

Electrical and Electronic Practical Ecodesign Guide

By:
Julio Rodrigo
Francesc Castells

with the collaboration of:
Juan Carlos Alonso

University Rovira i Virgili

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Authors & Acknowledgements

Authors:

Julio Rodrigo

(jrodrigo@stq.urv.es)

Environmental Management and Analysis Group
Technological Innovation Center SIMPPLE
University Rovira i Virgili

Francesc Castells

(fcastell@etseq.urv.es)

Environmental Management and Analysis Group
Department of Chemical Engineering
University Rovira i Virgili

with the collaboration of:

Juan Carlos Alonso

(jalonso01@lear.com)

Applied Research Department
European Technological Center
Lear Automotive (EEDS) Spain, S.L.
Electrical & Electronic Division

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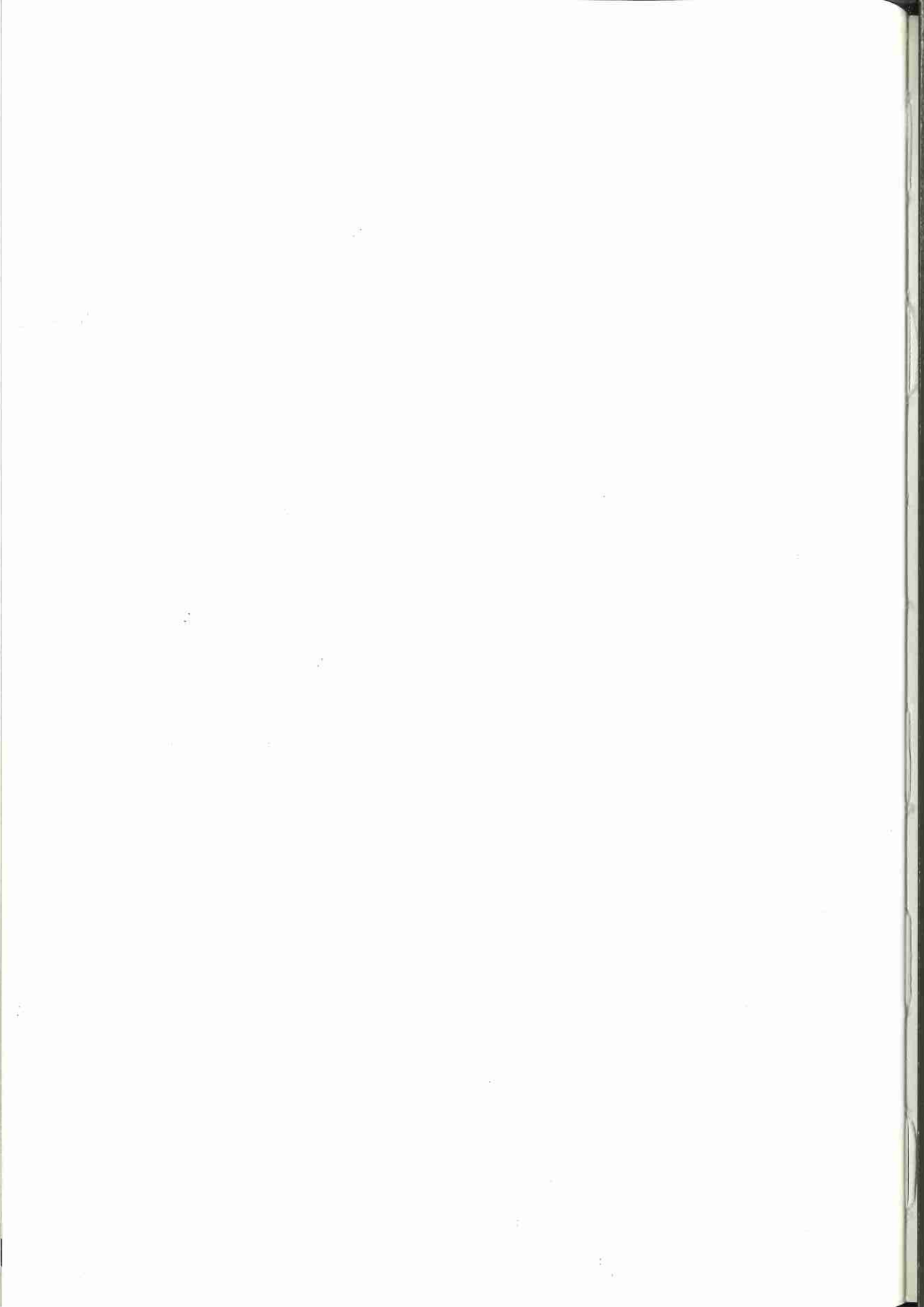
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PREFACE

This Electrical and Electronic Practical Eco-design Guide provides an insight into how the Electronics Industry can develop environmentally sustainable products. Evaluating the opportunities, risks, and trade-offs associated with products over their entire life cycle is now a fundamental element of company strategies on the road to sustainable development. This corresponds to the "UN Guidelines for Consumer Protection" which were revised and adopted by governments at the UN General Assembly in 1999. The UN Guidelines call on governments, together with industry, to take into account the environmental impacts of products throughout their entire life cycle, in order to improve their environmental performance and respond to the demands of consumers. This Eco-design Guide is also an important input into the development of cleaner and more resource efficient technologies for a life-cycle economy, as stated on 31 May 2000, in the "Malmö Declaration" agreed upon by Ministers of the Environment. The Electrical and Electronic Practical Eco-design Guide is a practical application for the Electrical and Electronic Industry and an exiting follow-up of the UNEP publication "Eco-design - A Promising Approach to Sustainable Production and Consumption".

Jacqueline Aloisi de Lardere

*Director of the Division of Technology, Industry and Economics
United Nations Environment Programme*





FOREWORD

This **Electrical and Electronic Practical Ecodesign Guide** intends to help the electrical and electronic industry introduce and apply Ecodesign methodology during the production of equipment. The application of this methodology will improve the environmental performance of manufactured equipment during their entire life cycle, and most importantly at the end-of-life stage when this equipment turns into waste.

Environmental considerations in electrical and electronic industry are becoming of increasing importance mainly due to emerging green markets, cost savings and an increasing legislative pressure. The increasing manufacture of new equipment has led to various proposals of directives that set a range of environmental measures, mainly on the management of waste electrical and electronic equipment (Directive WEEE, Directive ROHS and Directive EEE). Ecodesign methodology allows to introduce the environmental quality into industry in an effective way: minimising environmental harmful effects of equipment, during their entire life cycle, at the same time that important cost savings and profits are generated.

The Ecodesign methodology focuses on the central environmental issue in industry: the development and design of the product itself. Integrating the environmental issue into the product development and design process means that environmental product quality should be considered as another product requirement along with other conventional design objectives. This integration should be carried out without compromising other product properties and combining cost and environmental improvement in a sensible manner, all with the aim of manufacturing more environmentally compatible products.

Ecodesign, also called Design for the Environment (DfE), permits the identification of possible environmental improvement options in each stage of a product life cycle. This methodology also allows the identification of environmental improvement options and the most critical environmental stages of a product's life cycle. This global view makes it possible to consider the environmental issue further than the product manufacture boundaries and the pollution generated at this stage.

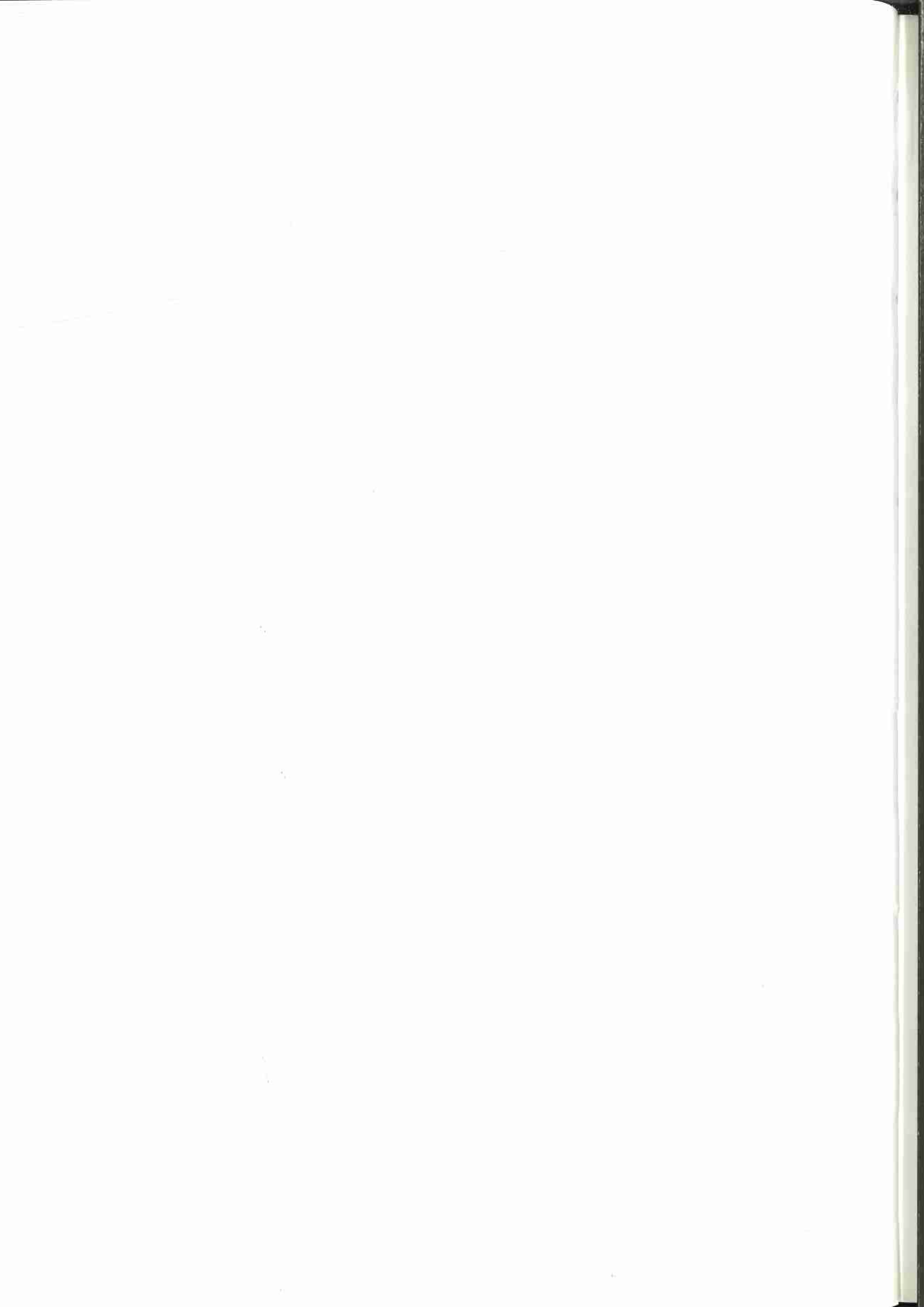
This Ecodesign guide provides different ways of improving the environmental behaviour of existing electrical and electronic products and assuring the environmental behaviour of new ones through the choice of various strategies, techniques, materials, design aspects, etc, all of them classified in the corresponding product life cycle stage.

This guide is mainly written for those who are active or interested in electrical and electronic product design processes as well as product development processes and for those responsible for developing the environmental issue in electrical and electronic companies. This guide also provides general Ecodesign guidelines applicable in other sectors different from the electrical and electronic industry.

We would also like to take this opportunity to thank all the support received from the following institutions: European Technological Center - Lear Automotive (EEDS), Spain, S.L., Centre per a l'Empresa i el Medi Ambient, PricewaterhouseCoppers, ANIEL and UNEP. We would also like to thank all the help received from Mónica Martínez (Technical School for Chemical Engineering, University Rovira i Virgili) during the update and linguistic correction of this book.

Julio Rodrigo and Francesc Castells

University Rovira i Virgili



The ecodesign's ecology

Ecodesign is developing hardly in almost all industrial sectors and beyond, up to services like tourism. And this development is influencing relationships between clients and suppliers all along the supply chain in each of these sectors. In building and construction for instance, research and demonstration programs such as the "Green building challenge", as well as the increasing "green purchasing" of local authorities are converging into a wave which involves material producers, renewable energy routes, or modern management and control techniques.

Ecodesign is spreading in industries like toys, furniture, lightning, etc. Despite of the diversity of application of ecodesign concept, one state that there are some similarities in the development from one industry to one another. Reciprocally, when one work more specifically in one industry, taking into account its features, one can draw lessons useful for other sectors. For instance, the short design cycle of electronic products (down to few weeks) has forced to simplify some aspects of ecodesign methodology - an effort which can benefit to others industries with or without short design cycles.

Outlining the experience gained in various industries since several years, one could compare ecodesign development with an ecological system where diversity of actors is combined through their interaction to transform effectively energy (constraints) coming from outside into internal drivers for evolution and into improved performance of products and services, integrating environmental dimension with others. Indeed, taking into account the environment in the design or re-design of a core product can lead to competitive advantage if and only if the environmental dimension is fully integrated in all aspects of product strategy, that is to say, linked to market, to finance, to the service delivered. Of course, to set up such multidimensional strategies implies that the linkage between the various dimensions of the product strategy are identified and, if possible, quantified. Here is where methodology really matters. For paving the way to right ideas, and from these ideas to practice, it is necessary to assemble knowledge and talents - people. Ecodesign is first of all a matter of organisation.

Moreover, the internal logic of ecodesign should extend this co-operation to the stages of the supply chain which are relevant from a product life cycle point of view, which imply co-operation between companies, and with universities, consultants, trade organisations, etc. In a certain way, through the contribution of different authors, the present guide illustrates this logic. There are still a lot of experiments to be undertaken and understood and shared in ecodesign. We are only at the beginning. To you, reader who already entered the play, I wish fascinating reading and endeavour. And fruitful co-operation.

Laurent Grisel

First President of the French ecolabelling committee
First President of APEDEC (French association of ecodesign professionals)
Former managing director of Ecobilan (PriceWaterhouseCoopers)



About this Guide

1.1. GOALS OF THE GUIDE

This practical Ecodesign guide intends to help the electrical and electronic industry introduce and apply Ecodesign methodology during the production of equipment. The application of this methodology will improve the environmental behaviour of manufactured equipment during their entire life cycle, and most importantly at the end-of-life stage when this equipment turns into waste.

Environmental considerations in electrical and electronic industry are becoming of increasing importance mainly due to emerging green markets, cost savings and an increasing legislative pressure. The increasing manufacture of new equipment has led to various proposals of directives that set a range of environmental measures, mainly on the management of waste electrical and electronic equipment (WEEE). Some of these are the Proposal for a European Parliament and Council Directive on Waste Electrical and Electronic Equipment (Directive WEEE), and on the Restriction of the use Of certain Hazardous Substances in electrical and electronic equipment (Directive ROHS), and the proposal for a European Parliament and Council Directive on the impact on the Environment of Electrical and Electronic Equipment (Directive EEE). Ecodesign methodology allows to introduce the environmental quality into industry in an effective way: minimising environmental harmful effects of equipment, during their entire life cycle, at the same time that important cost savings and profits are generated.

The Ecodesign methodology focuses on the central environmental issue in industry: the development and design of the product itself. Integrating the environmental issue into the product development and design process means that environmental product quality should be considered as another product requirement along with other conventional design objectives such as performance, reliability, cost, serviceability, usability, etc. This integration should be carried out without compromising other product properties and combining cost and environmental improvement in a sensible manner, all with the aim of manufacturing more environmentally compatible products, or in other words, products with a lower environmental burden related to their entire life cycle.

Ecodesign, also called Design for the Environment (DfE), permits the identification of possible environmental improvement options in each stage of a product life cycle: from acquisition of raw materials, production and supply of materials and

components, end product manufacture, distribution to customers, product use and product end-of-life. This methodology also allows the identification of the most critical environmental stages of a product's life cycle.

This global view makes it possible to consider the environmental issue further than the product manufacture boundaries and the pollution generated at this stage. These aspects should also be considered: raw material origin, raw material elaboration process, energy consumption along the process, product transportation and distribution, product use and product end-of-life disposition. All with the aim of integrating the product environmental improvement as another part of the general purpose of achieving a more sustainable society.

This Ecodesign guide provides different ways of improving the environmental behaviour of existing electrical and electronic products and assuring the environmental behaviour of new ones through the choice of various strategies, techniques, materials, design aspects, etc, all of them classified in the corresponding product life cycle stage.

1.2. TARGET GROUP

This guide is mainly written for those who are active or interested in electrical and electronic product design processes as well as product development processes and for those responsible for developing the environmental issue in electrical and electronic companies. So, the primary audience is thus product managers, product developers, product designers, process design engineers, packaging designers and environmental managers. Nevertheless, this guide also contains useful information for marketing managers, purchasing managers, distribution managers, customers, etc.

This guide also provides general Ecodesign guidelines applicable in other sectors different from the electrical and electronic industry.

1.3. SCOPE

This guide focuses on the stages of a product life cycle, providing several improvement options in each life cycle stage of an electrical and electronic equipment. This guide considers that an equipment's entire life can be totally covered by considering the following five life cycle stages:

- production and supply of materials and components
- end product manufacture
- distribution to customers
- product use
- product end-of-life

Environmental equipment evaluation, based on the Life Cycle Assessment (LCA) methodology, allows the identification of environmental improvement options and also the most critical environmental stage/s. That objective and valuable information together with the practical Ecodesign guidelines provided in this book becomes a powerful tool that allows electrical and electronic companies to improve the environmental performance of their existing products and assure the environmental

performance of new ones. All with the aim of producing products with the lowest global environmental impact associated to their entire life cycle, without compromising other product properties and finding the right balance between ecological and economic requirements.

1.4. STRUCTURE

This Electrical and Electronic Practical Ecodesign Guide is divided in the following seven chapters and one annex:

- **Chapter 1: About this Guide** is a general presentation describing general goals, target group, scope and structure of this Electrical and Electronic Practical Ecodesign Guide.
- **Chapter 2: Importance of Ecodesign** justifies why it is interesting from an environmental and business perspective to include environmental considerations in industry. It focuses on how effective Ecodesign is in integrating environmental quality into industry.
- **Chapter 3: Ecodesign Methodology** describes the essence of the Ecodesign approach and the differences between Ecodesign and traditional product design and development process. It is also described in this chapter how environmental improvement options can be detected and how the most critical environmental stage/s of a product life cycle can be identified.
- **Chapter 4: Practical Ecodesign Guidelines** is the backbone of the book. This chapter provides a high amount of various strategies, techniques, materials, design aspects, etc, that allow the improvement of the environmental behaviour of electrical and electronic equipment during their entire life cycle. All those instructions are classified in their corresponding product life cycle stage (production and supply of materials and components, end product manufacture, distribution to customers, product use and product end-of-life).
- **Chapter 5: Ecodesign and LCA Practical Application at Lear Corporation** shows the result achieved by the practical application of Ecodesign and Life Cycle Assessment (LCA) methodologies at Lear Automotive (EEDS) Spain S.L. (Electrical and Electronic Division) and the actual problems encountered during its implementation conducted from the European Technological Center, placed in Valls (Tarragona, Spain).
- **Chapter 6: Environmental Trends in the Electrical-Electronic and the Automobile Industry** provides an overview of the international activities and market trends in environment related to the electrical and electronic industry as well as the automobile industry.
- **Chapter 7: Organisations** provides useful addresses related to Ecodesign, Life Cycle Assessment (LCA), electrical and electronic equipment, environment, etc.
- **Annex I: Ecotools** presents and describes some ecotools that can be used in Ecodesign activities in order to analyse and improve the environmental performance of products, processes and activities.

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Importance of Ecodesign

The following chapter justifies why including environmental considerations into industry is interesting from an environmental and business point of view. It focuses on how effective Ecodesign is in integrating environmental quality into industry.

2.1. THE ENVIRONMENTAL POINT OF VIEW

It is known that present immoderate human activity causes multiple environmental impacts on the environment. This situation is responsible for increasing constantly the deterioration of the environment, placing the need of a responsible product design and development in a environmental perspective.

Any industrial activity, including electrical and electronic industry, contributes in a major or minor grade in the continuous deterioration of the environment. In this context, it can be said that any electrical and electronic equipment (and obviously, any other product, industrial process or activity) is responsible of multiple environmental impacts:

- Any electrical and electronic equipment consumes both renewable and non renewable resources. For example, some electrical and electronic equipment use scarce and non renewable resources: rare metals (Thallium, Rubidium, Cesium...), earth metals (Europium, Dysprosium, Gadolinium...), etc. The immediate consequence of the extraction and consumption of those resources is their extinction.
- Hazardous and non hazardous wastes are generated during any equipment's entire life cycle, from raw materials acquisition up to end-of-life product disposition. Many wastes are released directly to the environment in the form of air emissions (VOC's from PCB wave soldering process), water discharges (PCB etching process) or landfill dispositions (habitual electrical and electronic equipment end-of-life disposition).

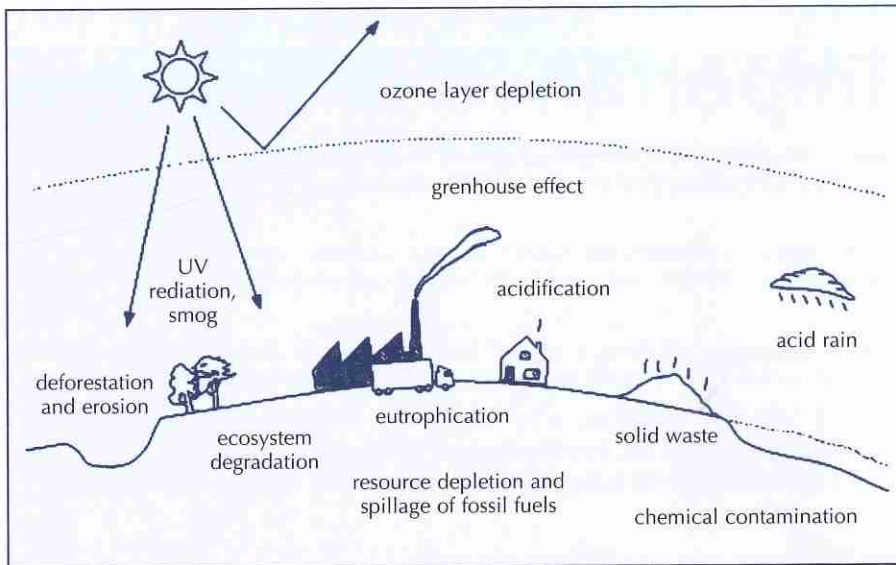


Figure 1. Overview of general environmental problems
(Source: Delft University of Technology)

Immoderate consume, of both renewable and non renewable resources, and immoderate waste generation, both hazardous and non hazardous, causes pollution in all forms that degrade ecosystems, harm human health and become global environmental problems from short to long term (figure 1). In some cases, links between environmental burdens and their potential effects or impacts are obvious, but in other cases it is difficult to establish their relationship. Their effects can be unexpected in time and magnitude.

As briefly mentioned before, environmental problems can be classified in two main categories:

- Environmental problems that affect the **Quality** of the environment: problems that cause deterioration of the ecosystems and/or cause problems on human health (greenhouse effect, ozone depletion, air toxicity, summer smog, winter smog, air acidification, water toxicity, water eutrophication, waste production, etc.).
- Environmental problems that affect the **Quantity** of the environment: problems that contribute to the depletion of raw materials and physical space (raw material depletion, energy depletion, water depletion, etc.).

Another way to classify environmental problems is in accordance with a geographical scale of the caused environmental damage. Environmental effects can occur on local, regional, fluvial, continental or global scales:

- **Local:** noise, smell, air pollution...
- **Regional:** soil pollution, water eutrophication, air pollution, waste disposal...
- **Fluvial:** river pollution, regional water pollution...
- **Continental:** acidification, winter smog, ozone levels, heavy metals...
- **Global:** climatic change, higher sea levels, ozone layer...

When a product, process or activity environmental evaluation (Life Cycle Impact Assessment, LCIA) is performed, different impact indicators are used (figure 2):

Impact Indicator	Description
Raw Material Depletion (RMD)	Depletion of natural resources (year ⁻¹).
Energy Depletion (ED)	Consumption or use of energy (MJ).
Water Depletion (WD)	Consumption of water (m ³).
Global Warming Potential (GWP)	Contribution to the global warming of the atmosphere by the release of specific gases (g of CO ₂).
Ozone Depletion (OD)	Contribution to the depletion of the atmospheric ozone layer by the release of specific gases (g CFC-11).
Photochemical Ozone Depletion (POD)	Potential creation of tropospheric ozone by the release of specific gases which will become oxidants in the low atmosphere under the action of the solar radiation (g of C ₂ H ₄).
Air Acidification (AA)	Air acidification by gases released to the atmosphere (g of H ⁺).
Air Toxicity (AT)	Air toxicity in a human environment (m ³ of bad air).
Water Toxicity (WT)	Water toxicity (m ³ of bad water).
Water Eutrophication (WE)	Enrichment in nutritive elements of lakes and marine water by the release of specific substances in the effluents (g of PO ₄ ³⁻).
Hazardous Waste Production (HWP)	Quantity of hazardous waste produced for a given product (kg).

Figure 2. Environmental impact indicators

(Source: PricewaterhouseCoopers, potential environmental impact indicators used in the software EIME).

Environmental criteria are not always considered at the beginning of the design or development process, when it is easy and cheap to improve any product's environmental behaviour. It usually is at the end of the project when environmental issue appears, and this clearly reflects past ineffective and expensive practices: end-of-pipe treatments. Many companies are still spending too much time and money solving problems rather than preventing them.

Product environmental behaviour and most of its associated environmental impacts caused during its entire life cycle (from acquisition of raw materials, production and supply of materials and components, end product production, distribution to customers, product use up to product end-of-life) have been settled before the product has been manufactured or used. Integrating environmental quality into the development and design process is an effective way of improving a product's environmental behaviour and minimising its harmful effects. Designers have the unique opportunity to make an important contribution to the creation of more environmental products.

Integrating environmental issue into a product development and design process is an active and effective contribution for achieving a more sustainable society: a society that satisfies today's needs without compromising the ability of future generations to satisfy their needs, promoting sustainable resource management and ensuring environmental quality for future generations.

2.2. THE BUSINESS POINT OF VIEW

Fortunately, many strategies for preventing environmental damage and minimising its harmful effects are cost effective, permits to comply with present and future legislation, have social acceptance, satisfy company customers, motivate company employees, allow innovation, etc. That is why environmental integration into industry is interesting from a business perspective, or in other words from a competition, cost and social perspective. Integrating environmental considerations into business activities is clearly becoming more habitual.

Ecodesign can be considered an effective way of introducing environmental quality into business activities, improving products environmental behaviour during their entire life cycle, without compromising other product properties at the same time that important cost savings and profits are generated. Several internal and external influences motivate its implementation, some of them are listed here:

- **Legislative regulations:** environmental considerations in companies are becoming of increasing importance due to legislative pressure in their own country as well as in the countries to which they export (Directive WEEE, ROHS and EEE).
- **Competition:** pioneering companies may gain some competitive advantage by integrating efficiently environmental quality into product and process design and development.
- **Market pressure:** environmental considerations in companies are becoming of increasing importance due to a growing sense of responsibility for conserving the environment and nature both of end-users and other customers. Environmental market pressure has an important influence on the environmental behaviour of companies. Ecodesign can be an effective way of improving companies environmental behaviour and satisfying the environmental wishes of their customers.
- **Public opinion:** integrating environmental quality into product design and development processes is an effective way of improving companies environmental behaviour and satisfying the increasing social environmental concerns and wishes.
- **Customers requirements:** suppliers are being required to meet their customers environmental requirements (ISO 14000, EMAS, product environmental declaration, etc.). Integrating efficiently environmental quality into companies helps meeting environmental customers' requirements.
- **Total product quality:** the environmental variable should be included in the total product quality.
- **Innovation:** integrating environmental quality into a product's design and development process facilitates and stimulates product and process innovation. New markets may be penetrated with new and innovative environmental product concepts.

