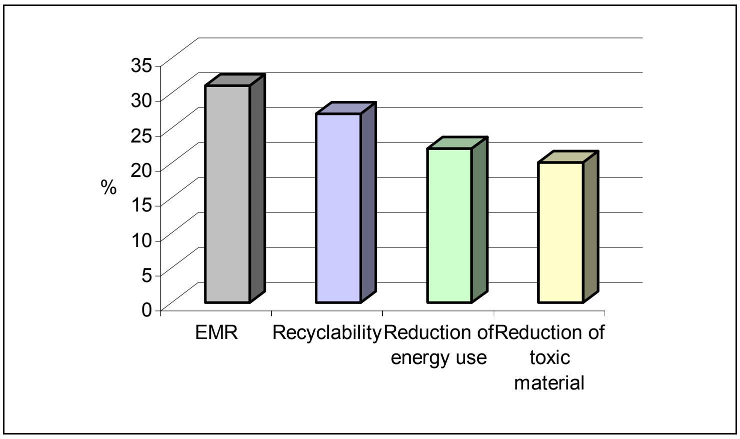


Figure 32: Major issues for EPP for consumers

- the economic barrier (Figure 33);

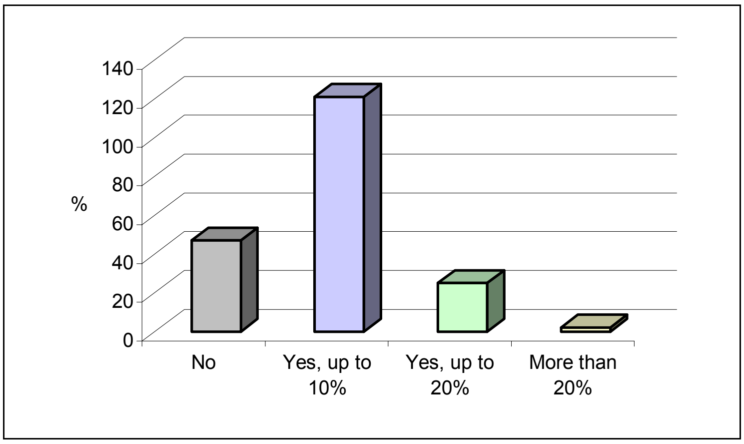


Figure 33: Willingness to pay for an EP cell phone

- their attitude towards the use of recycled materials (Figure 34).

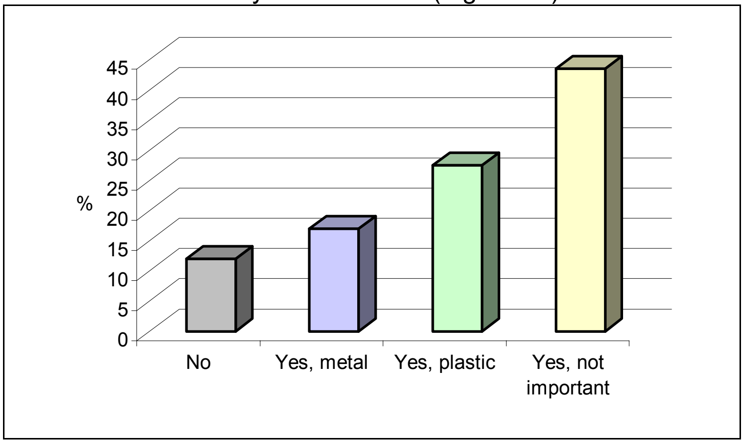


Figure 34: Willingness to buy a cell phone with a housing made of recycled material

The feedback was very positive. Customers were pleased to see that Swisscom and Motorola were involved in the development of environmentally friendly products.

5.1 PARTNERSHIP AND SUPPLY CHAIN

The development of environmentally friendly products implies the use of environmentally friendly components. It is necessary to translate a company's internal environmental requirements into requirements for materials purchased, components, and Original Equipment Manufacturer products and services.

Case Study 5 b – Xerox integrated supply chain networked and digital documents

Product stewardship and end-of-life customer dialogue

THE DOCUMENT COMPANY

XEROX®

See

APPENDIX 23

Xerox Green World Alliance

Written with the contribution of ***Malcolm HEMMING***

Xerox operates a closed loop process (Figure 35) in which reverse logistics are integrated into the supply chain. Thus products are removed from the customer premises by reversal of the processes by which products are supplied or serviced. For supplies, these processes are supplemented by a postal return system, the overall programme being entitled the "Green World Alliance".

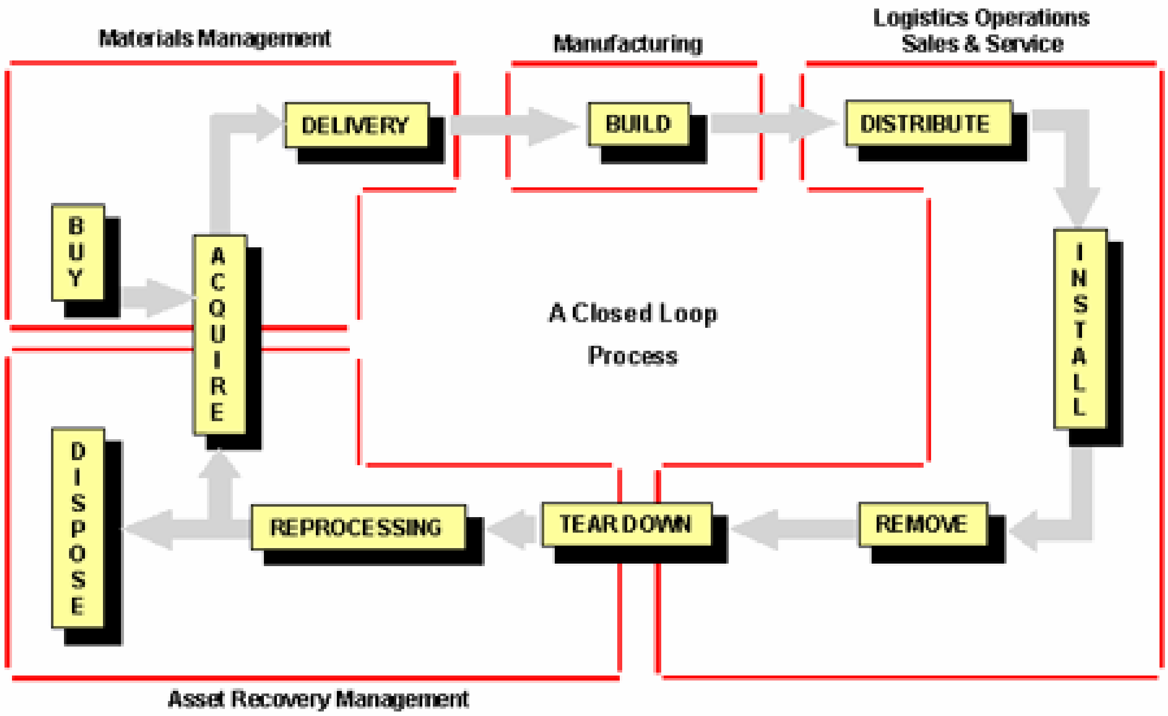


Figure 35: Close loop process

Returned products and supplies are transported to the Logistic Return Centre where they are inspected and allocated to the appropriate product line and category (Figure 36):

- Category (Cat) 1 products are repaired;
- Cat 2 products are remanufactured or converted;
- Cat 3 products are broken down to retrieve usable parts or to recycle the material;
- Cat 4 products are sent to scrap dealers or, as a last resort, to controlled disposal.

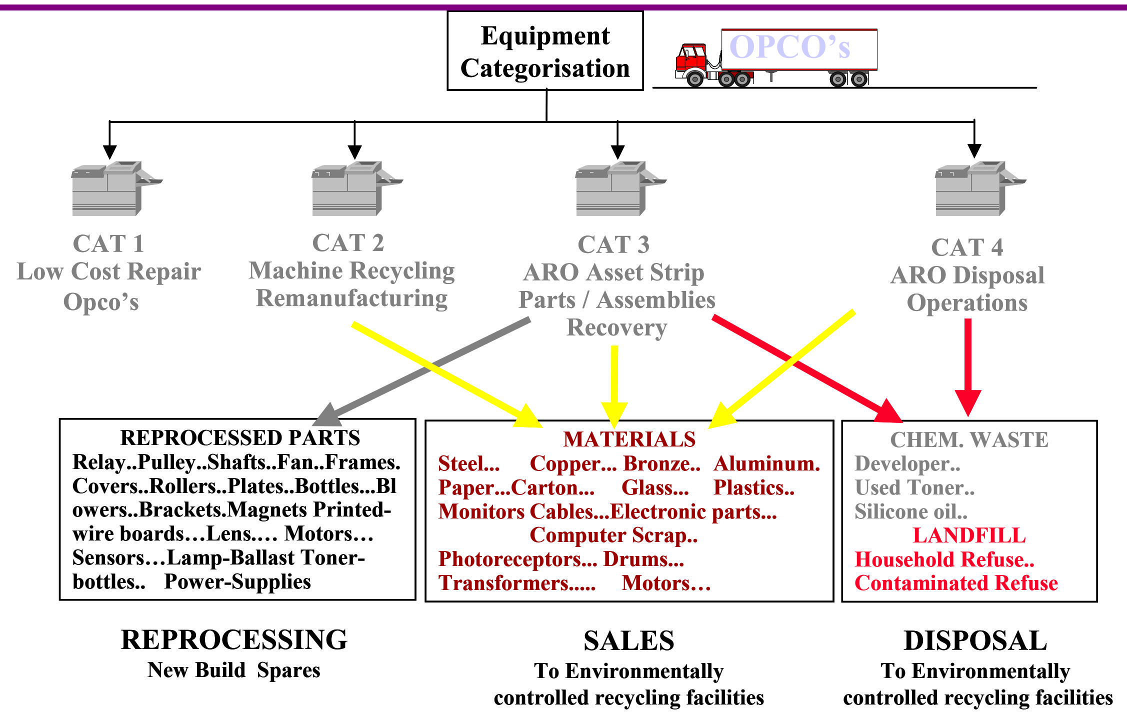


Figure 36: Reverse supply chain operations

Parts and components are certified for reprocessing in-house, or returned to the supplier for certification or recycling. Materials are sent to specialist recycling companies for the regeneration of material to be used for new parts and components, or for alternative uses.

5.2 INFORMATION PROVISION AND TRAINING

The insights gained from the following case studies can be applied to both SME's and to large multinational corporations. This is in line with the concepts of dialogue and partnership, through which interactions along the supply chain can be developed.

Case Study 5 c – Schneider Website Communications Schneider Electric	See APPENDIX 15	

Written with the contribution of ***Isabelle FERNANDEZ***

Because of a lack of environmental information in the Schneider intranet roadmap, an intranet website to provide environmental information to designers was initiated in 1999. The main subjects concern environmental policy, standards and regulations. The website also illustrates Schneider Electric's guidelines and gives a list of hazardous substances, as well as products' end-of-life📖 information.

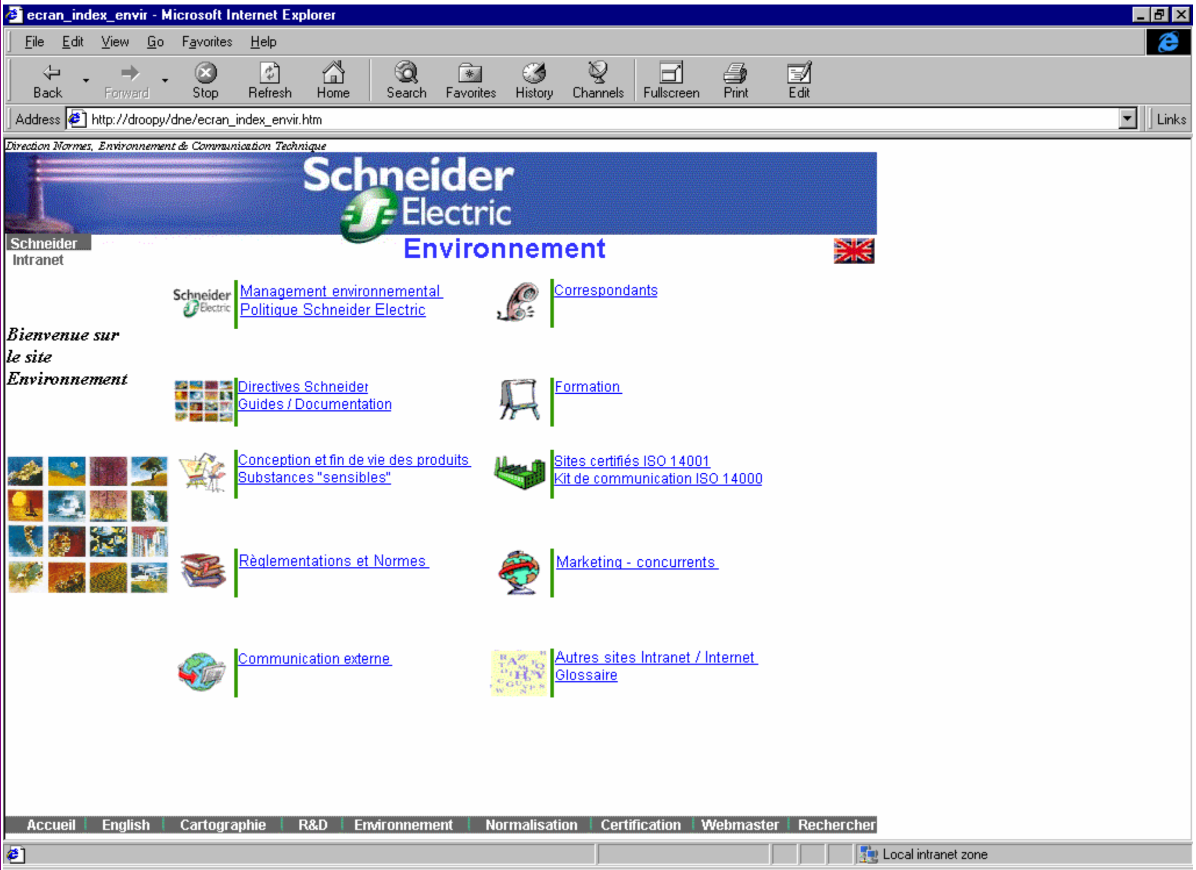


Figure 37: Page of Schneider internal website

Case Study 5 d – Crawford Hansford & Kimber ETMUEL Training programme for SME's **Crawford Hansford & Kimber Ltd**	See APPENDIX 3	

Written with the contribution of ***Steve SCARLETT*** *and* ***Martin CHARTER***

In order to remain competitive in its field, in spite of a difficult period (increasing outsource production of items like PCB's, speed of technology), Crawford Hansford & Kimber (CH&K), a designer and manufacturer of electronic and electrical equipment, decided to set up an eco-design policy.

CH&K then took part in the CfSD ETMUEL programme, a training programme for SMEs (CfG 21 programme), designed to increase awareness of strategic environmental issues and business competence of participants, to best practice benchmarking, and to provide new business opportunities.

Two staff members received specific training on:

- Smart eco-design©, which has ten training modules focused on the eco-design needs of the electronics sector. The courses are designed for cross-functional teams combining awareness raising, skill development and practical exercises, and can be customised to individual requirements, time and budgetary constraints.

Supply Chain Partnership

- to work directly with small and medium-sized electronics companies in manufacturing, component supply, design and recycling, and to communicate and implement eco-design issues;
- to organise a series of workshops over two years involving key in-house and/or ex-house personnel, e.g. directors, designers and purchasing managers, with the aim of exploring opportunities and problems associated with the implementation of eco-design. Other employees participated in several internal workshops and conferences organised by CfSD in order to better understand the hands-on eco-design process in SME's;
- to adapt existing eco-design checklists for use in companies. Checklists were established to help the designer in choosing environmentally preferred material, in avoiding using hazardous substances and to allow recycling;
- to develop new eco-design tools, where appropriate.

The knowledge achieved allowed CH&K to completely revise the PCBs' development process taking into account environmental aspects. The production process was improved to reduce wastes without additional cost. Finally, as a result of the emphasis on eco-design, new commercial contacts were made.

Recent studies have shown that, in terms of achievements, internal factors ("culture") have a strong influence. In particular, management decisions and cross-functional capabilities are of major importance. In fact, the internal organisation seems to be more important than the external one.

Business conditions, external influences and the possibility to obtain a competitive advantage, particularly influence the time scale on which eco-efficiency can be realised [CRAMER 2001].

5.3 INFORMATION COLLECTION

Product development always requires extensive technical information in the form of data. The quality of the data is important to facilitate decision-making. This is particularly relevant when assessing the product. Exact requirements for data to be gathered are defined by the metrics that the organisation has chosen.

Case Study 5 e – Hotpoint New washing machine from Whitebox project

Information collection

Written with the contribution of ***Matthew SIMON***

The "Whitebox" project was a pilot research project, involving engineers from the Life Cycle Design Research Group at Sheffield Hallam University and the Mechatronics Research Group at De Montfort University. GDA, the industrial collaborator, are manufacturers of Hotpoint / Creda / Cannon domestic appliances. The project was conceived in response to the EU WEEE Directive (waste from electrical and electronic equipment). The aim of the project was to prototype Life Cycle Data Acquisition (LCDA) devices, and assess the quality and value of the data obtained for product life cycle management; the project, thus, had economic and environmental goals. (The concept was termed a "Whitebox", by analogy with aircraft "black boxes".)

The Vogue II, launched in May 2000, was GDA's first washing machine with single-board electronic control across the complete range; many other components were also new. This radical redesign permitted an assessment of the costs and benefits of life cycle data acquisition by GDA's designers, resulting in additional functions. Some memory within the controller is used to store the lifetime use data. Fault diagnosis is significantly improved. The front panel carries two-way optical communication (via LED and IR) so that the machine can be controlled, tested and diagnosed for errors by handheld computer. These communication functions are utilised during manufacture for end-of-line tests, in-life tests and will be employed by service engineers. This development places GDA in a good position to deal with end-of-life environmental issues when they arise: data on the lifetime use of the machines will be readily available.

The Whitebox project has demonstrated the wider benefits of LCDA systems, which integrate the data over the whole product life-cycle, namely, manufacturing, distribution, use and disposal. Significant environmental benefits plus cost savings can be gained with the use of LCDA devices, components or systems. For the Vogue II washing machine, for example, cost reductions in end-of-line testing result from the use of Whitebox functions. For an estimated annual production of 750,000 machines and a product life of 5 to 7 years, savings from informed and more efficient servicing can be very significant.

The environmental balance of LCDA systems is undoubtedly on the positive side. The only additional burden is some extra hardware which consumes a little extra energy, plus a centralised database. On the credit side, there are four principal benefits:

- The system can be used on the production line to configure and test appliances;
- Smart control of the appliance can reduce energy or water consumption in use: for example, a networked appliance can be integrated into a home automation system to optimise the use of preheated water;
- Preventive maintenance allows servicing and adjustment of a product for optimum efficiency; in the event of a failure, LCDA data can prevent unnecessary part replacement by correctly identifying the fault;
- Removed parts and end-of-life recovered parts can probably be assessed for reuse more effectively using their life history. This has not yet been tested, but any increase in reuse would save resources.

Concluding remarks

The editors of this Guide asked the contributors to express their own vision of eco-design.

