ECODESIGN Toolbox for the Development of Green Product Concepts – Applied examples from industry

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1. Abstract

This paper describes the results of a project carried out at the Institute for Engineering Design of the Vienna University of Technology. The project aimed 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 research partners and partners from industry. The method is implemented on three different products: a digital voice recorder, a golf swing analyzer and an injection moulding machine and fulfils the specific needs of small and medium sized companies.
The methodology used in the project will be introduced and exemplary results from the three industry products will be shown in the paper. The project will be finished in June 2007.
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2. Introduction into Project

The project team consisted of the research partners ECODESIGN Research Group, Vienna University of Technology, Profactor Produktionsforschungs GmbH and KERP Competence Centre for Electronic and Environment and the following industry partners:

- Philips Dictation Systems (http://www.dictation.philips.com)
- ABATEC Electronic AG (http://www.abatec-ag.com)
- ENGEL Austria GmbH (http://www.engel.at)

The three product examples show a big variety in terms of functionality, complexity, environmental aspects, business model, target audience, etc. This presented a challenge for the development and application of the ECODESIGN Toolbox but at the same time guarantees the application to a wider range of products and industries. Within the project the method was developed and also implemented. One goal was to present an easy to use methodology which is flexible enough to be applicable for different kind of products, but not to broad which would make various aspects obsolete for most of the products.

Figure 1 shows the products investigated during this research project: a Digital Voice Recorder, a Golf Swing Analyzer and an Injection Moulding Machine.

Source: Philips Dictation Systems

Source: ABATEC Electronic AG

Source: ENGEL Austria GmbH

Figure 1: Product examples investigated in the project

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 six steps of the ECODESIGN Toolbox

The ECODESIGN Toolbox combines two different approaches, namely environmental requirements and stakeholder requirements, to achieve an green product concept. In the following, the six steps of the ECODESIGN Toolbox will be described in detail and experiences with implementing on the three product examples will be shown.

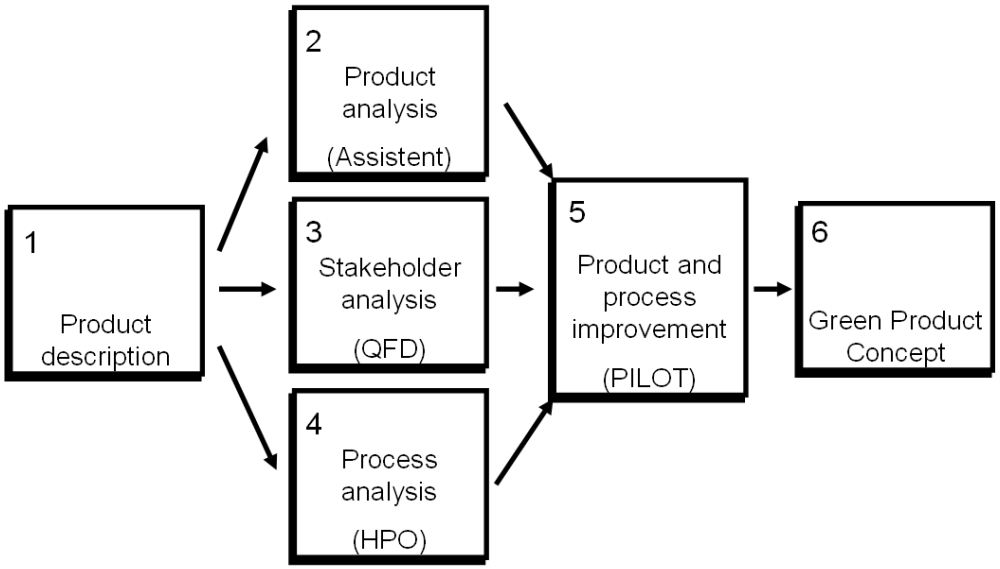


Figure 2: The six steps of the ECODESIGN Toolbox for Green Product Concepts [2]

2.1. Step 1: Product description

With the first step the product characteristics of the investigated product are described and documented in a quantitative and qualitative manner. Figure 3 shows an excerpt of the product description of the digital voice recorder. 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 analysing steps 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 and presents the essential basis for the following steps.