- **Cost savings:** integrating environmental issues into a product's design and development process can result in considerable cost savings, both at short and long term: less raw materials consumption, less wastes generation, less waste disposal costs (classical end-of-life disposition waste charges are expected to rise in order to stimulate waste minimisation and other waste management alternatives: reuse, recycle...), efficient energy consumption, efficient water consumption, etc.
- **Employee motivation:** introducing the environment issue in companies is an effective way to implicate and motivate employees. They can contribute actively reducing their company's environmental impact and improving their life quality at their work sites.
- **Environmental information:** during the coming years, companies will be required to provide information on their products, processes and activities environmental behaviour.
- **Ecolabelling programmes:** the efficient integration of environmental quality into products is a common goal of ecolabelling programmes. The number of ecolabelling products and product group programmes is increasing and constantly gaining more attention.
- **Companies responsibility:** Companies are getting more aware of their important role in conserving the environment and obtaining a more sustainable society.
- **Corporate communication:** Integrating the environmental quality into business, moving towards an active attitude in conserving the environment and nature, allows companies to improve effectively their products and company's image.
- **Supply chain relationship:** benchmarking programmes are being developed between different companies, between companies and their trade companies, their customers, their suppliers, etc. These strategies are currently being used in all business areas, including the environmental area. Ecodesign can be considered a powerful environmental tool that may be used in environmental supply chain benchmarking and relationship programmes.
- **Subsides:** several environmental subsidies programmes have been developed on a world basis. Some of them are trying to stimulate the integration of environmental issue into industry and consequently improve efficiently the environmental behaviour of their products and processes.

As it has been described above, the choice of a company's environmental strategy or policy is strongly affected by competitive, financial and social influences, or in other words, an environmental company's strategy has important, competitive, financial and social consequences (figure 3).

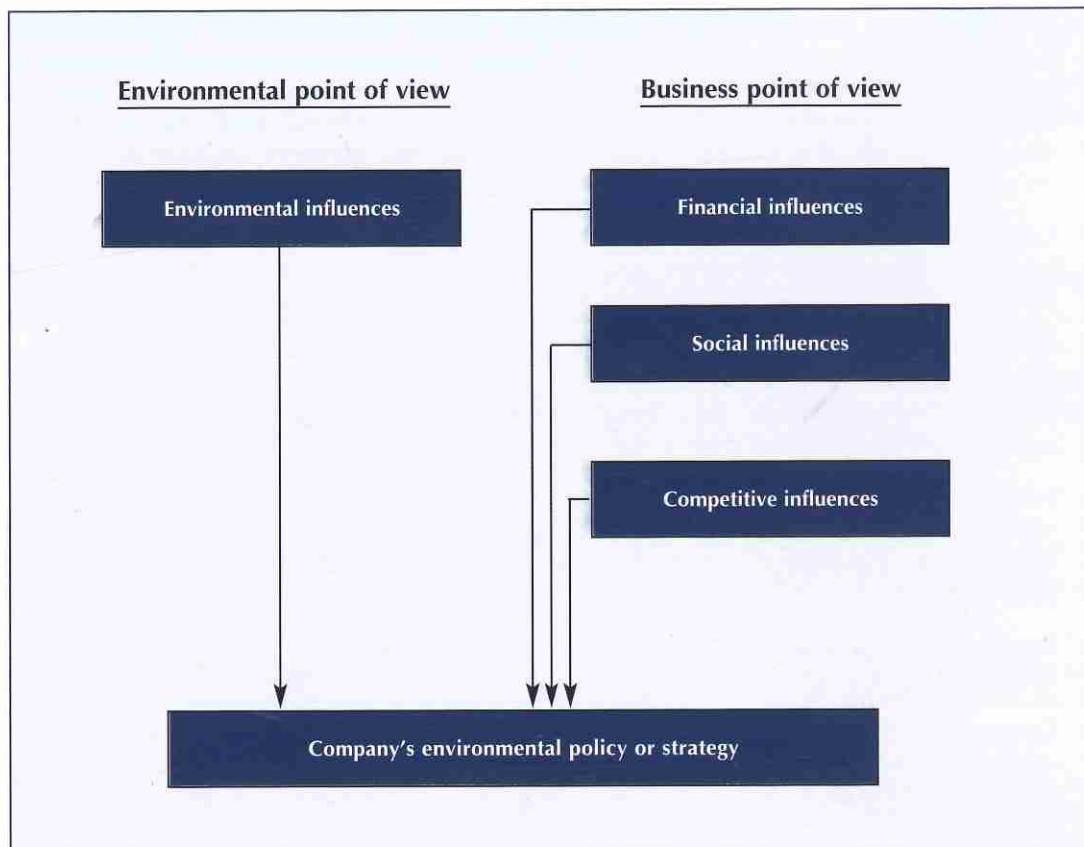


Figure 3. Company's environmental policy or strategy

2.3. ECODESIGN AND THE DIFFERENT SUSTAINABILITY TOOLS

There has been developed, during the last years, various concepts, analytical tools, procedural tools, policy instruments, etc, with the common final objective of facilitating the achievement of a more sustainable development. Ecodesign, being a methodology that permits in an optimal manner the acquirement of a major sustainability, is not the only possible approximation. Figure 4 shows some of the most important elements (concepts, tools, etc.) that intervene in the achievement of the common objective of a sustainable development.

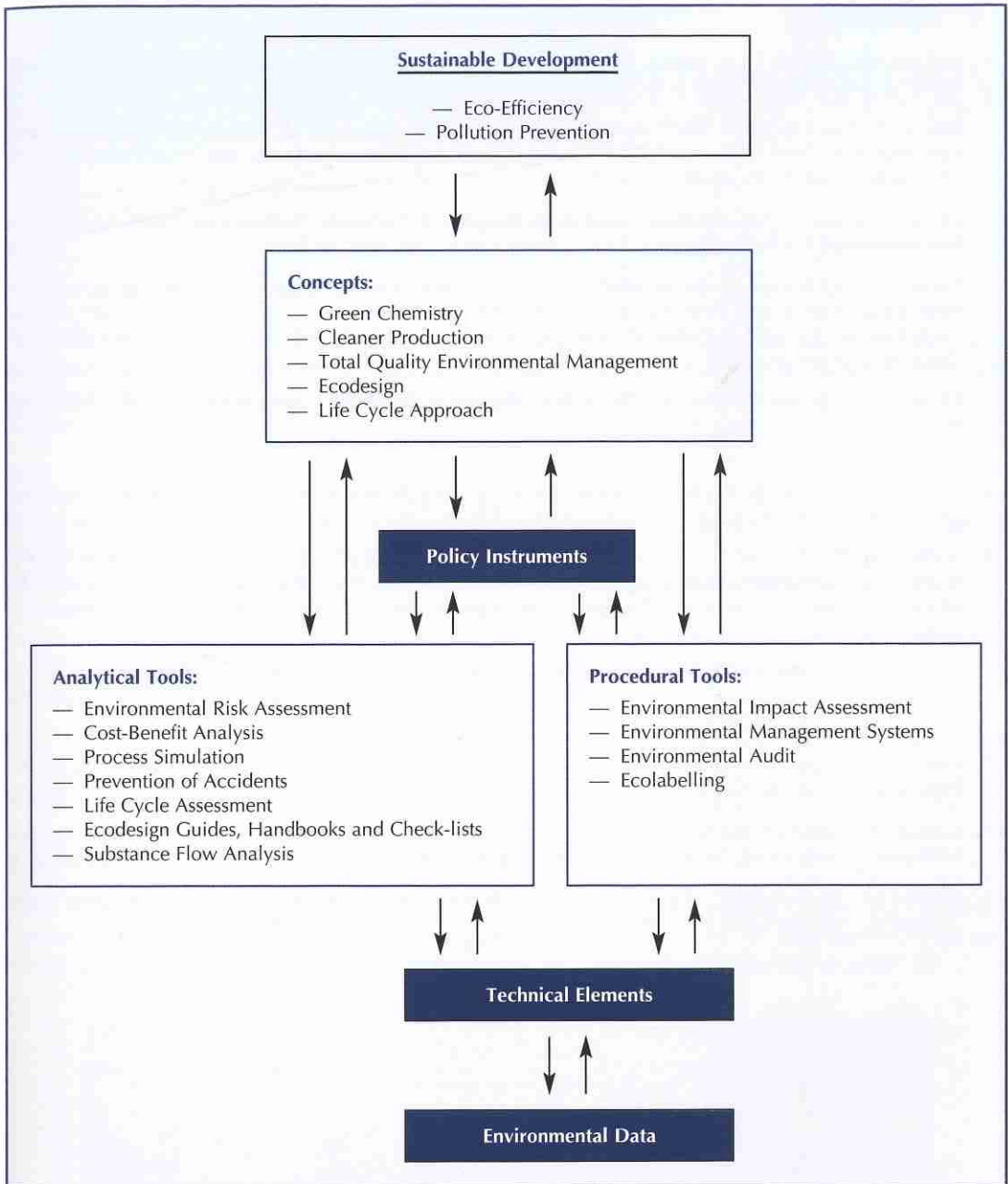


Figure 4.- Distribution of different environmental approaches

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Ecodesign Methodology

The following chapter describes the Ecodesign methodology focusing on the new concepts and activities that should be considered in the integration of environmental quality into traditional product design and development processes.

3.1. ECODSIGN

Environmental considerations in electrical and electronic products are becoming of increasing importance due mainly to legislative pressure (Directive WEEE, Directive ROHS and Directive EEE), cost savings and emerging green markets. Electrical and electronic industry is confronted with increasing responsibility for the environmental impacts of its products during their entire life cycle, and especially when these turn into waste. These influences are motivating the implementation of environmental quality into electrical and electronic business.

The Ecodesign methodology, presented in this chapter, allows the introduction of environmental quality into electrical and electronic industry in an effective way: minimising environmental harmful effects of electrical and electronic equipment during their entire life cycle (from acquisition of raw materials up to disposal) at the same time that important cost savings and profits are generated.

This new approach considers the environmental issue further than the product manufacture boundaries and pollution generated in this stage. In this global view the entire product life cycle is considered (life cycle approach or thinking) (figure 5):

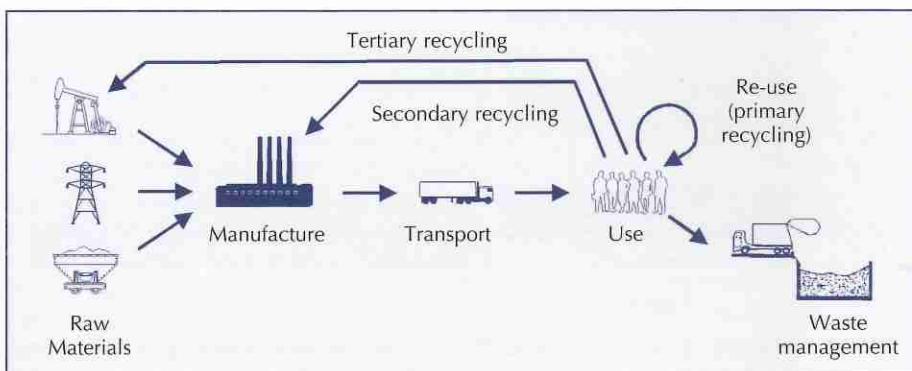


Figure 5. The product life cycle

The Ecodesign approach (figure 6) is an effective way of introducing the environmental quality into electrical and electronic industry since this methodology focuses on the central environmental issue: the development and design of the product itself.

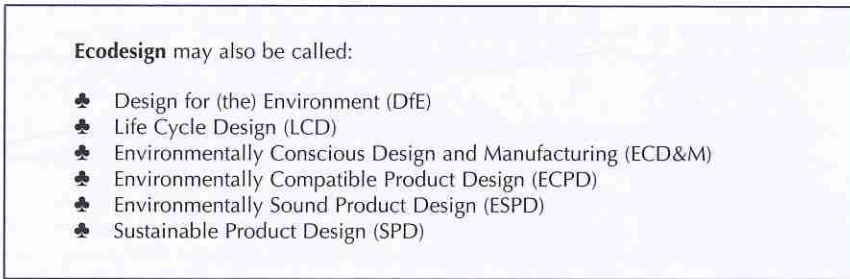


Figure 6. Ecodesign synonymous

This approach (figure 7) can improve, from an environmental perspective, all the stages of an electrical and electronic equipment's life cycle (reducing the amount of raw materials and energy used, and the equipment's impact on the environment and health) and generate profits and cost savings, but it is needed that environmental aspects are considered and integrated into design requirements right from the beginning of the equipment development process (when it is easier and cheaper to do so).

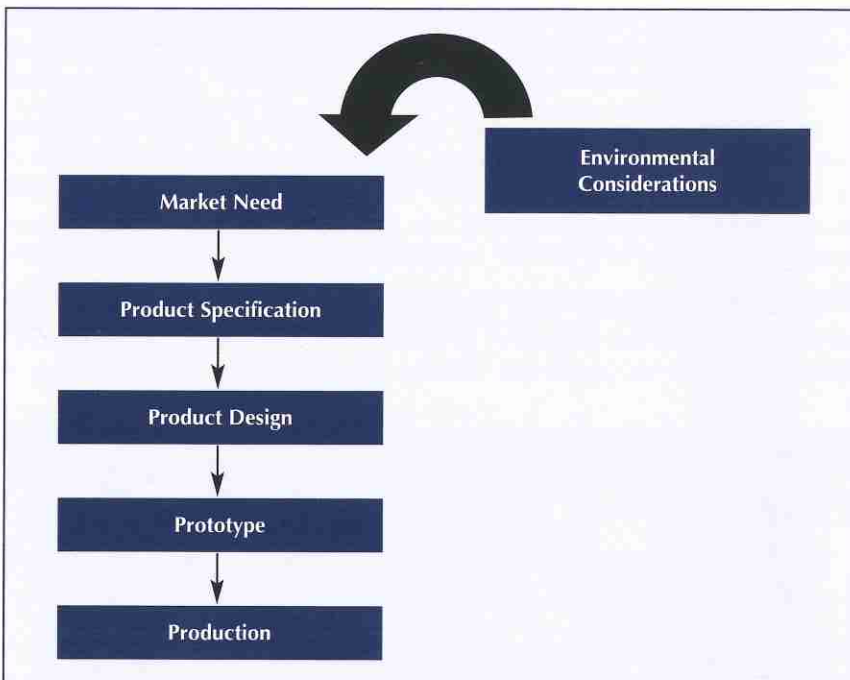


Figure 7. The product development process

Concurrent engineering approach allows to carry out simultaneously these stages and involve other disciplines (marketing, quality, etc.) in product design and development processes.

The basic structure of electrical and electronic equipment's development processes do not change significantly when the environmental quality is integrated in it. However, this integration (figure 8), as another product requirement, implies the consideration of some additional aspects in the traditional product development process:

1. Product requirements readjustment
2. Environmental product evaluation
3. Ecodesign guidelines application

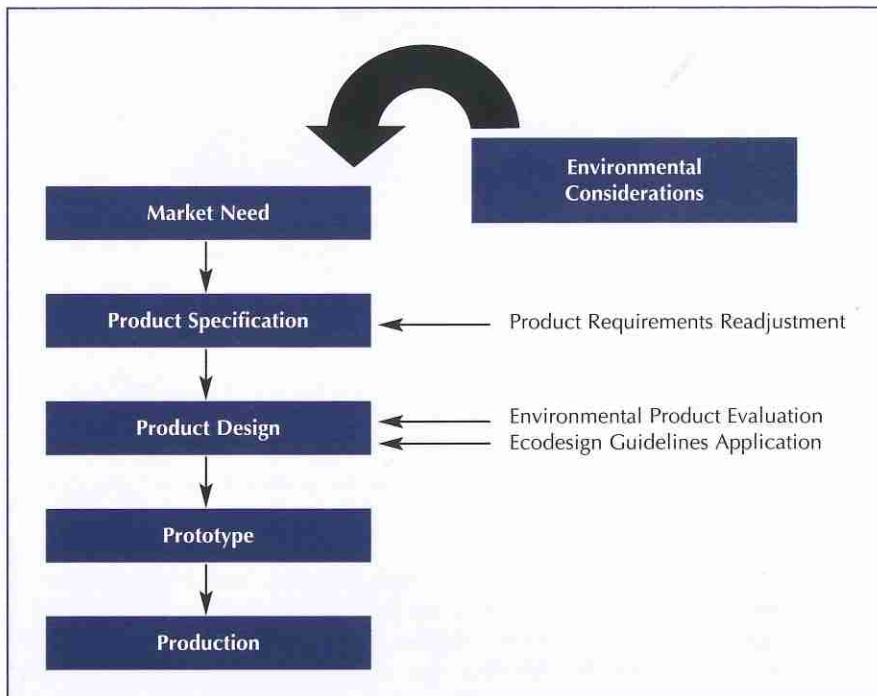


Figure 8. The new product development process

3.1.1. Product requirements readjustment

The integration of environmental quality into a product's development process (figure 9) means that the environmental quality should be considered as another product requirement along with other conventional design objectives such as safety, performance, reliability, manufacturability, cost, serviceability, usability, etc.

This integration should be developed without compromising other product properties, combining cost and environmental improvement in a sensible manner. All with the aim of manufacturing more environmentally compatible products, or in other words, products with a lower environmental burden associated to their entire life cycle.

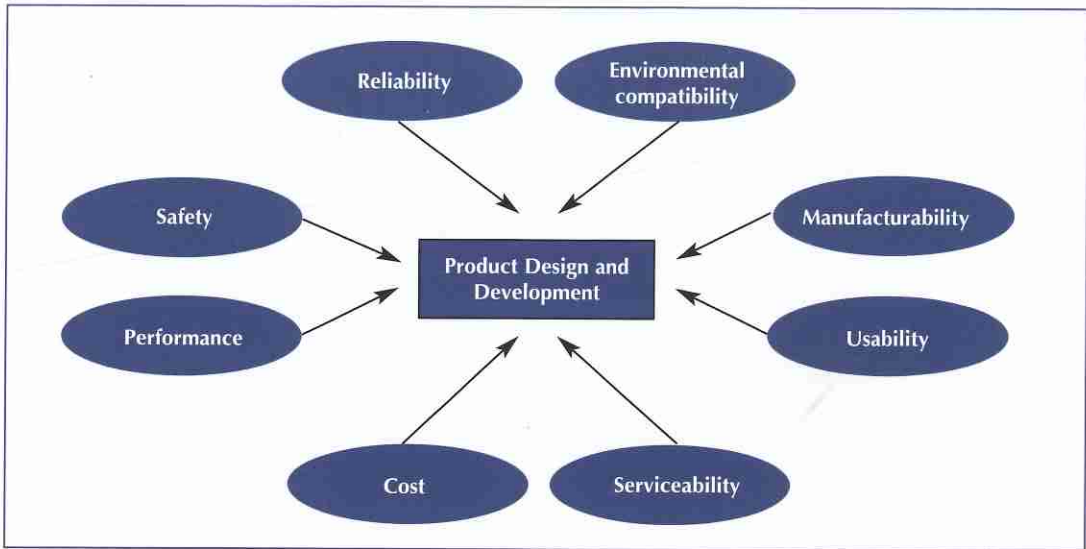


Figure 9. Product requirements readjustment

3.1.2. Environmental product evaluation

The introduction of environmental quality into a product's design and development process implies a qualitative or quantitative environmental evaluation of electrical and electronic equipment covering all the stages of a product's life cycle. The purpose of the environmental evaluation is to provide objective information to support the decision-making in design and development processes, thus, the most critical stages, from an environmental point of view, with its respective environmental problems, may be identified and the best environmental solution, with the least potential environmental impact through the equipment's entire life cycle, may be chosen. Obviously, in the implementation of any environmental improvement it is necessary to find the right balance between ecological and economic requirements as well as other product properties.

Traditionally, the focus on environmental improvement has been set on the production stage. This stage is only one of the stages of an equipment's life cycle and in any of them (product use, product end-of-life, etc.) there are different environmental impacts on air, water, soil, etc. A holistic approach is needed to consider the environmental issue further than the product manufacture boundaries and pollution generated in this stage.

3.1.2.1. Qualitative and abridged life cycle assessment:

A qualitative or an abridged product environmental evaluation may be done with different levels of detail. These methods are not very thorough, but cheap and easy to do. The environmental product evaluation allows the identification of areas that need improvement and that may be considered in the equipment design and development process.

Hereafter are presented some qualitative and abridged life cycle assessment methods:

a) MET Matrix

The **MET Matrix** evaluation method (figure 10) was developed under an Ecodesign project in the Netherlands. The aim of this method is to identify the main environmental problems covering the entire product life cycle (from acquisition of raw materials up to disposal) and classify them into the following three categories: **M** (Material Cycle), **E** (Energy Consumption) and **T** (Toxic Emission).

How to fill in the MET Matrix?

Certain background knowledge is necessary in order to be able to fill in the MET Matrix. However, the matrix may be filled in by considering the aspects mentioned below, related to an electrical and electronic equipment's environmental behaviour, and covering its entire life cycle.

	Material Cycle (M)	Energy Consumption (E)	Toxic Emission (T)
Production and supply of materials and components	<ul style="list-style-type: none"> — Materials and components needed — Acquisition of raw materials 	<ul style="list-style-type: none"> — Energy consumption for raw material extraction — Transport energy requirements of raw materials and components 	<ul style="list-style-type: none"> — Toxical waste generated during the acquisition and preparation of raw materials
End product manufacture	<ul style="list-style-type: none"> — Auxiliary materials and substances that are not included in the previous stage 	<ul style="list-style-type: none"> — Energy consumption during the production process 	<ul style="list-style-type: none"> — Toxical waste generated during production — Left-overs
Distribution to customers	<ul style="list-style-type: none"> — Transport packaging, bulk packaging and retail packaging — Type of transportation 	<ul style="list-style-type: none"> — Energy consumption during packaging production and product distribution 	<ul style="list-style-type: none"> — Packaging waste — Emissions from transportation
Product use	<ul style="list-style-type: none"> — Kind and quantity of consumables — Auxiliary materials for repairing operations 	<ul style="list-style-type: none"> — Energy consumption during product use 	<ul style="list-style-type: none"> — Waste from replacement parts and consumables
Product end-of-life	<ul style="list-style-type: none"> — Use of raw materials and auxiliary materials for end-of-life treatments 	<ul style="list-style-type: none"> — Energy consumption during certain end-of-life processes (incineration, recycling, etc.) 	<ul style="list-style-type: none"> — Toxic waste generated by the product — Recycling — Landfill disposition

Figure 10. The MET matrix (matrix 1)

After the first matrix has been filled in, the environmental effects identified should be classified in a second matrix (figure 11) prioritising their environmental importance. Instead of being classified under the life cycle stages,

the environmental effects are classified under the following categories: heavy, medium or light effect (a reasonable level of background knowledge is also required).

	Material Cycle (M)	Energy Consumption (E)	Toxic Emission (T)
Heavy effect			
Medium effect			
Light effect			

Figure 11. The MET matrix (matrix 2)

Source: [5] Brezet H., Van Hemel C. (1997) Ecodesign. A Promising Approach to Sustainable Production and Consumption. Delft University of Technology. United Nations Environmental Programme (UNEP).

This simple method of assessing and prioritising environmental effects can save a substantial amount of time and money, but it is not the optimum method to be used in the environmental evaluation of a product, process or activity.

b) AT&T product improvement matrix and target plot

This 6x6 matrix has been developed by AT&T and covers the entire product life cycle and its environmental aspects. Every cell of the matrix is represented by a value between 0 (bad) and 5 (good). These values are then represented in a plot that allows the identification of areas that need improvement.

c) Eco-indicator 99 methodology

This PRé Consultants abridged LCA tool describes how to perform a simple product life cycle inventory, based on a small database provided in the Manual for Designers. It uses the eco-indicator assessment system for the evaluation stage (free download available at: <http://www.pre.nl>).

d) Telecommunications Abridged Life Cycle Assessment Tool

Manchester Metropolitan University in co-operation with British Telecom has developed this matrix. It is a 5x5 matrix and each cell is complemented with a description of what should be mentioned in it.

e) Ecoscan 3.0

An abridged LCA software tool developed by the department of Sustainable Product Innovation of TNO Industrial Technology (The Netherlands). This simplified tool allows environmental evaluation and comparison of products (further information may be found at: <http://www.ecoscan.nl/>).

3.1.2.2. Quantitative life cycle assessment:

A quantitative life cycle assessment studies the environmental aspects and potential impacts throughout a product, process or activity's entire life cycle (from raw materials acquisition up to product final disposal), thus, the most critical stages, from an environmental point of view, with its respective environmental problems may be identified and the best environmental solution, with the least potential environmental impact through the entire product life cycle, may be chosen. The quantitative life cycle assessment methodology has been especially developed by SETAC (Society of Environmental Toxicology and Chemistry) and is being standardised by the International Organisation for Standardisation, ISO (ISO 14040). The quantitative life cycle assessment methodology is, by no means, the optimum method that can be used in an environmental product, process or activity evaluation, it is also expensive and difficult to do properly.

According with the definition of ISO/DIS 14040, a LCA study consists of the following four main steps (figure 12):

1. Goal Definition and Scoping. Definition of the aim, the boundaries of the system, the target audience, the data requirements and their degree of confidence.
2. Inventory Analysis. The Inventory Analysis identifies and, where possible, quantifies the inputs from the environment and the outputs to the environment of the product system investigated.
3. Impact Assessment. Impact Assessment identifies, characterises and assesses the effects on the environment of the loadings identified in the Inventory Analysis.
4. Interpretation. This is the phase of LCA in which the findings from the inventory analysis and the impact assessment are combined together, in line, with the defined goal and scope. The findings of this interpretation may take the form of conclusions and recommendations to decision-makers.

These four parts are interconnected. The inventory and the impact assessment steps generate information that form the basis for product, process or activity redesign.

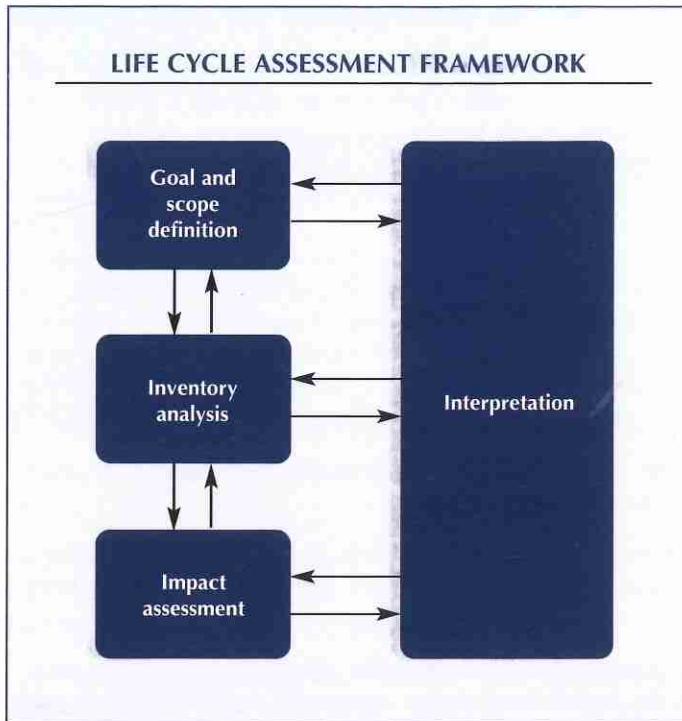


Figure 12. The Life Cycle Assessment (LCA) framework

It should be remembered that life cycle assessment comparisons between products, activities or processes ought to be done between the same functional unit.

In **Annex I** there are listed some ecotools that may be used in a quantitative life cycle assessment.

Some general conclusions extracted from some Life Cycle Assessments (LCAs) studies of electrical and electronic equipments are:

- ♣ The end product manufacture or assembly stage usually has a low contribution to the total equipment environmental impact.
- ♣ The energy consumption during the product use stage has a significant contribution to the total equipment environmental impact.
- ♣ In some cases, the transportation stage has an important contribution to the total equipment environmental impact (it depends on the kind of transportation, distance, product weight, product packaging, etc).
- ♣ The raw material depletion, caused by copper, tin, lead and other metals habitual in electrical and electronic equipment, have an important contribution to the total equipment environmental impact.

- ♣ A great impact is associated with the Integrated Circuits (ICs), made from Silicon, due to their complex production process. Chip manufacture includes mask manufacturing lithography, etch, wet etch, thin films, ionic implantation, chemical/mechanical polishing, cleaning, testing, backside grinding, dicing, picking, etc.
- ♣ The wave soldering process, used in the components assembly process to a printed circuit board (PCB), has an important contribution to the total equipment environmental impact due to its high lead and tin consumption and the use of VOCs in the solder flux.
- ♣ Printed circuit boards have a relevant contribution to the global equipment's environmental impact due to their important contribution to water eutrophication (nutritive elements), their high copper consumption and the etching process' contribution to water toxicity.
- ♣ End electrical and electronic equipment disposal has relevant consequences in the global equipment environmental impact.

