Ecodesign in a life cycle perspective

Waste prevention of products – a question of design and consumer patterns

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Abstract

In the paper the interdependency of product design and waste arising will be portrayed. The generation of waste appears in all stages of the life cycle not only at the end of life when a product turns into waste. In the early stage of product development the majority of the environmental effects are determined – usually unintended referring to lack of knowledge or a lower degree of priority of environmental aspects. There are different Ecodesign strategies which focus on the minimization and prevention of waste. Selecting the right materials, dematerialization and minimizing waste during manufacturing, reducing waste during the use phase and design for recycling or reuse will be discussed. Specific improvement strategies will be generated to optimize the end-of-life performance of selected products.

In the conference paper a practical procedure for implementing environmental aspects into the product development process will be introduced and its application demonstrated. The main focus lies on different Ecodesign improvement strategies on waste prevention and minimization applied on product examples from three Austrian manufacturing companies. This procedure called "ECODESIGN Toolbox for Green Product Concepts" is developed in an ongoing research project funded by the Austrian Research Promotion Agency. The examples shown in the paper are preliminary results from this project (Huber, M. et al.2006).

1 Introduction into Ecodesign - Life Cycle Thinking

Sustainable product design/Ecodesign aims at considering and **reducing the environmental impacts of a product along its entire life cycle**. These stages include the extraction of the raw materials, the manufacturing of the product, its distribution, the use and finally, the disposal of the product. Design in this respect compiles the engineering design of a product as well as its form and functionality.

The goal of Life Cycle Thinking (LCT) is to identify phases and processes within the whole product life cycle (raw material, manufacturing, distribution, use, end of life) which have or could have significant influence on the environmental impacts. Ecodesign should concentrate on these phases with the highest improvement potential. Ecodesign has to fulfill the customers needs with causing a minimum of environmental impact, merely the amount of raw material used, the energy needed along product life. An Ecodesign product serves its purpose with only a minimum of environmental impact. The question is how to design such products. Green Product Concepts are needed.

2 Interdependency of product design and waste arising

Product development has a decisive influence on the individual stages of the product life cycle and therefore on the waste arising in each product phase. Defining dimensions and tolerances, for instance, largely predetermines the sequences of the manufacturing process as well as the possibilities for refurbishing for components that are exposed to wear or deformation (Figure 1).

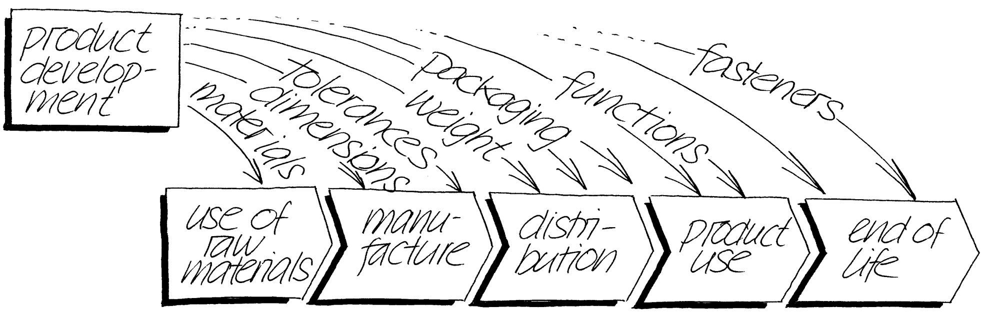

Figure 1: Influence of Product Development on the life cycle (Wimmer, W. and. Züst, R. , 2002)

Products should not go through the individual stages in a linear way. Establishing cycles is a main task to avoid or minimize waste. Possible product life cycles are:

- Repair and upgrading (prolong useful product life)
- Recycle (avoid disposal of valuable materials) and
- Reuse (avoid disposal of product components)

Different approaches for **avoiding waste through establishing cycles** on material and component level are presented in Figure 2. At the stages manufacture, use and the end-of-life, production waste, defective parts and components, and the product itself may be integrated into a **cyclical process**. The principal approaches aim at recycling (closed cycles at the level of materials) and reuse (closed cycles at the level of individual parts and components). As **reuse** does not destroy the structure of components nor impairs the quality of materials this approach to the after-use stage represents the highest value. Wear or even failure of parts and components may occur during usage. Prolonging the useful life of a product can be reached by means of **repair** and maintenance.

