Education and Culture
Lifelong Learning Programme
ERASMUS

ECODESIGN FOR SUSTAINABLE DEVELOPMENT

VOLUME 4

PRODUCT DEVELOPMENT

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Foreword

In Europe, in the last ten years, the responsible persons are concerned more and more about sustainable development and ecodesign, as a path towards it, imposing the applying of a new European legislation in this field. Due to it, there will be an increasing demand of engineers educated in the field of ecodesign in the future, to allow industries to meet the standards required by this new legislation.
Considering the labour market needs for engineers and designers with a wide eco-perspective, in the close future, in Transilvania University of Brasov, Romania, in 2005, was made the decision to start the enrichment of the engineering courses curricula with a module of ecodesign. The ecodesign module was developed in an European partnership consisting by Technical University of Vienna-Austria, Technical University of Tallinn-Estonia, Technological Educational Institution of Athens-Greece, University of Brighton-United Kingdom and three Romanian Institutions: „Petru Maior" University of Targu Mures, University of Bacau and Transilvania University of Brasov as coordinator, with the financial support of the European Commission in the frame of the curricula development project "ECODESIGN: an innovative path towards sustainable development", with the number 51388-IC-1-2005-1-RO-ERASMUS-MODUC-04.

The ECODESIGN Module consists in four subjects, for which the teaching aids (manuals and CD-roms) were prepared:

- Ecodesign Fundamentals;
- Product Life Cycle Assessment;
- Product Recycling Technologies;
- Embedding Ecodesign in Product Development.

„Product Development", the fourth volume of the book "Ecodesign for Sustainable Development" represents, for the students, a guide for how to analyze a product, considering its environmental impact and how to improve its design in order to be less harmful for the nature. This subject can be included to all Industrial Design engineering courses as an advanced subject, after the study of the other three subjects of the Ecodesign module.

The book is structured in 14 lessons, corresponding to the 14 weeks of an academic semester, from the Romanian universities. At the beginning of each lesson, the lesson objectives are presented and at the end of the lesson, some home exercises and additional lectures are suggested.
During the semester, the students will develop a project, supported by the information from "Embedding Ecodesign in Product Development" volume, with the aim to improve a product, considering the environmental constrains.

I would like to thank all those who have supported the project "Ecodesign: an innovative path towards sustainable development", especially to Prof.Dr.Eng. Ion VIŞA, Rector of the "Transilvania" University of Braşov and Prof.Dr.Eng. Anca DUŢĂ, coordinator of the Department of "Management of the research and educational projects". I also want to express my deep gratitude to all the colleagues and friends from the partnership team for the commitment and their inspired contribution in preparation and development of the teaching aids of the Ecodesign Module.

Anca Barsan
Ecodesign Project Coordinator
Brasov, August 2007

Ecodesign for Sustainable Development

Volume 1

FUNDAMENTALS

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PRODUCT LIFE CYCLE ASSESSMENT

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PRODUCT DEVELOPMENT

Book Contents

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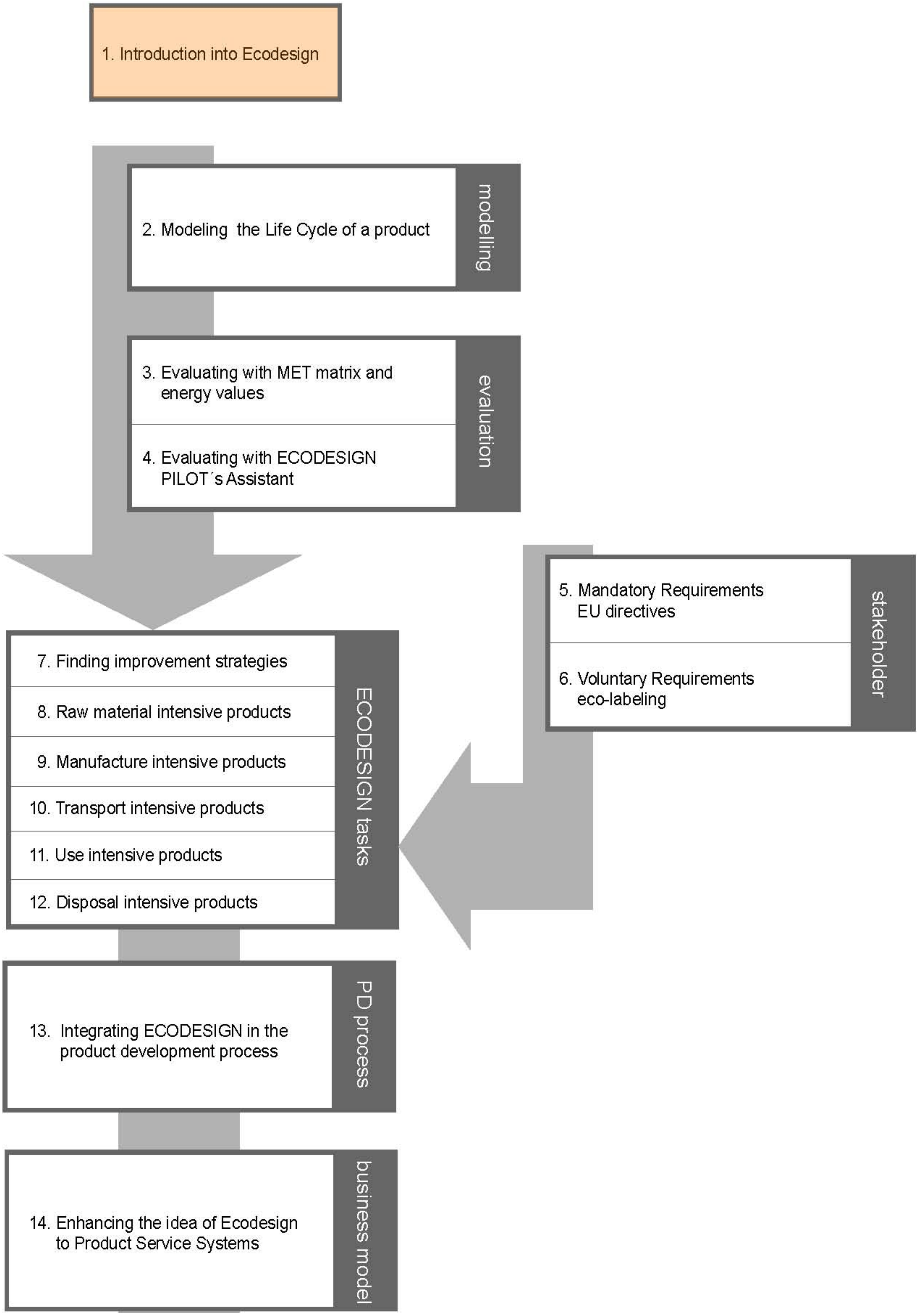
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LESSON 1

Introduction into Ecodesign

KEYWORDS: ECODESIGN, LIFE CYCLE STAGES, RECYCLING, REPAIR, REVERSE MANUFACTURING

Lesson objectives

Lesson 1 will focus on some considerations how and why products cause harm to the environment through their life cycle. The different life cycle stages of products will be described more detailed. The focus will be turned on the interaction between the different processes in the individual life cycle stages and the environment. You will find out that any process in any of the life cycle stages will have an effect on the environmental impact.

It will be pointed out why it is necessary to consider environmental aspects of products and why it is important to integrate environmental aspects into the product development process.

Further you will get comfort with the idea of Ecodesign. This lesson will give a definition of Ecodesign and will describe its concept more detailed.

At the end of this lesson you will know what Ecodesign means and why it is necessary to implement Ecodesign into the product development process.

ECODESIGN – WHAT IS THAT?

Ecodesign is the design of products with respect to their ecological effects. It considers the contribution of the product to environmental impact through all of its life cycle stages. The five life cycle stages of a product are shown in Fig.1.1.

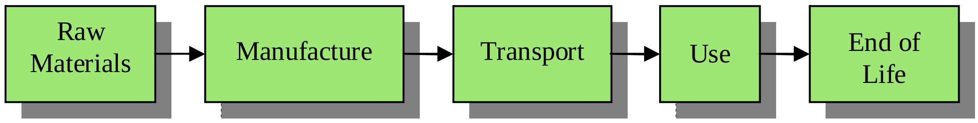
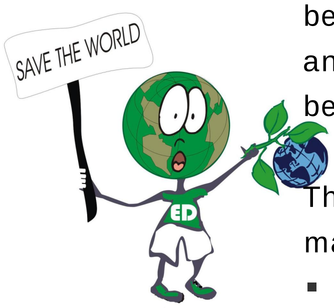


Fig.1.1: The five life cycle stages of a product

By applying Ecodesign resources are used intelligently and therefore benefit for all involved actors along the value creation chain is increased and, at the same time, environmental impacts are reduced. This should be achieved under social fair conditions.



The motivation for implementing Ecodesign can be divided into three main groups:

- *Ecological reasons*: to secure an intact environment for future generations, consumptions of non-renewable resources and impacts to the environment must be reduced now. Ecodesign is an effective approach to translate this aim into reality.
- *Economical reasons*: implementing Ecodesign in companies can lead to innovative products with improved quality and optimized functionality. This can open new consumer segments. Ecodesign also helps to build up confidence and credibility in stakeholders and achieve better ratings of the company. Reduced use of materials and energy helps to save costs.
- *Social reasons*: socially compatible conditions and quality of life as well as job creation, which are all factors for economical and political steadiness, can be provided by the implementation of Ecodesign.

Nowadays the idea of Ecodesign is widely spread over the different technical disciplines such as architecture, civil engineering, mechanical engineering or industrial design. The different disciplines use the term 'Ecodesign' in different ways. The approach of Ecodesign given above is based on the approach which is used for product development. It is more based on ecological than on economical aspects.

Innovative companies show interest in implementing Ecodesign. This is not only because laws and directives forces them to do so. They have realized that Ecodesign is part of future oriented technology; Ecodesign is considered as an investment in a technology which allows, beneath other advantages, saving a lot of internal costs.

Since engineers in product development are not necessarily environmental experts, implementation of Ecodesign still is a challenging task. Industrial projects often show that Life Cycle Thinking (LCT), this is, according to (Wimmer, Züst, Lee, 2004) the holistic consideration of environmental impacts of a product caused throughout its life cycle stages, is still not well established among engineers in product development. The influence of the design of a product to its environmental performance, viz the caused impacts to the environment by the product, is still unclear to most engineers in product development. Therefore it will be shown in the next lessons how Ecodesign can be embedded effectively into product design.

ECODESIGN - WHY?

When thinking about the quality of a product, what considerations do you take into account? What qualities of a product do you evaluate before you buy a product? What properties of a product give direction to your decision?

By holding two products in our hands sometimes we think the heavier product is the better one. How comes that? Is it because we think the heavier product contains somehow ‘better’ materials by using for example metals instead of plastics? Is it because we think the product might have a longer lifetime then? Is it because plastics are considered as ‘cheap’ or somehow ‘weak’? Beneath the materials used in the product its performance, its design and its appearance are important parameters which are considered when buying a product. Sometimes we are ready to spend a lot of money just for a design which appeals to us. The sales price is another important parameter to consider when intending to buy a product.

But have you ever thought of evaluating a product from an environmental view? Have you ever thought about the impacts a product is causing to the environment? Have you ever considered how much impact a product will cause until its end of life? Have you ever thought of considering the environmental performance of a product as a quality criterion?

Imagine you want to buy an office chair: can you imagine that this product could have caused some toxic waste (without containing any toxic substances of course)? Have you ever considered that by using the air conditioner of your car you contribute to global warming? Did you know that usual jeans trousers travel about 50000 km around the world before you can buy them in a store? Can you imagine that for the production of a personal computer more than 14000 kg of materials and additional 30000 litres of water are needed?

Maybe you were not familiar with such ideas? This is because you probably have only considered the use stage of the product where you are directly confronted with the product and where you interact with it. But the product has passed through different stages before you can buy it in a store and will pass different stages after you dispose it. All these stages cause some impact to the environment. In the following these stages are introduced and briefly explained.

RAW MATERIALS

To be able to produce any kind of products different materials are needed. Imagine some household appliances such as a washing machine. In a washing machine different materials such as metals (e.g. steel plates), glass or plastics are used amongst others.

Environmental considerations must start from the point where for example iron ore is extracted to produce steel or crude oil is extracted to produce plastics. Raw materials are processed to materials which can be used in products. If we want to go more into detail we should also take all energies needed for the extraction and the further processes of the raw materials into account. By going a level deeper into detail we should also consider for example the land transformation which occurs by extracting raw materials.

It was stated that the energies needed should be considered. Which kind of energies are there and how are they obtained? Let us consider electric energy: electric energy can be supplied by hydroelectric power plants, solar power plants or windmills; so called “renewable sources of energy”. But today most of the electric energy is supplied by power plants which require fossil fuels such as coal or gas or by nuclear power plants. By incinerating fossil fuels a lot of other co-products such as carbon black, carbon dioxide (CO_2) or methane (CH_4) occur. CO_2 and CH_4 are greenhouse gases. The emission of a huge amount of these gases into the atmosphere is causing the phenomenon called “global warming”.

For any kind of processes energy is needed and for the production of energy mostly fossil fuels are used. As researches predict again and again the resources of fossil fuels are limited. With the rise of industrialisation the need to fossil fuels and other resources rises too. Tab.1.1 shows the annual energy consumption and CO_2 emission of some selected countries.

Tab.1.1: Energy consumption and CO2 emission of some selected countries (Worldwatch Institute, 2004)

Country	**Oil**	**Electricity**	**CO_2 emission**
Unit	Barrel per day and 1000 inhabitant	kWh per person	Tons per person
United States of America	70.2	12.331	19.7
Japan	42.0	7.628	9.1
Germany	32.5	5.963	32.5
Poland	10.9	2.511	8.1
Brazil	10.5	1.878	1.8
China (without Hong Kong)	4.2	0.827	2.3
Ethiopia	0.3	0.022	0.1

It was the German forester Hans Carl von Carlowitz who introduced the term “sustainability” in the 17th century. The rising need for wood and the intense felling of trees lead to the deforestation of the woods. He stated that for being able to prevent wood destruction the felling of trees must be in balance with the amount of trees which grow again. The need to wood must be either adapted to this balance or if not possible, some other resources must be found which can satisfy the needs...the concept of sustainability was born!

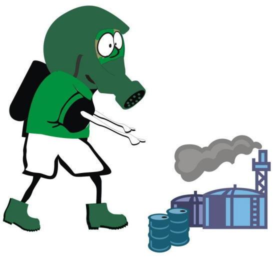
Nowadays the term “sustainability” is also present in industry, especially in product development. Integrating the idea of sustainability as well as environmental considerations into the product development is the guiding idea of Ecodesign. The European Environment Agency defines Ecodesign as *“the integration of environmental aspects into the product development process, by balancing ecological and economic requirements. Ecodesign considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle.”* (European Environment Agency, 2006)

As already stated the main problem of using fossil fuels is that during their incineration gases such as CO_2 which are key factors for global warming occur. The effects of global warming are various: changes in weather and ecosystems, glacier retreat or rising of sea levels are some effects to be pointed out here.

It has also to be mentioned that nowadays economy is based on oil and gas, hence fossil fuels. Each year new sources of these resources are found but the annual need for these resources rises much faster than the sources can supply. Since these resources are not renewable and therefore limited, this ongoing trend means that we will be confronted with a scarcity of these resources in future. If we want these resources to be available for our future generations we must either reduce our consumption which means a change in our life style or we must find some other resources which can replace fossil fuels.

MANUFACTURE

Once materials are extracted they can be processed to parts and components during manufacturing. The components can be assembled to form the final product.



For manufacturing tools and machine equipment are necessary. Machines again require energy to operate. Beneath that, process materials such as chemical substances, coolants, glue or water are necessary in many production steps.

If we want to go more into detail, all energies needed to lighten, warm or cool the factory must be taken into account too. These additional energies are called “overhead energies”. Experience shows that the overhead energies can rise up to 200% of the energy needed for the actual manufacturing processes.

But there is more: all energies needed to transport parts and components of a product to manufacture sites must be considered as well.

Let us consider jeans trousers. A common pair of jeans travel more than 50000 km before a customer can buy them in Europe. What does this “travel around the world” consists of? We have to consider that the cotton needed for the jeans grows in Kazakhstan. The cotton is harvested and sent to Turkey where it is yarned. In Taiwan the yarn is woven. The dye needed to colour the textile comes from Poland, the textile itself is dyed in Tunisia. In Bulgaria the textile is smoothened by different processes. In China the knobs which were imported from Italy as well as the linings which come from Switzerland were sewed on the jeans. In France the surface of the jeans textile is processed with pumice which is imported from Turkey. The trousers are sent to Portugal then, were a label ‘Made in

Portugal" is sewed. From Portugal the trousers are distributed all over Europe for sale[1] .

Just imagine the huge amount of energy needed for the transport among the different factories for the manufacture of the product and try to imagine the amount of generated emissions! *Note*: the combustion of 1 kg fuel produces approximately 3 kg of CO_2 (Wimmer, Züst, Lee, 2004)!

TRANSPORT

The final product needs to be packaged and delivered to the consumer or retailer. Depending on the mode of transport, e.g. airplane, ship, train or truck, energy is used and emissions are generated.

USE

In the use stage the product is operated. In order to provide the functions properly, the product may require energy or secondary materials, e.g. lubricants, water or coolants.

A product has to fulfil its functionality in the use stage. The lifetime of a product is the time the product can fulfil its functionality properly. Most consumers are directly confronted with the product in this stage. Some impacts to the environment in the use stage may also cause stress for the user: imagine products, e.g. household products, which cause high level of noise or vibrations during use. Also imagine for example products which need batteries to function: beneath the high environmental impacts caused by the batteries when they are treated after reaching their end of life, the user of such products has to spend a lot of money for the purchase of batteries. In case of battery operated products one can see that by reducing the need for batteries not only the environmental impact of the product can be reduced but also the operating costs for the product decrease.

Occurring environmental impacts as well as emerging costs also depend on the user's behaviour, viz how the product is used. Imagine a washing machine which is only filled up half with laundry: The amount of water, and electrical energy needed may be the same as it is the case when fully filled. But the output, that is washed clothes, is just half. This means that the costs per washing cycle and the relative environmental impact (related to the output) are twice as high. Designers have no influence on

[1] Example taken from (Praxis Umweltbildung 2006)

the way the product is used. All they can do is to provide a design which avoids an inappropriate use of the product. In the case of a washing machine for example the device could be provided with different programs which optimize the amount of water used in dependence to the amount of laundry filled in.

In the use stage of a product, the interaction between the user and product is most important. Usually this interaction ends when the product is not able to operate properly anymore and is disposed by the user. The product enters another stage called the 'end of life' stage.

END OF LIFE

When a product is defect or is not able to provide its function anymore, it has reached its end of life stage. There are several and different ways to treat the product and its part in the end of life (EoL) stage. The product can be for example disassembled. The components and the parts can be used again or the materials used in the product can be entered into a recycling cycle. A detailed description of this life cycle stage is given in lesson 12.

SUMMARY

The reasons for implementing Ecodesign into the product development process are various: occurring scarcity of raw materials in the near future, raising consumption of energy, occurring environmental impacts through product development processes, social as well as economic reasons.

To be able to apply Ecodesign to products it is important to take all five life cycle stages into consideration and to keep in mind that the life cycle stages often contain complex loops and cycles.

The next lesson further deals with the product's life cycle in the context of Life Cycle Thinking in product development process as well as introducing qualitative description approaches for a product by using environmental parameters.

HOME EXERCISES

	Assignment of products for improvement to the students. Presentation of the results in lesson 8-12.

1. Have a look at your product:
   a. What function does it have to fulfil?
   b. Is your product design able to fulfil its function properly? What are the weak points of the design? Could there be any harm or danger in case of malfunction or abuse?
   c. Give a brief description of your product, e.g. estimated purchase price, used materials, estimated and guaranteed life time etc. You can use the information on the packaging or the manual.

2. Environmental issues of your product:
   a. Give a general qualitative description of the different life cycle stages of your product.
   b. How do you believe is your product manufactured? Which technologies are used?
   c. How do you think is your product distributed? What is the transport distance?
   d. How should this product be used? What are the environmental impacts in the use stage?
   e. How is the product disposed and how is the product treated when it reaches its end of life? Is recycling possible? Can parts and components be reused?

3. How do you believe could Ecodesign be applied to your product?

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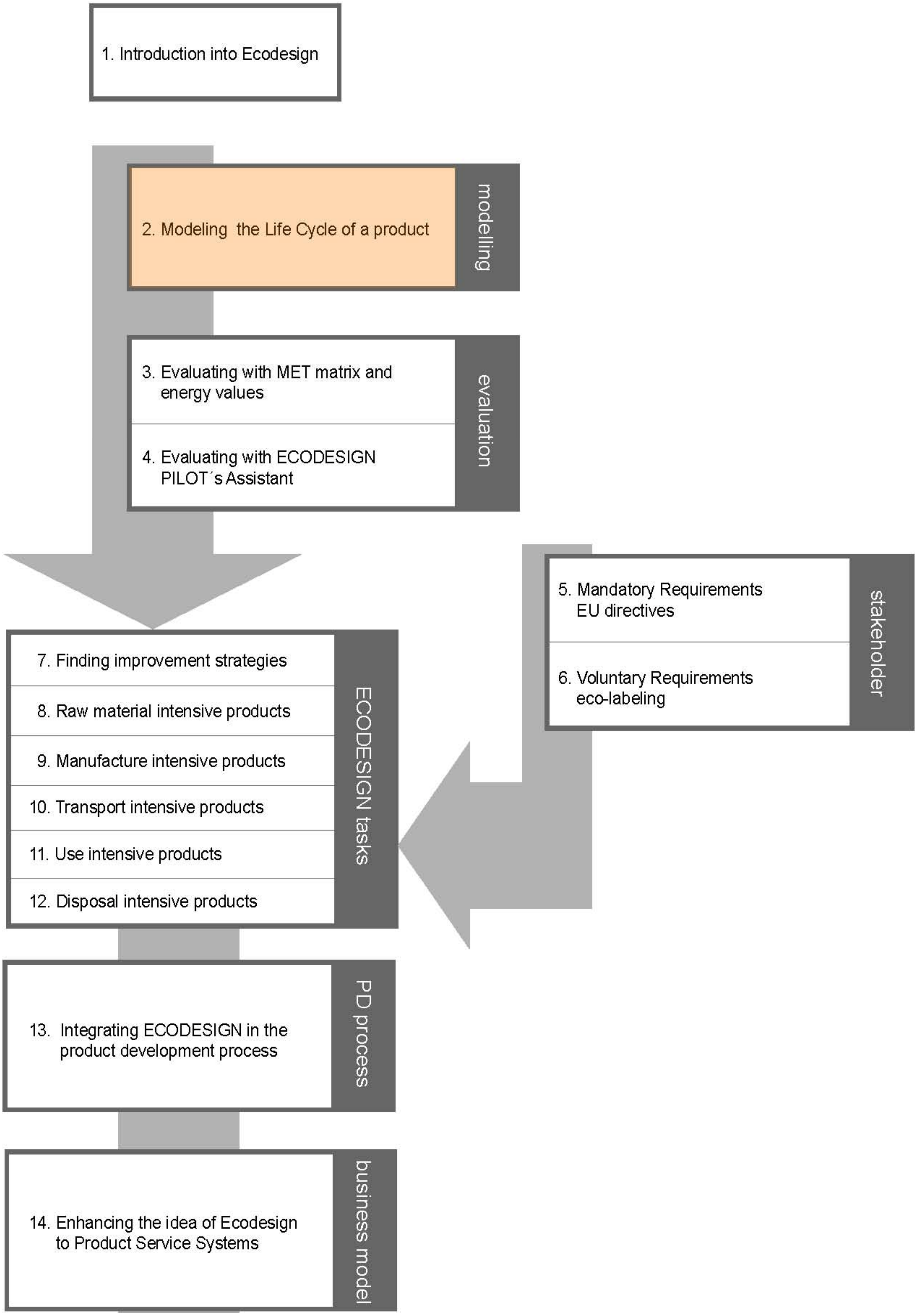
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LESSON 2

Modelling the Life Cycle of a Product

KEYWORDS: LIFE CYCLE THINKING (LCT), LIFE CYCLE THINKING DIAGRAM, QUALITATIVE DESCRIPTION, QUANTITATIVE MODELLING

Lesson objectives

This lesson aims at introducing different ways of modelling the life cycles of a product. Two different approaches can be pursued: one is a qualitative and one is a quantitative description of a product. Therefore two types of data can be differed, namely qualitative data and quantitative data. Qualitative data can be expressed e.g. as ratings.

Considering just parts of the life cycle stages of a product (e.g. only the use stage from the view of the consumer) is a common and wide spread mistake. In the sense of Ecodesign, all life cycle stages, starting from raw materials, manufacture, transport over use and the end of life stage, have to be taken into account when a product is analyzed.

To achieve an overall view of the product, the concept of Life Cycle Thinking (LCT) is introduced in this lesson.

At the end of this lesson you will be able to:

- *Include Life Cycle Thinking in your considerations when analyzing your product*
- *Give a qualitative description of your product using environmental parameters*
- *Quantifying environmental parameters of your product*

In this lesson three examples are discussed:

1. *Juice extractor*

In this example special attention is given to where *system boundaries* have to be set and which influence the definition of system boundaries have on the environmental profile of a product.

2. *Washing machine*

In the example of the washing machine different use scenarios are investigated. The different use scenarios lead to different relative environmental impacts in the life cycle stages. The engineer in product development can optimize a product in view of the different use scenarios.

3. *Office chair*

An office chair is introduced as an example for a product which has its most environmental impact in the first life cycle stage, namely *raw materials*.

LIFE CYCLE THINKING

Commonly, producers and users focus only on one part of the product life cycle. The former may pay attention to the optimization of manufacture processes whereas the latter have interest in the product use stage and end of life stage. Life Cycle Thinking is a key for an overall attention to all five life cycle stages of a product.

PRODUCT DESCRIPTION

Generally, data for product description can be divided into quantitative data and qualitative data.

A quantitative product description is based on quantifiable data, where quantified input and output factors are considered, e.g. amount of kg material used. A Life Cycle Assessment (LCA) according to ISO 14040 requires quantifiable data.

Qualitative data may be expressed as scale ratings, e.g. 1 representing ‘best’ and 5 representing ‘worst’, or as relative rating terms such as ‘better than’ or ‘worse than’. Qualitative data can be used in matrix LCAs, compare module 2.

A qualitative description of a product gives a first overview of the product. This can be achieved by using general data such as, e.g.:

- Name of the product
- Name of components
- Parts and components which has to be purchased from other manufacturers
- Use scenarios
- Functionality
- Functional unit
- …

Qualitative product description may also include textual descriptions of products.

For the evaluation of environmental aspects of a product by qualitative data, so-called ‘environmental parameters’ should be addressed. Environmental parameters related to the product life cycle are listed in Tab.2.1.

Tab.2.1: Environmental parameters related to product life cycle stages

Life cycle stage	Environmental parameter
Raw materials	• Materials used • Problematic materials • …
Manufacture	• Production technology • Production waste • …
Transport	• Packaging • Transportation • …
Use	• Usability • Energy consumption • Waste, generated • Noise and vibrations • Emissions • Maintenance • Reparability • …
End of life	• Fasteners and joints • Time for disassembly • Rate of reusability • Rate of recyclability • …

EXAMPLES

Fig.2.1: Juice Extractor [www.philips.at]

In the following a juice extractor will be considered. A description results in the following data:

Tab.2.2: General environmental parameter of the juice extractor

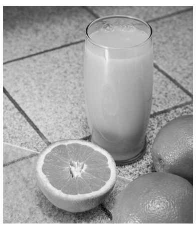
General environmental parameter (qualitative and quantitative)	
Name of the product	Juice extractor
Weight of Product	705 g
Weight of product incl. packaging	1.055 kg
Measures	Height: 192 mm Highest diameter (housing): 82 mm
Volumetric capacity	750 ml
Components	Motor (85 g) Press cone (135 g) Housing (170 g) Juice-container (190 g) Cable (65 g) Packaging (345 g)
External parts	Cable, motor, packaging
Use scenario	Use scenario: 1 time per day, 50 weeks a year over 5 years
Lifetime	5 years
Functionality	The extracted juice drops directly into a container via a sieve. The juice extractor is switched on via a contact during pressing the fruit against a cone and runs as long as a contact force exists.

Considerations about the life cycle and specific environmental parameters according to Tab.2.1 are summed up in the Tab. 2.3.

Before you go on, try to consider following questions:

- *Do you believe that the juice extractor is fully described by Tab.2.2 and Tab.2.3? If not, what remains open?*
- *What does the juice extractor need to be able to fulfil its function?*
- *Where should system boundaries be set? What influence may different system boundaries have on the environmental profile of a product?*

Since a juice extractor needs fruits (e.g. oranges) for fulfilling its function the fruits needed for the extraction should be also taken into considerations.



This can be explained as follows:
To provide juice the juice extractor needs fruits. An ideal juice extractor would extract all juice content included in the fruit and would not waste any juice at all. Therefore it may be useful to find out how these fruits can be quantified and what the maximum amount of juice in an orange is.

Specific environmental parameter	Explanation (qualitative)
Use of raw materials	
Materials used:	ABS, PMMA, PP, PS Motor contains metal parts Cable contains copper
Manufacture	
Production technology:	Mainly injection moulding
Production waste:	Packaging of external parts, sprue bushes of injection moulding
Transport	
Packaging:	Cardboard
Transport:	Truck
Product use	
Usability:	Extracting juice, collecting juice, cleaning
Energy consumption:	15 Watt
Generated waste:	Fruit pulps (biological waste), orange peels
Noise and vibrations:	Gearbox is not damped, may cause noises during operation
Maintenance:	Washing after using, dishwashing detergent needed
Reparability:	Extractor is completely exchanged in case of damages
End of life	
Fasteners and joints:	Connectors
Time for disassembly:	Disassembly in less than 2 minutes possible, motor itself is not disassembled
Rate of reusability:	Motor can be reused after inspection
Rate of recyclability:	Approximately 40%

Tab.2.3: Description of specific environmental parameters for the juice extractor

In the following a quantification of oranges is described briefly:

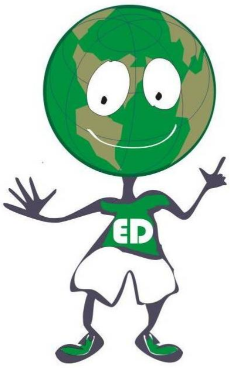
Oranges are needed for the life cycle stage ‘use’.

	Explanation
Origin :	Brazil (From July to September) Spain (Rest of the year)
Transport:	From Spain: via lorry over 3000 km From Brazil: via ship over 10000 km Additional 2000 km via lorry for transport
Irrigation:	1 kg of oranges need 1000 litres of water
Mix of oranges:	A mix of 75% of Spanish oranges and 25% of Brazilian oranges is assumed
Juice:	For the extraction of 750ml orange juice 11 oranges (this is an empirical number) mixed of oranges from Spain and Brazil are needed
Average weight of orange	150 g
Content of juice	105 g (100% of juice)

Tab.2.4: Quantitative description of oranges

Testing of the juice extractor shows that approximately 45% (43 g) of the juice content of an orange can be extracted. 55% are wasted.

To be able to achieve a precise environmental profile of a product it is important to define precise system boundaries. An appropriate functional unit must be defined at the beginning of the considerations. A functional unit quantifies the function of a product, see lesson 4. The functional unit of a juice extractor can be defined as: “extracting 750 ml of juice”.



By Life Cycle Thinking weak points of the product can be found. Since the ‘oranges’ have a serious influence on the environmental profile of the juice extractor, especially on the life cycle stage ‘use’, the optimization criteria for the juice extractor may be its capability of extracting as much as possible juice from the fruits. An evaluation of the juice extractor and the fruits shows that approximately one third of the environmental impact during the use stage can be assigned to the oranges. Therefore an optimization of the extraction process of the juice extractor seems to be most relevant. This optimization would minimize the contribution of the oranges to the overall environmental impact in the use stage.

Defining proper system boundaries remains an important task. In order to define system boundaries, the different processes, activities or materials through the entire life cycle of a product must be evaluated. Significant processes should be included within the system boundary; less significant ones can be neglected.

Different decision rules for the evaluation of the significance of processes and activities can be used. According to (Wimmer, Züst, Lee, 2004) a decision rule for mass inclusion can be considered. Unit processes are excluded if their fractional weight to the product is less than a certain percentage. Unit processes are elements of the so called ‘product system’, where all components, parts and materials as well as all development activities are considered. Decision rules based on energy flows are also possible.

System boundaries may also be chosen in a way that a compromise between the accuracy of the product description and evaluation (e.g. LCA, see module 2) and the time needed for description and evaluation as well as the associated cost is achieved.

Another example explained here is a washing machine, as explained in (Wimmer, Züst, 2002). Life Cycle Thinking leads to interesting results in this example.

Fig. 2.2: Typical washing machine [www.sem.or.at]

Consider two different types of washing machines, one costs 500€, the other one costs 2000€. Let's assume that a washing machine for a household with 50 washing cycles a year and a washing machine for a dormitory with 2 washing cycles a day has to be purchased. Well, if the purchasing price is the only considered parameter, the first machine is the one to chose.

But Life Cycle Thinking leads to extended considerations. Obviously the consumer is confronted with different use scenarios. An Input-Output analysis where all input needed to wash clothes (energy, process materials, etc...) as well as the output from the washing process (clean clothes, heat, etc...) are drawn in a flow chart. This helps to describe the use stage of the washing machine more precisely. Fig. 2.3 shows such an Input-Output chart.

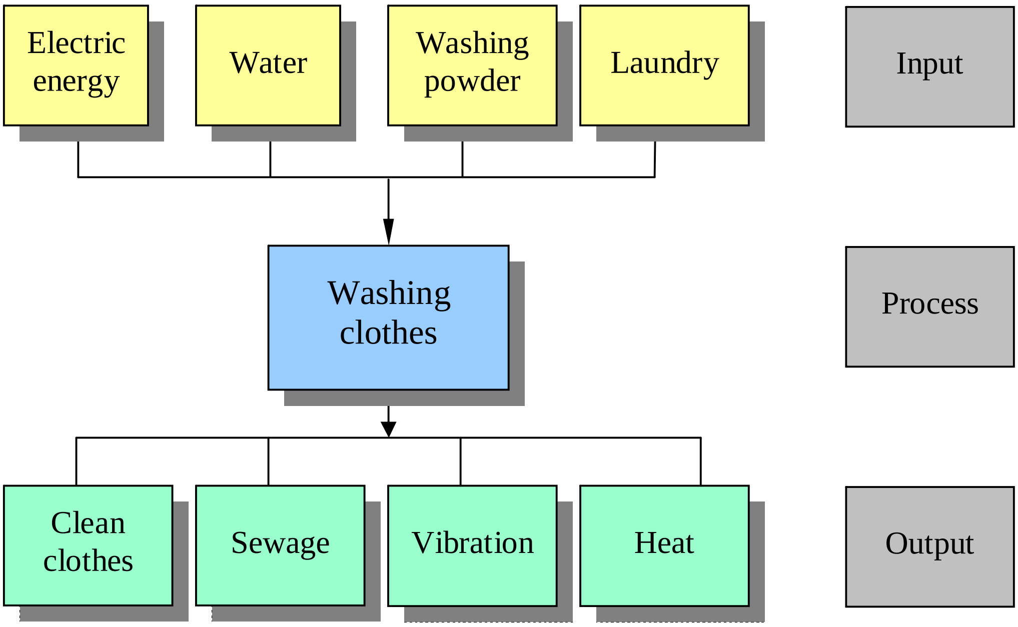


Fig.2.3: Input-Output analysis for a washing machine

A detailed quantitative description of the use stage of a washing machine is given in Tab. 2.5.

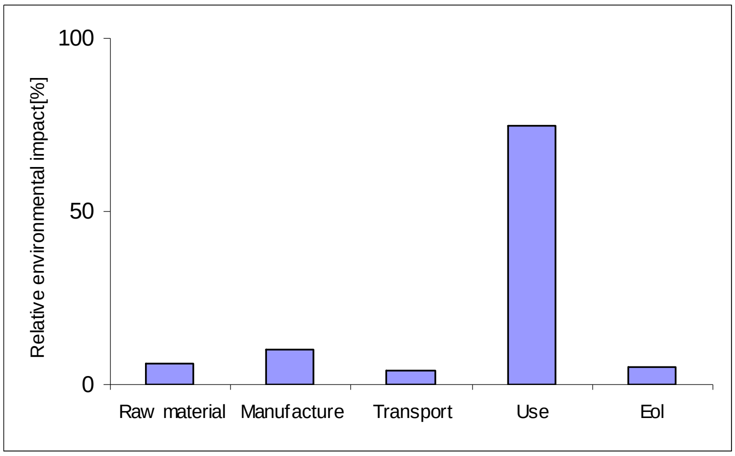
Tab.2.5: Cost analysis of two different washing machine models (Wimmer, Züst, 2002)

	Machine A	Machine B
Purchasing price	500€	2000€
Energy consumption per washing cycle	1,2kWh	1 kWh
Detergent per washing cycle	50g	50g
Water consumption per washing cycle	70l	50l
Washing cycles per year	50	600
Service life	20 years	16 years
Total washing cycles	1000	9600
Servicing per year	20€	60€

Portion purchase price	0,50€	0,21€
Portion servicing	0,40€	0,10€
Costs of water	0,21€	0,15€
Costs of electricity	0,18€	0,15€
Costs of detergent	0,13€	0,13€
Costs per washing cycle	1,42€	0,74€
Unit prices:		
Costs per m^3 water	3,0€	
Costs per kWh electricity	0,15€	
Costs for detergent (50g)	2,50€	

The results of Tab. 2.5 show that although washing machine B is four times more expensive than machine A, the different use scenarios implement that washing machine B is half expensive in each washing-cycle.

Fig.2.4: Percentage of environmental impact in each life cycle stage of machine B

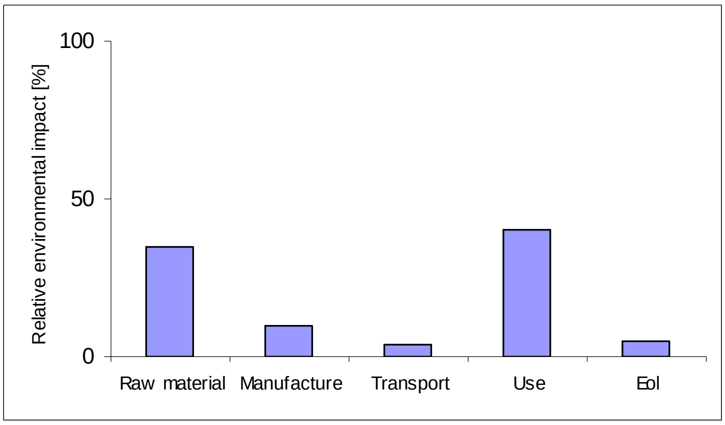


Life Cycle Thinking and the consideration of the different use scenarios also lead to different relative environmental impact in the life cycle stages.

In the proposed use scenarios, washing machine B is used more intensive than washing machine A. Since washing machine B is used up to twice a day, its life cycle stage 'use' contributes most to the overall environmental impact of the product. Fig. 2.4 shows a Life Cycle Thinking diagram (LCT diagram) of the washing machine where the environmental impact of each life cycle stage of the washing machine is drawn.

This view of the environmental impact of the different life cycle stages can be obtained by Life Cycle Thinking, a way to consider environmental aspects of all life cycle stages of the product.

Fig.2.5: Percentage of environmental impact in each life cycle stage of machine A



In case of washing machine A, which is not used as intensive as washing machine B, the relative environmental impact of its life cycle stage 'use' is not as high as washing machine B.

In case of a less intensive use, the first life cycle stage, namely raw materials, becomes significant too, see LCT diagram in Fig. 2.5.

Different scenarios can be matter of investigation in other life cycle stages too. Imagine your product is going to be sold and used in different countries or continents and reaches its end of life stage there. Since each country has different waste management systems, different disposal scenarios have to be taken into account. For example recycling rates differ in Europe where 13% of the disposed waste is recycled, in North America where recycling rates are not so high since most of the municipal waste is disposed in a landfill compared to Japan where recycling rates are very high.

Fig.2.6: Office chair [www.steelcase.com]

The last example introduced in this lesson is an office chair, see Fig. 2.6, which is further discussed in lesson 6 and 8.