3.1.3. Ecodesign guidelines application

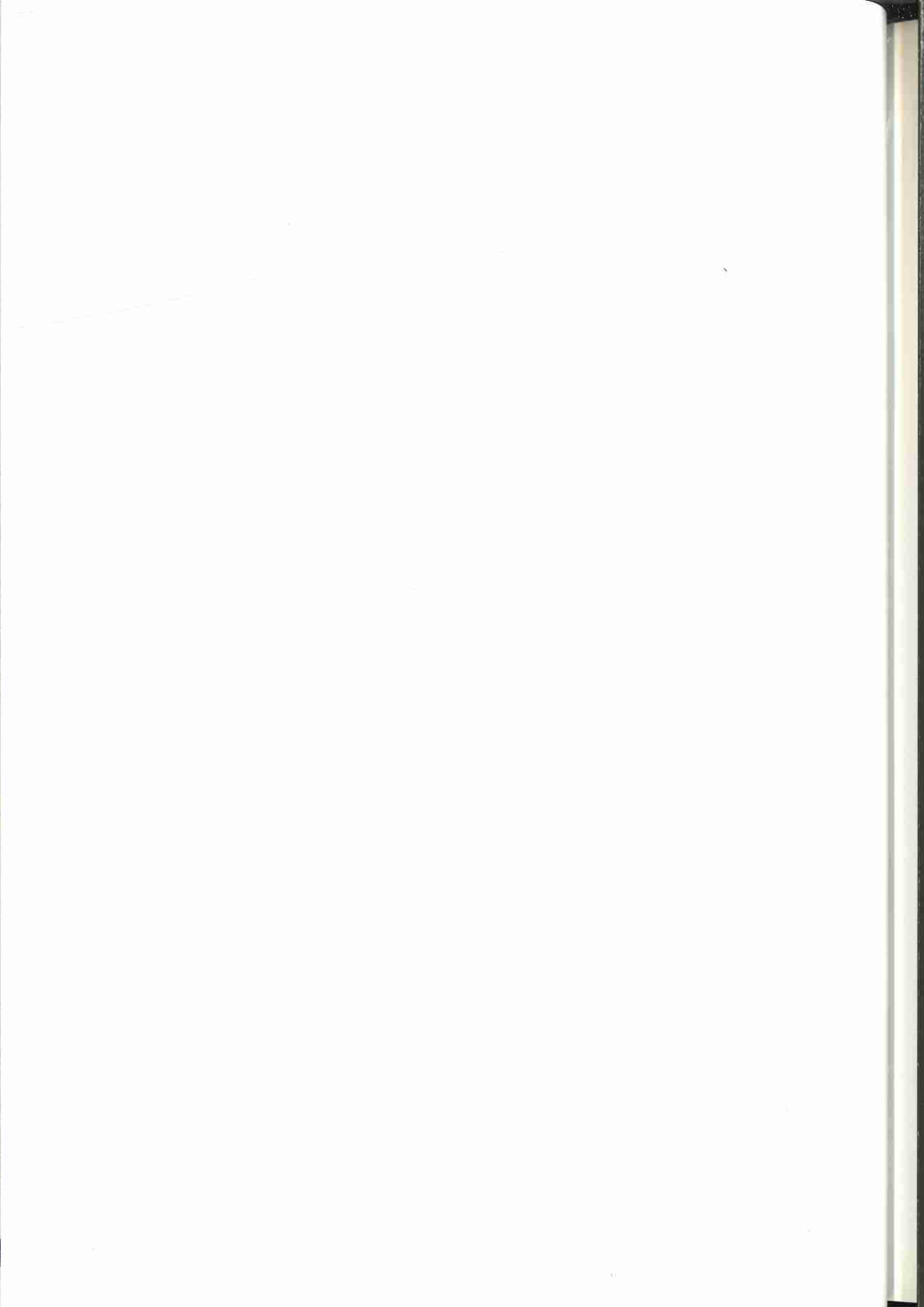
Product designers are particularly well-placed to significantly reduce the global environmental impact caused by a product through its entire life cycle, but it is necessary to inform them about how to improve and how to ensure the environmental quality throughout all the life cycle phases of new products (Ecodesign) or existing ones (Ecoredesign). It is needed to provide them Ecodesign guidelines: this electrical and electronic practical Ecodesign guide provides in the next chapter (Chapter 4) many different ways of improving electrical and electronic equipment environmental performance. It may be used to improve critical aspects detected in product evaluation (life cycle assessment) through the choice of various design alternatives.

This chapter has described how the introduction of the environmental quality in business modifies the classical product development process by the introduction of new concepts and activities (product requirements readjustment, environmental product evaluation and Ecodesign guidelines application). It should also be remembered that the introduction of environmental quality into product development processes is highly influenced by a company's environmental attitude, strategy or policy, in other words, the mixture of what a company can, want and must do in the environmental issue, influenced by competitive, financial and social considerations.

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Practical Ecodesign Guidelines

This electrical and electronic practical ecodesign guide has been written to help electrical and electronic industry to introduce and apply the ecodesign methodology in order to improve the environmental behaviour of produced electrical and electronic equipment during their entire life cycle.

Environmental considerations in electrical and electronic industry are becoming of increasing importance due mainly to legislative pressure (Directive WEEE, Directive ROHS and Directive EEE), cost savings and emerging green markets. The ecodesign methodology allows the introduction of environmental quality into industry in an effective way: minimising environmental harmful effects of electrical and electronic equipment during their entire life cycle at the same time that important cost savings and profits are generated.

As it has been described in Chapter 3, the introduction of the environmental quality into electrical and electronic equipment require a qualitative or quantitative environmental evaluation covering the equipment's entire life cycle, with the aim of obtaining objective information about the environmentally most critical stages and their respective environmental problems.

The next step is to select and apply those design instructions that allow a quantitative improvement of the equipment's environmental behaviour, especially focused on the most critical stages detected in the evaluation performed. This way, the optimum overall environmental design strategy with the least potential impact through the equipment's entire life cycle can be chosen. Obviously, in the implementation of any improvement, it is needed to find the right balance between ecological and economic requirements as well as other product properties. This can lead to several dilemmas during the equipment design process due to opposing design interests that may be encountered. Therefore, it is highly recommended to have a holistic view and implement those instructions that permits the best overall environmental behaviour of the equipment.

Product designers and product developers are particularly well placed to considerably reduce the global environmental impact caused by a product, process or activity through its entire life cycle, but it is needed to provide them with ecodesign guidelines.

In this chapter, the backbone of this book, there are provided many different ways (ecodesign guidelines) of improving the environmental performance of existing electrical and electronic products and assuring a proper environmental behaviour of

new ones, through the choice of several environmentally sound strategies, techniques, materials and other design considerations, all of them classified in the corresponding product life cycle stage:

1. Production and supply of materials and components
2. End product manufacture
3. Product distribution to customers
4. Product use
5. Product end-of-life

This guide is mainly intended for those who are active or interested in electrical and electronic product design and product development and for those responsible for developing environmental issue into electrical and electronic companies, so the primary audience is thus: product managers, product developers, product designers, process design engineers, packaging designers and environmental managers. Nevertheless, this guide also contains useful information for marketing managers, purchasing managers, distribution managers, customers, suppliers, etc.

This guide also provides general ecodesign guidelines applicable in other industrial sectors.

4.1. PRODUCTION AND SUPPLY OF MATERIALS AND COMPONENTS

The environmental impacts related to an electrical and electronic industry's chain supply, should not be obviated due to their importance and contribution to the overall environmental behaviour of an electrical and electronic equipment's entire life cycle. Environmental considerations should be incorporated into purchasing decisions (Supply Chain Management approach, SCM).

The following guidelines focus on the type of materials and components purchased and used in a conventional electrical and electronic equipment, with the aim of selecting less materials with a lower environmental impact associated. The ecodesign guidelines presented are particularly focused on selecting less materials, cleaner materials, renewable materials, low energy-intensive materials, recycled materials and fewer parts and components with lower material content.

Guideline	Reason	Comments
1.- Consider environmental criteria in suppliers selection.	Improve the environmental behaviour of your product by selecting more environmentally sound materials and components.	It is highly recommended that the purchasing department selects suppliers according to environmental criteria in addition to other conventional considerations. Ask them to provide environmental data on materials and components that are going to be supplied. It is very useful to issue an environmental questionnaire to them.
2.- Work preferably with proximate suppliers in order to avoid long-distance transport.	Reduce emissions released during transport.	It is recommended that the purchasing department selects suppliers according to proximity criteria in addition to other environmental criteria and other conventional considerations. This will result in a substantial reduction of the equipment's environmental impact through lower emissions released during transport.
3.- Reduce the number of components and parts used in the equipment.	Reduce material and energy consumption and waste generation.	It is possible to reduce the number of materials and components used, for example: by integrating more functions on silicon (Integrated Circuits), integrating more functions in other components and parts, decoupling capacitors, etc. With fewer components and parts, obviously, less material and energy consumption is required and also less waste will be generated.
4.- Select small components and parts.	Reduce material and energy consumption and waste generation.	Small components and parts need less material and energy consumption during their manufacture process, consequently, less waste will be generated.
5.- Select surface-mounted components rather than their hole-mounted homologous.	Reduce material and energy consumption and waste generation.	Surface-mounted components are often smaller than their hole-mounted homologous, consequently, they need less material and energy consumption during manufacture process and less waste will be generated.
6.- Avoid the use of Printed Circuit Boards (PCBs) with thick copper films.	Reduce material and energy consumption and waste generation.	Metals need a high quantity of energy for being obtained and processed. Try to use Printed Circuit Boards (PCBs) with thinner copper films if they fulfil all the equipment specifications. This way, less material and energy consumption is required during their manufacture process, consequently, less waste will be generated.
7.- Reduce the amount of material used in plastic walls.	Reduce material and energy consumption and waste generation.	Plastic walls (in plastic cases, parts, components, etc.) with a minor amount of material results in substantial savings of material and energy consumption during their manufacture process and also less waste is generated. It is highly recommended to select thinner plastic walls in accordance with realistic requirements for stiffness, strength, toughness, warpage, etc.

Guideline	Reason	Comments
8.- Select materials and components made of recycled materials.	Use fewer resources and generate less waste.	Using recycled materials results in substantial savings of natural resources, energy consumption and also less waste generation. Try to select materials and components made of recycled materials if they are available, are economically sound and fulfil all the equipment specifications. If they can not be used, try to select those made of a combination of virgin and recycled material. It should be remembered that primary, secondary and tertiary recycled materials are available (see figure 13). Obviously, from an environmental and economical perspective, primary recycling is preferred over secondary and tertiary, and secondary over tertiary. In order to facilitate stable markets for recycled materials, it is highly recommended to select and use them as much as possible. Obviously, when using recycled material equipment's safety and performance requirements should not be put at risk. In order to verify an admissible quality of the recycled material that is going to be used, ask the supplier for information and/or send a sample to an analytical lab.
9.- Select recyclable materials.	Use fewer resources and generate less waste.	If recycled materials can not be used, use materials and components made of a virgin material with a well established recovery and recycling system (aluminium, unmixed thermoplastics, etc.).
10.- Select secondary metals rather than their virgin equivalents.	Use fewer resources and generate less waste.	Using secondary metals results in substantial savings of natural resources, energy consumption and also less waste generation. For example, secondary aluminium, copper, etc. can be used instead of their virgin equivalents.
11.- Use recycled plastics rather than their virgin homologous.	Use fewer resources and generate less waste.	Using recycled plastics results in substantial savings of natural resources, energy consumption and also generates less waste. Recycled plastics, in some cases, are not totally appropriate for appearance parts because of colour-matching issues, but they are excellent for interior or non-appearance applications, especially for supportive functions: partitions, card guides, frames middle layers of multi-layers parts, etc. In these cases they do not require a high mechanical, hygienic or tolerance quality.
12.- Try to minimise the use of scarce non-renewable resources.	Preserve scarce non-renewable resources.	Some consequences of extracting scarce non-renewable resources can be severe, for example: copper, etc. may become extinct. It is also highly recommended that these valuable non-renewable materials have a well established recovery and recycling system.

The Recycling Cascade

There are several levels of recycling:

Primary Recycling or Reuse (for original application)



Secondary Recycling (for a lower grade of application)



Tertiary Recycling or Feedstock Recycling (for material decomposition into elementary raw materials)

Primary Recycling is preferred, of an environmental and economical perspective, over Secondary and Tertiary. Obviously, Secondary Recycling is preferred over Tertiary.

Figure 13. The recycling cascade

Substances that should be avoided in Electrical and Electronic Equipment no later than 1 January 2007

Directive of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment (ROHS)

"Lead, mercury, cadmium, hexavalent chromium, PBB and PBDEs should be substituted on 1 January 2007". This article shall apply to electrical and electronic equipment falling under the categories set out in Annex I A to Directive WEEE (figures 30 and 31) and to electric light bulbs, lighting for living areas and compact fluorescent lamps. It shall not apply to electrical and electronic equipment falling under categories 8 and 9 of Annex I A to Directive WEEE (figures 30 and 31), to spare parts and consumables for, and for the repair of, equipment placed on the market before 1 January 2007.

The applications of lead, mercury, cadmium and hexavalent chromium listed hereafter (Annex of the Directive ROHS) are exempted from this requirement:

- Mercury in compact fluorescent lamps not exceeding 5 mg per lamp.
- Mercury in straight fluorescent lamps not exceeding 10 mg per lamp.
- Mercury in lamps not specifically mentioned in this Annex.
- Lead in glass of cathode ray tubes, light bulbs and fluorescent tubes.
- Lead as an alloying element in steel containing up to 0.3% lead by weight, aluminium containing up to 0.4% lead by weight and as a copper alloy containing up to 4% lead by weight.
- Lead in electronic ceramic parts.
- Lead contained in high melting temperature type solder.
- Lead in glass in electronic components.
- Lead in piezoelectric devices.
- Lead in servers, storage and storage array systems, voice and data transmission and networking equipment.
- Cadmium passivation as an anti-corrosion in specific applications.
- Hexavalent chromium as an anti-corrosion of the carbon steel cooling system in absorption refrigerators.

Figure 14. Substances that should be avoided in electrical and electronic equipment (Directive ROHS)

Guideline	Reason	Comments
13.- Prefer abundant non-renewable materials rather than scarce non-renewable ones.	Preserve scarce non-renewable resources.	Scarce non-renewable resources can be preserved by using more abundant non-renewable ones. For example, aluminium is more abundant than copper, despite of being much more energy-intensive.
14.- Avoid energy-intensive materials.	Reduce energy consumption.	Some materials need a high quantity of energy for being obtained and processed. Their use should be avoided or minimised unless any environmental reason justifies it. For example: aluminium is an energy-intensive material and its use can be environmentally justified in a product that is often transported, in a product with a long lifetime, etc. It is also highly recommended that these valuable (energy-intensive) materials have a well established recovery and recycling system.
15.- Try to use plastic fasteners of the same plastic as the parts they are joining, or which are compatible for recycling, rather than metal fasteners.	Reduce energy consumption.	Generally, metals need higher quantities of energy for being obtained and processed than plastics. Try to use plastic fasteners of the same plastic as the parts they are joining, or which are compatible for recycling. Irrespective of how the energy is generated it is an extra adverse environmental effect.
16.- Use few different materials.	Improve from an environmental and economical perspective the equipment behaviour.	Minimising the selection of different materials used can reduce production costs through economies of scale. In this way, with a smaller amount of materials used, it will be easier to assess their environmental impact.
17.- Ask suppliers for information about the content of restricted, toxic or hazardous substances in materials, parts and components supplied.	Reduce the use of health and environment hazards.	Since materials and components containing restricted, toxic or hazardous substances, which could have an adverse environmental or health impact at any stage of the equipment lifetime, are not usually marked today, it is highly recommended to ask suppliers for information about their content.
18.- Avoid materials and components containing restricted, toxic or hazardous substances which could have an adverse environmental or health impact at any stage of the equipment's life.	Reduce the use of health and environment hazards.	Avoid materials and components that contain health and environment hazards or that are suspected of having. In accordance with the Directive ROHS the use of some substances will be phased out by no later than 1 January of 2007 (see figures 14, 15 and 16).

Guideline	Reason	Comments
19.- Avoid using plastic additives formulated with hazardous, toxic or restricted materials.	Reduce the use of health and environment hazards.	Plastic additives (colorants, fire retardants, stabilisers, plasticizers, or reinforcement materials and fillers) formulated with hazardous, toxic or restricted materials should be avoided. It is highly recommended to check the Material Safety Data Sheets (MSDS) which will provide toxicological data and regulatory classification information for a particular material.
20.- Do not use components that contain halogenated (brominated and chlorinated) flame retardants.	Reduce the use of health and environment hazards.	Halogenated (brominated and chlorinated) flame retardants can form dioxins and furans if burned under uncontrolled conditions (in landfill fires, etc.). Some of them are health and environment hazards (PBB and PBDEs) or suspected of being (TBBA). In accordance with ROHS Directive the use of PBB and PBDEs will be phased out by no later than 1 January of 2007 (see figure 14 and 16).
21.- Do not use Printed Circuit Boards (PCBs) that contain halogenated (brominated and chlorinated) flame retardants	Reduce the use of health and environment hazards.	Usually, Printed Circuit Boards (PCBs) contain halogenated flame retardants (especially TBBA, which is suspected of being a health and environment hazard). Today PCBs are available in the market without halogenated flame retardants (with nitrogen and phosphor-based flame retardants, for example: FR-N, G-10 etc.). In accordance with the ROHS Directive the use of PBB and PBDEs will be phased out by no later than 1 January of 2007 (see figure 16 and 17).
22.- Do not use components containing cadmium, hexavalent chromium or mercury.	Reduce the use of health and environment hazards.	Cadmium, hexavalent chromium and mercury are health and environment hazards. In accordance with the ROHS Directive the use of cadmium, hexavalent chromium and mercury will be phased out by no later than 1 January of 2007 (exempt of accomplishment are the cases listed in the Annex of the ROHS Directive (see figure 14)).
23.- Do not use Printed Circuit Boards (PCBs) that contain paper-phenolic resins.	Reduce the use of health and environment hazards.	Usually, paper-phenolic resins contain a polybrominated diphenyl ether (PBDE) flame retardant: penta-BDE, which is a health and environment hazard. In accordance with the ROHS Directive the use of PBB and PBDEs (included penta-BDE) will be phased out by no later than 1 January of 2007 (see figures 14 and 16).

List of some hazardous materials and chemical substances that should be avoided in the automotive and electrical and electronic industry (figure 15):

SUBSTANCE	CAS NUMBER	RISK	USES
Aromatic amine (p.e. Biphenyl amine)	several	T	Several
Asbestos	several	C	Insulation material
Bis (2 chloromethyl) ether	542-88-1	C, T	Intermediate for ionic-change resins
Brominated Flame retardants	several	E	In textiles/ In plastics
Cadmium	7440-43-9	T,C	Pigment*/ Surface treatments*/ plastic stabilizers*/soldering/electric contacts.
Carbon tetrachloride	56-23-5	T, E	Solvent/ Cooling/ In semiconducting / Metals degreasing
CFC's (chlorofluorocarbons)	several	O	Cooling agent
1,1,2,2 -Tetrachloroethane	79-34-6	T	Solvent
1,1,1,2-Tetrachloroethane	630-20-6	T	Solvent
Chlorinated paraffins	several	E	Fire retardant/Lubricants/ Plastifizer
Chromium (VI)	7447-40-3	E, A, T, C	Surface treatment/ Alloy
DBBT (Methyl Dibromodiphenal methane)	99688-47-8		In hydraulic liquids
1,2 - Dichloroethane	107-06-2	T,C	Additive in fuel / Solvent
1,1 - Dichloroethylene	75-35-4		
Ethylene Glycol	107-21-1	T	In foams/ Adhesives / Electronics/ Cooling/ Antifreeze
2 Ethoxyethanol	110-80-5	R, T	Solvent
2 Ethoxyethanol Acetate	111-15-9	R, T	Solvent/ Oils/ Resins
2 Methoxyethanol	109-86-4	R, T	Solvent/ Dye
2 Methoxyethanol Acetate	110-49-6	R, T	Solvent
HCFC (Hydrochlorofluorocarbons)	several	O	Cooling agent
HFC (Hydrofluorocarbons)	several		
HBFC (Hydrobromofluorocarbons)	several	O	Fire retardants
Hexachloro 1,3-Butadiene	87-68-3	E, T	Solvent/ In hydraulic fluids
Lead	7439-92-1	T	Battery/ Paint/ Soldering
Lead bicarbonate	1319-46-6	T	In paints*
Lead carbonate	598-63-0	T	In paints*
Lead sulphate	744-14-2	T	In paints*
Lead chromate	7558-97-6	T, E, R	In paints*
Limonene	5989-27-5/138-86-3	A, E	Solvent
MDA (4,4' Methylene Diamiline)	101-77-9	C	Hardener/ In paints
Mercury	7439-97-6	N, E	In electric equipments
Methane dichloride	75-09-2	C	Solvent/ For plastics and foams

SUBSTANCE	CAS NUMBER	RISK	USES
Methylbromide	74-83-9	T, O	Solvent
Methyl Ethyl Ketone	78-93-3	T	Solvent/ Cleaning agent
n-Hexane	110-54-3	N	Solvent
n-Phenyl-2-Naphtalamine	135-88-6	C	Antioxidant/ Lubricant
Nitrosoamines	several	T, E	Several
Nitrosoamides	several	T, E	Several
4 - Nonyphenol	several + 104-40-5	E	Tenside/ As etoxylate
Nonyphenol etoxylates	9016-45-9		In paints and adhesives/ Binding agent/ Cleaning agent
o-Toluene	108-88-3	T	Solvents/ In PU resins
Organic Tin	several + 56-35-9	E, T	Water treatment*/ Antifouling paints*/ Coatings/ Additives in paints/ Stabilizers
PAH's (Polyaromatic Hydrocarbons)	50-32-8 + several	C	In lubricants and oils
PBB (Polybrominated Biphenyls)	several	E, N, C	Flame retardant in plastics
PBDE (Polybrominated diphenylethers)	several	E	Flame retardant in plastics
PCB (Polychlorinated Biphenyls)	several	E	Insulators/ Oils
PCP (Pentachlorophenol)	87-86-5	E	Fungicide/ alguicide/Bactericide
PCT (Polychlorinate Terphenyls)	several	E	Insulation oil/ Lubrication oil/ Machining oil
Di-N-Octyl (DOP)	117-84-0	T	Plastifier/Softener
Diethyl Hexyl (DEHP)	117-81-7	T	Softener
Tetrachloroethylene	127-18-4	C	Solvent
Thiocarbamide	62-56-6	C	In rubbers and plastics/ In amino resins/ Dyes
Thiram	137-26-8	T	Biocide/ Additive for lubricant oils
1,1,1-Trichloroethane	71-55-6	O	Solvent
1,1,2-Trichloroethane	79-00-5	I	Solvent
Trichloroethylene	79-01-6	C	Solvent/ Desengrase
Tris (azinidinyl) Phosphinoxide	545-55-1	T	Flame retardant/ In textiles*
Tris (2,3-dibromopropyl) Phosphate	126-72-7	C	Flame retardant/ In textiles*
Ugilec 121 (Methyl Dichlorodeiphenalmetane)			In dielectric liquids
Ugilec 141	76253-60-6		In dielectric liquids
Vinyl Chloride	75-01-4	T, C	Propellant gas *

Figure 15. List of some hazardous materials and chemical substances that should be avoided in the automotive and electrical and electronic industry.

Guideline	Reason	Comments
24.- Do not use plastics that contain halogenated (brominated and chlorinated) flame retardants.	Reduce the use of health and environment hazards.	Halogenated (brominated and chlorinated) flame retardants can form dioxins and furans if burned under uncontrolled conditions (in landfill fires, etc.). Some of them are health and environment hazards (PBB and PBDEs) or suspected of being (TBBA). Some constructional plastics are available which do not contain halogenated flame retardants: PC-ABS (without antimony, chlorine or bromine additives), PPOSP (phosphorous-based), etc. (see figure 16).
25.- Do not use cables and wires that contain chlorinated or brominated flame retardants or phthalates.	Reduce the use of health and environment hazards.	The great majority of brominated or chlorinated additives and phthalates used in cables and wires are health and environment hazards or suspected of being. For example, Polyvinylchloride (PVC) is often used in cables and wires together with chlorinated paraffin and/or phthalates. This type of cables should be avoided. In accordance with the ROHS Directive the use of PBB and PBDEs (brominated flame retardants) will be phased out by no later than 1 January of 2007 (see figure 14 and 16).
26.- If it is not possible to avoid the use of halogenated (brominated and chlorinated) flame retardants select reactive flame retardants rather than additive.	Reduce the use of health and environment hazards.	Reactive flame retardants form chemical compounds with the plastic whereas additive flame retardants are only mixed with plastic. Consequently, reactive halogenated flame retardants are closely linked to plastics and present more difficulties of being released. However, should be remembered that in accordance with the ROHS Directive the use of PBB and PBDEs (brominated flame retardants) will be phased out by no later than 1 January of 2007 (see figures 14 and 16).
27.- Select materials and components manufactured using environmentally sound processes.	Select materials and components manufactured with environmentally sound processes.	Avoid materials and components manufactured using non-environmentally sound processes and/or substances, for example: using ozone depletion substances, etc.
28.- Reduce the use of materials and components with metallic coatings.	Select materials and components manufactured with environmentally sound processes.	Materials and components containing the following non-ferrous metals: copper, zinc, brass, chromium and nickel, should be minimised, due to the harmful emissions associated with their production process. Metallic conductive coatings, including EMI and RFI shielding, contribute substantially to generate chemical waste and air and water emissions. The use of materials and components with metallic coatings should be minimised whenever feasible.

The commonly **brominated flame retardants** used:

- ♣ Brominated Diphenyl Ethers (BDE)
- ♣ Polybrominated Diphenyl Ethers (PBDE)
- ♣ Polybrominated Biphenils (PBB)
- ♣ Tetrabromobisphenol A (TBBA or TBBPA).

Figure 16. Commonly brominated flame retardants

The commonly **Printed Circuit Boards (PCBs)** used:

Epoxide Woven Glass Fibre Copper Clad (FR4)
 Phenolic Cellulose Paper Copper Clad (FR2)
 Epoxide Cellulose Paper Copper Clad (FR3)
 Composite – Epoxide Paper Core Epoxide Glass Outer Layers (CEM1)
 Woven Glass Filaments and PTFE Resin Copper Clad
 Non-woven Glass and PTFE Resin Copper Clad

Figure 17. Commonly Printed Circuit Boards (PCBs)

4.2. END PRODUCT MANUFACTURE

The following guidelines set out measures that aim at the environmental improvement of the overall end equipment's manufacture process. The following environmental strategies are focused on selecting more environmentally sound processes and techniques including low material and energy consumption and low waste generation.