"The integration of the environmental dimension into design is the result of a continuous and progressive process fed by new development in materials and processes, as well as on the better knowledge of existing recovery practices. This process is by definition never-ending.

This guide is a real success:

- it is a good way to convey the numerous approaches to eco-design;
- it gives each partner, the opportunity to set out his/her own experiences and processes."

Alain CLEMENT (Product Environnent Manager, Thomson Multimedia)

"As the first successful eco-design approaches develop, it is necessary to produce pragmatic eco-tools, which can be articulated with current and well known design process phases. To achieve a systematic eco-design methodology, both eco-tools and design process steps need to be adapted progressively."

Marc JANIN (ENSAM)

"Eco-design is part of Life Cycle Management and, therefore, part of business management. This fact has to be recognised much more explicitly than currently practised. It brings with it challenges, but also tremendous opportunities. If eco-design is applied in a proper way it is a powerful tool to enhance the competitiveness of those who tackle the challenges. It is my vision that, in the future, eco-design will be as widespread and commonly used as cost management for the benefit of businesses, customers, and the environment."

Gerald REBITZER (Swiss Federal Institute of Technology, Lausanne)

"Eco-design is often the work of committed individuals and many of the cases presented here are the product of their efforts within organisations. This is a welcome expression of professional ethics and personal ideals. All power to these progressive engineers, designers and managers who have a vision of sustainability!"

Matthew SIMON (Sheffield Hallam University)

"As eco-design practices are currently being developed and implemented in companies, no real conclusions can be made at the present time. The editors only wish to make it clear that motivation and creativity of all actors will be needed in the near future to really take up the challenge of sustainable design.

Good luck!"

Fabrice MATHIEUX (ENSAM)

DfD Design for Disassembly

Design allowing easier disassembly of a product.

DfEE Design for Energy Efficiency

Design of a product for low energy consumption.

DfE Design for Environment

DfE is a concept where the environment is one of the relevant criteria integrated during product design, as well as cost, quality and performance. It results from the decision of some companies to establish for designers specific environmental objectives for products. It is a way of taking into account environmental constraints as early as possible during the design process. It is also a way to decrease the harmful effects of a product during its life cycle in a continuous manner (see the continuous improvement concept outlined in Chapter 2.3 and in the ISO 14001 standard).

DfR Design for Recycling (or Design for Recovery)

Design allowing easier recovery of a product at the end of its lifetime.

ECDM Environmentally Conscious Design and Manufacture

ECDM is the most recent approach to the design for environment concept. It covers both, the design of products and the design of processes. The main idea behind ECDM is that designers are conscious that negative environmental effects will invariably take place during the life cycle of the product and that they should try to include some constraints in their design to decrease these effects.

Eco-design

The word *eco-design* will soon replace the earlier phrase "design for environment", although the latter is still used in some organisations. Eco-design reflects life cycle thinking, as opposed to the greening of designs, which might only involve one stage of the life cycle. Other largely synonymous terms are Environmentally Conscious Design and Manufacture (ECDM) and Environmentally Sensitive or Superior Design (ESD).

Energy Efficiency

A sustainable system is characterised by its ability to deliver required services without exhausting resources. The efficient use of all resources is necessary both in an environmental and economic sense. Using energy inefficiently creates waste in all the world's economies and has environmental impacts with local, regional and global implications. The steps to create a sustainable energy system begin with the sensible use of resources, and continue with increased use of renewable resources and controlled use of non-renewable one in advanced technology. Energy efficiency is a top priority in moving to a sustainable energy system.

Many technical developments have fostered more and more sophisticated equipment, which provides increased service with less use of energy. Much of the challenge in creating a sustainable energy system lies in how technological achievements can be put to use faster, be more broadly disseminated and how the behaviour of energy users adapts.

EHS Environmental, Health & Safety

EOL End-of-life

EPP Environmentally Preferred Product

ESD Environmentally Sensitive (or Superior) Design

LCA Life Cycle Assessment

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" [ISO 14040].

LCC Life Cycle Costing

Life Cycle Costing is the economic assessment of all money flows that are caused by the existence of a product [BLANCHARD and FABRYCKY 1998].

LCD Life Cycle Design

Life Cycle Design is defined as a life cycle systematic approach with the objective to give the most complete environmental profile of a product or service. The idea behind the LCD concept is that taking into account the complete life cycle of a product should help designers to develop products, for which the main potential environmental impacts are identified, minimised, and not simply displaced, as could happen in environmental engineering or pollution prevention. For example, the reduction of waste production during the manufacturing phase can generate an increase in waste in the overall life cycle.

LCM Life Cycle Management

"LCM aims at integrating environmental concerns into industrial and business operations by considering off-site, or supply chain, impacts and costs. LCM seeks to increase the competitiveness of new, and existing, products by examining advantages, and business risks, associated with the environmental and social aspects of a product, throughout its life cycle." [HUNKELER et al 2001].

PCB Printed Circuit Board

PLCM Product Life Cycle Management

See LCM (Life Cycle Management)

Pollution Prevention

Pollution prevention is considered as an essential alternative to end-of-pipe processing. It was introduced towards the end of the 70's in the United States, by companies such as 3M with its 3P programme that led to a drastic reduction in waste. The pollution prevention concept was refined in the 80's, and began to be used in Europe in the 90's. It gathers together a whole series of approaches which focus on the reduction of waste and recycling in open- or closed-loop production processes. The objective is to eliminate any type of pollution due to equipment or manufacturing processes by redesigning the products, substituting materials, modifying some technologies and eliminating unessential polluting stages. This approach always focuses on the manufacturing stage of products.

WEEE Waste from Electrical and Electronic Equipment

[de BEAUFORT-LANGEVELD et al. 1997] Simplifying LCA: Just a Cut? - Final report of the SETAC-Europe Screening and Streamlining Working Group. Amsterdam: SETAC (ed.), 1997.

[BLANCHARD et al. 1998] BLANCHARD B. S., FABRYCKY W. J: *Systems Engineering and Analysis*. Prentice Hall, Upper Saddle River, New Jersey, USA, 1998.

[BRAS 1997] BRAS Bert, *Incorporating environmental issues in product design and realization*, UNEP Industry and Environment, January-June 1997, p.8.

[BREZET 1997] BREZET J. C., *Dynamics in eco-design practice*, UNEP Industry and Environment, January-June 1997, p. 22.

[BREZET et al. 1997] BREZET J.C., VAN HEMEL C., *Eco-design: a promising approach to sustainable production and consumption*, UNEP, Paris, 1997.

[BRUNDTLAND 1987] *Our Common future*, report of the World Commission on Environment and Development, Bruntland Commission, Oxford University Press, Oxford, UK, 1987.

[CRAMER et al2001] CRAMER J.M., STEVELS A., *The unpredictable process of implementing eco-efficiency strategies,* Chapter 18 in *Sustainable Solutions*, Martin Charter and U. Tischner, eds, Greenleaf Publishers Ltd, Sheffield, UK, 2001.

[ECOLIFE 2001] REBITZER G., MATHIEUX F., FERRENDIER S., *Working Paper for the ECOLIFE Network*, 2001.

[EEE 2001] Working paper for a Directive of the European Parliament and of the Council on the impact on the environment of Electrical and Electronic Equipment (EEE), European Community, Brussels, February 2001.

[EENHOORN et al 2000] EENHOORN G. J., and STEVELS A. L. N., *Environmental benchmarking of computer monitors,* Proceedings of the Electronics Goes Green Conference, Berlin, September 2000.

[EHRENFELD 1997] *Implementing design for environment*, a primer guide developed by Digital Equipment and the Massachusetts Institute of Technology programme on Technology, Business & Environment, USA, 1997.

[FELDMANN et al 1999] FELDMANN K., MEEDT O., TRAUTNER T., SCHELLER H., HOFFMANN W., *The Green Design Advisor: a tool for Design for Environment*. Journal of Electronics Manufacturing, Vol. 9, No.1, March 1999, p. 17-28.

[FLEISCHER et al. 2000] FLEISCHER G. (ED.), BECKER J., BRAUNMILLER U., KLOCKE F., KLÖPFFER W., MICHAELI W. (CO-EDS.), *Eco-Design – Effiziente Entwicklung nachhaltiger Produkte mit euroMat*, Berlin, Germany, Springer, 2000.

[FRANKL et al. 2000]	FRANKL P., RUBIK F., *Life Cycle Assessment in Industry and Business – Adoption Patterns, Applications and Implications*, Berlin, Germany, Springer, 2000.
[GABILLET et al 2000]	GABILLET JP, HEUDE M. *New energy saving cooling architecture for switching equipment*, Proceedings of the Electronics Goes Green 2000 Conference, Berlin, September 2000.
[GRAEDEL et al 1996]	GRAEDEL T.E., ALLENBY B.R., *Design for Environment*, AT&T.
[HUNKELER et al. 2001]	HUNKELER D., REBITZER G., *Life Cycle Costing – Paving the Road to Sustainable Development?* Gate to Environmental and Health Sciences, ecomed, Germany, 2001 (internet Journal: www.scientificjournals.com/ehs).
[HUNT et al. 1998]	HUNT R. G., BOGUSKI T. K., WEITZ K., SHARMA A.: *Case Studies Examining LCA Streamlining Techniques*, The International Journal of Life Cycle Assessment, Vol. 3, No. 1, 1998, pp. 36-42
[IEA 1998]	*Energy Efficiency Initiative - Volume I: Energy Policy Analysis*, International Energy Agency, Denmark, 1998.
[ISHII et al 2000]	ISHII K. and STEVELS A.L.N., Proceedings, International Conference On Electronics and Environment, San Francisco, May 2000.
[ISO 1997]	*ISO 14040 – Environmental Management – Life Cycle Assessment – Principles and Framework*, Berlin, Beuth, September 1997.
[ISO 2001]	*ISO 14062 – Environmental management – Integrating environmental aspects into product design and development*, draft of the ISO/TC 207/WG3, April 2001.
[JANIN 2000]	JANIN M., *Démarche d'éco-conception en entreprise – Un enjeu: construire la cohérence entre outils et processus"*, PhD. Thesis, Institute of Design, Mechanical Engineering and Environment, Chambéry (France), April 2000.
[KOCH 2000]	KOCH, F.: *Managing Environmentally Compatible Product Design - the Siemens Way*, MEIE´2000, 2nd European Conference on Industrial Electrical Equipment and the Environment, Paris, 2000.
[REBITZER 1999]	REBITZER G.: *Vereinfachung und Aussagesicherheit von Ökobilanzen*. In: GDMB (Hrsg.): Nutzen von Ökobilanzen, Heft 85 der Schriftenreihe des GDMB Gesellschaft für Bergbau, Metallurgie, Rohstoff- und Umwelttechnik. Clausthal-Zellerfeld, 1999.
[REBITZER and al. 2000]	REBITZER G., FLEISCHER G., *Identifying the Environmental Impact Drivers and Tradeoff Options in the Life Cycle of Automobiles – A Software Based Methodology for the Sound Restriction of System Boundaries,* Proceedings of the SAE Total Life Cycle Conference, Detroit, 2000
[REMANDE et al 2000]	REMANDE E., CHARBONNEAU M. FERNANDEZ I., *Designing product with less environmental impacts: masterpact, a pragmatic approach*, MEIE 2000, 2nd European conference on Industrial Electrical Equipment and Environment, Paris, 2000.
[ROSE 2000 a]	ROSE, C., *Design for environment: a method for formulating product end-of-life strategies*, PhD thesis, Stanford University, December 2000.

[ROSE et al 2000 b] ROSE, C.M., ISHII, K., STEVELS, A., *Tools for building product end-of-life strategy*, submitted to Journal of Sustainable Product Design, September 2000.

[ROYSTON 1979] ROYSTON M. G., *Pollution Prevention Pays*. Oxford: Pergamon Press, Oxford, UK, 1979.

[SIMON et al. 1998] SIMON M. and al., *Eco-design Navigator*. Cranfield University, Cramfoeöd. UK, 1998.

[STEVELS 1996] STEVELS A., Inaugural address, Rathenau Institute, September 4, 1996.

[STEVELS and al. 2000] STEVELS A., ROSE C., *Environmental Metrics to classify End-of-life Strategies (ELSEIM).* Proceedings International Symposium on Electronics&Environment, Denver, CO, May 7-9, 2001, pp100-105.

[VAN NES et al. 1998] VAN NES C.N., CRAMER J.M., STEVELS A., *Determinants of replacement behaviour for electronic products*, Care Innovation '98, Vienna, Austria, November 1998.

Web sites

These websites contain information about the environmental policies of the companies and organisations which have contributed to this Guide.

Alcatel

http://www.alcatel.com/environment/

Alstom

www.alstom.com

Centre for Sustainable Design

http://www.cfsd.org.uk/
http://www.cfsd.org.uk/etmuel/
http://www.cfsd.org.uk/etmuel/chk_case_study.html

Crawford Hansford & Kimber Ltd

http://www.crawfordhk.com/

Design for Sustainability Research Group

http://www.io.tudelft.nl/research/dfs/index.html

ENSAM Chambéry

http://www.chambery.ensam.fr

International Energy Agency

http://www.iea.org/public/studies/blip.htm
http://www.iea.org/public/studies/blipdef.pdf

The International Journal of LCA

http://www.scientificjournals.com/lca/welcome.htm

Manchester Metropolitan University

http://www.mmu.ac.uk/research.html

Motorola

http://www.motorola.com/EHS/environment/

Philips Consumer Electronics

http://www.philips.com
http://www2.ce-europe.philips.com/do?session=new&vsid=1215&jsp=index&ccode=CE_Global
http://produkte.philipsinfoservice.de/cgidal/dalcgi2/phprod/01runtime/01main/01main.htd?Audioprodukte

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SAT

http://www.ihrt.tuwien.ac.at/sat/base/sat/index.html
http://www.ihrt.tuwien.ac.at/sat/base/ECOLIFE/

Schneider

http://www.schneider.fr/html/kiosque2/references/references9/machines.htm

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Sheffield Hallam University

www.shu.ac.uk/design-research

Shipley

http://www.shipley.com/

Siemens

http--www.siemens.com-Daten-Event-2001-02-26-umweltber2000_e.pdf
http://www.ic.siemens.com/CDA/Site/pss/1,1294,209191-1-999,00.html

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School of Engineering - Stanford University – Manufacturing Modeling Lab

http://www.stanford.edu/
http://www-mml.stanford.edu/
http://mml.stanford.edu/Research/DFE/index.html

Sony

http://www.sony.co.jp/en/SonyInfo/Environment/

Swiss Federal Institute of Technology in Lausanne

http://gecos.epfl.ch/lcsystems/

Swisscom

http://www.swisscom.com/gd/information/corporate_profile/environment_report/ecology_products-en.html

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Technical University Berlin/euroMat

http://www.euroMat-online.de

THOMSON multimedia

http://www.thomson-multimedia.com/gb/01/018.htm
http://www.thomson-multimedia.com/gb/04/doc/env.pdf
http://www.thomson-multimedia.com/gb/04/doc/cycle.pdf

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http://www.xerox.com

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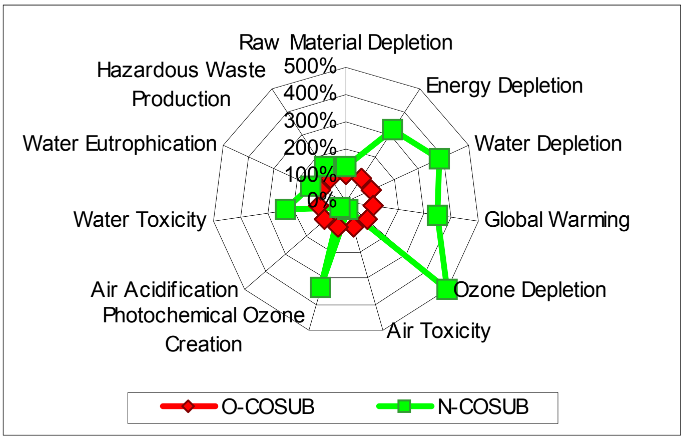
Appendix

APPENDIX 1. ALCATEL - COOLING SUB-ASSEMBLY FOR TELECOM EQUIPMENT

Written with the contribution of ***Marc HEUDE***

Organisation	Alcatel
Sector	Electrical / Electronic
Product	Cooling sub-assembly for telecom equipment 
Background	Willingness to decrease manufacturing costs.
Benefits, success	Demonstration of the possibility to obtain simultaneous improvements in 3 fields: - Reduction of Alcatel manufacturing costs; - Reduction of customers' operating costs through energy bill savings; - Reduction of environmental impacts.
Tools and resources invested	- Use of eco-design software (EIME®) to quantify the environmental consequences of the design options and to compare them, in order to highlight improvement opportunities; - Collaboration between environmental experts and development manager.
Problems or possible issues for improvement	Integration of such environmental studies, earlier in the design process, should reinforce awareness of designers about environmentally conscious design.
Results	In spite of higher manufacturing impacts, the new product has globally a better environmental profile. Energy consumption in use, while halved compared to the previous system, indeed remains the main contributor to environmental impacts. Such improvements may also create a competitive advantage.  **Figure 38: Manufacturing impact**

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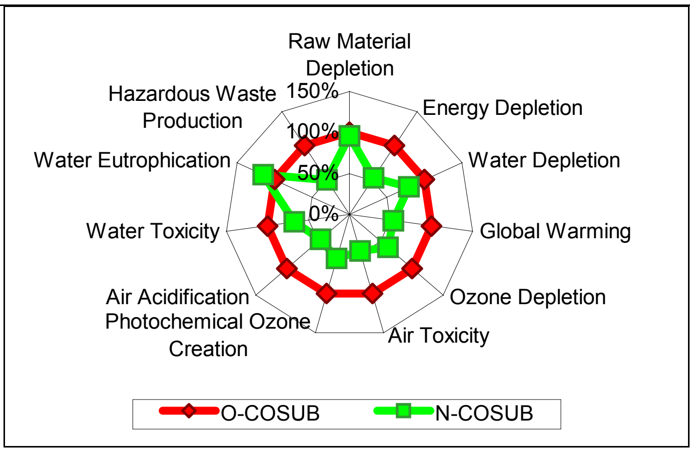


Figure 39: Manufacturing + Use impact

Observations based on qualitative analysis reveals that the recovery rate of the new product is greater than that of the old one.
The profits are beneficial for all:

- the product is less expensive to produce for Alcatel (because of a very simplified assembly);
- the costs of ownership for the customer are reduced (energy saving for the customer is about 5.2 MWh for the ten years of use of the cooling sub-assembly);
- the environmental impacts during the sub-assembly life cycle are reduced.
</td>
</tr>
<tr>
<td>For more information</td>
<td>GABILLET JP, HEUDE M. - "New energy saving cooling architecture for switching equipment" – Proceedings of the Electronics Goes Green Conference, Berlin, September, 2000.</td>
</tr>
</table>

APPENDIX 2. ALSTOM – ENVIRONMENTAL PERFORMANCES EVALUATION OF CIRCUIT BREAKERS

Written with the contribution of ***Jean-Luc BESSEDE***

Organisation	Alstom T&D (Electricity Transport & Distribution)
Partners	Ensam Chambéry
Sector	Electrical
Product	High Voltage circuit-breaker 
Project Name	Environmental performance evaluation of high voltage circuit breakers.
Duration	Since 1998
Background	Alstom product & environment strategy - Alstom T&D is involved in the improvement of the environmental quality of its products. - Together with several electr(on)ic industries, Alstom T&D took part in the development of the integrated software EIME® (based on LCA studies and other criteria) which is available to all business units at Alstom T&D. - The first step of eco-design implementation at Alstom T&D consists in knowing better the real environmental performances of its products during their development. Alstom T&D lead environmental analysis on some high voltage circuit breakers (Air Insulated and Gas Insulated types) using the EIME® tool. During this development process, problems such as the availability of data for LCA and the reliability of the results arose.
Benefits, success	Alstom T&D now has accurate environmental analysis of some high voltage circuit breakers. The reliability of such evaluation has been established and it makes them more profitable for environmental experts and designers.
Tools and resources invested	Tools - Environmental analysis of products made using the EIME® software
Results	Objectives: the main objective of the studies is to have better knowledge of the environmental performances of Alstom T&D High Voltage Circuit Breaker. The reliability of these studies has also been evaluated.

