Editorial: The function of the electrical and electronics industry as a cross-sectoral supplier

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1 Introduction

In addition to introducing the subsequent articles, this editorial also gives a short review of the current state of design for the environment and the life cycle approaches in the context of the requirements of the EU Directives. The EU pressure will determine the environmental policies of business companies in the area of the Electrical and Electronics Industry (EEI) during the next years.

The EEI serves as a ‘cross-sectoral supplier’ because it is equally important both for the production of goods and services as well as for the final consumers. This fact calls for several approaches in order to fulfil the complex task of developing the perspectives for sustainability and to comprehend them in the field of research as well as in their practical application.

The products and methods of the EEI have led to some improvements in ecological performance. At the same time, however, they have remained ecologically critical or became even more critical in some aspects.[1] Table 1 gives some examples.

Table 1 Two directions for action of EE products

Sustainable development	*Unsustainable development*
Helps save energy	Only works with energy
Accelerates and simplifies the work processes	Exerts organisational and social effects, up to the point of unemployment
Creates new cultural techniques and jobs (*e.g.*, web media)	Creates new inequalities (*e.g.*, digital divide)
Works as a medium and tool	Is also a 'purpose and end' device

The table with the contrasting pairs shows that the application of EE technologies and products generates conflicts of objectives and hence, enables the exemplary depiction of the task's complexity, which is associated with sustainable development and most of all, with the contribution that the companies can make.

The eight articles presented here are arranged in a matrix which covers a spectrum between the life cycle perspective and the life cycle-orientated design for the environment and the range of microeconomic corporate policies (Figure 1).

1 The paper by Unger *et al.* presents the methods and tools to perform life cycle evaluation with respect to the environmental aspects. The authors focus on the early stage of the life cycle, where the product and process characteristics are determined. Many tools exist, but no simple rules to choose the right one are available.

2 The paper presented by Huisman and Stevels discusses the implementation of the European Waste Electrical and Electronic Equipment (WEEE) directive against the background of efficiency. The key question discussed here is: 'How much environmental improvement can be realised per amount of money invested?' The authors develop recommendations for more eco-efficient take-back and recycling systems.

3 The linkage between the product design and the product end-of-life stages is the frame for the paper written by Herrmann *et al.* The product and process data build up the base for a tool to determine and evaluate the end-of-life characteristic values, such as the disassembly time and cost in the design stage, as well as for a second tool to support a simulation-based planning of the disassembly systems in the end-of-life stage.

4 Spengler and Stölting present a framework for the strategic planning of remanufacturing systems. Remanufacturing is the most valuable recovery option for a product and a key element of closed-loop supply chains. To support decision-makers by evaluating the decision alternatives, a life cycle costing approach is developed.

5 Mathematical models can be used to support the planning of the disassembly processes. But often, the necessary data (*e.g.*, the disassembly time, the composition of the returned materials) is not available to put the mathematical models at work. Against this background, Schultmann and Sunke present an approach for short-term dismantling planning, including process-induced uncertainty modelled with fuzzy techniques.

