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ECODESIGN TOOLBOX FOR THE DEVELOPMENT OF GREEN PRODUCT CONCEPTS – CASE STUDY DIGITAL VOICE RECORDER

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ABSTRACT
The paper describes a recently finished research project called "ECODESIGN Toolbox for Green Product Concepts" in short "ECODESIGN Toolbox". This project aimed at developing a systematic approach for sustainable product design as well as innovative product concepts in cooperation with partners from the industry e. g. Philips Dictation Systems Austria. The approach developed in the project as well as preliminary results gained so far will be demonstrated on a digital voice recorder, which was launched on the market in March 2007.

Keywords: Ecodesign tools, implementing Ecodesign, product improvement, sustainable product design

1 INTRODUCTION

This paper describes the results of a project carried out at the Institute for Engineering Design of the Vienna University of Technology. The project aims at developing a systematic approach for sustainable product design and is called "ECODESIGN Toolbox for Green Product Concepts". With application of the systematic approach innovative product concepts have been developed during this project in cooperation with partners from industry. The method is implemented on three different products: a digital voice recorder, a golf swing analyzer and an injection moulding machine.
In the paper the procedure and the results of the case study "digital voice recorder" in form of a Green Product Concept will be introduced. This project was funded by the Federal Ministry of Transport, Innovation and Technology and the Austrian Research Promotion Agency (Project number: 810777).

Research questions answered in the project:

1. How to environmentally describe a product as complete and easy as possible? Which technical parameters (e.g. weight and used energy) have to be considered?
2. How to quantify environmental impacts of a product in a practical way?
3. How to consider stakeholder requirements (e.g. from environmental legislation) systematically?
4. How to record, analyse and assess production processes and how to derive improvements out of this analysis?
5. How to derive improvement strategies from process, product and stakeholder requirements?
6. How to assess process, product and stakeholder improvement ideas and how to combine them to a Green Product Concept?

2 DESCRIPTION OF THE METHOD

The ECODESIGN Toolbox combines three different approaches, namely environmental requirements from product and process view and stakeholder requirements, to achieve a Green Product Concept. A Green Product Concept is obtained by the following six steps (Figure 1):

In the first, product description step system boundaries for the products to be analyzed have been defined and a schedule for the systematic description of the product by using environmental parameters has been worked out.

In the second, product assessment step the product was assessed to identify the life cycle phase which contributes most to the environmental impact. For this purpose the ECODESIGN Assistant [1] was applied which enables the application of Life Cycle Thinking. By using the data gained from the product description step the ECODESIGN Assistant identifies the life cycle phase with the largest environmental impact and suggests ECODESIGN improvement strategies for the product.

In addition to analysing the product a method called Holistic Process Optimization (HPO) has been developed in the third step. To achieve this optimization social, ecological and economical aspects have been considered. By integrating the process view into the Ecodesign process a more holistic view has been gained.

In the fourth step stakeholder requirements from retail and business to business (B2B) customers or employees have been taken into account. For analysing the stakeholder requirements parts of the method Quality Function Deployment (QFD) have been used. Additionally compulsory requirements from legislation were considered in this method as mandatory stakeholder requirements.

In the fifth step ECODESIGN improvement measures based on the suggested strategies from the Assistant have been developed. Further, appropriate process parameters and technical parameters derived from QFD have been taken into account as well.

Finally the results gained from the improvement step have been evaluated with a feasibility study for implementation. After evaluation the results have been gathered to frame an innovative Green Product Concept.

The six steps have been completed and applied to the products of the cooperating partners from industry. The application of the ECODESIGN Toolbox and the achieved results for the digital voice recorder from Philips Dictation Systems Austria will be shown in the following.

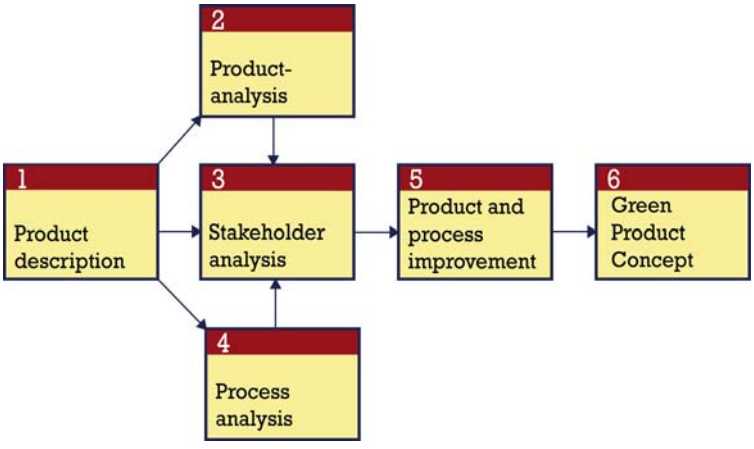

Figure 1. Six steps of the ECODESIGN Toolbox [2]