These design strategies may be used to reduce the amount of material used in plastic walls without compromising strength, stiffness, toughness, warpage, etc.:

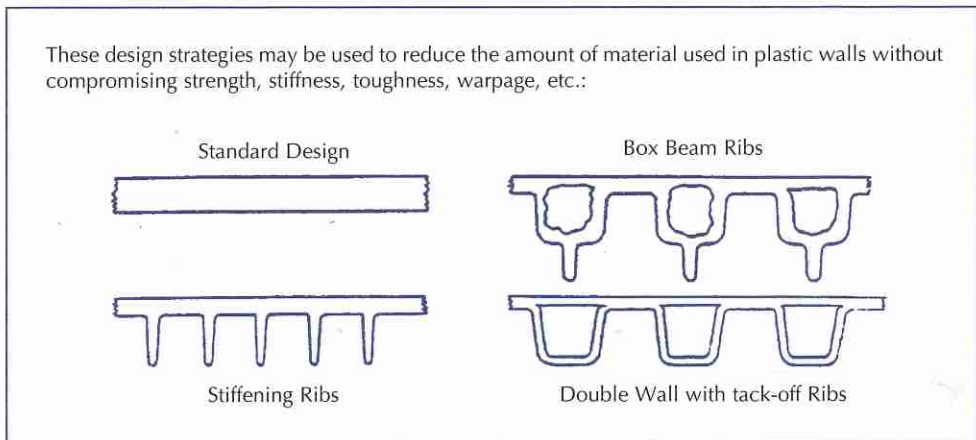


Figure 18. Design strategies for thinning plastic walls
 (Source: American Plastics Council)

Guideline	Reason	Comments
29.- Reduce the amount of material used in plastic walls.	Reduce material and energy consumption.	Thinning plastic walls, in accordance with realistic requirements for stiffness, strength, toughness, warpage, etc, is an effective way of reducing material and energy consumption and generate less waste during the manufacture process, but it should kept in mind that over-thinning plastic walls could compromise those product properties mentioned before. Thin walls may be reinforced through narrow ribs (a larger number of narrow ribs is preferable to a smaller number of large and heavy ribs), bosses for reinforcing holes or for mounting an assembly, gussets, etc. Some design strategies can also be used to reduce the amount of material used in plastic walls without compromising other product properties (see figure 18).
30.- Select interconnection technologies that require low material consumption.	Reduce material and energy consumption.	The majority of electrical and electronic components and parts are connected to a Printed Circuit Board (PCB). Different technologies are available to do this, each of them with different interconnection material requirements and with different PCB area requirements. Through Hole Mounting (THM) is the interconnection technology with the highest material consumption and highest PCB area requirements associated. THM allows the connection of only a small quantity of components on the opposite side of a PCB. Other alternative mounting technologies: SMT, TAB, Wire bonding, Flip-Tab and Flip-Chip, have low interconnection material requirements and none of them require a PCB area significantly greater than the size of the component to be connected (see figure 19 and 20).
31.- Maximise the equipment density.	Reduce material and energy consumption.	By maximising the equipment density, wasted space may be substantially reduced and this will result in a reduction of the use of primary materials (in PCBs, plastic cases, etc.) as well as a reduction of the energy associated for being processed. Consequently, less waste will be generated. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
32.- Minimise the number of components and parts used.	Reduce material and energy consumption.	It is possible to reduce the number of components and parts used by integrating more functions on silicon (Integrated Circuits), integrating more functions in other components and parts, decoupling capacitors, etc. With fewer components and parts, obviously, the Printed Circuit Board (PCB) area requirement is reduced and, consequently, the size of the plastic case, etc, are also reduced. This will result in a reduction of primary materials usage and the energy associated for them being processed. Less waste will also be generated. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.

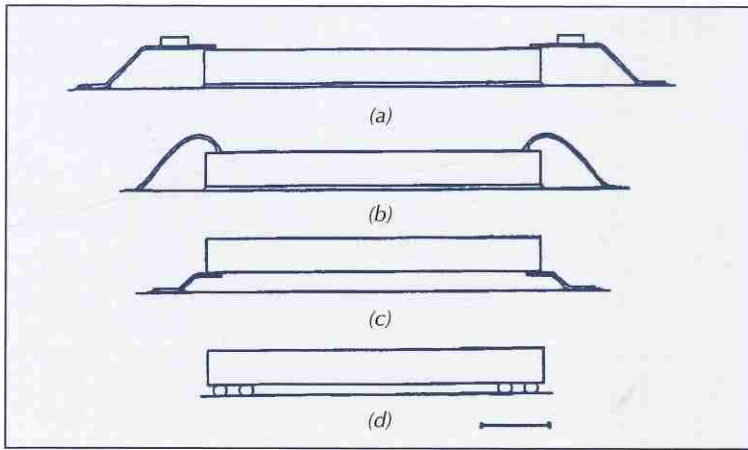


Figure 19. Interconnection technologies: a) TAB b) Wire bonding c) Flip-Tab and d) Flip-Chip
 (Source: The Swedish Institute of Production Engineering Research - IVF)

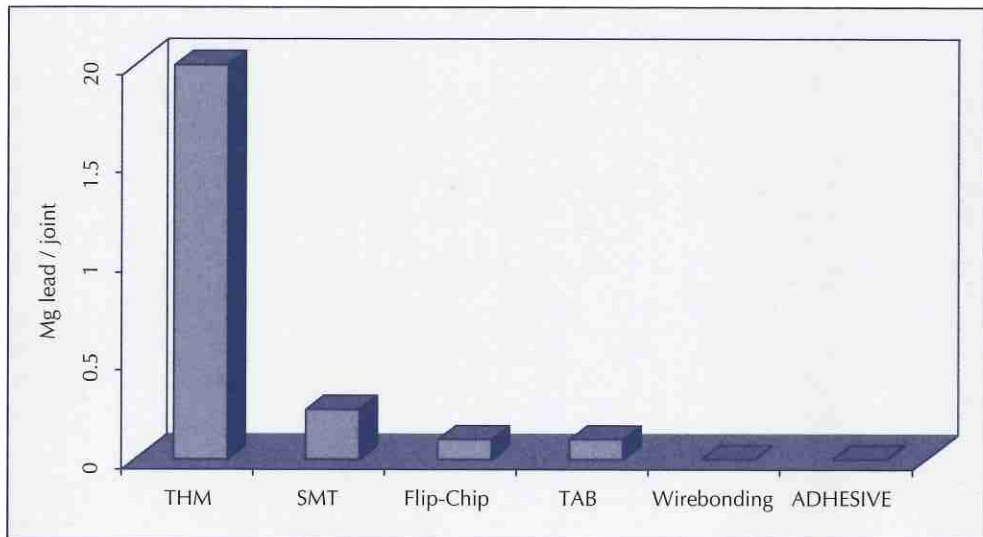


Figure 20. Material consumption of different interconnection technologies
 (Source: The Swedish Institute of Production Engineering Research - IVF)

Guideline	Reason	Comments
33.- Select small components and parts.	Reduce material and energy consumption.	If small components and parts are used, they can be positioned more closely on a Printed Circuit Board (PCB). Consequently, PCB area requirements, the size of the plastic case, etc, could be substantially reduced. This will result in a reduction of primary materials usage and the energy associated for them being processed. Less waste will also be generated. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
34.- Mount components on both sides of the Printed Circuit Board (PCB).	Reduce material and energy consumption.	Mounting electrical and electronic components and parts on both sides of a Printed Circuit Board (PCB) results in a substantial reduction of its area requirements (approximately 1/2). Consequently, less material and energy is required and also less waste will be generated. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
35.- Select surface-mounted components rather than their hole-mounted homologous.	Reduce material and energy consumption.	Surface-mounted components are often smaller than their hole-mounted homologous. Thus, they can be positioned more closely on a Printed Circuit Board (PCB). Consequently, PCB area requirements are reduced, less material and energy is required and also less waste will be generated. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
36.- Reduce the amount of copper used in Printed Circuit Boards (PCBs).	Reduce material and energy consumption and waste generation.	Metals need high quantities of energy for being obtained and processed. Try to manufacture Printed Circuit Boards (PCBs) with thinner copper films if they fulfil all the equipment specifications. This way, less material and energy consumption is required and also less waste will be generated.
37.- Reduce the energy used in the production process.	Reduce energy consumption.	Since the amount of energy consumed during the manufacture process can have a significant contribution to the overall equipment's environmental impact, it is important to consider how this amount of energy can be substantially reduced. Some general principles can be followed to save energy consumption during the manufacture process: purchase low power-consumption machines or with an automatic power-down feature that automatically switches the machines down to a standby state when they are not being actively used, turn off the plant in any idle periods, optimise the use and consumption of refrigeration equipment, etc. Irrespective of how the electricity is generated it is an extra adverse environmental effect.
38.- Use renewable energy sources in some processes or activities.	Use more environmentally sound sources of energy.	The environmental behaviour of the overall end product manufacture process may be substantially improved through the use, in some processes or activities, of energy from renewable sources, for example: solar energy for heating water, solar light for illumination, etc.

Guideline	Reason	Comments
39.- Minimise the amount of copper removed from Printed Circuit Boards (PCBs).	Reduce waste generation.	By reducing the amount of copper removed from Printed Circuit Boards (PCBs), during the etching process, the amount of waste generated and its impact associated can be substantially reduced. This will additionally result in a extension of the etchant lifetime.
40.- Recover valuable materials from production scrapped Printed Circuit Boards (PCBs) and other valuable production scrapped materials and components.	Reduce waste generation.	The overall environmental and economical behaviour of the end product manufacture process can be substantially improved by recovering copper, gold and other valuable metals in scrapped Printed Circuit Boards (PCBs) and other valuable scrapped materials and components.
41.- Recycle all the waste of the chemical processes implicate in the end product manufacture processes.	Reduce waste generation.	Waste produced during etching, plating and other chemical processes implicated in the end product manufacture process should be recycled, whenever feasible, in order to improve the overall equipment's environmental behaviour. It is highly recommended to perform in-house recycling strategies in order to recover chemical substances (metals, solvents, etc.).
42.- Improve the overall behaviour of the end product manufacture process.	Reduce the environmental impact associated to the end product's manufacture process.	The overall environmental behaviour of the end product manufacture process may be substantially improved by reducing the emissions of the cleaning and soldering plant. This can be achieved through good plants, sound work practices, sound good processes and in-house-recycling whenever feasible.
43.- Select solders that do not require clean fluxes.	Reduce the environmental impact associated to the end product's manufacture process.	The number of processes required during the product manufacture can be reduced by using a solder that does not require clean fluxes. In this way, all the environmental impacts associated to this process can be totally eliminated. If cleaning can not be avoided, it is highly recommended to select an environmentally sound method, for example: aqueous and/or ultrasonic agitation (remember that if the board should be dried, this process will require energy for being performed). In all cases, any non-environmentally sound clean solvent should be avoided, for example: HCFCs hydrochlorofluorocarbons (ozone-damaging solvents), HFCs hydrofluorocarbons and HFEs hydrofluoroethers (solvents that contribute to global warming), etc.

Guideline	Reason	Comments
44.- Improve from an environmental perspective the soldering process.	Reduce the environmental impact associated to the end product's manufacture process.	Try to minimise emissions from the soldering plant, for example caused by ethanol + propanol solder flux, which contributes to photochemical ozone creation. This can be achieved by using fluxes without Volatile Organic Compounds (VOCs) or by using low activation fluxes in conjunction with nitrogen inerting.
45.- Use reflow soldering process rather than wave soldering process.	Reduce the environmental impact associated to the end product's manufacture process.	Reflow soldering processes have less environmental impact associated than wave soldering processes, due to their lower flux use.
46.- Select interconnection technologies that do not require lead (Pb) consumption.	Reduce the environmental impact associated to the end product's manufacture process.	Lead is a heavy metal that is considered a health and environment hazard. Lead-Tin compound is usually used for soldering electrical and electronic components and parts to Printed Circuit Boards (PCB). Lead requirements depend on the interconnection technology selected. Hereafter, they are presented in declining order of lead consumption: THM, SMT, Flip-chip and TAB (see figures 19 and 20). Few interconnection technologies are available that avoid the use of lead entirely, two examples are: Wire Bonding and Electrically Conducting Adhesive. In accordance with the ROHS Directive the use of Lead in soldering will be phased out by no later than 1 January of 2007 (see figure 14). Tin-Silver compound can be an alternative used in THM, SMT, Flip-Chip and TAB technologies.
47.- If a decorative appearance of plastic parts is needed, select an environmentally sound option.	Reduce the environmental impact associated to the end product's manufacture process.	Coatings and finishes in plastic parts contribute to increase waste generation and air and water emissions (solvent-based paints, etc.) and they also make more difficult and more expensive the recycling process in the equipment's end-of-life. Some more environmentally sound options of improving plastic parts appearance are here presented, first choices are: use of low-gloss and textured plastic surfaces, integral finishes, use of water-based paint rather than solvent-based, etc.
48.- Avoid surface treatment techniques with a high environmental impact associated.	Reduce the environmental impact associated to the end product's manufacture process.	Try to avoid the following surface treatment techniques: hot-dip galvanisation, electrolytic zinc plating and electrolytic chromium plating, etc, due to their high environmental impact associated.

4.3. PRODUCT DISTRIBUTION TO CUSTOMERS

The distribution system of electrical and electronic equipment should be performed in an efficient manner, this will result in an environmental and economical improvement of the product behaviour in this stage. The key factors are: transport distances, mode of transport, equipment and its packaging weight and volume, and type of packaging material used.



Guideline	Reason	Comments
49.- Consider environmental criteria in your packaging suppliers selection.	Improve the environmental behaviour of the product by selecting an environmentally sound packaging.	It is highly recommended that the purchasing department selects packaging suppliers according to environmental criteria in addition to other conventional considerations. Ask them to provide environmental data on packaging that is going to be supplied. It is also very useful to issue an environmental questionnaire to them.
50.- Work preferably with proximate packaging suppliers in order to avoid long-distance transports.	Reduce energy consumption and emissions released during transport.	It is recommended that the purchasing department select packaging suppliers according to proximity criteria in addition to other environmental criteria and other conventional considerations. This will result in a substantial reduction of the product environmental impact through lower energy consumption and lower emissions released during transport.
51.- Introduce more efficient forms of distribution.	Reduce energy consumption and emissions released during transport.	It is recommended that the sales department considers efficient forms of distribution: for example, simultaneous distribution of different products, efficient routes, organisation, etc. This will result in a substantial reduction of the product environmental impact through lower energy consumption and lower emissions released during transport.
52.- Select more environmentally sound transport methods.	Reduce energy consumption and emissions released during transport.	The sales department should consider environmentally sound transport methods. The following considerations should be kept in mind during the selection of the transport method to be used: generally, the environmental impact associated to transport by ship or train is less than the associated to transport by lorry. Since the environmental impact associated to transport by air is too high, this method should be avoided whenever feasible.
53.- Maximise loading by transporting the product in separate parts that can be nested.	Maximise loading and reduce energy consumption and emissions released during transport.	Transporting products in separate parts, which can be nested, is an efficient way of maximising loading. Final product assembly can be done by a third party or by the end customer. This will result in a substantial reduction of the product environmental impact through lower energy consumption and a reduction of emissions released during transport.
54.- Maximise the equipment density.	Maximise loading and reduce energy consumption and emissions released during transport.	By maximising the equipment density, wasted spaces are reduced and this will reduce the overall equipment weight and volume. This will contribute considerably in the loading maximisation and, consequently, this will result in a substantial reduction of the product environmental impact through lower energy consumption and a reduction of emissions released during transport. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.

Guideline	Reason	Comments
55.- Mount components on both sides of the Printed Circuit Board (PCB).	Maximise loading and reduce energy consumption and emissions released during transport.	By mounting electrical and electronic components on both sides of Printed Circuit Boards (PCB) the equipment weight and volume can be substantially reduced. This will contribute in loading maximisation. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
56.- Select small and light components and parts.	Maximise loading and reduce energy consumption and emissions released during transport.	If small and light components and parts are used they can be positioned more closely and consequently the equipment weight and volume can be substantially reduced. This will contribute in loading maximisation. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
57.- Select surface-mounted components rather than their hole-mounted homologous.	Maximise loading and reduce energy consumption and emissions released during transport.	Surface-mounted components are often smaller than their hole-mounted homologous and also have less Printed Circuit Board (PCB) area requirements. Consequently, they can be positioned more closely and the equipment weight and volume can be substantially reduced. This will contribute in loading maximisation. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
58.- Reduce the number of materials and components.	Maximise loading and reduce energy consumption and emissions released during transport.	It is possible to reduce the number of materials and components used, for example: by integrating more functions on silicon (Integrated Circuits), integrating more functions in other components and parts, decoupling capacitors, etc. With fewer components and parts, obviously, the equipment weight and volume can be substantially reduced. This will contribute in loading maximisation. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
59.- Avoid the use of Printed Circuit Boards (PCBs) with thick copper films.	Maximise loading and reduce energy consumption and emissions released during transport.	Electrical and electronic equipment weight can be substantially reduced through using Printed Circuit Boards (PCBs) with thinner copper films. It is highly recommended to use thinner PCBs if they fulfil all the equipment specifications. This will contribute in loading maximisation.
60.- Reduce the amount of material used in the equipment plastic walls.	Maximise loading and reduce energy consumption and emissions released during transport.	Thinning plastic walls, in accordance with realistic requirements for stiffness, strength, toughness, warpage, etc, is an effective way of reducing the equipment weight, but keep in mind that over-thinning plastic walls can put at risk all these properties mentioned before. Some design strategies can reduce the amount of material used in plastic walls without compromising other properties. This will contribute in loading maximisation (see figure 18).

Guideline	Reason	Comments
61.- Use standardised transport packaging in order to maximise loading.	Maximise loading and reduce energy consumption and emissions released during transport.	The use of standardised transport packaging (for example, Europallets, etc.) will contribute substantially to loading maximisation. Another way of achieving the same effect is by reducing packaging weight and volume. Loading maximisation will contribute in a substantial reduction of the product environmental impact through lower energy consumption and a reduction of the emissions released during transport.
62.- Reduce packaging weight and volume.	Use fewer resources, generate less waste and reduce the environmental impact during transport.	By relocating the equipment and its separate parts in the package the use of packaging material can be substantially reduced and, consequently, its overall weight and volume. This will contribute in loading maximisation at the same time that fewer resources will be used and less waste will be generated through using less packaging material. In all cases, it is highly recommended to use the minimum packaging volume and weight.
63.- Avoid energy-intensive packaging materials.	Reduce energy consumption.	Some materials need a high amount of energy for being obtained and processed (for example, plastic is more energy-intensive than cardboard). It is highly recommended that these valuable (energy-intensive) materials used have a well established recovery and recycling system.
64.- Use more environmentally sound materials in packaging.	Reduce the use of health and environment hazards.	Try to use environmentally sound materials in packaging. Avoid using materials with substances that are health and environmental hazards or suspected of being, for example: packaging made of PVC, containing plastic additives formulated with hazardous, toxic or restricted substances, etc, especially if they are used in non-returnable packaging.
65.- Use as few different materials as possible in packaging.	Improve the environmental behaviour of the packaging end-of-life.	To facilitate sorting of materials that are suitable for re-use and recycling, at the end of the packaging life, it is recommended to use as few different materials as possible. This will also increase the quantity of a particular material available at the packaging end-of-life and therefore the value of such material.
66.- Mark packaging with the identification of its type of material.	Improve from an environmental and economical perspective the equipment's packaging end-of-life.	In order to facilitate sorting and recycling, the European Commission has introduced an identification system for packaging materials in the Commission Decision (C(97)255 final). This identification system is based on a series of letters and numbers. The Packaging and Packaging Waste Directive (94/62/EC) aims to promote collection, re-use and recovery, including recycling of packaging waste.

Guideline	Reason	Comments
67.- Use recycled materials instead of virgin materials in packaging.	Use fewer resources and generate less waste.	<p>Using recycled packaging reduces material and energy consumption and also generates less waste. Select recycled packaging if it is available, economically sound and fulfil all the product's packaging specifications. If it can not be used, select packaging made of a combination of virgin and recycled material. If it can not be used, select a packaging made of virgin material with a well established recovery and recycling system. It should be remembered that primary, secondary or tertiary recycled materials can be used. Obviously, from an environmental and economical perspective, primary recycling is preferred over secondary and tertiary, and secondary over tertiary.</p> <p>In order to facilitate stable markets for recycled materials, it is highly recommended to select and use them as much as possible.</p>
68.- Select packaging materials that are easily recyclable.	Facilitate material recycling process.	<p>To improve from an environmental and economical perspective the packaging end-of-life, it is recommended to select materials that can be easily recycled (cardboard, thermoplastics: PET, PS, etc, and polyolefines: HDPE, LDPE, PP, etc.) and with a well established recovery and recycling system.</p>
69.- Avoid packaging combinations of plastics that are not compatible in recycling.	Facilitate material recycling process.	<p>Ideally, the same plastic should be used throughout all the packaging equipment.</p> <p>As it may be seen in the plastics compatibility table presented (see figure 26), there are many plastics and only some of them are compatible for recycling, or in other words, few of them do not need to be separated for recycling because the resulting blend will be a usable alloy. Obviously, incompatible combinations of plastics should be separated prior to recycling. This can be performed by an hydro-separation technique. To facilitate the hydro-separation process, it is preferable that plastic densities differ at least 0.05 specific gravity units (see figure 27).</p>
70.- Use reusable packaging.	Use fewer resources and generate less waste.	<p>By using reusable packaging, the packaging and equipment environmental behaviour will be improved through reducing material and energy consumption and also generating less waste. It is highly recommended to establish efficient return systems of empty reusable packaging. In order to determine the optimum balance between packaging weight and its durability it is highly recommended to perform an environmental evaluation (LCA).</p>

Guideline	Reason	Comments
71.- Use biodegradable materials in packaging.	Improve the environmental behaviour of the packaging end-of-life.	Try to use more biodegradable materials in packaging in order to facilitate and improve the environmental behaviour of the packaging end-of-life. For example: Polyhydroxybutyrate (PHB) is a biodegradable plastic material.
72.- Avoid the use of scarce non-renewable resources in packaging.	Preserve non-renewable resources.	Try to preserve scarce non-renewable resources and avoid their extinction (for example: oil to produce plastics) .
73.- Use attractive but also environmentally sound packaging.	Use environmentally sound packaging.	In some electrical and electronic equipment, packaging gives them a certain appeal. With an environmentally sound packaging, obviously, this effect may also be achieved.
74.- Provide to your customers clear information about the available and properly packaging end-of-life treatment systems.	Facilitate and improve the end-of-life packaging treatment.	It is highly recommended, from an environmental and economical perspective, to provide to your customers with clear instructions about properly and available packaging end-of-life treatment systems.

4.4. PRODUCT USE

The following guidelines set out measures that aim at the reduction of the environmental impact associated to the use of electrical and electronic equipment. The following environmental guidelines are focused on reducing its energy consumption, encouraging the use of cleaner energy sources, allowing fewer consumables consumption, reducing equipment's waste generation and caused impact, increasing equipment reliability and durability and also allowing an easy maintenance, repair, refurbishment and upgradation of the equipment.

Eco-labelling

Eco-labelling, also called environmental labelling, is a guide for consumers to choose products and services that cause less damage to the environment. Eco-labelling makes a positive statement that identifies products and services as less harmful to the environment than similar products or services used for a specific function.

Environmental criteria are developed, or are currently under development, to cover everyday consumer goods, for example those that can be bought in supermarkets and shops, with the exception of food, drink and medicines. An eco-label is awarded only to products which have a reduced environmental impact. Therefore, the ecological criteria are set so as to allow up to 30% of the products available on the market to qualify for the eco-label. This means that only some of the products already on the shelves will qualify without needing to be modified (redesigned).

Manufacturers are not forced to apply for an eco-label. It is up to them to decide, providing that their products comply with the criteria whether or not to apply. If they choose to apply, producers of eco-labelled products benefit from a competitive advantage.

Generally, the ecological criteria for each product group are defined using a cradle to grave approach (Life Cycle Assessment) which identifies where the products harm the environment at each stage of their life cycle beginning with the extraction of raw materials and ending with the final disposal. Many environmental labelling schemes currently apply electrical and electronic products, for example the European Union (the EU Eco-label) has established ecological criteria for the following product groups: washing machines, refrigerators, dishwashers, personal computers, copying paper, lightbulbs, portable computers and other product groups are currently under development.

Some of the most important eco-labels:

- a) Blue Angel (Germany, <http://www.blauer-engel.de>)
- b) Austrian Eco-Label (Austria, <http://www.bmu.gv.at>)
- c) Environmental Choice (Canada, <http://www.terrachoice.ca/>)
- d) Energy Star (USA, <http://www.epa.gov>)
- e) Green Seal (USA, <http://www.greenseal.org/>)
- f) AENOR Medio Ambiente (Spain, <http://www.aenor.es>)
- g) The Emblem of guarantee of environmental quality for products and services (Catalonia – Spain, <http://www.gencat.es/mediamb/>)
- h) EU Ecolabel (EU, <http://europa.eu.int>)
- i) NF – Environmental (France, <http://afnor.fr>)
- j) Stichting Milieukeur (The Netherlands, <http://www.milieukeur.nl>)
- k) Nordic Swan (Nordic Countries, <http://www.svanen.nu>)

Guideline	Reason	Comments
75.- Add to the equipment an automatic power-down feature.	Reduce energy consumption.	<p>Energy consumption by electrical and electronic equipment is in some cases the greatest environmental impact associated to their entire life cycle. For this reason, it is highly recommended to incorporate, in the equipment, an automatic power-down feature that will automatically switch the equipment down to a standby state when it is not being actively used. This will result in substantial savings of energy consumption during the use phase. Obviously, the equipment should also permit to be switched off by the user.</p> <p>As a general rule, the default state of an electrical and electronic equipment should be the most desirable of an environmental perspective (for example: the lowest energy consumption state, the lowest consumables usage state, etc.).</p> <p>Irrespective of how the electricity is generated will be an extra adverse environmental effect to be considered.</p>
76- Incorporate switched power supplies in the equipment.	Reduce energy consumption.	<p>It is highly recommended that any electrical and electronic equipment has a switched power supply despite of having an automatic power-down feature. The incorporation of such supply will allow substantial savings of energy consumption during the use phase.</p>
77.- Reduce the number of components and parts used.	Reduce energy consumption.	<p>It is possible to reduce the number of components and parts used in electrical and electronic equipment, for example: by integrating more functions on silicon (Integrated Circuits), integrating more functions in other components and parts, decoupling capacitors, etc.</p> <p>With fewer components and parts, obviously, the equipment energy consumption will be reduced during the use phase.</p> <p>A reduction in the number of components and parts used also implies a reduction of the area required to position them (they can be positioned more closely). This will result in a reduction of the average length of the conductors between components and parts and, consequently, the equipment capacitance will be reduced as well as its energy consumption, due to the fact that it is directly proportional to the conductor capacitance. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.</p>
78.- Pressure and motivate suppliers to design and produce more energy efficient components and parts.	Reduce energy consumption.	<p>In order to reduce the equipment's energy consumption during the use phase, it is highly recommended to use more energy efficient components and parts. In this way, it is necessary to pressure and motivate suppliers to design and produce them.</p>

Guideline	Reason	Comments
79.- Select components and parts with low energy consumption.	Reduce energy consumption.	Selecting components and parts with low energy consumption will result in substantial savings of energy due to several reasons: using these components and parts will directly result in lower energy consumption during the equipment use, but also indirectly their use will suppose less equipment heating and consequently lower the needed for energy to cooling it.
80.- Avoid non-efficient energy accessories.	Reduce energy consumption.	In order to reduce the equipment's energy consumption during the use phase, avoid incorporating to the equipment of any non-efficient energy accessories.
81.- Select interconnection technologies that require low material consumption.	Reduce energy consumption.	Several interconnection technologies are available to connect electrical and electronic components and parts to a Printed Circuit Board (PCB). Each technology has different interconnection material and area requirements. Energy losses, during the use phase, are higher when more interconnection material and/or more area is required. For these reasons, it is recommended to select an interconnection technology with low material and also with low area requirements. The following mounting technologies are presented in declining order of material requirements and consequently, in declining order of energy losses: THM, SMT, TAB, Wire Bonding and Flip-Chip (see figures 19 and 20). Remembered none of them, except THM, require a PCB area significantly greater than the size of the component to be connected.
82.- Mount components on both sides of the Printed Circuit Board (PCB).	Reduce energy consumption.	Mounting electrical and electronic components and parts on both sides of Printed Circuit Boards (PCB) will result in a substantial reduction of area requirement (approximately 1/2) and consequently the average length between components and parts. This way, the equipment capacitance will be reduced and also its energy consumption, due to the fact that it is directly proportional to the conductor capacitance. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
83.- Design the equipment to use different working frequencies in their different parts.	Reduce energy consumption.	The different parts and components of an electrical and electronic equipment, obviously, can work perfectly with different frequencies. It is not necessary to use the highest working frequency, needed elsewhere in the equipment, in all parts and components. Different or lower working frequencies can be employed in some parts and components. This strategy will result in substantial savings of energy through: reducing the equipment's energy consumption during the use phase and reducing the amount of energy required for cooling it due to a lower equipment's warming.