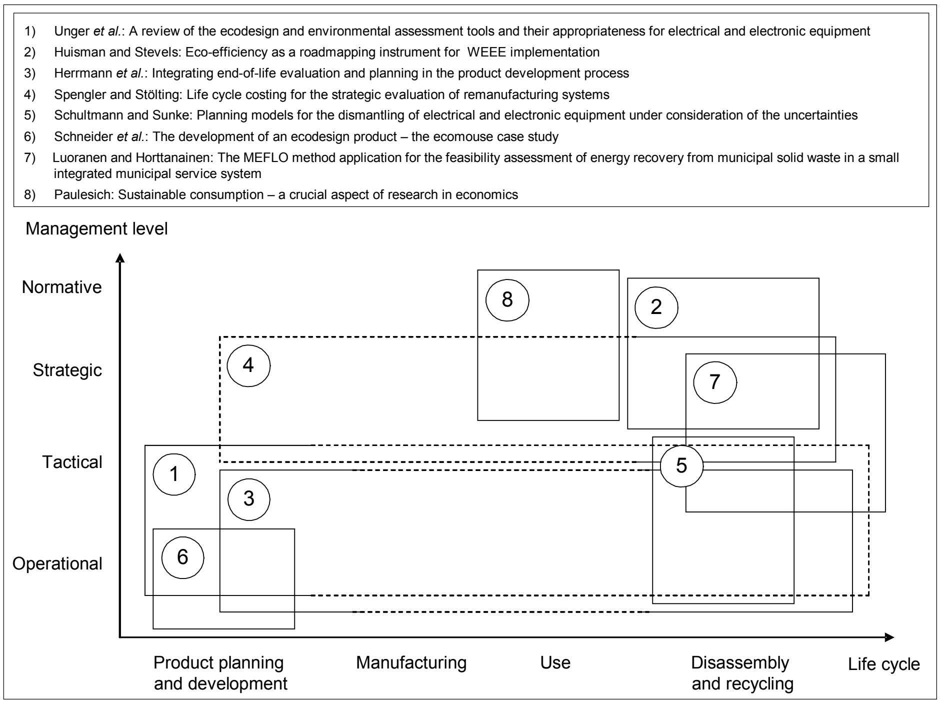
6 New technologies can be drivers to reduce the environmental impact of a product. The authors chose a computer mouse as the product, which is widely used to demonstrate how the environmental aspects can be considered in the design process and design phase of the product life cycle (design for the environment/ecodesign). The different technical alternatives are presented and a (streamlined) life cycle assessment is applied to compare a conventional computer mouse with a new product concept, the so-called 'ecomouse'.

7 The paper by Luoranen and Horttanainen presents a ranking method and concept for assessing the feasibility of integrated energy and waste management system alternatives. The method takes mass, energy and financial flows, legislative criteria and criteria such as local political guidelines into account.

8 Sufficiency requires changes in the use and consumption of products and resources. The paper by Paulesich gives a view inside the research in the field of sustainable consumption. He proposes an argument in the case of the end consumer markets to put the research focus more on the milieu studies than the demographic characteristics to get a deeper understanding of the preferences.

The eight peer-reviewed article contributions of this special issue on 'Design for the environment' obviously are not able to cover all the demands and challenges of sustainable development. Their classification into microeconomic categories, from operational over tactical to strategic and normative, implies a planning interval of seven to 12 years. Only the term 'normative' comprises the planning intervals which can outlast a generation. Therefore, the question for the perspectives which outlast generations and continents and which concern (sustainability) research more than what is directly relevant to a company remains unresolved here. In the following sections, we will discuss how and with which methodologies this question can be approached.

Figure 1 The presentation of contributions/overview of the articles



2 The situation in the electronics industry

In Europe, there are basically three directives which influence the environmental discussion in the electronics industry. First, there is the directive on WEEE and second, the directive on the Restriction of the use of certain Hazardous Substances (RoHS) in electrical and electronic equipment. The directives comprise clear requirements for products and especially for the producers. Examples are:

- the cost responsibility for waste disposal and the obligation to take back products from the end consumer without charges (WEEE)
- the minimum quotas for the amount of material as well as material and energy recycling in the disposal of products (WEEE)
- the restrictions for selected materials which are potentially hazardous to the environment and for materials which are difficult to dispose of, *e.g.*, heavy metals such as cadmium, lead and hexavalent chrome as well as flame retardants containing bromine (WEEE, RoHS).

Further demands on the development of new products are to be expected by the EU Directives. These directives sets the frame for the determination of the demands for the sustainable design of energy-driven products. The concretisation of the demands is realised either by administrative regulations or by the self-regulation initiatives of the concerned industries.