Results (cont)

- The first step is to perform environmental analysis of four circuit-breakers, with EIME® software, on 11 environmental indicators: Raw Materials Depletion (RMD); Energy Depletion (ED); Water Depletion (WD); Global Warming (GW); Ozone Depletion (OD); Air Toxicity (AT); Water Toxicity (WT); Photochemical Ozone Creation (POC); Hazardous Waste (HW); Air Acidification (AA); and Water Eutrophication (WE). The impact of design and constituting materials is evaluated, and the impacts of manufacturing and use are compared for each switchgear. Figure 40. gives an example of the type of results obtained on one particular switchgear.

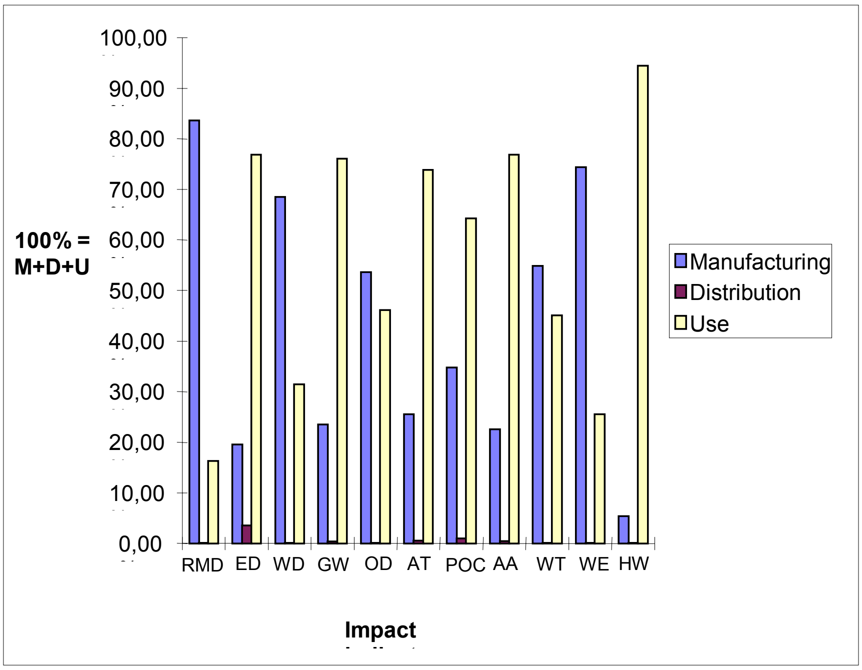
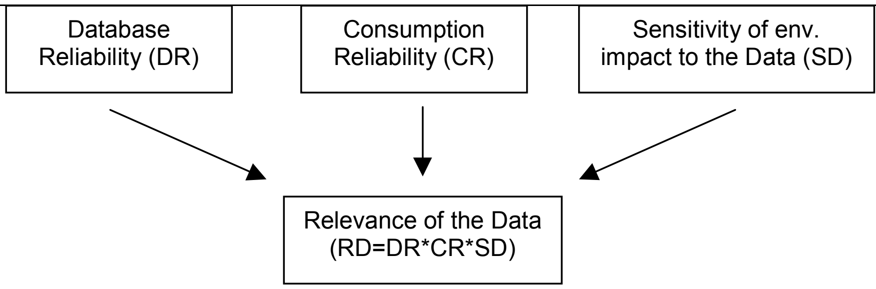


Figure 40: Environmental Impacts of a HV circuit breaker

- The second step of the study is to determine the reliability of the environmental evaluations. For that purpose, a qualitative study of the environmental evaluation of the product is performed. The data taken into account is identified (surface treatment, fastening mode between parts, electricity origin, distribution phase, life span, etc.) and its influence on the final results is calculated.

In fact, these data reliability evaluations are based on the idea that the more the product element (material, process, etc.) has influence on environmental indicators, the more reliable it should be. The Relevance of the Data indicator is defined as follows (see Figure 41):

- Data Reliability (DR): is a function of the type, the date and the completeness of considered data,
- Consumption Reliability (CR): this index is a subjective measurement of the certainty of data. The index is optimal if the consumed data (km, kg) is known and decreases if it is based on hypotheses which are not justified,
- Sensitivity of environmental impact to the Data (SD): for each environmental indicator, the influence of data is evaluated from a qualitative and quantitative point of view.

	 **Figure 41: Construction of the indicator Relevance of the data** - Using a software application, the Relevance of Data Indicator is calculated for each element of data used in the LCA study. The relevance of the study is then compiled for the whole product. - This environmental analysis reliability assessment for Alstom T&D products leads to the identification of the main missing and/or insufficient elements in the database for materials and processes, and allows environmental experts to determine which data modules should be developed as a priority. - Alstom T&D is continuing to capitalise information on the real environmental performances of its products. It makes the set-up of some eco-design rules more effective.
For more information	- Evaluation environnementale de disjoncteurs haute tension - Résultats et limites de l'étude, Bessede, J.L., Journée Primeca, ENSAM Chambéry (France), 16 November 2000. - Evaluation of EIME® software for studying high voltage switchgear environmental impact, MEIE'2000, Paris (France), 24-25 janvier 2000. - Contact: Jean-Luc BESSEDE jean-luc.bessede@tde.alstom.com **Alstom T&D - ARC** 130 rue Léon Blum F - 69611 VILLEURBANNE FRANCE Phone number: +33 4 72 68 35 87 Fax number: +33 4 72 68 35 76 - www.alstom.com

APPENDIX 3. THE CENTRE FOR SUSTAINABLE DESIGN (CFSD) - DATA LOGGER INTERFACE (DLI)

Written with the contribution of ***Steve SCARLETT*** *and* ***Martin CHARTER***

Organisation	The Centre for Sustainable Design (CfSD) The Centre for Sustainable Design **Crawford Hansford & Kimber Ltd**
Sector	Electronic
Product	Data Logger Interface (DLI) Market: 10 years Life duration: 20 years
Project Name	Eco-design Training for Manufacturing, Use and "End-of-life" (ETMUEL) for SMEs
Duration	Collaboration CfSD/CH&K: ongoing since 1998 Design of the DLI : 6 months (end of 1999)
Background	CfSD: - received funding via the Adapt programme of the European Social Fund (ESF) to develop a two year training programme focusing on the implementation of environmental considerations in product development and design (eco-design) in the electronics sector (ETMUEL), - Network for Electronic Product Design (NEPD) http://www.cfsd.org.uk/nepd/index.html; CH&K: - legislation put a curb on lead and other substances used in products - move by large manufacturers to increasingly outsource production of items like PCBs (Printed Circuit Boards), - speed of technology innovation, - new Managing Director wanted to differentiate the company from its competitors.

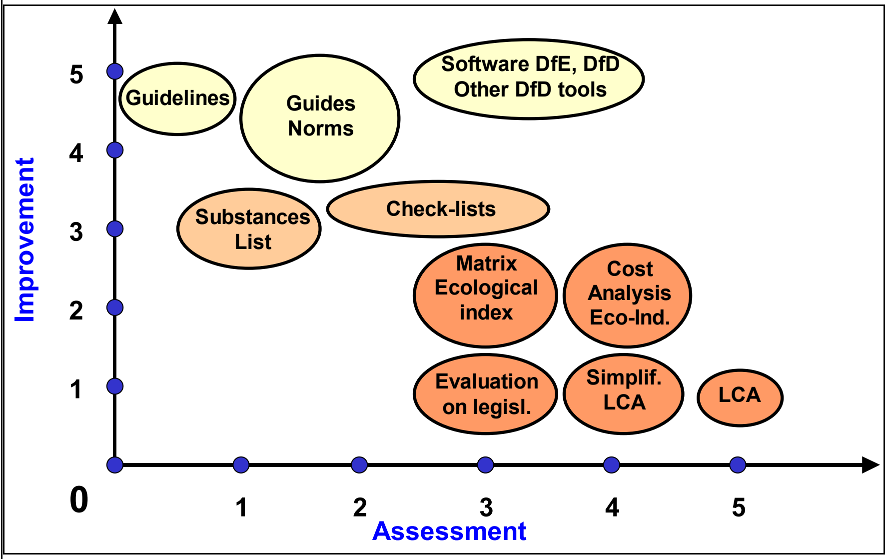
Benefits, success	- Environmental benefit: design and production of a new type of PCB
	  - new materials,
	  - new track design,
	  - less mechanical fixings,
	  - less chemicals in the production process,
	  - substitution of lead by organic silver in the soldering process (-70% lead use),
	  - identification and implementation of a new soldering process,
	  - recycling - only one screwdriver type for disassembly;
	- Financial / commercial benefit:
	  - rationalise suppliers,
	  - no additional costs,
	  - no need for a subcontractor to remove hazardous waste after the PCB etching process,
	  - after this project, CH&K hopes to supply power supplies with reduced lead content to schools,
	  - new contacts won partly because of its eco-design capabilities,
	  - as a result of knowledge gained from the ETMUEL project and the datalogger practical project, CHK was able to deal with a tender call from CERN, Switzerland asking about lead-free, BFRs;

Benefits, success (cont)	- Educational benefit: For CH&K: - Perhaps the main benefit from was educational. The company learned that lead can be eliminated from the solder and the use of acid wash greatly reduced during PCB production, - eco-design can stimulate innovation and increase competitiveness, - skills development - - For CfSD: - better understanding of the hands-on eco-design process in SMEs, - allows it to develop the most appropriate tools; - CHK will be better placed to supply customers when they start to demand "cleaner" products; - Networking: John Simmonds, the Managing Director of CH&K, was made Chairman of the Advisory Board of the ETMUEL project and has been asked to join the Advisory Board of the regional initiative SEEBA (www.cfsd.org.uk/seeba).
Tools and resources invested	- Training programme through ETMUEL (= "a key to the success"): - hands-on training from an experienced business-oriented eco-design consultant, - CfSD organises workshops directly for CH&K in its premises, - CH&K personnel attend some "open" workshops and conference, - specific training for two members of staff (designer and Managing Director) based on Smart eco-design© & Supply Chain Partnership; Tool: adaptation of existing Eco-design check-list to specific PCB design - material choice, - reducing the use of hazardous substances, - design for disassembly.
Problems or possible issues for improvement	Always hard to find information on product / sub-assembly contents
For more informations	**The Centre for Sustainable Design (CfSD)** University College - Faculty of Design The Surrey Institute of Art & Design Falkner Road Farnham Surrey GU9 7DS UNITED KINGDOM Phone number: +44 1252 892772 Fax number: +44 1252 892747 Martin CHARTER mcharter@surrart.ac.uk http://www.cfsd.org.uk/etmuel/chk_case_study.html **Crawford Hansford & Kimber (CH&K)** Steve SCARLETT sscarlett@crawfordhk.com Phone number: + 44 1252 377077 http://www.crawfordhk.com/

APPENDIX 4. ENSAM – DOWNLIGHT EUROPA 2

*Written with the contribution of **Marc JANIN** and **Fabrice MATHIEUX***

Organisation	ENSAM Chambéry ENSAM Ecole Nationale Supérieure d'Arts et Métiers Institut de Chambéry
Partners	PHILIPS Lighting, Lamotte Beuvron PHILIPS
Sector	Electrical
Product	Downlight Europa 2  *Comparison with the former version Europa 99*
Project Name	Eco-design in companies – A stake: building coherence between tools and design process.
Duration	- PhD research: 3.5 years; - Validation at Philips: about 12 months.
Background	- For ENSAM: PhD study on eco-design tools (1996 – 2000) needed an industrial field to test and validate research; - For Philips: after ISO 14001 certification and packaging mass decrease programme, Philips Lighting Company wanted to implement an integrated eco-design approach.
Benefits, success	- Proposal of a design process adapted to the company (environmental adaptation of the Philips PCP (Product Creation Process)); - Validation of some eco-tools to be used during the PCP.
Tools and resources invested	Tools - Use of Ecoscan software: (LCA software based on eco-indicator method); - Use of many other eco-design tools (guidelines, checklist, guide, etc.). Resources - ENSAM: 1 PhD student for 12 months (half-time presence in the company) - Philips: 2 people involved (10 and 20% of their time respectively) - Some meetings organized with design team to make new eco-tools fit the product design activities

Problems or possible issues for improvement	The LCA tool software does not seem to be a tool adopted for use in the design team: it takes a lot of time to gather all the data, which yields poor results (few differences between the both the Downlights; and the results in "eco-points", which are difficult to understand and interpret by a designer).
Results	- Theoretical approach of the PhD research consisted in identifying the main benefits and problems of the integration of eco-design tools into the product development process. Eco-design tools have been classified according to their degree of evaluation and their degree of improvement (see Figure 42).  **Figure 42: Classification of some tools according to their degree of evaluation and their degree of improvement [JANIN 2000].** It has been shown that each tool is specific in terms of: - the environmental impacts it considers; - the design phases during which it can be used; - the input data which are needed to use it; - the results which can be obtained (nature, quality, uncertainties, usefulness, etc.); - the actor who can use it. It thus appears that tools should be chosen carefully in order to be as efficient as possible during the design process. For that purpose, tools can be classified according to three levels of classification: the type of tool (inventory, assessment or improvement), the product life cycle stage (raw materials extraction, manufacturing, use and end-of-life) being considered, and the product design process stage (see Figure 43).

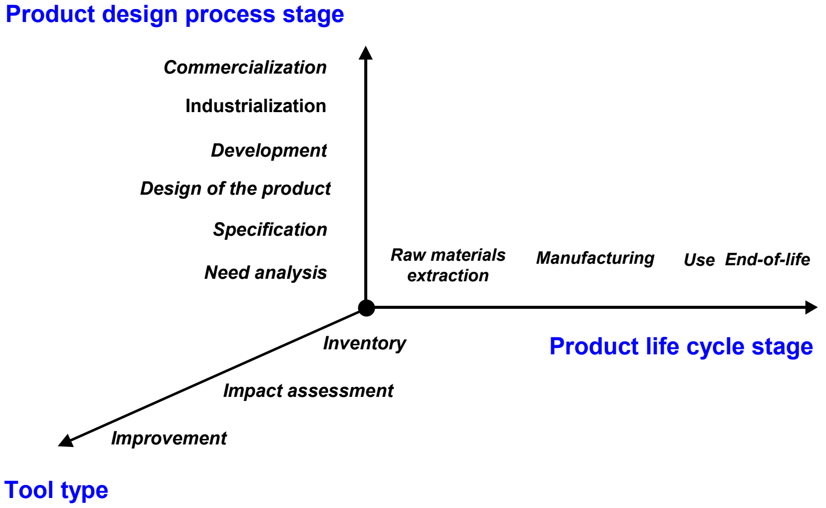


Figure 43: Three levels of classifications for eco-design tools (adapted from [EHRENFELD 1999]).

Figure 44 sums-up which tools can be used by design teams in the product design process. This model cannot be considered as a reference: as each company has its own activities, knowledge and financial and human resources, the company should adapt such a model to its own characteristics.

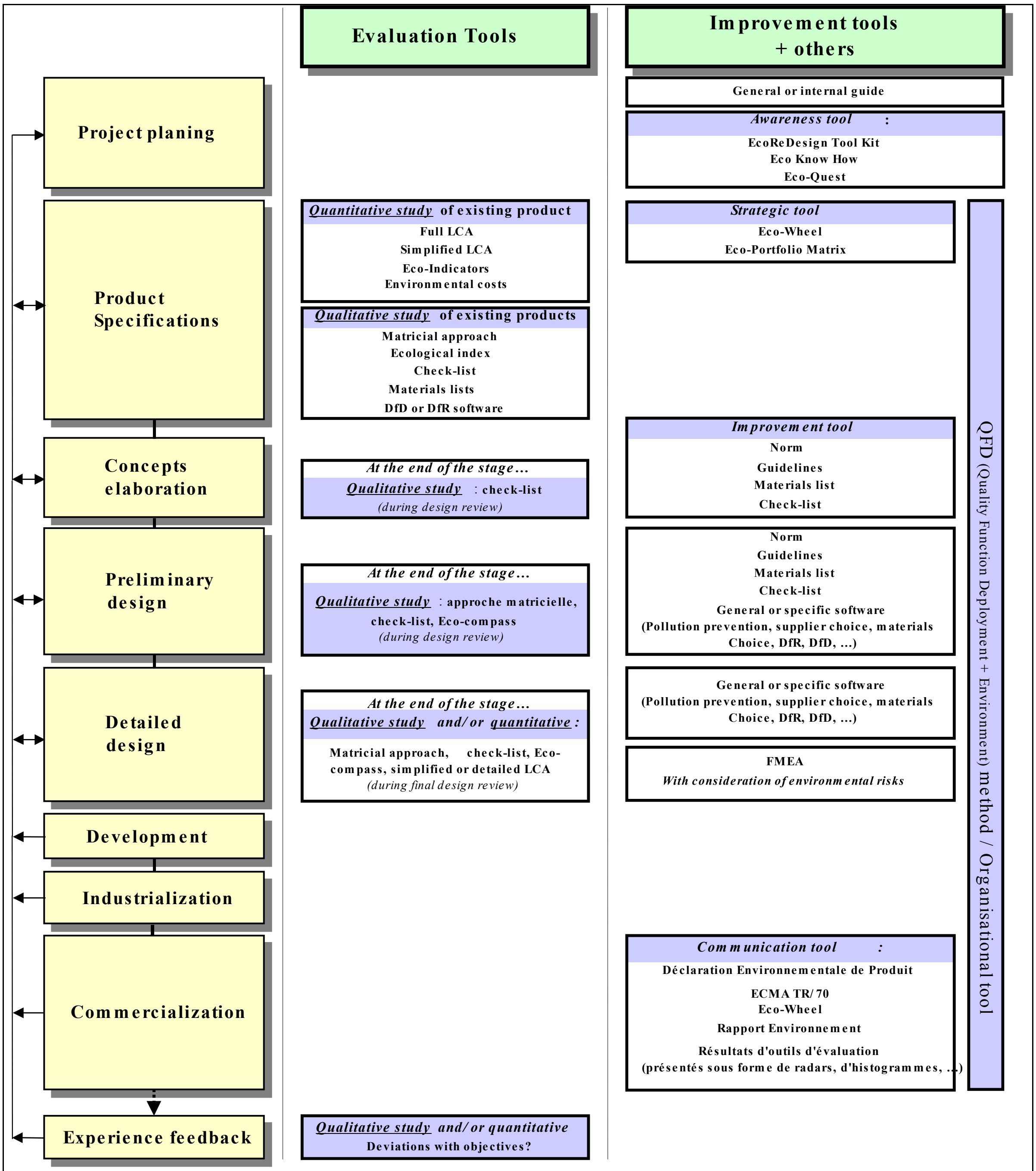


Figure 44: Tools in the eco-design process: when should they be used?