Guideline	Reason	Comments
84.- Select small components and parts.	Reduce energy consumption.	Small components and parts can be positioned more closely on a Printed Circuit Board (PCB) and in the equipment. This will result in a reduction of the average conductor length between all the components and parts used. Consequently, the equipment capacitance will be reduced and also its energy consumption, due to the fact that it is directly proportional to the conductor capacitance. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
85.- Select surface-mounted components rather than their hole-mounted homologous.	Reduce energy consumption.	Surface-mounted components are often smaller than their hole-mounted homologous. Thus, they can be positioned more closely and the average conductor length between them can be substantially reduced. Consequently, equipment capacitance will be reduced and also its energy consumption, due to the fact that it is directly proportional to the conductor capacitance. In all cases, it is highly recommended to analyse possible problems with EMC and heat dissipation.
86.- Position close to the energy source those components or parts which are most often working.	Reduce energy consumption.	This layout strategy is an effective way of reducing the equipment's global capacitance through particularly reducing the average conductor length of those components or parts which are most often working. They should be positioned as near as possible to the energy source. This strategy will result in a substantial reduction of the energy consumption during the equipment's use phase.
87.- Avoid the use of cooling fans.	Reduce energy consumption.	By avoiding the use of cooling fans the equipment's energy consumption during its use phase can be substantially reduced, since this type of components are very power demanding. Several strategies can be followed in order to avoid the need of cooling fans, for example: do not position components extremely close to each other, improve the design's thermal tolerance (it is highly recommended to perform thermal simulations during the design process), etc.
88.- Provide customers with clear instructions and friendly user controls.	Reduce energy consumption.	For most electrical and electronic equipment their highest environmental impact comes associated with their use phase. By providing to customers clear instructions and friendly user controls, the equipment will be used more efficiently and this will result in a substantial reduction of their energy consumption.

Guideline	Reason	Comments
89.- Encourage the use of rechargeable batteries.	Encourage the use of cleaner energy sources.	Electrical and electronic equipment can be supplied with a battery charger, which will encourage the use of rechargeable batteries. This is an effective way of encouraging the use of a more environmentally sound source of energy.
90.- Minimise the use of auxiliary materials and/or consumables during the use phase.	Use fewer resources, generate less waste and reduce the environmental impact during product use.	An effective way of improving the environmental behaviour of equipment during their use phase can be achieved by minimising their consumption of auxiliary materials and/or consumables, for example: it is recommended to use a permanent filter in coffee makers instead of paper filters. Providing calibration marks that inform the user about the exact quantity of auxiliary material required is also an effective way of reducing the consumption of materials. This strategy will result in a substantial reduction of the resources consumed and waste generated.
91.- Provide customers with clear instructions and friendly user controls.	Increase equipment lifetime.	In some cases, disuse of equipment can be originated by complicated instructions and/or inappropriate user controls design. Providing to customers clear instructions and friendly user controls, the equipment lifetime can become substantially extended and its replacement delayed.
92.- For securing plastic cases, select an assembly strategy that facilitates the dismantling process in order to repair, maintain, refurbish and upgrade the equipment easily.	Increase equipment lifetime.	Electrical and electronic equipment should allow easy assembly and disassembly of plastic cases in order to repair, maintain, refurbish and upgrade the equipment easily and consequently extend their lifetime. The number of fasteners used should be reduced and also their variability in type in order to speed the disassembly process and reduce the number of tools required. Fasteners should allow an easy removal of parts and it is recommended that they remain unbroken during the disassembly process. It is also highly recommended to minimise the number of disassembly operations required, avoid the necessity of specialist tools, provide enough space that allows an easy disassembly and provide a dominant disassembly route.
93.- Modularise equipment parts in order to repair, maintain, refurbish and upgrade easily the equipment.	Increase equipment lifetime.	Equipment reparability, maintainability, refurbishability and upgradability should be considered in order to extend the equipment lifetime. Equipment should allow easy assembly and disassembly of parts and components prone to fail, prone to be functionally obsolete, etc. These parts and components should be modularised and positioned in an accessible location in the equipment.

Guideline	Reason	Comments
94.- Design all parts of the equipment for similar lifetime.	Increase equipment lifetime.	Since the failure of a single component or part will often result in the whole product disuse, it is highly recommended to design all the equipment parts and components for a similar lifetime. With this strategy a high amount of materials and energy will not be unnecessarily wasted.
95.- Introduce a reset function in the equipment design.	Increase equipment lifetime.	Especially for products that can be resold in a second market, repaired, maintained, upgraded or refurbished, it is interesting to consider how their RAM can be quickly erased. This characteristic can be achieved through the introduction of a reset function in the equipment design.
96.- Use standardised interfaces in the equipment design.	Increase equipment lifetime.	Especially for products that can be resold in a second market, repaired, maintained, upgraded or refurbished, it is interesting that they use compatible sockets, plugs and other electrical and electronic interfaces in order to facilitate these operations and the extension of their lifetime.
97.- Provide to customers information about how to get a product repaired, maintained, refurbished or upgraded.	Increase equipment lifetime.	In order to increase equipment lifetime, it is recommended to provide information to customers about how to get the equipment repaired, maintained, refurbished or upgraded.
98.- Improve the availability of equipment standard parts and consumables.	Increase equipment lifetime.	In order to increase product lifetime, the availability of equipment standard parts, components and consumables to customers should be increased and improved.
99.- Avoid non-resistant aesthetic surfaces.	Increase equipment lifetime.	Some aesthetic surfaces can become deteriorated during the equipment lifetime and this can result in a substantial degradation of the equipment appearance and motivate their disuse or turn them into waste. The equipment's aesthetic life should be as long as its technical life. Due to this, avoid using aesthetic surfaces or try to use a resistant one in order to increase their aesthetic lifetime.
100.- Design equipment that can be used in habitual or standard conditions (voltage, temperature, humidity, etc.)	Increase equipment lifetime.	Especially for products that can be resold in second markets, it is highly recommendable to design them so that they may operate under habitual or standard conditions of voltage, temperature, humidity, etc. in order to facilitate their reuse permitting them to be resold, consequently increasing their lifetime.

Guideline	Reason	Comments
101.- Design the equipment appearance avoiding that it can become unfashionable easily.	Increase equipment lifetime.	As a general rule, the product aesthetic lifetime should be as long as its technical life. This consideration should be kept in mind during the product appearance design in order to prolong, as much as possible, its lifetime.
102.- Avoid re-using materials and components if they can put at risk the safety, reliability or aesthetically acceptance of the resulting equipment.	Increase equipment lifetime.	The environmental behaviour of an equipment can be substantially improved by re-using materials and/or components. But their re-usage should not put at risk the overall safety, reliability nor the aesthetically acceptance of the resulting equipment. In this way, the risk of re-using these materials and components should be assessed (considering risk thresholds) and consequently avoided any risk situation or actuation that could compromise the overall product quality.
103.- Avoid design weak links.	Increase equipment lifetime.	It is highly recommended to use a design check method in order to avoid weak design links. For this purpose it may be useful to use a Failure Mode and Effect Analysis.
104.- Reduce the number and size of materials and components used in the equipment.	Prevent waste generation.	Obviously, any reduction in the number and/or size (weight and volume) of materials and components used in equipment will result in substantial environmental and economical improvements through disposing and treating a smaller quantity of wastes.
105.- Select materials and components made of recycled materials.	Prevent waste generation.	<p>Using recycled materials results in substantial savings of natural resources, energy consumption and also less waste generation. In this way, try to select materials and components made of recycled materials if they are available, are economically sound and fulfil all the equipment specifications. If they can not be used, try to select those made of a combination of virgin and recycled material. It should be remembered that primary, secondary or tertiary recycled materials are available. Obviously, from an environmental and economical perspective, primary recycling is preferred over secondary and tertiary, and secondary over tertiary.</p> <p>In order to facilitate stable markets for recycled materials, it is highly recommended to select and use them as much as possible.</p> <p>Obviously, when using recycled material equipments safety and performance requirements should not be put at risk. In order to verify an admissible quality of the recycled material that is going to be used, ask the supplier for information and/or send a sample to an analytical lab.</p> <p>Consider the following processing recommendations in order to reduce the heat history and thermal degradation of plastics, facilitating multiple recycling of plastic material: use a properly sized moulding machine, do not process plastics above their recommended melt temperatures, do not expose plastic to long heating cycles and minimise regrind.</p>

4.5. PRODUCT END-OF-LIFE

In this stage, the environmental improvements proposed to be incorporated in the equipment design stage are oriented to improve the overall environmental behaviour of the equipment end-of-life and particularly to: prevent waste generation, improve and increase the amount of value that can be recovered from the product in its end-of-life stage (by re-using, recycling and other forms of recovery) and to minimise the environmental risks and impacts associated with the treatment and disposal process of such electrical and electronic waste.

Most of the products from the electrical and electronic industry contain: printed circuit boards (PCB), cables, plastics containing flame retardants, wiring, mercury switches and breakers, light generating devices, capacitors, batteries and accumulators, resistors and relays, sensors and connectors, and display equipment such as cathode ray tubes and liquid crystal displays. All of these components contain several different materials, some of them which are environmentally problematic if they are disposed of as landfill or incinerated without appropriate pre-treatment like heavy metals (mercury, lead, cadmium and chromium), halogenated substances including CFCs (chloro-fluorocarbons), PCBs (polychlorinated biphenyls), PCNs (polychlorinated naphthelenes) and the brominated flame retardants PBDEs (polybrominated diphenylethers) and PBBs (polybrominated biphenyls).

- **Mercury:** used in thermometers, thermostats, lightning and medical equipment. When electronic devices are destroyed, it may leach into soil and groundwater being absorbed by living organisms, such as fish, entering in this way the food chain. It can cause serious brain damage.
- **Cadmium:** found in printed circuit boards (PCB) and in cathode ray tubes (CRT) in TVs and computers. Causes kidney damage and cancer.
- **Lead:** used in soldering printed circuit boards, soldering and glass in light bulbs and fluorescent tubes. It can leach into soil especially where the carrier material such as glass is broken or granulated. Can cause damages in the nervous system, endocrine system and kidneys.
- **Hexavalent chromium:** it is no longer used by most of the producers of equipment, but it has still an application as a corrosion protector for steel plates. It is very toxic and easily absorbed.
- **Brominated flame retardants:** found in plastic castings. Can form potentially dangerous dioxins and furans when subjected to heat.
- **CFCs:** found in coolants and plastic foam inside refrigeration equipment. Provokes great damage to the ozone layer.
- **PCBs and PCNs:** found in older capacitors. They accumulate in the food chain and can cause genetic damage.

The disposal of electronic waste in landfill sites or its incineration may cause serious environmental damage:

- **Landfill:** - possible leaching of heavy metals (lead, cadmium, mercury, etc.) into ground water.
 - emission to air that arise from evaporation, a particular problem with metallic and dimethylene mercury.
- **Incineration:** - emissions of mercury.
 - high concentration of heavy metals in the slag.
 - emissions of polychlorinated and brominated dioxins and furans which can be released during the incineration of PCB- containing capacitors and plastics containing brominated flame retardants.

Together with the environmental impact, a great amount of resources may be lost if electronic and electric equipment is sent to a landfill site or incinerated. Some materials and components could be reused and/or recycled.

In addition to the loss of actual resources, there is associated a huge environmental benefit to the reuse and recycle of materials. There is a reduction in the need to extract new materials and manufacture new products. One of the main benefits is the energy saved, for example: the energy needed in mining copper is six times the amount of energy needed in recycling the same amount.

In accordance with the future environmental legislation, the costs for collection, treatment, recovery and environmentally sound disposal of waste of electrical and electronic equipment from private households will bear on producers, so any environmental design consideration that increases the amount of value that can be recovered from the equipment at its end-of-life will, obviously, result in an improvement of the equipment environmental behaviour, but will also result in an important source of cost savings for manufacturers.

The Directive WEEE shows the ways in which electrical and electronic equipments end disposition should be approached. These ways are presented hereafter in order of environmental priority:

1. Prevention of waste:

- ♣ Prevention of waste: measures aiming at the reduction of the quantity and the harmfulness for the environment of waste electrical and electronic equipment, their materials and substances.

2. Re-use:

- ♣ Resale: the product is resold, with minimal refurbishment, for the same purpose for which it was conceived.
- ♣ Remanufacture/refurbish: the product is restored to its original condition for resale.
- ♣ Upgrade: the product is modified to give it additional functions.

Note: Re-use, as an extension of the equipment life, has been treated in section 4.4.- Product use.

3. Recycling:

- ♣ Recover materials and/or components: means the reprocessing in a production process of the waste materials for the original purpose or for other purposes but excluding energy recovery.

4. Reclaiming energy:

- ♣ Recover energy: use of combustible waste as a way to generate energy through direct incineration with or without other waste but with recovery of the heat.

5. Landfilling:

- ♣ Product landfilling: the product is disposed in a landfill.

Recovery targets (Directive WEEE):

Member States shall ensure that, within 46 months of the entry into force of the Directive, the following targets for separately collected waste, less the weight of the complete equipment re-used, are met by producers (figure 21):

Equipment	Rate of recovery (% weight)	Re-use Recycling of components, parts and substances (% weight)
(1) Large household appliances	80	75 (minimum)
(2) Small household appliances	70	50 (minimum)
(3) IT & Telecommunication equipment (except of equipment that contains cathode ray tubes)	75	65 (minimum)
(4) Consumer equipment	75	65 (minimum)
(5) Lighting equipment (with the exception of light bulbs, incandescent lamps and household lightning equipment)	70	50 (minimum)
(6) Electrical and electronic tools	70	50 (minimum)
(7) Toys, leisure and sports equipment	70	50 (minimum)
(8) Medical equipment systems (with the exception of all implanted and infected products)	-	-
(9) Monitoring and control instruments	70	50 (minimum)
(10) Automatic dispensers	70	50 (minimum)

Figure 21. Recovery targets (Directive WEEE)

The following guidelines sets out measures that aim at the prevention of waste electrical and electronic equipment, at the re-use, recycling and other forms of recovery of such waste and at minimising the risks and impacts to the environment associated with the treatment and disposal of this waste.

Guideline	Reason	Comments
<p>106.- Use reusable materials and components.</p>	<p>Prevent waste generation.</p>	<p>By using reusable materials and components equipment's environmental behaviour can be improved through reducing material and energy consumption and also generating less waste.</p>
<p>107.- Do not use metal fasteners in plastic parts. Use plastic fasteners of the same plastic as the parts they are joining, or which are compatible for recycling.</p>	<p>Facilitate recovery process.</p>	<p>Metal fasteners in plastic parts make difficult and expensive the recycling process due to the fact that they should be removed prior to recycling (they can affect the quality of the recycled material obtained and damage equipment teeth or blades during recycling process). There are several methods of joining plastic parts (avoiding metal fasteners): — plastic fasteners (of the same plastic as the parts joined or using a plastic fastener compatible for recycling with the plastic parts joined), for example: plastic rivets, plastic ratchet fasteners, snap fits, plastic hinges, spring or speed clips, etc. — welding and bonding methods for joining plastic parts, for example: ultrasonic welding, focused infrared welding, solvent bonding, etc. These strategies are environmentally and economically sound since nothing should be removed prior to recycling. If metal fasteners in plastic parts are unavoidable consider the following recommendations: — Prefer ferrous fasteners due to the fact that they can be magnetically separated from plastic and other equipment materials. — Avoid entirely the use of metal rivets due to the difficulty of getting them removed (bolts, screws, etc, are preferred). — Provide weak points in plastic parts for metal fastener's easy removal (see figure 22). — Thread-forming inserts are preferred over moulded-in or inserted metal fasteners (a through hole should be provided for easy removal) (see figure 22).</p>
<p>108.- Mark plastic parts weighing more than 50 g with the identification of the type of plastic.</p>	<p>Facilitate recovery process.</p>	<p>To facilitate the identification and sort of plastic parts which are suitable for recycling, at the end of the equipment life, it is necessary to use visibly located identification marks. Some different methods exist for marking plastic parts: labels, pad printing, bar coding, laser inscribing, etc. but the moulding-in marking is the most environmentally sound method since it does not require other materials, chemicals, processes, etc. In accordance with the Directive WEEE, producers should apply coding standards, for example: ISO criteria (International Organization for Standardization). In marking plastic parts weighing more than 50 g (see figures 23, 24 and 25).</p>

Guideline	Reason	Comments
109.- Mark plastic parts weighing more than 50 g with the identification of the type of plastic and including other information: additives used, the number of previous cycles of recycling or re-using, etc.	Facilitate recovery process.	To facilitate the identification and sort of plastic parts which are suitable for re-use and recycling, at the end of the equipment life, it is necessary to use visibly located identification marks with the identification of the type of plastic. It is useful that the code also includes other information as: additives used, number of previous cycles of recycling or re-using, material age, etc.
110- Select plastic types with a well established recovery and recycling system.	Facilitate recovery process.	To improve from an environmental and economical perspective the equipment end-of-life, it is highly recommended to select plastic types that can be easily recycled (thermoplastics: PET, PS, etc, and polyolefines: HDPE, LDPE, PP, etc.) and with a well established recovery and recycling system.
111.- Avoid combinations of plastics that are not compatible in recycling.	Facilitate recovery process.	Ideally, the same plastic should be used throughout a product. As can be seen in the plastics compatibility table (see figure 26), there are many plastics and only some of them are compatible for recycling, or in other words, they do not need to be separated for recycling because the resulting blend will be a usable alloy. Obviously, incompatible combinations of plastics should be separated prior to recycling and this can be performed by an hydro-separation technique. To facilitate the hydro-separation process, it is preferable that plastic densities differ at least 0.05 specific gravity units (see separability plastics table figure 27).
112.- Avoid using labels on plastic parts if they contain dissimilar or contaminating materials.	Facilitate recovery process.	Labels and their adhesives (e.g. glues, epoxies, etc.) usually introduce a dissimilar or contaminating material to potentially recyclable plastic parts that can affect seriously the physical, chemical, mechanical, etc, properties and also the appearance of the recycled material obtained. If these labels and materials are not thermally stable, or incompatible with the plastic part to which they adhere, they should be removed prior to recycling and consequently the process results more difficult and more expensive. Some environmentally sound labelling methods are available: moulded-in labels, printed labels of the same type of plastic as the part to be adhered and an attachment method that does not leave any contamination (ultrasonic welding, solvent bonding, etc.), labels snap fitted onto enclosures, etc.

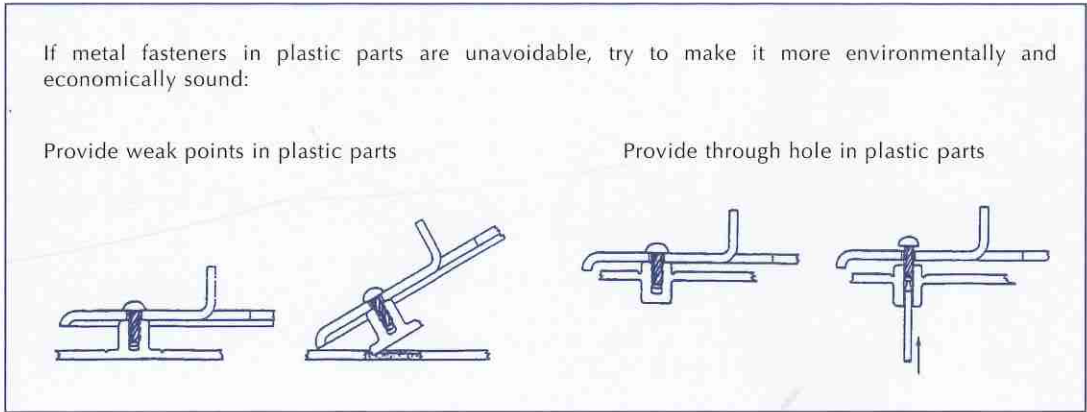


Figure 22. Metal fasteners more environmentally-economically sound
(Source: American Plastics Council)

Standard (ISO)	Comments
ISO 11469 Plastic-Generic Identification and Marking of Plastic Products (first edition format)	All polymeric parts, including plastics, rubber, and thermoplastic elastomers, should be marked using this standard.
ISO 1043-1 Plastic-Symbols-Part 1: Basic Polymers	Plastic parts should be marked using this standard.
ISO 1043-2 Plastic-Symbols-Part 2: Fillers and Reinforcing Materials	Plastic parts with filler and reinforcing materials should be marked using this standard with amounts specified by weight, with an accuracy of $\pm 2.5\%$, by increments of five.
ISO 1629-1 Rubber-Nomenclature-Part 1: Dry Rubber and Latex	Rubber parts should be marked using this standard. Fillers and reinforcing materials should not be specified.
ISO 1629-2 Rubber-Nomenclature-Part 2: Fillers and Reinforcing Materials	Thermoplastic elastomer parts should be marked using this standard with amounts specified by weight, with an accuracy of $\pm 2.5\%$, by increments of five.

Figure 23. ISO marking recommendations for polymeric parts

Example of marking:



> PA 66 - GF 30 <

Identification of plastics in accordance with ISO 1043-2 (polyamide plastic 66 (PA) with 30% of glass fibre (GF)).

Figure 24. Example of marking

Acronym	Name
ABS	Acrylonitrile/Butadiene/Styrene
EPDM	Ethylene/Propylene/Dimmer
EPM	Ethylene/Propylene/Monomer
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
LLPDE	Linear Low Density Polyethylene
PA	PolyAmide
PBT	PolyButylene Terephthalate
PC	PolyCarbonate
PEI	Polyetherimide
PET	PolyEthylene Terephthalate
PMMA	Poly (Methyl Methacrylate)
POM	PolyOxyMethylene
PP	Polypropylene
PPE	PolyPhenylene Ether
PS	Polystyrene
PVC	Poly (Vinyl Chloride)
SAN	Styrene/acrylonitrile
SBS	Styrene/Butadiene
TEEE	Ether Ester Block copolymer
ULDPE	Ultra Low Density Polyethylene

Figure 25. Plastic abbreviation in accordance with ISO 1043-1

Guideline	Reason	Comments
113.- For securing plastic cases select an assembly strategy which facilitate the dismantling process.	Facilitate recovery process.	For securing plastic cases, there should be chosen an assembly strategy that makes easy and cheap the dismantling and sorting process at the end of the equipment's life. The number of fasteners used should be reduced and also their variability in type in order to speed the disassembly process and reduce the number of tools required. Fasteners should allow part's easy removal and they should remain unbroken during the disassembly process. It is also highly recommended to minimise disassembly operations required, avoid the necessity of specialist tools, provide enough space that allows an easy disassembly and provide a dominant disassembly route.
114.- Avoid combining metals with other substances that can reduce or nullify the value of the recycled metal.	Facilitate recovery process.	Some combinations of metals with small amounts of other substances (other metals, etc.) can reduce or nullify the value of the recycled metal. In this way, non-alloyed metals are easier and cheaper to recycle (see metals compatibility table in figure 28).
115.- Use as few different materials as possible.	Facilitate recovery process.	To facilitate the sort of materials that are suitable for re-use and recycling, at the end of the equipment's life, it is recommended to use as few different materials as possible.
116.- Avoid the use of laminated or compounded materials.	Facilitate recovery process.	Laminated or compounded materials are difficult to recycle at the end of the equipment life, therefore it is recommended to use as few laminated or compounded materials as possible.
117.- Mark your products with the symbol of electrical and electronic equipment.	Indicate their separate collection.	In accordance with the Directive WEEE a crossed-out wheeled bin should be printed visibly, legibly and indelibly in all electrical and electronic products indicating their separate collection (see figure 29).
118.- An environmental declaration should be produced for each electrical and electronic equipment.	Facilitate and improve the end-of-life equipment scenario.	In accordance with the Directive WEEE, in order to facilitate from an environmental and economical perspective the end-of-life equipment treatment, it is highly recommended that producers provide appropriate information which identify the different electrical and electronic equipment components and materials, and the location of dangerous substances and preparations in the electrical and electronic equipment. This environmental declaration can go further and contain information about: disassembly instructions, location of components containing hazardous substances, recyclable materials, energy demand in operation and in standby state, etc.

Different types of plastic can in principle be mixed as listed in the following table:

		Additive / Impurity											
		PE	PVC	PS	PC	PP	PA	POM	SAN	ABS	PBTP	PETP	PMMA
Base Materials	Plastic types												
	PE	◆	●	●	●	◆	○	○	○	○	○	○	○
	PVC	○	◆	○	○	○	○	○	◆	❖	○	○	◆
	PS	○	○	◆	○	○	○	○	○	○	○	○	❖
	PC	○	○	○	◆	○	○	○	◆	◆	◆	◆	◆
	PP	○	○	○	○	◆	○	○	○	○	○	○	○
	PA	○	○	○	○	○	◆	○	○	○	○	○	○
	POM	○	○	○	○	○	○	◆	○	○	○	○	○
	SAN	○	◆	○	◆	○	○	○	◆	◆	○	○	◆
	ABS	○	❖	○	◆	○	○	○	❖	◆	○	○	◆
	PBTP	○	○	○	◆	○	○	○	○	○	◆	○	○
	PETP	○	○	○	◆	○	○	○	○	○	○	◆	○
PMMA	○	◆	○	◆	○	○	○	◆	◆	○	○	◆	

- ◆ are compatible
- ❖ are compatible to a limited extent
- are compatible to a limited extent, with only small content of additive
- are incompatible

Figure 26. Plastics compatibility table
(Source: Verein Deutscher Ingenieure)

Table of plastic separation by density:

Material	Density (g/cm ³)																		
ABS	1,06																		
PA	1,13	2																	
PBT	1,30	2	2																
PC	1,20	2	2	2															
PC+ABS	1,15	1	0	2	1														
PC+PBT	1,22	2	2	2	0	1													
PE	0,95	2	2	2	2	2	2												
PEI	1,30	2	2	0	2	2	2	2											
PET	1,34	2	2	0	2	2	2	2	2	0									
PMMA	1,18	2	0	2	0	0	0	2	2	2									
POM	1,41	2	2	2	2	2	2	2	2	1	2								
PP	0,90	2	2	2	2	2	2	1	2	2	2	2							
PPE+PS	1,06	0	2	2	2	2	2	2	2	2	2	2							
PPE+PA	1,10	0	0	2	2	1	2	2	2	2	2	2	0						
PPS	1,35	2	2	0	2	2	2	2	0	0	2	1	2	2	2				
PS	1,05	0	2	2	2	2	2	2	2	2	2	2	0	0	2				
PVC	1,40	2	2	2	2	2	2	2	2	1	2	0	2	2	2	1	2		
TEEE	1,20	2	2	2	0	1	0	2	2	2	0	2	2	2	2	2	2	2	
		ABS	PA	PBT	PC	PC+ABS	PC+PBT	PE	PEI	PET	PMMA	POM	PP	PPE+PS	PPE+PA	PPS	PS	PVC	TEEE

2. Separable
1. Partially separable
0. Inseparable

Glass Fibre in plastic increases (0.075 g/cm³)/(10%)

Figure 27. Plastics separability table (Source: Ford, Worldwide Design Standard)

Guideline	Reason	Comments
119.- Provide to users of electrical and electronic equipment information about the end-of-life treatment systems available.	Facilitate and improve the end-of-life equipment scenario.	In accordance with Directive WEEE, it is highly recommended, from an environmental perspective to ensure that users of electrical and electronic equipment obtain the necessary information about: - the return and collection environmentally sound systems available to them. - their role in contributing to re-use, recycling and other forms of recovery of waste electrical and electronic equipment. - the meaning of the "crossed-out wheeled bin" symbol printed in electrical and electronic products.
120.- Design modules, parts, materials and components to be reusable rather than recyclable.	Improve from an environmental and economical perspective the equipment end-of-life scenario.	This strategy will result in saving energy that would have been consumed in reprocessing.
121.- Standardise materials and components that are highly valuable.	Improve from an environmental and economical perspective the equipment end-of-life scenario.	Standardising materials and components that are highly valuable (containing precious metals, etc.) can allow their re-utilisation in the equipment end-of-life. This strategy can result in important environmental and economical benefits due to the fact that parts with a high economical value can be recovered and re-used, and material and energy consumption is also reduced through parts re-utilisation.
122.- Avoid material contamination.	Improve from an environmental and economical perspective the equipment end-of-life scenario.	The equipment design should avoid material contamination, for example: electrochemical effects caused in other parts by a battery, mixtures of incompatible materials, parts contamination through dirt, grease, etc. This strategy can improve from an environmental and economical perspective the equipment end-of-life treatment (by recovering more value and making it easy to perform it).
123.- Use surface-mounted components.	Reuse components.	Surface-mounted components allow easy removal by using hot air guns.
124.- Avoid materials and components containing restricted, toxic or hazardous substances which could have an adverse environmental or health impact at any stage of the equipment life.	Reduce the use of health and environment hazards.	Avoid materials and components that contain health and environmental hazards or suspected of being. In accordance with Directive ROHS the use of some substances will be phased out by no later than 1 January of 2007 (see figure 14).

