Product innovation through ecodesign

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Abstract: This paper shows how to develop eco-products using the Ecodesign approach. Three different product case studies show how to proceed in developing environmentally improved products. These case studies have been carried out in collaboration with industry and the identified product improvements have been realised in commercial products, which are now available on the market. The first case study is an alpine ski, the second is office equipment (Digital Pocket Memo (DPM)) and the third is a new Golf Swing Analyser. Obtaining green product concepts using the ECODESIGN Toolbox with and without having a reference product to start with are presented.

Keywords: ecodesign; sustainable product development; design; environmental improvement.

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Biographical notes: Wolfgang Wimmer has been a Professor at the Vienna University of Technology in Engineering Design and ECODESIGN since 2002. He is the author of two books on ECODESIGN. Over the last 12 years he has been leading many research projects with leading companies such as Philips Austria, Steelcase Inc., Siemens Transportation among others. In 2005, he founded the 'ECODESIGN company' Engineering and Management Consultancy GmbH located in Vienna, Seoul and Ottawa. Since then he has been the Managing Director of the ECODESIGN company.

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Rainer Pamminger studied Mechanical Engineering at the Vienna University of Technology and at the University of Salford in Great Britain with specialisation in production and operation. Since 2002, he has been working at the Institute for Engineering Design at the Vienna University of Technology in the ECODESIGN research group. He is working on the development and realisation of methods for product development and of product service systems as well as on the development of teaching modules on the basis of eLearning and of booklets.

Maria Huber has a Degree in Environmental Consulting and graduated from the University of Natural Resources and Applied Life Sciences in Vienna. She also studied at the University of Technology and at the University of Economics in Vienna and specialised in Waste Management and Disposal Engineering. Since 2003, she has been working in the field of waste from electric and electronic equipment and sustainable product development. The focus of her work lies in the conceptual and content development in different applications of Ecodesign such as the ECODESIGN PILOT for the electronic industry and the Ecodesign Toolbox for Green Product Concepts.

1 Introduction

Continuous product innovations are essential in the global market. Delivering a unique selling proposition can be realised by developing eco-products. A rising awareness about the environmental performance of products leads to competitive advantage for those capable of producing eco-products. One way to achieve competitive advantage is to apply Ecodesign. Ecodesign aims at minimising the product's environmental impact across its entire life cycle, starting already from its design stage.

The basis for eco-product development is a good product analysis through Life Cycle Thinking (LCT). By applying LCT all life cycle stages of a product are evaluated, aiming at finding environmental improvement and innovation potentials. Table 1 lists the different life cycle stages and gives examples of processes and parameters to be considered in the different life cycle stages. In this paper these five life cycle stages will be considered in detail in order to improve products by applying Ecodesign. Two case studies have been chosen to demonstrate product improvement strategies – one case study focusing on sport equipment and the other on office equipment. The demonstrated approach is generic and can be applied to any type of product.

Table 1 Five life cycle stages of a product to be considered in LCT

Raw materials	*Manufacture*	*Distribution*	*Use*	*End of Life*
Polystyrene, Glass, Steel, Aluminium, …	Injection moulding, Machining, Welding, …	Air, Rail, Road, Packaging, …	Electricity, Batteries, …	Recycling, Incineration, …

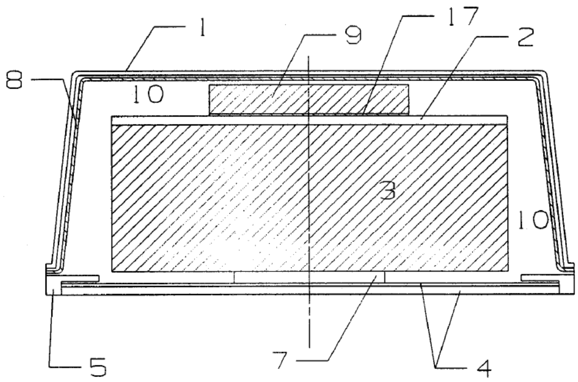
2 Product improvement

In the following section an alpine ski and a Digital Pocket Memo (DPM) for professional voice recording will be taken as case studies to demonstrate the product improvement approaches and strategies. These two products have been chosen because they have totally different environmental characteristics, as shown later in Section 2.2. As a first step, the product structure of both products has to be understood.