2.1 Product description

The analysed product is a professional digital voice recorder which is mainly used by doctors and lawyers. The voice is recorded in a special format and then transferred to the PC via using USB. The use scenarios can vary a lot. The estimated technical life time for the product is 4 years. The voice recorder consists of a body with buttons (plastics, aluminium, steel, etc.), electronic components (printed circuit board display, microphone, etc.) and is sold together with 4 cables for different countries, CD-Rom, power supply and 2 AAA-Batteries.

With the first step the product characteristics are described and documented in a quantitative and qualitative manner (Figure 2). 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.

This step should contain all information needed for realizing the following analysis of the product, the manufacturing processes and the stakeholder requirements. The product description contains relevant information along the entire product life cycle: raw materials, manufacturing processes, distribution, usage and end of life.

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]	?

Figure 2. Step 1 - Product description

2.2 Product analysis

The product analysis has been carried out by using and adapting the ECODESIGN Assistant. The Assistant is an add-on to the ECODESIGN PILOT [3], which helps to classify products and which enables to apply Life Cycle Thinking (www.ecodesign.at/pilot). The Assistant helps to identify the life cycle phase with the highest environmental impact. Based on this classification it suggests appropriate ECODESIGN strategies for product improvement.
The Assistant asks for product specific data with the help of six forms. For each of the life cycle phases, i.e. raw materials, manufacturing, 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 3.
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 ECODESIGN Assistant identifies the special characteristics and critical aspects of the product.

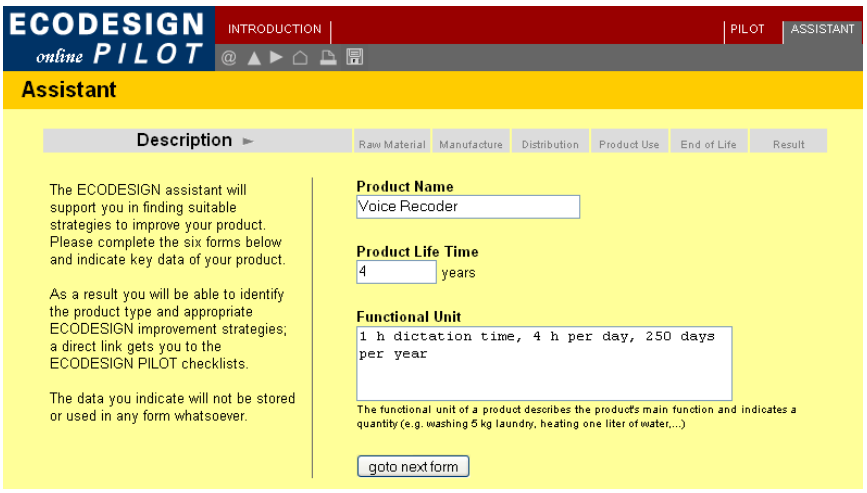

Figure 3. Step 2 - Product analysis with the ECODESIGN Assistant [1]

Further, the ECODESIGN Assistant recommends strategies for the improvement of the product. The strategies are divided into high priority strategies which should be realized since they lead to a significant product improvement and additional recommended strategies which can be realized at a later time. The corresponding checklists are derived from the ECODESIGN PILOT and can be used for generating improvement ideas for the product.
In the mentioned project the Assistant has been further developed and expanded. First the database has been updated with additional data for materials and processes. Second the results gained by the Assistant can be, among the ECODESIGN checklists for further improvements, visualized in a graph with quantified data. In this graph the relative environmental impact per life cycle phase of a product are displayed and the product type can be identified as well.
In the mentioned project the Assistant has been further developed and expanded. The Assistant is now based on Cumulative Energy Demand (CED), where the existing database has been updated with additional data for materials and processes based. This energy data have been simulated by using the LCA software SimaPro [4] with the EcoInvent [5] database. Further, the results gained by the Assistant can be, among the ECODESIGN checklists for further improvements, visualized 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.