With the given legal framework for the protection of the environment and human health, the EU Directives and their national applications, the companies continue to ask themselves if those regulations interfere with their competitive capability. During the last 15 years, a change has taken place in environmental protection attitudes and actions from ‘Command and Control’ to market-oriented instruments. The intention behind the legislation that followed was and still is to give incentives for the development of new technological solutions. In the past, this policy has been successful and has caused various industrial sectors to develop innovative methods and products.[2]

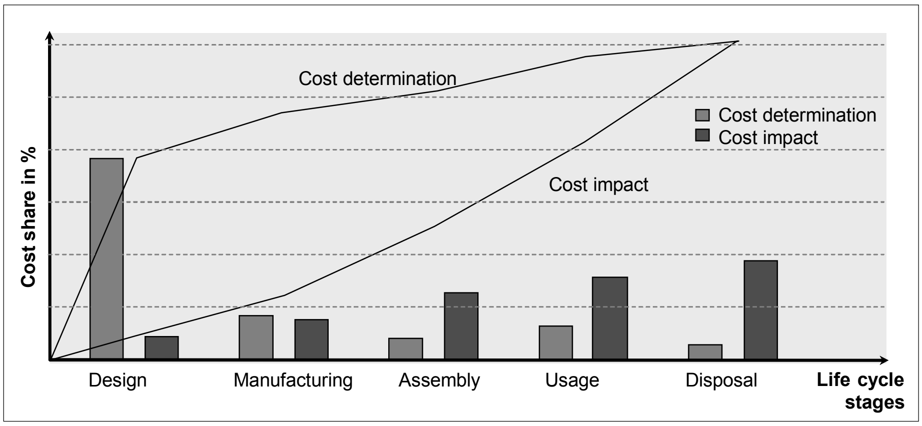
The consequence is an enhanced resource management and technological development process which outnumbers the targets, *e.g.*, the legally regulated emissions values. This seems to prove that a negative influence on the conventional business success is not the case:

- pollutant emissions can be avoided by substituting materials and by changing the process technologies; generally, an enhancement of resource efficiency and a cost reduction of the applied material's and energy is linked with it
- in an earlier stage, namely in the design phase, the market applicability, *i.e.*, the customer benefit, can also be improved; in many cases, this is linked to the willingness of the customer to pay a higher price.

2.1 The design and production of electric and electronic appliances

From a life cycle perspective, a major share of the costs occurring throughout the product life cycle is already determined in the product design stage (see Figure 2). At the same time, most of the environmental impacts throughout the life cycle are determined in the design stage, too (Luger and Herrmann, 2007).

Figure 2 The cost determination and cost impact throughout the life cycle



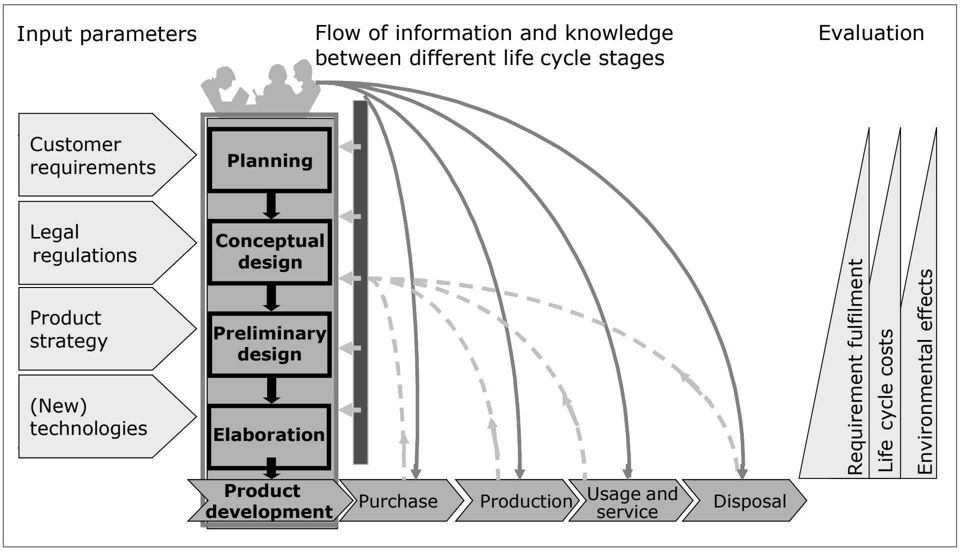
Source: Kahmeyer and Rupprecht (1996)