Figure 2: Avoiding waste with a closed loop system (Wimmer, W. and. Züst, R. , 2002)

In **“Reverse Manufacturing**“, the product is disassembled into its components after the use phase. After checking and cleaning, these components are used again in manufacture. A typical example would be a copy machine. The goal of “**upgrading**” is improving the functionality of an existing product and, at the same time, using as many parts and components of the old product. The product is upgraded in such a way as to meet current requirements. Personal Computers are typical examples.

3 Systematic approach – ECODESIGN Toolbox for Green product concepts

In the following chapter a practical procedure for implementing environmental aspects into the product development process is introduced. The procedure is currently developed in a research project and is called “ECODESIGN Toolbox for Green Product Concepts”. Innovative product concepts will be developed during this project in cooperation with partners from the industry. The project is carried out at the Institute for Engineering Design of the Vienna University of Technology together with research and industry partners. The project is still in progress and will be finished in August 2007. The ECODESIGN Toolbox for Green Product Concepts as shown in Figure 3 comprises of a six step process procedure. The Toolbox will comprise of different tools for sustainable product development which will be tested and applied by the product design teams of the three involved industry partners.

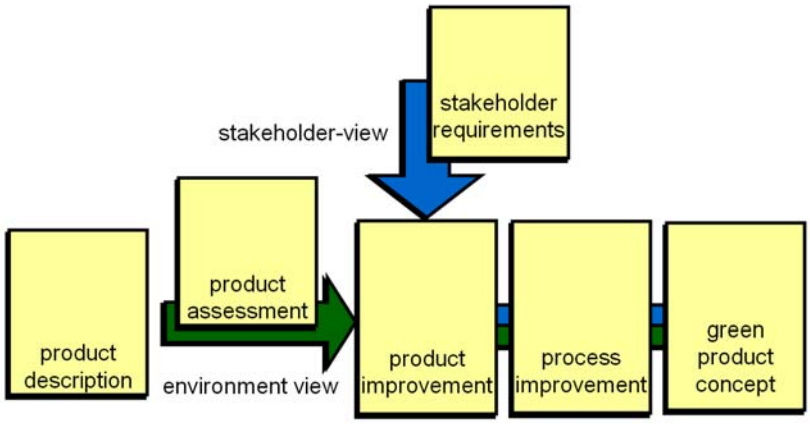

Figure 3: The six steps of the ECODESIGN Toolbox (Huber, M. et al., 2006)

3.1 Product description

With the first step the product characteristics are described and documented. Environmental parameters for classifying the product are selected and investigated. Environmental parameters are quantifiable parameters such as material input [kg], percentage of primary or secondary resources [%] energy demand [kWh] during manufacturing or use phase, waste generation [kg], hazardous substances [kg], etc.

3.2 Environmental Analysis

The **ECODESIGN Assistant** is an add-on to the ECODESIGN PILOT, which helps to classify products and enables to apply Life Cycle Thinking (Wimmer, W. and. Züst, R. (2002). Both tools have been developed at the Institute for Engineering Design. The ECODESIGN Assistant helps to identify the life phase with the highest environmental impact of a product. Based on this evaluation it suggests appropriate Ecodesign strategies for product improvement.

The Assistant asks for product specific data for each of the life cycle phases, i.e. raw materials, manufacturing, distribution, use and end of life, data can be entered in separate forms. Different assessment methods evaluate materials and processes by means of indicators, which facilitates a comparison of different materials with a view to their environmental performance.

During the project the database will be updated with generated data for materials and processes and the results gained by the Assistant should be a visualized graph with quantified data. In this graph the energy values per life cycle phase of a product are displayed and it is identified in which product phase the most environmental impact occurs.

3.3 Stakeholder requirements

The stakeholder requirements are derived from customer and market requirements as well as from existing and upcoming environmental laws and directives. Specific stakeholder requirements from legislations in the field of Electronics such as the European WEEE directive (WEEE 2003), the RoHS directive (RoHS 2003) as well as the new EuP directive (EuP 2005):

are integrated into the ECODESIGN Toolbox for Green Product Concepts (see Fig. 3). The voice of the customer is usually one of the strongest; a company has to fulfil the customers' needs in order to sell their products. Environmental aspects can be an essential issue, in many cases they are not or the awareness is just starting. The requirements from all named stakeholder are then transferred into technical parameters by using Quality Function Deployment. The technical parameters with the highest rankings are used for product improvement in the next step.