Results gained with the ECODESIGN Assistant

The voice recorder is classified as type D: *"use intensive product"* which means that the product has its most environmental impact during its use phase (Figure 4).

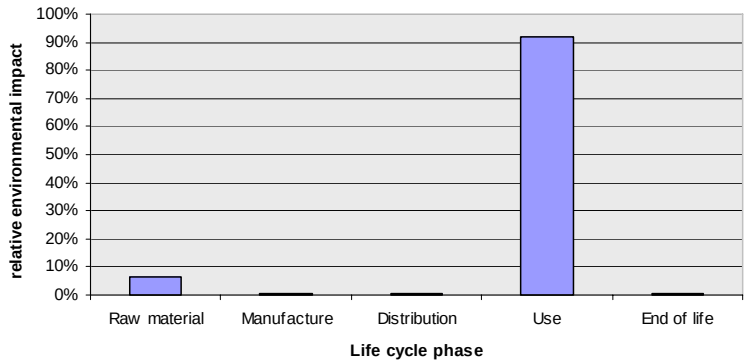

Figure 4. Step 3 - Environmental profile of the digital voice recorder [1]

The achieved result for the digital voice recorder 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 hours a day and 250 times a year over 4 years. The energy needed is supplied by AAA alkaline batteries. The voice recorder needs 800 batteries for its estimated life time.

Results of environmental product analysis:
The suggested strategies with high priority for the improvement of the voice recorder are:

- Reduction of energy consumption at use stage
- Avoidance of waste at use stage
- Ensuring environmental safety performance

Additionally recommended improvement strategies for the voice recorder are derived from the Assistant:

- Optimizing product functionality
- Improving maintenance

These strategies are linked to the checklists of the ECODESIGN PILOT and are used in step 5 for product improvement (see 2.5).

2.3 Stakeholder analysis

The stakeholder requirements are derived from customer and market requirements as well as from existing and upcoming environmental laws and directives. The voice of the customer is usually one of the strongest; a company has to fulfil the customers' needs in order to sell its 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 listed and then transferred into technical parameters (Figure 5) by using Quality Function Deployment (QFD) [6]. 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 agreed opinion. 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. For each parameter a suitable strategy of the ECODESIGN PILOT is assigned.

Design-Parameter / Stakeholder Requirements	Stakeholder weighting: very important(5), less important(1)	Weight	dimensions h, w, l	surface design	materials used	luminous intensity display	Size Display	Energy demand during use	Software
Direction of Improvement		↓	–	–	–	→		↓	–
Units		kg	cm			Lum	m²	kWh	
good usability	5	3	9	3	1	1	3	1	9
high functionality - performance	5	0	0	0	0	1	3	9	9
good readable display	2	0	3	1	1	3	9	1	0
long dictation time	3	3	3	0	0	1	1	9	0
atractive design	4	3	3	9	3	1	3	0	0
high reliability	5	0	3	0	3	0	0	3	9
less waste during use	3	0	0	0	0	3	3	9	0
free of hazardous substances	4	0	0	0	9	0	3	0	0
easy to recycle	2	3	0	3	9	0	1	0	0
	%	4,3	5,7	3,9	6,9	1,6	3,1	6,9	7,3

Figure 5. Step 4 - Quality Function Deployment [7]

Results of the Stakeholder Analysis –QFD - most important requirements

- Software
- Compatibility with other systems
- Use of energy during use
- Materials used, etc.

Additionally to QFD specific stakeholder requirements from legislations e.g. in the field of electronics such as the European WEEE directive [8] or the new upcoming EuP directive [9] are considered in the ECODESIGN Toolbox for Green Product Concepts. These requirements are investigated, listed and used in step 5 for product improvement.

Results Stakeholder analysis – Legal requirement- most important requirements

- Restriction of using lead (RoHS)
- Secure tack-back, collection and treatment (WEEE)
- Supply of information for users and treatment facilities (WEEE)
- etc.

2.4 Process analysis

The Holistic Process Optimization (HPO) investigates the production processes of the considered product. The integration of the production allows a more holistic view of the environmental impact of a product. As a result 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.
This method includes in- and output flow sheets for materials and energy. To get good comparable results special process ratios have been calculated e.g. resource efficiency or percentage of different overhead energies related to the total energy consumption. The ratios can be used on one hand for the process quality and on the other hand for finding potential improvements for the product. For example if the input/output ratio of raw materials is quite low it could be a result of a production process producing a lot of waste but it also could result from the product development department, where to much material for processing is calculated.