Results	A validation phase of the results has been carried out within a unit of Philips Lighting, in Lamotte-Beuvron. The PhD student took part in the development of the Downlight Europa 2. The aim of the study was to: - Perform a training period on eco-design issue for the design team, - Test some eco-design tools and evaluate their efficiency in this specific industrial context, - Define an eco-design process adapted to the activity and the business unit;

Results (cont)

- In this specific Philips Lighting context, research showed that:
  - The use of an LCA tool (e.g. the easy to use EcoScan software) brings little added value to the design team from an eco-design point of view. Such a tool does not seem to be adapted to such products (probably because of their low weight and the lack of data concerning electronic components). Moreover, in using such a tool, design team members did not understand what could be the real opportunities for improvement.
  - However, it was shown that more qualitative and simple tools, e.g. a benchmarking tool, seem to be more efficient: even if they focus on a few specific environmental issues, the design team more easily understands technical improvement. As an illustration of this, the results of the benchmarking study between two Philips products and two of its competitors are presented in Table 9.

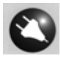
	Criterias	EUROPA 2 Philips	Europa 99 Philips	Competitor 1	Competitor 2
1	Mass				
2	Hazardous substances	NR	NR	NR	NR
3	Energy consumpltion				
4	Recyclability				
5	Packaging				
	TOTAL	2	3	-	-

Table 9: Results of the benchmarking study

Looking at the results of the benchmarking study (Table 9), it cannot be concluded that Europa 99 Downlight is better than Europa 2, as the criteria are not classified.

In conclusion, it appears that the success of a design project depends on the integration of various tools (e.g. benchmark and LCA) in the design process. Highly sophisticated tools, such as those based on LCA, cannot be efficiently applied if they are not embedded into the company structure and organisation.

It also appears that design teams need a structured approach to implement eco-design in their practices. Some research is focussed on the development of tools; others on eco-design organisation in companies, specifically in SMEs. However, little research connects tools and organisations.

The choice of the right tool, for the right purpose, by the right person and at the right moment is a critical issue, which should be fully incorporated in the company's eco-design practices. It is essential to articulate design and design processes and to test them in real life to assess their robustness.

For more information

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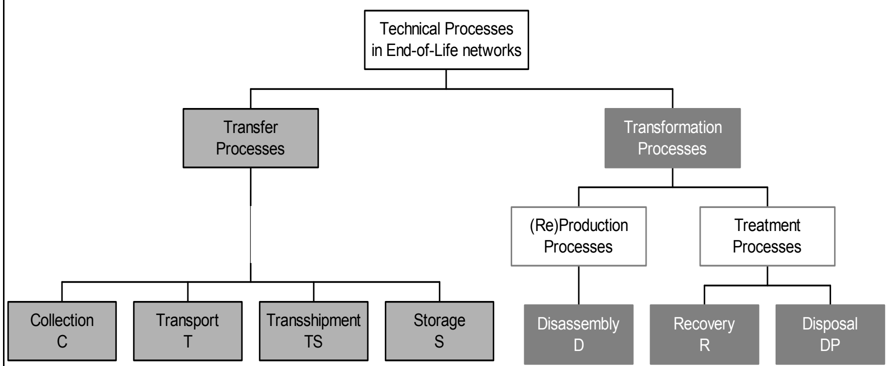
	http://www.chambery.ensam.fr daniel.froelich@chambery.ensam.fr - JANIN M., Démarche d'éco-conception en entreprise – Un enjeu : construire la cohérence entre outils et processus, Thesis, Institute of Design Mechanical Engineering and Environment, Chambéry (France), April 2000. - JANIN, M., MATHIEUX, F., FROELICH, D., L'environnement dans les métiers de la conception: un nouveau paramètre à intégrer dans le processus de développement de produits - Cas d'une stratégie de valorisation en fin de vie, Journée Primeca, Chambéry, 16 novembre 2000.

APPENDIX 5. FRAUNHOFER – REFRIGERATOR COLLECTION IN GERMANY

Written with the contribution of ***Gregor ECKERTH***

Organisation	Fraunhofer IML IML Institut Materialfluß und Logistik
Sector	Electronic
Product	Refrigerator
Project Name	Refrigerator collection in Germany
Background	Legal obligation to take back and recycle IT appliances and/or other electronic products; Several organisations work on EOL solutions: - municipalities and manufacturers set up recycling systems but there was a lack of efficiency, - high-level research initiatives tried to find suitable and sustainable EOL solutions, - industry-related organisations discussed with legislative participants in order to achieve a consensus policy on the take back and recycling of WEEE; - Current tools and models were not adapted to logistic transfer processes.
Benefits, success	Environmental benefit: saving material and energy due to the reuse of parts and materials and additional expenditures.
Tools and resources invested	Tool Fraunhofer's IML tool uses a multicriteria approach with an economical, ecological, technological and social (H&S) evaluation. It also takes into account logistics, recycling and disposal processes. - Flow analysis methodology  **Figure 45: Seven main logistic processes** Seven main processes are referenced. They are divided into two well-differentiated groups: transfer and transformation processes.

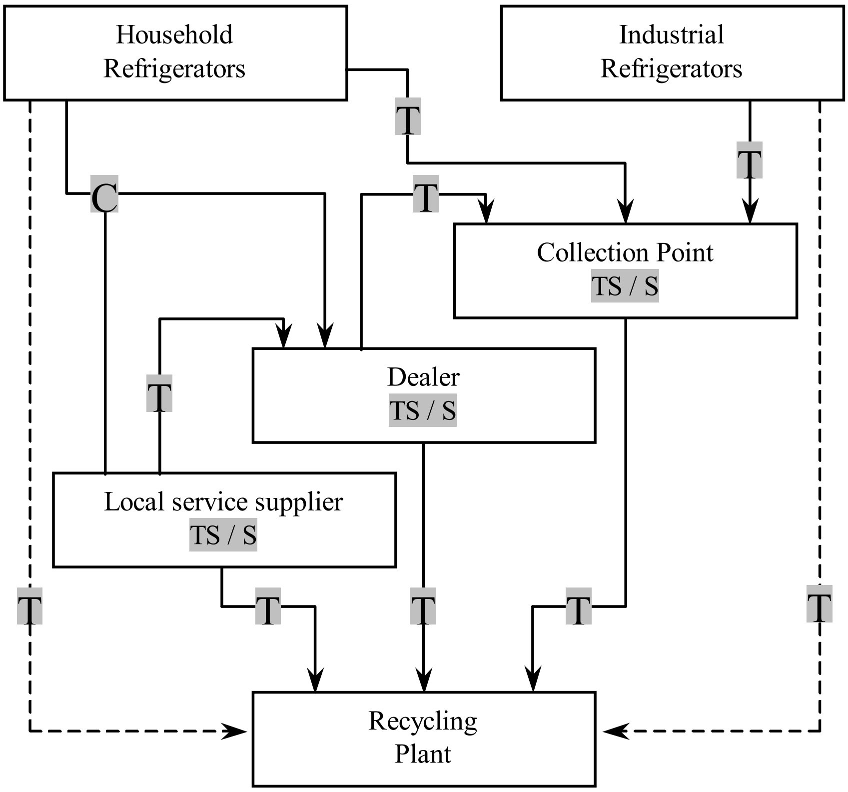
<table>
<tr><td>Tools and resources invested (cont)</td><td>EDS-Rlog software
This is a software support tool for the planning of integrated and cost-optimised take-back and recovery systems. The cost for all relevant processes (collection, transport, etc.) and the specific revenues earned from recycling are taken into account so that all scenarios can be evaluated in terms of:
- overall planning – cost optimisation;
- facility location planning – type, capacity, location and number of facilities;
- vehicle routing and scheduling, and district planning (route sequences, vehicle schedules).</td></tr>
<tr><td>Problems or possible issues for improvement</td><td>- There is a lack of information about specific EOL products, so it would be interesting to establish a "Green Port Identification Unit" which enables the participants to feed the used item into the economically and ecologically right recycling path: for example, the use of labels with serial number and bar codes corresponding to information stored in a database.
- An ecological factor appeared: depending on the waste product, recycling leads to an increase in transport volume which reaches a factor of 8 to 14 compared to the previous system.</td></tr>
<tr><td>Results</td><td>Collection system of refrigerator in Germany


Figure 46: Collection of refrigerators in Germany</td></tr>
<tr><td>For more information</td><td>- NAGEL Carsten, MEYER Peter, "Caught between ecology and economy: end-of-life aspects of environmentally conscious manufacturing", Computer & Industrial Engineering, n°36, 1999, pp 781-792.

- http://www.fraunhofer.de
http://www.iml.fhg.de/</td></tr>
</table>

For more information (cont)	- Contact: Dipl.-Ing. Gregor ECKERTH eckerth@iml.fhg.de **Fraunhofer IML (Institute for Materialflow and Logistics)** Department 3.1: Traffic, Environment and Disposal Joseph-von-Fraunhofer-Strasse 2-4 44227 Dortmund DEUTCHLAND Phone number: +49 231 9743 362 Fax number: +49 231 9743 451

APPENDIX 6. MANCHESTER METROPOLITAN UNIVERSITY – LAWN MOWER

Written with the contribution of ***Matthew SIMON** and **Stephen POOLE***

Organisation	Manchester Metropolitan University (MMU)
Partners (eventually)	FLYMO
Sector	Electrical
Product	Lawn mower  **Figure 47: Flymo lawn mowers**
Project Name	Lawn mower LCA
Duration	6 months
Background	- Flymo's desire to integrate Design for Environment within their current design procedures using a range of tools and methods; - Also develop MMU's understanding of LCA tools and their potential for use in manufacturing companies.
Benefits, success	Identification of the main areas of the environmental impact of a particular brand of lawn mower (and lawn mowers in general).
Tools and resources invested	- Simapro LCA software; - Flymo/MMU personnel time and expertise.
Results	The three most significant environmental impacts are: - Energy consumption during use: which contributes to a range of environmental impacts; global warming, acid rain, emissions of heavy metals and carcinogenic substances. This is mainly the result of fossil fuel based power production. However, compared to household energy consumption the lawn mower is quite small (0.5% per annum) or 24 kW/h, which is approximately the equivalent to the power consumption of a toaster.

- Manufacture of the product: the primary impacts are related to the extraction and refining of copper used in the motor and the extension lead, resulting from the polluting process of copper refining which results in acid rain and winter smog. These emissions originate in the country where the copper is refined, however acid rain spreads out over areas of several hundreds to thousands of kilometres. Therefore acid rain is considered to be a regional air pollution problem (compared to a local air pollution problem for smog and a global one for ozone depletion and greenhouse gases).

- Grass cuttings: Grass clipping are a substantial part of the domestic waste stream (organic waste accounts for 22% of UK household waste). The landfilling of these clippings also contributes to the production of greenhouse gases (methane and C02) and leachate in landfill. Preferred options to landfilling are grass cycling (the distribution of grass back onto the soil) or composting/mulching.

It should be noted, however, that the result of a multidisciplinary workshop with Flymo personnel produced noise as the key environmental impact that concerned purchasers.

Possible strategies to reduce these aspects are:

- Reducing energy consumption during use: Following brainstorming sessions at Flymo the general concepts that emerged were: use of more efficient motors with reduced wattage (which would require a change in the public perception on power ratings) and more efficient cutting systems. Reducing the time for which the mower is operating would also reduce energy consumption and be attractive to the customer. The current design which compacts grass to reduce the number of times the catcher needs to be emptied could assist with this aim, also grass cycling which does not require any emptying may reduce this further. Behavioural studies of mower use would greatly help the understanding of customer usage.

- Reducing the impacts of materials: Copper was highlighted as a particular concern due to the polluting nature of the extraction and refining process. To reduce this impact would require environmental purchasing policies for materials suppliers (such as compliance with ISO 14001) or asking for data on materials (for example, recycled content, and emissions data). The remanufacture of motors would also be a way to reduce the use of new copper. The current use of shared cables for garden equipment assists in reducing the use of copper compared to the individual cables used in household appliances.

- Reducing grass cuttings: From the literature examined for this study, it was concluded that the preferred option for the management of grass cuttings were:
  - Grass cycling: The environmental benefits of grass cycling are a reduced need for fertiliser by up to 25% (grass contains nitrogen, potassium and phosphorus) with similar saving on water. Other benefits are reduced mowing time as the grass clipping do not need to be emptied and transportation is not required to take the grass to landfill. Grass cycling does require more regular mowing during faster growth periods at taller mowing heights depending on the grass types. However, the purchase of the "Power compact 400" indicates a consumer preference for a grass collecting mower, as Flymo also sells products that distribute grass.

	- - Composting/mulching: grass cycling may not be appropriate for all areas particularly if the grass is wet or when the grass is mowed infrequently. Composting should then be considered as an option for grass clippings. Grass clippings play an important role in composting by providing nitrogen green waste to complement the carbon rich brown waste (food scraps leaves etc.). Composting provides an alternative to fertiliser for the garden and can also be used around plants and trees, this is called mulching. - - Landfilling should be the last option due to the effects of organic waste in landfill. The Power Compact range does reduce the volume of grass waste entering landfill but not the associated problems of gas and leachate emissions.
For more information	Contacts: Steve POOLE S.J.Poole@mmu.ac.uk **Manchester Metropolitan University** DfE Research Group Department of Engineering and Technology Chester St Manchester M1 5GD ENGLAND Matthew SIMON m.simon@shu.ac.uk **Sheffield Hallam University** Life Cycle Design Research Group School of Engineering City Campus Howard Street Sheffield S1 1WB ENGLAND Phone number: +44 114 225 3405 Fax number: +44 114 225 3433

APPENDIX 7. MOTOROLA – 2 WAY RADIO

Written with the contribution of ***Katrin MÜLLER*** *and* ***Markus STUTZ***

Organisation	Motorola
Sector	Electronic
Product	2-way-Radio 
Project Name	WARIS
Duration	1/2year
Background	Accomplish Motorola´s environmental policy: - manufacturing process improvement: 10% reduce on hazardous waste, VOM emission, HAP emission, water usage, energy consumption, etc. - product design and contents: design products to be highly recyclable, reduce use of hazardous materials, reduce energy use, etc. Next product generation/platform should be launched.
Benefits, success	Product improvement - The environmental impact could be reduced significantly - 15% reduction of mass; - Reduction of environmental relevant substances - Use of plastic regrind; - All plastic parts of more than 4 gm are marked; - Improved end-of-life performance. Beside the product improvement, the main benefits of the tool are that it provides a quick comparison of product alternatives, and complete data of the environmental performance of products

Tools and resources invested	Tools
	Environmental management system: uses the plan-do-check-act model.
	- Common Environmental Management System (EMS) framework throughout the company;
	- ISO 14001;
	- Environmental audit programme provides for routine assessment of all manufacturing sites, follow-up corrective actions and periodic management reviews with Board directors.
	
	Designing products for the environment
	- Use of DfE software Green Design Advisor (GDA):
	  - enables product designers to compare different materials and processes that could be used to create a product,
	  - provides the ability to choose and compare different materials and processes based on their potential environment impact;

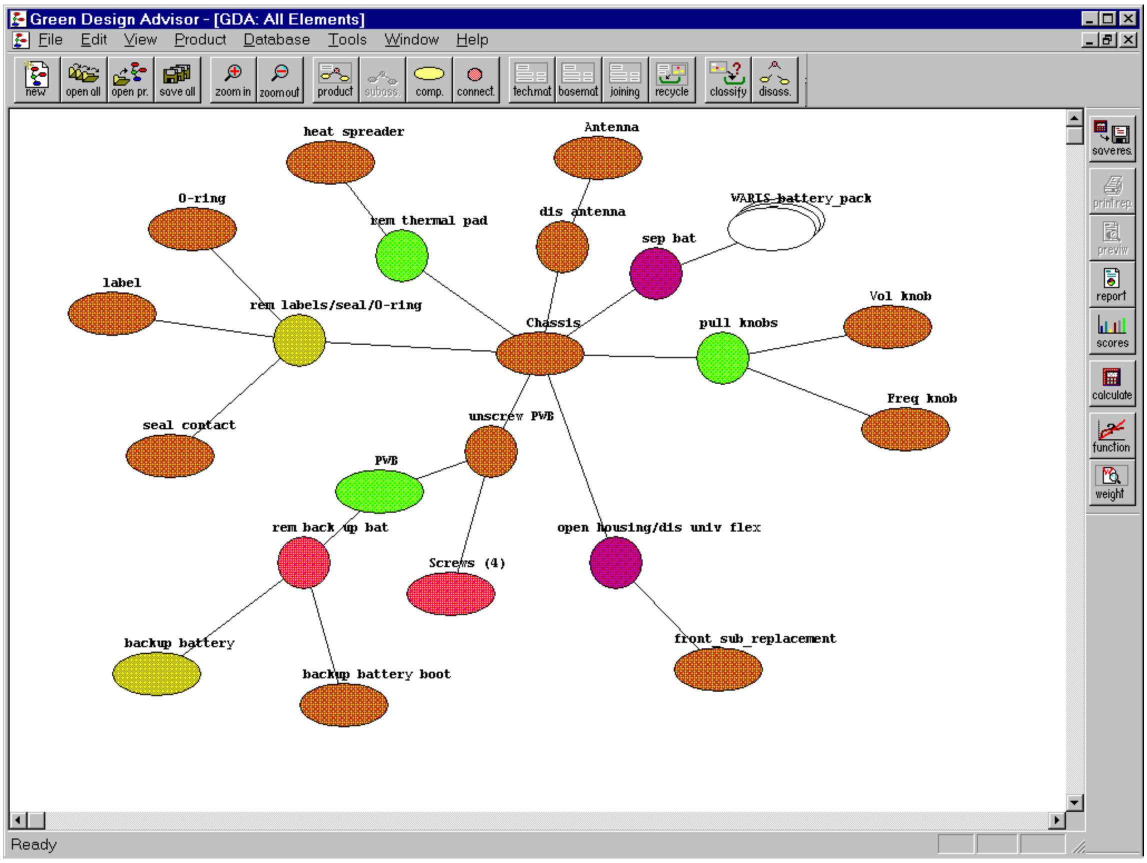
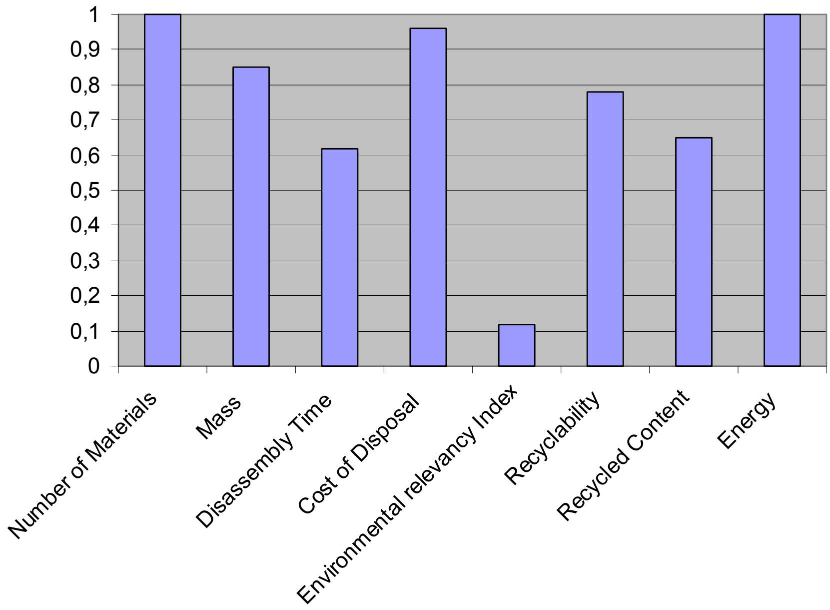


Figure 48: Elements of the WARIS 2-way-Radio

	Use of Product Environmental Template (PET): - assists design engineers, - contains product goals for packaging reduction, recyclability, energy reduction and material contents, - requires a documented end-of-life strategy for new products; Use of several checklists (e.g. restricted material list, plastic marking, regrind for plastic parts specification); Carry out material assays. Resources - Two people primarily used the tool; however, other project members were also involved; - Management of an international multidisciplinary team;
Problems or possible issues for improvement	Problems There were no significant problems Improving issues - The GDA is well developed. - The user friendliness has been improved. - A long-term issue is a direct link to the product database. So far an import interface exists.