3.4 Product improvement

The results of the previous steps and the analysis of the production processes (3.5) create the input for the central part of the ECODESIGN Toolbox: product improvement. These improvements are derived from the results of the environmental analysis in step 2 (3.2) by using the Ecodesign strategies of the **ECODESIGN PILOT** (Wimmer, W. and. Züst, R. (2002)**.** In creativity sessions within the project meeting optimization ideas are generated together with the developing teams of the companies.

3.5 Holistic Process Optimization

The Holistic Process Optimization investigates the production processes within the industry partners. The integration of the production allows a more holistic view of the environmental impact of a product. Interdependencies of the production and the product design are displayed. E.g. the selected material determines the production processes and the waste generation. The design and functionality of a product predicts the input materials and the manufacturing in turn.

3.6 Green Product Concept

The sixth step of the toolbox leads into the development of a green product concept for the products analyzed. Various improvement measures are generated and evaluated in terms of costs and realization potential.

Examples from the industry partners currently under investigation will be introduced in the following. The main focus will lay on different strategies on waste prevention and minimization along the life cycle and will be supported by the **preliminary results** of the project. The structure is based on the different phases of the life cycle.

4 Strategies on waste prevention and minimization along the life cycle – examples from industry by applying the ECODESIGN Toolbox

In the research project three varying Austrian products are under investigation:

- Golf Swing Analyzer (GSA) for recording and analyzing the golf swing for trainings
- Digital Pocket Memo (DPM) - a voice recorder for business use
- Injection Moulding Machine (IMM) for industrial production of plastics parts

With the application of the ECODESIGN Toolbox, a Green Product Concept for each of the products will be developed. The preliminary results concerning the improvement of the waste arising are introduced in the following chapters.

4.1 Raw material

Closed cycles form a constituent element of Ecodesign. Selecting the right materials is an essential factor for sustainable products and sets the limits for the later recycling or disposal processes. Apart from the material characteristics themselves the conditions for the production of comparable raw materials may vary greatly. One of the prerequisites in this context is to use only materials that are really recyclable and that ensure, at the same time, that its characteristics are also present in the secondary material to a sufficient degree (if necessary by adding new material). Inseparable composite materials should be avoided.

In the case of the golf swing analyzer, the housing consists of aluminum sheet. The primary aluminum should be replaced by secondary material. The ratio of the energy demand of secondary aluminum and the energy demand of primary aluminum is about 1 to 20. Additionally, the secondary aluminum has about the same properties than primary aluminum with no down-cycling effects. As the company has no influence on the composittion of the input material – usually 80 % primary, 20 % secondary material – a different strategy has to be chosen.

A design aiming at optimum strength and stability while reducing resource input contributes to a targeted utilization of the energy intense aluminum.

Single material components should be preferred wherever possible. This constitutes an essential contribution to closed materials cycles. This goal can certainly not be realized in all cases for reasons of function, strength, etc.

The housing of the digital pocket memo consisted of different materials such as aluminum, PA 6.6, PMMA and POM. The components form material compounds in many cases e.g. the display is permanently joined (glued) to the housing frame. The new shell technique leads to a reduction of materials, after the redesign the outer parts have been all-aluminium and joining techniques are widely separable.

Applied Ecodesign strategies (acc. to ECODESIGN PILOT: Wimmer, W. and. Züst, R., 2002):

- Selecting the right materials - no compounds, recycled material, recyclable materials
- Reducing material inputs – dematerialization, single materials
- No permanent joints to ease recycling

4.2 Minimization of waste during manufacturing

The goal of each production process consists of the transformation of raw materials into products. Thus, process waste may be considered as an indicator for inefficient use of materials. Apart from the environmental impact caused by the disposal of waste the consumption of raw materials extracted from the environment has to be taken into account. In many cases, the procurement of raw materials that are transformed into waste in inefficient production processes, is a decisive cost factor. Avoiding this type of waste not only reduces the cost of disposal but also purchase costs for raw materials.

The mechanical processes like milling, turning and cutting during manufacturing of the injection moulding machine generate a high volume of metal scrap and waster contaminated with oily emulsion. 25 % of the input materials turn out to be waste. A redesign of the components concerning material, component shape and optimizing metal machining may lead to a fundamental reduction of both metal scrap and lost emulsion, resulting in lower procurement, manufacturing and disposal costs. The disposal costs could be calculated into the manufacturing costs in order to make the procured, but not used raw materials more transparent.

The amount of waste from companies which do only the assembly of components is considerably low one may think. But the packaging of the components can have a major impact on the environmental performance of a product both in terms of quantity and quality e.g. PVC blisters. A change in materials or shifting to reusable packaging reduces the disposal as well as the procurement costs.