A common office chair can be described as consisting of five main parts, namely:

1. Base
2. Mechanism
3. Seat
4. Arm rest
5. Back

General information of the office chair is given below:

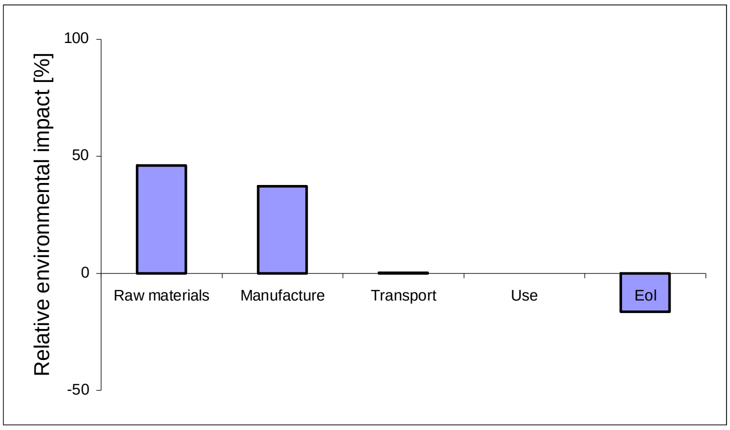
Tab.2.6: General environmental parameter of an office chair

General environmental parameter	
Name of the product	Office chair
Weight of product	24kg
Weight of product incl. packaging	28 kg
Main components	Base, mechanism, seat, arm rest, back
Lifetime	15 years
Use scenario	An average person, using the chair for eight hours a day, five days a week over a period of 15 years

Tab.2.7: Specific environmental parameters of an office chair

Specific environmental parameter	*Explanation (qualitative)*
Raw materials	
Materials used:	Metals: Steel, Zamak alloy Plastics: PA, PP, PS, PU, PVC, ABS, LDPE, HDPE Others : Cardboard, textiles, glue
Manufacture	
Production technology:	Injection moulding, welding, painting, anodising, polishing
Transport	
Packaging:	Cardboard
Transport:	Ship, over-sea Lorry, highway Lorry, urban
Use	
Usability:	Provision of comfortable office seating
End of life	
Disposal:	60% landfill, 27% incineration, 13% recycling

Fig. 2.7: Percentage of environmental impact in each life cycle stage of a office chair



By applying Life Cycle Thinking and evaluating the product, the life cycle stages 'raw materials' and "manufacture" of the office chair seem to contribute most to the overall environmental impact, see LCT diagram in Fig. 2.7.

A

ccordingly the office chair could be seen as a "raw-material and manufacture intensive" product.

Further improvement strategies for the office chair should focus on this life cycle stages. The relative environmental impact of the raw material stage is highest. In lesson 8 it will be discussed how this life cycle stage can be improved.

Fig. 2.7 also shows that in the 'use' stage of the office chair no environmental impact occurs at all.

SUMMARY

Life Cycle Thinking is a key issue for obtaining insight into the environmental impacts occurring along product life and is therefore a basic requirement for implementing Ecodesign. The examples above have shown that taking all life cycle stages into account and considering different possible scenarios for the life cycles, the environmental profile of a product can bring sometimes unexpected results.

Setting the right system boundaries, as shown in the juice extractor example, is also an important factor which has to be considered. Setting large system boundaries, too much and detailed information may be needed to obtain an environmental profile of a product. In many cases not all information can be gathered since either no information is available or facts are unknown. Too small system boundaries may lead to a wrong and insufficient description of the environmental profile of a product. In both cases the real weak points of the product may be overlooked. This can lead to wrong or ineffective improvement strategies of the product.

Sketching the relative environmental impact over the life cycle stages, as done in Fig. 2.4, 2.5 and 2.7, gives a good overview of the environmental profile of a product. Such a diagram clearly shows which life stages are the most relevant ones and where the focus of environmental improvement activities should lie on.

The next lesson will discuss how the environmental performance can be evaluated.

HOME EXERCISES

1. Describe your product by using environmental parameters:
   d. Give general environmental parameters of your product by following Tab. 2.2.
   e. How can the function and the functionality of your product be described? (*Note*: Testing may be useful)
   f. Which components and materials does your product contain? (Note: Disassembling may be required)
   g. Quantify this information (e.g. by weighting, measuring, etc...)

Caution: In case of disassembling your product for analyzing, DO NOT use the product again after re-assembling! Danger of malfunction and serious injuries!
Perform any testing BEFORE you disassemble your product!

2. Give qualitative explanation of the environmental parameters:
   f. Find information about the life cycle stages of your product.
   g. How can you define system boundaries? How much information is necessary to consider?
   h. Is there any product specific data to consider?

3. Give special attention to the use stage of your product
   a. Which use scenarios are possible?
   b. How do these different use scenarios influence the environmental profile of your product?

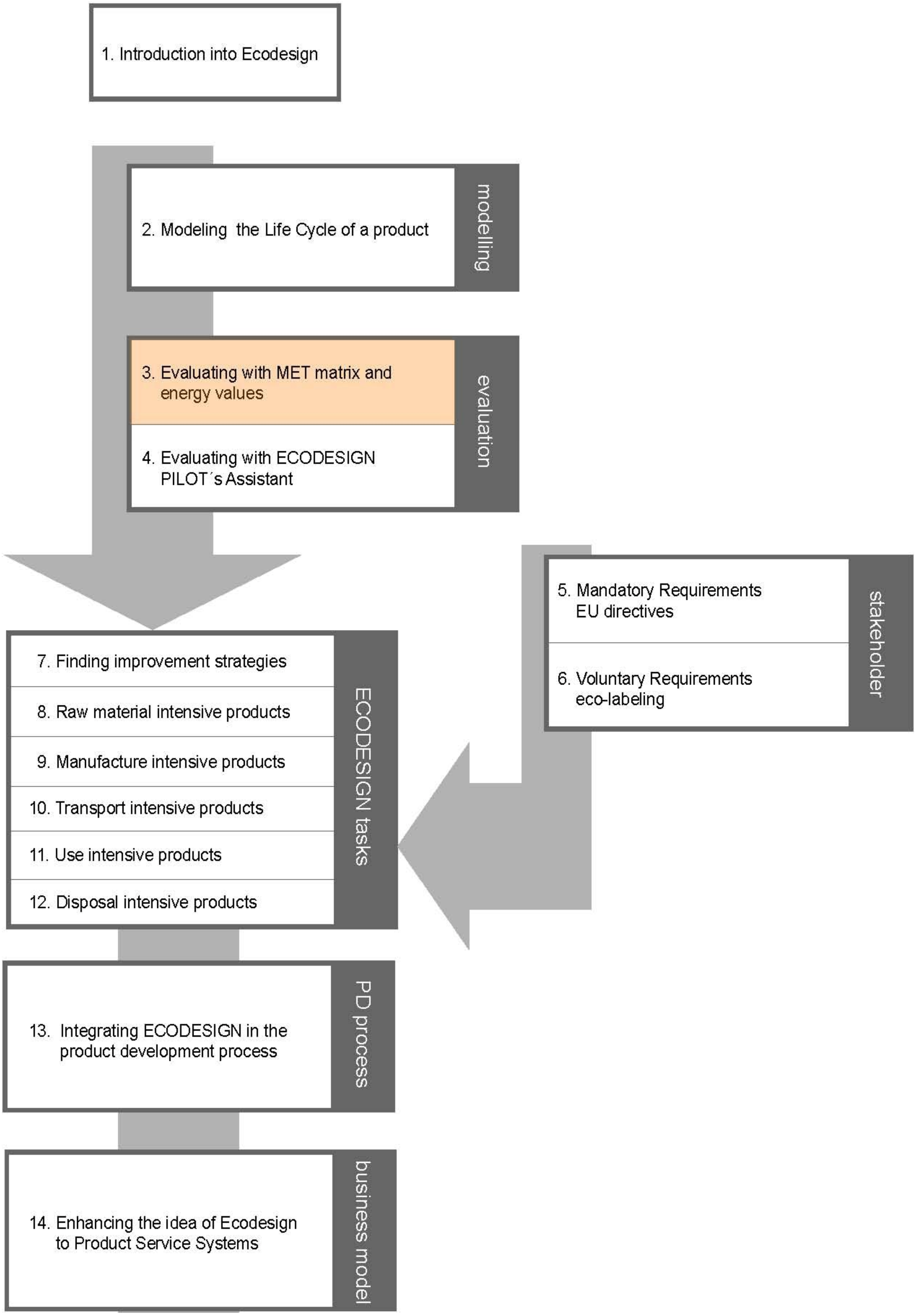
4. Which life cycle stage of your product contributes most to the environmental impact? Estimate the possible impacts and draw a first draft of a LCT diagram.

REFERENCES

- ✓ Wimmer, W., Züst, R., 2002. *Ecodesign Pilot - Product-Investigation-, Learning- and Optimization- Tool for Sustainable Product Development*. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- ✓ Wimmer, W., Züst, R., Lee, K.M., 2004. *ECODESIGN Implementation - A Systematic Guidance on Integrating Environmental Considerations into Product Development*. Springer, Dordrecht, Netherlands.

ADDITIONAL READING MATERIAL (AVAILABLE ON CD)

Wimmer, W., Bey, N., *The way to do ECODESIGN in companies – installing a continuous improvement process*, Proceedings of the Design2004, D. Marjanovic, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, The Design Society, Glasgow, 2004, 1565-1570.


1. Introduction into Ecodesign
2. Modeling the Life Cycle of a product
modelling
3. Evaluating with MET matrix and energy values
4. Evaluating with ECODESIGN PILOT´s Assistant
evaluation
5. Mandatory Requirements EU directives
6. Voluntary Requirements eco-labeling
stakeholder
7. Finding improvement strategies
8. Raw material intensive products
9. Manufacture intensive products
10. Transport intensive products
11. Use intensive products
12. Disposal intensive products
ECODESIGN tasks
13. Integrating ECODESIGN in the product development process
PD process
14. Enhancing the idea of Ecodesign to Product Service Systems
business model

LESSON 3

Evaluating the Environmental Performance of Products Part I: Using MET-Matrix and Energy Values

KEYWORDS: **QUALITATIVE EVALUATION METHOD, MET-MATRIX, ENERGY VALUES**

Lesson objectives

Once a product is described, the next step is the environmental evaluation of the product. There are various evaluation methods, starting from qualitative, easy to apply evaluation methods over very complex methods using quantitative data, e.g. EDIP-method used in LCA, see module 2.

This lesson deals with methods which are easy to apply for product developers and which give a reliable and good overview of the environmental performance of the product to find appropriate Ecodesign improvement strategies.

The introduced Material-Energy-Toxicity-matrix (MET-matrix) allows a simple qualitative as well as a quantitative evaluation of the product.

A MET-matrix contains data for the different life cycle stages of a product and gives a first overview of the environmental situation of the product.

As introduced in module 2, energy values are applied in this lesson for a more detailed analysis. By selecting pre-calculated values from a list one can obtain a quantitative evaluation of a product in form of LCT diagrams. The application of the energy values is simple since no deeper insight to complex life cycle assessment theories and methods is necessary.

At the end of this lesson you will be able to:

Evaluate your product by using:

- *MET-matrix or modifications of the MET-matrix*
- *Energy values for LCT diagrams*

EVALUATION WITH THE HELP OF THE MET-MATRIX

Assume you should measure "environmental impact". How would you proceed? There is no single value that is able to fully express this. Obviously a combination of different parameters can lead to an appropriate description of environmental impact. One of these parameters is certainly the energy consumption of the product. Another one could be resource or material consumption. Special attention has to be paid to small quantities with large environmental impacts, i.e. toxic substances.

The simplest and easiest way to apply environmental evaluation is therefore the Material-Energy-Toxicity-matrix (MET-matrix.). In the columns of the matrix the five life cycle stages are listed and the rows contain the three parameters: material, energy and toxicity; see Tab. 3.1.

Tab.3.1: Example for a MET-matrix

		Raw materials	Manufacture	Transport	Use	End of Life
Environment	Material	Steel, aluminium	Glue, lubricants	Packaging	Detergent	
	Energy	Oil	Oil, electricity	Fuel		Electricity
	Toxicity	Alloy		PVC		

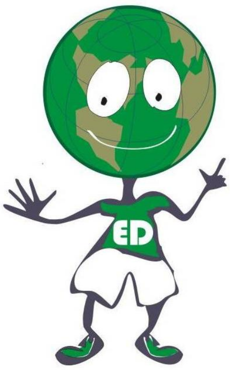
The different elements of the matrix collect qualitative data of the three parameters material, energy and toxicity in the different life cycle stages.

In case of the parameter material, the used material in the product can be written down in the life cycle stage raw materials. In the manufacture stage the relevant process materials such as glue, lubricants are coolants shall be considered. In the life cycle stage transport materials needed for packaging and safe transporting shall be listed. If additional materials are necessary in the use stage to ensure the fulfilment of the function of the product, these materials shall be written down in the use stage (e.g. detergents for washing process of washing machine). Process materials needed for the end of life processes, e.g. for recycling, should be mentioned in the last column of the matrix.

Same shall be done for the parameters energy and toxicity. In case of the parameter 'energy' the processes needing energy as well as the kind of energy needed in the different life cycle stages, e.g. electrical energy or fossil energy, can be mentioned.

In case of toxicity, toxic materials and emissions which occur in the different life cycle stages shall be addressed in the matrix elements.

In general it is possible to write down any known data into the MET-matrix, also including quantitative data, e.g. amount of material used in the life cycle stages, amount of energy needed or amount of emissions generated.



A MET-matrix gives a first impression of how the environmental influence of the different life cycle stages can be evaluated and which life cycle stages are relevant. With the help of a MET-matrix first "hot spots" of the most significant parameters can be determined. This is done in Tab. 3.1 by marking the important life cycle stages and parameters.

Modifications of the MET-matrix may contain for example characterized impact values used in Life Cycle Assessments (LCA), e.g. global warming potential expressed as CO_2-equivalent or acidification expressed as SO_2-equivalent, see module 2. Known quantified or qualitative data can be written down for these parameters throughout the entire life cycle, see Tab.3.2.

Tab.3.2: Modified MET-matrix

	Raw materials	Manufacture	Transport	Use	End of Life
CO_2-equivalent					
SO_2-equivalent					
...					

EXAMPLE 1: JUICE EXTRACTOR

Let us consider the juice extractor introduced in lesson 2. As we have already seen the juice extractor consists of different parts and different materials.

Fig.3.1 shows the different materials in the different parts of the juice extractor.

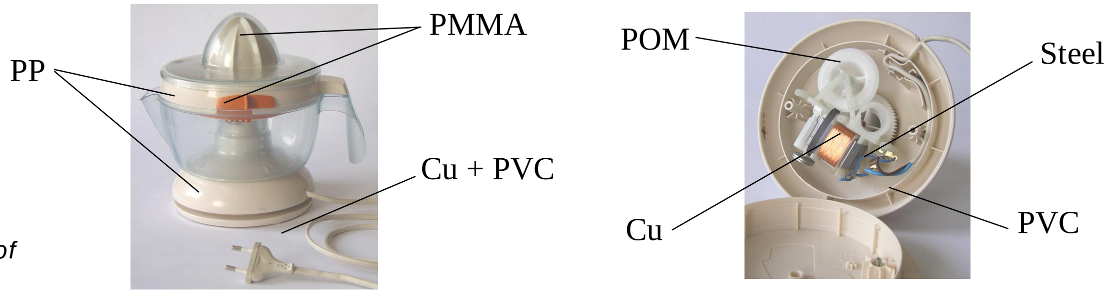


Fig.3.1: Materials of the juice extractor

Tab. 3.3 lists the amount of materials used in the juice extractor as well as the estimated end of life treatment of the materials.

Tab.3.3: Amount of materials used in a juice extractor

Material	Weight [g]	End of Life Treatment
Polypropylene (PP)	120	Recycling
Steel + Copper	150	
Polymethyl methacrylate (PMMA)	250	Thermal recovery
Polyoxymethylen (POM)	50	
Polyvinylchlorid (PVC)	30	
Polyethylen (PE) Polystyrol (PS) Acrylnitril-Butadien-Styrol (ABS)	105	Landfill[2]
Total	705	

A first evaluation of the juice extractor can be obtained by establishing a MET-matrix where qualitative data are written down, as shown in Tab. 3.4.

Tab.3.4: MET-matrix for the juice extractor

	Raw materials	**Manufacture**	**Transport**	**Use**	**End of life**
Material	Metals (Cu, steel) Plastics (e.g. PP, PVC, ABS...)	Injection tools Motor, Cable Lubricants, Coolants	Packaging	Fruits, Water Detergents	Process materials, recycling of materials
Energy	Energy for refining or granulating	Injection moulding, metal processing	Fuel (diesel)	Electric energy during operation	Energy for recycling Recovery of energy
Toxicity	Emissions during extraction	Emissions	Emissions	-	PVC, Electro-parts

Where do you believe are the "hot spots" of the MET-matrix in Tab. 3.4?

[2]*Remark*: The materials listed here could also be recycled but in this example they are disposed to a landfill

Additional remarks:

Some considerations about the compatibility of the different materials could be taken into account as well. Since the end of life treatment of the materials is different, the compatibility and mix of different materials should also be taken into account in respect to ensure an unproblematic separation and treatment. Tab. 3.5 shows a matrix where the compatibilities of the materials are shown qualitatively by using ☺ meaning 'good compatibility', 😐 'average compatibility' and ☹ 'bad compatibility'.

Tab.3.5: Compatibility of materials used in the juice extractor, bad compatibilities marked in grey

	PMMA	PP	POM	PVC	ABS	PE	PS
PMMA	☺						
PP	☹	☺					
POM	😐	😐	☺				
PVC	☹	😐	☺	☺			
ABS	☺	☹	😐	😐	☺		
PE	☹	☹	☹	☹	☹	☺	
PS	☹	☹	😐	☹	☹	☹	☺

Although a qualitative MET-matrix provides some insight, it remains difficult to evaluate which life cycle stage contributes most to the environmental impact of the product. Therefore it is not really known which life cycle stages need an improvement or even where to start to improve the product.

A quantitative evaluation is needed. Quantifying the environmental impacts allows identifying effective strategies and tasks for an improvement of the environmental performance of the product.

To achieve quantified environmental impacts and in order to minimize the effort needed to obtain these data, energy values, as introduced in module 2, are used. Tab. 3.6 lists the energies needed to obtain the materials used in a juice extractor.

In the following Tab. 3.7 to Tab. 3.10 energy values for the other life cycle stages of the juice extractor are listed.

Injection moulding and metal forming are applied processes to manufacture the juice extractor. The required energies for producing one piece of a juice extractor are listed in Tab. 3.7.

Tab. 3.6: Energy values for the materials used in a juice extractor

Material	[MJ/kg]	Weight [kg]	Result [MJ]
Polypropylene (PP)	78	0.120	9.36
Steel	32	0.085	2.72
Copper	65	0.065	4.23
Polymethyl methacrylate (PMMA)	95	0.250	23.75
Polyoxymethylen (POM)	105	0.050	5.25
Polyvinylchlorid (PVC)	70	0.030	2.1
Polyethylen (PE)	80	~0.035	2.8
Polystyrol (PS)	96	~0.035	3.36
Acrylnitril-Butadien-Styrol (ABS)	100	~0.035	3.5
Total		0.705	57.07

Tab.3.7: Energy values for the manufacture stage

Manufacture	[MJ/kg]	Weight [kg]	Result [MJ/piece]
Injection moulding	78	0.555	43.29
Forming metals	32	0.15	4.8
Total		0.705	48.09

The juice extractor is transported over a distance of 3.000km from the producer to the customer. Tab. 3.8 shows the energy amount needed for the transport of one juice extractor.

Tab.3.8: Energy values for the transport of the juice extractor

Transport of juice extractor	Distance [km]	[MJ/ton-km]	Result [MJ/piece]
Truck	3000	1.5	4.5

Tab. 3.9 lists the results of the electrical energy demand of the juice extractor per extracting process of 750 ml juice.

Tab.3.9: Energy values fort he use stage of the juice extractor

Use	[kWh] per use	[kWh] during lifetime
Energy consumption	$8.06 \cdot 10^{-4}$	4.23
	[MJ/kWh]-average	[MJ] during lifetime
Energy consumption	10	42.3

The energy values for the treatment of materials in the end of life stage are given in Tab. 3.10.

Tab.3.10: Energy values for the end of life stage of plastics used in the juice extractor

End of Life	Weight [kg]	[MJ/kg]	Result [MJ]
Recycling/Re-melting of plastics	0.555	-20	-11.1

As stated in lesson 2, the juice extractor is able to extract 45% of the juice content of an orange. 55% of the juice content is wasted due to inefficiency of the device. Thinking in terms of an Input-Output analysis the wasted amount of the juice must be considered in the use stage of the juice extractor since the extractor uses oranges to provide its functionality.

The irrigation of 1kg oranges requires 1000 litres of water. Therefore fresh water must be provided by treating saltwater. In addition the fresh water must be pumped for irrigating the orange fields. From the five life cycle stages, the two stages manufacture and transport of oranges are the most important ones. Tab. 3.11 shows the energy values for the processes needed in these two stages.

Tab.3.11: Data for manufacture and transport stage of oranges

Life cycle stage			
Manufacture	[MJ/m^3]	[m^3]	Result [MJ]
Oranges (saltwater treatment)	13.0	1	13.0
Oranges (water pumping)	1.8	1	1.8
Transport	Distance [km]	[MJ/ton-km]	Result [MJ/kg]
Ship, from Brazil	10.000	0.11	1.1
Truck, from Spain	3.000	1.5	4.5
Truck to customer	2.000	1.5	3.0

Using data from Tab. 2.4 where a mix of oranges is introduced, the fractional amount of energy used for the oranges per use can be calculated, see Tab. 3.12. According to Tab. 2.4 for each use cycle 11 oranges (150 g each) are used to achieve 750 ml of juice.

Tab.3.12: Data for mix of oranges

	Weight / piece	Spain (75%)	Brazil (25%)	Transport (truck	Total
Weight	0.150g	1.2375 kg	0.4125 kg		1.650 kg
Transport		5.57 MJ	0.45 MJ	4.95 MJ	10.97 MJ
Irrigation					24.42 MJ
Total					35.39 MJ

By now, all relevant data are known and all relevant energy values are calculated. Let us make a last calculation using the tables above to see which amount of energy is needed over the lifetime of the juice extractor.

According to Tab. 2.2 the juice extractor is used 1 time a day, 50 weeks over a period of 5 years. This gives a total use of 1750 times. Tab. 3.13 sums up the results for the different life cycle stages of the juice extractor and the oranges. (*Note*: only the wasted amount of the oranges were taken into account)

Tab.3.13: Final results of energy amount needed for the juice extractor and oranges

		Raw Material	Manufacture	Transport	Use	EoL	Total
Juice extractor	Energy [MJ]	57.07	48.09	4.5	42.3	-11.1	141
Oranges	Energy [MJ]	-	1750x0.55x24.42= 23504.25	1750x0.55x10.97= 10558.625	-	-	34063
Total	Energy [MJ]						34204

When analyzing the juice extractor the wasted amount of oranges (including their two most important life cycle stage manufacture and transport) must be added to the use stage of the juice extractor since this waste is generated in the use stage of the extractor, see Tab. 3.14.

Tab.3.14: Data for the juice extractor including oranges

		Raw Material	Manufacture	Transport	Use	EoL	Total
Juice extractor	Energy [MJ]	57.07	48.09	4.5	42.3 + 34063	-11.1	34204

As it can be seen from the results in Tab.3.14 the wasted oranges contribute most to the environmental impact of the juice extractor.

By now the environmental impacts of the juice extractor are calculated. How do you think the juice extractor can be improved? How can the environmental impact of the juice extractor be reduced?

EXAMPLE 2: OFFICE CHAIR

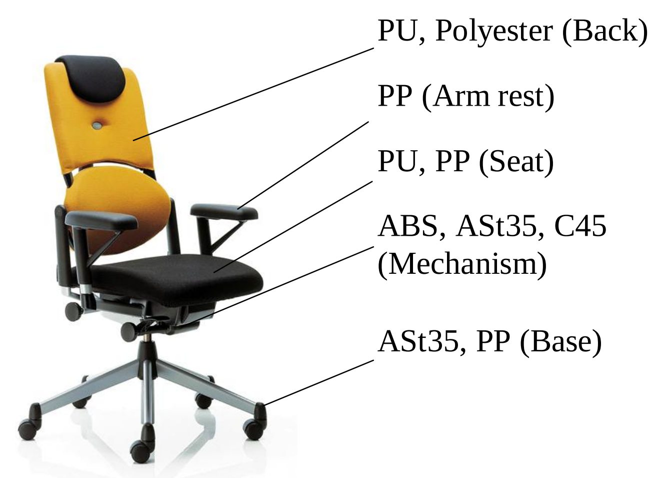


Fig. 3.2: Materials used in the components of an office chair [www.steelcase.com]

Now we want to evaluate the office chair introduced in lesson 2 more precisely by using again a MET-matrix, a modified MET-matrix and energy values. Fig. 3.2 shows the materials used in the components of the office chair.

To obtain a first evaluation of the office chair, a MET-matrix as introduced in the previous sections is established, see Tab. 3.15.

	Raw materials	Manufacture	Transport	Use	End of life
Material	Steel, Aluminium, Plastics	Glue, lubricants, varnish	Packaging	-	Recycling of materials (steel, aluminium)
Energy	Electric energy (e.g. aluminium) Fuel	Electric energy for processing (e.g. welding)	Fuel (lorry)	-	Recovery of energy
Toxicity	Toxic materials needed for anodising	Emissions	Emissions	-	Emissions

Tab.3.15: MET-matrix for an office chair

As already mentioned, a MET-matrix does not really indicate which life cycle stage contributes most to environmental impact. Therefore it remains difficult to choose adequate strategies for the improvement of the environmental performance of the product. But the MET-matrix contains all known and available data of the product and gives therefore a first impression of the environmental performance of the product.

If quantified data are known, e.g. the weight and amount of materials from a list of materials or list of parts or if the amount of energies needed is known from e.g. measuring, the values can be registered in the MET-matrix too.

To obtain quantified data for the evaluation of the environmental performance of the product, we use energy values as done for the juice extractor.

Tab.3.16 lists the materials and their amount used in the office chair as well as the corresponding energy values.

Tab.3.16: Energy values for the materials used in an office chair

Material	[MJ/kg]	Weight [kg]	Result [MJ]
ABS	100	0.1	10
Cardboard (Packaging)	28	4	112
PA	115	2.3	264.5
Polyester	98	0.4	39.2
Polypropylene (PP)	78	1.2	93.6
PS	96	0.1	9.6
PU	115	1.4	161
Steel	32	14.5	464
Wood	22	2.1	46.2
Zinc alloy	90	1.5	135
Total		27.6	1335.1

The tables 3.17– 3.19 give the energy values for the other life cycle stages of the office chair.

Tab.3.17 Energy values for the relevant manufacture processes of an office chair

Manufacturing	[MJ/kg]	Weight [kg]	Result [MJ/piece]
Injection moulding	78	5.1	397.8
Pressure Die Casting	134	1.5	201
Forming metals	32	14.5	464
	[MJ/m²]	Surface [m²]	Result [MJ/piece]
Anodising	39	0.33	12.87
	[MJ/m]	Surface [m]	Result [MJ/piece]
Welding steel	2	0.5	1
Total			1076.67

Tab.3.18: Energy values for the life cycle stage transport of the office chair

Transport	Distance [km]	[MJ/ton-km]	Result [MJ/kg]
Ship	20000	0.11	2.2
Truck	2000	1.5	3.0
Total			5.2

The office chair does not need any energy (or any process and auxiliary materials) in its use stage and therefore no environmental impact occurs in the use stage. The use stage is neglected further on.

Tab.3.19: Energy values for the end of life stage of the office chair

End of Life	[%] of total weight	Weight [kg]	[MJ/kg]	Result [MJ]
Landfill	61	16.836	0*	0
Incineration (50% recovery of energy)	26.5	7.314	-115**	-420.5 (50%)
Recycling	12.5	3.45	-16***	-55.2
Total				-475.8

* This value for landfill means that no energy is needed to put waste on a landfill and no energy can be recovered. This does not mean that no impact occurs at all. In case that the materials put on the landfill are not inert the may start chemical reactions which can be toxic and cause harm to the environment.

** Here the energy value for the material PA is taken, since PA is used most amongst plastics in the office chair.

*** This is an averaged value for the recycling of metals and the recycling of plastics.

In case of recycling or recovery, energy is recovered again which means a reduction of energy consumption and a benefit for the environment since less energy must be produced later on. Therefore a negative value is given for incineration and recycling in Tab. 3.19.

The final results in Tab. 3.20 indicate that the first and second life cycle stage, namely raw materials and manufacture are most energy consuming and therefore contribute most to the environment impact. Fig. 3.3 shows an LCT diagram achieved by using the results of Tab. 3.20.

Tab.3.20: Final results of energy amount needed for the office chair

	Raw Material	Manufacture	Transport	Use	End of Life	Total
Energy [MJ]	1335.1	1076.67	5.2	-	-475.8	1941.2

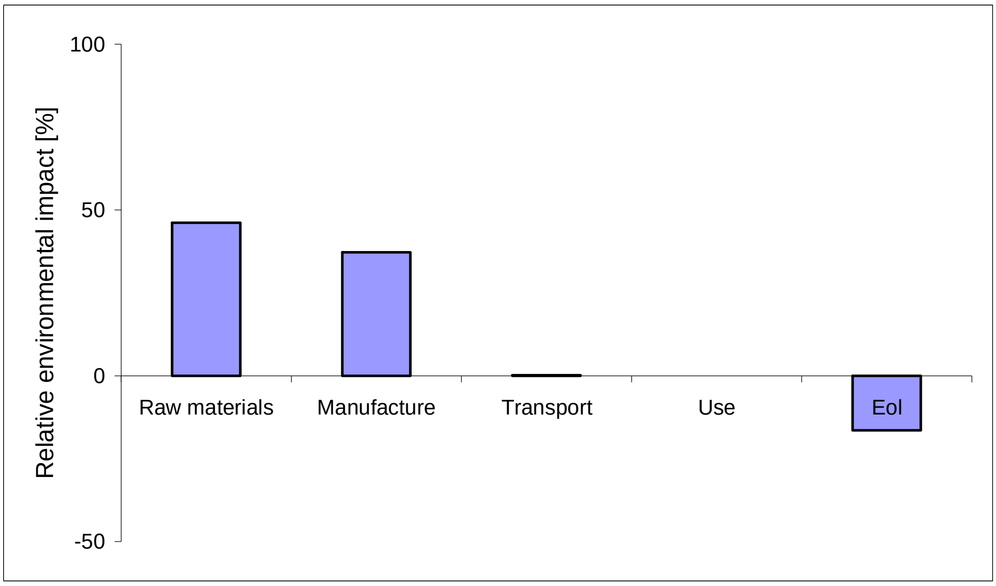


Fig.3.3: LCT diagram for the office chair

The negative value in the end of life stage indicates that in this stage energy recovery is possible due to recycling processes (which can be interpreted as a benefit for the environment).

If results of a Life Cycle Assessment (LCA) are available a modified MET-matrix can be established showing the characterized environmental impacts of each life cycle stage. There is no need to fill out each element of the matrix but only the known data are registered. Tab. 3.21 shows such a modified MET-matrix where quantified data of a full LCA according to ISO 14040 are registered.

In case a LCA was performed for a similar product and quantified data were generated these data can be used as a rough estimation and evaluation for the considered product. Differences between the products must be mapped carefully by using e.g. a conventional MET-matrix.

Category	Unit	Materials	Manufacture	Transport	Use	Disposal	Total
Global warming	[g CO2-eq]	66100	14500	7390	-	3550	91540
Acidification	[g SO_2-eq]	545	45	66	-	-11	645
Eutrophication	[g NO_3-eq]	543	43	110	-	-1	695
Photochemical Smog	[g C_2H_4-eq]	60	10	7	-	-1	76

Tab.3.21: Modified MET-matrix using quantified data

Fig.3.4 shows a diagram where the environmental profile of the office chair is drawn by using quantified data gained by LCA. The diagram shows the global warming potential of each life cycle stage expressed in gCO_2-equivalent.

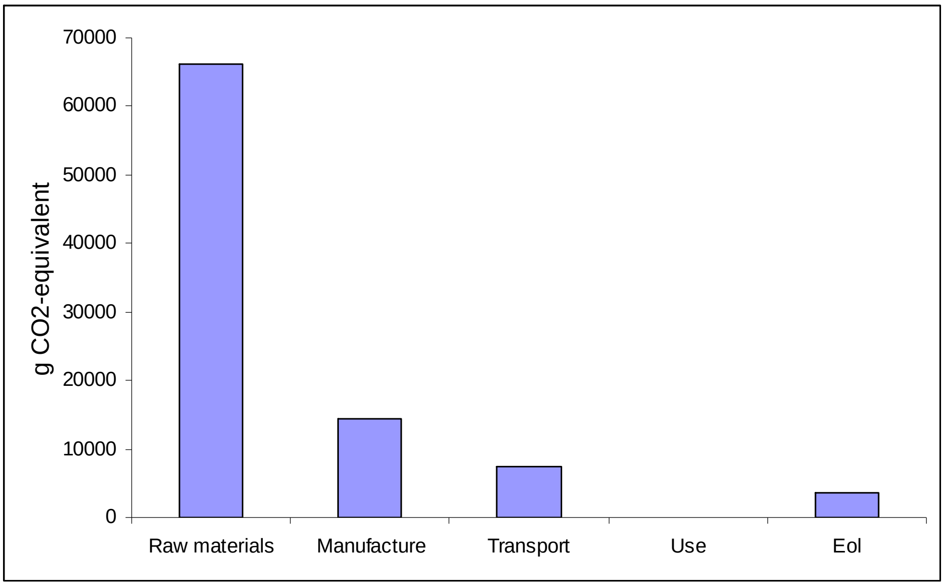


Fig.3.4: Environmental profile of the office chair expressed in CO_2-equivalent

Note: Although energy can be recovered in the end of life stage, see Fig. 3.3, the recycling processes may cause some emissions which can be expressed as CO_2-equivalents. Speaking in terms of emissions, the end of life stage of the office chair has a (positive) contribution to the environmental impact at this stage.

Question: Try to explain why the bars of the other life cycle stages in Fig. 3.3 and Fig. 3.4 differ from each other.

SUMMARY

After describing the product by applying Life Cycle Thinking and considering the environmental parameters described in lesson 2, the MET-matrix and its modifications introduced in this lesson provide a quick evaluation of the product. The elements of the MET-matrix can contain qualitative data as well as quantitative data or any known data of the considered parameters during the different life cycle stages of the product. The MET-matrix helps to identify "hot spots" of a product.

Quantitative data can be obtained easily by using energy values. For practical use, energy values are already calculated for different materials, processes, transportation modes, use and end of life scenarios and available in a list.

The appropriate use of energy values indicates the most energy consuming life cycle stages. High energy values are an indication for a high environmental impact.

In case of toxic substances the dose of the substance determines whether the substance is dangerous for environment or not. There are substances which cause a high environmental impact even when used in small quantities. These substances should be identified during the environmental evaluation of a product and be seriously considered when aiming at finding environmental improvement strategies for the product.

In lesson 4 the environmental performance of the washing machine is evaluated by using the ECODESIGN PILOT's Assistant.

HOME EXERCISES

Consider your product.

1. Try to evaluate your product:
   h. Establish a MET-matrix
   i. List all relevant materials, processes, transport-parameters as well as use and end of life parameters. Note: you may get the necessary information in the manual of your product, in the parts and material list if available, at the webpage of the producer etc...
   j. Identify “hot spots”
   k. Generate quantitative data by using energy values
   l. Draw a LCT diagram

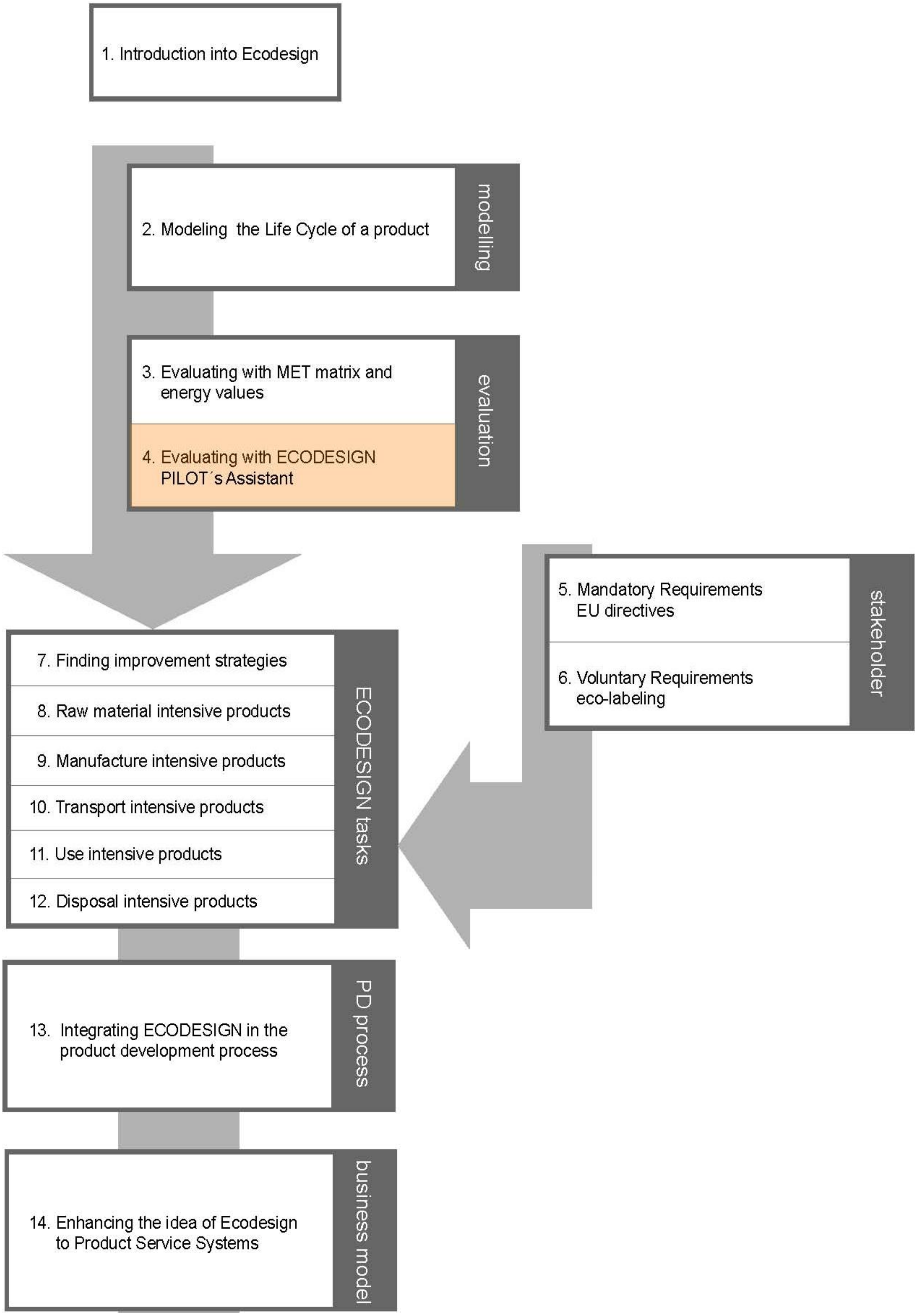
2. Consider different scenarios for the different life cycle stages of your product:
   a. Establish MET-matrixes for different scenarios (e.g. different materials and different manufacture processes, different transport modes, different use scenarios or different end of life scenarios). What are the differences in the results?
   b. Consider the life cycle stage which contributes most to environmental impact: compare the quantitative data obtained by energy values of the different scenarios.
   c. How does the relative amount of the energy values change in the different scenarios?
   d. What do these differences mean in case of an intended product improvement?

REFERENCES

- ✓ *CES EduPAck 2006* (software), Granta Design Limited, Cambridge, UK. (used for generating energy values)
- ✓ *SimaPro 7.0, 2006* (software), Pre Consultants, Netherlands. (used for generating energy values)

ADDITIONAL LINKS AND SUGGESTED READING MATERIALS

- ✓ Thrane, M., Schmidt, J., 2004. *Life Cycle Assessment- Chapter 4A*. Published in: Environmental Planning and Management – Tools for Sustainable Development. Red. Kørnov L, H. Lund and A. Remmen, Department of Development and Planning, Aalborg University. http://www.plan.aau.dk/~thrane/Publications/Personal%20publications.htm, accessed 01.2007
- ✓ Wenzel, H., Hauschild, M., Alting, L., 1997. *Environmental Assessment of Products*, Vol.1: Methodology, tools and case studies in product development. Chapman & Hall, London, UK.