Different process models have been developed for the planning and design processes for products. In general, all concepts are structured in different phases to increase the clarity and to allow an allocation of methods and tools to the different tasks that need to be performed. The common process steps are the clarification of the design task, the conceptual design, the embodiment design and the detail design. Thus, a product's impact during its use and disposal stages already needs to be considered as additional requirements and constraints in the product development phase. This approach is described as a life cycle-oriented product development. Basic concepts have been developed in the last decade under designations such as 'Life Cycle Design', 'Life Cycle Engineering' and 'Life Cycle Engineering Design' by, *e.g.*, Alting (1993), Koeleian and Menerey (1993) and Ishii (1995). In this context, the definition by Mansour (2006a) (see also Figure 3) shall be given:

> "Life cycle oriented product development (Life Cycle Design) describes the process of systematic consideration and optimization of a product's technical, economic and ecological characteristics and effects during the entire life cycle within the framework of the product development process. The goal is to meet the requirements of an extended product responsibility by using the scope for decision-making during the product development to realize a maximum product benefit for customers and producers during the life-cycle and to minimize its economic, ecological and social costs and risks."

Figure 3 shows the definitions and steps of a design process as a reference model for the life cycle design. The consideration of new technical, economic and ecological requirements from all life cycle phases within the product development leads to a complex decision problem in optimising a product's design.

Figure 3 The reference model for the life cycle design



Source: Mansour (2006b)

The evaluation of the product design does not only refer to the fulfilment of customer requirements, but also has to include the economic and ecological aspects of the after-use stages, in particular. For the evaluation, different methods and tools can be applied, *e.g.*, Life Cycle Costing (LCC) for the economic evaluation and Life Cycle Assessment (LCA) for the ecological evaluation.

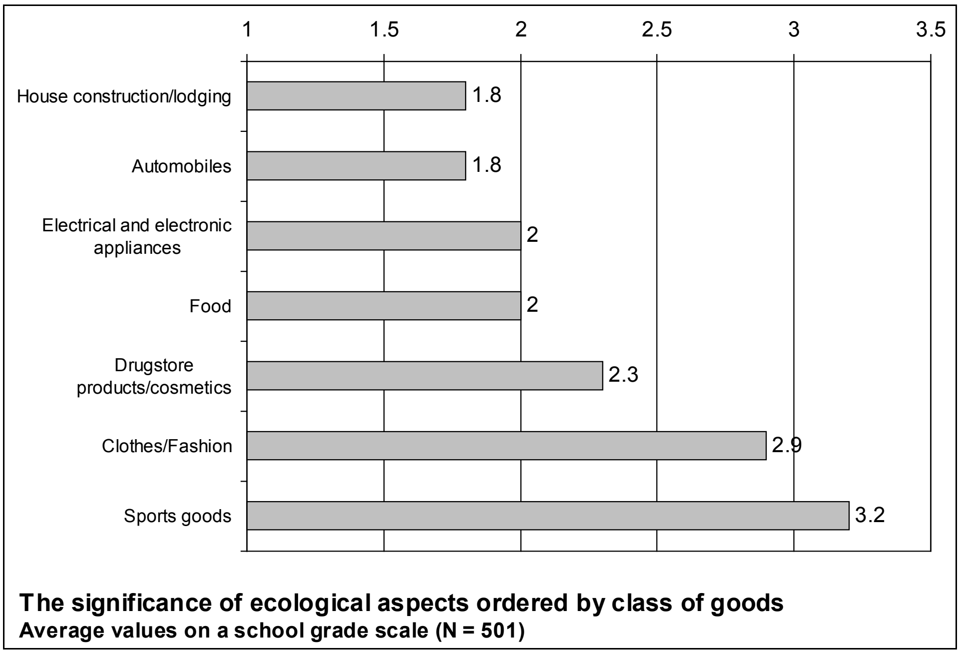
2.2 *The use of electrical and electronic appliances*

In the following paragraphs, some aspects on sustainable product utilisation from the consumer's point of view will be presented. It is useful to revisit the investigation conducted through a survey in Austria in 2004 (Paulesich *et al.*, 2005). Two components that are equally decision-relevant to research and to the industry can be identified: the planning interval, which is linked with ecology and sustainability, and the most relevant market segments.