Case study: Alpine ski

Figure 1 shows a cross-section of the reference alpine ski. The bottom of the ski consists of a PE running surface (4), which is bonded to a laminate and framed by a wrap-around steel edge (5). The interior of the ski is injected with foam (10), which constitutes the shape of the ski and ensures bonding of all components with each other. The graphic design of the ski is printed to the inner side of the transparent foil of the top surface (1). For reinforcement the inner side of this foil is bonded to a lattice (8). In the tip, centre and tail areas the ski features a wide-meshed plastic inlay (9) between foil (1) and wood core (3), which is fixed to the laminate (2) by means of an adhesive lattice (17). In the tip area the wood core has been replaced by an ABS plastic layer (not shown). At the tail of the ski, running surface, steel edge, and shell meet in the tail protector.

Figure 1 Cross section of an alpine ski



Source: Wimmer et al. (2001)

Case study: Digital Pocket Memo (DPM)

The product is a professional device which is mainly used by doctors and lawyers to record diagnosis, and respectively, trials. Figure 2 shows the current model, which serves as the reference model for the analysis. For developing a new model the Ecodesign approach has been used to achieve competitive advantage. The voice is recorded in a special format and then transferred to the PC by USB. The use scenarios can vary between running on batteries or on rechargeable batteries in case the customers buys an external charger. The life time of the product is estimated to be four years. The DPM consists of a body with buttons (plastics, aluminium, steel, etc.), electronic components (printed circuit board display, microphone, etc.) and is sold together with four cables for different countries, CD-Rom, power supply and two AAA size batteries.

Figure 2 Digital pocket memo – reference product

2.1 Product life cycle data

To obtain life cycle data the alpine ski was analysed. The total weight of the alpine ski considered is 1.8 kg, where 35% of the weight comes from the wrap-around steel edges, 20% from the wood core and 10% from the surface foil. The rest is mostly glues, foams, rubbers and fleece used for assembling the ski. The manufacturing stage consists of the following steps:

- *Preparing parts and components*. The steel edges are scoured and sandblasted. The foils which are delivered in reels are cut and the waist shape is milled.
- *Printing the surface*. The foils are printed by screen printing technique.
- *Pressing process*. The prepared parts and components are put and pressed together. The pressure for this process amounts to 5bar and the required temperature is 120°C.
- *Grinding*. Different parts of the ski are ground.

Further, it is assumed that, for distribution, a lorry is used and that the average distribution distance is 1000 km with shrinking foil used for packaging. In the use stage of the alpine ski additional materials are needed, such as wax. The end of life stage of the reference alpine ski is modelled as a combination of incineration to regain energy and material recycling.

For the DPM the product characteristic was described and documented in a quantitative and qualitative manner using spread sheets according to Wimmer et al. (2004), see Figure 3. Environmental parameters for classifying the product were 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.

With this step all the information needed for realising the following product analysis was collected. The product description contains relevant information along the entire product life cycle: raw materials, manufacture, distribution, use and end of life.

Figure 3 Product description of Digital Pocket Memo

Date	Product	Name	Person in charge
06.02.2007	Digital voice recorder	xxx	xxx

A1 Product description for casing - metal

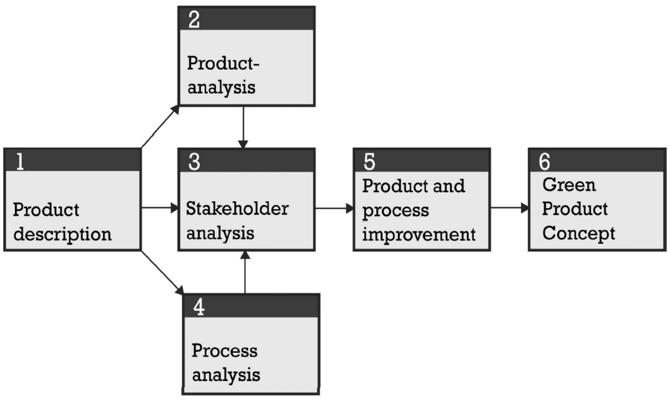
Gathering Data of external produced components

Components from supplier						
Name	Material	Production process	Amount	MJ/kg	Unit	Help
decoration elements	aluminium	punching	13,25	0,159	[g]	?
		anodising	18871	0,735969	[mm²]	?
Spring		wire drawing	0,155		[g]	?
Batterie springs	spring steel, gold plated	wire drawing	0,407		[g]	?
	spring steel	gold plating	420		[mm²]	?

2.2 *Environmental evaluation and environmental profile*

To obtain an environmental profile for the alpine ski and the DPM the "Ecodesign Toolbox for Developing Green Product Concepts" developed at the Vienna University of Technology was applied (Pamminger et al., 2006). The Ecodesign Toolbox comprises the following six steps, which lead to Green Product Concepts: product description, process analysis, product analysis, stakeholder analysis, process and product improvement and finally Green Product Concept according to Figure 4.