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 3: Step 1 - Product description data sheet

There should be a balance between the required parameters for a sufficient product description and reliable environmental analysis and a reasonable effort for the data collection. For the complex injection moulding machine the product description naturally took up more effort than for the other two products. A good documentation (SAP, material lists, supplier information…) can be very helpful in this first step of implementing the ECODESIGN Toolbox. The system boundaries have to be set at this point. The analysis of the manufacturing processes included the company site of the industry partners. The manufacturing processes at the site have been investigated more in detail than those of the supply parts and do not cover the single sub processes which are hardly quantifiable. Material declaration of the parts are mostly available, process data are kept secret along the supply chain.

Considered manufacturing processes at the company site:

- Digital Voice Recorder: assembly and testing
- Golf Swing Analyzer: printed wire board manufacturing, assembly and testing
- Injection Moulding Machine: Mechanical processes for manufacturing the main part of the components, assembly and testing

2.2. Step 2: Environmental Analysis

The product analysis has been carried out by using and adapting the ECODESIGN Assistant (www.ecodesign.at/assist). The Assistant is an add-on to the ECODESIGN PILOT (www.ecodesign.at/pilot) and helps classifying products and enables the application of Life Cycle Thinking [Wimmer, Züst 2002]. 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 4.

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.

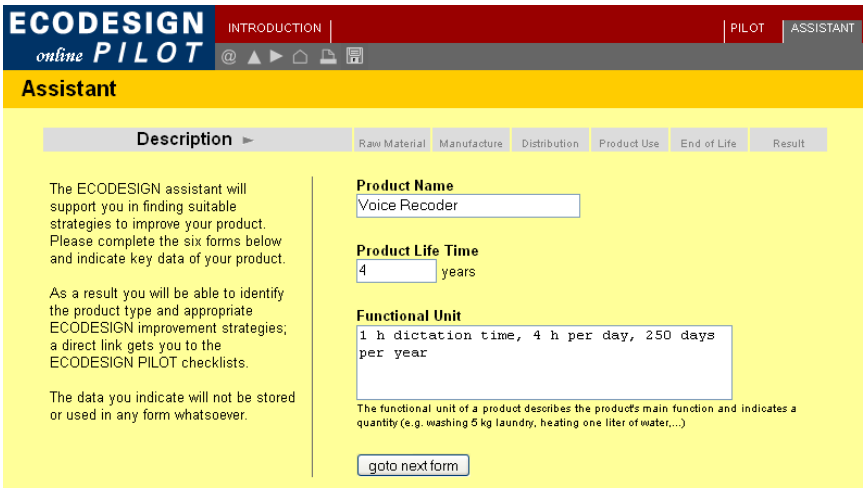


Figure 4: Step 2 - Product analysis with the ECODESIGN Assistant [1], Example digital voice recorder

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. The database has been updated with additional data for materials and processes based on the cumulated energy demand (CED). 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 digital voice recorder is classified as type D: *"use intensive product"* which means that the product has its most environmental impact during its use phase due to high battery consumption (Figure 5). The energy needed is supplied by AAA alkaline batteries. The voice recorder needs about 10 kg of batteries for its estimated life time.

The golf swing analyzer is classified as type A: *"resource intensive product"* which means that the product has its most environmental impact during its raw material extraction and material production phase. The result is referring to the massive aluminum housing of the investigated prototype which consumes a high amount of energy for the aluminum production. Depending on the use scenario e.g. estimating a more intensive business use at a driving range, the golf swing analyzer is classified as a mixture type A/D: *"raw material intensive and use intensive product"*. The use scenarios and consumer patterns have a major influence on the overall life cycle performance of a product.

The injection moulding machine is clearly classified as type D: *"use intensive product"*. This refers to the high energy consuming process during the injection moulding process. Again, the use phase has the main impact on the environmental performance of the product, although it weighs about 9,5 tons and a lot of raw material is transformed for producing the machine.