The results of the survey prove that ecological consciousness plays a role in the buying behaviour of the consumers. They show a clearly perceivable regard for the ecological criteria in the purchase, especially when long-lasting products and the products in the high-priced segment are concerned. This is true for the different market segments as well as for the products within the same category.

Figure 4 shows that the ecological aspects become more important in the purchase of products: the longer the service life, respectively, the higher the price of the product, the more important are the ecological effects to the consumer. The placement of the category 'house construction/lodging' on the first position and 'automobiles' on the second position points to the complexity of interdisciplinary research on sustainable development. In both cases, the consumers seem to be aware of the environmental relevance of their consumption (compared with other consumer goods). However, when taking a look at the market segments with the greatest share of material and energy flows, the reality shows a discrepancy. Construction and mobility consume 68% of the energy and nearly 45% of the material of a national economy.[3]

Figure 4 The significance of the ecological aspects



Notes: 1 = very high significance; 5 = no significance.

Source: Paulesich *et al.* (2005, p.49)

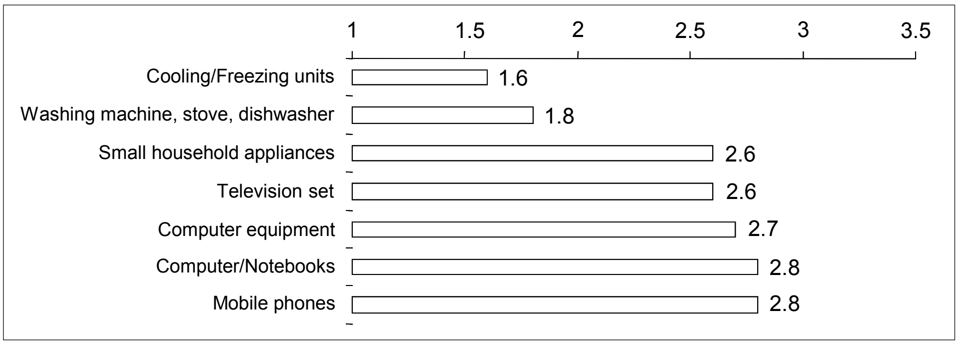
Compared to construction and automobiles, the subsequent product categories show a decrease in the relevance of the ecological aspects. Electrical and electronic appliances can be regarded as a relatively 'eco-sensitive' market segment. This can be seen by two characteristics:

1 the effects on health are being discussed in public

2 both segments of the groups of buyers measured by means of the quality orientation ('high price/low price') can be estimated as equal.

The following figure shows the data of a more profound survey within the category of EE appliances.

Figure 5 The relevance of the ecological aspects – EE appliances



Notes: 1 = very high significance; 5 = no significance.

Source: Paulesich *et al.* (2005, p.49)

Around 92% of the questioned consumers give two reasons for buying a new product: (1) an appliance is out of order and (2) repairing it is too expensive. There is a slight predomination of (2). This is true for all EE appliance categories. For 62% of the consumers (multiple answers were permitted), the availability of new technologies is a decisive reason for buying – which is also true for all EE categories. In some categories, however, *e.g.*, mobile phones, a 'new technology' is the decisive argument to substitute an old appliance with a new one.

From the point of view of companies with a sustainable economy, it is encouraging that the term 'eco' is consistently associated with 'positive' features (*e.g.*, environmentally friendly, the avoidance of pollutants, less energy consumption). The buying behaviour with regard to EE appliances can be interpreted in this way: 'eco' is especially esteemed when goods that are expensive and long-lasting are concerned. Environmentally friendly light bulbs, for instance, which are classified as extremely durable and energy-saving, induce the consumer to pay more than for bargain offers. The consumers are willing to pay about 50% more than usual.[4]

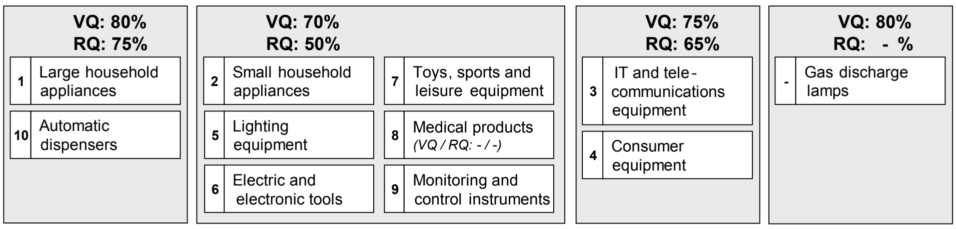
2.3 The end-of-life of electrical and electronic appliances