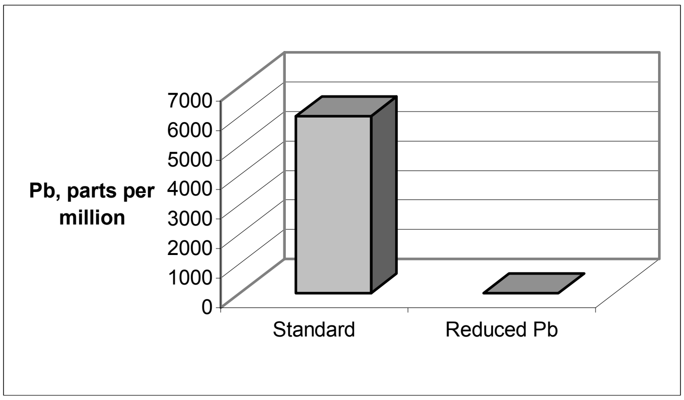
Results	 **Figure 49: Normalized GDA scores compare to the baseline of 1,0 (reduction and improvement means lower score)**
For more information	- FELDMANN K., MEEDT O., TRAUTNER T., SCHELLER H., HOFFMANN W., *The Green Design Advisor": a tool for Design for Environment*. Journal of Electronics Manufacturing, Vol. 9, No.1, March 1999, p. 17-28, World Scientific Publishing Company. - Contacts: Markus STUTZ Markus.Stutz@motorola.com Katrin MÜLLER katrin.mueller@motorola.com **Motorola Advanced Technology Centre – Europe** Motorola GmbH Hagenauer Str. 44 65203 Wiesbaden GERMANY

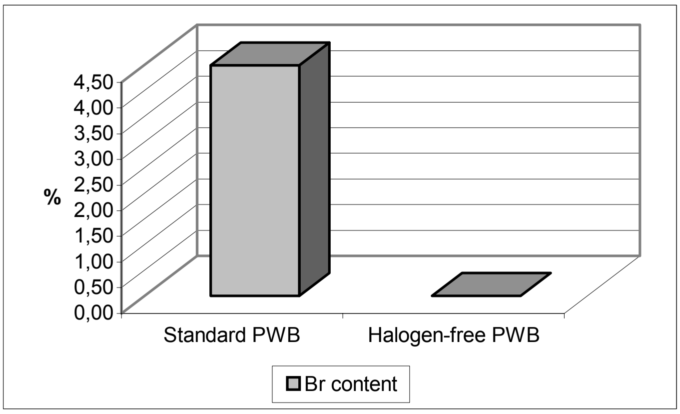
APPENDIX 8. MOTOROLA/SWISSCOM – V2288 WAP- ENABLED PHONE

Written with the contribution of ***Markus STUTZ*** *and* ***Katrin MÜLLER***

Organisation	Motorola
Partners	Swisscom
Sector	Electronic
Product	V2288 WAP-enabled phone 
Project Name	Environmentally Improved Mobile Phone Prototype
Background	Accomplish Motorola´s environmental policy: - product design and contents: design products to be highly recyclable, reduce use of hazardous materials, reduce energy use, etc. - manufacturing process improvement: increase of recycled materials, - minimize ratio of packaging material to product volume, - label all plastic parts weighing more than 4 gm to aid future recycling; Accomplish Swisscom´s environmental policy: - implementation and marketing of environmental-friendly services, - support suppliers in their effort to promote environmental-friendly products.
Benefits, success	4 winners: Motorola, Swisscom, customers and the environment Environmental benefit: - reduction of hazardous materials; lead-free solder phone, bromium-free wiring board, - reduction of emission of toxic substances, - facilitation of recycling, - saving of raw materials, - saving of energy resources; Company benefit: - better brand image, - development of competences to identify improvement possibilities and to apply them quickly in design, - leader of European telecommunications as far as the environment is concerned; Commercial benefit: - same quality of the products, - environmentally preferred products (EPP), - increased customers' choice.

<table>
<tr><td>Tools and resources invested</td><td>Resources:
Inquiry hotline for suppliers and customers
- ecological interest;
- economic barriers/concerns.

Tools:
Life Cycle Assessment Approach (LCA) project, with a focus on:
- material toxicity,
- energy;
Design for Environmentally Preferred Products
- reduction of hazardous materials,
- increase recyclability,
- increase use of recycled content of plastic housing,
- reduce of energy consumption.</td></tr>
<tr><td>Problems or possible issues for improvement</td><td>- Improve the design;
- Set about promoting green product;
- Improve environmental credentials of the products.</td></tr>
<tr><td>Results</td><td>- Lead-free solder phone;


- Bromium-free wiring board;


- Housing of recycled plastic;
Energy-efficient charger (reduction of energy consumption between 41 and 83 % depending on the input voltage).</td></tr>
</table>

For more information	- http://www.swisscom.com/gd/information/corporate_profile/environment_report/ecology_products-en.html - Contact: Markus STUTZ Markus.Stutz@motorola.com Katrin MÜLLER katrin.mueller@motorola.com **Motorola Advanced Technology Center – Europe** Motorola GmbH Hagenauer Str. 44 65203 Wiesbaden GERMANY

APPENDIX 9. MOTOROLA/SWISSCOM – GREEN PHONE

Written with the contribution of ***Markus STUTZ*** *and* ***Katrin MÜLLER***

Organisation	Swisscom
Partners	Motorola
Sector	Electronic
Product	Green phone
Background	Accomplish Swisscom´s environmental policy: - implementation and marketing of environmental-friendly services, - support suppliers in their effort to promote environmental-friendly products; Accomplish Motorola´s environmental policy: - product design and contents: design products to be highly recyclable, reduce use of hazardous materials, reduce energy use, etc. - manufacturing process improvement: increase of recycled materials, - minimize ratio of packaging material to product volume, - label all plastic parts heavier than 4 gm to aid future recycling.
Benefits, success	Environmental benefits: - reduction of hazardous materials; lead and halogenated flame retardants; - reduction of energy use: energy efficient charger; - use of recycled plastic for housing.

Tools and resources invested	Resources:
	- Customer enquiry via hotline
	  - ecological interest;
	  - economic barriers/concerns.

Results	- 40 % think that environmentally preferred products are very important; - 30 % think that EMR are major issues; - 20 % agree to pay up to 10% more for an environmentally preferred product; - 90 % prefer to buy a cell phone with a housing made of recycled material.
For more information	- http://www.swisscom.com/gd/information/corporate_profile/environment_report/ecology_products-en.html - Contact: Markus STUTZ Markus.Stutz@motorola.com Katrin MÜLLER katrin.mueller@motorola.com **Motorola Advanced Technology Center – Europe** Motorola GmbH Hagenauer Str. 44 65203 Wiesbaden GERMANY

APPENDIX 10. PHILIPS – "BRILLIANCE" PRODUCT LINE

Written with the contribution of ***Ab STEVELS***

Organisation	Philips Consumer Electronics, Business Creation Unit Monitors
Partners	Design for Sustainability Laboratory of Delft University of Technology
Sector	Electronic
Product	High end monitors of "BRILLIANCE" product line
Project Name	Typhoon
Duration	8 months (1996 - 1997)
Background	- Vision policy: drastically upgrade present product line; - Programme: wishing to make green flagship products.
Benefits, success	Since launch in 1998, above average sales (gain in market share) and profit margins.
Tools and resources invested	Investment of Consumer Electronics is general and specific. General - have environmental organisation in place, - have strategy, roadmap, policy, - have environmental teams, - have environmental programme, - develop tailored tools / processes, procedures, - give training to relevant members of organisation; Specific - support specific project, - establish local project team.
Problems or possible issues for improvement	- Original mindset of organisation; - Ensuring continuity of the success.
Results	

Item	Philips old	Philips adapted	Best competitors performance	DfS proposals	New generation (increased specification)
Energy life cost (USD)	94	91	87	85	80
Plastic material 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 (dm²)	15,6	14,3	9,8	13,5*	11
Number of PWB	6	3	2	2	2
Lenght of cable/wiring (cm)	4000	2270	2070	1925	1900
Number of components	1300	1250	800	900*	800
Calculated disassembly time	750	570	470	440	350
Porduction eco indicator score (mPt)	575	439	357	388	375
Life cycle indicator score (mPt)	1085	934	984	846	838

* Further improvement dependant on availability of a new viable IC generation

Table 9: Product characteristics of Philips monitor after the benchmark

For more information	- EENHOORN G. J., and STEVELS A. L. N., Proc. *"Environmental benchmarking of computer monitors "* Proceedings of the Electronics Goes Green Conference, Berlin, September 2000. - Contact: Ab STEVELS Ab.Stevels@philips.com **Design for Sustainability Research Group** Delft University of Technology Jaffalaan 9 2628 BX Delft THE NETHERLANDS Phone number: +31 15 2781524 Fax number: +31 15 2782956 **Philips Consumer Electronics** Department: Environmental Competence Centre Buildings SWA-4 P.O. Box 80002 5600 JB Eindhoven THE NETHERLANDS Phone number: +31 40 273 4169 Fax number: +31 40 273 5075

APPENDIX 11. PHILIPS – ECOVISION PROGRAMME

Written with the contribution of ***Ab STEVELS***

Organisation	Philips Consumer Electronics
Sector	Electronic
Product	All
Project Name	EcoVision Programme
Duration	5 years (1998-2002)
Background	- After the first environmental programme at Philips (the Environmental Opportunity, 1994), Philips wanted to acquire an environmental programme, which covered products, production, communication and control. EcoVision was set-up in 1997. - The Eco Vision programme is a company wide programme at Philips focussed on environmental communication. This programme requires the green performance of its flagship products to be significantly better than those of its competitors.

Results	In the EcoVision programme, Philips established the following goals:
	- Green as part of Philips' brand positioning;
	- Product development (Eco-design) and marketing and sales to be focused on one or more of the following Green Focal Areas:
	  - Weight,
	  - Hazardous substances,
	  - Recycling and disposal,
	  - Energy consumption,
	  - Packaging;
	- Every line of business was asked to nominate a "Green Flagship" product in 1998;
	- Every division was asked in 1998 to define increasing percentages of its product portfolio that would be Eco-designed in the period 1999 through 2001;
	- 15% packaging reduction in weight (bench marked to predecessor).
	
	Remarks
	Green Flagships and Eco-designed products in general are bench marked and improved on the five Green Focal Areas.
	
	Targets for manufacturing improvements
	- 35% waste reduction in 2002 (reference year, 1994);
	- 25% water reduction in 2002 (reference year, 1994);
	- Reduction in emissions to air and water (reference year, 1994),
	  - Restricted substances (category I): 98%,
	  - Hazardous substances (category II): 50%,
	  - Environmentally relevant substances (category III) 20%;
	- 25% energy efficiency improvement in 2000 (reference year, 1994) ISO 14001 certification of all manufacturing sites in 2000.

For more information	- Contact: Ab STEVELS Ab.Stevels@philips.com **Design for Sustainability Research Group** Delft University of Technology Jaffalaan 9 2628 BX Delft THE NETHERLANDS Phone number: +31 15 2781524 Fax number: +31 15 2782956 **Philips Consumer Electronics** Department: Environmental Competence Centre Buildings SWA-4 P.O. Box 80002 5600 JB Eindhoven THE NETHERLANDS Phone number: +31 40 273 4169 Fax number: +31 40 273 5075

APPENDIX 12. PHILIPS – FREE POWERED RADIO

Written with the contribution of ***Maarten TEN HOUTEN*** *and* ***Ab STEVELS***

<table>
<tr><td>Organisation</td><td>Philips Consumer Electronics, Business Creation Unit Audio</td></tr>
<tr><td>Partners (eventually)</td><td>None</td></tr>
<tr><td>Sector</td><td>Electronic</td></tr>
<tr><td>Product</td><td>Free Powered radio AE 1000
</td></tr>
<tr><td>Project Name</td><td>Wind-up radio</td></tr>
<tr><td>Duration</td><td>8 months (1999 – 2000)</td></tr>
<tr><td>Background</td><td>- Vision policy: go to higher levels of sustainability;
- Programme wishing to make green flagship products;
- Desire to be better than the competitors.</td></tr>
<tr><td>Benefits, success</td><td>Product launched on the market in March 2000.
It became a huge success and production cannot keep up with demand.</td></tr>
<tr><td>Tools and resources invested</td><td>Investment of Consumer Electronics is general and specific.
General
- have environmental organisation in place,
- have strategy, roadmap, policy,
- have environmental teams,
- have environmental programme,
- develop tailored tools / processes, procedures,
- give training to relevant members of organisation;

Specific
- support specific project,
- establish local project team.</td></tr>
<tr><td>Problems or possible issues for improvement</td><td>- This radical concept took much time to be taken on-board by the whole organisation (internal value chain);
- The crank of the free powered radio posed a specific problem, which took time to be solved.</td></tr>
<tr><td>Results</td><td>Benchmark approach
<table>
<tr><th></th><th>Philips</th><th>Comp1</th><th>Comp2</th><th>Comp3</th></tr>
<tr><td>Energy battery mode (mA)</td><td>18,6</td><td>N.A.</td><td>28,3</td><td>16,3</td></tr>
<tr><td>Human power mode (min)</td><td>30</td><td>20</td><td>20</td><td>20</td></tr>
<tr><td>Packaging weight (gm)</td><td>94</td><td>144</td><td>61</td><td>98</td></tr>
<tr><td>Product weight (gm)</td><td>350</td><td>900</td><td>300</td><td>325</td></tr>
<tr><td>PWB area (cm²)</td><td>50</td><td>70</td><td>63</td><td>70</td></tr>
<tr><td>Recyclability (%)</td><td>37</td><td>54</td><td>42</td><td>45</td></tr>
<tr><td>NiCd battery</td><td>No</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
</table>
Table 10: Characteristics of newly developed Philips wind-up radio AE1000</td></tr>
</table>

Results (cont)	
	(see table below)

	Philips AE 1000 (wind up)	Philips AE 2130 (conventional)	Competitors product I	Competitors product II
Energy consumption (W)	57	58	90	57
Product weight (gm)	350	600	1500	900
Hazardous substances	0	0	Ni-Cd cell	Cd in wiring
Packaging	cardboard	cardboard 1 plastic type	cardboard 1 plastic type	cardboard 2 plastic types
Life cycle load (Eco-indicator mPt)	20	40	25	49

Table 11: Characteristics of newly develop Philips wind-up radio AE1000

For more information

- http://produkte.philipsinfoservice.de/cgi-dal/dalcgi2/phprod/01runtime/01main/01main.htd?Audioprodukte

- Contact:

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APPENDIX 13. PHILIPS – GREEN TV

Written with the contribution of ***Maarten TEN HOUTEN** and **Ab STEVELS***

Organisation	Philips Consumer Electronics, Business Creation Unit Audio
Sector	Electronic
Product	Green TV 
Project Name	Green TV
Duration	1 year (1996)

Background	- Personal: the initiator of the programme was a very strongly motivated employee of the TV development department who wanted to move to a higher level structure of eco-design activities.
	- Vision policy: move to higher levels of sustainability
	  - Future housing designs,
	  - Alternatives for glass based CRT,
	  - 100% recyclable TV.

Benefits, success	- Success in developing novel and environmentally sound technologies for a TV set on the basis of consideration of the entire product life cycle;
	- Did not take it to the market, but results yielded valuable insights and solutions, which are still used in many products;
	- Partial success from which the main lessons were:
	  - integration of environment into all business aspects,
	  - clear focus on customers and benefits for customers from environmental programme,
	  - formulation of environmental messages in the language of the receiver, and not of the environmental sender;
	  - creation of the basis of the corporate Ecovision programme.

Tools and resources invested	Investment of Consumer Electronics is general and specific.
	General
	  - have environmental organisation in place,
	  - have strategy, roadmap, policy,
	  - have environmental teams,
	  - have environmental programme,
	  - develop tailored tools / processes, procedures,
	  - give training to relevant members of the organisation;
	
	Specific
	  - support specific project,
	  - establish local project team.

Problems or possible issues for improvement	The TV was never brought top the market because: - Lack of a clear value proposition to the potential customer; - Unclear position of product line-up; - No involvement of suppliers; necessary changes in supplier base not foreseen; - Cost issue not addressed in a way that criticism and prejudice (green product always cost more) could be deal with; - Consequences for production (investment in factory lay out) not very well addressed; - Logistics (availability of recycled material) turned out to be occasionally problematic. The main reason why the TV was not brought to the market was an insufficient analysis and management of the internal and external value chain. - Environmental communication and competition, production technology, cost, investment and time to market were not mapped out very well; - Suppliers and logistic were not addressed at all.
Results	(see Table 12 below)
For more information	- ISHII K. and STEVELS A.L.N., Proceedings, International Conference on Electronics and Environment, San Francisco, May, 2000. - Contact: Ab STEVELS Ab.Stevels@philips.com **Design for Sustainability Research Group** Delft University of Technology Jaffalaan 9 2628 BX Delft THE NETHERLANDS Phone number: +31 15 2781524 Fax number: +31 15 2782956 **Philips Consumer Electronics** Department: Environmental Competence Centre Buildings SWA-4 P.O. Box 80002 5600 JB Eindhoven THE NETHERLANDS Phone number: +31 40 273 4169 Fax number: +31 40 273 5075

Achievements for Green TV	**%**
Reduction of energy consumption	39
Reduction of plastic weight	32
Reduction of hazardous substances	100
Use of recycled material	69
Recycle potential	93
Reduction of life cycle impact	30

Table 12: Environmental improvements for Green TV

APPENDIX 14. SCHNEIDER - CIRCUIT-BREAKER MASTERPACT

Written with the contribution of ***Isabelle FERNANDEZ***

Organisation	Schneider Electric
Partners	Ensam Chambéry
Sector	Electrical
Product	Circuit-breaker MasterPact 
Project Name	Masterpact eco-design policy
Duration	3 years
Background	- Eco-design according to the environmental product policy of Schneider; - Anticipate WEEE; - Improvement of the latest generation of products; - Answers to customers requirements.
Benefits, success	Environmental benefits - Consumption of raw materials has been reduced between 20% and 50%; - Plastics contain less than 0.01% halogen; - All plastics are marked; - Power consumption has been reduced by 20% during the use phase; - It is possible to extract the battery without any specific tool when the product reaches its end-of-life.
Tools and resources invested	Tools - Analysis of product recyclability (End-of-life); - Intranet website implementation;

Tools and resources invested (cont)	Design-aid software (EIME®).