Metal (foundry process)	Elements that nullify the recycled metal's value	Elements that reduce the recycled metal's value
Copper (Cu)	Mercury (Hg) Beryllium (Be) Polychlorobenzene	Arsenic (As) Antimony (Sb) Nickel (Ni) Bismuth (Bi) Aluminium (Al)
Aluminium (Al)	Copper (Cu) Iron (Fe) Polymers	Silicon (Si)
Iron (Fe)	Copper (Cu)	Tin (Sn) Zinc (Zn)

Figure 28. Metals compatibility table.

(Source: Design for Environment Research Group, Manchester Metropolitan University)

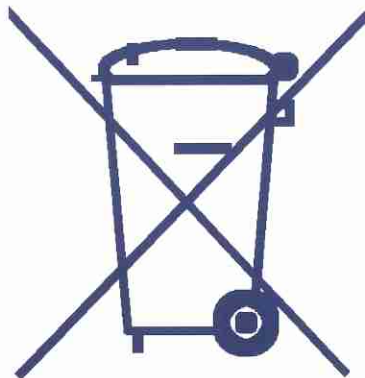


Figure 29. Crossed-out wheeled bin

ANNEX I A Directive WEEE

Categories of Electrical and Electronic Equipment covered by the Directive WEEE

Electrical and Electronic Equipment means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields falling under the categories listed below (Annex I A Directive WEEE) and designed for use with a voltage rating not exceeding 1000 Volt for alternating current and 1500 Volt for direct current. **Waste Electrical and Electronic Equipment** includes all components, sub-assemblies and consumables.

1. Large household appliances
2. Small household appliances
3. IT & Telecommunication equipment
4. Consumer equipment
5. Lighting equipment (with the exception of light bulbs, incandescent lamps and household lightning equipment)
6. Electrical and electronic tools
7. Toys, leisure and sports equipment
8. Medical equipment systems (with the exception of all implanted and infected products)
9. Monitoring and control instruments
10. Automatic dispensers

Figure 30. Categories of electrical and electronic equipment (Directive WEEE)

ANNEX I B of the Directive WEEE

Examples for those products which are falling under the categories of Annex I A of the Directive WEEE

1. Large household appliances

Large cooling appliances
Refrigerators
Freezers
Washing machines
Clothes dryers
Dish-washing machines

Cooking
Electric stoves
Electric hot plates
Microwaves
Heating appliances
Electric heaters
Electric fans
Air conditioners (not built in)

2. Small household appliances

Vacuum cleaners
 Carpet sweepers
 Irons
 Toasters
 Fryers
 Coffee grinders
 Electrical knives
 Coffee machines
 Hair dryers
 Tooth brushes
 Shavers
 Clocks
 Scales

3. IT& Telecommunication equipment

♣ Centralised data processing:

Main frames
 Minicomputers
 Printer units

♣ Personal computing:

Personal Computers (CPU, mouse, screen and keyboard included)
 Lap-top computers (CPU, mouse, screen and keyboard included)
 Note-book computers
 Note-pad computers
 Printers
 Copying equipment
 Electrical and electronic typewriters
 Pocket and desk calculators
 User Terminals and systems
 Facsimile
 Telex
 Telephones
 Pay telephones
 Cordless telephones
 Cellular telephones
 Answering systems

4. Consumer equipment

Radio sets (clock radios, radio-recorders)
 Television sets
 Videocameras
 Video recorders
 Hi-fi recorders
 Audio amplifiers
 Musical instruments

5. Lighting equipment (with the exception of light bulbs, incandescent lamps and household lightning equipment)

Luminaries
 Straight fluorescent lamps
 Compact fluorescent lamps
 High intensity discharge lamps, including high pressure sodium lamps and metal halide lamps
 Low pressure sodium lamps
 Other lighting equipment

6. Electrical and electronic tools

Drills
 Saws
 Sewing machines

7. Toys, leisure and sports equipment

Electric trains or car racing sets
 Hand-held video game consoles
 Video games
 Leisure and sports equipment

8. Medical equipment systems (with the exception of all implanted and infected products)

Radiotherapy equipment
 Cardiology
 Dialysis
 Pulmonary ventilators
 Nuclear Medicine
 Laboratory equipment for in-vitro diagnosis
 Analysers
 Freezers

9. Monitoring and control instruments

Smoke detector
 Heating regulators
 Thermostat

10. Automatic dispensers

Automatic dispensers for hot drinks
 Automatic dispensers for hot or cold bottles or cans
 Automatic dispensers for solid products

Figure 31. Examples of electrical and electronic equipments (Directive WEEE)

Guideline	Reason	Comments
125.- Avoid using plastic additives formulated with hazardous, toxic or banned materials.	Avoid the use of health and environment hazards.	Plastic additives (colorants, fire retardants, stabilisers, plasticizers, reinforcement materials and fillers) formulated with hazardous, toxic or banned materials should be avoided. It is highly recommended to check the Material Safety Data Sheets (MSDS) which will provide toxicological data and regulatory classification information for a particular material.
126.- Avoid using conformal coatings or protective lacquer to protect the equipment.	Increase the number of materials and components that can be removed in the product end-of-life.	Since conformal coatings or protective lacquer to protect the equipment make difficult the removal of materials and components this should be avoided whenever feasible. Avoid the use of epoxy-based varnishes.
127.- Confine to a particular section of the equipment the hazardous materials and components used.	Facilitate to hazardous materials and components a properly treatment in the equipment end-of-life.	Confining to a particular section of the equipment the hazardous materials and components used is an effective way of facilitating their identification and removal. Obviously, where possible, these materials and components should be avoided.
128.- Any hazardous or toxic material and component should be marked.	Facilitate to hazardous materials and components a properly treatment in the equipment end-of-life.	Marking the equipment hazardous or toxic materials and components used is an effective way of facilitating their identification and removal in the equipment end-of-life. Obviously, where possible, these materials and components should be avoided.
129.- Minimise the use of materials and components that require special or controlled disposal.	Improve from an environmental and economical perspective the equipment end-of-life.	By reducing the use of materials and components that require special or controlled disposal (for example: batteries, heavy metals, etc.) the environmental and economical behaviour of the equipment in its end-of-life should be substantially improved, due to the reduction of parts containing environmental and health hazards, and due to the simplification of the end-of-life equipment treatment required.
130.- Find out how electrical and electronic equipment waste processing is currently organised.	Improve from an environmental and economical perspective the equipment end-of-life scenario.	Considering in the equipment design the current organisation of electrical and electronic products waste processing is an effective way of improving from an environmental and economical perspective the equipment end-of-life treatment process.
131.- Facilitate removal of batteries.	Improve from an environmental perspective the equipment end-of-life scenario.	In accordance with the EEC Directive 91/157/EEC, batteries and accumulators containing certain dangerous substances, equipment containing batteries should be properly designed and labelled to facilitate their removal.

Guideline	Reason	Comments
132.- Do not use components that contain halogenated (brominated and chlorinated) flame retardants.	Avoid the use of health and environment hazards.	Halogenated (brominated and chlorinated) flame retardants can form dioxins and furans if burned under uncontrolled conditions (in landfill fires, etc.). Some of them are health and environmental hazards (PBB and PBDEs) or suspected of being (TBBA). In accordance with The Directive ROHS the use of PBB and PBDEs will be phased out by no later than 1 January of 2007 (see figures 14 and 16).
133.- Do not use Printed Circuit Boards (PCBs) that contain halogenated (brominated and chlorinated) flame retardants.	Avoid the use of health and environment hazards.	Usually, Printed Circuit Boards (PCB) contain halogenated flame retardants (especially TBBA, which is suspected of being a health and environmental hazard). Halogenated (brominated and chlorinated) flame retardants can form dioxins and furans if burned under uncontrolled conditions (in landfill fires, etc.). Today PCBs are available in the market without halogenated flame retardants (for example: with nitrogen and phosphor-based flame retardant FR-N, G-10 etc.) (see figures 14 and 16).
134.- Do not use Printed Circuit Boards (PCBs) that contain paper-phenolic resin.	Avoid the use of health and environment hazards.	Usually, paper-phenolic resins contain a polybrominated diphenyl ether (PBDE) flame retardant: penta-BDE, which is a health and environmental hazard that can also form dioxins and furans if burned under uncontrolled conditions (in landfill fires, etc.). In accordance with Directive ROHS the use of PBB and PBDEs (included penta-BDE) will be phased out by no later than 1 January of 2007 (see figures 14 and 16).
135.- Do not use cables and wires that contain chlorinated or brominated flame retardants or phthalates.	Avoid the use of health and environment hazards.	The great majority of brominated or chlorinated additives and phthalates used in cables and wires are health and environment hazards or suspected of being. Especially if they burned under uncontrolled conditions (in landfill fires, etc.). Polyvinylchloride (PVC) is often used in cables and wires together with chlorinated paraffins and/or phthalates. This type of cables should be avoided due to their adverse environmental effects. In accordance with the Directive ROHS the use of PBB and PBDEs will be phased out by no later than 1 January of 2007 (see figures 14 and 16).



Selective Treatment for Materials and Components of Waste Electrical and Electronic Equipment

Directive on Waste Electrical and Electronic Equipment (WEEE)

Treatment of waste electrical and electronic equipment that is separately collected, as a minimum, must include the removal of all fluids and a selective treatment according to the following list (Annex II of Directive WEEE) provided that this treatment does not hinder the re-use and recycling of components or whole appliances.

1) As a minimum the following substances, preparations and components have to be removed from any separately collected waste electrical and electronic equipment:

Lead

Electrolyte capacitors (height > 25 mm, diameter > 25 mm or proportionately similar volume).

Mercury

Cadmium

Hexavalent chromium

Polybrominated biphenyls (PBBs) and polybrominated diphenyl ether (PBDE) and other brominated flame retardants.

PCBs

Asbestos

CFC, HCFC or HFCs

External electric cable

Components containing refractory ceramic fibres

Components containing radioactive substances

Liquid crystal displays of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps

Note: *these substances, preparations and components shall be disposed of or recovered in compliance with Article 4 of Council Directive 75/442/EEC.*

Equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, e.g. contained in foams and refrigeration circuits: The gases must be properly extracted and destroyed. Ozone depleting gases must be treated according to Regulation (EC) No 2037/2000 of the European Parliament and the Council of 19 June 2000 on substances that deplete the ozone layer.

As a minimum, 5 % of the plastic components of WEEE (by weight) should be recycled.

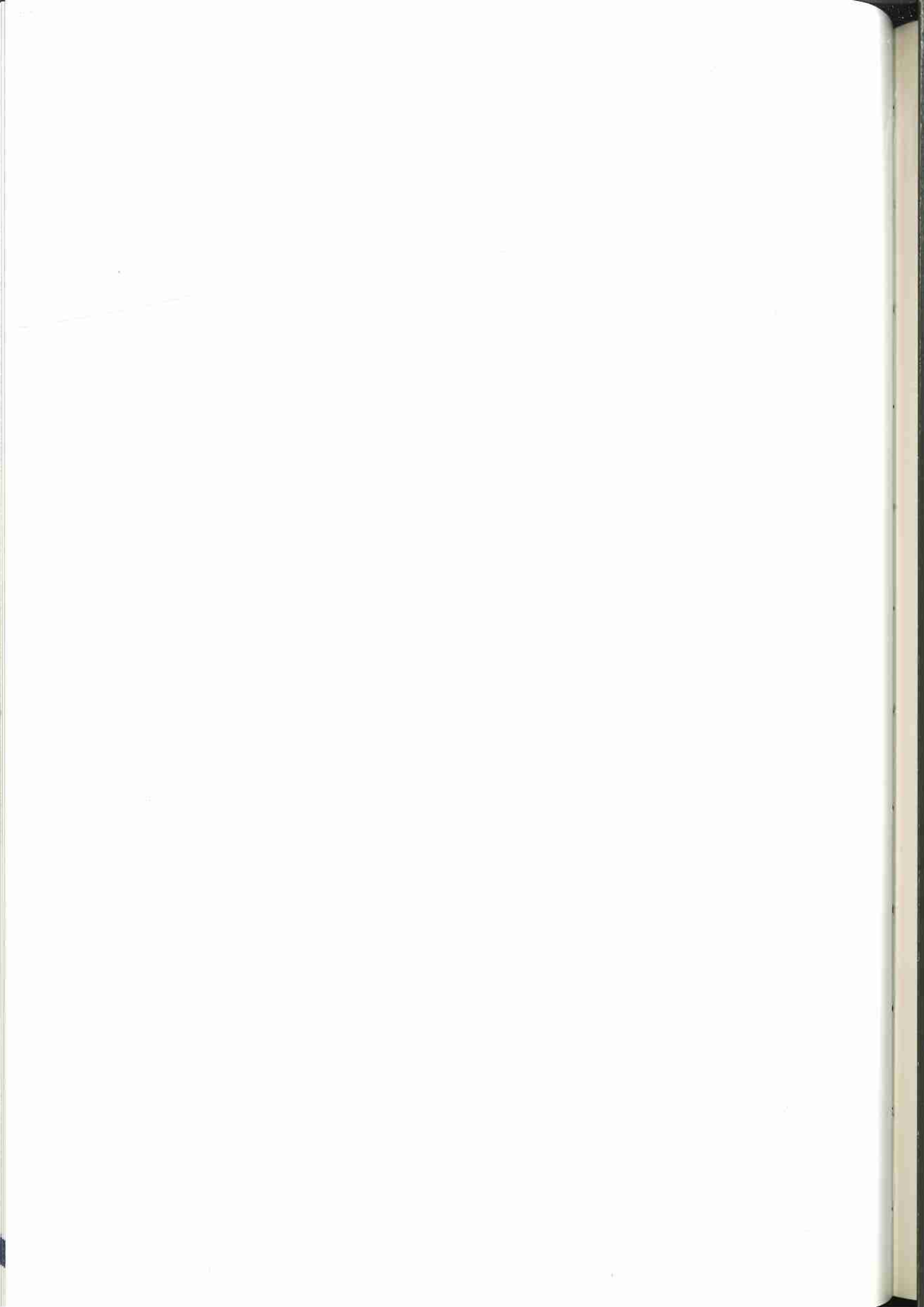
Figure 32. Selective treatment for materials and components of waste from electrical and electronic equipment (Directive WEEE)

Guideline	Reason	Comments
136.- Do not use plastics that contain halogenated (brominated and chlorinated) flame retardants.	Avoid the use of health and environment hazards.	Halogenated (brominated and chlorinated) flame retardants can form dioxins and furans if burned under uncontrolled conditions (in landfill fires, etc.). Some of them are health and environmental hazards (PBB and PBDEs) or suspected of being (TBBA) (see figures 14 and 16). Some constructional plastics are available which do not contain halogenated flame retardant: PC-ABS (without antimony, chlorine or bromine additives), PPOSP (phosphorous-based), etc.
137.- If it is not possible to avoid the use of halogenated (brominated and chlorinated) flame retardants select reactive flame retardants rather than additive.	Reduce the use of health and environment hazards.	Both additive and reactive halogenated flame retardants can form dioxins and furans when burned under uncontrolled conditions (in a landfill fire, etc.). Reactive flame retardants forms a chemical compound with the plastic and additive flame retardants are only mixed with plastic. Consequently, reactive halogenated flame retardants are closely linked to plastics and shows difficulties in being released.
138.- Do not use components containing cadmium, hexavalent chromium or mercury.	Avoid the use of health and environment hazards.	Cadmium, hexavalent chromium and mercury are health and environmental hazards. In accordance with Directive ROHS the use of cadmium, hexavalent chromium and mercury will be phased out by no later than 1 January of 2007 (exempt of accomplishment are the cases listed in the Annex II of Directive ROHS) (see figure 14).
139.- Select interconnection technologies that do not use lead (Pb).	Reduce the environmental impact associated to the end product's manufacture processes.	Lead-Tin compound is usually used for soldering electrical and electronic components to a Printed Circuit Board (PCB). Lead is a heavy metal considered an health and environmental hazard. In accordance with the Directive ROHS the use of Lead in soldering will be phased out by no later than 1 January of 2007 (see figure 14). Tin-Silver compound can be an alternative used in THM, SMT, Flip-Chip and TAB technologies. Few interconnection technologies are available that avoid the use of lead entirely, for example: Wire Bonding and Electrically Conducting Adhesive (see figures 19 and 20).

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Ecodesign & LCA Practical Application at Lear Corporation

5.1. INTRODUCTION

The objective of this chapter is to show the results obtained by the practical application of DfE and LCA Methodologies at Lear Automotive (EEDS) Spain S.L. (Electrical and Electronic Division) and the actual problems found during its implementation. The analysis of these methodologies, the case studies and the projects co-ordination has been conducted by the European Technological Center, placed in Valls.

Although the DfE methodology explained in the references books or manuals is easy to understand, its actual application in a real product or process could be difficult due to the following problems:

Method:

- There are not available specific DfE guidelines for all the materials or processes used in a real case study.
- The design teams usually do not have the required knowledge of environmental topics to apply directly the DfE Methodology. So, the development of easy to apply and easy to understand checklists, environmental matrixes, etc. is needed to help them in the DfE application.
- In some cases it is needed to decide between opposite criterions presented in the general DfE Guidelines (for example decision between the use or not of a lighter material with a high-energy consumption during its manufacturing process). To decide between the different options it is needed the assistance of a LCA "expert" and the use of a LCA software (analysis of all the life cycle steps –manufacturing, transport, use, recycling, etc.-).
- There are not standard methods to prioritise the different environmentally friendly options.

Information about the product:

- It is not easy to identify the major environmental loads associated with the products (eg. lack of information about recovery options, about hazardous materials content in the supplied components, etc.).
- Lack of environmental information to decide between raw materials options and to identify the best material for a specific component (e.g. best plastic considering environmental and quality requirements, etc.).
- Difficulties in the definition of the best end-of-life scenario for long life products (e.g. car components with a ten years expected lifetime). It is difficult to predict the Best Available Technologies in the future (e.g. waste treatments, recycling processes, etc.).

Company organisation:

- Environmental improvements have to be compatible with other company targets (cost, reliability, manufacturability, logistics, etc.).
- The DfE implementation requires the involvement of other company departments (e.g. Purchasing Dept., EHS Dept.; Design Teams, etc.), which could have different strategies and objectives.

Market and external topics:

- Narrow margin for the re-design (e.g. strict customer specifications about product characteristics, durability, dimensions, etc.).
- The DfE methodology is not standardised at an international level (different approaches).
- The recycling market structures are not developed yet for some materials.
- Externalities cost are not considered in the final product price (eg. collection cost, end-of-life treatment, etc.). In some cases, an environmentally friendly product could be more expensive than a pollutant one.

5.2. COMPANY OVERVIEW

Lear Corporation product portfolio covers all major interior systems: seat systems, overhead systems headliners, door panel systems, flooring & acoustics systems, instrument panels, electrical & electronic distribution systems, and electric motors. For more detailed information about the company, visit our web at www.lear.com.

Lear Automotive (EEDS) Spain S.L core business is the design, production and selling of Electrical and Electronic Distribution Systems (EEDS). The company product portfolio includes among others: junction boxes, terminals & connectors, electronic devices, switches as the main runner lines. These products include all the electrical car system as it is showed in figure 33.

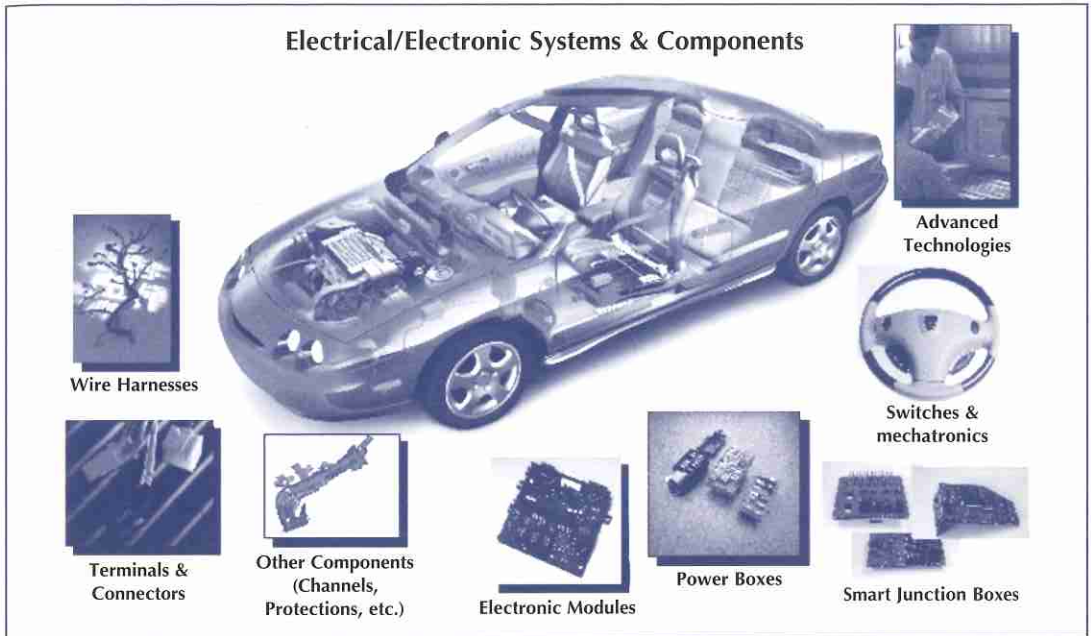



Figure 33. Products designed and manufactured at Lear Automotive EEDS Spain SL.

The final objective of Lear Corporation Environmental, Health and Safety Policy (EH&S) (figure 34) is to reduce as much as possible the environmental impact associated to its processes and products.




LEAR CORPORATION


Environmental, Health and Safety Policy

"Lear Corporation is dedicated to environmental protection, employee health and safety, regulatory compliance, and pollution prevention through a strategy of continual improvement and teamwork."

The foundation for achieving our commitment is based upon:

- Striving for the prevention of pollution and the elimination of health and safety hazards by maintaining environmental, health, and safety management as core values;
- Providing leadership for environmental, health, and safety improvement through management example and employee involvement and empowerment; and
- Developing and utilizing environmentally acceptable, safe, and efficient production methods and processes.


Robert J. May
Chief Environmental Officer


Robert J. Bruster
Chief Operating Officer



James W. Strohmeier
Chief Financial Officer



Figure 34. Lear Corporation environmental, health and safety policy

Following this Policy, all the manufacturing plants in Spain are certified by ISO-14001 Standard and a holistic approach was implemented to reduce as much as possible the environmental impact associated with our processes and products.

The European Technological Center (ETC) (figure 35) was created in Valls (Spain) in 1997. Its main mission is to become a creative centre, generating new ideas and fostering the integration of new technologies in new products and processes, checking their industrial feasibility, reliability and environmental impact.



Figure 35. Picture showing the ETC building at Valls-Tarragona (Spain)

Applied Research & Technological Development Department

Its main objectives are focused on different Technological Research areas that are directly related to our core products, the Electric & Electronic Distribution systems and specially those elements for which Lear Corporation in Valls is Center of Excellence world-wide. These technological areas are related to materials, joining technologies, Printed Circuit Boards substrates, reliability, advanced EEDS architectures and systems (eg. 42 volts), process development and environment.

The major environmental activities developed at the ETC are the following:

1. Support to the EH&S department in the ISO-14001 certification.
2. Study and application of Life Cycle Assessment methodology to LEED's products and processes. Identification of the major environmental impacts associated to them considering their life cycle.
3. Obtain accurate environmental information about supplied components and materials (hazardous material use, etc.).

4. Development and application of Design for Environment (DfE) methodology to LEED's products.
5. DfE implantation in the Design Departments (use of a LEED DfE Checklist in the normal project development process).
6. DfE practical cases. Application of the DfE Guidelines to actual products and developing of new environmental-friendly prototypes (i.e. "Green" ASJB project).
7. Favour the use of recycled materials in LEED products (material specifications, quality requirements, etc.).
8. Customer and legislative requirements monitoring (e.g. hazardous substances content, recycled material content, European Commission Draft Directives, etc.).
9. Best Available Technologies monitoring, specially those that could be used to recover/recycle our products.
10. Environmental Projects with suppliers and customers. In some cases these projects are included in the THE FIFTH FRAMEWORK PROGRAMME of the European Commission (e.g. grEEEn project).

The activities directly related with LCA&DfE are deeply explained in the following points 5.3 and 5.4.

5.3. APPLICATION OF LIFE CYCLE ASSESSMENT TO OUR PRODUCTS AND PROCESSES.

The Life Cycle Assessment Methodology allows the definition of the life cycle environmental profile of a product or process identifying and quantifying the aspects with a greater environmental impact. This analysis covers from raw materials extraction to product's final disposal, including manufacturing process, transport, packaging, etc.

Nowadays, the following LCA case studies were developed at the ETC:

- a) Three Electrical and Electronic Distribution Systems used in commercial cars.
- b) Three Power Distribution Junction Boxes (a passive box, a "smart" box with electronic modules and an advanced prototype with a high percentage of electronic components).
- c) Wire manufacturing process. Simulation of two PVC and three PP wire formulations.
- d) Printed Circuit Boards Manufacturing Process.
- e) Raw materials comparison. Comparison of three different plastics and six metallic alloys.
- f) Simulation of the car use step (impact of our products during car use considering their weight).
- g) Streamlined LCA of a dashboard and its wire-harness.

The complexity of LEED's products (high number of components and materials) is showed in the figure 36, which shows the material content of a typical wire-harness.

	Materials	Percentage of total mass
Boxes	PBT	1.95
	PA	0.90
Channels	PA	0.61
	PBT	1.86
	PP	5.85
Metallic channels	Steel	2.77
Terminals	CuZn30	0.57
	CuZn15	0.02
	CuSn4	0.50
	CuFe2	1.85
	CuNi9Sn2	0.03
	CuNiSi	0.23
Connectors	PBT	8.20
	PA	1.08
	PP	0.09
Grommets/rubbers	Rubber	4.89
Overmoldings	PU	0.43
Tubes	PE	0.31
	PP	0.17
	PVC	0.49
Tapes	PET	0.23
	Polyester	2.12
	Paper	0.06
	PVC	1.12
Straps/clips	PA	1.34
Fuses	Copper	0.11
	PC	0.18
	Others	0.07
Solder	Sn/Pb	0.03
Plastic bags	PE	1.57
Labels	Paper	0.13
	PE	0.01
Wire	PVC	18,0
	Copper	42,1
Others	Steel	0.15
TOTAL		100.00

Figure 36. Materials used in a high range vehicle Wire-harness (Electrical & Electronic Distribution System)

Because of the lack of accurate information about end-of-life processes (e.g. car shredding processes, recycling recovery rates, etc.) and the great logistic and time required to obtain information about second or third tier suppliers, the systems boundaries of the studies were drawn from direct suppliers to LEAR-plant gate. The other steps (raw material acquisition, end-of-life scenario, etc.) were simulated with bibliographic data.

The two first LCA studies (an EEDS and a passive box) were done in collaboration with the University Rovira i Virgili (Tarragona-Spain). These studies gave us the opportunity

to practice with the methodology and to solve the problems associated with its real application.

A standard procedure was drawn up to conduct internally the rest of LCA studies. A person from each department was included in the LCA Team, which participated in periodical meetings during the LCA project development. Standards forms were also included in this procedure for information interchange between the LCA Team members.

The steps followed in the development of the LCA studies were:

- a) Selection of the most representative products or processes.
- b) Goal and Scope definition.
- c) Process analysis (division in sub-processes, input/outputs identification, etc.).
- d) Information gathering (from suppliers and in-house process analysis).
- e) Input of this information in the LCA software (environmental loads allocated according to the function unit defined in step b).
- f) Inventory and Impact Assessment calculation using the SIMAPRO model (from PRé Consultants).
- g) Results analysis and validation (Interpretation Step).
- h) Results presentation to the involved staff.

The following flow-chart (figure 37) shows the different steps, the main points to consider in each step and the departments to be involved.

The major contributors to the product/process environmental impacts were detected in the Interpretation phase. Some examples are given hereafter:

- Significant contribution of wire in total wire-harness environmental impact due to its weight (material use).
- Importance of electricity for cooling systems in total plant energy consumption.
- Important effect of lead-based stabiliser in PVC wire formulation.
- Important effect of brominated flame retardants in PP wire formulation.
- Significant contribution of Integrated Circuits in Smart Junction Boxes impact, due to the energy requirements during their manufacturing step.
- Contribution of lead soldering in total Junction Boxes impact.
- Contribution of copper content in Printed Circuit Boards impact.
- Relevant effect of total weight in car use phase (product transportation in the car's life).

These results allowed the definition of Environment targets that were quantified in order to evaluate their accomplishment. Also, they helped us to define new research projects to reduce these impacts such as lead free solders, alternative welding methods, PVC wire substitutes and system efficiency.