In 2003, the European Parliament and the Council enacted the directive on WEEE. The goals of the directive are to reduce the amount of WEEE and to prevent these materials from leaking into the environment. The directive distinguishes between the ten categories of WEEE from private households as well as from professional use. The key regulations are:

- WEEE have to be collected separately from unsorted municipal waste (at least 4 kg per year per inhabitant)
- the collected WEEE has to be treated complying with the detailed requirements for certain hazardous substances and components that are harmful to the environment or may disturb the subsequent processes. Recycling WEEE must meet category-specific target quotas for recycling and recovery (see Figure 6)
- the product and financing responsibility for treatment and recovery is transferred to the producers of the equipment
- information and reporting obligations for the producers and treatment facilities
- design for recycling and design for the environment is promoted.

In other countries, similar legislative acts regulate the recycling of WEEE, such as the Electronic Waste Recycling Act of 2003 in California, the forthcoming WEEE regulations in China, as, *e.g.*, the regulation on 'Pollution control and management of IT products' and Japan's Home Appliance Recycling Law. These regulations define the general framework in which WEEE recycling has to be conducted.

Figure 6 The recycling targets according to the WEEE directive, including the collection groups following the German transposition

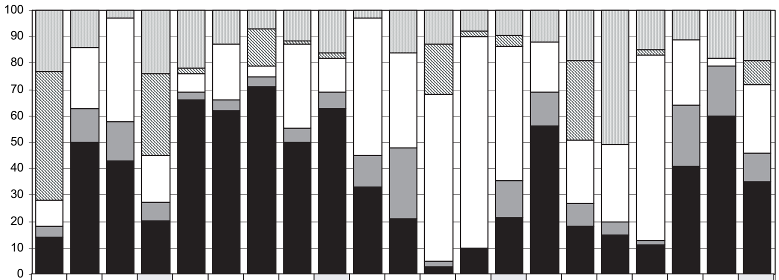


Notes: VQ: Recovery rate.
RQ: Reuse and recycling rate.
1…10: Category.
Source: ElektroG (2005)

The quantities of WEEE are growing each year all over the world. It is assumed that in 2005, around 1.1 million tons of WEEE have been collected in Germany alone. The worldwide amount of WEEE is expected to rise to 95 million tons in 2010, if the current developments in the worldwide adaptation of standards of living persist. WEEE contains a large variety of different materials (Figure 7). On average, the largest shares are ferrous and nonferrous metals. However, the composition varies from product to product: small household appliances or consumer equipment, for example, have higher shares of plastics. In an overall view, metals are the largest material fraction. In addition to these large shares of materials, these products contain various hazardous materials such as lead, mercury, cadmium and other heavy metals, but also other carcinogenic and hazardous materials, *e.g.*, in plastic flame retardants (Herrmann and Luger, 2006).

The economic aspect of WEEE recycling is determined by the process costs, on the one hand, and by the costs and profits for the generated fractions, on the other hand. The process costs can be differentiated into costs for logistics, treatment and recycling/disposal, management and clearing. As studies have shown, the overall value and share of each type of cost differs from product category to product category (Herrmann and Luger, 2006). Figure 8 shows, on the one hand, the distribution of the total costs on the product categories and on the other hand, the cost structure for the different types of electrical and electronic equipment.