1. Introduction into Ecodesign
2. Modeling the Life Cycle of a product
modelling
3. Evaluating with MET matrix and energy values
4. Evaluating with ECODESIGN PILOT´s Assistant
evaluation
5. Mandatory Requirements EU directives
6. Voluntary Requirements eco-labeling
stakeholder
7. Finding improvement strategies
8. Raw material intensive products
9. Manufacture intensive products
10. Transport intensive products
11. Use intensive products
12. Disposal intensive products
ECODESIGN tasks
13. Integrating ECODESIGN in the product development process
PD process
14. Enhancing the idea of Ecodesign to Product Service Systems
business model

LESSON 4

Evaluating the Environmental Performance of Products Part II: Using the ECODESIGN PILOT´s Assistant

KEYWORDS: **ENVIRONMENTAL PROFILE, ECODESIGN PILOT'S ASSISTANT**

Lesson objectives

In this lesson the ECODESIGN PILOT's Assistant, further just named as 'Assistant', is introduced. The Assistant helps to identify the most relevant life cycle stage of a product and to find appropriate Ecodesign strategies and improvement tasks.

Different from a formal Life Cycle Assessment or Life Cycle Thinking with energy values where absolute numbers are derived, the Assistant only calculates relative environmental impacts by comparing the occurring impacts of the different life cycle stages of the product.

The Assistant contains a sequence of six forms where product data such as product mass, energy consumption, transport distance, the kind of packaging or the waste treatment can be entered. Based on these data, the Assistant gives detailed guidelines how the product can be improved by proposing strategies which are directly linked to the

ECODESIGN PILOT, see lesson 7. The Assistant is a kind of expert system advising appropriate improvement options for a certain product.

At the end of this lesson you will be able to identify the life cycle stage of a product which contributes most to environmental impact by using the ECODESIGN PILOT's Assistant available on the Austrian Ecodesign Platform under: www.ecodesign.at/assist.

The Assistant asks for product specific data with the help of six forms which will be described more detailed in the following. The washing machine will be analyzed with the help of the Assistant more detailed.

FORM 1 – GENERAL DATA

In the first form general data of the product have to be entered. Starting with the description of the product name and the quantification of the product lifetime, the functional unit of the product can also be registered in this form, see Fig. 4.1.

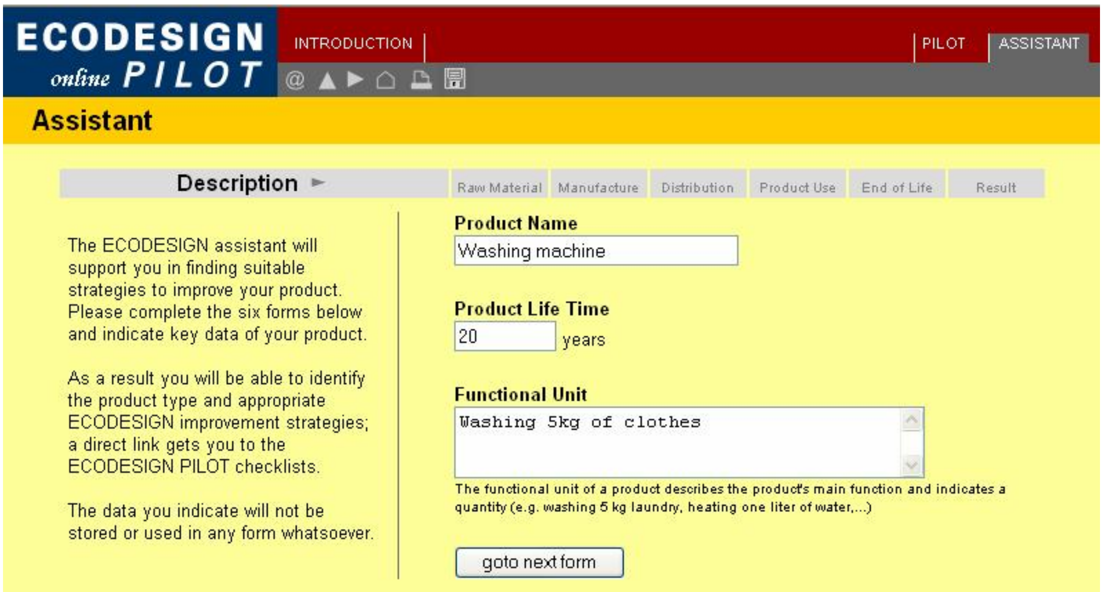
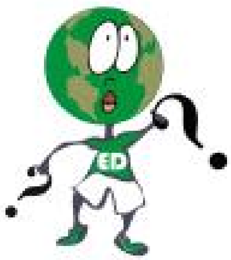


Fig.4.1: General data form of the Assistant (Austrian Ecodesign Platform, 2006)

What is the difference between function and functional unit?

A function is what the product provides to the user. It is something abstract and may depend on the viewpoint and the expectance of the user. It is important to define a basic function for the product. Imagine some different models of mobile phones. The basic function may be providing the possibility to make phone calls. But there is more to it than



that: some models of mobile phones include a photographing camera, a radio or a MP3-player. Some provide an internet access or contain a high tech organizer.

The question to answer is: what is the basic function? Is the product an organizer with phoning possibilities or a mobile phone which also provides a good organizer?

In case of multifunctional products, such as the mobile phone, the complication of defining an exact function is obvious. But what about other products which seem to have just one function?

Imagine an office chair which should provide 'comfortable seating'. How can the term 'comfortable' be defined? Which additional functions to the basic function (seating) are needed to provide comfort?

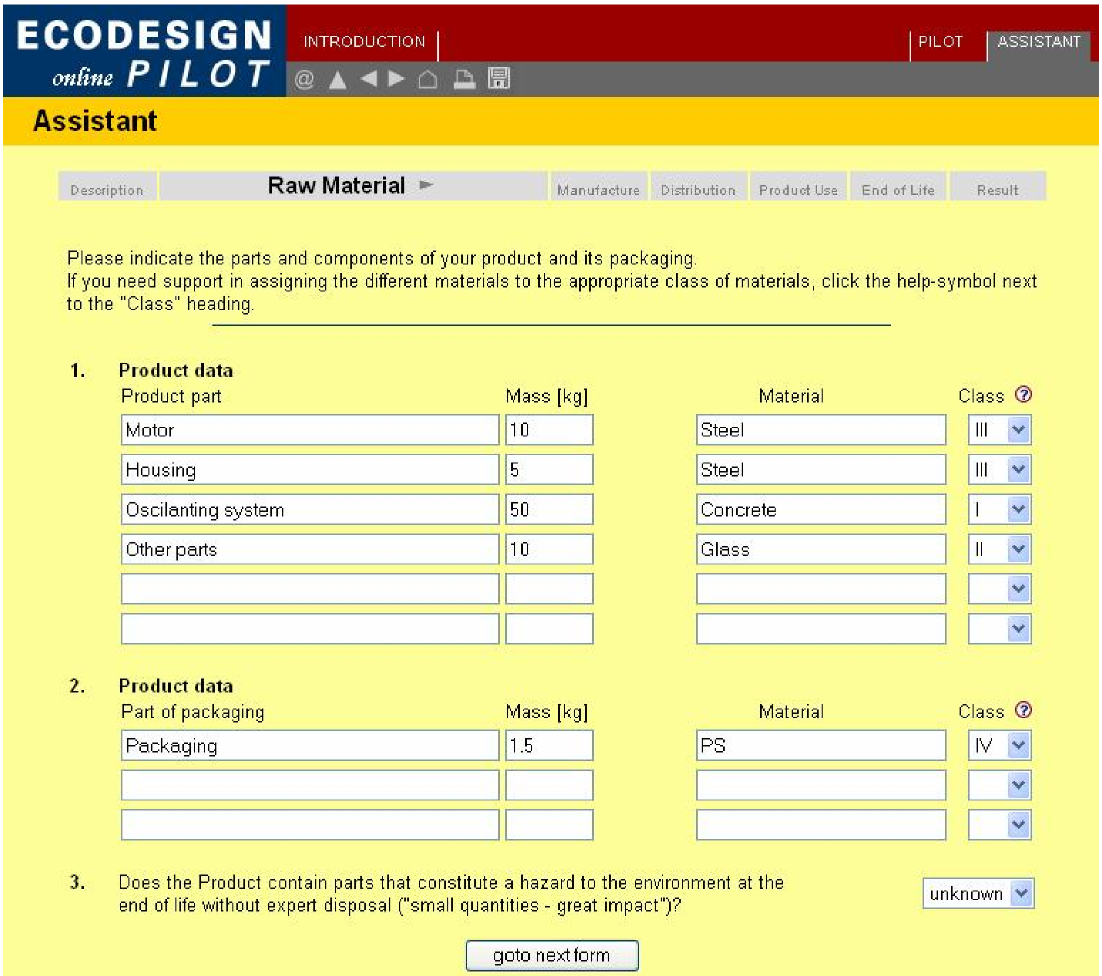
The questions above show that functions are something abstract. The functional unit quantifies the function. The main question is which measurable metric to choose to quantify the function. Since the function of the washing machine is providing the possibility to wash clothes, the functional unit of the washing machine was chosen as 'washing 5 kg of clothes (per use), see Fig. 4.1. The lifetime of the washing machine is assumed to be 20 years.

FORM 2 – RAW MATERIAL DATA

Fig. 4.2 shows the second form, namely the raw material data form, of the Assistant.

In the second form of the Assistant data about the product parts as well as the packaging must be defined, see Fig. 4.2. It is important to identify the most important parts and components. A first approach for identifying the most relevant components is to take those with highest mass into account. Beneath the definition of the mass and materials of each part and component, the materials must be assigned to a class. The materials are grouped into eight different classes: materials of class I cause little environmental impact whereas materials of class VIII cause high environmental impact with small quantities. Another approach to identify the most important components is to take into account those materials which have a high environmental impact when used in small quantities. Tab. 4.1 gives an overview of the material classes and the related materials.

Fig.4.2: Raw material data form of the Assistant (Austrian Ecodesign Platform, 2006)


ECODESIGN online PILOT

INTRODUCTION | PILOT | ASSISTANT

Assistant

Description | Raw Material ► | Manufacture | Distribution | Product Use | End of Life | Result

Please indicate the parts and components of your product and its packaging.
If you need support in assigning the different materials to the appropriate class of materials, click the help-symbol next to the "Class" heading.

1. Product data

Product part	Mass [kg]	Material	Class
Motor	10	Steel	III
Housing	5	Steel	III
Oscilanting system	50	Concrete	I
Other parts	10	Glass	II

2. Product data

Part of packaging	Mass [kg]	Material	Class
Packaging	1.5	PS	IV

3. Does the Product contain parts that constitute a hazard to the environment at the end of life without expert disposal ("small quantities - great impact")? unknown

goto next form

Tab.4.1: Material classes as defined in the Assistant (Austrian Ecodesign Platform, 2006)

Material Class	Metals	Plastics	Other materials
I			- Concrete - Wood, solid - Plaster
II	- Electric steel (secondary) - Aluminum (secondary) - Steel plate (90% recycled)		- Porcelain - Glass, bottles etc. (100% recycled) - Glass, bottles etc. (88% recycled) - Sheet glass (float glass) - Glass fiber - Glass, bottles etc., brown (61% recycled) - Glass, bottles etc., green (99% recycled) - Glass, bottles etc., clear (55% recycled) - Linoleum - Cardboard - Paper (100% recycled) - Glass, bottles etc. (primary)
III	- Steel (80% primary) - Steel (83% primary)		- Paper (65% recycled) - Leather

Material Class	Metals	Plastics	Other materials
	- Steel (89% primary) - Steel, top-blown (primary) - Steel, low-alloy		- Rubber, green, raw - Paper, free from chlorine - Coolant R134a - Ammonia NH3 - Fuel oil - Gasoline, unleaded
IV	- Cast iron - Sheet steel, galvanized - Cast steel	- PVC, non-rigid - PVC - PVC, rigid - PVC, high impact - HDPE - PP - LDPE - PPE/PS - PS (EPS), expandable - PS (HIPS), high impact - PS (GPPS), general purpose - PET, resin - PET - PET, foils - PET, for bottles - SAN	- Rubber - Rubber, polybutadiene - Rubber, EPDM - Rubber, natural - Rubber, SBR
V	- Copper (secondary) - Lead (50% primary) - Ferrochromium (53% Cr)	- PB - ABS - PE, foam - PUR, HR foam - PVDC - PU, non-rigid - PUR, flexible foam - PUR, semi-rigid foam - PUR, energy absorbing - PMMA (acrylic) - PC - PA 6.6 (nylon) - EP (epoxy resin) - PA (nylon)	- Glass fiber reinforced plastics. (GRP) - Technical ceramic material
VI	- Steel, V2A: 18%Cr, 9%Ni - Steel, V4A: 17%Cr, 12%Ni - Ferronickel (33% Ni) - Zinc alloys - Aluminum (58% primary) - Aluminum (70% primary) - Aluminum alloys - Aluminum (primary) - Steel, high-alloy (stainless) - Chromium		- Carbon fiber

Material Class	Metals	Plastics	Other materials
	- Magnesium alloys - Copper (50% primary) - Copper (60% primary) - Copper (65% primary) - Copper, cables - Copper (primary) - Copper alloys, brass - Metal powder		
VII	- Titanium alloys - Copper alloys - Zinc - Copper alloys, bronze - Nickel and nickel alloys		
VIII	- Silver - Palladium - Platin - Gold - Rhodium		

For the example of the washing machine the components motor, housing and oscillating system were taken into account since these components have the highest mass amongst the other parts of the product. Additionally some parts which contain glass and are heavy as well were considered.

The last input in this form needed deals with the question whether the product contains hazardous substances which need special attention in the end of life. The question can be simply answered by “yes”, “no” or “unknown”. In the example of the washing machine it is assumed that the content of hazardous substances is unknown.

FORM 3 – MANUFACTURE DATA

The third form of the Assistant requires data of the manufacturing stage of the product. It is assumed that the manufacture of one washing machine needs 15 kWh of electric energy.

“Thermal energy” is additional fossil fuel energy which is needed for manufacturing processes (e.g. burning of natural gas). Since the manufacture of the washing machine does not require this kind of energy, this field is left blank.

Another kind of energy which has to be taken into account is the so called “overhead energy”. The overhead energy of a factory includes for example the energy needed to warm or cool the manufacturing halls or for their lightening. This kind of energy consumption should not be neglected since experience shows that this energy consumption may rise up to 200% of the energy needed for the manufacturing of the product itself. It is clear that the overhead energy must be allocated to the total energy consumption of the product for manufacture. The Assistant does not require a specific amount of the overhead energy but asks whether the overhead energy is included in the manufacture energy considerations or not and if that is not case what the estimated value may be (100% or 200% of the manufacture energy).

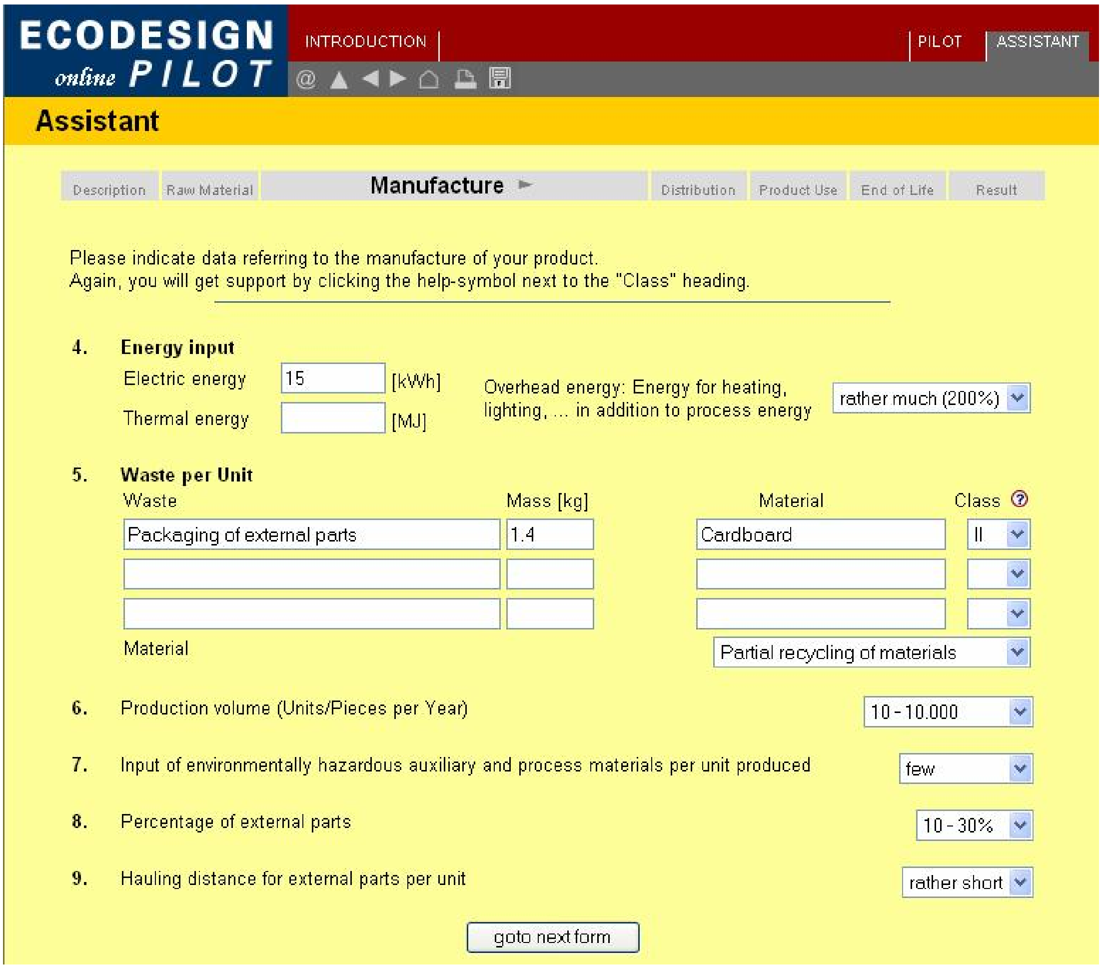


Fig.4.3: Manufacture data form of the Assistant (Austrian Ecodesign Platform, 2006)

In the next point the waste which is generated during manufacturing must be defined and quantified and the materials must be again related to a material class.

The third form of the Assistant requires some additional rough defined information: one is the approximate production volume which is a rough selection between the options “less than 10”, “10-10000”, “10000-100000” and “over 100000”. Next is the definition how much toxic, auxiliary and process materials are used during manufacturing. Again, no quantitative but only qualitative data are needed. By choosing one of the options “few”, “rather few”, “rather more” or “more” this question is answered.

In the next steps the percentage of external parts in the product as well as the transport distance of the external parts must be entered.

FORM 4 – TRANSPORT DATA

In the fourth form of the Assistant transport data for the product are collected. In this form different means of transportation (e.g. ship, railroad, truck or aircraft) are listed. For each of these means the transportation distance can be entered.

The washing machine is transported over a distance of 1000 km from the manufacturer to the customer, see entry in Fig. 4.4.

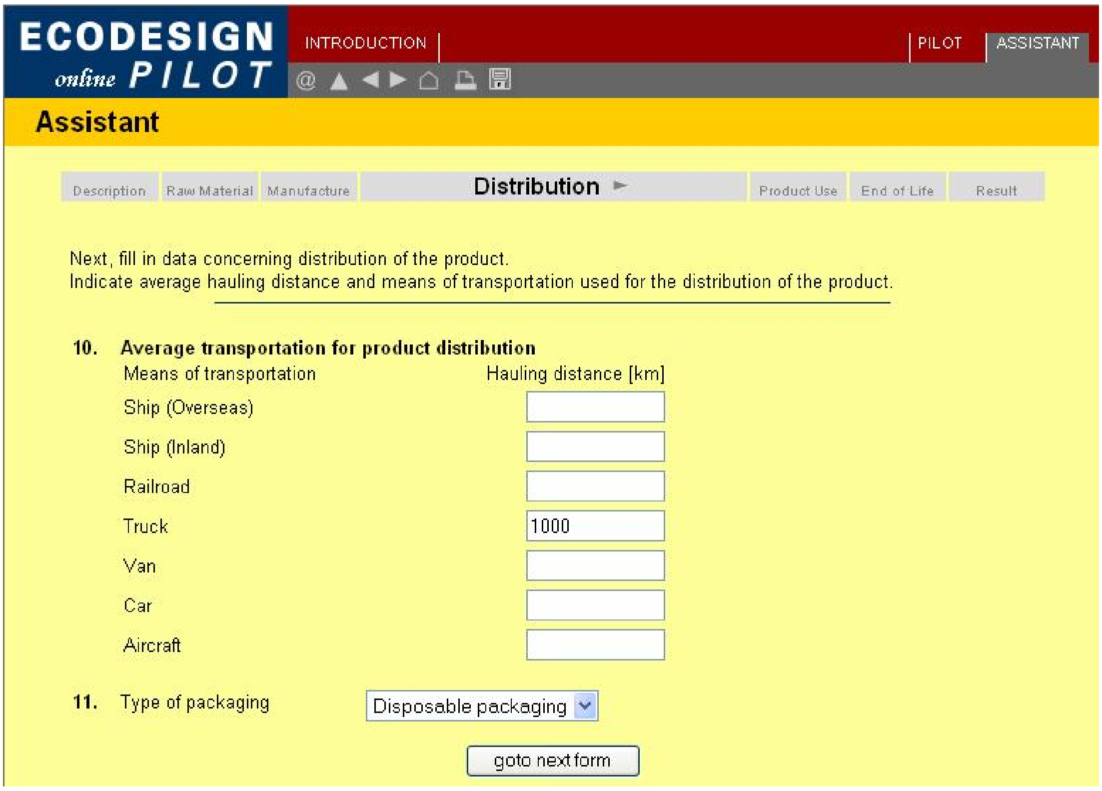


Fig.4.4: Transport data form of the Assistant (Austrian Ecodesign Platform, 2006)

The last input deals with the question whether the packaging of the product is disposable or returnable. The packaging of the washing machine is disposable.

FORM 5 – PRODUCT USE DATA

In the fifth form of the Assistant data about the use stage of the product are asked. According to Tab.2.5 it is assumed that the washing machine (machine A) is used for 50 washing cycles a year over 20 years.

Although water and detergents are needed during the use phase but since they can not be classified in the Assistant so far they will be neglected here.

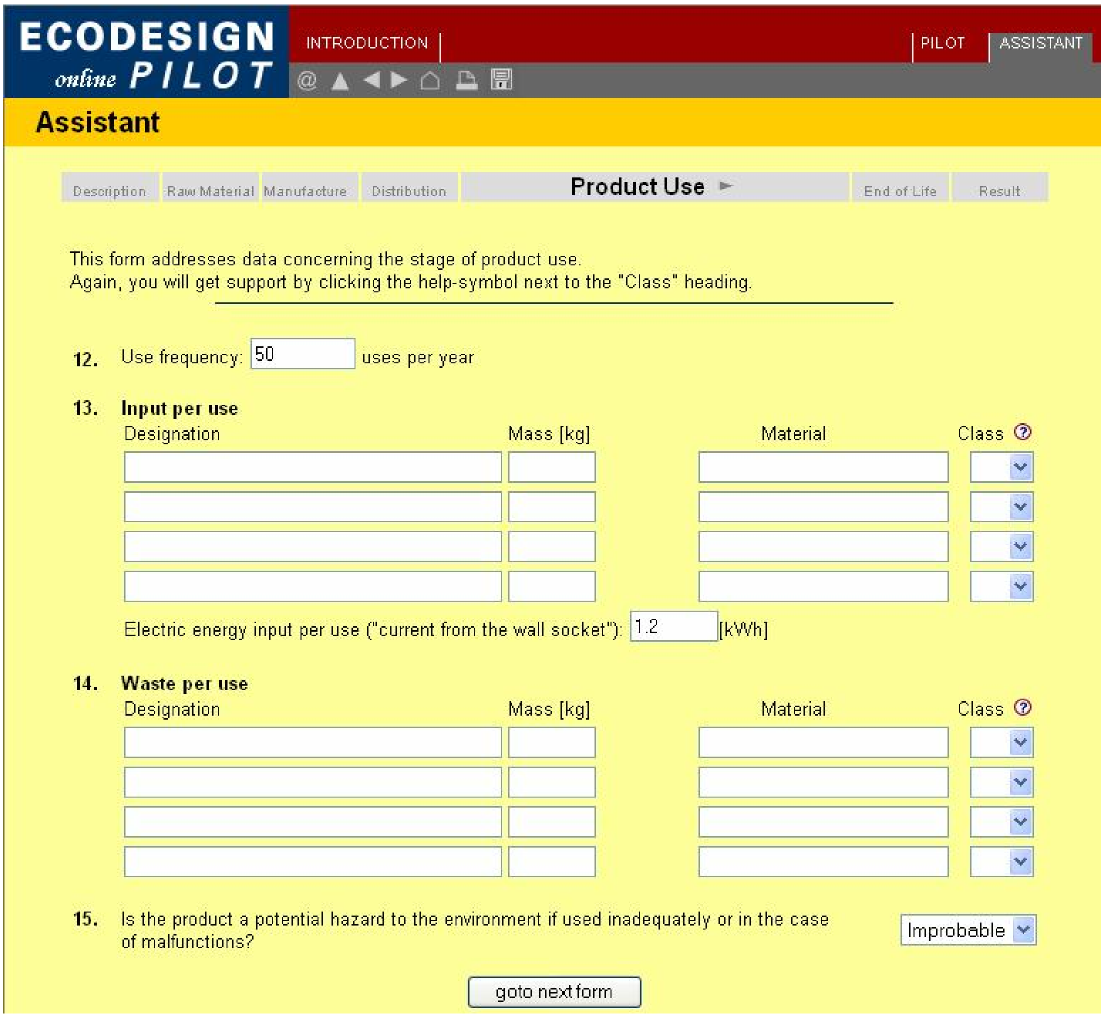


Fig.4.5: Product use data form of the Assistant (Austrian Ecodesign Platform, 2006)

It is assumed that the washing machine needs approximately 1.2 kWh per washing cycle.

The last question in this form asks for the potential of hazard to the environment in case of malfunctions or improper use. In case of the washing machine this is impossible.

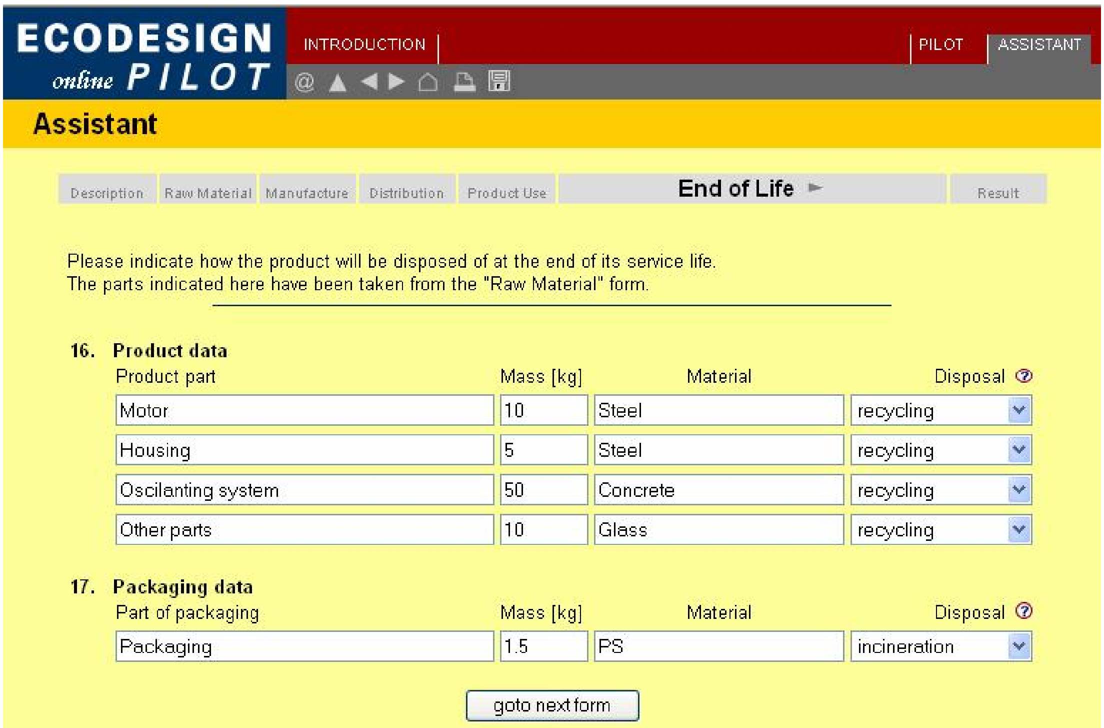
Fig. 4.5 shows the completed form for use data of the washing machine.

FORM 6 – END OF LIFE DATA

The end of life data sheet requires just little input. Except for the disposal field, see Fig. 4.6, all other fields are already completed since the data defined in the previous forms are adopted.

The disposal method can be selected from a list. The available disposal scenarios defined in the Assistant are described in Tab. 4.2.

Fig.4.6: End of life data sheet of the Assistant (Austrian Ecodesign Platform, 2006)



Tab.4.2: Description of disposal and recycling methods defined in the Assistant (Austrian Ecodesign Platform, 2006)

Selection	Disposal method
Reuse	Reuse of parts and components
Recycling	Recycling of extracted materials
Incineration	Generation of (thermal) energy
Landfill	Dumping
Hazardous waste	Special treatment of hazardous substances Also select in the following cases: - Dumping of hazardous substances without special treatment - Incineration of PVC or glass - etc ...

RESULTS FORM

In the result form, see. Fig. 4.7, the product is related to one of the basic types A – E where

- Basic type A is a raw material intensive product
- Basic type B is a manufacture intensive product
- Basic type C is a transportation intensive product
- Basic type D is a use intensive product and
- Basic type E is a disposal intensive product

The washing machine is identified as a use intensive product, which means that the use stage of the product causes the most environmental impact. Based on the classification of the product type, the Assistant suggests different improvement strategies, which are gained from the ECODESIGN PILOT, see lesson 7.

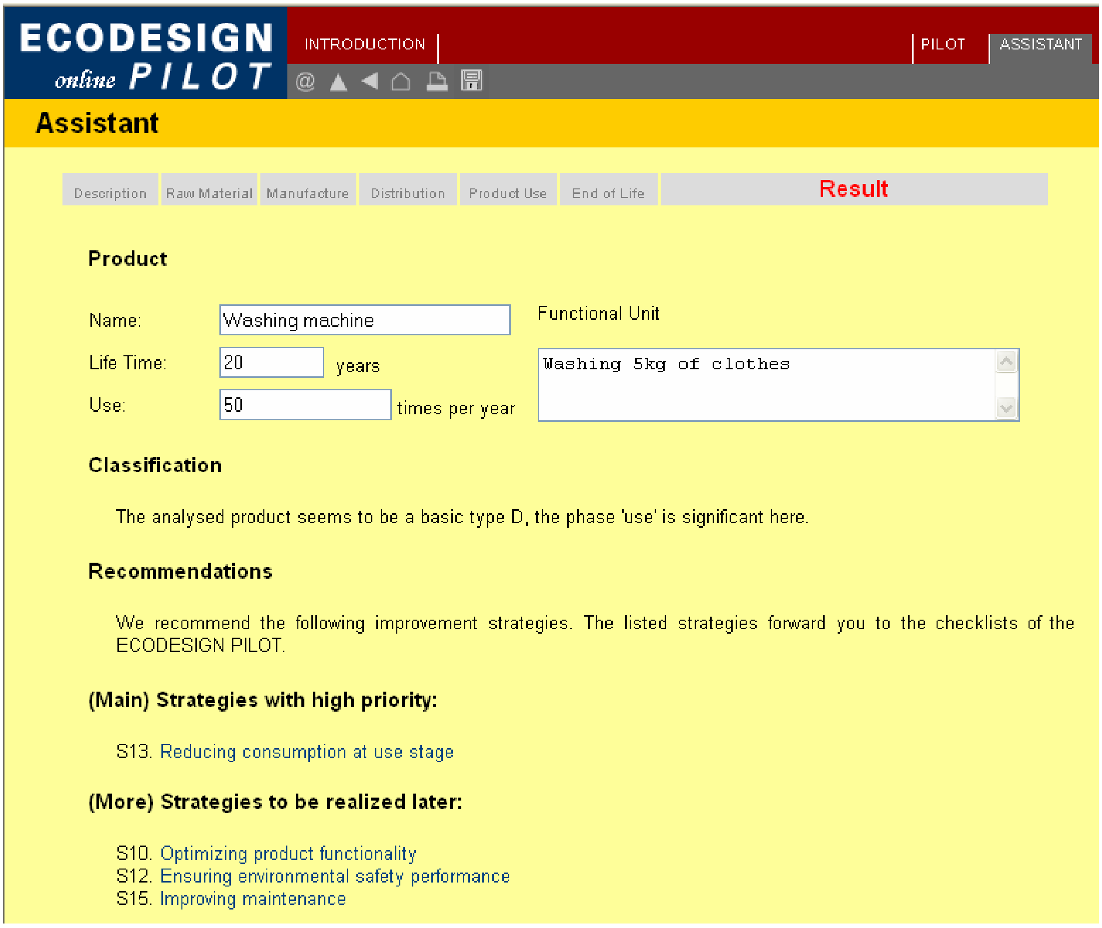


Fig.4.7: Result form of the Assistant (Austrian Ecodesign Platform, 2006)

The improvement strategies are divided into main strategies which should be applied immediately with a high priority to obtain an improvement of the product. The Assistant suggest “reducing consumption at use stage” as the main strategy to improve the product.

Further there are strategies which can be realized at a later date. The Assistant suggests “optimizing product functionality”, “ensuring environmental safety performance” and “improving maintenance” for further improvement.

A product developer can now focus on finding improvement tasks for the realization of the suggested strategies. The proposed strategies are linked to improvement tasks and checklists of the ECODESIGN PILOT which can help the product developer in finding the appropriate product improvement tasks. The ECODESIGN PILOT will be introduced in lesson 7.

SUMMARY

The ECODESIGN PILOT's Assistant allows identifying the life cycle stage of a product which contributes most to the environmental impact. It does not give any absolute numbers but allows comparing the relative environmental contribution of products. By linking the results of this evaluation with improvement strategies of the ECODESIGN PILOT specific improvement tasks for a product can be obtained.

But before those tasks and strategies are realized and put into action it is necessary to know which legal requirements from directives and laws exist. Improvement tasks for the product must be selected with respect to these requirements. Therefore some legal requirements affecting product development are introduced in the next lesson.

HOME EXERCISES

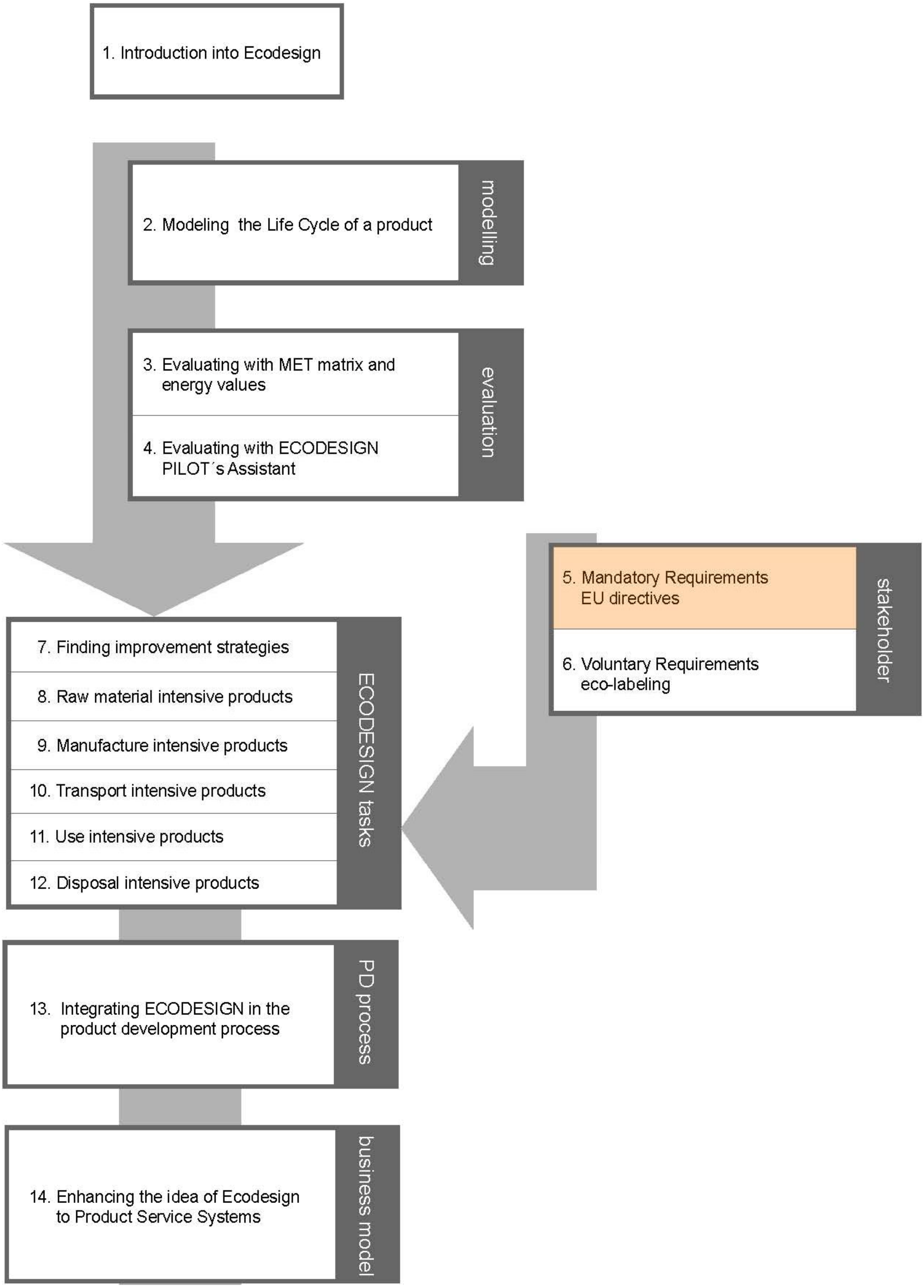
1. Evaluate your product:
   m. Evaluate your product and identify which product type it is by using the ECODESIGN PILOT's Assistant.
   n. Establish an environmental profile of your product.
   o. Think about the improvement strategies the ECODESIGN PILOT's Assistant suggests for your product: how can these strategies be put into the design? How can they be realized?

References

- ✓ *Austrian Ecodesign Platform:* http://www.ecodesign.at, accessed 01.2007.

Additional links and suggested reading materials

- ✓ Goedkoop, Spriensma, 2001. *The Eco – indicator 99 A damage oriented method for Life Cycle Impact Assessment. Methodology Report*, Pre- Consultants b.v., Amersfoort, Netherlands. http://www.pre.nl/download/EI99_Manual.pdf, accessed 12.2006


1. Introduction into Ecodesign
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14. Enhancing the idea of Ecodesign to Product Service Systems
business model

LESSON 5

Identifying Mandatory Environmental Requirements from EU Directives

KEYWORDS: DIRECTIVES OF THE EUROPEAN UNION, WEEE, ROHS, ELV, EUP, EEE PILOT

Lesson objectives

In this lesson some legal stakeholder requirements which are important and relevant for the product development and product improvement process are introduced. This chapter focuses on following four directives of the European Union:

1. ***W**aste **E**lectrical and **E**lectronic **E**quipment (WEEE)*
2. ***R**estriction of the Use **o**f Certain **H**azardous **S**ubstances (RoHS)*
3. ***E**nergy **U**sing **P**roducts (EuP)*
4. ***E**nd of **L**ife **V**ehicle (ELV)*

An adaptation of the ECODESIGN PILOT where detailed information about the WEEE directive as well as the RoHS directive is provided will also be introduced in this lesson.

At the end of this lesson you will get familiar with the content of four important directives of the European Union. You will know which issues must be considered when optimizing an electronic product (example washing machine) respectively automobile.