Figure 4 Six steps for developing green product concepts



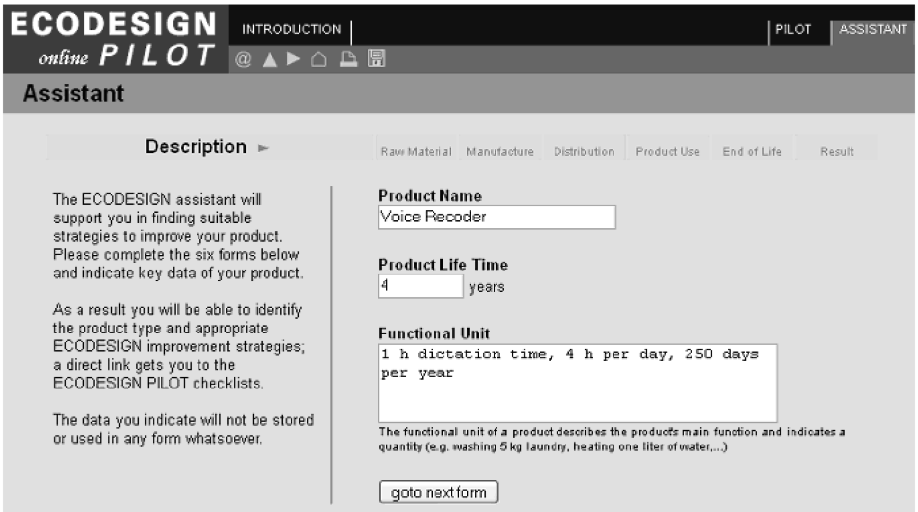
Source: ECODESIGN Toolbox (2007c)

The product analysis has been carried out by using the ECODESIGN Assistant (in short: Assistant). The Assistant is an online available evaluation tool for the ECODESIGN Product Investigation, Learning and Optimisation Tool for Sustainable Product Development (PILOT) which was developed at the VUT (PILOT, 2007; Wimmer and

Züst, 2002). This tool helps to classify products and enables application of LCT (ECODESIGN PILOT's Assistant, 2007b). The life cycle phase with the most significant environmental impact can be identified. Based on this classification, appropriate Ecodesign strategies for product improvement are proposed.

The Assistant asks for product specific data with the help of six forms. For each of the life cycle phases, i.e., raw materials, manufacture, distribution, use and end of life, data can be entered in a separate form. The first form collects general data about the product such as the product life time or the definition of the functional unit; see Figure 5 for the DPM.

Figure 5 Product analysis



Source: ECODESIGN PILOT's Assistant (2007b)

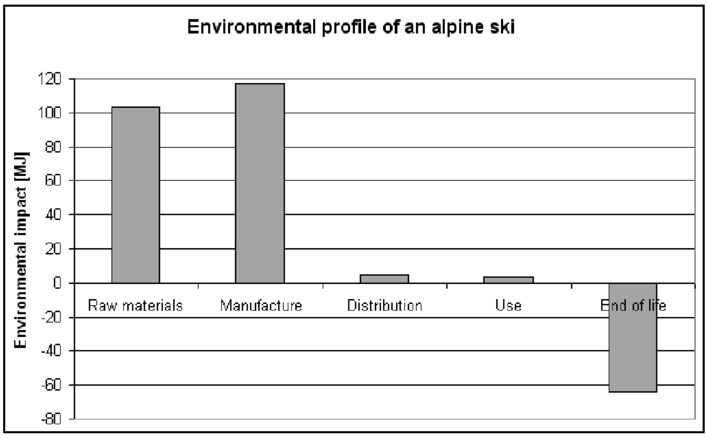
With the data from the product description the Assistant is able to identify the product type. There are five different product types depending on which life cycle phase contributes most to the environmental impact of the product (raw material, manufacture, transport, use or disposal intensive). Based on the product data input the Assistant identifies the special characteristics and critical aspects of the product.

Further, the Assistant calculates the environmental profile of a product based on Cumulative Energy Demand. The results gained by the Assistant can be, among the Ecodesign checklists for further improvements, visualised in a graph with quantified data. In this graph the relative environmental impact per life cycle phase of a product is displayed and the product type can be identified.