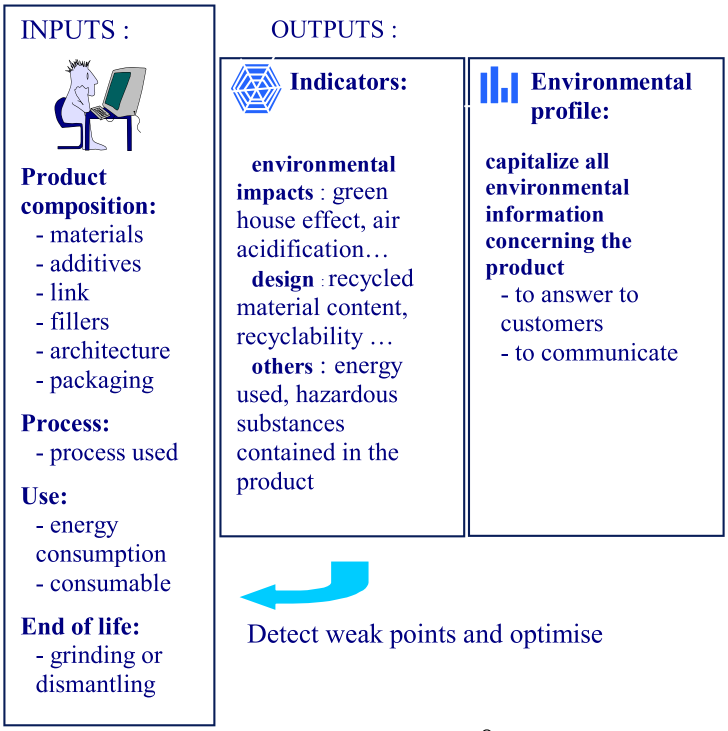


Figure 50: Structure of the EIME® software

Specific warning messages were created in order to alert designers when using unfriendly environmental components.

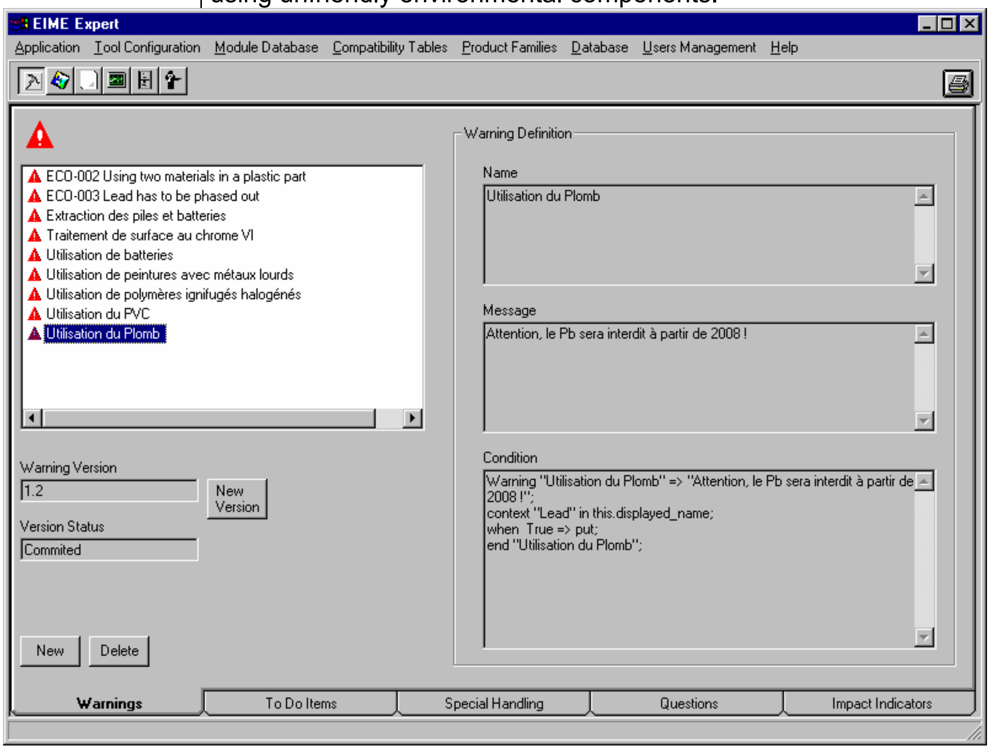


Figure 51: Warning message for the MasterPact batteries

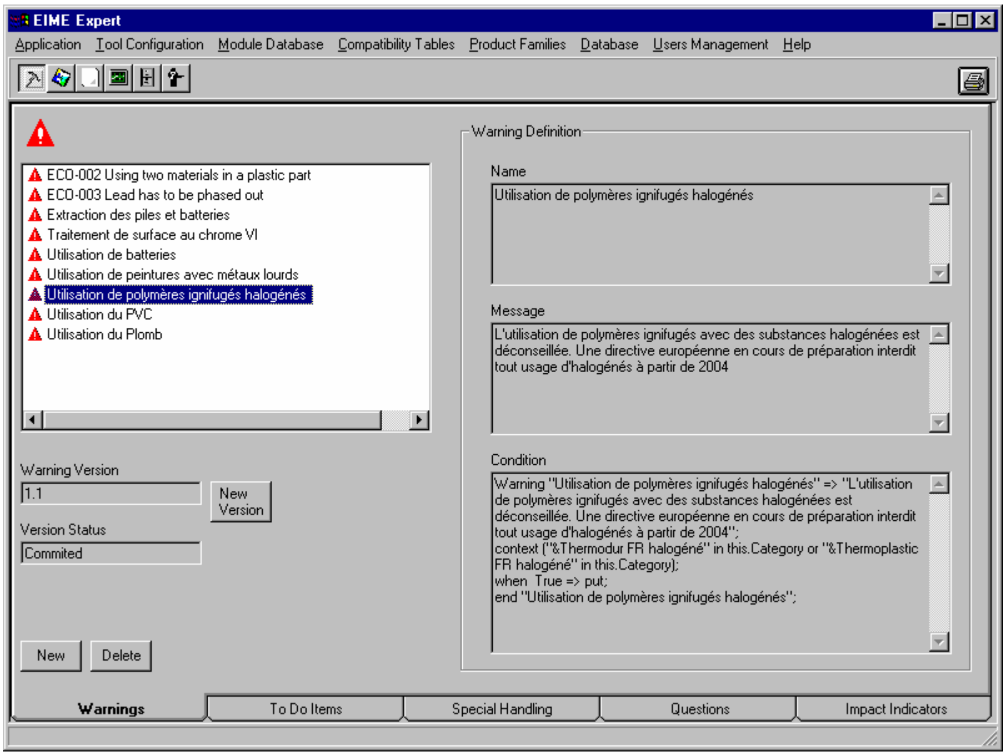


Figure 52: Warning message for the MasterPact lead use

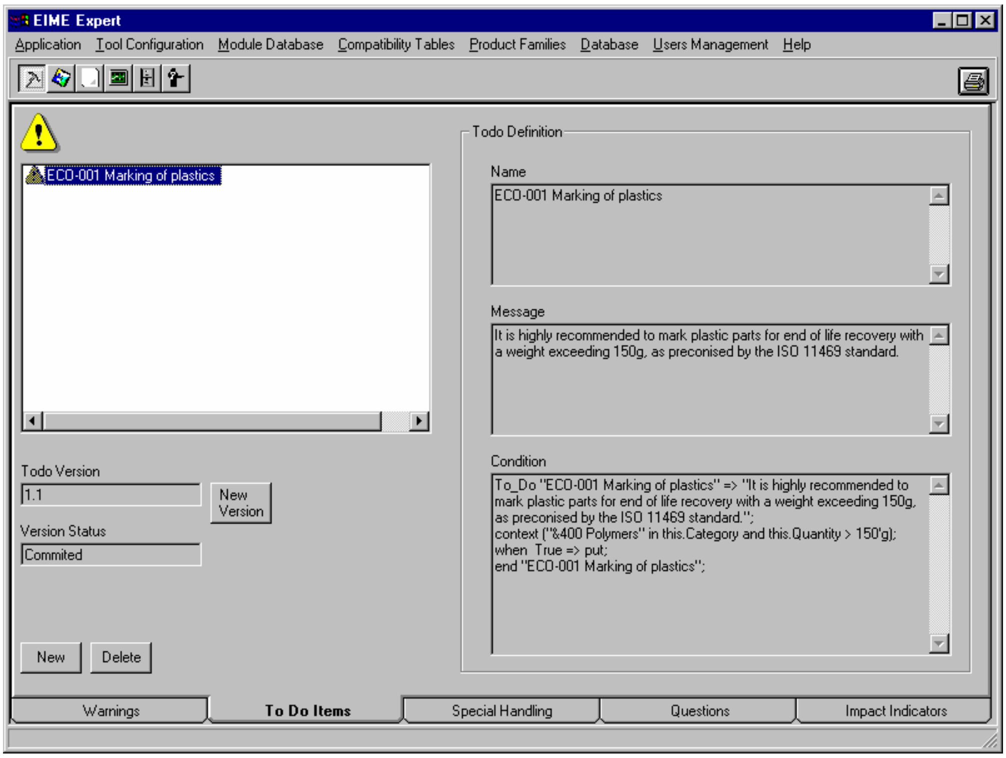


Figure 53: Warning message for the MasterPact plastics not to be filled up with halogenous fire retardants

Schneider product databases contain a plastics marking guideline.

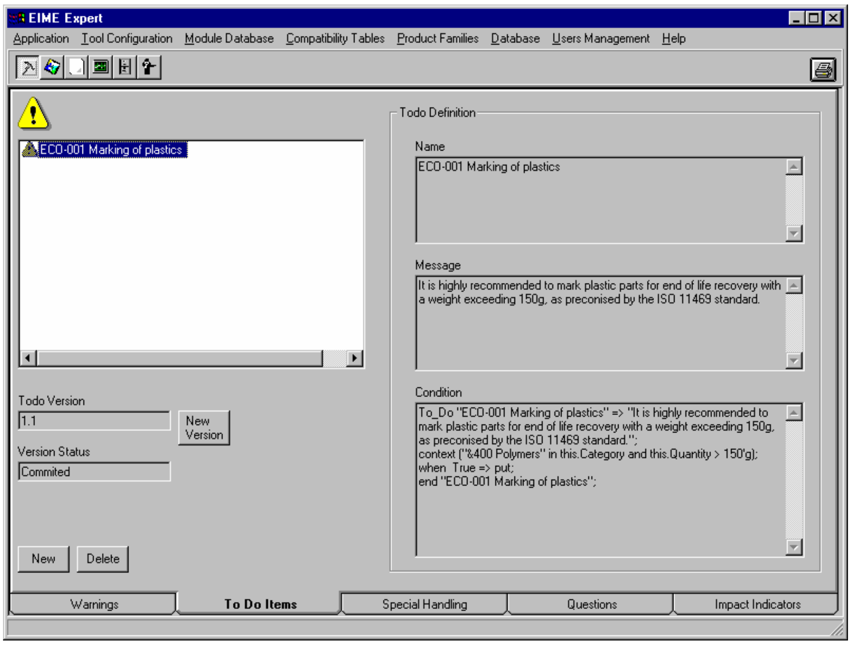
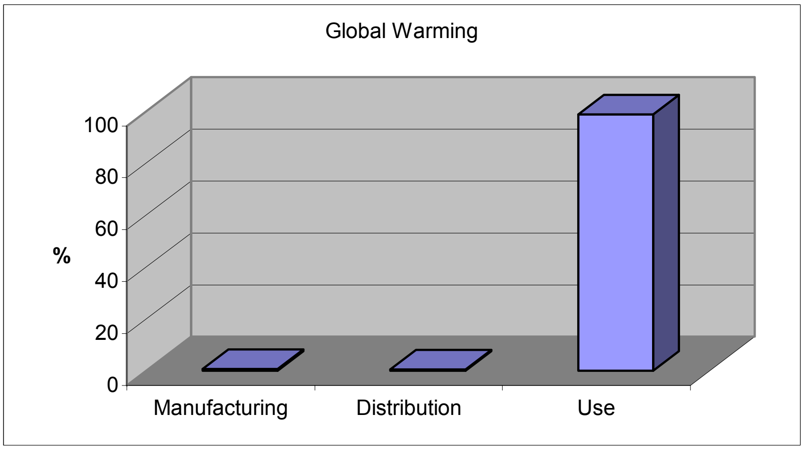
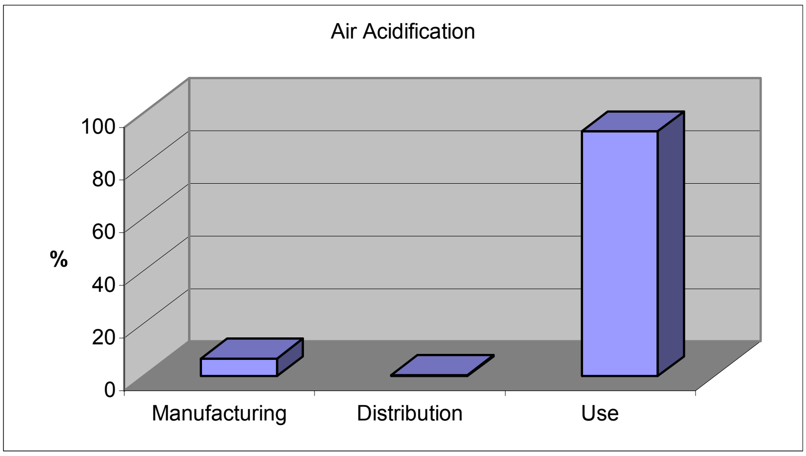
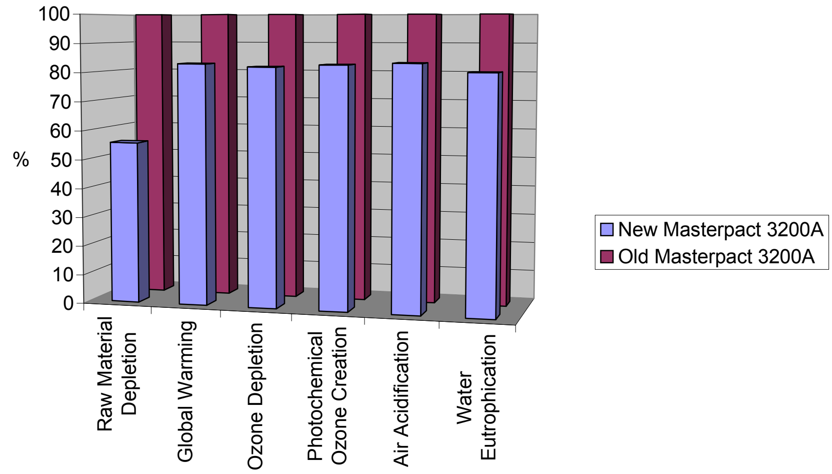


Figure 54: Guideline message for the Masterpact plastics to be marked for end-of-life recovery with a weigh exceeding 150gm

	Others - Collaboration with recyclers; - Training of multidisciplinary project teams (designer, marketing, project manager, purchaser, etc.), - Study of running project.
Problems or possible issues for improvement	The environmental analysis was integrated during the detailed design stage. The next step will be to integrate this approach as far upstream as possible in the design.
Results	- Major environmental impacts, computed with EIME®:



	 - Comparison with old product: 
For more information	REMANDE E., CHARBONNEAU M., FERNANDEZ I., *"Designing product with less environmental impacts: masterpact, a pragmatic approach"*, MEIE 2000, 2nd European Conference on Industrial Electrical Equipment and the Environment, Paris, 2000.

APPENDIX 15. SCHNEIDER - ENVIRONMENTAL INTRANET WEBSITE

Written with the contribution of ***Isabelle FERNANDEZ***

Organisation	Schneider Electric
Sector	Electrical / Electrotechnical
Project Name	Environmental intranet website
Duration	6 months
Background	Lack of environmental information in the Schneider intranet roadmap
Benefits, success	Environmental corporate website open since November 1999.
Tools and resources invested	FrontPage software – Environmental experts knowledge
Problems or possible issues for improvement	Difficulties to obtain environmental information from our correspondents in different countries.
Results	

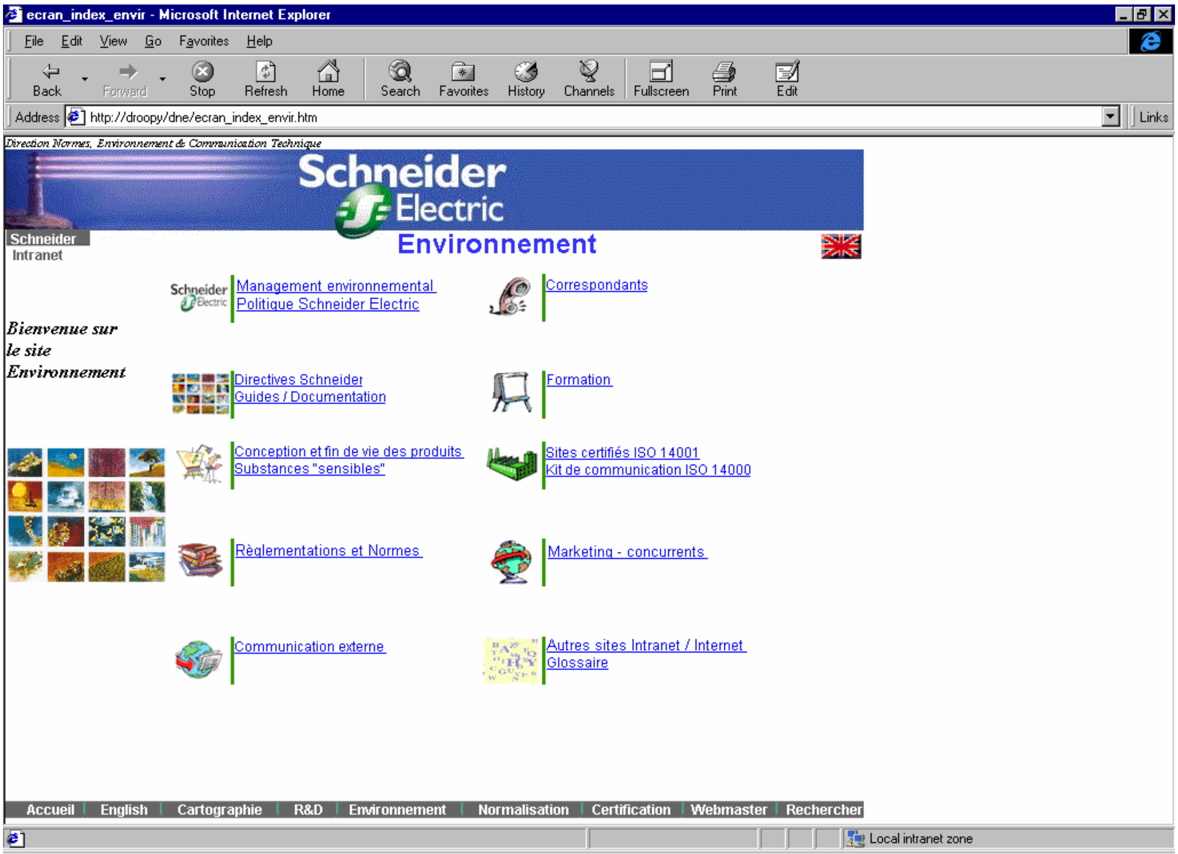


Figure 55: Page of Schneider internal website

For more information	Contact: Isabelle FERNANDEZ isabelle_fernandez@mail.schneider.fr

APPENDIX 16. SHIPLEY – PRINTED CIRCUIT BOARD

Written with the contribution of ***Martin GOOSEY***

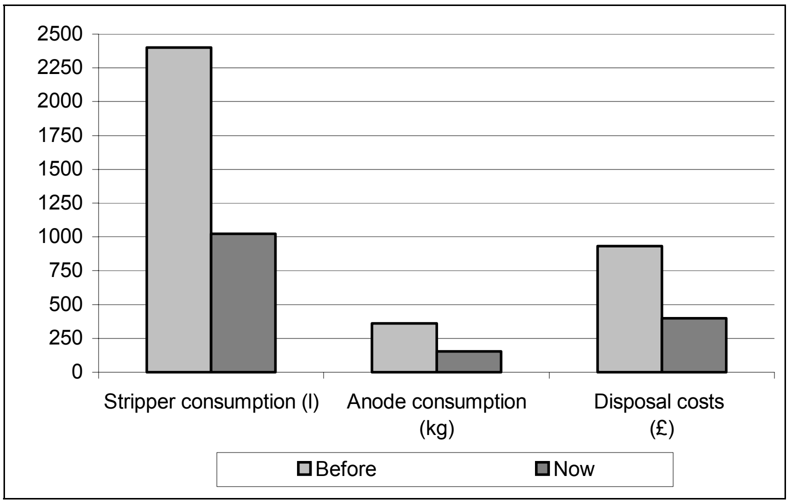
Organisation	Shipley Europe Ltd
Sector	Electronic
Product	Printed Circuit Board (PCB)

Background	- Accomplish Shipley´s Environmental Health and Safety (EHS) policy concerning Pollution Prevention and Sustainable Development: products and processes are developed, designed, and managed to reduce any harmful environmental effects. Shipley strive to efficiently utilize energy and natural resources.
	