Applied Ecodesign strategies (acc. to ECODESIGN PILOT: Wimmer, W. and. Züst, R. 2002):

- Minimization of waste through redesign and production optimization
- Raising awareness through transparency of inefficient use of raw materials
- Optimization of packaging waste from components

4.3 Distribution

As packaging material is useful only for a limited period of time (unless it is returnable) the type and quantity of material used for packaging have to be optimized. Especially with products that have to be transported over long distances, the weight of the packaging material, too, has a large influence on the overall consumption of resources.

The amount of the later not used packaging sometimes surpasses the weight of the actual product, e.g. the pocket memo weighs 80 g, compared to the packaging weighing 300g.

Minimizing packaging with a view to weight can be realized either by optimization of packaging or by appropriate product design, for instance by casings that endure transportation without or with only a minimum of packaging. The golf swing analyzer which presents a high valuable life style product is aimed at being delivered in a fashionable, high quality packaging which can be re-used as storage and transporting vehicle on the way to the driving range.

Applied Ecodesign strategies (acc. to ECODESIGN PILOT: Wimmer, W. and. Züst, R., 2002):

- Reducing amount of packaging with optimization of packaging design or product
- Re-use of packaging during usage

4.4 Use

The influence of the use scenario on the environmental impact is shown with the results of the voice recorder. In the performed analysis it is assumed that the voice recorder is used intensively over 4 years. The energy needed is supplied by AAA alkaline batteries. The voice recorder is therefore classified as a use intensive product. Its major environmental impact occurs during the use phase (Figure 4).

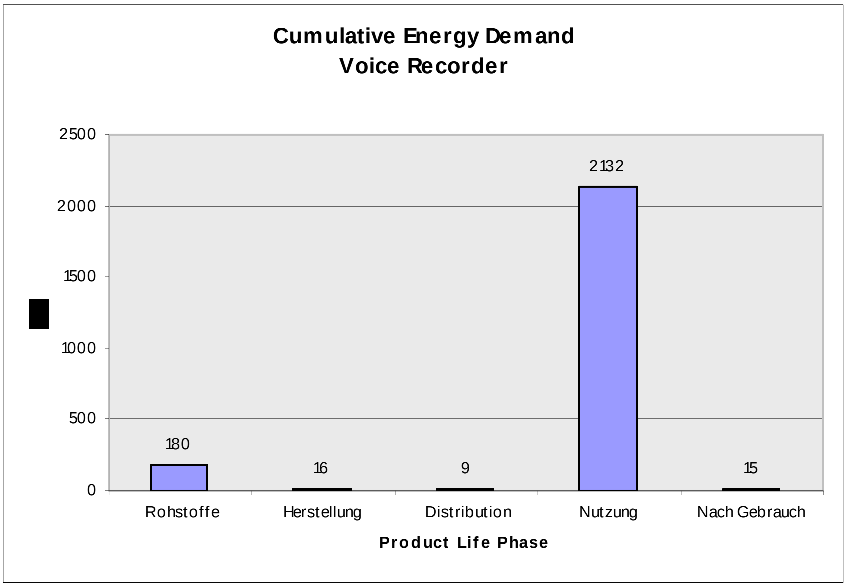

Figure 4: Distribution of the cumulative energy demand over the life cycle

An approach for realizing an optimization during use is to change to rechargeable batteries. This approach leads to a reduction of the energy use and the amount of hazardous waste created by the usage of the batteries. Another improvement lies in an alternative energy supplement with different functionality: charging with an USB cable via PC has the lowest environmental impact. The achieved result for the voice recorder depends on the considered use scenario as well as the energy management of the device (Figure 5). The improvements show very distinctly that changes in the parameters can have major influence on the environmental impact of a product. It has to be stated clearly, that environmental impacts should not be shifted from one phase to another. The positive effects in one phase should not be compensated by the negative effects in another phase. The change leads to a relative increase of the raw material phase because a battery charging device would be needed.