External presentations about LEED environmental activities and results were done in different Technical Meetings, such as in the SAE International Congress and Exposition, Detroit, Michigan, March, 1999 or in the SETAC 6th. LCA Case Studies Symposium Presentation Summaries, Brussels, December 1998.

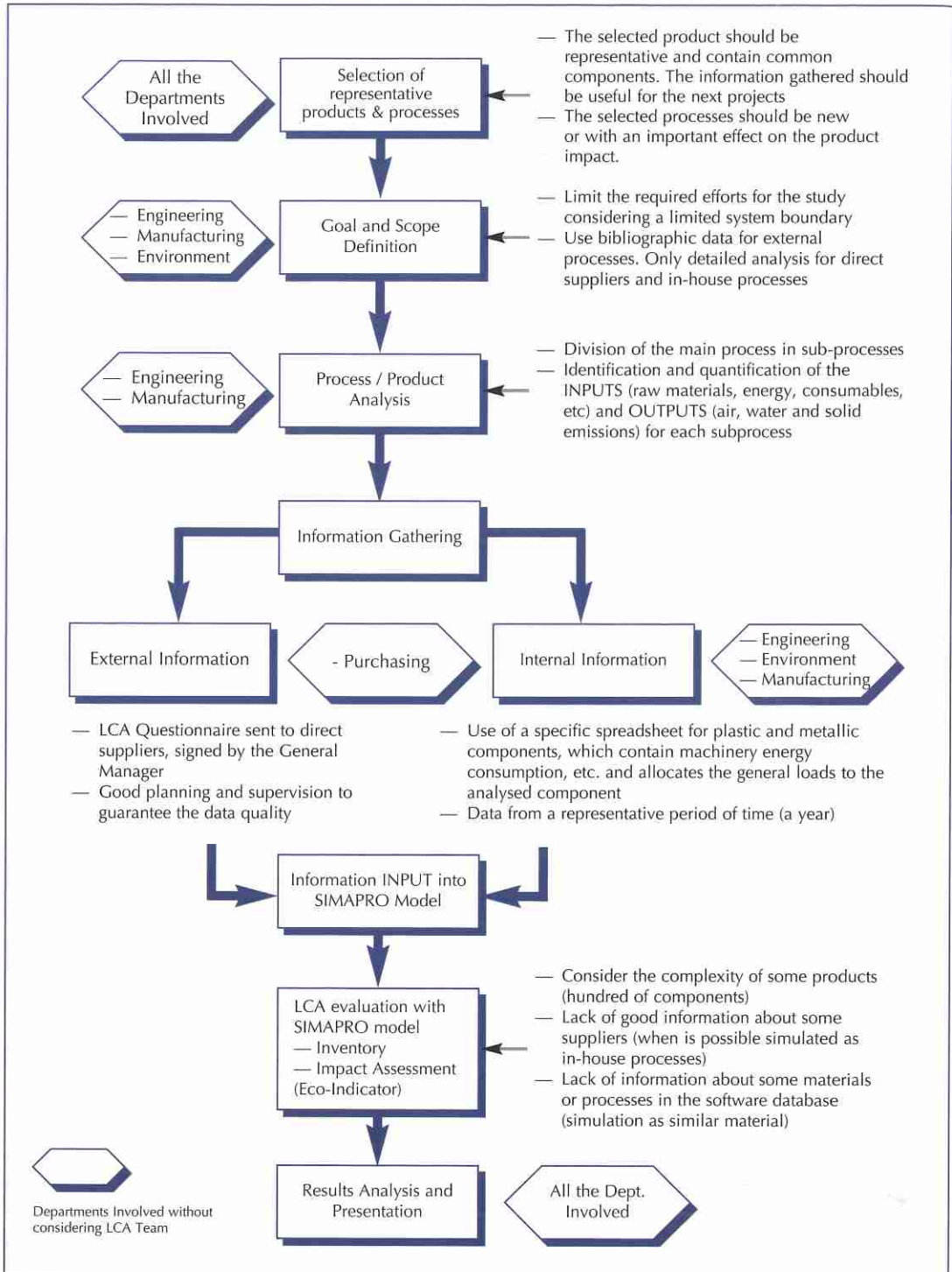


Figure 37. LCA steps and departments involved

5.4. DESIGN FOR ENVIRONMENT APPLICATION AND IMPLEMENTATION

The best way to reduce the environmental impacts of processes and products is avoiding them in the design step, where the major improvements could be achieved with the lowest cost. This is the reason why the company is implementing the DfE methodology in the product development step. The phases followed at LEED to this implementation were:

- Methodology study through bibliographic researches.
- Case studies developed in collaboration with external experts. Application of this methodology to real products.
- Definition of a DfE Team, with a representative of each Design Department (architecture, junction boxes (plastics and PCB), electronics and terminal & connectors).
- Development of a DfE Checklist that includes all the information gathered in the previous steps. The draft document was revised by the DfE Team members, which explained and presented the Checklist to the rest of the Department staff.
- Inclusion of the DfE Checklist as a step of the Lear Product Management Process (LPMP) procedure.
- Development of a DfE practical case study (application of the DfE Guidelines to a real product obtaining a more environmental friendly prototype).

The DfE case studies developed at the ETC are presented briefly hereafter:

5.4.1. DfE application to a Passive Junction Box

With the assistance of the University Rovira i Virgili (Tarragona-Spain), a study about the Recyclability performance of a passive junction box at the end of its useful life was carried out and Design for Environment Guidelines was deployed to improve this concept. This study involved the following tasks:

- 1) Bibliographic search on several subjects, such as End-of-Life Vehicles, Materials Recovery (Plastic and Metals), Electronic Components Recovery and Design for the Environment Methodology.
- 2) Elaboration of Generic DfE Guidelines.
- 3) Elaboration of specific DfE Guidelines applied to the analysed passive box.
- 4) Analysis of recovery options for the passive box end-of-life scenario.

All the information gathered was used to develop some general Guides containing suggestions for the designers on subjects such as materials selection, production, transport & distribution, use and end of life.

The application of these general guides to a specific product such as the passive junction box resulted in the generation of specific Guides for this product, which contain suggestions for each of the materials used in its fabrication and for each of its life cycle stages. These DfE guides were distributed and presented to the design teams.

Some favourable and unfavourable points of the passive junction box design are showed in figure 38.

FAVOURABLE	UNFAVOURABLE
Components and materials	
Standard identification of the plastic parts by molding	Employment of lead as PVC stabiliser in the wire harness
The used plastics are separable by density	Two types of plastics (PA and PP) with high content of filler material
Non external painting	A metallic insert (non ferric metal) in the plastic part
Majority employment of a kind of metal (copper)	Terminals tinplated with Sn/Pb
Production Phase	
Accomplishment with the forbidden material list	Use of lead in the PCB welding process
Transportation and distribution	
Implementation of returnable / recyclable packaging policy	Long distance to some suppliers
Use of product	
Easy accessibility to the fuses (item with major repair frequency)	High weight of the bracket (ferric part joining the box to the car)
PCB and other components protected against external damage	Not easy access to the relays (difficult substitution and maintenance)
End of life	
Type of fasteners (snap fit type)	High number of fasteners (difficulty in opening the box)
Easy separation of the junction box from the car (only joined through two screws to the bracket)	Difficult extraction of the connectors (for separation of the wire harness from the junction box)
—	Difficult access to the junction box

Figure 38. Favourable an unfavourable design aspects of a passive junction box

The analysis of the current recovery methods showed the disadvantages of recovering the box at its end-of-life scenario due to the expensive extraction from the car, storage, transport and cleaning processes and the low prices of the recycled materials. Despite these facts the company is trying to increase the potential recyclability of its products to satisfy the increasing customer and legal demands on this subject.

5.4.2. DfE application to Wire-harness Recyclability

The objective of this project was to develop design guidelines for wire harnesses, junction boxes and integrated products that will, if they are applied, increase the recyclability of the product under economical boundaries.

The steps of the project were the followings:

- a. End of Life Scenario: Investigate the nowadays End of Life Scenario of cars in the different European countries. How does this scenario handle Lear's products (wire Harnesses, electronics integrated products) and which changes can be expected in the future. This future scenario includes trends in legislation as well as customer points of view.
- b. Disassembling of Cars: The disassembly process is the first process in the process chain for handling end of life vehicles. It is one of the key processes if material gets recycled or not. The manual disassembly process is a major cost factor and the products have to be designed in a way that not much disassembly work is required. It was investigated which designs support the disassembly process and which not, especially for wire harnesses (EDS), junction boxes (electronics) and integrated products.
- c. Separation Technologies: It is required a good separation between the different materials in order to facilitate their recycling and increase the value of the recycled product. So the new developments in processing mixed plastic scrap were analysed.
- d. Material Re-processing: Recovered material from separation has to be re-processed to get a material that can be used in manufacturing processes again. A brief review of the different technologies was done to determine the recycling level of the material gained from the separation process.
- e. Guidelines for design engineers were created from the findings above for wire harnesses, junction boxes and integrated products, considering the limitations of the downstream steps (separation, reprocessing, etc.).

5.4.3. DfE application to Electronic Devices (Smart Junction Boxes)

This project, in collaboration with the University Rovira i Virgili, was done to test the use of the EIME DfE software (from Ecobilan) in three electronics devices (two commercial products and one advanced prototype). These products are showed in the following figure:



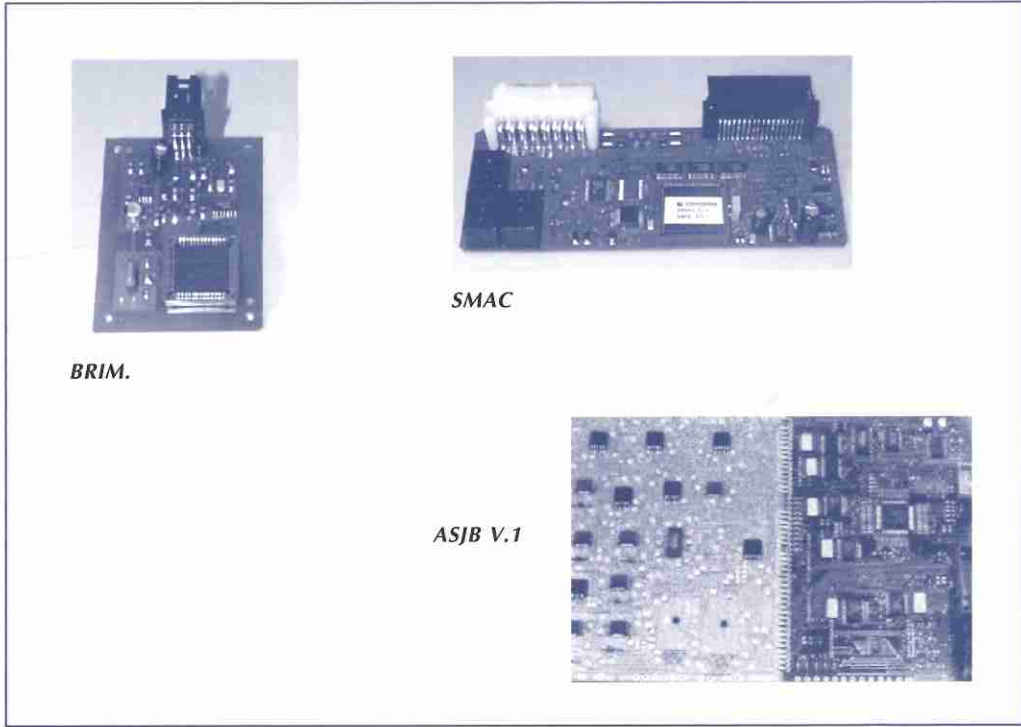


Figure 39. BRIM, SMAC and ASJB v.1 products

This tool allows the analysis of different designs from an environmental point of view, the analysis of their recyclability and the draw of Design Guidelines for these components.

As project result, an environmental profile of the three products was done, showing for example the major contribution of the Integrated Circuits to the total environmental impact. Also, General Design for Environmental Guidelines were drawn for electronic products applying them to these specific devices.

5.4.4. DfE Checklist development

All the DfE Guidelines developed or gathered during the bibliographic research and previous studies were joined in a unique checklist-form document. The objective was to develop a useful and easy to apply document that includes all the DfE information. This document was analysed for each design department (electronic, EEDS systems, terminal & connectors, boxes and PCB) and some comments from them were included in the final version. To facilitate this communication a person from each department were defined as DfE team member.

The DfE Checklist document should be filled in as a step of the LPMP (Lear Product Management Process) procedure that has to be done for any new project started at the Company.

5.4.5. DfE practical cases ("Green" ASJB)

A real DfE case application was done, selecting the Advanced Smart Junction Box prototype as the product to be improved from an environmental point of view. This new environmental friendly prototype was developed and prototyped considering the available "green" technologies and modifying the design considering the DfE Guidelines and LCA results obtained in the previous steps. The prototype passed all the functionality test in the Laboratory. Future tests should be done for specific application to commercial products.

The technical Green Issues Goals for this project were the following:

- Use of electronic components with low environmental impact (no brominated flame retardants, no hazardous materials, etc.). Contacts with different suppliers were done, but they did not have commercial products without brominated flame retardants in their encapsulation (these kind of products were in a developing step). However, useful information about material content and substances not used on their components was gathered giving us a better knowledge about them.
- Use of printed circuit board (PCB) substrate without brominated flame retardants. Collaboration with our major PCB supplier was carried out and a new substrate formulation was developed. The new substrate halogen free, which eliminates the risk of hazardous substances emission if the product was incinerated, was used in the new design. A reduction of the 95 % was achieved in the total bromide content.
- Electronic components integration. The design was changed in order to integrate the needed functions in less Integrated Circuits (IC). The LCA studies showed that these components have an important environmental impact due to the energy needed for their manufacture. The reduction of IC number was achieved without affecting Junction Box reliability. This integration allowed also the PCB surface optimisation.
- PCB surface optimisation/copper content reduction. The LCA studies showed the importance of the copper content in the total PCB environmental impact. So, less copper was used in the new design, decreasing the copper thickness (from 400 to 210 microns) and reducing the PCB surface. A copper weight reduction of 54 % was achieved.
- Use of Lead free solder. The use of alternative welding technologies (i.e. SnAg solder) reduced the lead content in a 99 % facilitating the possible recovery/disposal treatments at its end-of-life.
- Use of post consumer recycled plastic. Two parallel projects were carried out to analyse the possible use of recycled material for the plastic covers (PA) and isolator piece (PP). In the final prototype the isolator was manufactured using 100 % recycled PP.
- Total Weight reduction. The electronic component integration and the reduction in the copper content make possible the reduction of the total weight. This reduction was about 19 %.
- Facilitate the disassembly of components with hazardous substances placing them in accessible places.

The "green" version was analysed using the SIMAPRO software (Eco-Indicator 95 method for Impact Assessment). The environmental impact percentage reduction was the following:

- Design/Manufacturing Step: 46 %.
- Car use Step (total weight reduction): 19 % (the car use step represents a 30 % of the total box impact considering the original version).
- Total Impact Reduction: 38 %.

The end-of-life scenario was not analysed because of the lack of good information about this step. However this step would be favourable for the "green" version due to its lower hazardous material content.

In the following figure it is showed the differences between the two versions (top and bottom sides). On the right-hand it is showed the "green" version.

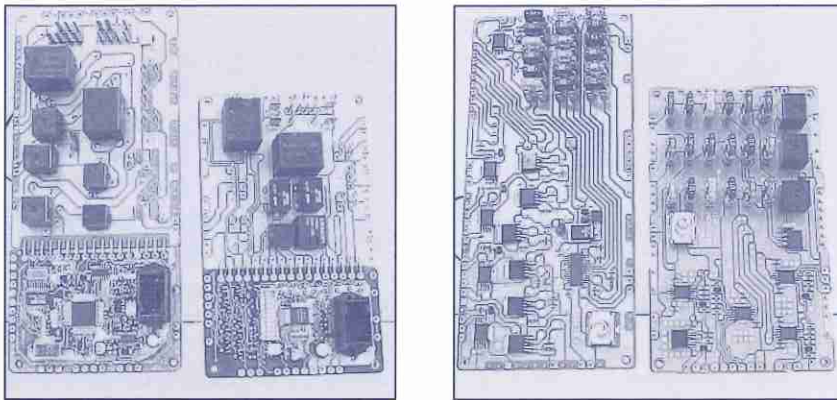


Figure 40. Differences between the two ASJB versions

5.5. CONCLUSIONS

The application of the LCA methodology allows us the identification and the quantification of the major impacts associated with our products and processes. These major impacts can be reduced in the design step using the DfE methodology and the improvement achieved can be monitored using Impact indicators.

The combination of the two methodologies is a powerful tool for a continuous improvement of the present and future products, anticipating the company to future legislative and customer requirements.

Environmental Trends in the Electrical-Electronic and the Automobile Industry

6.1. INTRODUCTION

World-wide, two key trends are driving the electrical and electronic industry and also the automobile industry to make important environmental changes in their organisations: regulation and cost. With internal environmental costs increasing, efforts to prevent pollution and waste are becoming essential. Controlling and reducing internal environmental costs, as well as minimising overall environmental impact, has become critical for holding onto a competitive position.

6.2. NEW REGULATIONS IN THE ELECTRICAL-ELECTRONIC AND THE AUTOMOBILE INDUSTRY

Government agencies have mainly, until recently, focused on end-of-pipe regulatory solutions rather than a proactive effort aimed at pollution prevention and source reduction. Consequently, industry has responded with ineffective and fragmental remediation programmes since today, fixing environmental problems rather than preventing them.

Electrical and electronic equipment and vehicles are two of the major focus of Extended Producer Responsibilities (EPR) policies which are being implemented by government agencies in different countries around the world. In this way, the European Commission is developing various directives for the electrical and electronic sector (Directive WEEE, Directive ROHS and Directive EEE) and has implemented one relative to End-of-life Vehicles (Directive 2000/53/EC).

In accordance with the future environmental legislation, the costs for collection, treatment, recovery and environmentally sound disposal of waste of electrical and electronic equipment from private households and also of end-of-life vehicles will bear on their producers (Extended Producer Responsibility, EPR).

Extended Producer Responsibility: can be defined as the extension of the responsibility of producers for the environmental impacts of their products to the entire product life cycle, and especially for their take-back, recycling and disposal.

EPR shifts the responsibility for discarded materials from local government to private industry, incorporating the costs of product end-of-life treatment into product price.

Most of the environmental problems generated by end-of-life vehicles and also by waste from electrical and electronic equipment derive from the fact that they are not designed and produced with a view to their dismantling, recycling and recovery. Obviously, any environmental design consideration that increases the amount of value that can be recovered from vehicles and electrical and electronic equipment at their end-of-life will result in an improvement of their environmental behaviour and will also result in an important source of cost savings for manufacturers.

6.3. ENVIRONMENTAL ACTIVITIES IN THE ELECTRICAL-ELECTRONIC AND IN THE AUTOMOBILE INDUSTRY

In the following section there are briefly presented some environmental activities and initiatives carried out by electrical-electronic and automobile industries. This section is mainly focused on a European context.

Electrical-Electronic industry:

Hereafter are presented some environmental activities in the electrical and electronic industry ([5] Microelectronics and Computer Technology Corporation (MCC) **Activities in Europe and Japan**, 1998):

- Implementation of electrical and electronic waste take-back programmes covering: disassembly, material recovery, recycling, assessing markets for used/recycled parts and components, etc. These initiatives are currently implementing in co-operation between governments and companies, for example: European Commission environmental policy in WEEE, activities carried out by the UK Industry Council for Electronic Equipment Recycling (ICER), activities carried out by the German trade association BDE, activities carried out by the Japanese Ministry of International Trade Industry (MITI), activities carried out by the UMEAK (UK Microelectronics Environmental Advisory Committee), etc.
- Solution of technical, infrastructural and economical problems related to electrical and electronic equipment valorisation, for example: CARE Vision 2000 project, Eureka project, Green-TV project, projects and studies carried out by MCC, etc.
- Development and implementation of internal and external methodologies of measuring electrical and electronic equipments environmental performance, for example: the software Environmental Information and Management Explorer (EIME). This tool, developed by Ecobilan Group (PricewaterhouseCoopers) and five industrial partners: IBM, Alcatel, Legrand, Schneider and Thomson, can be defined as an improved LCA tool specialised in the electrical and electronic sector.
- Replacement of lead-based solders with conductive adhesives and intrinsically conductive polymers for surface mount technologies (SMT). In this issue research is being carried out by: NORAD (a joint project consisting of 22 Finnish, Danish,

Swedish and Norwegian companies), Helsinki University of Technology, VTT (Technical Research Centre of Finland), IVF (The Swedish Institute of Production Engineering Research), Fraunhofer Institute, etc.

- Development of valorisation support tools and strategies, for example: disassembly techniques, ecodesign tools, inclusion of an identification unit (green port) in electrical and electronic equipment containing and registering data necessary for its valorisation, etc.
- Elaboration of electrical and electronic environmental design manuals and software that analyse equipment level of valorisation (for example: Siemens, Philips, etc.).
- Development of databases containing information on electrical and electronic product composition, for example: activities carried out by the IVF (The Swedish Institute of Production Engineering Research), etc.
- Implementation of LCA (Life Cycle Assessment) methodology in order to determine the environmental impact of electrical and electronic equipments manufactured and identify environmental improvement options, for example: in Nokia Telecommunications, Lear Corporation, etc.
- Implementation of DfE (Design for the Environment) methodology in order to improve the environmental behaviour of electrical and electronic equipments manufactured, for example: in Lear Corporation, activities carried out in the U.S. EPA DfE PWB project, etc.
- Development of more environmentally sound materials, parts, components and manufacture processes for electrical and electronic equipments, for example: Siemens has developed an halogen-free PCB, NEC has developed a system for recycling liquid fluoride chemicals used as etchant in semiconductor production, NEC has also developed a technique to separate copper from PCBs, Fujitsu has developed a non CFC cleaning process, Toshiba has also developed a vapour-phase cleaning agent as a substitute for CFC-113 and chlorine-based cleaning agents, etc.
- Reduction of displays energy consumption, especially motivated by consumer demands (Several display manufacturers are currently working in this issue).

Automobile industry:

In this section there are described several initiatives in the form of environmental agreements, covenants or self-commitments at national level that have been set up by economic operators in certain countries around the world, in order to improve the environmental situation in relation to the management of end-of-life vehicles (ELVs). This information has been fully extracted from the Explanatory Memorandum of the [1] Directive 2000/53/EC on End-of-Life Vehicles.

a) Development at European level:

Germany: aims at a reduction of end-of-life vehicle disposal to 15% by 2002 and 5% by 2015. It will come into effect only after the complementary legislation is

adopted. German industry agreed to take back free of charge only end-of-life vehicles which are more than 12 years old, provided a number of other conditions.

Italy: aims at recovering 85% of vehicles weight by 2002 and 95% by 2010. FIAT has set up a system which allows for free of charge take-back of end-of-life vehicles.

France and Spain: aims at ensuring that, by 2002, new models may be reprocessed to generate final waste not exceeding 10% of the total vehicle weight.

Austria: aims at 80% recycling and 95% recovery, but it is not specified by which year these targets should be attained. It came into effect in January 1996 and covers an unlimited period of time. In Austria vehicle owners are entitled to free take-back only if a new vehicle is purchased at the same time.

The Netherlands: agreed to re-use/recycle 86% by 2000. Legislation on the fee to be paid when a new vehicle is purchased is valid until January 1998. A take-back system has been created which is based on fees paid when the new vehicle is purchased and premiums paid to recyclers and which provide for a free of charge take-back scheme.

United Kingdom: aims at reducing the automobile shredder residues by 40% by 2002 and 80% by 2015. No date is included in this agreement.

Sweden: a take-back system has been created which is based on fees paid when the new vehicle is purchased and premiums paid to recyclers and which provide for a free of charge take-back scheme.

b) Development at international level:

End-of-life vehicles are also considered by the OECD (Organisation for Economic Co-operation and Development) as one of the priority areas for action in order to minimise waste. An OECD working group in this issue presented and discussed a report at an international Seminar held in Washington in March 1995. The measures proposed are very similar to those presented in the European End-of-life Vehicles Directive.

The US Environmental Protection Agency has identified the following strategies to promote the recycling of the plastic fractions of end-of-life vehicles: promote "design-for-dismantling" and "design for recycling", develop collection infrastructure; promote economical dismantling methods, particularly improving the systems for the identification of recyclable materials; encourage "fair" competition between raw materials and recycled materials. It is doubtful however how these strategies could achieve any results if not implemented via legislative measures.

The issue of recycling of end-of-life vehicles has also been considered a priority in Japan where, in 1990, a law for the promotion of use of recycled resources, applying in particular to automobile and household appliances industries, was passed. In addition, in October 1996 the Ministry for international trade and industry (MITI) drew up a set of quantified targets for the recycling of end-of-life vehicles (85% by 2002 and 95% by 2015). MITI also called for a drastic reduction of the use of lead in new vehicles.

6.4. MARKET TRENDS IN THE ELECTRICAL-ELECTRONIC AND IN THE AUTOMOBILE INDUSTRY

In the following section there are briefly presented some market trends in the electrical-electronic industry and in the automobile industry, especially influenced and motivated by the new environmental scenario expected in a near future.

Electrical-Electronic market trends:

The following information has been extracted from the [2] Kleijn R., Huppel G., McLaren J., Pesonen H., Steevens A., Vanakari E. and van der Wel H. (1999) **Electronic Consumer Goods case report**. A CHAINET Case Study Report, 2nd draft. In this publication, based on an ITEC document, electrical and electronic industry is defined as a dynamic and fast moving field, especially characterised by advancing technology and price reduction to support increasing demand.

The main market trends identified are the following:

- Component and product miniaturisation.
- Reduction in the use of precious metals within circuit boards and IC chips.
- Continuous dramatic growth of memory size (doubling chip storage ability every 18 months, for the same price).
- New battery technology will support longer operating times for mobile products (Lithium Ion technology will become prevalent in small portable electronics, and is likely to be superseded by Lithium Polymer).
- Operating time of portable products will be increased through using lower power technologies (for example: display screens, logic circuits, etc) and power management.
- Disposable electronics will continue to expand for applications such as talking Christmas cards and more sophisticated Tamagotchi-type toys.
- Cathode Ray tubes will probably remain dominant screen technology for the TV and desktop computer market. Desktop market share is likely to be penetrated by active matrix liquid crystal display technology, and the possibly plasma display panels which will be used primarily for larger TV screens. Liquid crystal displays will largely remain the dominant technology for small screen applications.
- Applications of image recognition technology is likely to enter into domestic products markets (full-body video games interface, virtual reality model generation from hand-held video, gesture driven interface for window operating system, etc).
- Speech recognition technology requires further progress. This technology is now being introduced for voice dialling in the cellular phone sector.
- Product functions will continue to converge within consumer products following the major convergence trend between information technology (IT) and

communication sectors, for example: continued development of personal digital assistant functionality with mobile phone technology.

Automobile environmental market trends:

Progress in the environmental performance of automobiles has been driven by legislation rather than by market demand or pressure. Nowadays, not many people are prepared to pay more for a "greener vehicle". However, the increasing environmental sensibility of people is going to play an important role in a near future in the environmental performance of automobiles.

Hereafter are presented some classical key elements necessary towards a more sustainable transportation. This information has been extracted from the [3] Kuhndt M., Bilitewski B., Krewitt W., Niederle W. (1999) **Towards Reduced Environmental Burden of Mobility: Improving the Automobile Life Cycle**. A CHAINET Case Study Report. Draft February.