Further, the ECODESIGN Assistant recommends strategies for the improvement of the product. The strategies are divided into high priority strategies which should be realised at once since they lead to a significant product improvement and additional recommended strategies which can be realised at a later time. The corresponding checklists are derived from the ECODESIGN PILOT and can be used for generating improvement ideas for the product.

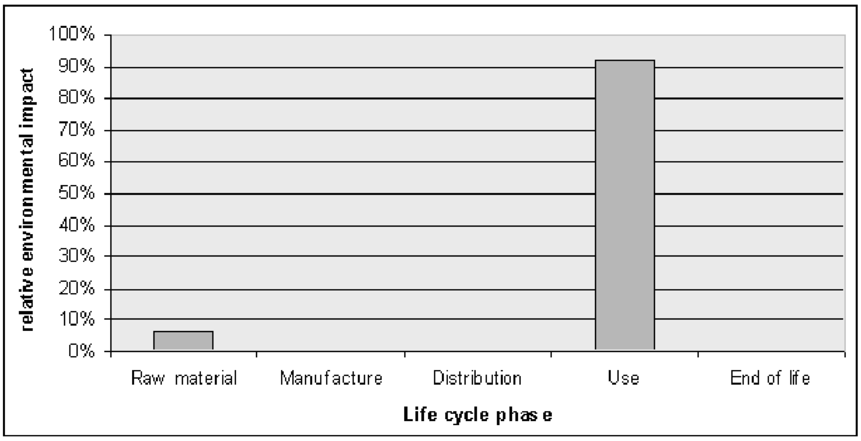
The calculated environmental profile of the alpine ski is shown in Figure 6. It can clearly be seen that the first two life cycle stages, namely raw materials and manufacture, contribute most to the environmental impact of the alpine ski. The modelled distribution scenario or the use stages have only minor contributions to the environmental impact of the product.

Figure 6 Environmental profile of the reference alpine ski



The environmental profile for the DPM shows a different result. The product can be classified as a 'use intensive product'. The achieved result for the DPM depends on the considered use scenario as well as the energy management of the device. In the analysis above it is assumed that the recorder is used for 4 h a day and 250 times a year over four years. The energy needed is supplied by AAA size alkaline batteries. The voice recorder needs 800 batteries for this estimated life time. The main environmental impact is, therefore, caused during its use phase – see Figure 7.

Figure 7 Environmental profile of the reference Digital Pocket Memo



Obviously, different strategies have to be applied to improve the alpine ski and the DPM respectively. Having a good understanding of the product life cycle and having a reliable environmental profile of the product is essential for the following improvement procedure.

2.3 Product improvement strategies

Following the next step of the Ecodesign Toolbox, product and process improvement strategies are obtained by using the Ecodesign checklists of the PILOT (Wimmer et al., 2004). For the ski manufacturer a special version of the PILOT has been developed providing ski-specific Ecodesign issues and checklists for each stage in the company's specific product development process. Figure 8 shows a screenshot of the PILOT which is adapted to ski development. Applying the Ecodesign SKI-PILOT resulted in the design strategies and design improvements listed in Table 2.

Figure 8 ECODESIGN SKI-PILOT adapted to the manufacturer's product development process

Table 2 Ecodesign strategies and design improvements for the alpine ski

General Ecodesign strategies selected with the PILOT checklists	*Product design improvements in detail*
Avoid or reduce the use of problematic materials and components	Reduction of printing width at the top surface foil
Prefer the use of recycled materials (secondary materials)	Increase of the portion of recycled material in the running surface
Reduce material input by integration of functions	New design of the bond laminate-running surface; the injected foam also provides bonding (no additional adhesive agents)
Use low material input, low emission production technologies	Modification of design for optimised cutting to size of material from wider raw material strips
Avoid waste and emissions in the production process	Less paint coat and reduction of bonding surfaces; reduction of foam waste by redesigning foam injecting nozzle
Close material cycles in the production process	Modification of product design to ensure single material cutting chips, recycling of the chips
Recycle/reuse waste for new materials	Recycling of waste from single material PE running surface
Waste sorting/separation whenever possible	Modification of the bond between laminate and PE running surface
etc.	etc.

In the next step the achieved design improvements had been evaluated against cost saving potential and later, the improvements resulting in environmental improvement and in cost reduction have been selected for implementation. All in all this procedure can be integrated into any continuous improvement process of a company.