	- Reports:
	  - The PCB industry use many chemicals and processes that are increasingly unacceptable,
	  - Cost of treatment/disposal is increasing,
	  - Environmental compliance cost is up to 7%,
	  - More legislation and regulation is coming,
	  - Competitiveness of European PCB industry can be significant

Benefits, success	- Benefits of reducing water consumption:
	  - cost reduction
	
	- Benefits of tin-lead etch resist saving:
	  - reduction of use of chemical products during production
	  - consumable reduction
	  - disposal coast reduction
	
	- Benefits of the use of direct plate
	  - avoids undesirable chemicals
	  - reduction of water consumption
	  - simplification of waste treatment
	  - increase productivity

Problems or possible improving Issues	- Some investigations were made to find new techniques for treating organic materials in effluent and waste - The next step is to improve recycling or reuse of plastic drums, which is only 14% at present

Results	- Water consumption:
	  - £40 k p.a. saved for an average PCB facility
	  - 850k gallons/year saved for 1000 boards produced
	
	- Tin-lead etch resists: for 500 panels per week
	  - reduction of 57,33% of stripper consumption
	  - reduction of 57,5% of anode consumption
	  - reduction of 57.12% of disposal costs
	  - ⇒ annual saving of 57%

Results (cont)	 **Figure 56: Tin-Lead etch resist savings** - Direct plate - 500 kg p.a. of copper recovered electrolytically
For more information	- http://www.shipley.com/ - Contact: Dr Martin GOOSEY mgoosey@shipley.com Phone number: +44 2476 654557 **Shipley Europe Ltd** Herald Way Coventry, CV3 2RQ UNITED KINGDOM Phone number: +44 24 7665 4400 Fax number: +44 24 7644 0331

APPENDIX 17. SHIPLEY – TIN LEAD RECOVERY UNIT

Written with the contribution of ***Martin GOOSEY***

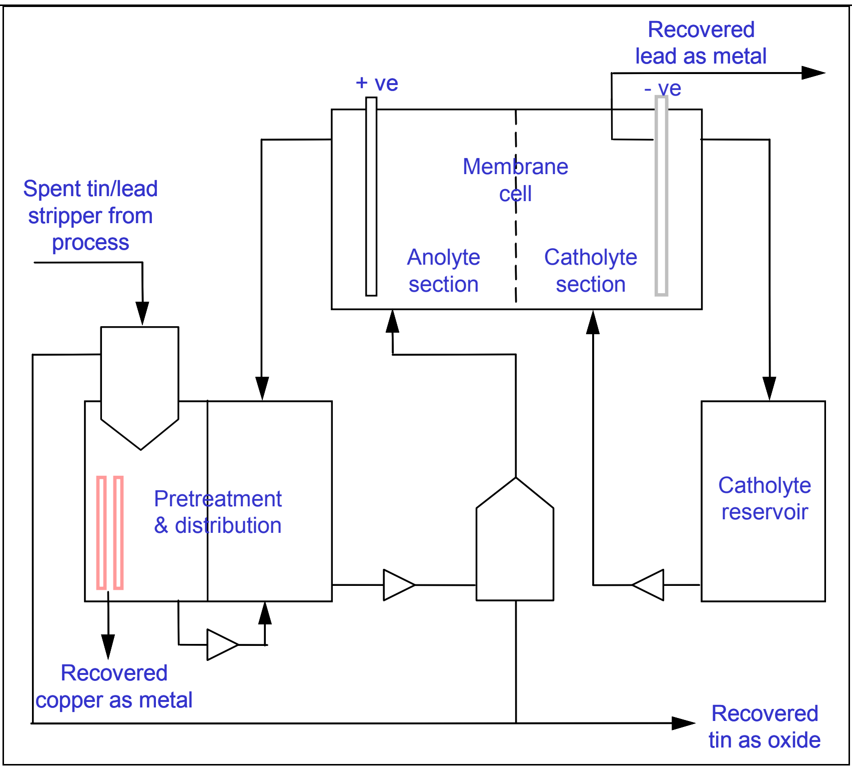
Organisation	Shipley Europe Ltd
Partners	Vero Electronics Ltd Finishing Technology Ltd
Sector	Electronic
Product	Piece of equipment capable of recovering tin and lead from spent tin-lead stripper solutions. 
Duration	9 months project developing the process and equipment to demonstrate feasibility.
Background	- This environmentally focused project, which has been carried out on behalf of the UK industry, has been managed by the PCIF and partly funded by the UK Government. - Tin-lead stripper solutions used in the PCB industry generate large quantities of spent solutions containing high concentrations of both tin and lead. These solutions are increasingly undesirable from an environmental/disposal perspective and in terms of waste treatment costs. The project was undertaken to evaluate waste treatment methods for these products.
Benefits, success	Benefits - Metal that would otherwise be disposed of to landfill would be recovered for reuse or recycling; - The possibility of pollution from such a source within the user's outfall would be removed; - The cost of offsite disposal would be eliminated; - Significant sales opportunities would be generated for manufacturers of the appropriate equipment and suppliers of suitable tin-lead strippers; - The recovery of metal from such stripping chemistry would open the possibility of recycling the stripping solution itself either in part or in whole, affording the industry additional cost benefits and waste minimisation opportunities. Success An optimised treatment methodology has been identified and a prototype piece of equipment manufactured, which is currently undergoing Beta site testing at Vero Electronics.

<table>
<tr><td>Tools and resources invested</td><td>Partners
- Shipley Europe, a leading supplier of chemical processes, including solder strippers to the Printed Circuit Board industry, based in Coventry. In addition to a volume manufacturing capability, Shipley Europe in Coventry also houses the European Technical Centre where both applications work and strategic R&D is undertaken. In recent years many new and innovative chemical processes for the PCB industry have been developed there by the highly qualified staff.

- Vero Electronics, an international manufacturer of electronic components, assemblies and systems based in Hampshire, and a key member of the PCIF's Environmental Working Group with its Works Chemist, Gary Morse, chairing the Waste Treatment Group. This Group is currently focusing its activities in the area of tin-lead etch resists and waste minimisation.

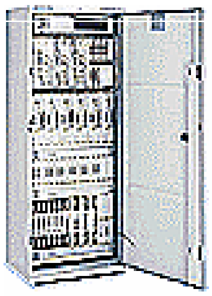
- Finishing Technology Ltd, a small British company based in Kempston, which has gained a reputation for the manufacture and supply of innovative chemical processing lines and equipment with an emphasis on the incorporation of novel waste and energy saving features.</td></tr>
<tr><td>Results</td><td>The equipment is capable of taking typical spent tin-lead stripper solutions and converting them into reusable tin oxide and lead deposits, whilst producing a metal free liquid component that can be treated with other PCB effluent.


Figure 57: Detail of the Tin-Lead recovery module
- The tin is recovered as tin oxide - widely used as a polishing medium, which is more valuable than tin metal - by use of a specially designed filtration technique.
- The lead is electrochemically recovered using a divided cell approach and ion permeable membrane technology. It can be recovered onto either stainless steel sheets or, alternatively, copper clad laminate.</td></tr>
</table>

	 **Figure 58: Tin-Lead recovery module**
For more information	- http://www.shipley.com/ - Contact: Dr Martin GOOSEY mgoosey@shipley.com Phone number: +44 2476 654557 **Shipley Europe Ltd** Herald Way Coventry, CV3 2RQ UNITED KINGDOM Phone number: +44 24 7665 4400 Fax number: +44 24 7644 0331

APPENDIX 18. SIEMENS – BASE STATION

*Written with the contribution of **Friedrich KOCH** and **Dr. Ferdinand QUELLA***

Organisation	Siemens (Munich)
Sector	Electrical / Electronic / Electrotechnical
Product	Base station BS 240/241 

Benefits, success	- Environmental benefit:
	  - 35% reduction of power uptake,
	  - 57 000 tons CO_2 saving in the first year of sales;
	
	- Financial benefit:
	  - 50% reduction of manufacturing cost.

Tools and resources invested	**Tools:**
	- Siemens Standards SN 36350
	
	The 6 parts of the Standard are as follows:
	1. Product development guidelines:
	  - principles of environmentally compatible product design;
	  - guidelines on environmentally compatible product design;
	  - integration of the environmentally compatible design into the product planning and development process.
	
	The guidelines consist of 40 rules for all phases. They follow a Life Cycle Approach (Figure 59). Focal points include:
	  - energy consumption in the use phase, especially in the case of a long-lasting product;
	  - reduction and recovery of end-of-life waste;
	  - substitution of hazardous substances.

Tools and resources invested (cont)	

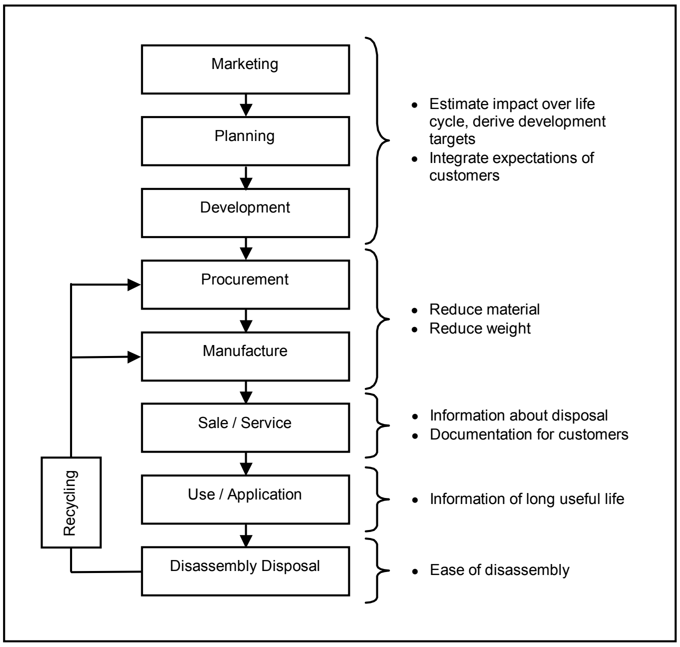


Figure 59: Examples of input of rules into development phase

The Base Station BS 240/241 has been developed in accordance with these guidelines. Table 13 below shows the improved points, and the design process steps.

Part of the product	Guideline part	Improvement
Base station	MPD	volume reduction: 8 transmission units instead of 6,
Cooling system	MPD	volume reduction: 38%,
Base station	MPD/PM	no more outdoor air conditioning system
Cooling system	PM	weight reduction 50%
Subrack	PM	reduction of the number of material: 1 pure instead of 4
Base station	PM	manufacturing cost reduction
Subrack	PM	cost reduction: 22% instead of 100%;
Cooling system	PM	cost reduction: 33%.
Cooling system	UA	energy consumption reduction: -180W
Cooling system	UA	better heat balance: +7 K
Cooling system	UA	MTBF improvement: 31%
Subrack	DD	reduction of the number of parts (17 instead of 66),

MPD: Marketing, Planning, Development PM: Procurement, Manufacture
UA: Use, Application DD: Disassembly, Disposal

Table 13: Improved Base Station

2. Hazardous substances, list of prohibited substances, list of substances to be avoided:

Informative list of legally banned or restricted hazardous substances: in European Union, Switzerland and some other countries.

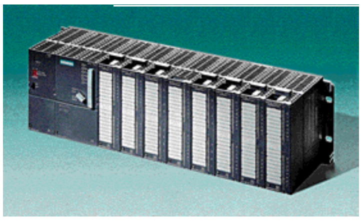
Tools and resources invested (cont)	Siemens-specific list of substances to be avoided or declared, based on the following criteria: - carcinogenic, mutagenic, toxic to reproduction (CMR); - acutely or chronically toxic; - easy formation of CMR, acutely or chronically toxic substances; - radioactive; - water-polluting; - persistent and bioccumulative; - contributing to global warming; - ozone depleting. If one of these substances cannot be avoided for technical reasons, it must be declared to all those who need the information, e.g. the recyclers. 3. Polymers: assessment of suitability for recycling and miscibility of thermoplastic polymers. Gives advice on selection of recyclable polymers not containing harmful additives. Additionally a miscibility matrix shows which polymers can be combined without hampering recyclability. This is helpful in cases where different polymers must be joined inseparably because of technical reasons. 4. Metallic materials: classification of recycling properties and miscibility. Classifies frequently used metals, metallic alloys and combinations of metals with respect to their recyclability. 5. Ecological requirements for packaging - principles of environmentally compatible packaging design; - preference list of packaging materials; - avoidance list of packaging materials; - prohibitions; - marking of packaging. 6. Record of substances in products Provisions for recording substances, which are contained in products, based on IEC Guide 113 “Materials Declaration Questionnaires – Basic guidelines”.
Problems or possible issues for improvement	**Positive aspects** - The 40 rules of the Siemens Standard provide wide coverage of an LCA and extend it, because LCA does not contain design principles; - All 40 rules can contribute to innovation; - Environmental improvement (degree of fulfilment of the 40 rules) can be combined with cost estimations; - Solutions for the environmental improvement can be different. Negative aspects - The rules might be contradictory, so the application of all of them cannot be mandatory; - The rules might not be applicable (e.g. for components); - The system to which the product is applied has to be integrated in the analysis.

Results	Environmentally compatible design
	- Base station
	  - volume reduction: 8 transmission units instead of 6,
	  - new air conditioning concept so there is no need to use an outdoor system,
	  - manufacturing cost reduction: Al, chem. oxidized. + coated + printed inscription replaced by noble steel + laser inscription.
	
	- Subrack
	  - reduction of the number of parts (17 instead of 66),
	  - 1 pure material instead of 4,
	  - cost 22% instead of 100%.
	
	- Cooling system
	  - weight reduction 50%,
	  - volume reduction 38%,
	  - 7 K better heat balance,
	  - energy consumption reduction 180W,
	  - MTBF improvement 31%,
	  - cost reduction 33%.

For more information	- http://www.ic.siemens.com/CDA/Site/pss/1,1294,208143-1-999,00.html Contact: Dr. Ferdinand QUELLA Ferdinand.Quella@mchp.siemens.de Friedrich KOCH Friedrich.Koch@mchp.siemens.de **Product Related Environmental Protection** Siemens AG D 81730 München GERMANY Phone number: +49 89 636 40170

APPENDIX 19. SIEMENS – SIMATIC S7-300

Written with the contribution of ***Friedrich KOCH*** *and* ***Dr. Ferdinand QUELLA***

Organisation	Siemens AG
Sector	Electrical / Electronic / Electrotechnical
Product	Programmable Controller SIMATIC S7-300 
Project Name	Further development of the SIMATIC product family
Duration	3 years
Background	Siemens Environmental Mission Statement
Benefits, success	Reduced production costs
Tools and resources invested	- Siemens Standard SN 36350 "Environmentally Compatible Products", parts 1-5; - Diploma thesis on minimizing adverse environmental impacts in the production phase; - Eco-COMPASS (Comprehensive Product Assessment), takes into account ecological, economic and technical aspects along the entire product life cycle.
Problems or possible issues for improvement	Availability of suitable substitutes, e.g. halogen-free printed circuits
Results	- 40% less energy consumption; - 46% less weight; - Assembly time halved; - No maintenance necessary; - Better recyclability; - Upgradability; - One halogen-free polymer for the housing; - No batteries necessary; - Less waste in the production processes; - No solvents in coating processes; - No cleaning processes with solvents; - Minimized soldering.
For more information	- Koch, F.: "*Managing Environmentally Compatible Product Design - the Siemens Way*", MEIE´2000, 2nd European Conference on Industrial Electrical Equipment and the Environment, Paris, 2000. - Friedrich KOCH Friedrich.Koch@mchp.siemens.de **Product Related Environmental Protection** Siemens AG D 81730 München GERMANY Phone number: +49 89 636 40170

APPENDIX 20. SONY – MOBILE PHONES

Written with the contribution of ***Thomas FISCHER***

Organisation	Sony International (Europe) GmbH Digital Telecommunication Europe
Partners	Sony International (Europe) GmbH Advanced Technology Centre Stuttgart Environmental Centre Europe
Sector	Electronic
Product	Mobile phones designed at Sony International (Europe) DTCE from 1996 onwards: CM-DX1000, CMD-Z1, CMD-X2000, CMD-C1, CMD-CD5, CMD-Z5, CMD-J5
Project Name	Environmental evaluation of mobile phones
Duration	1996 - continuous
Background	The aim of the environmental evaluation of mobile phones: - decrease environmental impact of the product; - set product development strategy; - document improvement of 'environmental friendliness'; - comparison with competitors' products concerning environmental features.
Benefits, success	Based on the environmental evaluation numerical targets are set for various features of the phone and its packaging: - material use in packaging; - maximum number of plastic elements in packaging; - maximum time of disassembly of the phone; - maximum power consumption of the charger of the phone in stand-by mode. Also other, non-numerical, targets are defined concerning: - marking of plastic parts of the phone; - absence of certain hazardous chemical substances - e.g. halogenated flame retardants; - material used for users' manual - recycled chlorine free paper; - presence of information on battery disposal in users' manual; - All the targets are included in project design.
Tools and resources invested	- Environmental evaluation: method established at Sony International (Europe) Advanced Technology Centre Stuttgart, Environmental Centre Europe. - Measurements needed for the environmental evaluation are made at Sony International (Europe) Digital Telecommunication Europe and at Environmental Centre Europe.
Problems or possible issues for improvement	A big improvement is expected after implementing chemical analysis into environmental evaluation (a project led in co-operation with the Environmental Centre Europe - currently in a start-up phase).
Results	- Low weight of packaging for the phone; - High contents of paper in packaging (close to 100%); - Users' manual made from recycled, chlorine free paper; - Low stand-by power consumption of the charger of the phone; - Design for recycling (easy disassembly); - Benchmarking with competitors.