In the previous lessons qualitative and quantitative evaluation methods for the environmental performance of a product were introduced. This evaluation gives an environmental profile of the product or helps to determine which life cycle stage, and within the life cycle which parameters have to be improved to gather an improvement of the environmental performance of a product. Before attempts for product optimization based on environmental considerations are put into action, one should envision other stakeholder requirements on product design as well (compare lesson 7 QFD). What do customers expect from a product? Which legal requirements have to be considered (see Fig.5.1)?

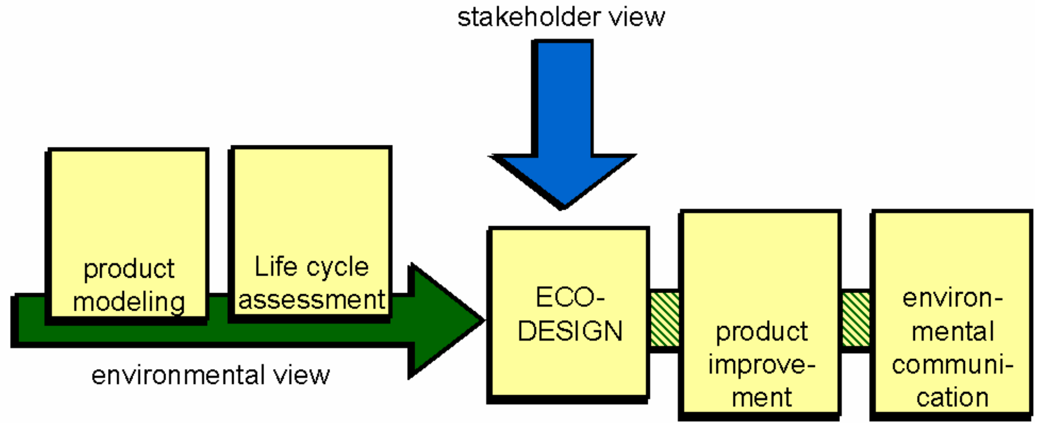
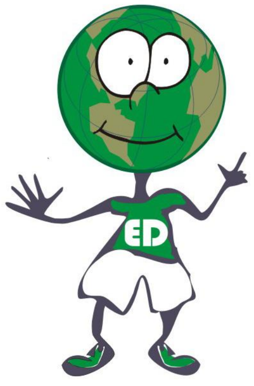


Fig.5.1: Inputs to the Ecodesign process (Institute for Engineering Design, 2007)

If we consider the example of the washing machine, the environmental assessment shows that the environmental impact is dominant in the use stage because of the energy and water consumption during usage. If we would ask customers about their expectations on a washing machine we might hear: easy to use, long life time, low energy consumption, low sales price etc. These requirements should be taken into consideration as well as legal frameworks.

WEEE Directive



The directive 2002/96/EC on “Waste Electrical and Electronic Equipment” of the European Parliament and of the Council aims at preventing the waste of electrical and electronic equipment (WEEE, 2003). The directive provides a basic legal setting for the collection, recycling and disposal of the waste of electrical devices and should also evoke a reduction of the final disposal amounts applying reuse, material recycling or other forms of recovery. Another goal of the WEEE directive is to reduce the amount of hazardous substances in waste. The underlying purpose is to promote the avoidance, recovery and risk-free disposal of waste of electrical and electronic equipment.

The WEEE directive became European law in February 2003 and since August 2005 the member states of the European Union have had to put the directive into national legislation. The main aim of the directive is to extend the responsibility of the manufacturers concerning:

- Financing the collection, treatment and recovery
- Labeling
- Information for users, treatment facilities and government
- Product design
- Re-use of the products

The WEEE directive is valid for electrical and electronic equipment which fall into the following ten categories:

1. Large household appliances
2. Small household appliances
3. IT & telecommunication equipment
4. Consumer equipment
5. Lighting equipment
6. Electrical & control equipment
7. Toys, leisure and sports equipment
8. Medical devices
9. Monitoring and control systems
10. Automatic dispensers

Tab.5.1: Selected product examples for the ten product categories

Selected product examples for the ten product categories are listed in Tab. 5.1. below.

Product category	***Selected product examples***
Large household appliances	refrigerators, washing machines
Small household appliances	toasters, kitchen scales
IT & telecommunication equipment	notebooks, printers
Consumer equipment	radio sets, TV sets
Lighting equipment	fluorescent lamps, discharge lamps
Electrical & control equipment	saws, drilling machines – with the exception of large-scale stationary industrial tools
Toys, leisure and sports equipment	electric model railroads, computerized home trainers
Medical devices	cardiology, dialysis – with the exception of implanted and infected products
Monitoring and control systems	smoke detectors, heating regulators
Automatic dispensers	automatic dispensers for hot drinks or for money

The member states of the European Union should encourage the producers of electric and electronic equipment towards product design and production which facilitate dismantling, recovery, reuse and recycling of the products. It must be ensured that the features of the product do not inhibit reuse and recycling. The member states must also ensure that the return of the waste of electrical and electronic household appliances is free of charge for the end user, e.g. in case of take back systems.

Furthermore authorized collection facilities for the WEEE must be established. The directive aims at a minimum rate of WEEE collection of 4 kg/inhabitant/year from private households by 31 December 2006 at the latest.

Companies putting electric and electronic equipment into circulation - manufacturers, retailers and importers - have financial responsibility for a separate collection of the waste from electric or electronic equipment. They are required to establish a minimum of one collection facility per administrative district. In order to comply with the directive's requirements, there is the option of joining a collection and treatment system which overtakes these duties. When participating in a collective system, the obligation to establish collection facilities is transferred onto the collective collection and treatment system. Private end-users must have the possibility to return waste equipment free of charge.

Consequently, this collection and treatment fees will be added on the products' sales price. A disassembly-friendly device design is very likely to reduce the cost of selective treatment substantially and as a consequence, the price for the end customer as well.

Manufacturers and importers shall bear the financial responsibility for transportation from the collection points to the treatment facilities, and for the actual treatment of waste equipment from private households. Furthermore, they are responsible for the systems' adherence to quality standards. Treatment facilities must also set up systems to provide the best available treatment, recovery and recycling techniques. The treatment operation itself requires a permit from government. By regular inspections, the type and quality of the waste as well as the general technical requirements of the treatment operations are ensured. Furthermore, the safety precautions of the treatment facility are evaluated as well.

Before the treatment of WEEE, following materials and components must be removed and treated separately as a minimum pre-treatment:

- polychlorinated biphenyls (PCB)
- mercury containing components, such as switches or backlighting lamps
- batteries
- printed circuit boards of mobile phones generally and those bigger than 10 cm^2
- toner cartridges, liquid and pasty, as well as colour toner
- plastic containing brominated flame retardants
- asbestos waste and components which contain asbestos
- cathode ray tubes
- hydro/chloro/fluorocarbons: CFC, HCFC, HFC, HC
- gas discharge lamps
- liquid crystal displays and all those back-lighted with gas discharge lamps
- external electric cables

The targeted recovery and reuse/recycling rates in the WEEE directive are summed up in Tab.5.2. The term "Recycling" includes material recovery only whereas the term "Recovery" also includes thermal recovery.

Tab.5.2: Targeted recovery and reuse rates by average weight

Category	Recovery	Reuse/Recycling
Large household	80%	75%
IT & Consumer	75%	65%
Others	70%	50%

Additionally, the Article 7 of the WEEE directive sets the reuse and recycling rate for the components, materials and substances in gas discharge lamps to an overall 80% of average weight per lamp.

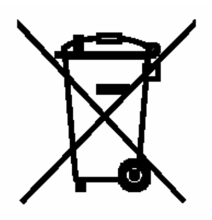
Let us consider the example of the washing machine, which was introduced in lesson 2. What has to be considered for the washing machine to be in accordance with the WEEE directive?.

The washing machine falls into the category "large household appliances".

1. Remove harmful substance, e.g. condenser (PCBs), switches (Hg) in older machines, printed circuit boards in newer machines
2. Reuse e.g. electric motor
3. Recycle steel sheets, plastic parts, …
4. Recovery and reuse rates: According to Tab.5.1: min. 75% reuse/recycling, min. 5% thermal recovery, max. 20% disposal

The WEEE directive also requires that appropriate information is given to users, treatment facilities and the government. The user must be informed what to do with the equipment when it reaches its end of life; the treatment facilities must be informed about how to dismantle the product and which hazardous substances it contains and how to remove it before shreddering. Finally, the government must be informed about the amount of equipment sold, collected and recycled.

Manufacturers shall supply information what facilitates the reuse and an adequate, environmentally sound treatment of waste electrical and electronic equipment. This treatment should encompass maintenance, upgrade, refurbishment and recycling. Producers must provide details about the various components and materials contained in a product and also specify those parts which contain hazardous substances and preparations.



In addition producers must mark their product with a crossed wheel bin symbol, see picture. It indicates that the user is obliged to bring back the device to a collection point and not discard it in a bin. In exceptional cases (e.g. small size), the symbol shall be printed on the packaging, on the instructions for use and/or on the warranty of the product. For medical devices the WEEE symbol must be printed on the packaging, etc. of such devices.

RoHS Directive

As one may have realized, even if the waste of electrical and electronic equipment is collected and submitted to treatment facilities, there are still harmful and toxic substances in the waste which must be separated and removed before treatment. Substances such as heavy metals and brominated flame retardents like polybrominated biphenyls - PBB and polybrominated diphenyl ethers - PBDE pose risks to human health and the environment. Restricting the use of these hazardous substances is likely to enhance the possibilities and economic profitability of recycling of WEEE and decreases the negative impacts both on workers in recycling plants and the environmental.

The directive 2002/95/EC on the “Restriction of the Use of Certain Hazardous Substances” (RoHS) of the European Parliament and of the Council therefore aims at eliminating and reducing certain hazardous substances in the production, treatment and disposal of electrical and electronic equipment (RoHS, 2003). This directive also aims at reducing the waste of electrical and electronic equipment as well as improving and maximizing the recycling, reuse and other forms of recovery of waste of these appliances.

The RoHS directive became European law in February 2003. Furthermore, by 1st July of 2006 new electrical and electronic equipment which are put on the EU market shall not contain more than 0.1 percent by weight (% w/w) of the following substances per homogenous material:

- Lead
- Mercury
- Cadmium (exemption: not more than 0.01 % w/w)
- Hexavalent chromium
- Polybrominated byphenyls (PBB)
- Polybrominated dyphenyl ethers (PDBE)

Homogeneous material means a unit that can not be mechanically disjointed into separate single materials. Examples of "homogeneous materials" would be individual types of plastics, ceramics, glass, metals, alloys, paper and coatings.

Take an electrical cable, for example. It has a metal core, a plastic insulation and perhaps tinned terminations. The cable as a whole is not homogenous as it can obviously be separated by cutting, crushing etc. The metal core, even though it may be an alloy of more than one element, is still considered homogeneous, as mechanical disjointing cannot separate these alloys. The same applies to the plastic insulation. So the metal conductor, the plastic insulation and the solder used to tin the terminations are each homogeneous elements and must all comply individually with the requirements of the RoHS directive. In essence, the legislation applies to the lowest common denominator of an item of uniform composition (Lead free Info, 1/2007).

Presumably, the RoHS directive will affect logistics and change it - from semi-finished products down to the consumer. Lead-containing and lead-free components must at all times be identifiable as such. The retail package might feature a logo, such as Pb-free, or the RoHS logo. Additionally, conformity declarations must be obtained from suppliers of materials and components in order to provide for legal protection of devices which are declared to be RoHS-compliant.

With measuring methods like X-ray fluorescence spectroscopy (XRF) the identification of the contained elements and their concentration is possible. However, there is no standardized procedure given for complying the restriction of the substances according RoHS and no product checks supervised by government are existing so far. Standard testing procedures for RoHS compliance are under development (draft IEC TC111 WG3). Manufacturers have the possibility to make labor tests themselves or have to rely on their component suppliers for being RoHS compliant which bears a certain uncertainty. Communication along the supplier chain is very much important! RoHS does NOT apply to suppliers, the legal responsibility lies within the producers.

EEG PILOT

Since the new directives of the European Union introduced above affect different kind of products and since it is still not clear for some manufacturers, retailers and importers if and how the directives applies to their products, the ECODESIGN PILOT which will be introduced in detail in lesson 7, was adapted to become an information basis for the detailed information about the two directives WEEE and RoHS.

This PILOT, called EEG PILOT (from German: **E**lektro- und **E**lektronik**g**eräte – means electric and electronic devices), can be found on http://www.ecodesign.at/pilot/eeg/ENGLISH/INDEX.HTM. PILOT stands for Product Investigation, Learning and Optimization Tool for sustainable product development. Fig. 5.1 shows the home page of the EEG PILOT.

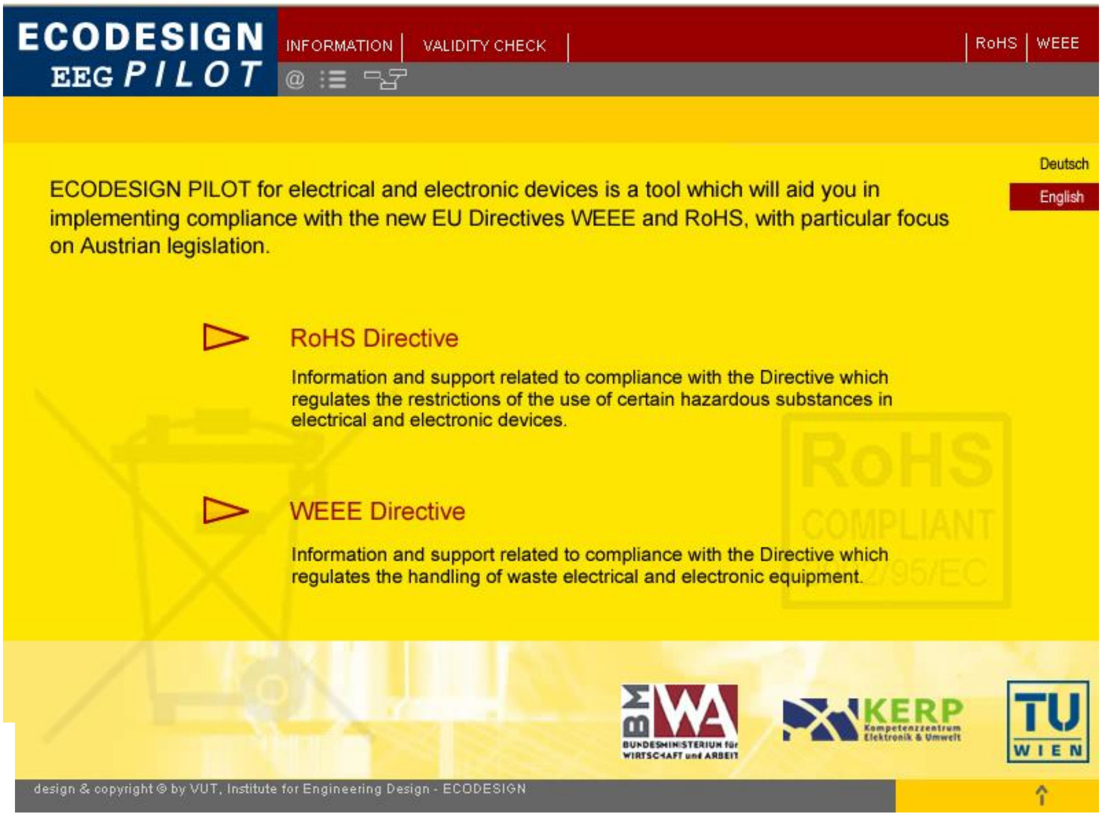


Fig.5.2: Home page of EEG PILOT (EEG PILOT, 2004)

Upon general information about the directives a validity check is offered. With this validity check it can be found out whether the directives are relevant for an organization or not. Additionally, there are two other accesses, the RoHS and the WEEE. By entering the EEG PILOT by these two approaches, detailed information about how, when and what to implement as well as who has to implement the requirements of these directives are provided. Improvement strategies for the product design and examples for the different aspects of the directives are given.

Fig.5.3: Improvement measure for replacing lead with other substances (EEG PILOT, 2004)

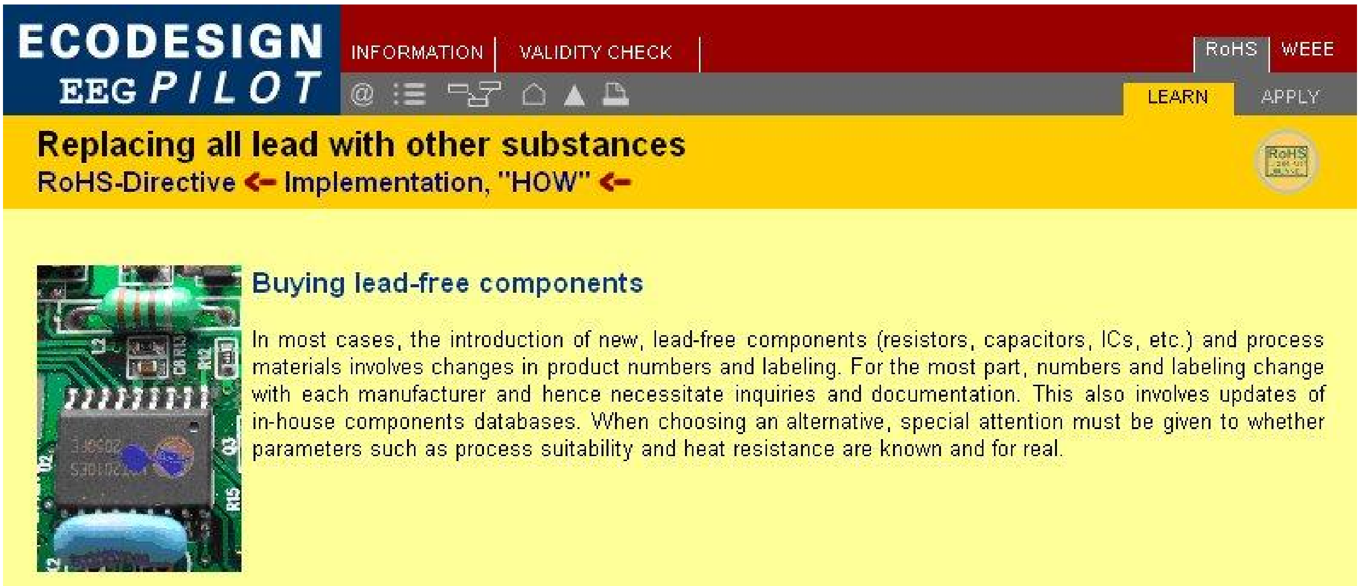
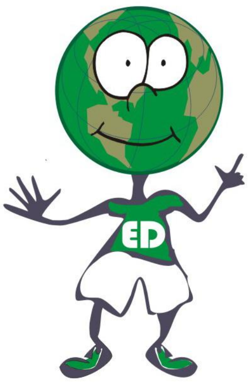


Fig.5.4: Improvement measure for selective treatment – WEEE access (EEG PILOT, 2004)

For the improvement strategy *"Replacing all lead with other substances"* (RoHS access) the following improvement suggestions are given:

- Buying lead-free components
- Buying lead-free solders
- Adjusting logistics to different order specifications and customer requirements
- Choosing an alternative joining technology
- Choosing lead-free PCB surfaces
- Inspecting the existing soldering system as to its suitability for lead-free production
- Setting your system to a new soldering profile
- Redesigning modules
- Adjusting logistics to different order specifications and customer requirements

EuP Directive



Another important directive to be mentioned is the directive 2005/32/EC of the European Parliament and of the Council on "Establishing a Framework for the Setting of Ecodesign Requirements for Energy Using Products" (EuP, 2005).

As it can be concluded from the name, an energy using product is a product which needs energy input to work as intended. It does not matter which kind of energy is used, it could be for instance electricity, fossil or renewable fuels.

The objective of this directive is to establish a framework for the integration of environmental aspects into the product design as well as improving the overall performance of energy using products. As a framework, manufacturers are not affected by the directive directly; environmental considerations into product design are given in general and not yet binding. For the following product categories preparatory studies have been financed by the European Union to investigate their environmental performance along the whole life cycle and the resulting need for action:

- Boilers and combi-boilers (gas/oil/electric)
- Water heaters (gas/oil/electric)
- Personal Computers and Monitors
- Imaging equipment – copy and fax machines, printer, scanner, multi-functional devices
- Consumer electronics, TV sets

- Stand-by and off-mode losses of EuPs
- Battery chargers and external power supplies
- Office lighting
- (public) street lighting
- Residential room conditioning appliances
- Electric motors 1-150 kW, pumps, circulators in buildings and ventilation fans
- Commercial refrigerators and freezers
- Domestic refrigerators and freezers
- Domestic dishwashers and washing machines.

The studies are expected to be finished in 2007. The studies for the battery chargers and street lighting are predicted to be finished in March 2007, the majority in December 2007: boilers, water heaters, copiers, conditioning appliances, electric motors, commercial refrigerators and freezers. With the input of the gained results, detailed Ecodesign requirements for the specific product categories will be developed with the so called “implementing measures” by the European Union. By then, specific requirements for the product design of the mentioned product categories will be established.

In general, specific Ecodesign requirements will be developed for products which

- have a sales volume of more than 200.000 pieces for the whole product category, not for single producers
- cause considerable environmental impact
- present considerable potential for improving the environmental performance without causing exceeding costs

Before putting energy using products on the market the manufacturer shall perform a conformity assessment. The main procedures here for are design control and environmental management systems (EMS).

The conformity of the product with the EuP directive is documented with the “CE” marking. Any new electrical or electronic equipment put on the European market must have its environmental impact measured using life cycle analysis and have followed Ecodesign principles before it can be “CE“-marked and sold in Europe. The CE marking should then also ensure that the energy using product complies with the defined Ecodesign requirements.

How can Ecodesign requirements be set?

The EuP directive suggests therefore an assessment of the environmental aspects considering the whole life cycle. During this assessment the following should be assessed:

- predicted consumption of materials, energy and other resources (e.g. fresh water)
- anticipated emissions to air, water or soil
- anticipated pollution through physical effects such as noise, vibration, radiation or electromagnetic fields
- expected generation of waste material
- possibilities for reuse, recycling and recovery (in accordance with WEEE)

Based on the results of the assessment, an environmental profile of the energy using product can be established. The environmental profile helps to identify those factors which are capable of being influenced in a substantial manner through product design. Alternative design solutions should be evaluated in which a reasonable balance between environmental and other considerations (e.g. technical, economic ...) should be achieved.

The EuP directive intends to reduce energy consumption throughout the entire life cycle of the product. Further materials issued from recycling activities should be used as well as substances which were classified as hazardous should be avoided (in accordance with the RoHS directive). Furthermore following improvements are intended by the EuP directive:

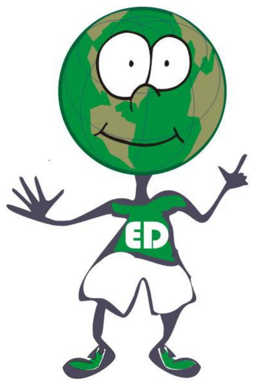
- ease for reuse and recycling (disassembly time, number of parts, ...)
- incorporation of used components
- extension of lifetime, modularity, upgradeability
- reduction of the amount of waste generated
- reduction of emissions (to air, water and soil)

Companies are supposed to use European standards to meet the requirements of the directive.

It is to be expected, that products marked with voluntary environmental labels, in particular with the EU eco-label “EU flower”, are in conformity with the EuP directive. Details about environmental labels are provided in chapter 6.

As there are no binding requirements set so far, there is uncertainty about the needed actions for gaining conformity with the EuP in detail. Implementing measures are currently under development and EU wide information campaigns offer help for especially small- and medium-size enterprises (Awareness raising campaign for SMEs, 2005).

ELV DIRECTIVE



The directive 2000/53/EC of the European Parliament and of the Council on "End of Life Vehicles" aims at minimizing the impact of end of life vehicles on the environment, thus contributing to the protection, preservation and improvement of the quality of the environment and energy conservation. By obtaining this directive waste from end of life vehicles should be prevented. Parts or components of end of life vehicles should be reused or recycled.

The directive shifts the responsibility for cars at their end of their life cycle to the producers. By making the producer financially responsible for the reuse, recycling, recovery, and the environmentally-sound treatment of their products, producers will design new products to minimize the activity costs.

The objectives of the directive are:

- prevention of waste from vehicles
- reuse, recycling, and other forms of end of life vehicles recovery and their components to
- reduce the disposal of waste
- improvement of the environmental performance of all economic operators involved in the life cycles of vehicles; especially operators directly involved in end of life vehicle treatment

Producers as well as importers must ensure that the materials and components of vehicles put on the market after 1st July 2003 do not contain:

- lead
- mercury
- cadmium
- hexavalent chromium

The following materials and components are excepted from of the directive:

- Lead as an alloying element
    - Steel (including galvanised steel) containing up to 0,35 % lead by weight
    - Aluminium containing up to 0,4 % lead by weight

  - Aluminium (in wheel rims, engine parts and window levers) containing up to 4 % lead by weight
  - Copper alloy containing up to 4 % lead by weight
  - Lead / bronze bearing-shells and bushes
- Lead and lead compounds in components
  - Batteries
  - Coating inside petrol tanks
  - Vibration dampers
  - Vulcanising agent for high pressure or fuel hoses
  - Stabiliser in protective paints
  - Solder in electronic circuit boards and other applications
- Hexavalent chromium: Corrosion preventative coating on numerous key vehicle components (maximum 2 g per vehicle)
- Mercury: Bulbs and instrument panel displays

Furthermore the design of the vehicle should take into full account and facilitate dismantling, reuse and recycling of end of life vehicles, their components and materials respectively.

The producers of vehicles must guarantee that the vehicles are designed and manufactured in a way that the targeted reuse, recycling and recovery rates can be achieved. In January 2006 it is law to reuse or utilize 85 % of the mass of a vehicle at its end of life. In the year 2015 the quote for reusing and utilizing will grow up to 95 % by mass.

The targeted rates for reuse, recovery and recycling are summed up in Tab.5.3.

Tab.5.3: Targeted reuse, recovery and recycling rates of the ELV directive by an average weight per vehicle and year

until	01/01/2006	01/01/2015
Reuse and recovery	85%	95%
Reuse and recycling	80%	85%

Producers should use component and material coding standards, in concert with material and equipment manufacturers, in particular to facilitate the identification of those components and materials which are suitable for reuse and recovery.

SUMMARY

The introduced EU directives contain requirements which have to be fulfilled by the product design of the affected branches respectively in the near future. The electric and electronic industry and the automotive industry are in the focus of recently released EU directives.

The directives have in common, that they address the producers responsibility for their marketed products directly.

Before realizing any improvement strategy or improvement task these requirements must be investigated and put into action. There are different means of aid for companies for implementing the mentioned requirements: information sites and campaigns, easy to use tools etc. However, it is still a challenge for the companies to be in line with the requirements. Keeping an eye on the current developments in the branches and new releases of the requirements and involving the responsible person in time help gaining conformity.

Beneath the legal requirements, the product developer might consider voluntary stakeholder requirements from eco-labeling programs. Fulfilling criteria from eco-labels leads to a better environmental performance as well as to a better performance on the market. Eco-labels provide environmental information for interested customers and present a decision support based on a certified label. The application of different types of eco-labels will be introduced in the following lesson.

HOME EXERCISES

1. Consider your product:
   p. Which of the directives apply to your product?
   q. Investigate the detailed design requirements for your product.
   r. How can the requirements of the directives be implemented in your product design?
   s. Prepare a comparison between the stakeholder requirements coming from the directives and the requirements from environmental assessment you derived in the previous chapters.

REFERENCES

- ✓ *EEG PILOT, 2002*: http://www.Ecodesign.at/pilot/eeg/ENGLISH/INDEX.HTM.
- ✓ *Lead free Info*: http://www.pb-free.info/jargon.htm#homogeneous accessed 1/2007.
- ✓ *Awareness raising campaign for SMEs, 2005*: http://www.EcoDesignARC.info accessed 2/2007.
- ✓ *Summaries of legislation of the EU*: http://europa.eu/scadplus/leg/en/s15000.htm accessed 2/2007.

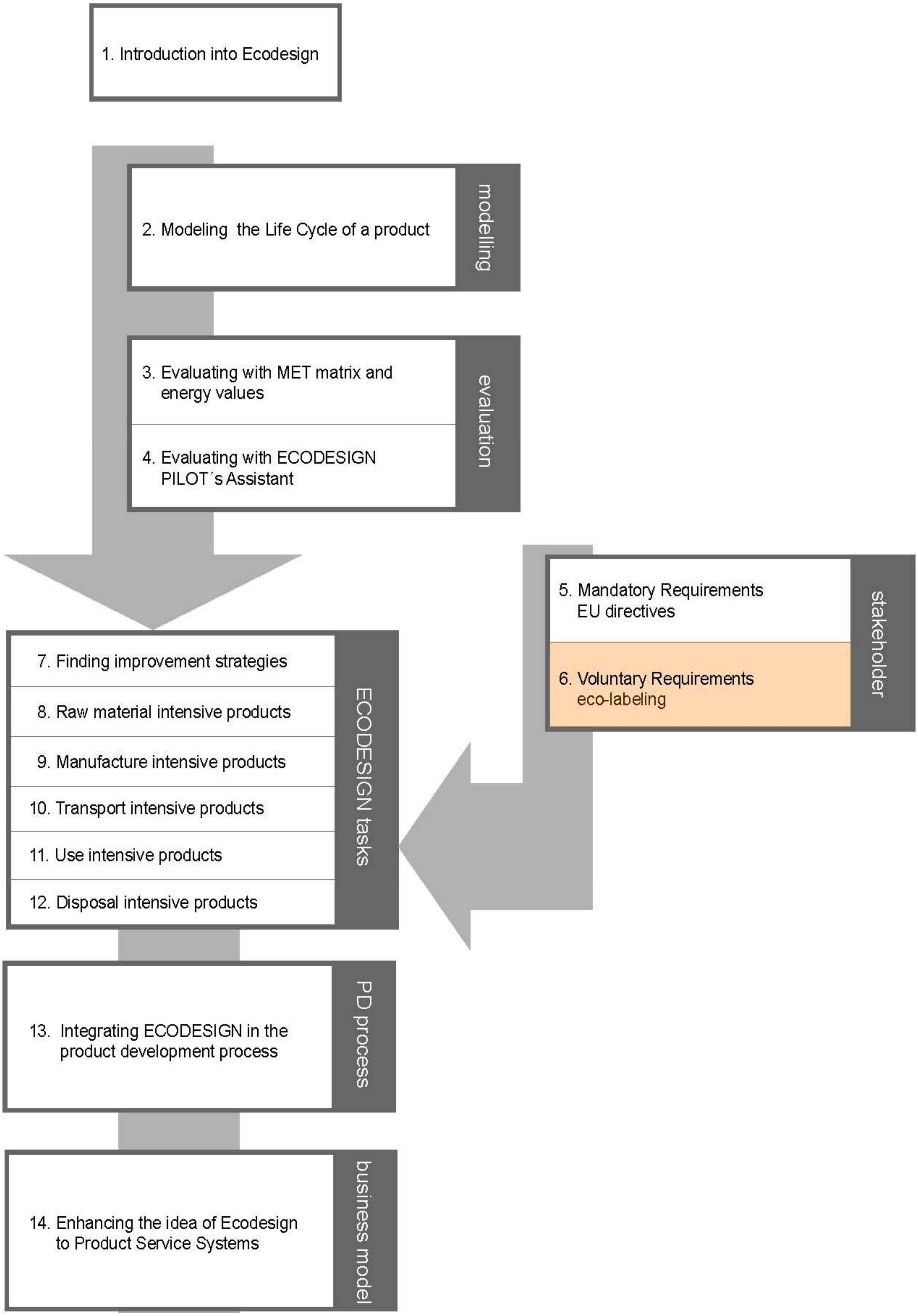
ADDITIONAL READING MATERIAL (AVAILABLE ON CD)

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*.

EuP (2005), *Directive 2005/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on "Establishing a Framework for the Setting of Ecodesign Requirements for Energy Using Products"* .

End-of-Life Vehicle directive (2000), 2000/53/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 September, 2000.


1. Introduction into Ecodesign
2. Modeling the Life Cycle of a product
modelling
3. Evaluating with MET matrix and energy values
4. Evaluating with ECODESIGN PILOT´s Assistant
evaluation
5. Mandatory Requirements EU directives
6. Voluntary Requirements eco-labeling
stakeholder
7. Finding improvement strategies
8. Raw material intensive products
9. Manufacture intensive products
10. Transport intensive products
11. Use intensive products
12. Disposal intensive products
ECODESIGN tasks
13. Integrating ECODESIGN in the product development process
PD process
14. Enhancing the idea of Ecodesign to Product Service Systems
business model

LESSON 6

Identifying Voluntary Environmental Requirements from Eco-Labeling Programs

KEYWORDS: ENVIRONMENTAL LABELING PROGRAMS, ECO-LABELING, ISO 14020 SERIES STANDARDS

Lesson objectives

Aside mandatory legal requirements there are voluntary environmental measures concerning the product design, so called environmental labeling programs. All types of environmental labels and declarations have the same goal: encouraging the demand for and supply of products that cause less stress to the environment, thereby stimulating the potential for market driven continuous environmental improvement (ISO 14020, 1998). The objective of eco-labeling is to provide information to consumers, to enable them to select products that are the least harmful to the environment within the certain product category. It is aimed at encouraging customers to select a product because it causes less environmental impact compared to those without a label. Eco-labeling is intended to stimulate environmental concern in product development and a sustainable society.

In this lesson selected eco-labels and their requirements for environmentally sound product design are introduced. The chapter focuses on eco-labels according to ISO 14020 series:

5. *Type I: environmental labeling - eco-labeling (ISO 14024, 1999)*
6. *Type II: self-declared environmental claims (ISO 14021, 1999)*
7. *Type III: environmental product declaration (ISO 14025, 2003)*

Selected labels and their requirements are presented and their different characteristics are shown with examples from office furniture and electronic equipment.

At the end of this lesson you will get familiar with different types of voluntary eco-labeling programs and you will know which requirements and advantages they have. The requirements of three different eco-labeling programs applicable on our example products juice extractor, washing machine and office chair will be investigated.

DIFFERENT TYPES OF ECO-LABELS

Eco-labels, also called *Type I environmental labeling* according to ISO 14024, are awarded to products which fulfill certain environmental requirements defined in the specific eco-label program. The certification process is verified by an authorized third party. Product specific requirements can be related to more general product characteristics like product functions or to more specific criteria like energy consumption, percentage of recyclable materials etc. Product specific requirements of selected eco-labeling programs will be introduced in chapters 6.1 to 6.3 with practical examples. For the different national eco-labeling programs there are criteria for several product groups set by experts from industry, consumer organizations, environmental protection agencies etc. ISO 14024 includes the requirements that criteria should be objective, reasonable and verifiable, that interested parties should be given the opportunity to participate and that their comments are evaluated. If there is the need for action, interested parties can also trigger the development for new criteria for a product group not yet covered by an eco-labeling program. The criteria are based on evaluation of the environmental impacts during the products' whole life cycle by an independent third party.

Upon approved application all products meeting the criteria are awarded the environmental label. Eco-labeled products cause less environmental impact within the particular product category. Products that cannot obtain the label, or choose not to apply, may have disadvantages in competing against products that do have the label in the same market. Applying for an eco-label by the producer is voluntary. However, since the environmental awareness of consumers is rising, eco-labels help putting the product on the market and present a decision support for the retail customers.

Tab. 6.1 shows an excerpt of product categories the selected wide spread national eco-labels are awarded to. National eco-labels also exist in Hungary, Czech Republic, Slovac Republic and in Poland (EU-Eco-label, 1.2007):

Tab.6.1: Selected national eco-labels and product category examples

Name	Blue Angel	Nordic Swan	NF Environment	EU Flower	Eco Mark
Country	Germany	Nordic countries	France	EU	Japan
Appliance (Excerpt)	Products made of wood and paper Sanitary paper products made of recycling paper Textiles Vehicles Construction machinery Biodegradable lubricants and forming oils Low-emission wall paint Products made from recycled plastics Photovoltaic products Reusable packaging	Electric household appliances Rechargeable batteries Textiles Detergents Building and decorating products Car products Domestic chemicals Domestic heating Machinery Office equipment Office products Paper and pulp products Services	Coolants in vehicles Office furniture Furniture Refuse bags Paint Interior fittings and decorative profiles	Textiles Electric household appliances Vehicles Products made of wood and paper Cleaning products appliances Paper products Home and garden Clothing Lubricants	Textiles Office appliances Copying devices Printer Printer ink Hot water supplies using solar systems Water saving equipment Products from thinned wood and reused wood Building Products using recycling materials

As there are many different eco-labeling programs, the single national eco-labels are rather unknown beyond the national borders. The listed labels in Tab. 6.1. though, are widely used even outside of the labeling nation. The EU flower is an attempt towards harmonization of the different national eco-labels. A manufacturer, retailer or service provider who meets the criteria for a product group and who applies for the award of the EU Eco-label, can market the eco-labeled product throughout the

25 Member States of the European Union (EU-Eco-label 1. 2007/2). In contrast, the type II self-declared environmental claims may be internationally used and known in different countries.

Type II *self-declared environmental claims* use text and symbols emphasizing a particular environmental aspect of a product or service on the product or in product advertisements. It does not cover the environmental impacts along the life cycle of a product. There are no criteria set for selected product groups, the ISO 14021, however, lists vague or unspecified terms which are not allowed to be labeled on a product (ISO 14021, 1999):

- Environmentally sound
- Environmentally friendly
- Clean
- Green
- Nature friendly
- Ozone friendly

A specific and clear declaration of the labeled environmental aspect is required. For the manufacturing process terms like the following are widely used:

- Content of recycling material used in the product
- Reduced amount of resources
- Reduced amount of energy
- Recovered energy
- Reduction of waste

For the use phase terms like reduced energy or water demand and long life time are permitted labeling terms. The end of life phase is often described with reusable, refillable, recyclable, demountable into single parts for disposal or separate recycling and biodegradable.

The purpose of this type of label is to increase market share by promoting the environmental features of a product to the environmentally conscious retail consumers.

Environmental claims made by the company (self-declared environmental claims), however, are often difficult to verify and not easy to compare. This can lead to marketplace confusion for the consumer. These environmental claims may be unsupported and thus counter-productive to helping consumers make informed environmental choices among products and services. For this reason, regulations regarding the use of environmental terms and symbols have been introduced in many parts of

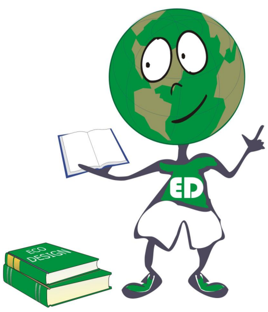
Fig.6.1. Examples for type II labeling in the furniture industry

the world. Many of these regulations are now based on the international standard, ISO 14021. These regulations are not only applicable to domestic products but also to imported products and thus common on the global market (Lee, K.-M., 2003).

Examples from the furniture industry for a single aspect type II labeling are the Forest Stewardship Council (FSC) which focuses on the production process and the ECO-Tex Standard 100 which focuses on the product characteristics e.g. content of harmful substances of the labeled textiles (Forest Stewardship Council, 1.2007; Oeko-Tex Standard 100, 1.2007). Fig.6.1 shows the labels of the two mentioned self-declared environmental claims.

The advantage of an environmental claim lies in the less complexity of the labeling procedure, as the companies do not have to go through the rather long application and certification process. On the other hand, some companies use self-declared environmental claims for misleading information about their “green” products.

The self-declared environmental claim of the Siemens Metro in Oslo presents a reliable and profoundly researched example. This environmental claim refers to more than one single aspect and includes data about the material composition and recycling potential, the total energy consumption and the derived global warming potential. The product declaration was performed in the course of a dissertation at the Institute for Engineering Design, Vienna. (Environmental Product Declaration Metro Oslo, 2006).



The third labeling system in the ISO series, Type III according to ISO 14025: *environmental product declaration (EPD)* is defined as "quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards (ISO 14025, 2000).