For the DPM, the online available PILOT (www.ecodesign.at/pilot) has been used. Together with the product engineers in charge of doing the redesign, the following improvement strategies and suitable Ecodesign tasks have been found:

Product analysis with ECODESIGN Assistant and PILOT

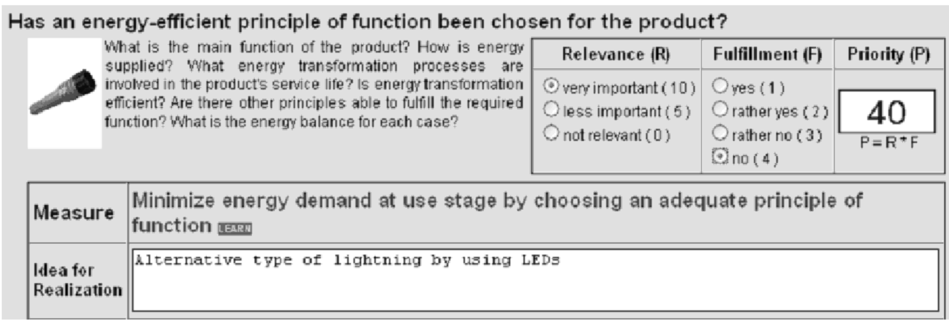
- reducing consumption at use stage
- ensuring environmental safety performance
- avoidance of waste at use stage.

Stakeholder analysis with QFD

- improvement of software usability
- compatibility with other systems
- use of energy during use
- materials used
- restriction of using lead, cadmium, etc., according RoHS – Directive
- ensure take-back, collection and treatment and supply of information for users and treatment facilities according to WEEE – directive.

For each of the above improvement strategies the PILOT provides a checklist of improvement measures, which helps the product development team to evaluate the tasks and get the initial ideas for product improvement. For each item mentioned in the checklist an assessment question can be found, where the relevance and the fulfilment of the measure have to be evaluated. If the calculated priority is high the measure should be chosen for further product improvement. Figure 9 shows such a checklist item. The measure "Minimise energy demand at use stage by choosing an adequate principle of function" of the strategy "Reducing consumption at use stage" is shown. High priority is given to this by the project team since the energy consumption of the DPM is the main environmental impact.

Figure 9 Checklist item



Source: ECODESIGN PILOT'S Assistant (2007b)

Product improvement ideas for realisations have been worked out within the companies in several creativity sessions. The generated improvement ideas for implementation are listed in Table 3 according to the selected strategies.

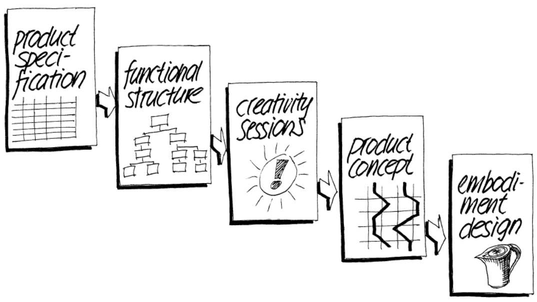
Table 3 Product improvement strategies and appropriate ideas for implementation

Derived strategies and appropriate measures	*Improvement ideas for implementing – What to do?*
Product and process improvement Digital Pocket Memo	
Product analysis	
Reducing consumption at use stage	
Minimise energy consumption at use stage by increasing efficiency of product	Use of energy efficient components
	Redesign of the electronics
	Minimising stand-by consumption
Make possible use of renewable energy resources at use stage	Energy supply for the cradle using photovoltaic
Minimise energy demand in the use stage by choosing an adequate principle of function	Possibility to turn LCD display on and off
	Optimise sleep modus
	Reduce power loss during charging
	Alternative energy supply (rechargeable batteries)
Avoidance of waste at use stage	
Avoid and/or minimise waste at use stage	Use of rechargeable batteries
Stakeholder requirements	
Stakeholder requirements – QFD	
Improvement of software usability	Intuitive, self-explanatory software, user interface
Compatibility with other systems	Improving data processing interface
Restriction of using lead – RoHS	
Usage of lead free product parts	Certifications from subcontractors for lead free parts (resistors, printed circuit boards, etc.) have been obtained
Investigation of the existing soldering machine on lead-free usage	Usage of lead-free soldering
	Reduction of hand soldering points
Secure treatment according to WEEE	Joining a collection system
Product conception for recycling	
Improving recycling	Use PS, ABS and PP which can be recycled with a rate of nearly 100%
	Shell technique – using just one shell, one material for the outer parts and not a plastic part as body and additionally aluminium as design elements
Improving disassembly	Changing fasteners

3 Product development process

In some cases there are no reference products to do an analysis as outlined in Section 2. The question is, then, how to deal with environmental issues in such product development tasks. The product development process can be seen as an optimisation between sometimes conflicting targets. Finding a certain material for a certain price to fulfil a certain function is difficult enough. Now, additionally adding the environmental dimension (e.g., considering the energy to produce the material but also considering the recycling behaviour of the material), may become challenging. Common to most development processes is a certain sequence of developing product specifications first, then deriving the functional structure and using creativity techniques to develop several possible product concepts before one concept is selected for embodiment design through an evaluation and assessment procedure, see Figure 10.