Key elements towards a more sustainable transportation:

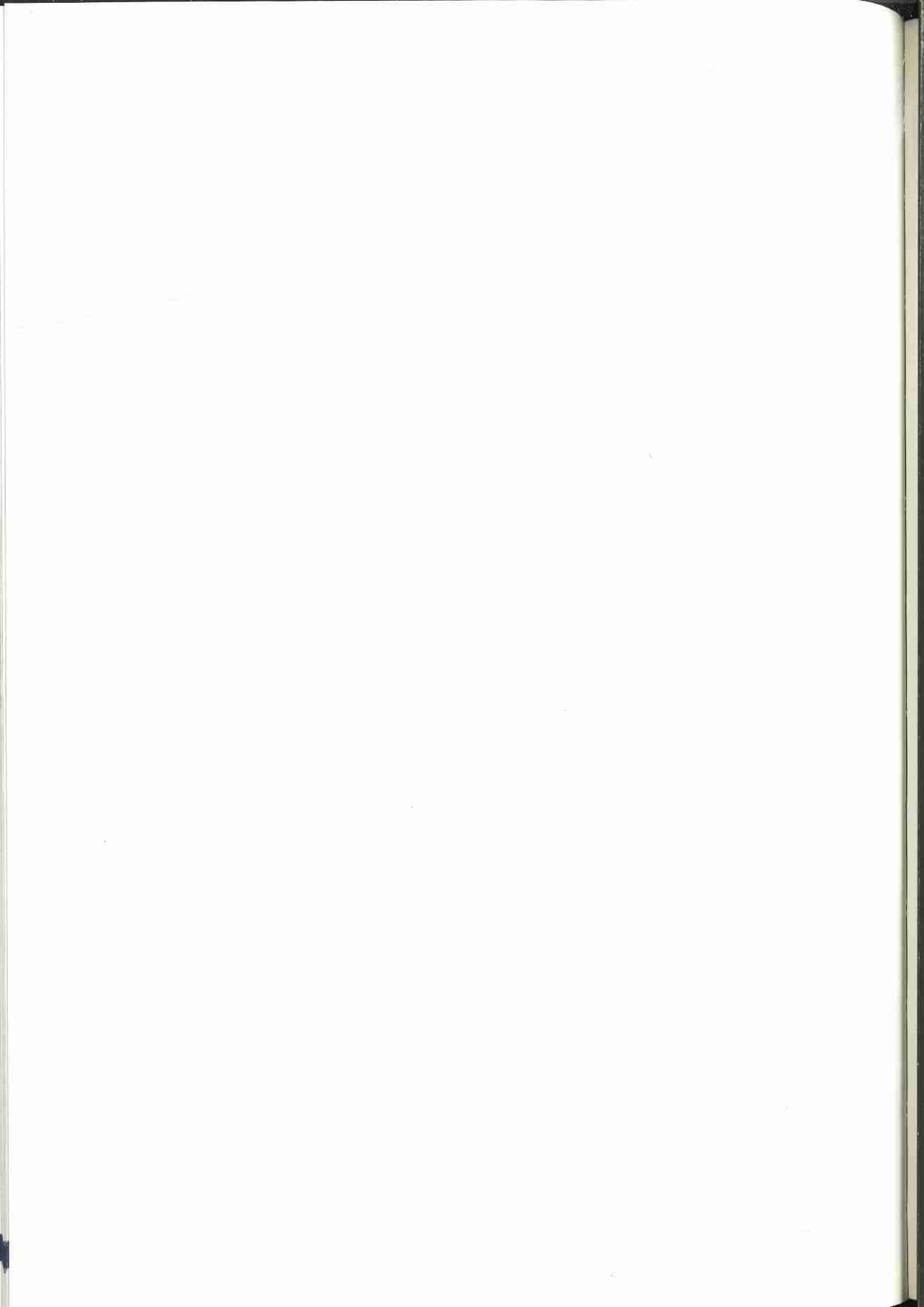
- Vehicles with high recyclable capabilities (including modular construction).
- Vehicles made of lighter weight materials: plastic, aluminium, copper and magnesium (including also the reduction of the amount of materials used).
- Vehicles with more aerodynamic shapes.
- Reduction of fuel consumption during the vehicle use.
- Lower and harmfulness emissions during vehicle use (due to legislative pressure).
- Alternative fuels (liquefied petroleum gas, natural gas, etc.)
- Alternative vehicles (electrical vehicles and hybrid vehicles).
- Development of procedures to recover factory waste.
- Development of new technologies to facilitate the use of recycled materials.
- Design vehicles with the concept "recycling" in mind.
- Increase the use of recycled materials.
- Establishment of recycling infrastructure in a co-operative way.
- Design and specify components which can be made out of recycled materials.
- Set up pilot disassembly facilities.
- Development of vehicle disassembly manuals.
- Establishment of corporate environmental policies that encourage chain management.
- Extension of the responsibility of automakers for the environmental impacts of their vehicles entire life cycle, and especially for their take-back, recycling and disposal.

Following these trends, most of the car manufacturers have developed Ecodesign Guidelines to improve the recyclability and recoverability potential of their products. Some examples are given hereafter:

- Design for Environment (Saab).
- Worldwide Design Standard (Ford).
- Design for Recycling (PSA/Renault).
- Environmentally Compatible Product Design (BMW).
- Environmental Guidelines for Engineers (Volvo).
- Recyclability, Recoverability Guidelines (GM).

6.5. REFERENCES:

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4. Lindhqvist T., Lifset R. (1997) **What's in a Name: Producer or Product Responsibility?**, Journal of Industrial Ecology Vol. 1 Nr.2.
5. MCC, Microelectronics and Computer Technology Corporation (1998) **Activities in Europe and Japan**.
6. MCC, an Industry-led Study Sponsored in part by the United States Department of Energy and coordinated by the Microelectronics and Computer Technology Corporation, MCC (1993) **Environmental Consciousness: A strategic Competitiveness Issue for the Electronics and Computer Industry**, United States.
7. Proposal for a Directive of the European Parliament and of the Council on **Waste Electrical and Electronic Equipment** (Directive WEEE) and Proposal for a Directive of the European Parliament and of the Council on the **restriction of the use of certain hazardous substances in electrical and electronic equipment** (Directive ROHS) (amendments adopted before August 2001 included). The European Commission, Environment Directorate-General, Brussels (Belgium).



Organisations

In the following section there is presented a list of addresses of some organisations world-wide evolved with this book topic (LCA, Ecodesign, electrical and electronic equipment, etc.). These contacts can be very useful to find further environmental specific information.

AGA Group (Environmental Management and Analysis Group)

University Rovira i Virgili (URV)
Technical School for Chemical Engineering (ETSEQ)
Avinguda dels Països Catalans, 26
Campus Sescelades
E-43007 Tarragona, Spain
AGA@etseq.urv.es, fcastell@etseq.urv.es, jrodrigo@stq.urv.es
http://www.etse.urv.es/DEQ/web_cat/recerca/aga/

American Plastics Council

1275 K Street NW
Suite 400
Washington, DC 20005
1-800-2-HELP-90, USA
<http://www.ameriplas.org/>

ANIEL (Spanish Association of Electronic and Telecommunications Industries)

Príncipe de Vergara, 74-4
E-28006 Madrid, Spain
aniel@aniel.es
<http://www.aniel.es/>

Association of Plastic Manufacturers in Europe (APME)

<http://www.apme.org/>

Austrian Ecodesign

TU Wien, Institut für Allgemeine Maschinenlehre
Abteilung Konstruktionslehre, Getreidemarkt, 9
A-1060 Viena, Austria
l-ecodesign@iuinfo.tuwien.at
wimmer@ecodesign.at/ecodesign
<http://www.ecodesign.at/ecodesign>

Centre for Design at Royal Melbourne Institute of Technology (RMIT)

GPO Box 2476V Melbourne
Victoria, 3001, Australia
cfid@rmit.edu.au
d.koel@rmit.edu.au
<http://www.cfd.rmit.edu.au>

Centre for Sustainable Design

Faculty of Design
The Surrey Institute of Art & Design
Falkner Road
Farnham – Surrey GU9 7DS, UK
cfsd@surrat.ac.uk
<http://www.cfsd.org.uk/>

Chalmers University of Technology

Institut of Physical Resource Theory
S-41292 Göteborg, Sweden
rt@fy.chalmers.se
<http://www.frt.fy.chalmers.se>

Consortium on Green Design and Manufacturing (CGDM)

University of Berkeley
Faculty of Mechanical Engineering
5145 Etcheverry Hall
Berkeley, CA 94720-1740, USA
psheng@euler.me.berkeley.edu
<http://greenmfg.me.berkeley.edu/green/Home/Index.html>

Design for Environment Research Group

Department of Mechanical Engineering, Design and Manufacture
Manchester Metropolitan University
John Dalton Building
Chester Street
Manchester M1 5GD, UK
S.J.Poole@mmu.ac.uk
<http://www.mech-eng.mmu.ac.uk/>

Electronics Tampere University of Technology

Tampere University of Technology
FIN-33101 Tampere, Finland
jukka.kaipainen@ele.tut.fi
<http://ele.tut.fi/>

European Comissions's Environment Directorate-General

European Commission
Rue de la Loi 200
B-1049 Brussels, Belgium
<http://europa.eu.int/comm/environment/>

European Environment Agency

Kongens Nytorv, 6
1050 Copenhagen, Denmark
info@eea.dk
http://eea.eu.int/

European Partners for the Environment (EPE)

Avenue Mounier, 83
B-1200 Woluwe
Brussels, Belgium
eupe@glo.be
http://www.epe.be

Federation of Finnish Electrical and Electronics Industry

P.O. Box 10 FIN-00131, Helsinki, Finland
name.surname@electroind.fi
http://www.electroind.fi

General Electric Plastics

http://www.ge.com/

Green Design Initiative - Carnegie Mellon University

Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213-3890, USA
hsm@andrew.cmu.edu
http://www.ce.cmu.edu/GreenDesign/index.html

IHOBE (Sociedad Pública Gestión Ambiental)

Gobierno Vasco
Departamento de Ordenación del Territorio, Vivienda y Medio Ambiente
C/ Ibáñez de Bilbao 28-8ª planta
E-48009 Bilbao, Spain
info@ihobe.es
http://www.ihobe.es

Institut de la Durée – The Product-Life Institute

18 Cemin Rieu, P.O. Box 3632
CH-1211 – Geneva 3, Switzerland
http://www.product-life.org

Institut for Product Development – IPU (Life Cycle Center)

Technical University of Denmark
Build 403, 2
2800 Lyngby, Denmark
ipuadm@ipv.dtu.dk
http://www.dtu.dk/ipu

Institut Zuverlässigkeit und Mikointegration (IZM)

Gustav-Meyer-Allee 25
Building 17, Staircase 2
D-13355 Berlin, Germany
griese@izm.fhg.de
<http://www.izm.fhg.de/>

Institute of Electrical and Electronics Engineers (IEEE)

(Electronics and the Environment Conference Proceedings)
334 Hoes Lane
Piscataway, NJ 08855-1331, USA
j.cerone@ieee.org
<http://www.ieee.org/>

Institute of Industrial Technology (TNO)

De Rondom 1
5612 AP Eindhoven, The Netherlands
info@ind.tno.nl
<http://www.ind.tno.nl/homepage.html>

Intelligent Systems and Modelling of Production Processes and Logistics for Enterprises (SIMPPLE)

Edif. Servei de Tecnologia Química – URV
Av. Països Catalans, s/n
E-43007 Tarragona, Spain
simpple@stq.urv.es
<http://www.stq.urv.es/simpple/>

International Electrotechnical Commission

<http://www.iec.ch/>

International Journal of Life Cycle Assessment

<http://www.ecomed.de/journals/lca/welcome.htm>

International Organization for Standardization (ISO)

<http://www.iso.ch>

Lear Automotive (EEDS) Spain, S.L.

Electrical and Electronic Division
European Technological Center
Carrer Fusters, s/n
Polígono Industrial, Planta 1
P.O. BOX 23
43800 Valls (Tarragona), Spain
jalonso0@lear.com
<http://www.lear.com>

Massachusetts Institute of Technology

Center for Technology, Policy and Industrial Development
77 Massachusetts Av., MIT Building E40-21
Cambridge MA 02139-4307, USA
<http://web.mit.edu/ctpid/www/>

Microelectronics and Computer Technology Corporation (MCC)

3500 West Balcones
Center Drive
Austin, TX 78759, USA
ask@mcc.com
<http://www.mcc.com>

Ministry of Environment - Government of Catalonia

Diagonal, 523-525
E - 08029 Barcelona, Spain
wsia@correu.gencat.es
<http://www.gencat.es/mediamb/>

Multi-lifecycle Engineering Research Center (MERC)

3400 GITC Building,
323 Martin Luther King Blvd.,
Newark, NJ, 07102, USA
caudill@admin.njit.edu
<http://www.njit.edu/MERC/>

O2

<http://www.o2.org/>

PricewaterhouseCoopers

Edificio Caja de Madrid
Avenida Diagonal, 640
E-08017 Barcelona, Spain
<http://www.pwcglobal.com/>
<http://www.pwcglobal.com/environment>

Society of Environmental Toxicology and Chemistry (SETAC)

SETAC-Europe
Av. E. Mounier 83 Box 3
1200 Brussels, Belgium
setac@ping.be
<http://www.setac.org/>

Swedish Institute of Production Engineering Research (IVF)

Argongatan 30
S-43153 Mölndal, Sweden
<http://www.ivf.se/>
<http://extra.ivf.se/dfee/>

TU Delft

Design for Sustainability Program
Subfaculty of Industrial Design Engineering
Jaffalaan 9
2628 BX Delft, The Netherlands
<http://www.io.tudelft.nl/research/dfs/index.html>

United Nations Environmental Programme (UNEP)

Working Group on Sustainable Product Development (SPD)
University of Amsterdam. J.H. van't Hoff Institute
Nieuwe Achtergracht 166
B-315, NL – 1018 WV Amsterdam, The Netherlands
unep@unep.frw.uva.nl
<http://unep.frw.uva.nl>

US Environmental Protection Agency (U.S. EPA)

<http://www.epa.gov/>
<http://www.epa.gov/dfe/>

VDI The Association of Engineers

VDI-Richtlinien Postfach 10 11 39
D-40002 Düsseldorf, Germany
<http://www.vdi.de/>

Xarxa Temàtica d'Anàlisi del Cicle de Vida

<http://www.gencat.es/mediamb/xarxaacv/acv.htm>

Ecotools

This chapter presents a list of ecotools (software and non-software) that can be used in ecodesign activities in order to analyse and improve the environmental performance of products, processes and activities. As it can be observed, there is a large number of ecotools available and the problem for users is to find the tool that serves their needs best. Most ecotools have not been developed for any specific industrial sector, however there can be found several specialised ecotools in the packaging, electronic and chemical areas.

The ecotools presented and briefly described in this section are classified under the following five categories:

- a) Life Cycle Inventory (LCI) ecotools: these tools provide a list of all the environmental aspects (emissions, waste, energy consumption, etc.) released and consumed during all the product, process or activity life cycle.
- b) Life Cycle Assessment (LCA) ecotools: these tools provide the environmental information (environmental aspects) classified and characterised under some potential environmental impact indicators (global warming potential, ozone depletion, raw material consumption, etc.).
- c) Materials Selection ecotools: these ecotools can be defined as databases containing environmental information that will be useful to assess which materials create most harm. This information is very useful during product materials process selection.
- d) Design for "X" (DfX) ecotools: these type of ecotools analyse product designs and provide useful information in order to make easier the disassembly product process (Design for Disassembly, DfD), make easier the recycling product process (Design for Recycling, DfR), improve the product serviceability (Design for Serviceability, DfS), etc.
- e) Handbooks and Checklists: these tools, normally in non-software format, provide useful and practical environmental information applicable to the environmental analysis and improvement of products, processes or activities. These tools are considered the best starting point.

a) Life Cycle Inventory (LCI) ecotools:**a1) The Boustead Model**

This extensive environmental database contains about 6000 unit operations. The database information has been collected from industries from over 23 countries through questionnaires.

Contact details:

Boustead Consulting Ltd.,
Black Cottage, West Grinstead
Horsham, West Sussex, RH13 7BD, UK
sales@boustead-consulting.co.uk
http://www.boustead-consulting.co.uk/

a2) Euklid

This is a software system to carry out life-cycle inventories for industrial products and product chains in conformity with ISO.

Contact details:

Mrs. A. Diers
Frauenhofer-Institut
Für Lebensmitteltechnologie und Verpackung
Gieggenhauer Strasse 35
D-85354 Freising, Germany
diers@ivv.fhg.de
http://www.ivv.fhg.de/

a3) Eco-view

This LCI software, developed by NEC, was put on the market by the Japan Environmental Management Association for Industry (JEMAI) in March 1995. Its database, with 165 modules, is oriented towards the electrical and electronic sector (only available in Japanese).

Contact details:

Mr. Shigeyuki Miyamoto
Ecology based Systems Research Laboratory
Resources & Environment Protection Research Laboratories, NEC Corporation
1-1 Miyazaki 4 – Chome
Miyamae – ku, Kawasaki 216, Japan

a4) LCA Inventory Tool

The original programme was based on inventories for packaging only, but the software and its database have evolved into a more general Life Cycle Inventory (LCI) tool.

Contact details:

Mr. Elin Eriksson (Head of CIT Ekologic)
Chalmers Industriteknik
Chalmers Teknikpark
S-412 88 Göteborg
Sweden
elin.eriksson@cit.chalmers.se
http://www.ekologik.cit.chalmers.se/desc.htm

b) Life Cycle Assessment (LCA) ecotools:**b1) ECO-IT (Eco-Indicator Tool)**

This tool calculates the environmental load associated to a product and shows you which parts of the product contribute most. The Eco-indicator values are computed using the experimental Eco-indicator methodology.

Contact details:

PRé Product Ecology Consultants
Plotterweg 12
3821 BB Amersfoort
The Netherlands
info@pre.nl
http://www.pre.nl/

b2) ECOPACK 2001

This software, available in German and English, based on the data sets created by BUWAL (the Swiss EPA) is specially oriented towards packaging industry.

Contact details:

Max Bolliger Consulting
Esslen Strasse 26
CH – 8280 Kreuzlingen
Switzerland

b3) Ecopro

This software is specially oriented towards packaging industry, but it can also be applied in other sectors. Its database information has been collected from BUWAL, EMPA and ETH.

Contact details:

EMPA St. Gall
Lerchenfeldstrasse 5
CH-9014 St. Gallen
Switzerland
caroline.allenspach@empa.ch
http://www.empa.ch/

b4) EDIP LCV tool

This software is available in English and Danish and its database contains about 750 modules.

Contact details:

Mr. Leo Alting
(IPT) University of Denmark DTU
Building 423 DK
2800 Lyngby, Denmark
alting@ipt.dtu.dk
http://www.ipt.dtu.dk/

Errata:

The correct e.mail of the EIME
contact person is:
Patrick.Dubots@alcatel.fr

b5) EIME (Environmental Information and Management Explorer)

This ecotool can be considered a Design for Environment (DfE) tool originally customized for designers of electric and electronic industry. It has been developed by Ecobilan, S.A. for Alcatel, Legrand, THOMSON Multimedia, IBM and Schneider, with the support of French environmental agency (ADEME), following industry specifications. Its database contains about 185 modules (+50 extra modules with the new version) of electronic and electrical components, chemicals, materials, and processes used in electric and electronic industry. It now maintained by the industry consortium itself.

Contact details:

Patrick.Bubots@alcatel.fr

b6) GaBi

In contrast to conventional Life Cycle Assessment software tools, GaBi also offers the opportunity to carry out cost evaluation of assessed systems (Life Cycle Costing, LCC).

Contact details:

Institute for Polymer Testing and Polymer Science (IKP)
University of Stuttgart
Boeblinger Strasse 78
D-70199 Stuttgart, Germany
gabi@pe-europe.com
http://www.gabi-software.com/

b7) KCL ECO

This software has been developed by the Finnish Paper and Pulp Research Institute and therefore it is specially oriented towards paper and pulp industry. Its database contains about 250 modules covering the environmental information requirements of this sector.

Contact details:

The Finnish Pulp and Paper Research Institute
P.O.Box 70
FIN-02151 Espoo
Finland
eco@kcl.fi
http://www.kcl.fi/eco/

b8) LCAdvantage

This software is provided with a United States commodity database covering fuels production and distribution, power generation, and cradle-to-gate operations for selected forest products, paper, metals, cement, and basic chemicals and plastics.

Contact details:

Mr. Keneth K. Humphreys
Batelle
Pacific Northwest National Laboratory
Batelle Boulevard
PO Box 999, Richland, WA 99352, USA
kk_humphreys@pnl.gov
http://www.battelle.org/environment/lcm/LCAdvantage2.stm

b9) PEMS

This software was initially developed for packaging industry but has evolved into a more general Life Cycle Assessment (LCA) tool.

Contact details:

PIRA International
Randall Road
Leatherhead
Surrey KT22 7RU, United Kingdom
adamn@pira.co.uk
http://www.piranet.com/

b10) Simapro

This software is one of the most widely used LCA tools for the environmental assessment of products. Its database information has been collected basically from European and Dutch sources.

Contact details:

PRé Product Ecology Consultants
Plotterweg 12
3821 BB Amersfoort
The Netherlands
info@pre.nl
http://www.pre.nl/

b11) TEAM

This software is a professional tool developed by Ecobilan since 1992 for evaluating the life cycle environmental and cost profiles of products and technologies. Its database contains over 500 modules with world-wide coverage. Continuously developed, including industry specific versions with remote access through internet.

Contact details:

PricewaterhouseCoopers
<http://www.pwcglobal.com/>
<http://www.pwcglobal.com/environment>
info@ecobilan.com

b12) Umberto

This software package has been developed by IFEU (Institute for Energy and Environmental Research) together with IFU (Institute for Environmental Informatics) in Germany in 1994. This tool supports the preparation of LCAs, company ecobalances or more generally material flow analyses.

Contact details:

Ifeu-Institut
Wilckensstrasse 3
D-69120 Heidelberg, Germany
ifeu@ifeu.de
<http://www.ifeu.de/umberto.htm>

b13) WISARD (Waste-Integrated Systems Assessment for Recovery and Disposal)

This software is a tool designed to assess the economic and environmental impact of municipal solid waste management, based on LCA methodology. It has been developed for entities such as Eco-Emballages, S.A. (France) or the England Environmental Agency (UK). Data, methodology and calculation process have been peer-reviewed in UK and France by international panels of independent experts, following ISO 14040 standard.

Contact details:

PricewaterhouseCoopers
<http://www.pwcglobal.com/>
<http://www.pwcglobal.com/environment>

b14) Other qualitative Life Cycle Assessment ecotools

As described in Chapter 3 (Ecodesign methodology), a qualitative product, process or activity's environmental evaluation can be done with different levels of detail. These methods are not very thorough, but they are cheap and easy to carry out.

Several qualitative LCA tools are available for this purpose (they have been briefly described in Chapter 3):

- ♣ MET Matrix
- ♣ AT&T product improvement matrix and target plot
- ♣ Eco-indicator 99 methodology
- ♣ Telecommunications Abridged Life Cycle assessment Tool
- ♣ Ecoscan 3.0

c) Materials Selection ecotools:**c1) CAGE**

CAGE is a pollution prevention tool for paints and coatings users. This tool contains an expert system designed to recommend low-volatile organic compound/hazardous air pollutant coatings that may serve as drop-in replacements for a user's existing coating operation. This guide has been developed by the Surface Cleaning Program at Research Triangle Institute in co-operation with the U.S. EPA Air Pollution Prevention and Control Division.

Contact details:

Mrs. Rebecca Switzer
 Research Triangle Institute
 PO Box 12194
 Research Triangle Park, NC 27709-2194, United States
switzer@rti.org
<http://cage.rti.org/>

c2) Ecotox

This tool evaluates the toxicity of certain chemicals for aquatic life, terrestrial plants and wildlife by providing some Ecotox Thresholds (ET's). It has been developed by the U.S. EPA, concretely by: Office of Research and Development (ORD), National Health and Environmental Effects Research Laboratory (NHEERL), Mid-Continent Ecology Division, toxicology effects databases.

Contact details:

U.S. EPA Superfund Docket Organisation
 401 Street
 SW 5202G
 Washington, DC 20460, United States
ecotox.support@epa.gov
<http://www.epa.gov/ecotox/>

c3) Idemat

It can be defined as a computer database for designers that provides technical information about materials and processes in words, numbers and graphics, and puts emphasis on environmental information. This software has been developed by the section for Environmental Product Development of the faculty of Industrial Design Engineering at the Delft University of Technology.

Contact details:

Delft University of Technology
Faculty of Industrial Design Engineering
Section for Environmental Product Development
Jaffalaan 9
2628 BX Delft
The Netherlands
idemat@io.tudelft.nl
<http://www.io.tudelft.nl/research/dfs/idemat/index.htm>

c4) SAGE

SAGE is a comprehensive guide designed to provide pollution prevention information on solvent and process alternatives for parts cleaning and degreasing. This guide has been developed by the Surface Cleaning Program at Research Triangle Institute in co-operation with the U.S. EPA Air Pollution Prevention and Control Division.

Contact details:

Mrs. Rebecca Switzer
Research Triangle Institute
PO Box 12194
Research Triangle Park, NC 27709-2194, United States
switzer@rti.org
<http://sage.rti.org/>

d) Design for "X" (DfX) ecotools:**d1) AMETIDE (A METHodology for TIme Disassembly Estimation)**

This is a tool to optimise disassembly constraints in product design.

Contact details:

Consortium on Green Design and Manufacturing CGDM
University of California
Elcheverry Hall 1750, Berkeley
CA 94720 – 1750, United States
<http://greenmfg.me.berkeley.edu/green/cad/ametide/>

d2) **BDI Software**

Four different DfX software tools are available from Boothroyd Dewhurst, Inc.: Design for Assembly (DfA), Design for Manufacture (DfM), Design for Service (DfS) and Design for the Environment (DfE). This last one simulates the disassembly of products at end-of-life and reveals the associated cost benefits and environmental impacts of a product design.

Contact details:

Boothroyd Dewhurst, Inc.
138 Main Street
Wakefield, RI 02879
United States
info@dfma.com
http://www.dfma.com

d3) **ELDA (End-of-Life Design Advisor)**

This is a basic software tool. It asks very basic questions about your product and then determines the recommended end-of-life strategy.

Contact details:

Manufacturing Modeling Lab, Thornton 207
Mechanical Engineering Design Division
Stanford University
Stanford, CA 94305-4021
United States
rose@cdr.stanford.edu
http://mml.stanford.edu/

e) **Handbooks and Checklists:**

- e1) Bergendahl C.G., Hedemal P., Segerberg T. (1995) **Handbook for Design of Environmentally Compatible Electronic Products**. IVF-Research Publication 95851. Göteborg, Sweden (ISSN 0349-0653 / ISRN IVF – S –95/851 – SE).
- e2) Billatos S.B., Basaly N.A. (1997) **Green Technology and Design for the Environment**. Taylor and Francis, United States (ISBN 1-56032-460-0).
- e2) Brezet H., Van Hemel C. (1997) **Ecodesign. A Promising Approach to Sustainable Production and Consumption**. Delft University of Technology. United Nations Environmental Programme (UNEP). The Netherlands (ISBN 92-807-1631-X).
- e3) Burnett Jung L. (1997) **A Design Guide for Information and Technology Equipment**. American Plastics Council, USA (free download able at: http://www.plasticsresource.com/reading_room/reports/report_enviro_design.html).
- e4) Clark T., Charter M., (1999) **Eco-design Checklists for Electronic Manufacturers, Systems Integrators and Suppliers of Components and Sub-assemblies**. The Centre for Sustainable Design, Surrey Institute of Art and Design, Surrey, UK. (free download able at: <http://www.cfsd.org.uk/>).

- e5) Fiksel J. (1995) **Design for Environment: Creating Eco-Efficient Products and Processes**. Mc Graw Hill (0-07-135074-8).
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- e8) ICER, Industry Council for Electronic Equipment Recycling (1997) **Design for Recycling Electronic and Electrical Equipment**. London, England.
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- e10) Kärnä A. (1998) **Environmentally Oriented Product Design. A guide for companies in the electrical and electronics industry. Federation of Finnish Electrical and Electronics Industry**. Helsinki, Finland (free download able at http://www.electroind.fi/ymparisto/eng_guide.htm).
- e11) RMIT (1996) **The Ecoredesign Kit**. Centre for Design at RMIT, Melbourne, Australia.
- e12) U.S. EPA, United States Environmental Protection Agency (1994) **Design for the Environment: Product Life Cycle Design Guidance Manual**. United States (ISBN 0-86587-384-4).

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2. Menke D.M., Davis G.A., Vigon B.W. (1996) **Evaluation of Life-Cycle Assessment Tools**. Center for Clean Products and Clean Technologies, University of Tennessee and Batelle Strategic Environmental Management, USA. Prepared for Hazardous Waste Branch, Environment Canada (to obtain a copy send your request to: dmenke@utk.edu).
3. Simon M., Evans S., McAlloone T., Sweatmen A., Bhamra T. and Poole S. (1998) **Ecodesign Navigator – A key resource in the drive towards environmentally efficient product design**. Manchester Metropolitan University and Cranfield University, England (ISBN 1-871315-74-3).