The key feature of an EPD is the identification and reporting of the total environmental impact of products along their life cycle. The aim of an EPD is to inform about environmental performance of products and services with key environmental characteristics. The target group of environmental product declarations is industry as well as retail customers. The quantified data are based on Life Cycle Assessment (LCA) according to ISO 14040f. This may be run by a practitioner as a third party program or operated on a self-declared basis. The type III declaration is based on preset categories of parameters that are determined from LCA results. Environmental loads and impacts accrued

from the life cycle of a product are cataloged according to these preset categories of parameters. Preset environmental parameters (e.g. CO_2) are linked to the following impact categories:

- Global warming potential – greenhouse gases (CO_2, CH_4...)
- Ozone depleting gases - CFCs
- Acidification
- ground level ozone
- Eutrophication - Oxygen consumption

The type III environmental declaration presents the quantified information of the product's environmental load through its entire life cycle and consists of four parts:

1. *product description*
2. *material description along the life cycle – inventory data*
3. *scientifically verified impact categories*
4. *certificate*

The content of an environmental declaration is based on scientific research data on the total environmental impact of the investigated product. An EPD is a highly reliable, independently verified and a comparable mean for communicating environmental information. The system is applicable to all products and services, it is non-selective. As additional reading material, the EPD of an office chair manufactured by Steelcase in France is provided (Environmental Product Declaration, Steelcase, 2004)

Completely confused? Tab. 6.2 and 6.3 give you an overview of the differentiation between the three types of eco-labeling. Key information on the characteristics and advantages as well as disadvantages of the eco-labels will help you finding an appropriate label for your home exercise.

Table 6.2 shows the three types of environmental labels and declarations according to the ISO 14020 series standards and their main distinctive features.

Tab.6.2: Comparison of different types of environmental labels and declarations (according to Lee, K.-M. and Uehara, H. 2003)

Item	Type I	Type II	Type III
Name	Eco Labeling	Self-declared Environmental Claim	Environmental Product Declaration
Target Audience	Retail Consumer	Retail Consumer	Industrial/Retail Consumer
Communication Method	Environmental Label	Text & Symbol	Environmental Profile Data Sheet

Item	Type I	Type II	Type III
Scope	Whole life cycle	Single aspect*	Whole life cycle
Criteria	Yes**	None	None
Use of LCA	No	No	Yes
Practitioner	Third party	First party	Third/First party
Certification	Yes	Generally No	Yes/No
Effort of procedure	High	Moderate	High
Governing body	Eco-Labeling Body	Consumer Bureau	Accreditation Body

* A specific aspect of a life cycle or a single environmental attribute

** Environmental and functional product criteria

Tab. 6.3. gives an overview of the advantages and disadvantages and special features of the mentioned eco-labels.

Tab.6.3: Advantages and disadvantages and special features of Type I, Type II and Type III environmental labels (based on Lee, K.-M. and Uehara, H. 2003)

	Type I	Type II	Type III
Advantage	Easily identified Quick decision Credibility through third party	Market oriented Flexible approach to market needs Tool for business competition	Detailed data via common method Credibility via scientific quantitative data
Disadvantage	Uses only a symbol No detailed information High effort procedure	Relatively low credibility Need to face directly to consumers Claim is a single parameter or limited	Complicated LCA analysis Insufficient back ground data Difficult to comprehend
Special features	Home use products Simple function products Low priced products Retail consumers	Products in general Retail consumers/ Industrial purchasers	Products for Industrial use/ relatively complicate and high priced products/durable goods Industrial purchasers/consumers

In the following chapters product specific requirements for household appliances and office furniture will be discussed with three examples: a juice extractor, a washing machine and an office chair. Three different Type I eco-labeling programs will be introduced more in detail.

PRODUCT SPECIFIC REQUIREMENTS OF THE NORDIC SWAN – EXAMPLE JUICE EXTRACTOR

In this section criteria for the eco-labeling of the juice extractor introduced in lesson 2 will be investigated. The Nordic Swan label contains criteria for kitchen appliances and equipments. The

environmental requirements of this label will be viewed more detailed and will be combined with the mandatory requirements from WEEE and RoHS directive.

The Nordic Swan's criteria vary between the different products. Criteria common to all product groups is the attention to the product's impact on the environment from raw materials to waste through the product’s life cycle. These design criteria apply to all household appliances:

- Modular design
- Disassembly without difficulty
- Housing contains max. four types of plastic
- No permanent bonds in the form of glue or welding
- Labels/Stickers of the same material as the component to which they are attached

The juice extractor can be assigned to the product category “food processors” for which the noise level during normal operations should be notified with the application. Further, the Nordic Swan labeling program requires a modular design of the product. A module is defined as *“a part of the product that can be separated from the product and reused as a single unit”.* The design of the module must facilitate reuse of the module in common recycling systems when separated from the product. Disassembly as well as possibilities for repairing the module must be ensured. The following requirements must be fulfilled by the product design (Nordic Eco-labeling, 2005):

- Modules must be separable and reassembled without difficulty.
- Points of attachment or disassembly points must be easily accessible with tools.
- The connections between different materials must be easy to locate (e.g. with the aid of visible labels on the product or by means of information from disassembly data sheets).
- No permanent bonds in the form of glue or welding between different types of materials must be used.
- Housings may contain a maximum of four different types of plastic or plastic alloys, and these must all be separable from one another.
- Plastic parts (>25g) must be capable of identification in accordance with ISO 11469 or an equivalent labeling system.
- Plastic parts must not be painted or varnished in any way that might reduce the reusability of the material.
- Labels/tabs/stickers must be made of the same material as the components to which they are attached to.

The Nordic Swan defines some requirements to the materials used in the product. The requirements do not apply to reused parts in case of plastics (Chlorinated plastics, haloginated flame retardants and metals), but to primary and recycled materials.

In case of plastics the use of chlorinated plastics is not permitted. In addition, it is not permitted to add halogenated flame retardants to plastic parts since halogenated flame retardants may

- cause cancer,
- cause heritable genetic damage,
- impair fertility or
- cause harm to the unborn child.

The use of some phthalates (softener) in the product, such as Dicylohexy phthalate or Benzylbutyl phthalates and many more are prohibited.

The use of chlorinated plastic in the packaging is not allowed. The products must be designed and labeled so it is possible to identify, separate and recycle the components and modules in accordance with the WEEE-directive. For food processors it is demanded that the noise level during normal operations should be notified with the application. Therefore the producer must enclose test results from measurement of noise according to European standards.

In case of heavy metals, cadmium, lead, hexavalent chromium and mercury compounds must not be added. This requirement is in accordance with the RoHS directive (RoHS, 2003).

The criteria of the Nordic Swan make an effort to comply with the mandatory requirements of the EU-directives WEEE and RoHS (compare lesson 5).

Requirements for category 2: small household appliances according to WEEE (WEEE, 2003)

- rate of recovery of 70 % of average weight per appliance
- reuse and recycling rate of 50 % of average weight per appliance for components, material and substances

Before the treatment of the juice extractor, following materials and components must be removed and treated separately as a minimum pre-treatment:

- mercury containing components, such as switches
- printed circuit boards bigger than 10 cm²

- plastic containing brominated flame retardants
- external electric cables

PRODUCT SPECIFIC REQUIREMENTS OF THE EU FLOWER – EXAMPLE WASHING MACHINE

In this section criteria for the labeling of the washing machine introduced in Lesson 2 will be investigated. The EU Flower label contains criteria for electric household appliances including washing machines. The environmental requirements of this label will further be viewed more detailed.

- The key criteria for washing machines are (http://www.eco-label.com/ 12/06):

  1. Energy efficiency: use less than or equal to 0,17 kWh per kg of wash load (standard 60°C cotton cycle)
  2. Water consumption: use less than or equal to 12 liters of water per kg of wash load
  3. Spin drying efficiency: achieve a residual moisture content of less than 54%
  4. Noise: < 56dB(A) during washing, <76 dB(A) during spinning
  5. Prevention of excessive use of detergent: provide volumetric or weight related markings on the detergent dispenser allowing the user to adjust the detergent quantity used according to the type and amount of load and its degree of soiling.

- Additional criteria:

  6. Appliance design: for identifying the appropriate settings according to fabric type and laundry code and energy and water saving programs and options.
  7. User instruction manual shall provide advice on the correct environmental use and recommendations for optimal use of energy, water and detergent
  8. Take-back and recycling: has to be free of charge

     - Identifying the material: permanent marking for plastic parts heavier than 50 grams
     - Plastic parts heavier than 25 grams shall not contain flame retardants that are or may be assigned any of the risk phrases R45 (may cause cancer), R46 (may cause heritable genetic damage), R50 (very toxic to aquatic organisms), R51 (toxic to aquatic organisms), R52 (harmful to aquatic organisms), R53 (may cause long-term adverse effects in the

aquatic environment), R60 (may impair fertility) or R61 (may cause harm to the unborn child)

- Design for disassembly: joints are easy to find and accessible, electronic assemblies are easy to find and to dismantle, the product is easy to dismantle by using commonly available tools, incompatible and hazardous materials are separable

9. Lifetime extension

- guarantee to ensure that the washing machine will function for at least two years
- availability of compatible replacement parts shall be guaranteed for 12 years from the time that production ceases

PRODUCT SPECIFIC REQUIREMENTS OF THE NF ENVIRONMENT – EXAMPLE OFFICE CHAIR

In this section criteria for a different product group will be discussed in detail: The NF Environment label contains criteria for office furniture. Therefore the product specific criteria for the office chair introduced in Lesson 2 will be indicative for the environmental requirements of this label.

The ecological criteria of the technical regulation “NF Environment” eco-label for furnishings consist of overall furniture characteristics as well as criteria affecting specific items of office furniture. A major difference lies in the requirements for parts of the manufacturing process, i.e. not only the product itself is investigated but also the amount and character of manufacturing waste. The criteria for the French eco-label for furniture address a variety of aspects. In the following the criteria exemplary office chair (NF Environment Mark for Furnishings, 2000):

- ***Overall furniture characteristics relevant for the exemplary office chair*** (NF Environment Mark for Furnishings, 2000):

Criterion 1 Possibility of separation, at end of service life, of any item whose weight is bigger than 50 grams.

Criterion 2 Optimization of space requirements during transportation and storage

- ***Criteria affecting specific constituent items***

Criterion 6 Marking of plastic parts for their upgrading/utilization

Case 1: For any item whose weight is bigger than 50 grams, the applicant must carry out permanent marking on the plastic parts; example office chair: arm rests

Case 2: Permanent marking on a part of the product for plastic parts whose unit weight is less than 50 grams but whose total weight (added together per kind and per product) is greater than the weight of the product by 10%; example office chair: small plastic parts of the main compounds

Criterion 7 Ban on use of CFCs during manufacture of foams used in the composition of the end product; example office chair: PU foam of the back rest

- ***Relative to finishing and gluing***

Criterion 8 Elimination of manufacturing wastes which have not been upgraded in situ

Criterion 9 Finishing products in the paint family

Criterion 10 Limitation of quantity of VOCs discharged in natural surroundings, for solvent-base finishing

Criterion 11 Limitation of discharges and arrangements necessary for products affected by the certification

- ***Limitation of specific energy for the relevant office furniture items*** - Criterion 12

The specific energy consumption necessary to obtain and transform the material used in the office chair is limited to 700 MJ in total for the whole chair for work-seats (compare Example 2: office chair, lesson 3). When applicable, the actual or average recycling rates (aluminum, for example), consumption of energy necessary to transform the raw material (primary aluminum) and second-life material (recycled aluminum) has to be taken into account. The energy values are listed exemplary in the APPENDIX A of the criteria document (NF ENVIRONMENT MARK for FURNISHINGS, 2000).

- ***Information and Services for the user***

Criterion 13 Information for user:

1. NF-Environment marking and information
2. Information on the furniture's end of service life (general information, pointing out that used furniture must be taken to the place best suited for its upgrading/utilization (solid-waste reception centers, specific dismantling centers...).

3. Information on maintenance of the furniture

Criterion 14 Services for the user - Durability of supply

The possibility of acquiring products per unit item throughout the actual period of their industrial manufacturing has to be ensured. The manufacturer commits the supplement of the original functional items or items fulfilling equivalent functions for a period of 5 years from the date when production of the relevant range is stopped.

- ***Packages***

Criterion 15 Package system

The packaging of the office chair has to make use of readily recyclable materials and/or materials taken from renewable resources. The use of complex compounds which are not recyclable in actual fact is authorized if multi-use packages are involved. This requirement applies both to packages for end products and to packages of supplies or subassemblies used in its composition (supplier packages). The manufacturer must ensure that his package supplier complies with these requirements.

SUMMARY

The World Trade Organization (WTO) recognized that environment related regulations and practices and environmental terms and symbols could be potential trade barriers and communicate misleading information about a products environmental performance. This lead to a standardization of the environmental evaluation process and labeling by the International Standardization Organization (ISO). Thus, three types of environmental labeling have been defined by ISO: Type I: third party verified eco-labeling programs, Type II: self-declared environmental claims by companies and Type III: environmental product declaration based on life cycle analysis (LCA).

Taking part in an environmental labeling program helps to decrease the environmental impact of the product through its life cycle and raises the value of the product on the market. Eco-labeling is intended to stimulate environmental concern in product development and customer behavior. The requirements of the eco-labeling programs show big differences both in effort and demand. The distinctive features as well as the advantages and disadvantages of the environmental labels according to the ISO 14020 series are worked out. Three different examples of type I eco-labeling program (Nordic Swan, EU Flower and NF Environment) were investigated for their application on the mentioned product examples juice extractor, washing machine and office chair. The examples present the basis for the home exercise in this chapter.

Now that the legal and voluntary requirements are investigated further improvement tasks for the product design can be found by using the PILOT which is introduced in the next lesson.

HOME EXERCISES

1. Consider your product:
   t. Which type of eco-labeling program applies to your product?
   u. Which product specific requirements do apply to your product in particular?
   v. How do the requirements influence the design of your product?
   w. What are the advantages and disadvantages of eco-labels in general? Which type of label would you favor?

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ADDITIONAL READING MATERIAL (AVAILABLE ON CD)

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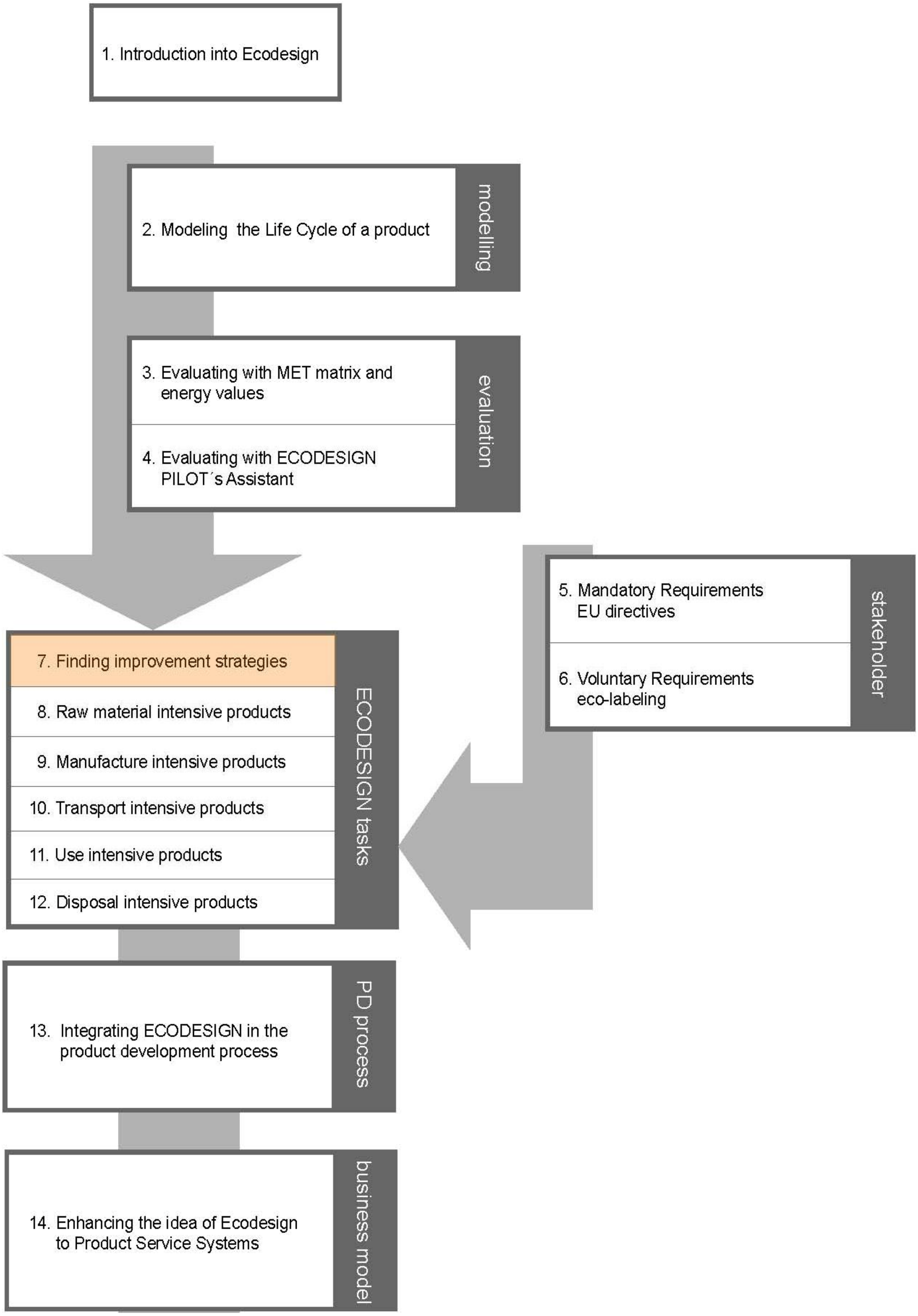


1. Introduction into Ecodesign
2. Modeling the Life Cycle of a product
modelling
3. Evaluating with MET matrix and energy values
4. Evaluating with ECODESIGN PILOT´s Assistant
evaluation
5. Mandatory Requirements EU directives
6. Voluntary Requirements eco-labeling
stakeholder
7. Finding improvement strategies
8. Raw material intensive products
9. Manufacture intensive products
10. Transport intensive products
11. Use intensive products
12. Disposal intensive products
ECODESIGN tasks
13. Integrating ECODESIGN in the product development process
PD process
14. Enhancing the idea of Ecodesign to Product Service Systems
business model

LESSON 7

Finding Improvement Strategies

KEYWORDS: **ECODESIGN PILOT, IMPROVEMENT STRATEGIES, ECODESIGN TASKS, QFD**

Lesson objectives

In the previous lessons products have been described by using environmental parameters, qualitative as well as quantitative data. Based on these data, environmental profiles of products were established.

Based on the results of the environmental evaluation of the product the life cycle stage contributing most to the environmental impact of the product as well as relevant parameters and processes could be identified.

Lesson 5 introduced the legal requirements which have to be fulfilled by a product. Considering the environmental profile of the products and keeping the legal requirements in mind it is now possible to search for improvement strategies for the product.

To be able to find specific strategies for the improvement of products, the Ecodesign - "Product Investigation, Learning and Optimization Tool for sustainable development" (PILOT) is introduced in this chapter (Wimmer, Züst, 2002). The PILOT allows finding suitable tasks for the implementation of the strategies into the product improvement process.

Further, Quality Function Deployment (QFD) (Akao, 1990) will be introduced in this chapter. This methodology is used to consider customer, or in general, stakeholder requirements in the product development and product improvement process.

It will be discussed how environmental considerations and stakeholder requirements can be brought together to achieve a product that on the one hand has a good environmental performance and on the other hand fulfils customer, respectively stakeholder requirements.

At the end of this lesson you will be able to:

- *Find specific improvement strategies for your product by using the Ecodesign PILOT*
- *Consider stakeholder requirements in your product improvement process by applying Quality Function Deployment*
- *Combine environmental considerations and stakeholder requirements*

ECODESIGN PILOT

The Product Investigation, Learning and Optimization Tool (PILOT) which is available under www.ecodesign.at/pilot helps product developers to find specific improvement strategies and suitable Ecodesign tasks to improve products.

Fig. 7.1 shows the navigation bar of the PILOT. At the left side the entrance to the PILOT and the Assistant can be found.

Fig.7.1:Right: Entrance for PILOT and Assistant (Austrian Ecodesign Platform, 2006)

By clicking on the PILOT button you get access to the core of the tool. The PILOT defines five types of products, depending in which life cycle stage the most environmental impact occurs. These five product types are:

- Type A: Raw material intensive product
- Type B: Manufacture intensive product
- Type C: Transportation intensive product
- Type D: Use intensive product
- Type E: Disposal intensive product

A raw material intensive product needs different types or a huge amount of materials or materials which need different, complex and/or energy intensive extraction processes. The office chair described in the previous lessons is an example for a raw material intensive product.

The manufacture intensive product needs different manufacture technologies or needs lots of process and auxiliary materials during manufacture. An example for a manufacturing intensive product would be a desk which is made of wood. It contains of a material which can be easily “extracted”, can be produced locally and sold in a local area, does not need any energy or additional process materials during use and can be incinerated in its end of life stage. Therefore the only relevant life cycle stage is the manufacturing stage, which, compared to the other life cycle stages, contributes most to the environmental impact.

A transportation intensive product needs different means of transport (e.g. plane, train, truck etc...). Large distances have to be covered to distribute a transportation intensive product from the producer to the customer.

A use intensive product needs a lot of energy during its use stage or a high amount of auxiliary materials to function properly. A washing machine is an example for a use intensive product.

A disposal intensive product causes its most environmental impact during its end of life stage. Either complex waste treatment processes due to e.g. special connection techniques used in the different parts and components of the product are necessary or the product contains problematic or hazardous materials which need special treatment.

Depending on which of the five product types the concerned product belongs to, different improvement strategies for the product are necessary. The ECODESIGN PILOT defines 19 different strategies which help to improve the different product types. These strategies are listed in Tab. 7.1. The appropriate strategies for the different product types are selected as well.

Tab.7.1 Strategies defined in the ECODESIGN PILOT and their assignment to the different product types

Strategy	Type A	Type B	Type C	Type D	Type E
Selecting the right materials	×				×
Reducing material inputs	×				
Reducing energy consumption in production processes		×			
Optimizing type and amount of process materials		×			
Avoiding waste in the production process		×			
Ecological procurement of external parts		×			
Reduction of packaging			×		
Reduction of transportation			×		
Optimizing product use	×	×			
Optimizing product functionality	×	×		×	
Increasing product durability	×	×			×

Strategy	Type A	Type B	Type C	Type D	Type E
Ensuring environmentally safe performance				×	
Reducing consumption at use stage				×	
Avoidance of waste at use stage				×	
Improving maintenance	×	×		×	
Improving reparability	×	×			×
Improving disassembly	×	×			×
Reuse of product parts	×	×			×
Recycling of materials	×				×

For each of the product types described above the suitable strategies are listed and linked to Ecodesign checklists in the ECODESIGN PILOT.

Fig. 7.2 shows the allocated strategies for improving a use intensive product.

Fig.7.2: Improvement strategies for a use intensive product (product type D) (Austrian Ecodesign Platform, 2006)

By clicking on the "learn" button (which can be found on the right upper corner of the navigation bar) additional information about the allocated Ecodesign strategies can be found.

There are different approaches how a specific strategy can be realized. By entering the learning site for e.g. the strategy "optimizing product functionality" one can find up to six different suggested tasks. The ECODESIGN PILOT provides additional detailed information about each of these tasks and the given examples.

Fig. 7.3 shows part of the site where information is provided for the task "prevent environmentally harmful abuse of product". Beneath this task, the following tasks can be pursued to fulfil the concerned strategy:

- Indicate consumption of product along use stage
- Minimize energy consumption at use stage by increasing efficiency of product
- Minimize energy demand at use stage by choosing an adequate principle of function
- Make possible use of renewable energy resources at use stage
- Design product for minimum consumption of process materials
- Make possible use of environmentally sound process materials
- Make possible use of process materials from renewable raw materials

Not all of the strategies and within the strategies not all of the tasks may be useful for a product at same time. Therefore the team which works on the product and the product improvement has to evaluate the individual tasks individually.

Fig.7.3: Additional information for Ecodesign tasks (Austrian Ecodesign Platform, 2006)

To help the product development team in evaluating the tasks, the ECODESIGN PILOT provides checklists, see Fig. 7.4. For each task an assessment question can be found. First, the team has to evaluate the relevance of the assessment question by choosing between "very important" (10 points), "less important" (5 points) and "not relevant" (0 points). In a second step the fulfilment of the concerned task can be evaluated by simply choosing "yes" (1 point), "rather yes" (2 points), "rather no" (3 points) and "no" (4 points). The priority of the task is achieved by a multiplication of relevance and fulfilment. The Ecodesign tasks showing a high priority should be chosen for product improvement.

The checklists help to identify systematically those improvement tasks showing high improvement potentials which help to improve the product significantly and are not realized yet.

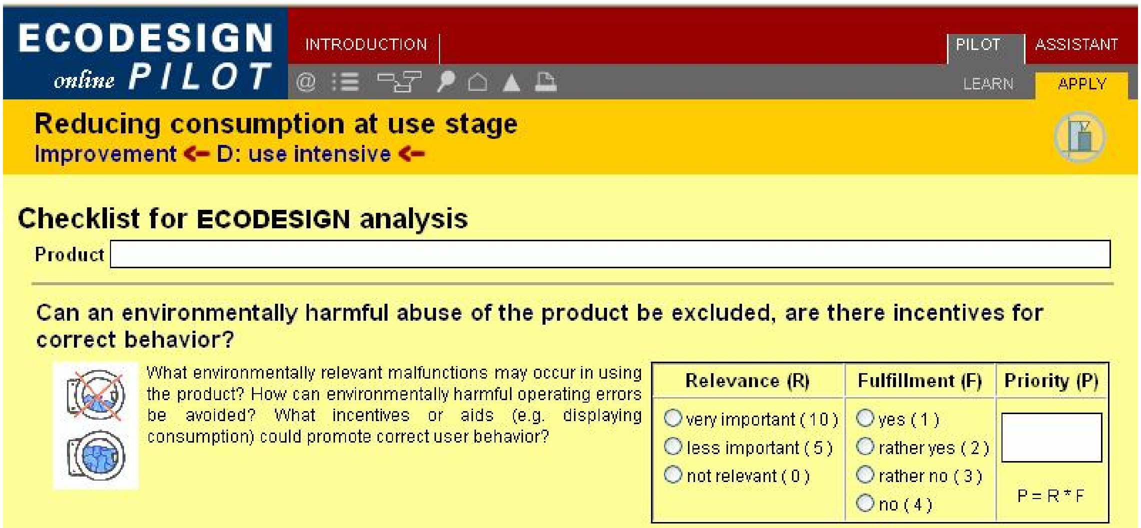


Fig.7.4: Evaluation of the assessment question (Austrian Ecodesign Platform, 2006)

Further, first ideas for the realization of the task can be noted in the checklists, see Fig. 7.5. Switching to the learning pages of the ECODESIGN PILOT may be useful that for.

Beneath the ideas, a first estimation about the additional costs for putting the improvement tasks into action and the feasibility of the task has to be evaluated. Also deadlines and the responsible department or person for putting the task into action can be defined in the checklists, see Fig. 6.5.

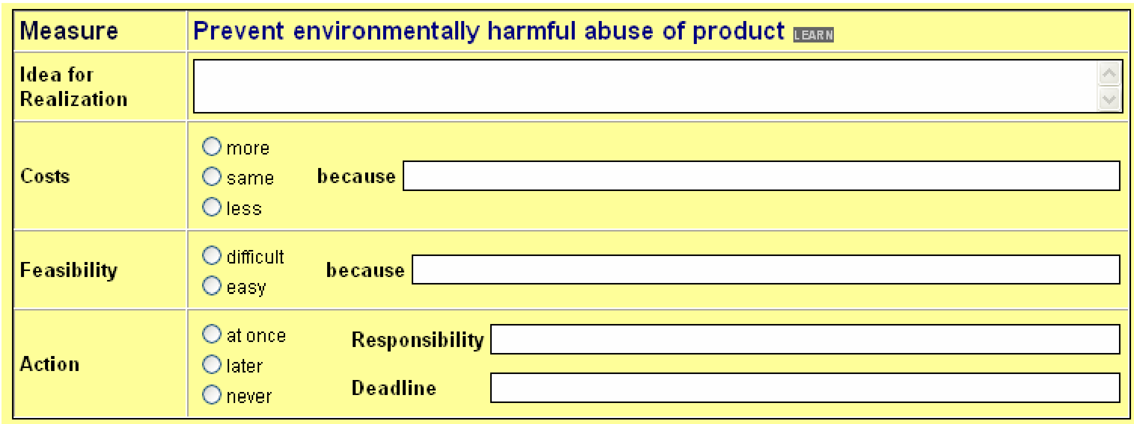


Fig.7.5: Further evaluation measures for the Ecodesign tasks (Austrian Ecodesign Platform, 2006)

EXAMPLE

In lesson 4 the Ecodesign Assistant was used to identify the most relevant life cycle stage of a washing machine. Based on the product type classification the Assistant suggested the most effective strategies for the improvement of the product which will be further described in this example.

The main strategy for the improvement of the washing machine is the "reduction of consumption at use stage". The PILOT suggests eight different tasks for this strategy. Not all of them are useful for the washing machine. The associated checklist helps to identify the most important ones.

The first suggested task is: “Prevent environmentally harmful abuse of the product”. This task is relevant for the washing machine. In average 50 l of water is needed for washing 5 kg of clothes. The current washing machine is not able to differ between different amounts of clothes in the machine. This means that if the washing machine is only filled up half it will need the same amount of water. Since for each washing process all the water has to be heated up to 40°C or 50°C, no optimization of energy consumption of the washing machine is realized yet. The idea is to provide intelligent software which is able to adapt the amount of water needed to be heated up to the amount of clothes in the machine.

Fig. 7.5 shows the checklist which is filled out for this task. The information input helps to evaluate the priority of the task. The relevance of this task is “very important” and it is not fulfilled yet since the machine does not provide different washing programs. The priority for this task is 40 points which is highest possible (highest priority).

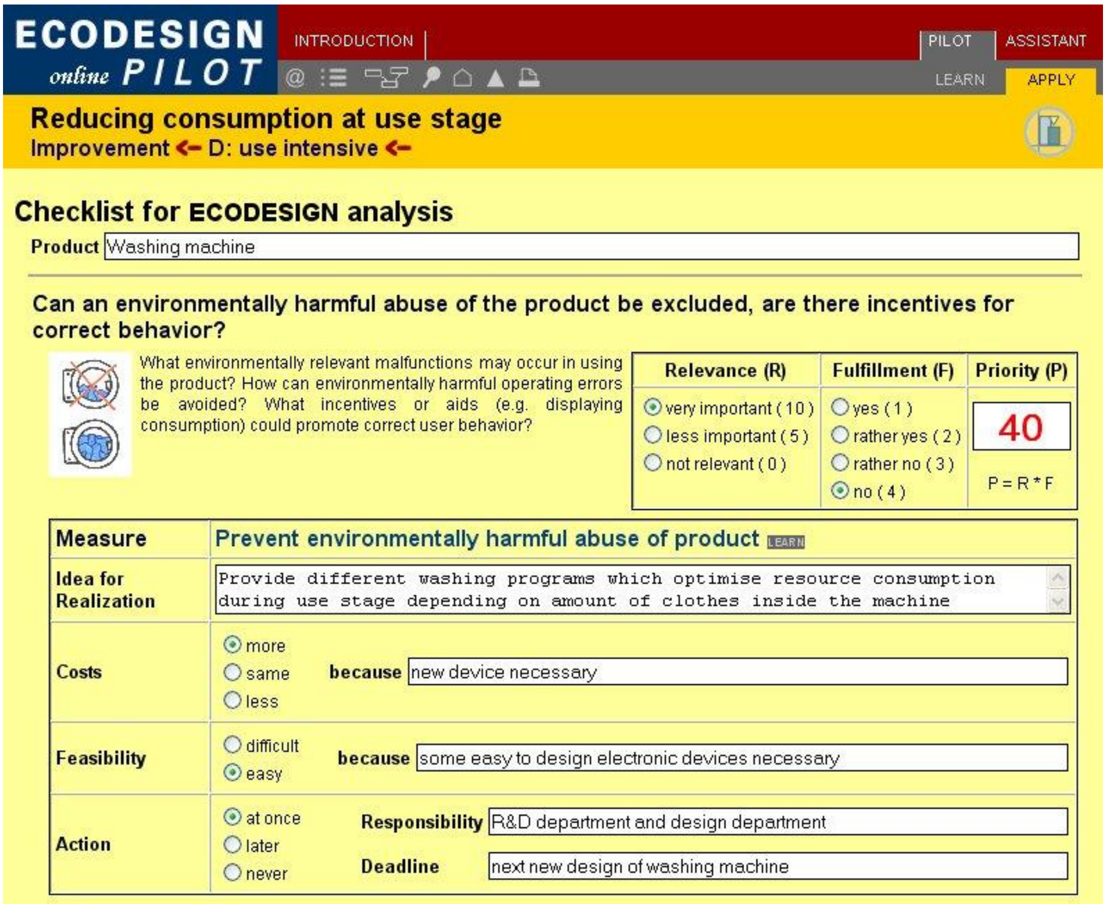


Fig.7.6: Completed checklist for washing machine (Austrian Ecodesign Platform, 2006)

Further a first idea for the realization of the task can be noted. It is expected that a new electronic device which contain the software will help to optimize energy consumption of the washing machine. The costs are pretended to rise since new electronic devices have to be designed and manufactured. The redesign should be implemented at once since the environmental improvement potential of the new design is expected (and evaluated) to be very high.

Beneath the task above, another task, namely “design product for minimum consumption of process materials” seems to be important. The amount of water and detergents needed should be taken into consideration as well. As stated above, the amount of water is related to the amount of (electrical) energy needed to heat up the water for the washing process. The more efficient the washing process is (e.g. optimal use of water, of detergents etc...) the lower the need to process materials (and energy) will be.

The checklist helped to find the most relevant improvement tasks of the concerned strategy. Further the different suggested strategies by the Assistant can be worked through to find more improvement tasks for the product.

Quality Function Deployment

By now strategies with high improvement potential have been determined and some ideas for the realization for the improvement strategies have been formulated.

The next question now is how to consider stakeholder requirements in the product improvement process and in the product design?

Before being able to consider these customer demands it is necessary to “translate” these demands into a technical language. This is achieved with the Quality Function Deployment (QFD) method (Akao, 1990).

The concept of QFD was invented by Yoji Akao in Japan back in 1966. The break through of the concept was in 1972 when Mitsubishi Heavy Industries began to use this concept. It was not until 1987 when QFD found its way to Europe. Nowadays QFD is an important method to integrate stakeholder requirements into the product development process. QFD asks for customer demands which are translated to technical design parameters.

The idea of Environmental Quality Function Deployment (EQFD) is similar to that of QFD. According to (Wimmer, Züst, Lee, 2004) EQFD links stakeholder requirements to environmental parameters.

Environmental parameters were defined in lesson 2. EQFD helps to identify the most relevant environmental parameters among the various customer demands and stakeholder requirements respectively.

Tab. 7.2 shows a list of possible environmental stakeholder requirements.

Tab.7.2: Environmental stakeholder requirements (Wimmer, Züst, Lee, 2004)

Environmentally safe
Free of hazardous substances
Lightweight
Durable
Less transportation
Energy saving
Easy to use
Easy to maintain
Easy to repair
Easy to recycle
Easy to disassemble
Easy to reuse

Not all of the requirements listed in Tab. 7.2 may fit to a specific product. The stakeholder requirements are weighted by using a scale of 0-10 where 0 indicates that the requirement is not important and 10 that it is very important. Any number between 0 and 10 can be chosen to express an importance.

Let us continue with the example of the washing machine, see Tab.7.3

Tab.7.3: Weighting factors of environmental stakeholder requirements of a washing machine (Wimmer, Züst, Lee, 2004)

Environmental stakeholder requirements	Weight factor	Explanation
Environmentally safe	0	No emissions during use expected
Free of hazardous substances	10	Very important due to RoHS
Lightweight	3	No important design specification
Durable	7	Important for business to business customers (e.g. laundry services)
Less transport	3	Not really important
Energy saving	10	Very important for end user, eco-labelling
Easy to use	5	Usability important for end user
Easy to maintain	3	Less important
Easy to repair	7	Important for end user
Easy to recycle	10	Important due to WEEE
Easy to disassemble	10	Important due to WEEE, eco-label
Easy to reuse	7	Important due to WEEE

To relate the environmental stakeholder requirements with environmental parameters a relation matrix is established, see Fig. 7.7. In this matrix the environmental stakeholder requirements are written in a column and the design parameters in a row. To indicate how strong the relation between the stakeholder requirements and the environmental parameters is, relation factors are used. A weak relation is expressed with 3, a medium relation expressed with 6 and a strong relation is expressed with 9.

The matrix in Fig. 7.7 shows the (quantified) relations between the stakeholder requirements and the environmental parameter. The relative importance of the environmental parameter is achieved by multiplying the weight factor (stakeholder importance) by the relation factor and summed up for every environmental parameter.

Fig. 7.7 shows that the relative importance of the environmental parameter “supply parts” is 12% and highest due to the stakeholder requirements of WEEE and RoHS to the parts and components of the washing machine. Among this parameter, following environmental parameters are rated as important:

- Supply parts (12%)
- Materials used (9%)
- Time for disassembly (8%)
- Rate of recyclability (8%)

Again, these parameters are important due to the WEEE and RoHS directive. The appropriate stakeholder requirements were weighted high, see Tab. 6.3.

Now that stakeholder requirements have been weighted and most important environmental parameters have been identified, improvement strategies for the environmental parameters can be found by using the ECODESIGN PILOT. Tab. 7.4 shows appropriate improvement strategies for the different environmental parameters by following (Wimmer, Züst, 2002) and (Wimmer, Züst, Lee, 2004).

Fig.7.7. Matrix showing relation between stakeholder requirements and environmental parameters for a washing machine (Wimmer, Züst, Lee, 2004)

9.. strong relationship
3.. medium relationship
6.. weak relationship

Environmental stakeholder requirements / Environmental parameters	Stakeholder weighting factor	weight	volume	supply parts	lifetime	functionality	materials used	problematic materials	production technology	production waste	packaging	transportation	usability	energy consumption	generated waste	noise and vibrations	emissions	maintenance	reparability	fastener and joints	time for disassembly	rate of reusability	rate of recyclability
Direction of improvement		↓	↓	↑	↑	↑	↓	↓	↓	↓	↓	↓	↑	↓	↓	↓	↓	↓	↑	↓	↓	↑	↑
Units		kg	m^3		h				kWh	kg	kg	km		kWh	kg	dB					h	%	%
environmentally safe	0							9	9						9		9						
free of hazardous substances	10			6			9	9			9												9
lightweight	3	9					9				6		6										6
durable	7	6		6	9								6					6	6				
less transportation	3		6	6							6	9											
energy saving	10					6								9									
easy to use	5	6	6			6							9			9							
easy to maintain	3																	9		3			
easy to repair	7			6	6														9	6	6	3	
easy to recycle	10						9	6		9													9
easy to disassemble	10			6																9	9	9	
easy to reuse	7			9	6																9	9	
Importance (relative %)		4	2	12	6	4	9	6	0	4	5	1	4	4	0	2	0	3	4	6	8	7	8

Tab.7.4: ECODESIGN PILOT's improvement strategies for the environmental parameters

Environmental parameter	Improvement strategies proposed by ECODESIGN PILOT
General	
Weight	Reducing material inputs
Volume	Reduction of packaging
Supply parts	Ecological procurement of external components Reuse of product parts
Lifetime	Increasing product durability
Functionality	Optimizing product functionality
Raw materials	
Materials used	Selecting the right materials
Problematic materials	Selecting the right materials
Manufacture	
Production technology	Reducing energy consumption in production process Optimizing type and amount of process materials
Production waste	Avoiding waste in the production process
Transport (Distribution)	
Packaging	Reduction of packaging
Transportation	Reduction of transportation
Use	
Usability	Optimizing product use
Energy consumption	Reducing consumption at use stage
Generated waste	Avoidance of waste at use stage
Noise and vibrations	Optimizing product functionality
Emissions	Ensuring environmental safety performance
Maintenance	Improving maintenance
Reparability	Improving reparability
End of life	
Fasteners and joints	Improving disassembly
Time for disassembly	Improving disassembly
Rate of reusability	Reuse of product parts
Rate of recyclability	Recycling of materials

SUMMARY

After describing and evaluating the product in the previous lessons, specific improvement tasks and strategies were identified in this lesson by using the PILOT and by applying EQFD to consider customer demands in the product design and development. In the next lessons a product example for each product type is analyzed more detailed by using approaches and tools introduced so far.

The situation now is as follows: we know what to do and which strategies to follow to obtain a product improvement but we do not exactly know how to realize and to put into action of what is known.