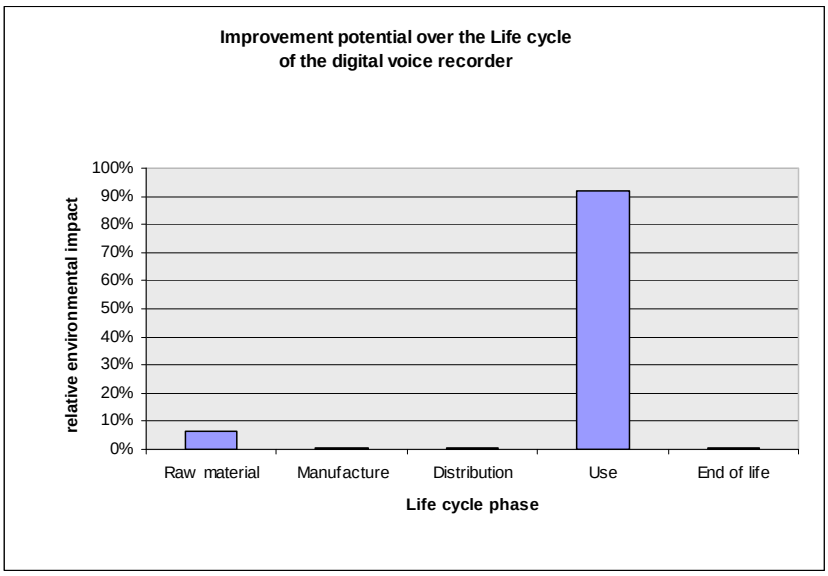


Figure 5: Result of Step 2 - Environmental profile of the digital voice recorder [1]

The achieved results depend on the considered use scenarios as well as on the energy management of the products. The essential aspect in this step is to identify the key impact parameters for the gained results. The main question here is: What influences the energy demand most and how can it be improved?

With this step first improvement strategies for the improvement of the reference products are suggested. These strategies are linked to the checklists of the ECODESIGN PILOT and are used in step 5 for product and process improvement (see 2.5 Product and Process Improvement).

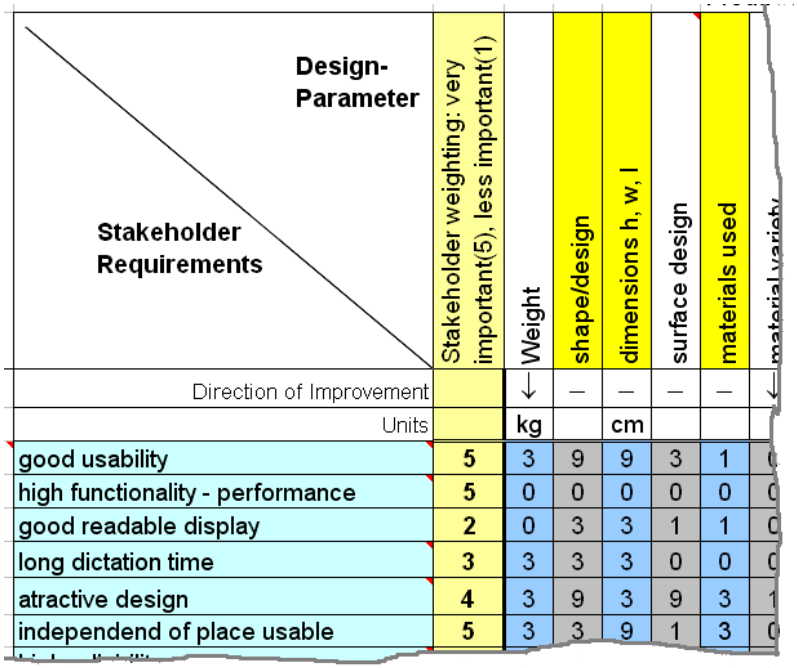
2.3. Step 3: Stakeholder Analysis

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 6) by using Quality Function Deployment (QFD). 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.