On the other hand a risk assessment of working materials on behalf of toxic effects, fire danger, danger for the environment, possibilities of explosions, etc. is applied in the toolbox. The input data can be gathered from the material safety data sheet.
As there is no manufacturing activity besides assemblage and testing the results for the process analysis bear rather low improvement potential at Philips Dictation Systems. The manufacturing processes at the other two partners from industry have been investigated more in detail.

Results of the process analysis:

- PVC is used in the packaging material at their supplier. This should be replaced for a simple recycling process.

2.5 Product and process improvement

In this step it will be discussed how to derive improvement ideas from process and product view and from stakeholder requirements. The results of the previous steps, the analysis of the product, the stakeholder and the production process present the input for the central part of the ECODSIGN Toolbox: product improvement. By using the Ecodesign strategies of the ECODESIGN PILOT [3, 10] product improvements are derived.

The Product Investigation, Learning and Optimization Tool (PILOT) which is available under www.ecodesign.at./pilot help product developer to find specific improvement strategies and suitable Ecodesign tasks to improve products in terms of environmental considerations.

The PILOT defines up to 19 different strategies which help improving the different product types. Depending on the life cycle phase with the most environmental impact, different improvement strategies for the product are necessary. Additionally improvement strategies for the parameters derived from QFD or improvement parameter derived from process analysis can be formulated.
The results from the previous steps present the basis for the improvement strategies and idea generation process for implementing:

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

Stakeholder analysis with legal requirements

- Restriction of using lead (RoHS)
- Secure tack-back, collection and treatment (WEEE)
- Supply of information for users and treatment facilities (WEEE)

Process analysis with Holistic Process Optimization

- Avoid PVC waste in production

For the improvement strategies the PILOT provides a checklist of improvement measures, which helps the product development team in evaluating the tasks and getting first ideas for product improvement. For each measure an assessment question can be found, where the relevance and the fulfillment of the measure have to be evaluated. If the calculated priority is high the measure should be chosen for further product improvement.
In the project the product improvement ideas have been worked out within the companies in creativity sessions by using the ECODESIGN PILOTs checklists. In Figure 6 the measure "Minimize energy demand at use stage by choosing an adequate principle of function" of the strategy "Reducing consumption at use stage" is shown.

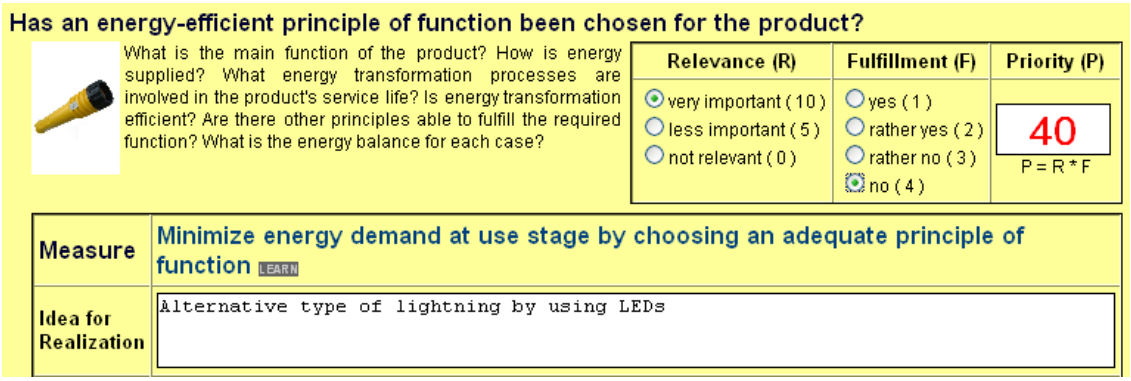

Figure 6. Step 5 – ECODESIGN PILOT [10]

The generated improvement ideas for implementation are listed in Table 1 according to the selected strategies.