Figure 10 Principle outline of the product development process



Source: Wimmer et al. (2004)

Introducing environmental thinking in the early phase of product development is most important. When laying down the product specifications environment should be on board already. The environmental target values sorted out shall be understood by the design team. This is essential in order to come up with a good overall environmental performance of a product. But the question is how to derive the correct environmental targets for a certain product? This should be demonstrated with the new development of a Golf Swing Analyser, see Figure 13.

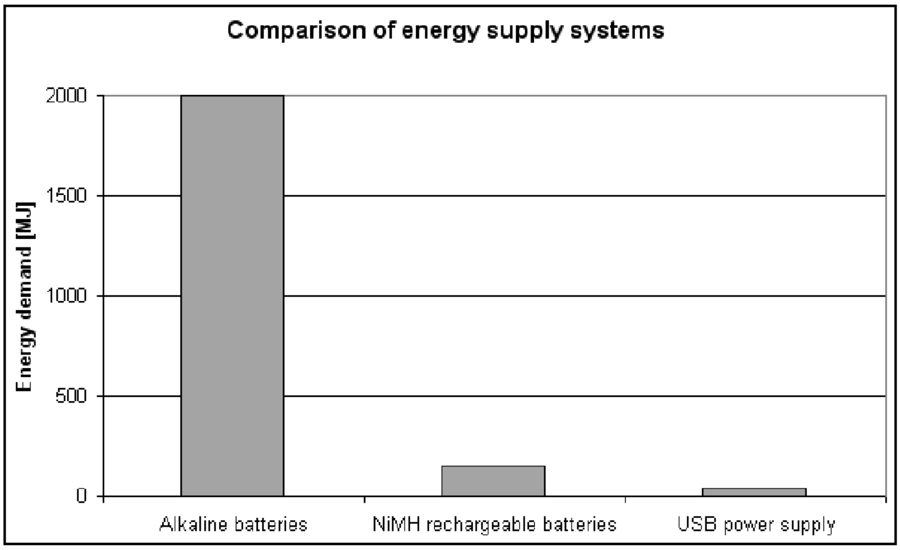
3.1 Understanding the environmental impacts

In the case of a newly developed product, estimations of potential impacts along the product's life cycle have to be done. This goes together with defining the system boundaries for the product and its interactions with the environment. Relevant questions are how far those upstream processes, until the product leaves the manufacturer, should be considered and how the use phase and end of life phase are modelled. In general a Material-Energy-Toxicity (MET) matrix is a good way to develop an environmental overview of a product – even with vague data. For the new development of the Golf Swing Analyser the MET-matrix showed that either the materials used in the device or the energy needed to operate will probably have a relevant environmental impact; manufacturing processes or distribution (transport and packaging), as well as end of life processes, will have minor impacts.

Regarding the materials, the Golf Swing Analyser (in a first basic outline of components) consists of aluminium housing containing two lenses, an electronic control unit and some connecting cables. To work properly a tripod and a sensor attached to the golf club are needed. Out of these components the electronic control unit is, environmentally, the most significant. One design task was to keep it as small as possible. The other design task is to have a robust but light weight housing and tripod. The appropriate energy supply is a more challenging task since there are more options to choose from. Assume that the device (as many other devices as well) could be operated with batteries or, alternatively, with rechargeable batteries.

A realistic assumption is that the Golf Swing Analyser will be used on a driving range for around 120 uses per year. Each use consists of half hour training. Two scenarios are generally available to deliver the energy needed: regular alkaline batteries or NiMH rechargeable batteries with external power supply unit. A third possibility applies in the case of the Golf Swing Analyser: since operating requires a Laptop for storing and calculating the measurements of the recorded golf swing the idea of using USB power supply came up. The environmental evaluation given in Figure 11 shows clearly which one is the best solution.