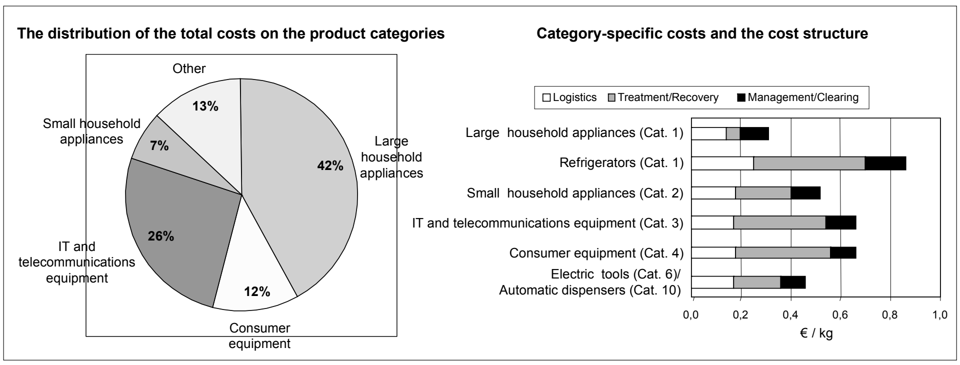
Figure 7 The average composition of the different types of WEEE



	TV set	Videorecorder	HiFi equipment	**Consumer electronics**	Washing machine	Dishwasher	Cooker	Refrigerator	**Large household appl.**	Vacuum cleaner	Iron	Coffee maker	Electric kettle	**Small household appl.**	PC	Monitor	Laptop	Telephone	Printer	Mainframe computer	**IT/Telecom. devices**
FE metals	14	50	43	20	66	62	71	50	63	33	31	3	10	21	56	18	15	11	41	60	35
NE metals	4	13	15	7	3	4	4	5	6	12	27	2	0	14	13	9	5	2	23	19	11
Plastics	10	23	39	18	7	21	4	32	13	52	36	63	80	51	19	24	29	70	25	3	26
Glass	49	0	0	31	2	0	14	1	2	0	0	19	2	4	0	30	0	2	0	0	9
Other materials	23	14	3	24	22	13	7	12	16	3	16	13	8	10	12	19	51	15	11	18	19

Source: Ohlendorf (2006)

Figure 8 The distribution of the costs associated with the recycling of WEEE



Source: Ohlendorf (2006)

Besides the process and disposal costs, the recycling of WEEE also comprehends the economic potentials through the profits for the secondary raw materials and reuse components, *e.g.*, 14 tons of electronics scrap contain an average of one ton of copper, which can be sold on secondary raw material markets. However, with only a few exceptions, the revenues for the secondary raw material sales from WEEE recycling are not considered to be cost-covering. To ensure efficient recycling processes, the systematic planning and economic evaluation of the recycling systems in terms of an end-of-life management comes into focus (Herrmann and Luger, 2006).

3 Future perspective

The EEI is in a key position for technology development and innovation. Furthermore, it has a special responsibility because the reasons and driving forces will not change in the next decade:

- the saturation of the market in early industrialised countries
- the increasing competitiveness of the threshold countries in the international markets
- shorter innovation and renewal cycles cause the 'time to market' to become a decisive factor in competitiveness. The considerations on the long-term results of product development or consumer behaviour are therefore regarded as hindering.

The current key approaches concerning the EEI are following two strategic paths:

1 the implementation of extended producer responsibilities
2 the promotion of closed-loop economies, *i.e.*, the reuse and recycling of waste materials.

The concept of producer responsibility imposes the responsibility for the environmental impact and performance of the product during its later life cycle stages to the manufacturer, *e.g.*, the end-of-life stage. Thus, the efficient recycling of the huge amounts of WEEE is a matter of current concern due to ecological reasons, the economic impacts and the new legal requirements. Hence, the manufacturers have to understand the processes in and the implications of the end-of-life stage and set up a proper end-of-life management for their products. The operationalisation of these paths is the result of the cooperation between the disciplines of engineering and economic science. Ideally, science takes the part of facilitator between the economy, society and ecology in making decisions. Cooperation between the disciplines means to enlarge the frame for interpretation by considering new aspects. They lead to new, mutual cognitions, which are comprehensible not only to experts.

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Notes

1 Studies on the energy efficiency of electrical appliances show considerable improvements per appliance. However, the increasing number of appliances and their use, particularly the standby mode, have caused an increase in the annual energy consumption, which is comparable to the power generation of two nuclear power plants.

2 Compare Porter and Linde (1995).

3 Compare Lorek (2003, p.224).

4 Compare Sammer and Wüstenhagen (2006).