Product and process improvement digital voice recorder	
Derived strategies and appropriate measures	**Improvement ideas for implementing – What to do?**
Product analysis	
Reducing consumption at use stage	
Minimize energy consumption at use stage by increasing efficiency of product	• Use of energy efficient components • Redesign of the electronics • Minimizing stand-by consumption
Make possible use of renewable energy resources at use stage	• Energy supply for the cradle using photovoltaic

Minimize energy demand in the use stage by choosing an adequate principle of function	• Possibility to turn LCD display on and off • Optimize sleep modus • Reduce power loss during charging • Alternative energy supply (rechargeable batteries)
Avoidance of waste at use stage	
Avoid and/or minimize waste at use stage	• Use of rechargeable batteries
Process analysis	
Improvement of supplier packaging	• Force supplier not to use PVC for packaging for an improved recycling process
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 aluminum as design elements
Improving disassembly	• Changing fasteners

Table 1. Step 5 - Product improvement strategies and appropriate ideas for implementation

2.6 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 effort (cost, time, etc.), benefit (environment, security, etc.) and risk for implementation.

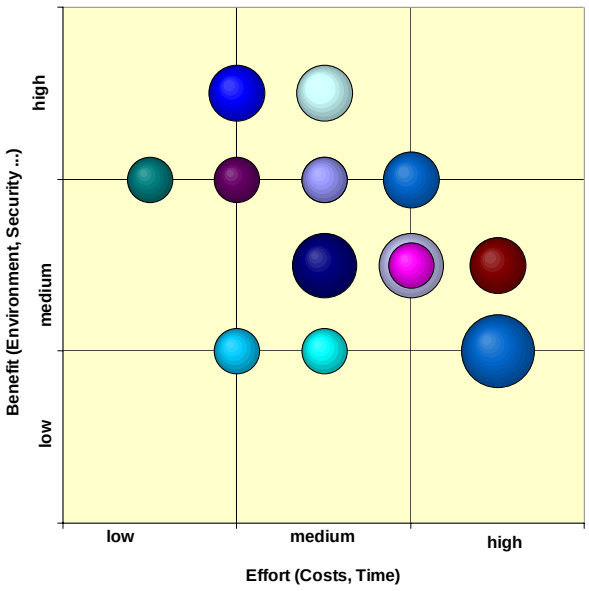

Figure 7. Evaluation of derived ideas

In the diagram in Figure 7 the ideas are evaluated in terms of effort to achieve product improvement and environmental benefit. Only those ideas with a good effort/benefit ratio are used for the Green Product Concept. After this improvement ideas have to be evaluated in terms of design and quality requirements.

For the digital voice recorder the following product improvement ideas have been selected and applied on the recent product model of the digital voice recorder with market launch March 2007.

Figure 7. Voice Recorder Previous and New Model

Reducing energy consumption at use stage

- Due to the use of energy efficient components the energy used for operating the digital voice recorder could be reduced by 25 %.
- The type of lightning system could be changed to LEDs. This leads to an energy reduction of 20% for lightning the display.
- For additional energy savings there is now the possibility to turn the LCD display on and off.
- The optimization of the sleep modus leads to an energy reduction of the sleep time over 50 %.
- The stand-by consumption could be minimized via USB cable charging (comp. interdependencies with material reduction).
- 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 digital voice recorder significant.

Material reduction

- The material consumption of the charger could be minimized 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.

Product conception for recycling

- The shell technique has been optimized. 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 multifunctional 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.

3 SUMMARY

The application of the systematic approach “ECODESIGN Toolbox for Green Product Concepts” is demonstrated on the case study “digital voice recorder”. The implementation shows the developed procedure steps consisting of product description, product analysis, stakeholder analysis, process analysis and generating of improvement ideas. As a result, the improvement ideas based on the previous steps have been gathered and formulated to a Green Product Concept for the digital voice recorder in the last step. The Green Product Concept has partly been realized within the recent product model of the digital voice recorder launched on the market in March 2007.

The digital voice recorder has been classified as a "use intensive product" because its environmental impact is the highest during the use phase due to high energy consumption. As the main improvement strategy the reduction of the energy consumption during usage has been identified. The energy demand could be reduced by 25 % using energy efficient components. An alternative energy supply - rechargeable batteries - reduced the energy demand for the production of hundreds of batteries and waste generation in the use phase to a high extend. Various other implemented improvement ideas lead to a highly optimized environmental performance of the digital voice recorder.

Summarizing the experiences made in the project, the systematical product improvement with the ECODESIGN Toolbox for Green Product Concept leads to better performance of the product concerning quality, operation and production costs and environmental impact.

Possible next step after using the ECODESIGN Toolbox and improving the product could be the communication of the environmental performance of the new eco-efficient-product to the market. Different tools exist e.g. environmental labeling, self-declared environmental claims and environmental product declaration. This will enhance the corporate image as a environmentally conscious company and may lead to an increased marked share.

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