Figure 11 Environmental evaluation of the different energy supply systems for the golf swing analyser



3.2 Understanding environmental regulations

Additionally to the environmental evaluation of a product, several environmental directives have to be considered in the development of electronic sports equipment. These include the Directive for the Restriction of the use of certain Hazardous Substances (Directive 2002/95/EC, 2003) and the Directive on Waste Electrical and Electronic Equipment (Directive 2002/96/EC, 2003) as well as the new and upcoming EuP-Directive setting Ecodesign requirements for energy-using products (Directive 2005/32/EC, 2005). EuP is currently under development with the aim of bringing Ecodesign requirements to a standard required in order to achieve CE-marking of a product. Evidence for the compliance with the directive is the CE marking on the product through conformity assessment. The assessment can be made either through internal design control or integration into the Environmental Management and Audit Scheme (EMAS) with the design function included within the scope of that registration. RoHS restricts the use of cadmium, lead, mercury, hexavalent chromium, and two bromated flame retardants. WEEE requires achieving a certain recycling percentage at the end of life of a product (EEE validity check, 2007).

Beside these requirements from EU-directives, stakeholder requirements are derived from customer and market requirements. The voice of the customer is usually one of the strongest since a company has to fulfil the customers' needs in order to sell its products. Environmental aspects asked from the customer can, therefore, be an essential issue; in many product categories environmental awareness is currently raising. The requirements from all the named stakeholders are collected and then transferred into technical parameters by using a modified version of Quality Function Deployment (QFD) originally published by Akao (1990). The modified version is shown in Figure 12. The relation between stakeholder requirements and design parameters has to be identified and rated (0 = no relation, 1 = weak relation, 3 = average relation, 9 = strong relation). This should be done in teamwork to achieve a consensus. Together with the weighted stakeholder requirements the importance of each design parameter can be calculated by multiplying for each column the assigned relation factor with the weighting factor of each row and summing up. The technical parameters with the highest rankings are used for product improvement in the next step.

Figure 12 Stakeholder analysis with modified quality function deployment

Design-Parameter / Stakeholder requirements	Stakeholder weighting: very important(5), less important(1)	Weight	Design	dimensions h, w, l	surface design	components/materials used	technical life time	Interface, Software	kinds of connections
Direction of Improvement		↓	–	–	↓	↓	↑	↑	–
Units		kg		cm			a		min
good usability	5	1	1	3	1			9	
high functionality - performance	5		1			9	9	9	3
long playing time	3					3			
atractive design	4	1	9	3	9	9		9	
independend of place usable	1	9	1	9	1	3			
high reliability	5				3	9	3	9	3
less use of energy during use	5					9		3	
long life time	5					9	9		9
free of hazardous substances	5				9	9			9
easy to recycle	3				9	9	3		9
	%	1,5	3,0	3,6	6,7	14,7	4,7	7,8	6,6

Source: According to Wimmer et al. (2004)

Applying QFD in the early design phase of the Golf Swing Analyser gave importance to the following design parameters:

- components/materials used
- interface, software
- surface design
- kinds of connection
- compatibility with other systems.

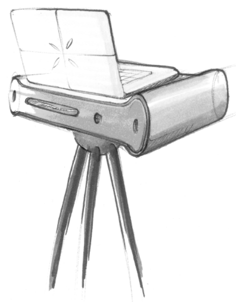
3.3 Developing green product concepts

Summarising the considerations above in the early stage of product development the environmental situation of the product becomes clearer and design targets can be set at the beginning of the product development process:

- low energy consumption through USB supply
- light weight design
- lead free soldering and RoHS compliant components
- design for recycling and recycling instructions according to WEEE.

Based on these findings a first design proposal could be achieved as shown in Figure 13.

Figure 13 Sketch of the golf swing analyser

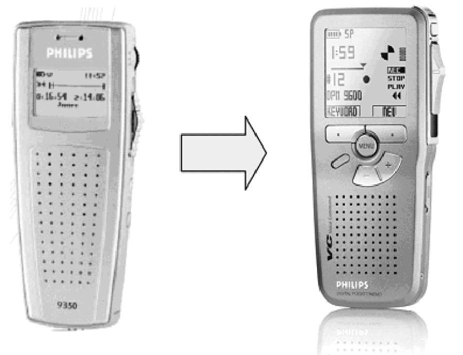


3.4 Communicating the environmental performance

Once product improvements and a better environmental performance have been achieved, the market needs to be informed about these achievements. A credible way of documenting the environmental performance is needed. There are several possibilities available to do so; international standard (ISO 14020, 2000) foresees three types: doing self declared environmental declarations, applying for an existing eco–labelling program or developing an Environmental Product Declaration (EPD). For the B2B market more and more companies are developing EPDs (ECODESIGN-company, 2007a). Documenting the environmental performance in this way sets the target values for the next redesign of the product – aiming at a better environmental performance.