Idea generation methods and approaches of how certain ideas can be realized in the product will be discussed in lesson 13.

HOME EXERCISES

1. Consider your product:

   x. Try to find improvement tasks for your product by using the PILOT and select the appropriate strategies.

   y. Determine the priority of the improvement tasks by applying the Ecodesign checklists.

2. Consider possible stakeholder requirements for your product:

   a. Use a matrix as shown in Fig. 6.7. Perform Environmental Quality Function Deployment and identify the important environmental parameters.

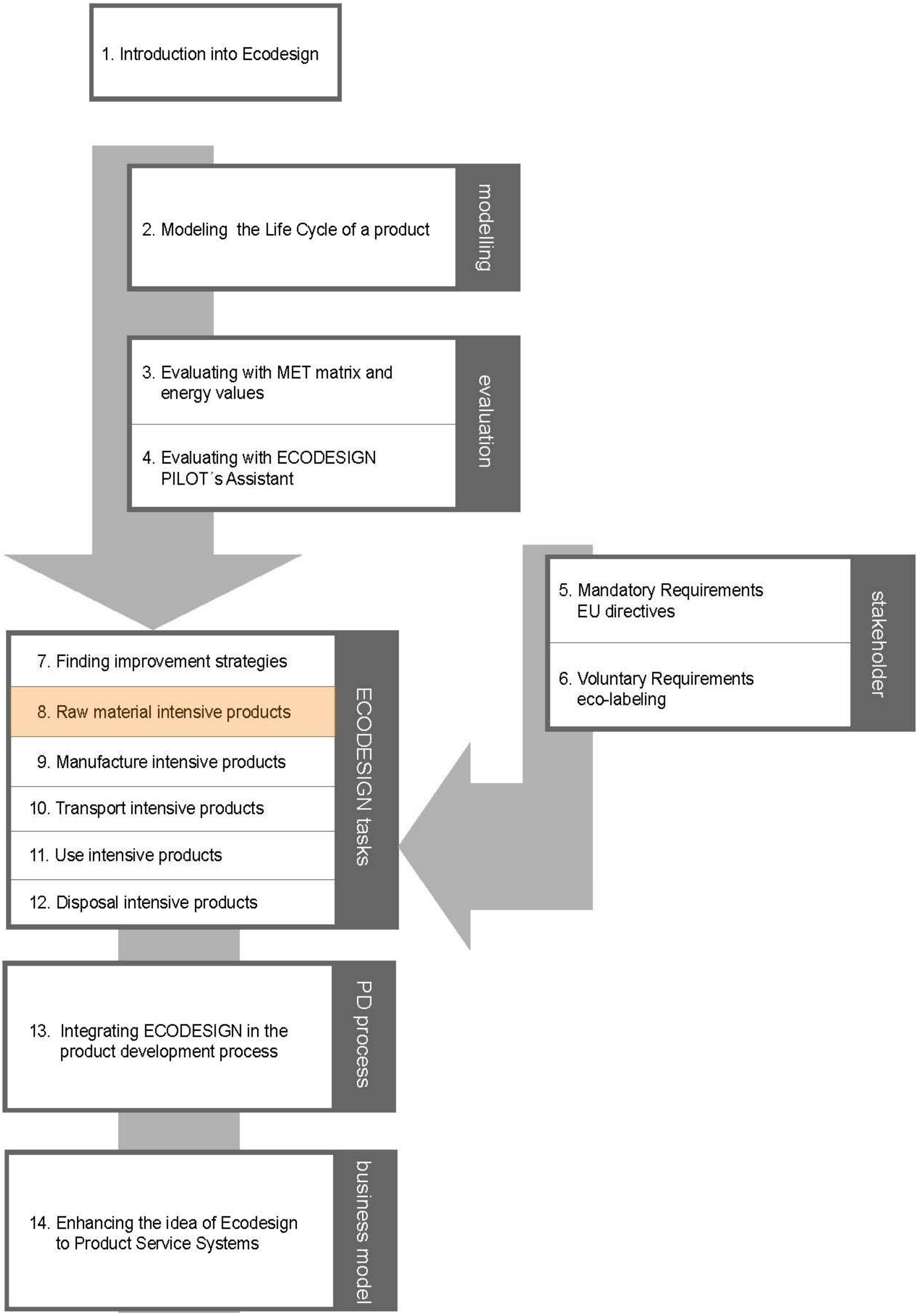
   b. Find appropriate strategies for the improvement of the environmental strategies.

REFERENCES

- ✓ Akao, Y., 1990. *QFD – Quality Function Deployment*. Productivity Press, Cambridge, Massachusetts.
- ✓ *Ecodesign Pilot, Product Investigation, Learning and Optimization Tool*, Institute for Engineering Design- Ecodesign, Technical University of Vienna. http://www.ecodesign.at/pilot, accessed 12.2006.
- ✓ Praxis Umweltbildung: http://www.praxis-umweltbildung.de, accessed 08.2006.
- ✓ Wimmer, W, Züst, R., 2002. *Ecodesign Pilot - Product-Investigation-, Learning- and Optimization- Tool for Sustainable Product Development*, Kluwer Academic Publishers, Dordrecht, Netherlands.
- ✓ Wimmer, W., Züst, R., Lee K., 2004. *Ecodesign Implementation – A Systematic Guidance on Integrating Environmental Considerations into Product Development*, Springer, Netherlands.

ADDITIONAL READING MATERIAL (AVAILABLE ON CD)

Wimmer W., Strasser Ch., Pamminger R., 2003, *Integrating environmental customer demands in product development – Combining Quality Function Deployment (QFD) and the ECODESIGN Product- Investigation-, Learning and Optimization-Tool (PILOT)*, Proceedings of the CIRP seminar on life cycle engineering Copenhagen, Denmark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business model

LESSON 8

Improving Raw Material Intensive Products

KEYWORDS: IMPROVEMENT, STRATEGIES, RAW MATERIAL INTENSIVE PRODUCTS, ECODESIGN PILOT

Lesson objectives

Through the previous lessons different product description methods as well as evaluation methods were introduced. In lesson 2 the idea of Life Cycle Thinking was discussed as well as qualitative product description and quantitative modeling. In lesson 3 the MET-matrix was used to find hot spots for product improvement. By introducing energy values the environmental impact of each life cycle stage of the product could be quantified.

Starting along with the ECODESIGN PILOT's Assistant in lesson 4 the most relevant life cycle stage of the product could be identified. An environmental profile of the product was established as well.

In the following lessons 8 – 12 selected product examples will be discussed in more detail. These lessons aim at finding improvement potentials and strategies for the different product types such as raw material intensive, manufacture intensive, transportation intensive, use intensive or disposal intensive, by using the tools and approaches introduced in the previous chapters.

In this lesson an office chair is considered. Different ideas for the improvement of the raw material stage of this product will be developed and evaluated. The ECODESIGN PILOT will be used to derive appropriate improvement strategies.

By the end of this lesson you will know about the characteristics of raw material intensive products and you will be able to find and evaluate improvement strategies for this product type.

CASE STUDY: OFFICE CHAIR

Fig.8.1:Office chair [www.steelcase.com]

As shown in lesson 2 and lesson 3 the office chair causes most environmental impact in its raw material stage.

Tab. 3.20 shows the energy values for each life cycle stage of the office chair. The first life cycle stage needs the highest amount of energy. This indicates that the environmental impact in the raw material stage of the office chair is highest among the other life cycle stages.

Fig. 8.2 shows an LCT diagram of the office chair. In this profile the relative environmental impact of each life cycle stage of the chair is shown.

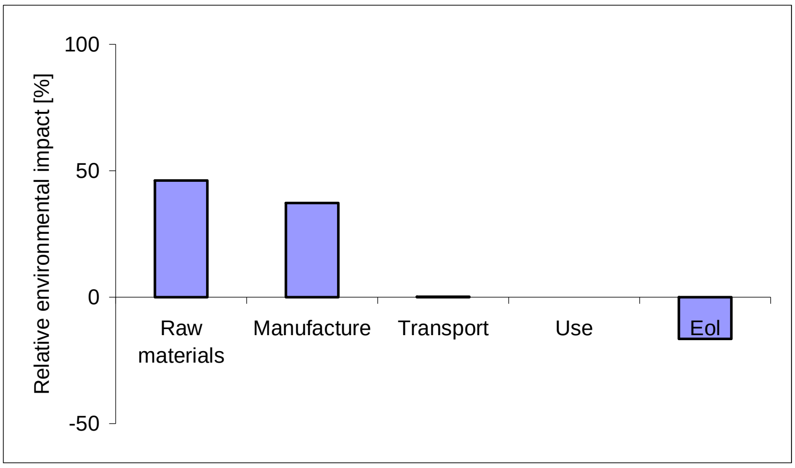


Fig.8.2: Environmental impact of each life cycle stage of the office chair

Fig. 8.2 indicates that 46% of the environmental impact of the office chair occurs in the first life cycle stage followed by the manufacture stage which contributes approximately 37%. The occurring environmental impact during transport is negligible. During the use stage no impacts occur at all. Due to end of life processes such as recycling and thermal recovery up to 16% environmental impact can be saved (indicated through a negative bar in Fig. 8.2 which can be interpreted as a benefit for the environment).

A look on the energy values of the raw materials used in the office chair helps to identify energy intensive materials and therefore materials which contribute significantly to the environmental impact, see Tab. 8.1.

In Tab. 8.1 some materials are highlighted. Those materials have high energy values and contribute significantly to the environmental impact when used already in small amounts. PA6 and PU are two of those materials: already 2.3 kg of PA (which is approximately 8% of the total weight) causes 20% of the environmental impact; 1.4 kg of PU (which is 5% of the total weight) is responsible for 12% of the total energy amount. In other words, 13% of the material weight of the chair causes 1/3 of the total environmental impact.

Tab.8.1: Energy values for materials used in the office chair

Material	[MJ/kg]	Weight [kg]	% of total weight	Result [MJ]	% of total energy
PA	115	2.3	8.3	264.5	19.8
PU	115	1.4	5	161	12.1
ABS	100	0.1	0.4	10	0.8
Polyester	98	0.4	1.5	39.2	2.9
PS	96	0.1	0.4	9.6	0.7
Zinc alloy	90	1.5	5.4	135	10.1
Polypropylene (PP)	78	1.2	4.4	93.6	7
Steel	32	14.5	52.5	464	34.8
Cardboard (Packaging)	28	4	14.5	112	8.4
Wood	22	2.1	7.6	46.2	3.5
Total		27.6		1335.1	

The question to address now is: which strategies will lead to an optimal product improvement? Is there a possibility to substitute the materials which cause high environmental impact with environmental sound materials?

The ECODESIGN PILOT will be used to gain appropriate improvement strategies for the office chair.

IMPROVEMENT STRATEGIES FOR THE OFFICE CHAIR

Since the first life cycle stage of the office chair causes most relative impact the ECODESIGN PILOT with its improvement objectives and strategies for a *"Type A: material intensive product"* is used to obtain improvement strategies for the product (Austrian Ecodesign Platform, 2006):

Use alternative materials

- Strategy: Selecting the right materials
  Target: Reduction of environmental impact by using environmentally sound materials, recycled materials, renewable materials...

Use less of a given type of material

- Strategy: Reducing material inputs
  Target: Reduction of amount of material by design aiming at optimum strength, integration of functions...

Make intensive use of resources

- Strategy: Optimizing product use
  Target: Improved usability of products through adaptability, ergonomics...
- Strategy: Optimizing product functionality
  Target: Improved functionality by means of upgrading, multi functionality...
- Strategy: Improving maintenance
  Target: Improving maintenance through wear detection...

Use resources as long as possible

- Strategy: Increasing product durability
  Target: Durability through dimensioning, surface design...
- Strategy: Improving reparability
  Target: Improving access to, disassembling, and exchange... of parts

Reuse materials contained in the product

- Strategy: Improving disassembly
  Target: Make possible product take back and ease of disassembling (fastness...)
- Strategy: Reuse of product parts
  Target: Make possible reuse of parts (access, remanufacturing...)
- Strategy: Recycling of materials
  Target: Make possible recycling of materials (separation, labelling...)

Not all of the strategies listed above may be useful for product improvement. Each strategy should be discussed in the team of involved actors to find out whether it is appropriate for the product. Obviously the strategy *"improving maintenance"* is not a useful strategy for the office chair since maintenance is not an issue. But the strategy *"selecting right materials"* is important as the energy values listed in Tab. 8.1 show. This discussion process should be done for all strategies. The strategies must be evaluated to assign them a priority for implementation. By doing so, a final selection of most appropriate strategies for product improvement can be done. The priority of the improvement strategies can be determined by using Ecodesign checklists of the ECODESIGN PILOT.

The material list of the office chair in Tab. 8.1 contains some materials which have high energy values (e.g. PA, PU...) and therefore contribute a lot to environmental impact. A good approach for product improvement would be either to avoid these materials or to use alternative materials instead or at least reduce the amount used.

The improvement objective "*Use alternative materials"* therefore seems to be one appropriate objective. The strategy *"Selecting the right materials"* includes different tasks which give guidance to the product developer in selecting materials. By analyzing the environmental profile of the office chair and by discussing the strategy in the team a high priority was assigned to this strategy. The proposed tasks are:

- *Use of materials with view to their environmental performance:* by using environmental evaluation methods and comparing the environmental performance of materials.
- *Avoid or reduce the use of toxic materials and components:* toxic materials contribute a lot to environmental impact even if used in small quantities. Attention should be focussed on the identification and replacement of such materials. The office chair does not contain toxic materials. This task can be neglected for this example.
- *Prefer materials from renewable raw materials:* which are not of fossil origin but mostly from plants (e.g. wood, corn...).
- *Prefer recyclable materials:* to reduce the need to virgin raw material.
- *Avoid inseparable composite materials:* which are difficult to separate for end of life treatment (e.g. recycling).
- *Avoid raw materials, components of problematic origin:* e.g. unknown production processes of raw materials...

Another appropriate improvement objective is *"Use less of a given type of material"*. The corresponding strategy here is *"Reducing material inputs"* which suggests following tasks for product improvement:

- *Prefer the use of recycled materials (secondary materials)*
- *Preferably use single material components and/or reduce number of different types of material:* which could make possible closed recycling loops.
- *Reduce material input by design aiming at optimum strength:* which allows a targeted use of materials.
- *Reduce material input by integration of functions:* which would also ease assembly and disassembly.

Let us consider a certain component of the office chair for improvement. As described in lesson 2 a common office chair consists of following five main parts:

6. Base
7. Mechanism
8. Seat
9. Arm rest
10. Back

Let us take a look at the component “back” of the chair. It mainly consists of polypropylene (PP), polyester and polyurethane foam (PU). Compared to PP, polyester and PU have higher energy values.

The question to address based on the suggestions of the ECODESIGN PILOT is: can alternative materials be used instead or can the amount of the used materials be reduced?

A detailed analysis of the design process shows that for example polyester can not be avoided and will be needed in small quantities. But through re-thinking the design of the component, a new design could avoid the use of PU. Additionally the new design looks modern and very attractive to customers. Fig. 8.3 shows at the left side a conventional design of the back containing PU and the right side an improved design which does not contain any PU.

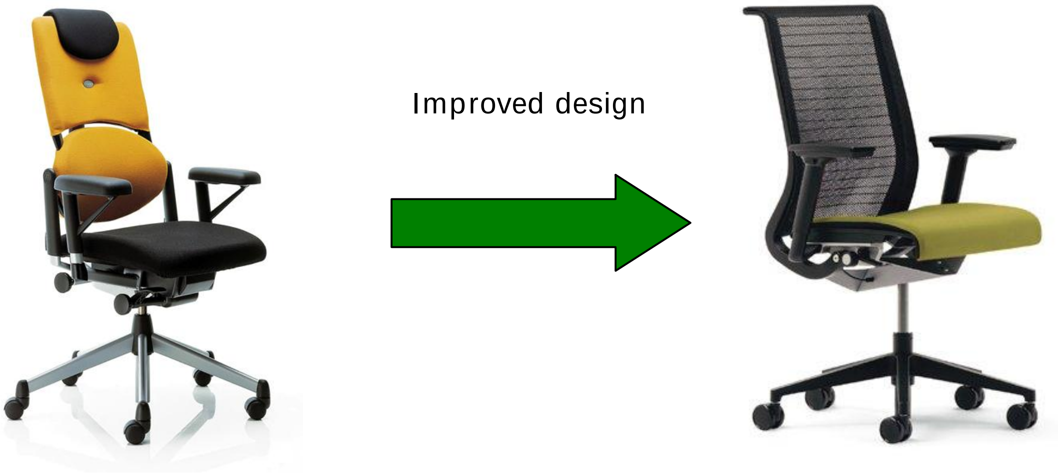


Fig.8.3: left: conventional back design, right: improved design [www.steelcase.com]

The improved design of the back has two stiff profiles at the right and left which are connected with steel wires. The back has a transparent textile mesh.

This new design of the back component reduces the weight of the component by approximately 3% whereas environmental impact of the component is reduced by approximately 11%.

In addition to the strategies discussed above some more strategies can be realized to gain more improvement ideas, e.g. *"Use resources as long as possible"*. The suggested strategies here are:

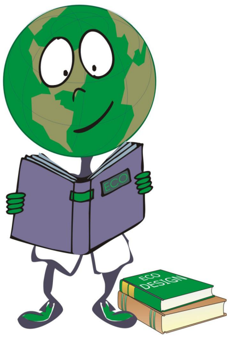
- *Increasing product durability*
- *Improving reparability*

Especially the first strategy seems to be important. Increasing the product life time of raw material intensive products will reduce the relative significance of the environmental impact in the raw material stage over lifetime. The ECODESIGN PILOT gives amongst others following ideas for the realization of this strategy:

- *Realize a timeless product design*
- *Ensure high appreciation of the product:* appreciated products will not be disposed easily by the user. The engraving of a personal name may raise appreciation among users.
- *Design product for long service life:* a product which fulfils its function properly and is not defect will probably be used for a longer time (i.e. in combination with a timeless design)
- *Realize a sturdy product design:* which can ensure a long service life.
- *...*

The new design of the back of the office chair is modern and attractive. It is unique amongst other office chairs which may raise appreciation of the product. It is designed in a way to withstand high level of stress and strain. It does not contain polyurethane (PU) at all. This new design reduces environmental impact of the office chair approximately by 30%.

SUMMARY



Products needing different materials or containing toxic materials which contribute a lot to the environmental impact may be considered as raw material intensive products. The ECODESIGN PILOT provides ideas, strategies and tasks for improvement of these kinds of products.

The other components of the office chair can be optimized the same way as shown for the back. In lesson 13 the office chair example will be treated again to demonstrate a methodology that allows taking environmental aspects into considerations in the early decisive design stages.

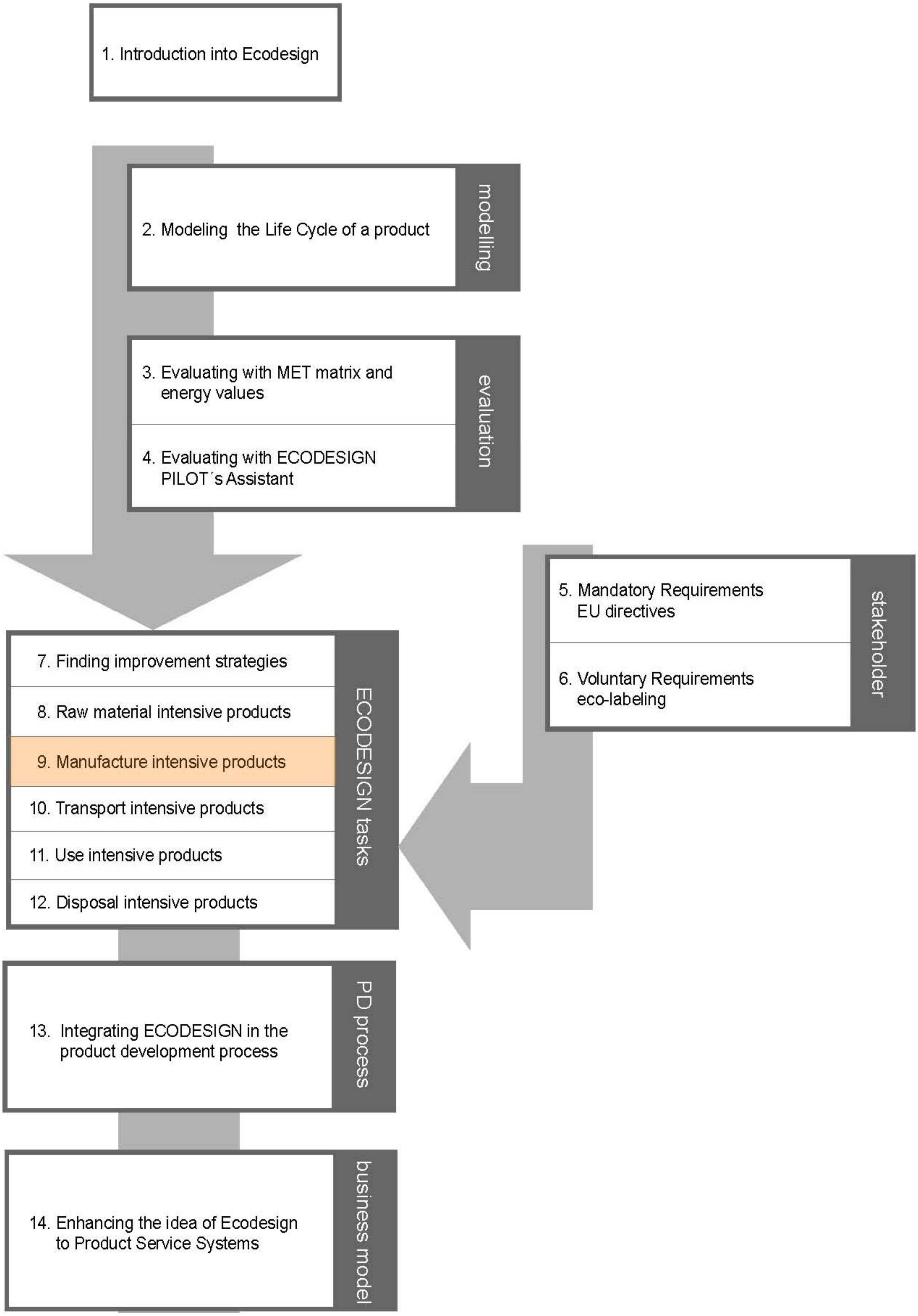
STUDENT'S PRESENTATION

In this lesson students will have the opportunity to present their products assigned at the beginning of the module and analyzed and described through the different lessons.

Student presentation (1hour)

REFERENCES

- ✓ *Austrian Ecodesign Platform*: http://www.ecodesign.at, accessed 01.2007.
- ✓ *ECODESIGN Product Investigation, Learning and Optimization Tool* (PILOT) for sustainable product development.
  http://www.ecodesign.at/pilot/ONLINE, accessed 01.2007.



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LESSON 9

Improving a Manufacture Intensive Product

KEYWORDS: Improvement Strategies, Manufacture Intensive Products, ECODESIGN PILOT

Lesson objectives

Some products may need many different and complex manufacturing steps during production. Any production processes requires energy and/or additional input materials: e.g. water for cooling, lubricants or glue. All energy and material inputs during manufacturing must be considered when evaluating a product and when defining the product type.

For being more precisely not only the energies which are used directly for the production but also those energies which are needed indirectly such as lightening the factory, cooling or warming the production halls must be take into account as well and must be allocated to the product. These indirect energies are called "overhead energies".

In this lesson different improvement strategies for a manufacture intensive product will be investigated by using the ECODESIGN PILOT. A table made of wood will be taken as case study and will be further discussed.

At the end of this lesson you will know more about the properties of manufacture intensive products. You will also know which strategies are appropriate for the improvement of those products.

CASE STUDY: TABLE MADE OF WOOD

Fig.9.1: Table made of wood

A table made of wood represents a manufacture intensive product. Fig. 9.2 shows an environmental profile of a wooden table.

As it can be seen from the environmental profile the manufacture stage of the table made of wood has a significant contribution to the environmental impact of the table.

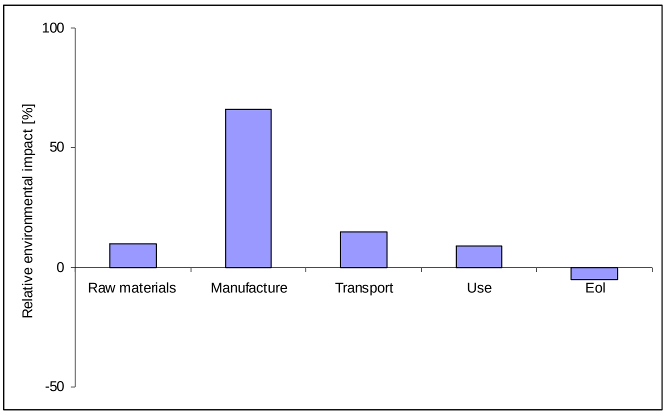


Fig.9.2: Environmental impact of each life cycle stage of a table made of wood

Wood is the only raw material used in the product. Wood is a renewable resource and its extraction (if no excessive deforestation assumed) does not contribute significantly to environmental impact.

Let us assume that the table is a regional product. That means that the carpentry which produces this wood gets its material from a local supplier and delivers its product to local markets and customers. That is the reason why the transport stage does not contribute significantly to environmental impact.

During the use stage of the wood table some substances are needed to maintain the wood such as special oils for the wood. These substances may cause some environmental impact.

In the end of life stage of the wooden table energy can be recovered. By incinerating wood thermal energy can be gained.

Most environmental impact is caused during manufacture processes of the wooden table in the carpentry. For product improvement attention should be paid to the manufacture life cycle stage.

Using the ECODESIGN PILOT to gain ideas for improvement strategies for a *"Type B: manufacture intensive product"* results in the following proposed objectives:

Use less energy and material in the production process

- Strategy: Reducing energy consumption in production process
  Target: Reduction of energy consumption throughout production by means of optimized processes, renewable energy...
- Strategy: Optimizing type and amount of process materials
  Target: Reduction of environmental impact caused by consumption of process materials in production process (closed cycles...)

More efficient use of materials used in the production process

- Strategy: Avoiding waste in the production process
  Target: Reduction of waste in production through material efficiency, recycling..., Purchase of external materials/components
- Strategy: Ecological procurement of external components
  Target: Environmentally sound procurement of product parts

Use the product as intensively as possible

- Strategy: Optimizing product use
  Target: Improved usability of products through adaptability, ergonomics...
- Strategy: Optimizing product functionality
  Target: Improved functionality by means of upgrading, multi functionality...
- Strategy: Improving maintenance
  Target: Improving maintenance through wear detection...

Use the product for a longer period of time

- Strategy: Increasing product durability
  Target: Durability through dimensioning, surface design...
- Strategy: Improving reparability
  Target: Improving access to, disassembling, and exchange of parts

Reuse components and/or the product

- Strategy: Improving disassembly
  Target: Make possible product take back and ease of disassembling (fastness...)
- Strategy: Reuse of product parts
  Target: Make possible reuse of parts (access, remanufacturing...)

By keeping in mind the environmental profile of the table made of wood and considering that the manufacture stage contributes most to environmental impact, putting into action those strategies which aim at optimizing the manufacture stage of the product seem to be most relevant.

By weighting the different strategies proposed by the ECODESIGN PILOT in the team of involved actors (e.g. by using checklists) the two objectives *"Use less energy and material in the production process"* and *"More efficient use of materials used in the production process"* seem to be the most effective ones.

The reason for giving these two strategies a high priority for realization will be explained in the following.

The first objective proposes the following improvement strategies:

- *Preferably use process materials from renewable raw materials:* by avoiding process materials made from e.g. petrochemicals.
- *Recycle process materials whenever possible*
- *Use environmentally acceptable auxiliary and process materials and avoid hazardous materials*: to minimize hazards to employees and environment.

In case of the table made of wood attention should be paid to which process materials are used to impregnate the wood, to varnish the table or to veneer the surface.

Some varnishes contain formaldehyde which is toxic and tend to volatilize easily when used in products. Although mostly restricted and prohibited environmentally unacceptable auxiliary and process materials can still be found in many products which in some cases are not only a threat to the environment but also to the health of the consumer. Producers should seriously rethink their manufacture technologies to be able to avoid the use of such materials.

The second objective *"More efficient use of materials used in the production process"* contains an important strategy namely *"Avoiding waste in the production process"*. Consider the table made of wood is made in a traditional carpentry: the fulfilment of this strategy depends on the craft and expertise of the carpenter, on how he saws the wood or on how "much table" he is able to make out of a piece of wood.

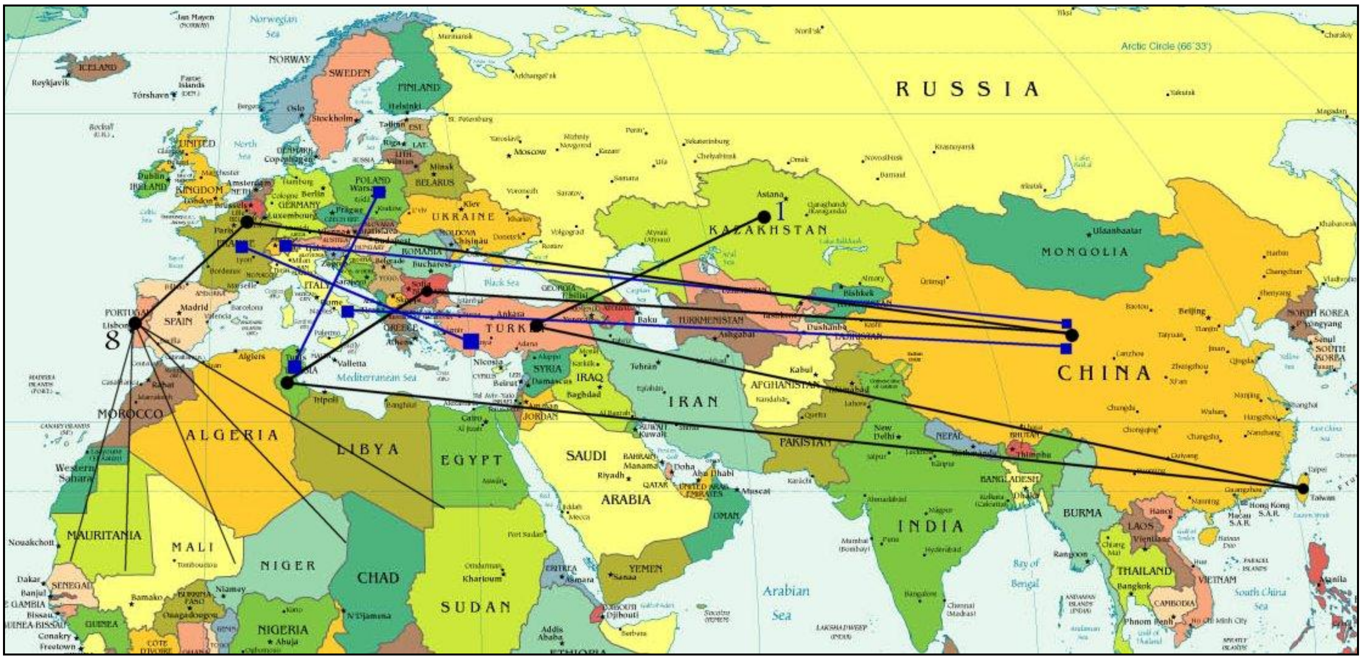
In case of industrial production of tables the considered strategy would mean to use the production machines properly and effectively, i.e. how these machines are programmed, how the material input is managed etc.…

ADDITIONAL NOTE:

A manufacture intensive product may also require a lot of transport during manufacture, e.g. in case different parts and components are produced in different countries. An example introduced here are jeans trousers.

The “around the world journey” of jeans trousers is illustrated in Fig. 9.3. The black path with the circles in Fig. 9.3 shows the path of the product which is sent from one country to the other. The blue path with the squares shows the additional material flows which are necessary for the production of the trousers. The journey starts in Kazakhstan (indicated by the number 1) were cotton is harvested. The harvested cotton is sent to Turkey were it is yarned. From Turkey the journey continues to Taiwan were the yarn is woven. The woven textile is sent to Tunisia were it is dyed. The dye itself comes from Poland (indicated by a blue path with squares). From Tunisia the dyed textile is sent to Bulgaria were it is smoothened. The journey continues to China were knobs and linings were sewed on the jeans. In Fig. 9.3 two additional material flows can be seen to China: one is for the knobs which come from Italy and one for the linings which come from Switzerland. From China the trousers are sent to France where the surface of the jeans is processed with pumice. Here one additional material flow is needed since the pumice needed for the surface processing comes from Turkey. From France the jeans are sent to Portugal (indicated by the number 8). In Portugal a label with “Made in Portugal” is sewed on the jeans. Furthermore, the final product is distributed to all Europe from Portugal. 45% of the jeans are sent to Africa after they are used in Europe as second hand clothes (Praxis Umweltbildung, 2006).

Fig.9.3: The complex and long journey of jeans



The distance covered by the journey described above is approximately 50000 km; as a comparison: the perimeter of the earth is approximately 40000 km.

As described above for the jeans trousers many different suppliers situated in different countries contribute to the manufacture of the product. These suppliers ship their components over long distances, e.g. linings from Switzerland to China to be sewed or pumice shipped from Turkey to France to be used for surface processes.

Since all the described transport is need to manufacture the product and since all the transport cause a lot of environmental impact jeans trousers are manufacture intensive products.

A first idea for improving the environmental performance of the product would be optimizing the logistics concept of the product by reducing or even cutting off the material flows. For example: the knobs are sewed in China, whereas the knobs were imported from Italy. The question to address is: is there a possibility to use Chinese knobs instead? Using Chinese knobs would cut off the material flow from Italy to China. If the surface process could be shifted to Turkey were the pumice comes from, another material flow, namely from Turkey to France, would be cut off.

But unfortunately it is not as easy as that. Any change in any of the parameters would influence global economy. Why is the textile sewed in China and not in Europe? The answer is clear: manpower is very cheap in China. Same considerations can be done for the dying process: it seems to be cheaper to dye the textile in Tunisia and import dye from Poland than to dye the textile in Poland.

Jeans trousers can be found in the market starting from 20 Euros, which is not much considering all the transport and process steps needed to produce the trousers. The more important question which should be addressed is: what are the real costs of the low cost? Who is paying the real costs?

SOCIAL ASPECTS

Beneath technical considerations also social aspects should be taken into account as well when talking about sustainable product development.

In Manila (this is the capital of the Philippines) women working as sewer earn only 2 cents for each shirt they sew. They work between twelve and fifteen hours a day. Talking is prohibited in some factories.

Women in China working as sewers live with 50 Euros salary a month. Women which become pregnant are sometimes fired from their jobs.

For the dyeing processes of cotton formaldehyde and other carcinogenic substances are used.

Are you aware how the price composition of usual jeans trousers is put together? Keep in mind that:

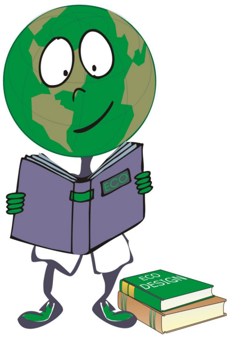
- (only) 1% of the final price is the salary of the sewers and workers
- 13% are material costs
- 11% are transport costs and customs dues
- 25% are costs for advertising, research and development by the brand company
- 50% are costs for retail sales staff, rental fee for the stores, administration and profit

The question everyone has to answer for himself is: do we want to encourage and tolerate these kinds of economics by our consumption habits and consumption patterns? Is it the engineer alone who can lead towards sustainable product development or is it also the consumer who has the power to direct technology and economy towards sustainability as well as social fairness?

Further one should think which other actors can have key roles in leading towards sustainability and sustainable product development. Government and politics could be a key actor by releasing legislations to force product developers towards sustainability and environmental friendly production. Some of the legislations put into action in the European Union were introduced in lesson 5.

The discussions about the social aspects of sustainability are too complex to be addressed here. It was aimed to give some impulses towards this direction as well as rising awareness that there are many different parameters to consider when thinking and acting towards sustainable product development. Be aware that sustainable product development is an interaction of different actors, e.g. producer, customer, politics etc...!

SUMMARY



A manufacture intensive product causes most environmental impact during its manufacture stage. Various (energy intensive) manufacture processes or environmental harmful process materials may be necessary to manufacture these products.

As shown with the jeans trousers example parts and components which are needed for the manufacture and are transported over long distances also contribute to the environmental impact of the manufacture stage.

The ECODESIGN PILOT could help to find appropriate improvement strategies for manufacture intensive products.

STUDENT'S PRESENTATION

In this lesson students will have the opportunity to present their products assigned at the beginning of the module and analyzed and described through the different lessons.

Student presentation (1hour)

REFERENCES

- *CES EduPAck 2006* (software), Granta Design Limited, Cambridge, UK.
- *ECODESIGN Product Investigation, Learning and Optimization Tool* (PILOT) for sustainable product development.
  http://www.ecodesign.at/pilot/ONLINE, accessed 01.2007.
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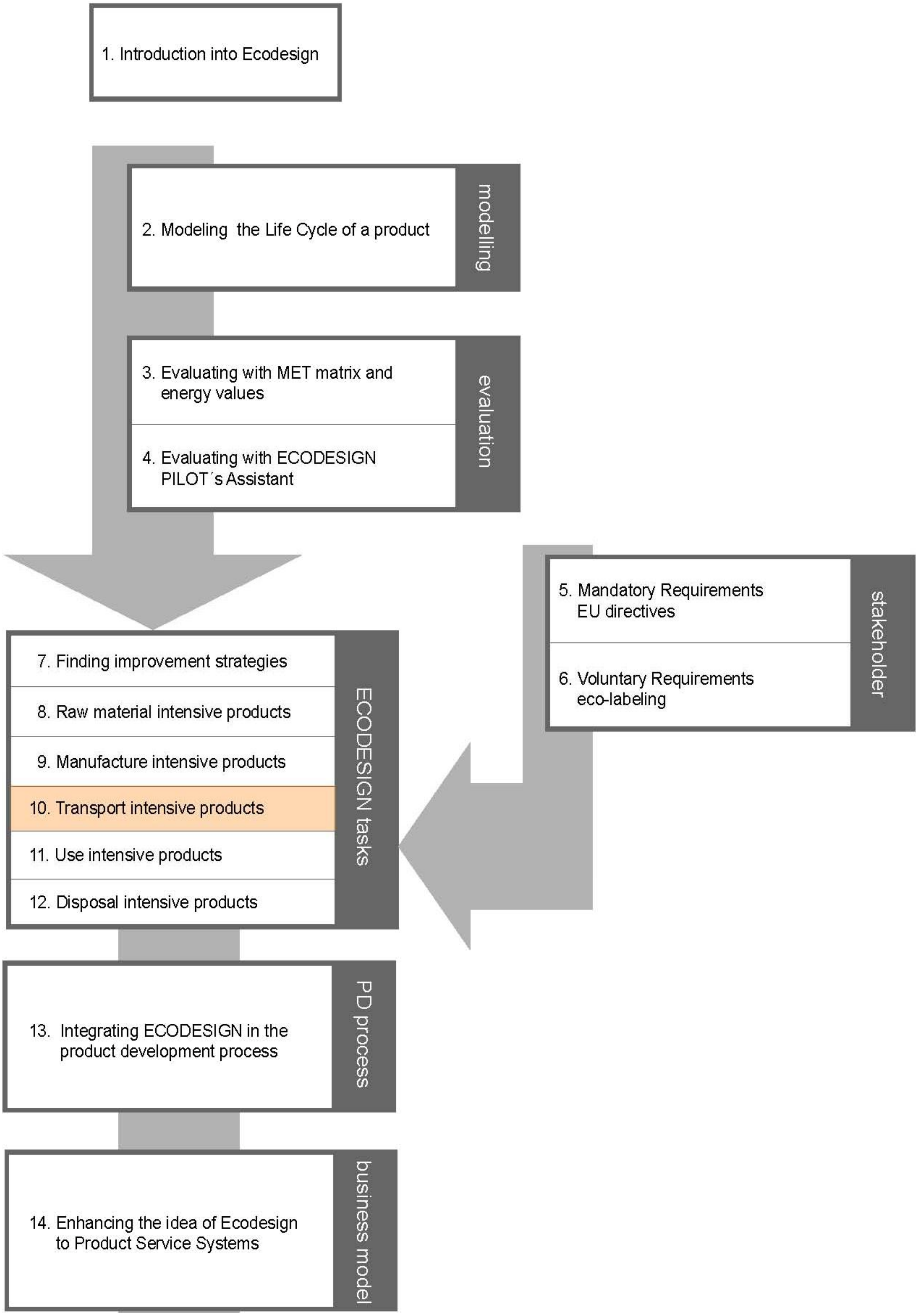
- *SimaPro 7.0*, 2006 (software), Pre Consultants, Netherlands.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LESSON 10

Improving Transport Intensive Products

KEYWORDS: IMPROVEMENT STRATEGIES, TRANSPORT INTENSIVE PRODUCTS, ECODESIGN PILOT

Lesson objectives

Transport intensive products cause most environmental impact in their transport stage. Large transport distances must be covered from the producer to the consumer. Another characteristic of transport intensive products is the high amount of packaging they may require. Since the packaging of products is only used during transport and usually has no additional function than preventing the product of being damaged during transport, packaging must be considered in this life cycle stage of the product (and not in the e.g. materials stage). Keep in mind that heavy packaging will raise the total product weight which will raise the amount of energy needed for transport, hence the raised amount of environmental impact.