For more information	http://www.sony-europe.com/mcp/index.x About Sony Environment http://www.sony.co.jp/en/SonyInfo/Environment/EnvironmentalReport/architecture/ Contact Thomas FISHER fischer@sony.de Kieren MAYERS mayers@sony.de Phone number: +49 (0) 711 5858476 **Environmental Centre Europe** Sony International (Europe) GmbH Advanced Technology Centre Stuttgart Hedelfinger Strasse 61 D-70327 Stuttgart DEUTCHLAND

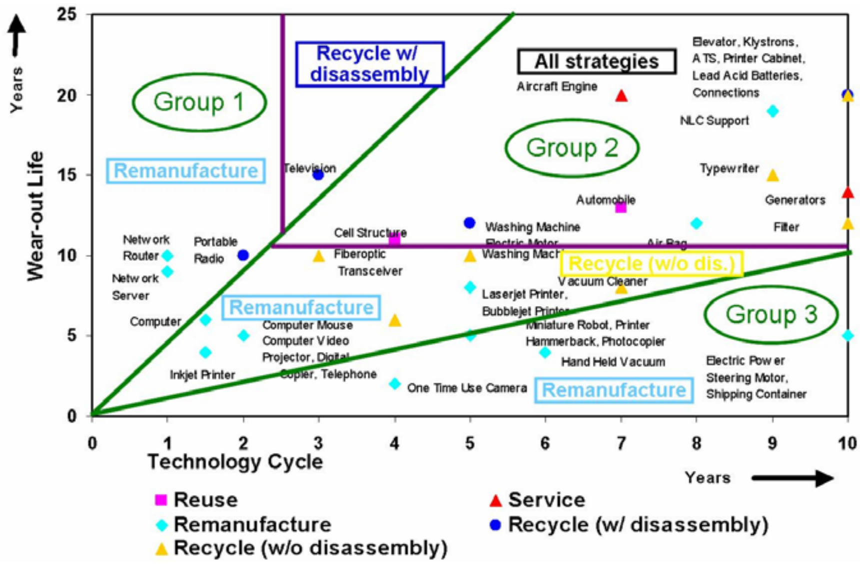
APPENDIX 21. STANFORD UNIVERSITY – ELDA

Written with the contribution of ***Catherine ROSE***

Concept initiator	Manufacturing Modelling Lab Stanford University
Concept partner	Delft University of Technology, Faculty OCP Design for Sustainability Lab
Sector	Electrical / Electronic
Product	Methodology development: End-of-life Design Advisor (ELDA)
Project Name	End-of-life Design Advisor (ELDA)
Duration	1997-2001
Background	Improving product environmental aspects at all stages of the life cycles is an important topic for manufacturers of electr(on)ic products. End-of-life is one of the stages of the life cycle gaining attention in the market and in public policies. Companies must understand how to improve their products so that the environmental impact will be lower at the end-of-life, while still being economically feasible. The end-of-life stage of the product life cycle has two challenges -technical (e.g. type of products and treatment procedures) and non-technical (e.g. consumer relationship at end-of-life). There is a need to develop metrics to take these aspects into account at the early stage of the design process: this is the aim of ELDA.

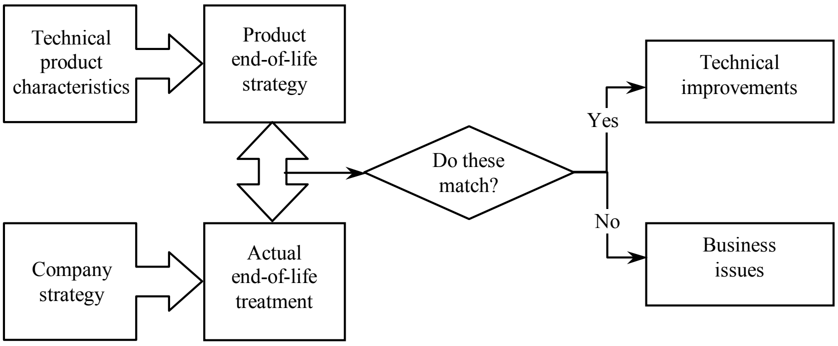
Benefits, success	- Philips Consumer Electronics has screened is product portfolio with the help of ELDA.
	
	Results:
	  - Cell phones have a large remanufacturing / upgrade business opportunity,
	  - TVs should focus on design for selective disassembly and not for higher levels of reuse,
	  - Audio products should be marketed as a family concept (upgrading by replacing parts of the system rather than remanufacture).
	
	- External participants in Stanford ME 217 class have benefited from ELDA exercises. They promoted Eco-design in their companies.

Tools and resources invested	- PhD project since 1997 at Stanford. - PhD student for one year at TUDelft (2000). - Philips Consumer Electronics makes resources available
Problems or possible issues for improvement	- ELDA addresses conventional strategy in a holistic way so that the outcomes can give rise to technical actions, but can also indicate that the environmental and business value chain have to be reorganised. This makes implementation difficult. - To be improved: taking into account that the functionality requirements of potential customers of products to be reused increases with time.

Results	- Since 1997, ELDA has been under development to determine product end-of-life strategies early in design as well as to provide a technical basis for decisions made by product planners and end-of-life treatment technology developers and to communicate with third parties (e.g. authorities, NGOs). - ELDA methodology considers the following hierarchy (classified from minor to major environmental impact - based on LCA approach): Reuse, Re-manufacture, Recycling with disassembly, Recycling without disassembly, Disposal. - Through the collection of extensive case studies on product end-of-life strategies, the following technical product characteristics have been identified as influencing most strongly the end-of-life strategy: wear-out life (0-20 years), technology cycle (0-10 years), level of integration (high, medium, low), number of parts (0-1000), design cycle (0-7 years), reason for redesign: original, minor/major and function/aesthetic). - ELDA leads to product classification as presented in Figure 60:  **Figure 60: Results of ELDA [Stevels et al. 00])**

Results (cont)

- ELDA classification method yields 89% agreement with current best practices.



Products	Current best end-of-life treatment implemented in industry	End-of-Life strategy recommended by ELDA	Action needed
TV	Recycle (with disassembly)	Recycle (with disassembly)	Match
Stereo System	Recycle (without disassembly)	Remanufacture	Mismatch
Monitors	Recycle (with disassembly)	Remanufacture	Mismatch
Cell phone	Recycle (with disassembly)	Remanufacture	Mismatch
VCR	Recycle (without disassembly)	Recycle (without disassembly)	Match

Table 14: ELDA and actual practice [STEVELS et al. 2000]

Table 14 can be examined in particular for two products:

- TV Set (current best practices and ELDA recommendation match);
- Cell Phone (current best practices and ELDA recommendation mismatch).

When two classifications match, it means that the end-of-life strategy is validated. It also means that technical modifications of the product can be made to improve the product's overall end-of-life performance. For example, for a TV set, Life Cycle calculations show that it is preferred to reduce energy consumption rather than trying to have a higher level of end-of-life strategy.

When two classifications mismatch, it means that more work has to be carried out on non-technical aspects. For the cell phone, ELDA shows that a higher-level end-of-life strategy (remanufacturing) is technically feasible (currently discarded phones are shredded and metals are removed through separation). In such a case primarily non-technical items have to be addressed (how to get products back, how to organise industrially, how to sell the remanufactured products) to make the strategy happen in reality.

For more information

- ROSE, C., "Design for environment: a method for formulating product end-of-life strategies", PhD thesis, Stanford University, December 2000.

- STEVELS, A., ROSE, C., *"Environmental Metrics to classify End-of-life Strategies (ELSEIM)"*, Presentation at 1st ECOLIFE Public Workshop, Vienna, Austria, November 15-16, 2000.

For more information	- ROSE, C.M., ISHII, K., STEVELS, A., "*Tools for building product end-of-life strategy"*, submitted to Journal of Sustainable Product Design, September 2000. - Contact: Prof. Ab STEVELS: ab.stevels@philips.com Dr. Catherine ROSE: c.m.rose@lucent.com **Delft University of Technology** Design for Sustainability programme Subfaculty of Industrial Design Engineering Jaffalaan 9 2628 BX Delft THE NETHERLANDS Phone number: +31 (15) 278 1524 **School of Engineering** Manufacturing Modeling Lab Terman 55 Stanford University Stanford, CA 94305-4021 Phone number: +1 650 728 7409 Fax number: +1 650 723 7349

APPENDIX 22. THOMSON MULTIMEDIA – TVS ECO-DESIGN INTEGRATION

Written with the contribution of ***Alain CLEMENT***

Organisation	THOMSON multimedia Product Development Europe	
Partners	ADEME Agency for the Environment and Energy Management France	
Sector	Electronic consumer equipment.	
Product	TV 21" – 4/3 	TV 28" – 4/3 
Project Name	TVs Eco-design integration.	
Duration	- Integrating the environmental concept in the product design was initiated in 1993-94. - The concept of environmentally friendly products has been applied since 1996.	
Background	- THOMSON multimedia is firmly committed to conduct business in a safe and environmentally responsible manner. THOMSON multimedia takes decisions on design and production methods based on this commitment. - Indeed, it has been successful in producing more and better quality products while consuming less natural resources, and ensuring that its products are designed responsibly to minimize their environmental impacts along their whole life cycle according to THOMSON multimedia EHS Charter and PLCM plan; - Pressure from customers for "greener" products: the comparative studies undertaken by central merchandising pushed the manufacturers to integrate requirements, which focus as much on the product, as on the company;	

: Environmental, Health & Safety.
: Product Life Cycle Management

Background (cont)	- By making decisions and investing in a greener future, THOMSON multimedia has launched flagship products designed for a wide audience that mark achievements as well as the embodiment of a global vision. The two products shown above are two among many, but were the forerunners of a whole new generation of products brought on the EU market; - THOMSON multimedia also works on the feasibility of a 100% recyclable TV set; - Commitment to build upon and innovate over previous product generation of TVs; - Anticipation of EU directives.
Benefits, success	A reduced use of scarce resources from the earth 1. From 5 to 20% of plastic used is recycled: - Chassis frame, embosses, etc. are made of 100% recycled plastic; 2. At least 5 % of the packaging is made of recycled material: - Recycled cardboard is used for the TV carton, - Use of a 100 % recycled EPS for fitting in mass-production process over 2 years; 3. Lower power consumption: - Around 30% less energy use over total product life compared to the typical product of 3 years ago, before these developments; 4. Improved production process: - 20% energy savings in moulding (new process technology), - THOMSON multimedia internally recycles plastics from moulding operation scraps and glass from picture tube operations scraps. Easy & clean recycling 5. No paint on the product as far as possible; no halogen (i.e. bromide) compounds in the plastics: - THOMSON multimedia has developed processes with suppliers to mould plastic without any further painting operation while achieving a high quality finish, and has removed bromide from plastics. Both initiatives prevent contamination by hazardous chemicals during manufacturing and recycling operations; 6. The packaging is 100% recyclable; 7. All main plastic parts are made from compatible plastics for easy recycling: - Standard TVs are designed with plastic components of ABS, of PC, of PMMA and other types needing complete disassembly for proper recycling. - Both TVs use only polystyrene and compatible plastics. This means that all the plastics can be melted down after disassembly and reused together. 8. Easy disassembly for easy handling by recycling companies: - All plastic parts are clearly marked, - Required labels on the back of the cabinet are also of compatible plastic material to avoid contamination by incompatible paper or glues at the time of recycling;

	9. Glass recycling: - THOMSON multimedia is committed to recycle glass from End-of-life Picture Tubes when available and comply with specifications.
Challenges	- These TVs have been mass-produced and launched on the market; - However, environmental friendliness has failed to be a criterion of product differentiation. These TVs were launched as standard TV sets without special mentioning of their greener attributes as: - Customers are neither ready nor willing to pay more for these "greener" products, - Clear positioning on the market of a "greener" TV is difficult, - Communication has to be adapted.
Tools and resources invested	Investment of THOMSON multimedia is at several levels: - Implementation of policy and programs integrating procedures, processes, and specifications; - Development and use of an LCA-based multi-criteria software (EIME®); - Support to specific projects development.
For more information	- Contact: Alain CLEMENT clementa@thmulti.com Product environmental manager **THOMSON multimedia** THOMSON TELEVISION Angers 17, boulevard Gaston Birgé BP 826 - 49008 ANGERS CEDEX 01 FRANCE Phone number: +33 2 41 37 39 45

APPENDIX 23. XEROX – INTEGRATED SUPPLY CHAIN NETWORKED AND DIGITAL DOCUMENTS

Written with the contribution of ***Malcolm HEMMING***

Organisation	THE DOCUMENT COMPANY XEROX®
Partners	Suppliers and recycling companies
Sector	Electrical / Electronic / Electrotechnical
Product	Xerox Document System
Project Name	Integrated Supply Chain
Duration	From early 1990s
Background	To optimise return of products and supplies for recovery.
Benefits, success	Increased rate of return for products and supplies.
Tools and resources invested	Logistic return centre certified to quality and environmental management standards.
Problems or possible issues for improvement	- Xerox can set up programmes to facilitate and encourage product return, but cannot compel customers to return their property at end-of-life; - The reverse logistic programme will be adversely affected if take-back regulations are applied in a way that forces equipment away from individual product stewardship schemes and into general schemes for the collection and recovery of equipment; - The programmes will be more effective if measures are taken to remove marketplace barriers to the purchase of equipment containing reprocessed parts.
Results	- 92% recovery rate for returned products;

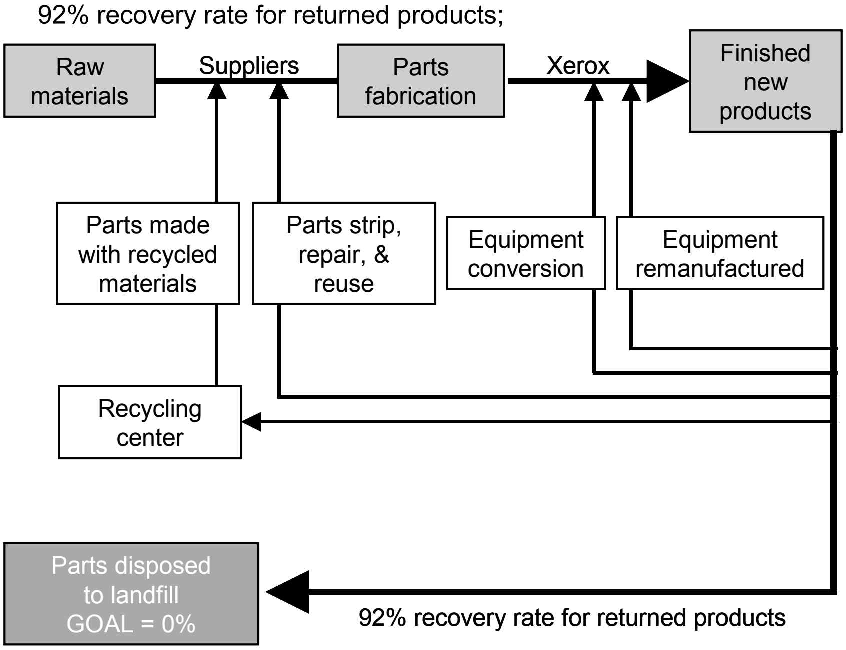


Figure 61: Recycle process

Results	- Cartridge return rate 60% for office equipment in last 3 years, whilst the return rate for cartridges from retail customers has doubled over the last 3 years.

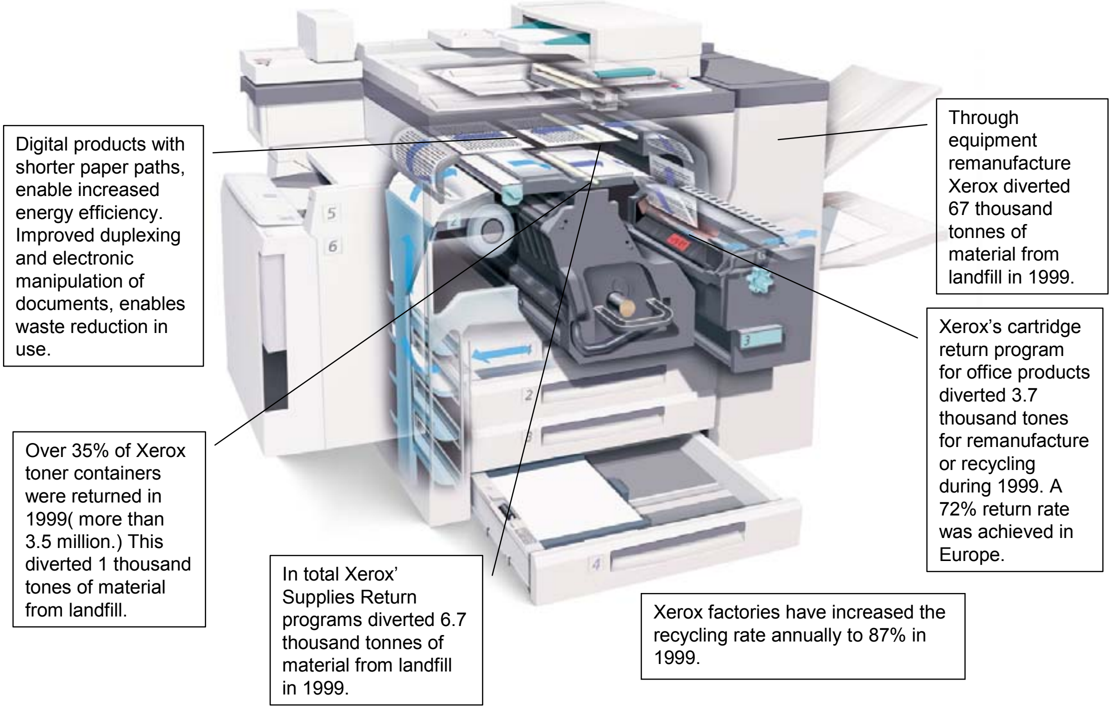


Figure 62: A Commitment to Reuse, Remanufacture & Recycle

For more information	- http://www.xerox.com - Contact: Elaine GRANGE Elaine.Grange@gbr.xerox.com Phone number: +44 1707 353434 **Xerox Europe Environment Health & safety** Bessemer Road Welwyn Garden City Hertfordshire AL7 1HE