Applied Ecodesign strategies (acc. to ECODESIGN PILOT: Wimmer, W. and. Züst, R. (2002):

- Reduce consumption during usage
- Alternative energy supply
- Avoidance of waste during use stage

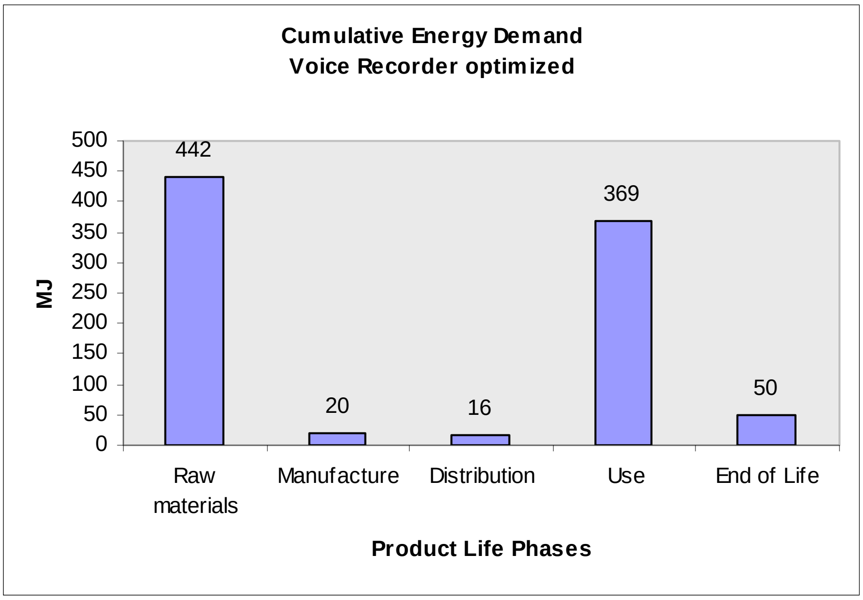

Figure 5: Resulting shift of the cumulative energy demand over the life cycle

4.5 End of Life

When the product is not used anymore, it has reached the end-of-life stage. The obsolete product can be disposed in different ways or becomes a resource itself and be subsequently integrated in manufacturing or utilization processes based on reuse or on recycling.

Additionally product designer have to consider the technological standards for recycling and remanufacturing. The structure of some plastics causes an inefficient recycling process or down-cycling effects. Polyamide (PA), Polystyrene (PS), ABS and Polypropylene (PP) which can be recycled up to 100% should be preferred.

Disassembly accounts for a great part of recycling costs and efficiency. The joints of the housing of the pocket memo used to be glued, after the re-design they are screwed, other components are snapped. The extraction of components containing hazardous is made easier as well. The injection moulding machine is a solid high quality product which is re-used on the second hand market. Repair is possible and spare parts are available, no machine has become waste yet.

Applied Ecodesign strategies (acc. to ECODESIGN PILOT: Wimmer, W. and. Züst, R., 2002):

- Design for disassembly
- Design for recycling
- Design for Re-use

5 Conclusion

Ecodesign aims at considering and reducing the environmental effects of a product along the entire product life cycle. Waste generation and waste management is a central issue in sustainable product design. The shift from waste management to sustainable resource management can only take place if the design process is involved. During product development, the possibilities for a closes loop system are initiated: design for recycling, design for disassembly, design for re-use.

In the paper a research project is introduced, where a practical procedure for implementing environmental aspects into the product development process will be developed. The main focus lies on different Ecodesign improvement strategies on waste prevention and minimization applied on product examples from three Austrian industry partners. A digital voice recorder, a golf swing analyzer and an injection moulding machine are analysed in terms of waste minimization and waste prevention along the product life cycle.

The experiences from the mentioned project show, that the life phases are tightly linked to each other. Interdependencies have to be considered and the effects of the planned improvement measures have to be analyzed beforehand. The positive effects in one phase should not be compensated by the negative effects in another phase. This is a central aspect of Life Cycle Thinking. The research project is still in progress and will be finished in August 2007.

References

EuP (2005): “DIRECTIVE 2005/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products".

Pamminger, R., Wimmer, W., Huber, M., Ostad, H.: The ECODESIGN Toolbox for the Development of Green Product Concepts – First steps for product improvement, CARE 2006, Vienna.

RoHS (2003): "DIRECTIVE 2002/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment".

WEEE (2003): "DIRECTIVE 2002/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on waste electrical and electronic equipment".

Wimmer, W. and. Züst, R. (2002): ECODESIGN PILOT, Product-Investigation, Learning- and Optimization-Tool for sustainable product development, with CD-ROM. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Wimmer, W., Züst, R. and Lee, K.-M. (2004): ECODESIGN Implementation - A Systematic Guidance on Integrating Environmental Considerations into Product Development, Springer.

Huber, M., Pamminger R. and Wimmer W., (2006): ECODESIGN Toolbox for Green Product Concepts, Interim Report, Factory of Tomorrow, Project number: 810777