Additionally specific stakeholder requirements from legislations e.g. in the field of electronics such as the European WEEE directive [5], the RoHS directive [6] as well as the EuP directive [7] are considered in the ECODESIGN Toolbox for Green Product Concepts. These requirement are investigated, listed and used in step 5 for product improvement.

Exemplary Results of Stakeholder Analyses – List of most important requirements from QFD

- Software (Swing Analyzer, Voice Recorder)
- Compatibility with other systems (Voice Recorder)
- Use of energy during use (Injection Moulding Machine)
- Recyclable Materials (Swing Analyzer, Voice Recorder)
- …



Design-Parameter / Stakeholder Requirements	Stakeholder weighting: very important(5), less important(1)	Weight	shape/design	dimensions h, w, l	surface design	materials used	material variety
Direction of Improvement		←	–	–	–	–	←
Units		kg		cm			
good usability	5	3	9	9	3	1	0
high functionality - performance	5	0	0	0	0	0	0
good readable display	2	0	3	3	1	1	0
long dictation time	3	3	3	3	0	0	0
atractive design	4	3	9	3	9	3	1
independend of place usable	5	3	3	9	1	3	0

Figure 6: Step 4 - Quality Function Deployment [4]

2.4. Step 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 the 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 [Midterm report 2006].

The analysis of the manufacturing processes of the injection moulding machine presented the most yielding example for the application of the HPO. A high improvement potential concerning heavy waste cuttings from mechanical processing of the components and the varnishing process has been identified.
The investigation of the production of the printed wire boards for the Golf Swing Analyzer showed an improvement potential regarding the cooling/heating system.

2.5. Step 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 and process improvement. By using the Ecodesign strategies of the ECODESIGN PILOT 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 to improve the different product types. Depending on the life cycle phase the product has its most environmental impacts, 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.

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 7 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 for the voice recorder. The result is a list of possible improvement measures to be evaluated for implementation (Step 6).

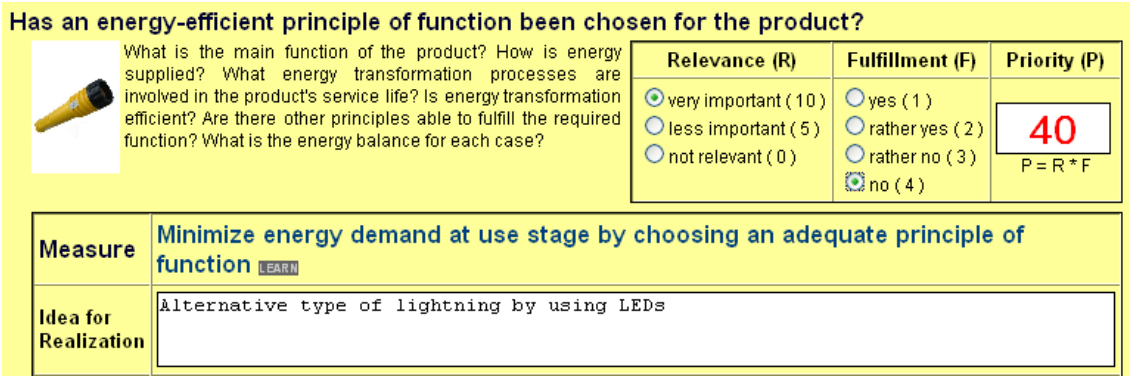


Figure 7: Step 5 – ECODESIGN PILOT, Example voice recorder [8]

2.6. Step 6: Green Product Concept

The sixth step of the ECODESIGN 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 and benefit for the environment and the company. Figure 8 shows the evaluation of the derived improvement ideas. The effort to achieve an improvement (costs, time…) is linked to the benefit (environment, security...). Only those ideas with a good effort/benefit ratio are used for the Green Product Concept. The size of the circles represent the risk (changing processes, customer acceptance…), the bigger the circle the higher the risk.

In the following, exemplary product improvement measures selected for implementing are shown for the Digital Voice Recorder and for the Golf Swing Analyzer.