The EPD for the DPM is currently under development to communicate the environmental achievements from the new DPM product launched in March 2007. Even the experienced customer was not able to see the environmental difference comparing the previous and the new design – see Figure 14. This was the main reason for engaging in more elaborate environmental communication.

Figure 14 Digital Pocket Memo previous (reference) model (left) and new model (right)



The following Key Environmental Performance Indicators (KEPI) have been selected to communicate the improvements. In the order of the product life cycle these KEPIs are:

- material consumption
- hazardous substances
- production waste
- packaging
- energy consumption
- recycling.

With the design of the new DPM the following improvements have been achieved:

Material reduction

- The material consumption of the charger could be minimised via USB cable charging.
- Multifunctional components consume less material for the same functionality e.g., integrating the power supply into the cradle (base station).
- The voice recorder is delivered with only one cable with local adapters for different countries.

Reducing energy consumption at use stage

- Due to the use of energy efficient components the energy used for signal processing could be reduced by 25%.
- The type of lightning system could be changed to LEDs. This lead to an energy reduction of 20% for lighting the display.

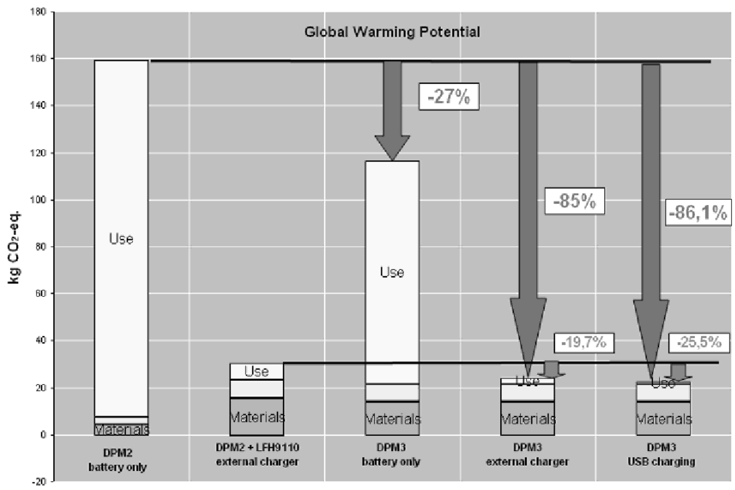
- For additional energy savings now there is the possibility to turn the LCD display on and off.
- The optimisation of the sleep mode leads to an energy reduction of the sleep time by over 50%.
- The stand-by consumption could be minimised via USB cable charging.
- With the use of rechargeable batteries the energy consumption and waste generation during the use phase decreases to a high extent and improves the environmental profile of the DPM significantly.

Product conception for recycling

- The shell technique has been optimised. The use of just one mono material for the outer parts makes material recycling possible and leads to material reduction.
- The reduction of the variety of components via multi-functional parts (inner cage holding most of the components) leads to a high reduction of the assembly costs.
- Separable connection techniques make easy assembly and disassembly possible (no glued connections for holding display, speaker and decoration elements, reduction of soldering points).
- Easy disassembly with a regular screw driver is possible.

In addition, Life Cycle Assessment (LCA) has been carried out to compare the previous DPM with the new model. Significant environmental improvements could be achieved. The LCA shows a reduction of the Global Warming Potential (GWP). Global warming is the rising of the global temperature due to emissions of greenhouse gases. Depending on the mode of operation up to 86.1% reduction of the GWP is possible. Figure 15 shows the possible reductions depending on the different use scenarios. DPM2 stands for the previous (reference) model. DPM3 is the new design.

Figure 15 Environmental improvements expressed in kg CO_2-eq. over entire life cycle – comparing different scenarios (battery use, rechargeable batteries with external charger and with USB charging (new model only)



4 Conclusion

What is needed in order to achieve a competitive advantage through Ecodesign is a full integration of environmental issues into the product development process. This requires staff training to the mostly new issue of understanding Key Environmental Performance Indicators in product development. This further requires customised company databases for material and processes in order to undertake LCT of products. Additionally, appropriate Ecodesign methods combined with a new consciousness are needed to enable comprehensive eco-product development. At the end environmental communication is needed to market the eco-products and to convey clearly the competitive advantages achieved through Ecodesign.

Three examples have been provided in this paper – many more are available to learn from others and to find one's own way to meet the future challenges of achieving, simultaneously, good environmental performance of products and competitive advantage, in a market that requires more and more environmental awareness, also from manufacturers of products.

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