In this lesson improvement strategies for transport intensive products will be discussed and evaluated. A heavy flower pot will be discussed as a case study.

The ECODESIGN PILOT will be used again to gain ideas for product improvement.

At the end of this lesson you will know about the properties of transport intensive products and you will be able to find and evaluate improvement strategies for these types of products.

CASE STUDY: FLOWER POT

Fig.10.1: Flower Pot

A flower pot made of clay which is made in Vietnam and is sold in Vienna represents a transport intensive product. Clay is the only material needed to produce the pot. Electrical energy is the only input during manufacture stage. The distance between Vietnam and Austria is approximately 9000km. The flower pot is transported to Austria by plane. Additionally 500km of transport with trucks is need for distribution. The packaging of the flower pots consists of cardboard. After use the flower pots are incinerated.

The use stage does not cause any environmental impact. Since the pot is incinerated at its end of life stage energy can be recovered.

Tab.10.1 sums up data for the flower pot.

Tab.10.1: Data for the flower pot

Life cycle	*Explanation*
Raw materials	Pots made of clay Weight: 2.5kg
Manufacture	1kWh per pot electrical energy for manufacture
Transport	From Vietnam to Austria by plane, distribution by truck Packaging: Cardboard, weight: 250g
Use	No environmental impact
End of life	Thermal recovery by incineration

Different means of transport cause different impact to the environment. The energy value expresses the energy needed for the transportation of 1 ton over 1 km, expressed as [tkm]. Tab. 10.2 gives the energy values for different means of transport.

Tab.10.2: Energy values for different means of transport

Mean of transport	Energy value [MJ/tkm]
Air, Freight in Europe	33
Truck	2.7
Freight train	0.8
Transoceanic freight ship	0.17

As it can be seen from Tab. 10.2 transport with airplane causes most environmental impact among the other means of transport.

Fig. 10.2 shows the environmental profile of the flower pot.

As it can be seen from the environmental profile, the transport stage of the flower pot is most significant. The contribution to environmental impact of the other life cycle stages can be completely neglected. The flower pot is a transport intensive product.

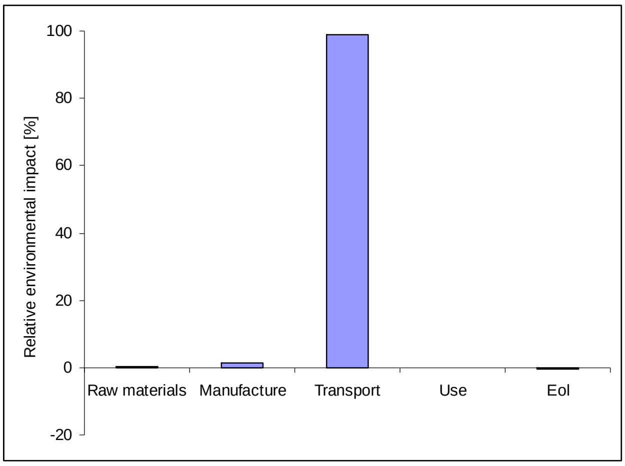

Fig.10.2: Environmental profile of the flower pot

How do you believe this product can be environmentally improved?

By using the ECODESIGN PILOT two improvement objectives for a *"Type C: Transportation intensive product"* can be achieved:

Change packaging

- Strategy: Reduction of packaging
  Target: Optimization of packaging by taking into account material characteristics, renewability, closed cycles...

Change transportation

- Strategy: Reduction of transportation
  Target: Reduction of the overall requirement for transportation

Packaging is not a significant concern of the flower pot. Approximately 10% of the impact of the transport stage can be assigned to the packaging.

Therefore the second objective is further investigated. The strategy *"Reduction of transportation"* includes several tasks which are listed in the following:

- *Minimize transportation for distribution of product:* by e.g. improving logistics concepts
- *Choose environmentally acceptable means of transportation for the distribution of the product:* different means of transport cause different environmental impacts; see Tab.11.2.

- *Prevent shipping damage:* by taking precautions (e.g. fixing moving parts...)
- *Use stackable product packaging:* to reduce the volume of cargo to be transported.

Since the flower pot is produced locally and since the product does not contain any problematic materials and no additional problematic process materials are necessary to manufacture the pot, the most important and effective strategy which should be put into action is: *Choose environmentally acceptable means of transportation for the distribution of the product".* Shipping the pots to Europe instead of sending them via airfreight could reduce the environmental impact about a factor of 190.

ADDITIONAL NOTE:

It is the consumer who can decide whether to buy products which are sent from the other side of the world or to search for the same or similar products which are produced locally. By taking (environmental) responsibility, the consumer's behaviour can signalize whether certain products are appreciated or not.

SUMMARY

Large distances for the distribution and high amount of packaging are two important properties of transport intensive products.

With the help of the ECODESIGN PILOT appropriate improvement strategies for a transport intensive product could be found.

STUDENT'S PRESENTATION

In this lesson students will have the opportunity to present their products assigned at the beginning of the module and analyzed and described through the different lessons.

Student presentation (1hour)

REFERENCES

- ✓ *CES EduPAck 2006* (software), Granta Design Limited, Cambridge, UK, (used for generating energy values).
- ✓ *ECODESIGN Product Investigation, Learning and Optimization Tool* (PILOT) for sustainable product development. http://www.ecodesign.at/pilot/ONLINE, accessed 01.2007.
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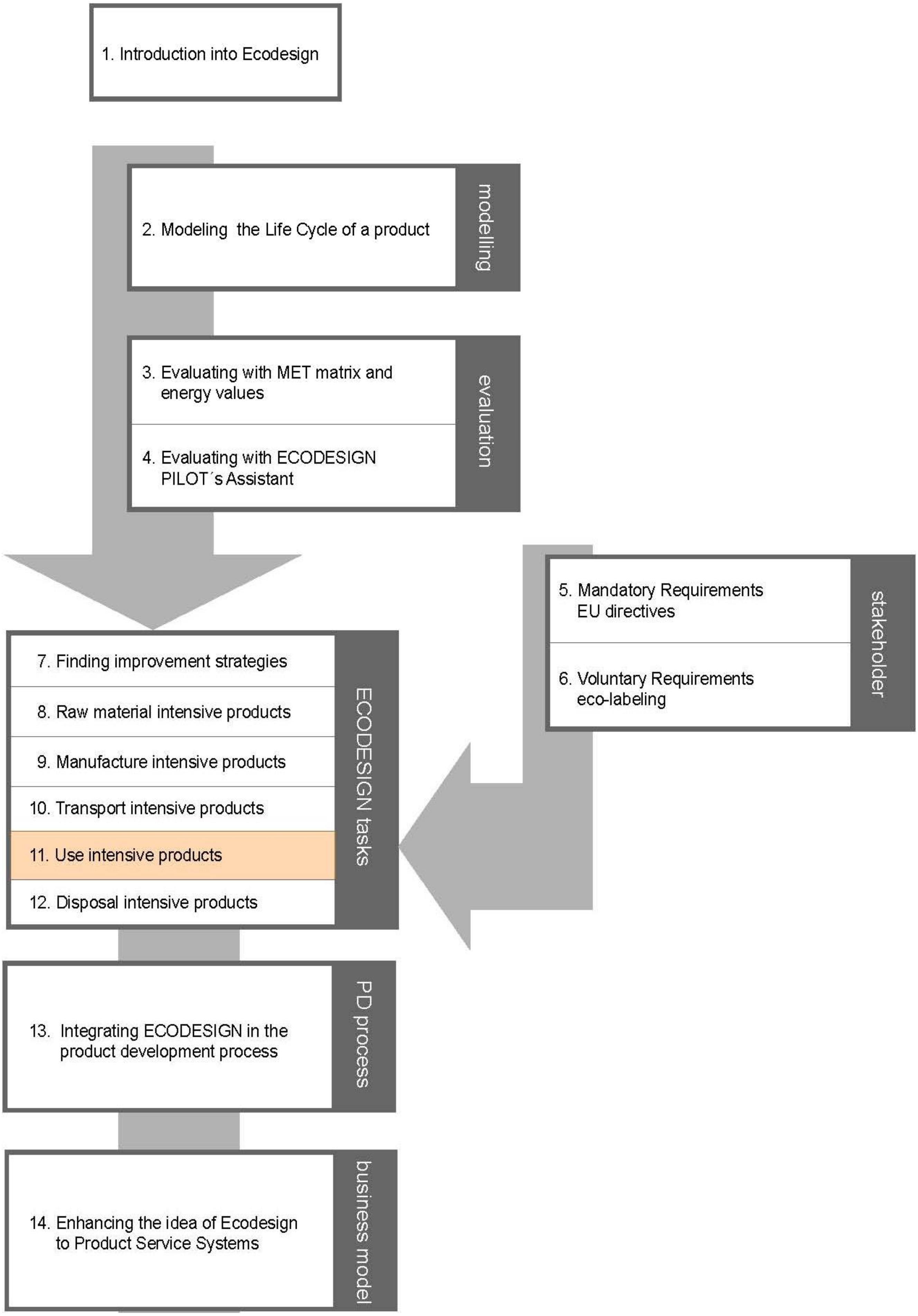
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LESSON 11

Improving Use Intensive Products

KEYWORDS: **IMPROVEMENT STRATEGIES, IMPROVEMENT IDEAS, USE INTENSIVE PRODUCTS, ECODESIGN PILOT**

Lesson objectives

In this lesson an electrical toothbrush will be investigated. This electrical toothbrush represents a use intensive product. Use intensive products cause most of their environmental impact during their use stage.

These kinds of products may need a lot of additional materials for proper operating (e.g. lubricants) which may cause harm to the environment. They could also release emissions to the environment, i.e. to the air. Think of a car which combusts fuel and releases carbon dioxide, carbon monoxide or carbon black amongst others to the air to be able to fulfill its function, namely to provide transport.

Use intensive products may also need a lot of energy to work properly. Think of electronic devices which need batteries. In case of rechargeable batteries consider all electric energy needed to recharge the batteries. In case of electrical devices such as household appliances, e.g. washings machines, think of the electrical energy needed for each use cycle, i.e. washing cycle. In case of a washing machine also consider that for each washing cycle detergents and water is needed and don't forget that after each washing cycle beneath clean clothes you also have a non negligible amount of waste water which must be treated afterwards to gain clean water again. The environmental impacts of such a product during use will rise by the frequency of use and the lifetime of the product: the longer the product is used, the more the relative contribution to environmental impact of the use stage of the life cycle will increase.

At the end of this lesson you will know more about the characteristics of use intensive products. By using the ECODESIGN PILOT you will learn about improvement strategies for these kinds of products.

CASE STUDY: ELECTRICAL TOOTHBRUSH

Fig.11.1: Electric toothbrush

In this lesson an electrical toothbrush is taken as an example for a use intensive product. It will be investigated how this device can be optimized.

Fig.11.2 shows the environmental profile of an electrical toothbrush.

As it can be seen from the environmental profile the relative environmental impact of the use stage is most significant.

Let us have a more detailed look at this product: the product consist of a device for recharging the battery. This device contains a transformer. The body contains an on/off switch and a rechargeable battery. The brush device which is attached contains a gear transmission. The brush itself needs to be replaced every second month. The lifetime of the product is approximately five years; this means 30 brush devices for every person during the lifetime of the product.

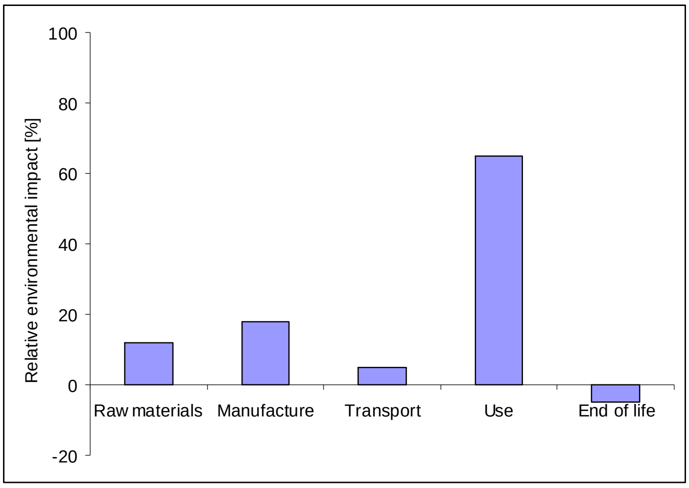


Fig.11.2: Environmental profile of each life cycle stage of a electric toothbrush

The product has a total weight of 440g and additionally 100g of cardboard, paper and plastic foils for packaging is needed.

Before continuing: how do you believe the high contribution in the use stage is composed? What factors and parameters do you believe have to be considered during use stage?

The main contribution results from the stand-by energy demand of the recharge device. This device needs 1.15 W energy. It is usually plugged in to electric energy 24 hours a day. This gives a total amount of 43800 hours of electric energy consumption during five years. The charging process of batteries takes only one hour a day. Depending on the energy mix (e.g. hydropower, nuclear power, etc...) a different amount of energy is needed to provide 1kWh of electrical energy in different countries. Tab. 11.1 lists energy values for different European countries.

Tab.11.1: Required energy for the production of 1kWh in different European countries and European average

Country	Energy value [MJ/kWh]
Austria	6.3
Denmark	11.3
France	12.3
Germany	12
Switzerland	8.1
Netherlands	11.5
Europe average	10

Considering that in Europe on average 10 MJ of energy are needed to produce 1kWh of electrical energy, the electrical toothbrush will need 503.7 MJ of energy during its lifetime to be able to charge the batteries of the toothbrush, where only 20.9 MJ are needed for the charging process. The rest is lost due stand-by consumption.

Fig.11.3 shows the environmental impact of the use stage of the electrical toothbrush more detailed.

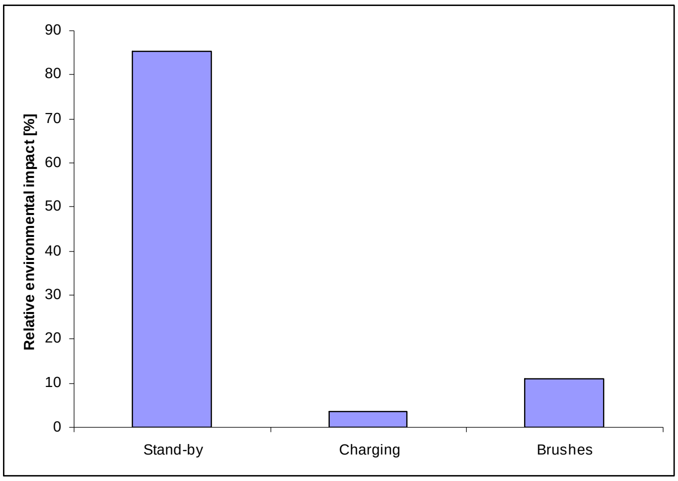


Fig.11.3: Environmental impacts during the use stage of the electrical toothbrush over its lifetime

Compared to the energy demand during the use stage all other energy demands occurring at the other life cycle stages are negligible. The significance of stand-by energy consumption is often underestimated whereas this stand-by consumption may be the most significant part of energy consumption of electrical devices. According to (Wien Energie, 2007) the sum of stand-by consumptions of different electrical devices in homes cause surplus costs of 85 euros in every single household every year.

When we look at electrical and electronic devices most of them nowadays are designed in a way they need stand-by power: this is due to guarantee that the device keeps information in its memory, that software is booted up more easily or that the user is able to switch on and off the device with a remote controller. Even though a device seems to be switched off, some electronic and electrical parts, such as the transformer, may still use energy. This is because some producers do not install a full switch off button in the device to keep production costs of the device low.

The electrical toothbrush is no exception. As calculated above most energy consumption of this product occurs during its use stage due to energy demand for the recharge device. It can be expected that most consumers will not unplug the device every time the battery of the toothbrush is charged. Another problem may be that there is no adequate display to show the status of the batteries. The user can not really find out if the batteries need to be reloaded or not.

To find appropriate improvement strategies and ideas for the toothbrush the ECODESIGN PILOT is used again.

The ECODESIGN PILOT suggests following improvement objectives and strategies for a *"Type D: use intensive product"*:

Realize a high degree of functionality

- Strategy: Optimizing product functionality
  Target: Improved functionality by means of upgrading, multi functionality...
- Strategy: Improving maintenance
  Target: Improving maintenance through wear detection...

Ensure safe use of the product

- Strategy: Ensuring environmental safety performance
  Target: Risk minimization

Reduce energy and material input at use stage

- Strategy: Reducing consumption at use stage
  Target: Reducing the consumption of energy and process materials during product use
- Strategy: Avoidance of waste at use stage
  Target: Avoiding waste during product use

By evaluating the product by using e.g. the Ecodesign checklists of the ECODESIGN PILOT and discussing the product in the team of developers, a high priority was assigned to the following two objectives: *"Reduce* *energy and material input at use stage"* and *"Realize a high degree of functionality".* These two objectives contain strategies for the improvement of the use stage of the toothbrush. Their realization leads to significant improvement of the product.

The strategies suggested by the first objective which are important for the toothbrush are:

- *Indicate consumption of product along use stage*: The current design of the toothbrush does not indicate the status of the battery. The user can not find out if the batteries need to be charged or not. To make sure the toothbrush is working properly all time he is forced to charge the batteries permanently.
- *Minimize energy consumption at use stage by increasing efficiency of product*: The efficiency of the charging process is very low. On the one hand there is no turn off once the batteries are fully charged. That means that the batteries are charged permanently. On the other hand the design of the electronic connection between batteries and charging device is not optimal which causes a low efficiency of charging.

The second objective contains following improvements which are relevant for the toothbrush:

- *Ensure high functional quality of product and minimize influence of possible disturbances*: the toothbrush should be able to fulfil its function even the user is not using it in a proper way.
- *Design product for possible upgrading*: this is almost fulfilled since the brushes can be changed easily
- *Realize simple principle of functioning*: the brush device contains a gearbox which has to be changed along with the brush. The brush device seemingly has no simple principle of functioning.

Considering these strategies above obtained by the ECODESIGN PILOT a more efficient charging process may be needed to gain a significant environmental improvement of the product.

Additionally some considerations could be taken into account of how the brush device can be designed in a way that the gear transmission can be used more often and how only the brush itself can be changed.

ADDITIONAL NOTES:

There are also electrical toothbrushes which work with non-rechargeable batteries which are not integrated in the product but can be changed easily.

Do you believe that using non-rechargeable batteries will reduce the environmental impact of the toothbrush?

Let us assume that the toothbrush is used on average 20 minutes a day in a four member family. This gives in total 608 hours of use during the lifetime of the toothbrush. Here fore approximately 120 batteries are necessary.

The energy value for a standard AA-size alkaline battery is 4 MJ/battery. This result is achieved by applying Life Cycle Assessment. The energy value for 120 batteries is 480 MJ. Additionally, batteries are difficult to treat in their end of life stage and cause harm to the environment if disposed improperly. These problems are discussed in lesson 12.

These simple considerations show that using batteries instead of a charging device is not an effective way to reduce the environmental impact of the toothbrush. Quite the contrary, the disposal of the batteries cause harm to the environment.

SUMMARY

Use intensive products cause most environmental impact during their use stage. The may require a lot of energy or additional operating materials which may cause environmental impact.

The toothbrush example showed a common problem of electrical and electronic devices nowadays: the high amount of energy losses due to stand-by consumption.

By using the ECODESIGN PILOT appropriate improvement strategies and ideas for the electrical toothbrush could be found.

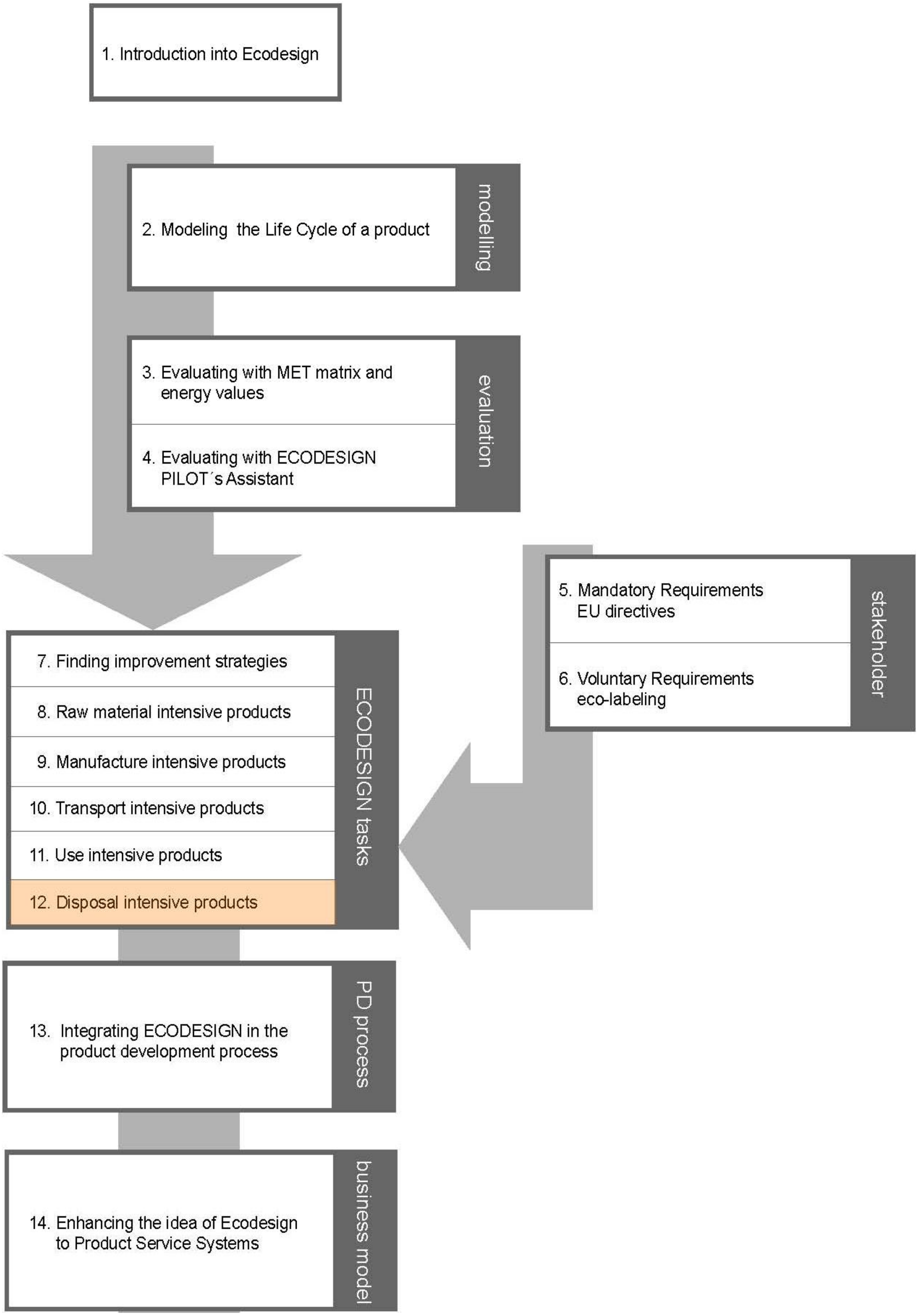
STUDENT'S PRESENTATION

In this lesson students will have the opportunity to present their products assigned at the beginning of the module and analyzed and described through the different lessons.

Student presentation (1hour)

REFERENCES

- ✓ *ECODESIGN Product Investigation, Learning and Optimization Tool* (PILOT) for sustainable product development.
  http://www.ecodesign.at/pilot/ONLINE, accessed 01.2007.
- ✓ *Wien Energie*: http://www.wienenergie.at, accessed 08.2006.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LESSON 12

Improving Disposal Intensive Products

KEYWORDS: DISPOSAL INTENSIVE PRODUCTS, END OF LIFE CYCLES, ECODESIGN PILOT

Lesson objectives

In the previous lessons different product types were discussed. An office chair was discussed representing a raw material intensive product, a wooden table for a manufacture intensive product, jeans trousers for a transport intensive product and an electrical toothbrush for a use intensive product.

If the relative contribution to the environmental impact of a product occurs at the end of life it is considered as a disposal intensive product.

Disposal intensive products may contain hazardous substances and materials which need specific treatment and precautions when disposed of. Complex and various recycling processes, low rate of recycle ability or a low rate of reusable parts are some other characteristics of disposal intensive products.

Once a product reaches its end of life stage, different paths and cycles can be followed: repair, recycling or up-grading cycles are some to name. Common end of life cycles will be discussed in this lesson.

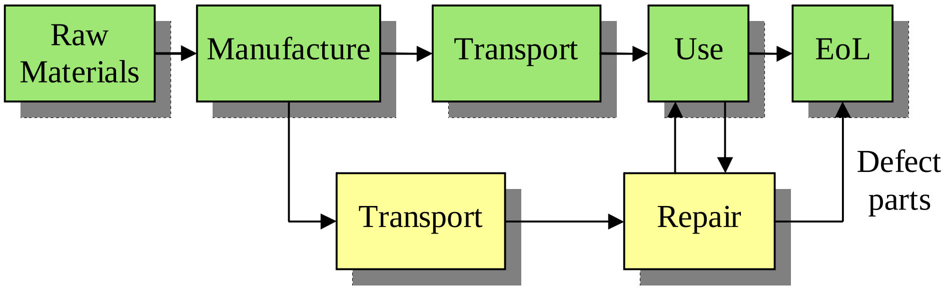
At the end of this lesson you will know more about the characteristics of disposal intensive products. You will learn more about improvement strategies for these kinds of products.

There are various ways to treat the product and its parts at the end of life (EoL) stage. The product can be disassembled for example. The components and the parts can be used again or the materials used in the product can be entered into a recycling process. In the following some possible cycles at the end of life stage are introduced (Wimmer, Züst, 2002).

REPAIR

A repair cycle delays the arrival of the end of life stage of a product. Parts and components of a product can be repaired several times and be used again. Defect parts, that are non repairable, e.g. broken, parts or worn out parts, must be replaced by new or refurbished parts. New parts must be manufactured first and then transported before they can be used in a repair cycle. Parts which are defect have reached their end of life stage. Fig. 12.1 shows a flow chart of a repair cycle.

Fig.12.1: Use stage with repair cycle (Wimmer, Züst, 2002)



The product usually reaches its end of life stage when some parts are defect which can not be repaired or replaced economically and therefore the product is not able to fulfil its functionality.

RECYCLING

As it can be seen from Fig. 12.2 the generated waste during the stages manufacture, use and end of life as well as defect parts and components and even the whole product itself can be brought into a recycling loop.

In general, there are closed recycling loops and open recycling loops. In closed recycling loops potential recycling materials of a product system are collected and recycled and entered into manufacture cycles of the same product system. This intention should be evaluated from an economical as well as from an ecological view since the processes needed to implement a closed loop may create environmental impacts again.

In an open recycling loop, materials are recycled in one product system and used in another product system, e.g. waste of packaging can be recycled to insulation or construction materials etc...

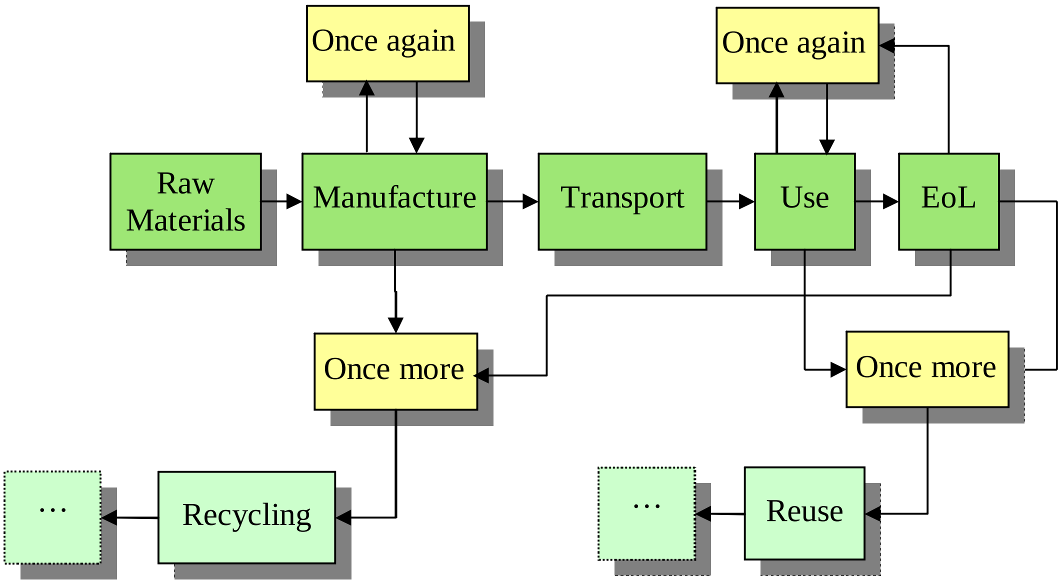


Fig.12.2: Recycling Cycle according to (VDI 2243, 2000)

It should be mentioned that the term ‘recycling’ is usually used to describe different processes: in case of material recycling used materials are processed to avoid the need for new virgin materials. Sometimes materials can not be processed in a way they can be recycled again. Then materials can be incinerated for example. The generated heat during incineration can be used for different purposes, e.g. for heating of houses. This kind of ‘recycling’ is called ‘thermal recovery’.

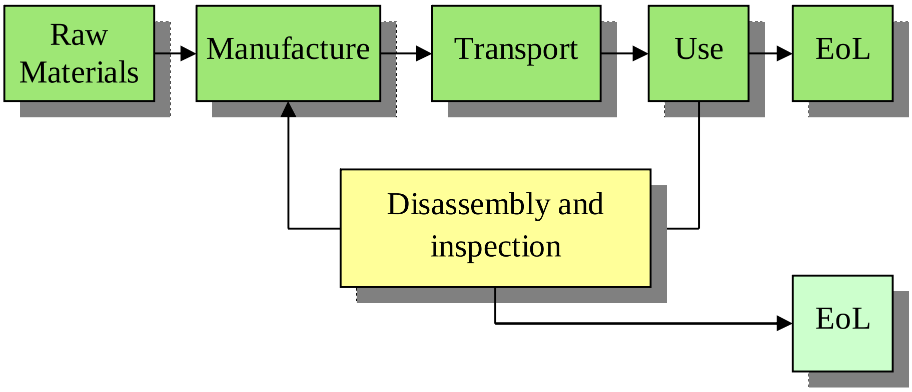
There are already several well established material recycling cycles such as recycling cycles for glass, metals, paper and some plastics, e.g. PET bottles.

In contrary to recycling, reuse of parts and components does not imply any structural change in the material or part itself. Materials and parts are taken from one product and are used in the production of the same product or another product. Imagine a washing machine which reaches its end of life: the electrical motor of the washing machine may still work properly. The motor can be disassembled from the defect washing machine and can be used again (eventually after inspection or repair) in another washing machine or in a different product again, hence, the motor is “reused”.

REVERSE MANUFACTURING

Fig.12.3 shows a reverse manufacturing cycle. In this cycle the product is disassembled into its parts and components after use. These parts and components are inspected and if necessary repaired. The inspected and repaired parts are then put to their original use again. In case of the motor of the washing machine that means that the motor is only used as a motor for a washing machine again. Fig.12.3 also shows that parts and components which can not be repaired and used further on have reached their end of life stage. These parts may now enter recycling cycles as introduced above.

Fig.12.3: Reverse manufacturing cycle (Wimmer, Züst, 2002)



UPGRADING

Fig.12.4 shows an upgrading cycle.

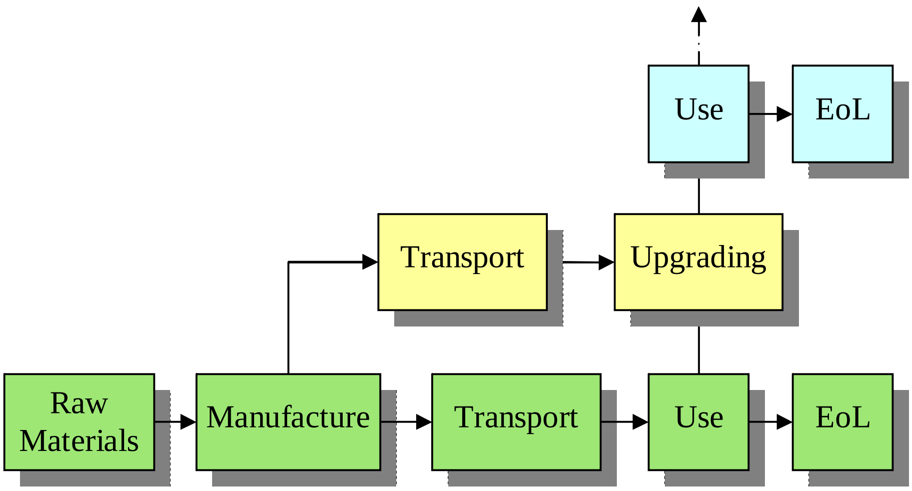


Fig.12.4: Upgrading cycle (Wimmer, Züst, 2002)

The product is inspected in a repair or maintenance cycle. Beneath the maintenance and repair of components it is aimed to raise and optimize the functionality of the product at the same time. Products which have a modular structure are easy to enter into such an upgrading cycle. By upgrading the arrival of the end of life stage of the product is delayed and therefore fewer resources are needed to provide the requested functionality.

Imagine a usual personal computer: by changing its components little by little, e.g. RAM, hard disk or graphic card, the performance and functionality of the personal computer is raised; the useful lifetime of the product is increased.

As it can be seen from the explanations above the different life cycle stages of a product are not just a linear sequence but contain different cycles and loops.

As one can see the end of life stage consists of different possible cycles which include different steps and processes for the treatment of the product, its components and its parts. New business models can be established following different cycles. The "Demontage- und Recycling Zentrum"* (D.R.Z) in Austria has established a network of factories specialised on repairing electric and electronical equipment.

Upgrading requires special product designs which allow changing and substituting parts and components of the product.

A disposal intensive product causes most of its environmental impact at the end of life stage. Various treatment processes may be necessary for e.g. repair or recycling. The end of life stage of products may contain different potential for recovery of materials or energy.

Imagine most of the waste produced is disposed in a landfill. This is the case for example in the United States where most of the generated waste in households is disposed in a landfill. This is possible because in the United States enough land is available (EcoWorld, 2007). The situation is completely different for example in Japan, where free land is rare (Web Japan, 2007). There, recycling rate is very high. If products are disposed in a landfill, no energy is used for the treatment of the waste. This does not mean that putting waste on a landfill does not cause any impact to the environment. The impact to the environment depends on the materials and chemicals put on the landfill. Some materials which are not inert may start dangerous and hazardous chemical reactions and release toxic substances during this reaction. The leakage water may become contaminated as well. It must be collected and treated carefully

* in English: Diassembly and recycling centre

to prevent that it drips into the ground water which would be a serious threat to human health and nature.

On the other hand no energy can be recovered by putting waste on a landfill. A landfill contains a lot of different materials, it is a material deposit. It could be stated that with future technologies the materials of this deposit could be recovered again. By now these technologies are either not efficient or too expensive.

Recycling and reuse processes need energy input but the processes also allow extracting energy out of the processes, e.g. thermal recovery. They might be able to compensate some of the environmental impact of the product, e.g. reusing the motor of the washing machine reduces the total environmental impact of the washing machine since no motor must be manufactured for each washing machine.

As an other example, consider batteries. Putting batteries on a landfill is prohibited. The “Directive on Batteries and Accumulators Containing Certain Dangerous Substances” (directive 91/157/EEC) applies to batteries which contain mercury, cadmium and lead and provides guidelines how these batteries must be collected after use and what duties the producers have. Mercury, cadmium or lead are hazardous substances which start chemical reactions if put on landfills.

The battery types covered by this directive are only 7% of all batteries which can be found in the European Union market.

To be able to prevent effectively that most batteries end up in landfills or incineration facilities, closed-loop recycling systems for all types of batteries must be established.

Considering the given amount of 72.155 tons of batteries which entered the market of the EU in 2002 it is estimated that recycling could recover following amounts of metals each year (Commission Proposal on Batteries and accumulators and spent batteries, 2003).

Tab.12.1: Amount of metals which could be recovered by recycling batteries (Q&A on the commission proposal for a new battery directive, 2003)

Material	Amount [tons]
Manganese	20.000
Zinc	20.000
Iron	15.000
Lead	7.500
Nickel	2.000
Cadmium	1.500
Mercury	28

Before effective recycling can be implemented it is necessary to establish appropriate collection facilities to make sure enough batteries are collected. This collection facility should avoid users to dispose their batteries via household waste.

Using recycled metals in batteries decreases primary energy demand for the production of batteries. Using recycled cadmium or nickel could imply savings in primary energy up to 75% (Q&A on the commission proposal for a new battery directive, 2003).

Using rechargeable batteries can reduce the amount of batteries needed for a certain device. Rechargeable batteries can be reused hundred of times before they reach their end of life.

Once a product is identified as a disposal intensive product, the ECODESIGN PILOT can be used to find appropriate strategies. The PILOT proposes following improvement objectives and strategies for a *"Type E: disposal intensive product"*:

Use alternative materials

- Strategy: Selecting the right materials
  Target: Reduction of environmental impact by using environmentally sound materials, recycled materials, renewable materials...

Prolonged use of the product

- Strategy: Increasing product durability
  Target: Increasing durability through dimensioning, surface design...
- Strategy: Improving reparability
  Target: Improving access to, disassembling, and exchange... of parts

Disassembly and recycling

- Strategy: Improving disassembly
  Target: Make possible product take back and ease of disassembling (fastness...)
- Strategy: Reuse of product parts
  Target: Make possible reuse of parts (access, remanufacturing...)
- Strategy: Recycling of materials
  Target: Make possible recycling of materials (separation, labelling...)

The objective *"Prolonged use of the product"* contains an interesting improvement strategy, namely *"Increasing product durability"*. Think of common alkaline batteries which can not be recharged. Even when the batteries are not used they discharge continuously. Batteries have a certain capacity and are able to provide power for a certain time. In case of non-rechargeable batteries the batteries are disposed after use and new batteries for the device are used instead. It is clear that if each battery was used for a longer period (this happens either by reducing energy consumption of the electrical and electronic device or by raising the power supply of the battery) the user would need fewer batteries over the product life time.

SUMMARY

As shown in this lesson, products may enter different cycles once they reach their end of life stage. New business models can be established by specializing on the different processes needed in these cycles, e.g. processes needed for repairing products.

Different waste treatment processes contain different potential for material or energy recovery. While disposing waste on a landfill does not require any energy and no energy recovery is possible, recycling processes are able to reduce the total environmental impact of a product by recovering material or energy.

The amount of the need to new virgin raw materials in the product can be reduced significantly by recycling processes. By reusing parts and components the amount of manufactured parts and components, hence the processed materials and the energies used can be reduced as well. Keep in mind that reduced energy demand means reduced environmental impact!

STUDENT'S PRESENTATION

In this lesson students will have the opportunity to present their products assigned at the beginning of the module and analyzed and described through the different lessons.