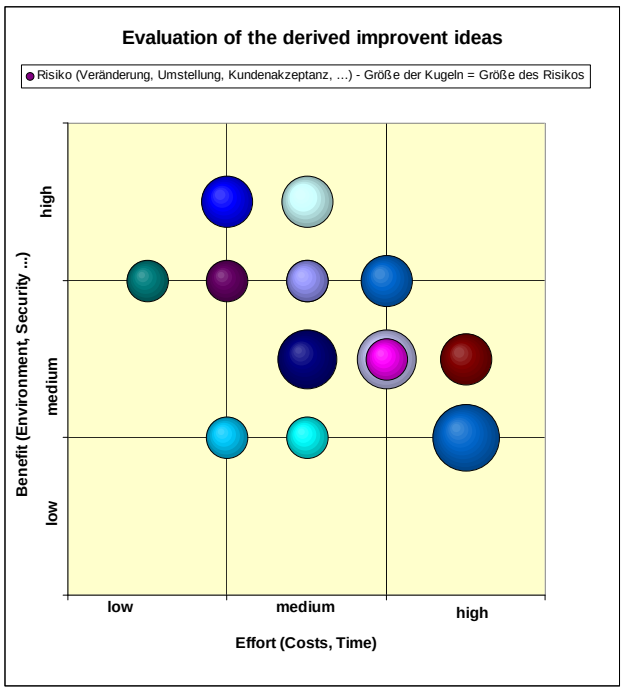


Figure 8: Step 6 - Evaluation of derived ideas

Applied ECODESIGN Strategy: Reducing energy consumption at use stage
Example Digital Voice Recorder

- Use energy efficient components: energy used for operating could be reduced to 25 %
- Change of lightning system to LEDs: energy reduction of 20% for lightning display
- The stand-by consumption could be minimized via USB cable charging
- Use of rechargeable batteries: energy consumption and waste generation during use phase decreases to a high extent and improves the environmental profile significantly

Applied ECODESIGN Strategy: Reducing material inputs
Example Golf Swing Analyzer

- Minimizing the raw material input via reducing the thickness of the metal sheet for the housing

Applied ECODESIGN Strategy: Improving disassembly
Example Golf Swing Analyzer and Digital Voice Recorder

- Design structure for easy assembly and disassembly
  - reducing number of screws for holding the optical elements – Golf Swing Analyzer
  - disassembly with a regular screw driver is possible - Golf Swing Analyzer
  - improved shell technique of housing, only separable connections and reduced number of connections through functional integration of parts – Digital Voice Recorder
  - connections are detachable manually or with shredding - Digital Voice Recorder
  - simple extraction of parts containing harmful substances
  - material separation for recycling purposes is possible

3 Summary

The application of the systematic approach “ECODESIGN Toolbox for Green Product Concepts” is demonstrated on the three case studies: digital voice recorder, golf swing analyzer and injection moulding machine. 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 three product examples in the last step.

The Green Product Concepts have already partly been realized. Within the recent product model of the digital voice recorder launched on the market in March 2007, selected improvement ideas derived from the project have been implemented.

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 to 25 % using energy efficient components. An alternative energy supply - rechargeable batteries - reduced the energy demand and waste generation in the use phase to a high extend. Various other implemented improvement ideas lead to a better environmental performance of the digital voice recorder.
The Golf Swing Analyzer is still under development and has currently reached prototype status. The improvement ideas for the product design as well as the production will be integrated in the continuing development process.
The company producing the investigated injection moulding machine is re-thinking the energy management of the use phase of the machine and is going to take further steps towards environmental product design.

The results show that the product design has major influence on the environmental impact of the products along their life cycle and that the impacts are determined during the development phase. 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.

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[6] WEEE: “DIRECTIVE 2002/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on waste electrical and electronic equipment (WEEE)”

[7] EuP: “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"

[8] ECODESIGN PILOTs Assistant, www.ecodesign.at/assist.

[9] ECODESIGN Online PILOT, http://www.ecodesign.at/pilot/.