Student presentation (1hour)

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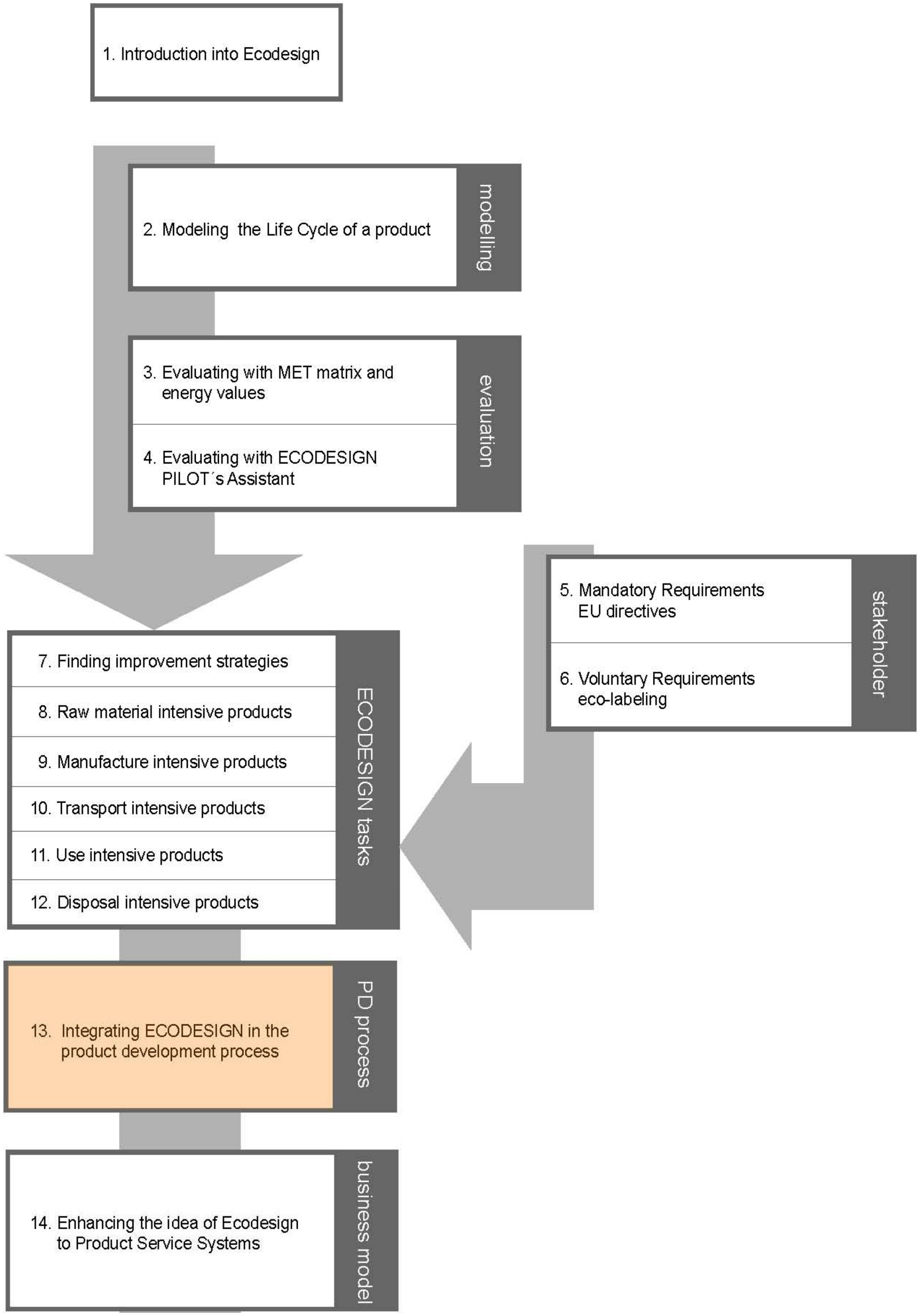
- Wimmer, W, Züst, R., 2002, *Ecodesign Pilot - Product-Investigation-, Learning- and Optimization- Tool for Sustainable Product Development*, Kluwer Academic Publishers, Dordrecht, Netherlands.

ADDITIONAL READING MATERIAL (AVAILABLE ON CD)

- "*Demontage- und Recycling Zentrum*" (D.R.Z) – Video.

Adobe PDF *Q&A on the commission proposal for a new battery directive*, 2003.

Adobe PDF *Directive of the European Parliament and of the Council on Batteries and Accumulators and Spent Batteries and Accumulators*, 2003. Directive.


1. Introduction into Ecodesign
2. Modeling the Life Cycle of a product
modelling
3. Evaluating with MET matrix and energy values
4. Evaluating with ECODESIGN PILOT´s Assistant
evaluation
5. Mandatory Requirements EU directives
6. Voluntary Requirements eco-labeling
stakeholder
7. Finding improvement strategies
8. Raw material intensive products
9. Manufacture intensive products
10. Transport intensive products
11. Use intensive products
12. Disposal intensive products
ECODESIGN tasks
13. Integrating ECODESIGN in the product development process
PD process
14. Enhancing the idea of Ecodesign to Product Service Systems
business model

LESSON 13

Integrating Ecodesign into the Product Development Process

KEYWORDS: PRODUCT DEVELOPMENT PROCESS, PRODUCT SPECIFICATION, FUNCTIONAL STRUCTURE, IDEA GENERATING TECHNIQUES, PRODUCT CONCEPT, EMBODIMENT DESIGN

Lesson objectives

In this lesson the product development process is described. It will be discussed how Ecodesign can be integrated efficiently into the product development process by following five main steps. It will be also discussed how Ecodesign can be integrated into the decisive early design stages of a product.

To be able to integrate and implement Ecodesign into the product development process product requirements and specifications must be brought together and defined in the first step.

In a second step the function or functions a product should fulfil are investigated more detailed. Since there are different possibilities to realize a function of a product it is important to evaluate the different realizations to find the optimal one for the product.

To be able to find different realizations of the function and of the design of a product, creativity and idea generation techniques are used to attain new innovative ideas in the third step of the product development process.

In the fourth step new product concepts are derived by combining new ideas to fulfil a product's function.

By comparing and evaluating the different product concepts, the optimal concept is evaluated and selected to be finally realized during the product's embodiment design.

Further in this lesson a methodology, the so called Ecodesign Decision Boxes, for the systematical integration of Ecodesign into the early decisive design stages will be introduced [Ostad A. Ghorabi et al. 2006].

At the end of this lesson you will gain an overview of how Ecodesign can be integrated and implemented into product development as well as in early decisive design stages. You will also get familiar with some effective idea generation techniques.

In the following the five steps of the product development process will be discussed more detailed and appropriate examples will be provided.

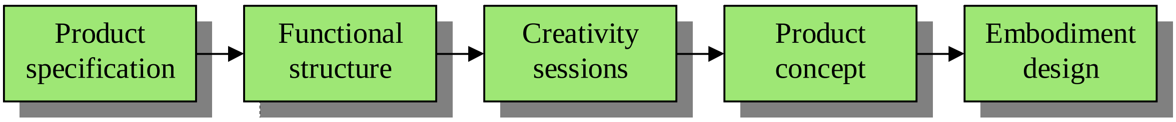


Fig.13.1: Product development process (Wimmer, Züst, Lee 2004)

PRODUCT SPECIFICATION

Speaking of Ecodesign and environmental friendly product development it is important to bring together environmental requirements from stakeholders, from benchmarking and requirements which result from an environmental stakeholder analysis evaluation of a product as well as requirements gained by an environmental assessment of a product.

In this first step of the product development process it is important to formulate all required specifications which implies all quantitative data as well as qualitative data, see lesson 2.

The main question to address in this stage is: how to formulate and combine product specifications for the re-design process of the product?

It is advisable to form a list with all specifications and their properties for each life cycle stage of the product. Additional explanations and remarks can be recorded in this list as well.

Let's consider the juice extractor which was introduced and analyzed through the previous chapters.

In Tab. 13.1 a specification list is shown for the juice extractor. In the following list only environmental specifications are mentioned.

Tab.13.1: Environmental specification list for the juice extractor

Life cycle	Specification	Remarks
Raw materials	No use of problematic materials such as lead	Gain conformity with RoHS
Product use	Optimize cones for extracting juice	Achieve better juice extraction
	Reduced noise and vibration	Fulfil customer requirements
End of life	Increase recycling rate	Gain conformity with WEEE

DEVELOPING THE FUNCTIONAL STRUCTURE

A key in developing products is thinking in functions the product should deliver in order to fulfil a need.

How can a function be described properly? Think in nouns and verbs or in measures and operations, see Tab. 13.2.

Tab.13.2: Finding functions

Noun/Measure	Verb/Operation
Cloth	Wash
Juice	Extract
Power	Transmit
Part	Connect
Data	Transfer

In practice, there are a lot of possibilities (often an unknown amount of possibilities) to realize a function of a system by combining its different sub functions.

In a function analysis a problem is described by its main function. This main function is separated in its sub functions then. Aim is to find better, alternative ways to realize the sub functions.

Therefore the main function is divided to its sub functions in a hierarchic way. Each of the sub functions is described from the view of technological, topographical or textual aspects.

In the following a hierarchic function tree for the juice extractor is drawn.

PERFORMING CREATIVITY SESSIONS

To be able to generate ideas for the realization of the different functions of the product idea generation techniques can be used. There are different techniques which allow finding ideas for simple problems as well as techniques for complex problems. Some of the techniques need a moderator, some are performed in a group, some take less time and some take a whole day.

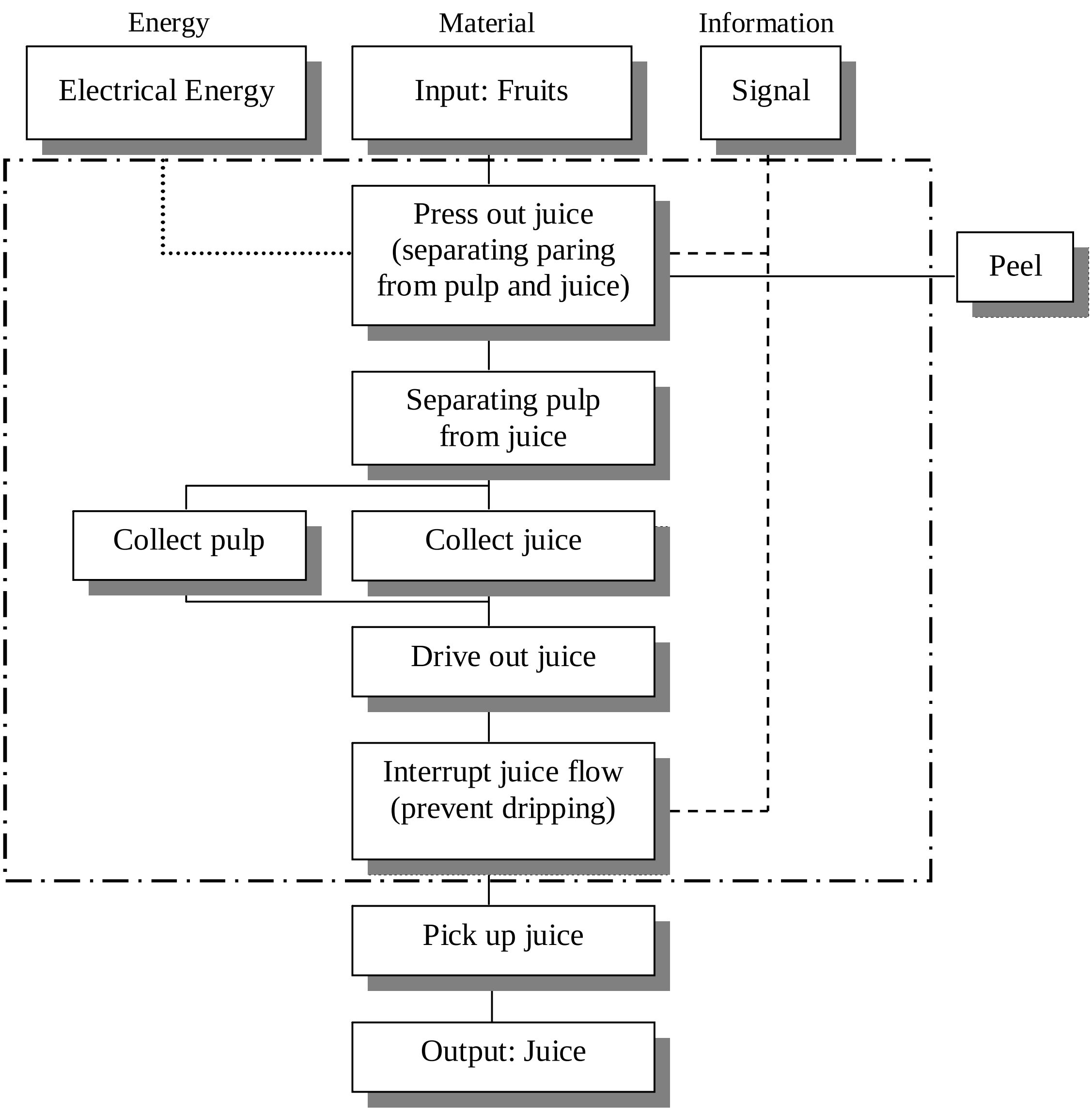


Fig.13.2: Functional structure of a juice extractor (Wimmer, 1999)

In the following some of these commonly used techniques are introduced briefly.

Brainstorming

Brainstorming is an idea generation method which is easy to apply and therefore often used in practice.

Commonly, a group of five to ten participants with different vocational education comes together to produce ideas for a certain problem. This phase of idea generation takes half an hour. The produced ideas of the participants are written down by a moderator in a way that they become visible for every participant.

The methodology is based on associativity. To guarantee a continuous flow of ideas, certain rules must be adhered. Especially during the idea generating phase the ideas should not be criticized or be commented by the participants as criticism may freeze the idea generation process.

Generally four main rules can be formulated. These rules should be adhered during the whole process. These rules are:

1. Evaluation or criticism of the ideas should be strictly separated from the idea generation phase.
2. The ideas of the other participants should be picked up in matter of expanding
3. The participants should have the opportunity to express their fantasy
4. Aim is to produce lots of ideas in a short time

Brainstorming results in an amount of ideas for a certain defined problem. Experience shows that approximately 3 – 6% of the named ideas can be further used effectively.

This methodology requires little time and gives a big amount of ideas at same time. The knowledge of several people can be used at same time to find an adequate solution. Unfortunately the quality of the generated ideas and solutions for the problem can vary widely. After a break the bunch of ideas are read by the moderator. The participants evaluate and sort the ideas. The ideas are then sorted thematically. Ideas which fit not to the problem are sorted out.

Brainwriting (Method 635)

At first, a clear definition of the aimed task is necessary. Then, a group, called 635 group, of six participants, seated in a circle, is asked to write down three ideas during five minutes on a form. After five minutes, the list is handed over to the right neighbour who has either to develop further the previous ideas or if this is not possible to write down some new ideas.

In further turns the time interval is increased up to eight minutes since there will be more content on the list which has to be read before developing new ideas. The procedure is finished when all lists are completed by every participant. This method lasts approximately 30 to 40 minutes. It is important that the ideas are formulated clearly and that the participants do not talk to each other during these 40 minutes.

Brainwriting aims at analyzing and synthesizing a clearly defined problem. The possible solutions for the problem are described by keywords, drafts or drawings.

The Brainwriting method gives in an ideal case 108 written ideas as well as associations on a list. Experience shows that approximately 15% of the generated ideas can be realized.

Advantage of this method is that people which cannot articulate very well have the same chance for communicating their ideas like well articulating participants. No moderator but a strict time keeper is needed for the method. The Brainwriting method allows complex formulation of ideas.

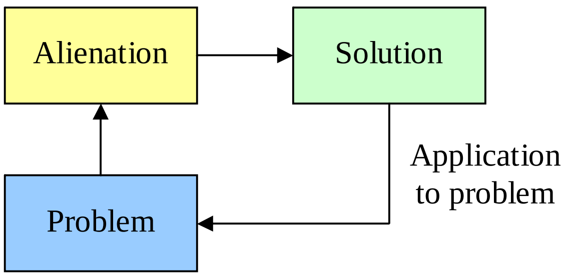
Disadvantages: the existing pressure of time for the formulation of the ideas may lead to black outs of some participants. Some participants may have good ideas but could face difficulties when writing them down.

Synectics

Another effective approach for finding new ideas and solutions for difficult problems is called synectics.

The flow chart in Fig.13.3 shows the general approach of this method.

Fig.13.3: Flow chart showing approach of synectics



In a first step of this method a problem is analyzed and defined properly and is reformulated then. In the second step the problem is alienated by searching analogies. Following analogies can be used:

- Analogies from nature (e.g. bionic: how does nature solve this problem)
- Personal analogies (e.g. how do I feel by being a...)
- Symbolic analogies (metaphorical expressions...)
- Fantasy analogies (what would a superhero do...)

In the next step the analogies are related and applied to the problem. Possible solutions are derived.

Example: a device for removing uroliths from the human body is developed by using the analogy of an umbrella. The device should span, tighten and unplug the stones.

Checklists

Checklists contain questions which are relevant for problem solving. Aim is to consider all relevant questions and avoiding missing or skipping one. Checklists can be used universally and can be adapted to different problems.

Different approaches and techniques can be followed when formulating questions. They will be explained in the following:

- *Inverting:* e.g. what would the opposite mean? What if turned from right to left…?
- *Combining:* e.g. what if ideas are combined? What if units are combined…?
- *Using differently:* e.g.: what if used differently with same shape, materials, etc…?
- *Adjusting:* What has already been done in the past? Is something similar to my problem…?
- *Altering:* Can the meaning/value of a parameter/product be changed…?
- *Making it bigger:* Should something be added…?
- *Making it smaller:* Should something be dropped…?
- *Replacing:* Can some other material be used? Can some other approach be found…?
- *New arranging:* New layout necessary? Should components be changed…?

Advantages of Checklists:

- Universal applicable and flexible use of different problems
- Any level of detail can be defined
- Summarized and generalized evaluations are avoided
- Forced to systematically work through projects and ideas were nothing can be forgotten

You have already used such checklists by using the ECODESIGN PILOT and by evaluating the priority of the improvement strategies of your product.

PRODUCT CONCEPTS

Products are designed to fulfil a function. The function of a product is derived by a combination of different sub functions (e.g. the function of the juice extractor is extracting juice, a sub function could be pressing out juice, another one collecting juice etc…)

To be able to find the optimal combination of the different sub functions each of the sub functions must be evaluated. According to (Luttropp, 1999) around 30 aspects need to be addressed in the product development process and must be therefore evaluated during the evaluation process of the sub functions. Some of the aspects are e.g. materials, reliability, quality or profit or environmental aspects.

Each product consists of different parts and components. The product fulfils a function (a main function). Each of its components fulfil a function as well, called a sub function. The different sub functions together provide the main function.

It is clear that the final product is able to fulfil its main function optimally if its parts and components (i.e. its sub functions) do so. By listing each sub function in a column and each realization in a row a morphological box is obtained, see Tab. 13.3.

In a morphological box, see Tab. 13.3, different sub functions can be listed in a column. The different possible realizations of the sub function are listed in a row. By combining different realizations of sub functions different variants of a product are obtained.

Tab.13.3: Morphological box (Roloff, Matek, 2001)

Sub-function	Realization of sub function					
	1	2	3	.	.	y
1	1.1	1.2	1.3	.	.	1.y
2	2.1	2.2	2.3	.	.	2.y
.	.	.	.	.	.	.
.	.	.	.	.	.	.
x	x.1	x.2	x.3	.	.	x.y

1. 2. 3. variant

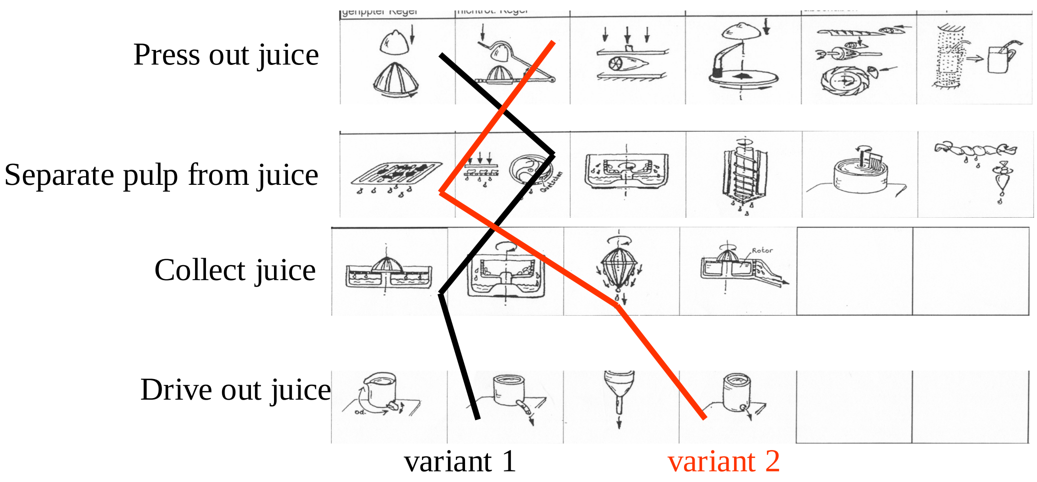
Tab. 13.3 shows three different possible variants of the various sub functions in the morphological matrix.

Tab. 13.4. shows a graphical morphological box for a juice extractor and points out two different realization variants of the different sub functions of the product. The sub functions were derived through functional analysis as described above.

As discussed in lesson 2 the juice extractor can be environmentally improved by finding a concept to extract as much juice as possible from a single orange. Designing an optimized cone would be an effective approach.

Once the combination of sub functions and concepts is defined the embodiment design can be processed.

Tab.13.4: Morphological box for the juice extractor



EMBODIMENT DESIGN

Through embodiment design preliminary layouts of parts and components are derived. In this part of the product development process the ideas and the environmental considerations discussed before are implemented into the design of the product. Through the embodiment design process parts and components are fully dimensioned and designed.

After embodiment design usually a prototype is build to be further tested. The design can then be further optimized by implementing and considering the test results gained with the prototype.

In case of the juice extractor example the following optimizations of the design could be gained:

- Different cone sizes for different fruits, e.g. limes, oranges, grape fruits...
- Transparent container to make visible how much juice has been extracted
- Reducing electrical energy consumption by optimizing gearbox
- Reducing noise and vibrations by damping gearbox
- Eased disassembly of parts for washing and cleaning

- Eased disassembly for reusing e.g. motor, eased disassembly for recycling

After the embodiment design stage and after testing and optimizing a prototype the product development process is finished.

Ecodesign Decision Boxes

Through the previous lessons it was shown that any development of products as well as any production activity causes environmental impacts. It was also aimed to show that decisions about the design of a product taken by engineers in product development influence the environmental performance of the product. Since the engineers select the materials used in the product and further determine production technologies necessary to manufacture the product. The design itself may influence means of transport needed, energy consumption of the product in its use stage as well as possible end of life scenarios.

The approaches discussed in the previous lessons were based on product improvement, which means that current product designs were investigated and evaluated and product improvements were gained by using approaches, methodologies and tools introduced so far.

In this chapter an approach will be discussed briefly of how environmental considerations as well as environmental product evaluations can be integrated into the decisive early design stages of a product.

The methodology introduced here is called “Ecodesign Decision Boxes” (in short EDB) and follows (Ostad Ahmad Ghorabi et. al 2006).

Let’s have a more detailed look on what *“design”* means and what it consists of. In (Hubka et al., 1996) ‘designing’ is defined as:

“The transformation of information from the condition of needs, demands, requirements and constraints (including the demanded functions) into the description of a structure which is capable of fulfilling these demands.”

Environmental considerations can be taken into account already in the early steps of the design stage where feasibility studies were done and priorities were set. Priorities could be shifted towards environmental friendly design which will have an influence on how functions were combined in the second step.

The EDB were developed in a way to fit into the design process. They consist of three different boxes, namely the Design Box, the Component Box and the Material Box: the Design Box allows optimizing the entire assembled product whereas the Component Boxes (one for each component in the product) and their corresponding Material Boxes (one for each Component Box) allow tracking the influence on environment of each component, part and of each material used in the components. Fig.13.4 shows a flow chart of how the EDB approach.

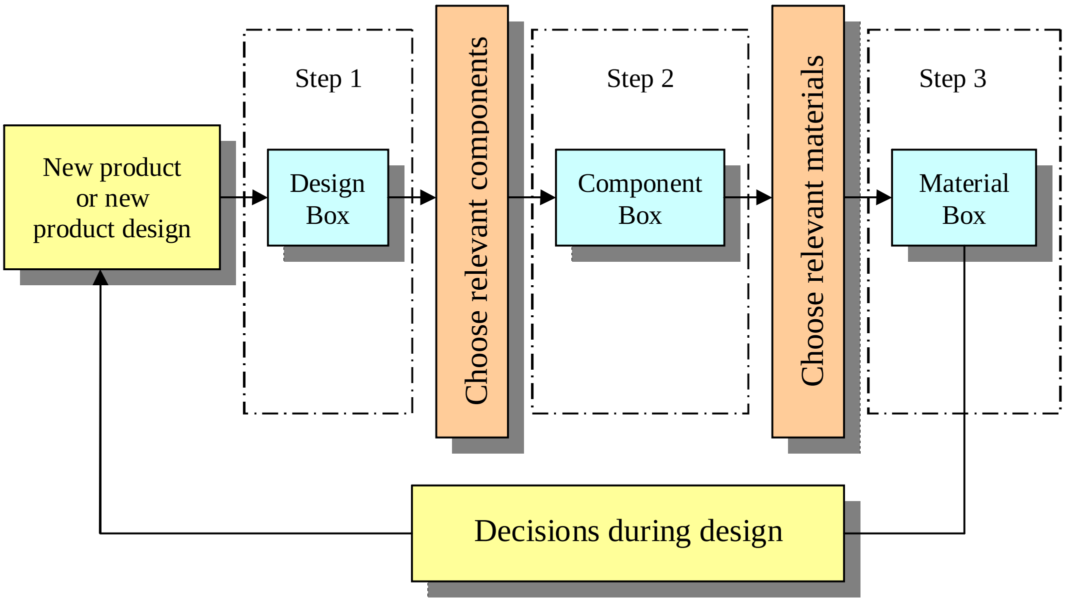


Fig.13.4: Flow chart for the approach of the EDB (Ostad Ahmad Ghorabi et al., 2006)

The evaluation of the different materials and processes in the Decision Boxes are based on Life Cycle Assessment (LCA). The Decision Boxes visualize the correlation of an environmental parameter, e.g. global warming potential expressed as CO_2 equivalents, cumulated energy demand expressed as energy equivalents or any other indicator which can quantify environmental impact and a technical parameter such as weight or volume.

As shown in Fig. 13.5, in the first step a Design Box is generated for the product. The Design Box shows the correlation between an environmental parameter and a technical parameter of the whole assembled product including components throughout its life cycle. In the second step Component Boxes are established for those components contributing most to the environmental impact of the product. The Component Box shows the correlation of the environmental parameter and the technical parameter of the parts of the component. In the third step for each component a Material Box is generated where the same correlation is visualized for the whole life cycle of the materials used in the parts of the components.

Let's consider an office chair again as an example. As introduced in lesson 2 a common office chair consists of five main parts, namely:

11. Base
12. Mechanism
13. Seat
14. Arm rest
15. Back

Fig.13.5: Office chair

For the production of the office chair shown in Fig. 13.5 the amount of materials listed in Tab.13.5 are used.

To be able to draw the graphs of the Ecodesign Decision Boxes the product including its components, parts and materials must be environmentally evaluated through its entire life cycle. Additionally some analysis is necessary to correlate the environmental parameter with the technical parameter.

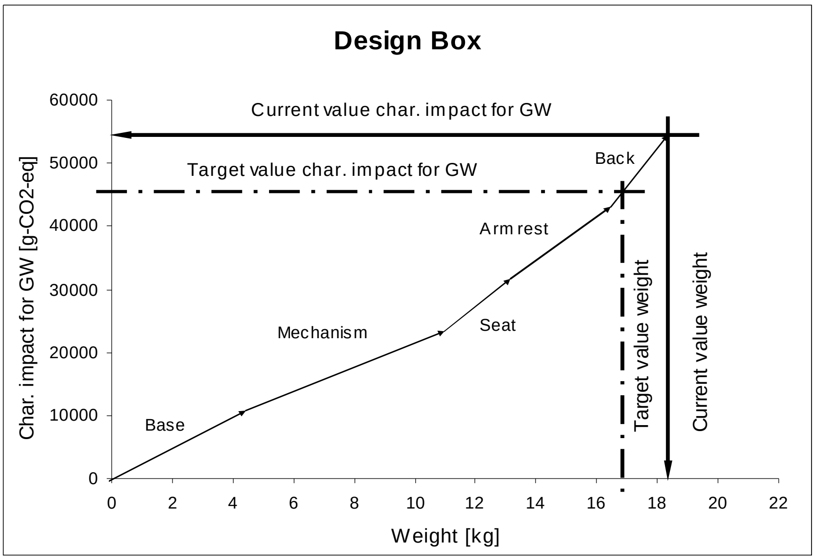
Tab.13.5: Amount of materials used in the office chair

Materials	Weight [kg]
ASt35	**13**
PP	**3**
PUR	**1.2**
C45	**0.6**
ABS	**0.4**
PA6	**0.4**
Polyester	**0.3**
PA6GF30	**0.2**
PC	**0.005**
Total weight:	19.1

For the Design Box of the office chair, see Fig.13.6, Life Cycle Assessment was applied. Since optimizing the weight of the office chair was one important design criteria, the product weight was taken as a technical parameter which is correlated to global warming potential.

The Design Box shows the contribution to environmental impact trough the life cycle of each component of the office chair. The current weight of the office chair and the current environmental impact of the office chair are also marked in the Design Box.

Fig.13.6: Design Box for the office chair (Ostad Ahmad Ghorabi et al., 2006)

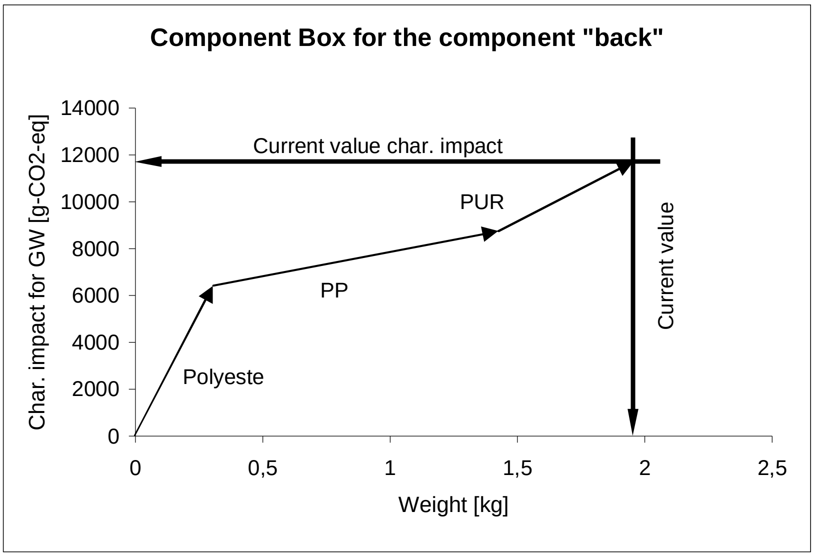


Let's assume now that an improved design of the office chair aims at reducing the weight of the chair by 10%. The contribution to global warming should be reduced by 20%. The new target values are also drawn into the Design Box.

As it can be seen in the Design Box the current design of the chair exceeds the new defined target values. The Design Box further shows that the components "Back", "Seat" and "Arm rest" have the highest slopes amongst the components which indicates that they contribute a lot to environmental impact.

Let's further investigate the component "Back" more detailed since it has a relatively low weight but contributes significantly to environmental impact. To be able to do that a Component Box for the "Back" is drawn, see Fig. 13.7.

Fig.13.7: Component Box for the component "Back" (Ostad Ahmad Ghorabi et al., 2006)



The life cycle data for the materials used for the component "Back" are listed in Tab. 13.6.

Tab.13.6: Life cycle data for the materials used in the component "Back" (Ostad Ahmad Ghorabi et al., 2006)

Material	Processing	Surface	Transport	End of Life (EoL)
Polyester	-	No treatment	1000 km with Lorry	European Scenario
PP	Injection moulding	Painted	1000 km with Lorry	European Scenario
PUR	Foaming	No treatment	1000 km with Lorry	European Scenario

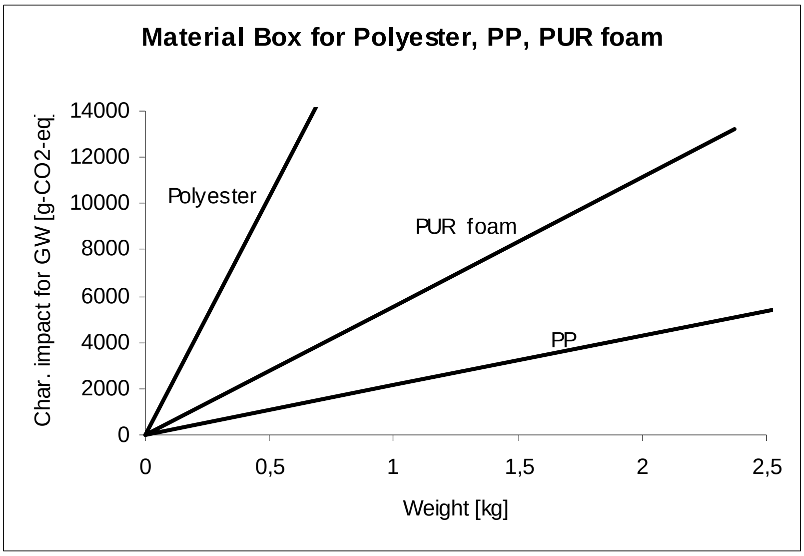
In the Component Box the current weight of the "Back" and its contribution to global warming by its current life cycle, i.e. use of raw materials, surface treatment, transport etc... is marked.

The component Box shows that polyester and PUR have a very high slope. This means that mostly these two materials form the contribution to environmental impact.

Considering a new design concept of the office chair it is useful to reduce or avoid the use of polyester and PUR in the back.

The Material Box in Fig. 13.8 shows the performance of the materials over their whole life cycle (from extraction until end of life). The Material Box for polyester, polypropylene (PP) and polyurethane (PUR) shows how much of each material can be used and which contribution to global warming occurs.

Fig.13.8: Material Box for Polyester, PP and PUR (Ostad Ahmad Ghorabi et al., 2006)



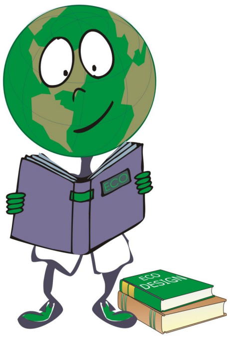
An investigation shows that the use of polyester can not be avoided completely. But a new and innovative design of the Back could avoid the use of PUR, see Fig.13.9. The Component Box shows that by avoiding

PUR the weight of the Back component can be reduced by approximately 30% and the contribution to global warming could be also reduced by 30%.

A Component Box can be established for each of the components of the office chair. With the help of the Decision Boxes successively improvement potentials for a product can be tracked and identified.

Fig.13.9: Left: current design of the component "Back", right: improved design avoiding the use of PUR (Ostad Ahmad Ghorabi et al., 2006)

SUMMARY



This lesson aimed at showing how and in which stage of the product development process environmental considerations can be implemented effectively.

Aiming at a product improvement an existing product is investigated and environmentally evaluated. Based on the results of the evaluation process improvement objectives and strategies can be derived and Ecodesign improvement tasks can be implemented in a re-design procedure. Various methods and tools therefore have been introduced through the previous chapters. The product development process was described more detailed in this chapter and it was shown how environmental considerations can be integrated into the process.

The Ecodesign Decision Boxes were introduced to show how environmental considerations can be integrated into the very beginning of the development process when aiming at designing a completely new product (in contrary to product improvement). The Ecodesign Decision Boxes can help the engineer in product development to make the right (environmental) decisions of the design in the decisive early design stages, i.e. when thinking about concepts, materials or processes.

HOME EXERCISES

1. Consider your product:
   z. How is your product manufactured? What techniques were used?
   aa. How do you believe the environmental impact of the product can be reduced by changing the design? Find some ideas (e.g. by using brainstorming) and prepare some sketches for an improved design of parts, components or the whole product.

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ADDITIONAL READING MATERIAL (AVAILABLE ON CD)

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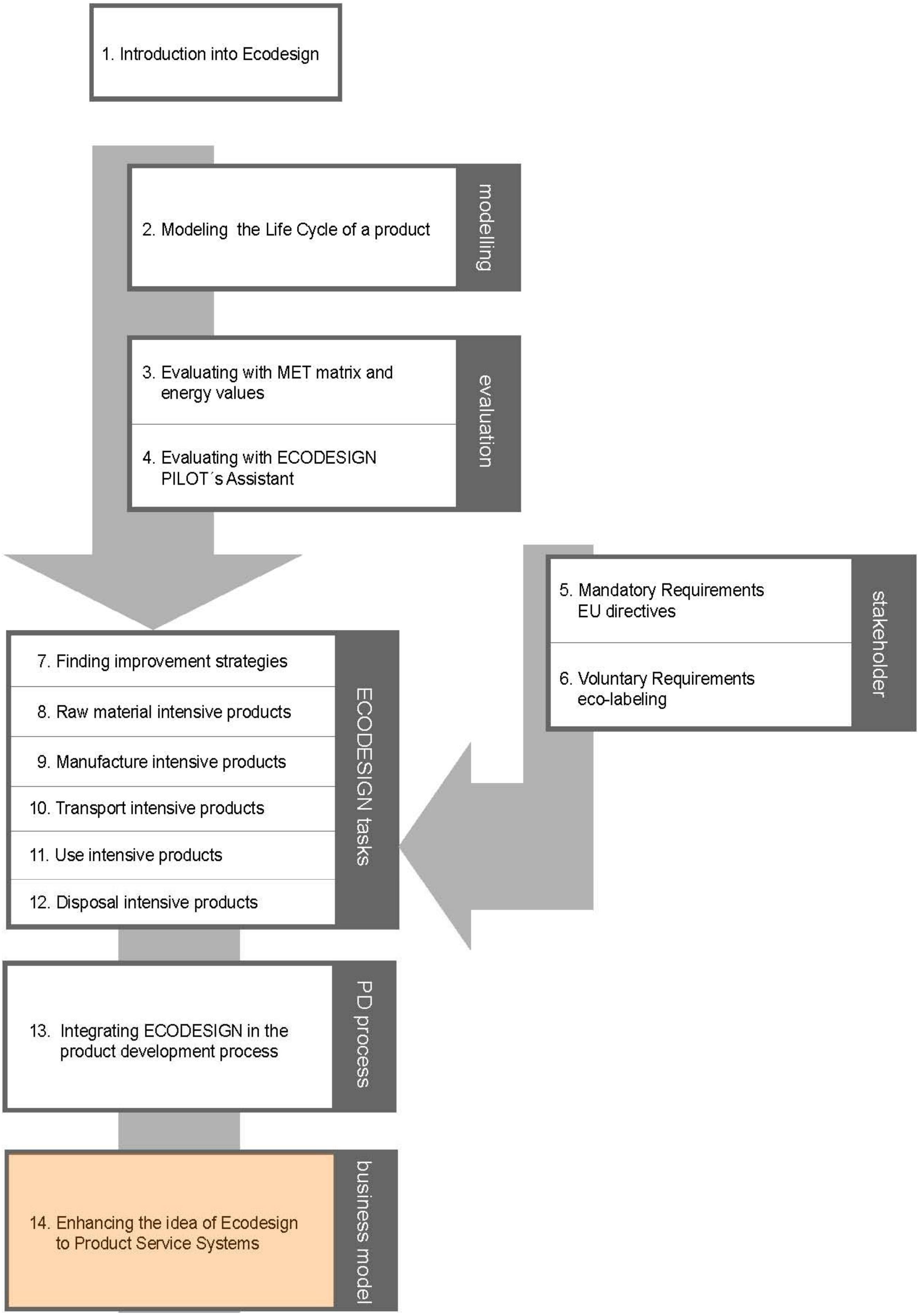
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PD process
14. Enhancing the idea of Ecodesign to Product Service Systems
business model

LESSON 14

Enhancing the Idea of Ecodesign to Product Service Systems

KEYWORDS: PRODUCT SERVICE SYSTEMS (PSS), CONSUMER NEEDS, PRODUCT USE

Lesson objectives

In this lesson the basic idea of Product Service Systems (PSS) will be introduced.

The concept of Ecodesign was introduced and described through the previous lessons. As already discussed Ecodesign considers all life cycle stages of a product, starting with the use of raw materials, manufacturing, transport, use and end of life and aims at avoiding or reducing the environmental impact of a product through all life cycle stages. The improvement objectives and strategies gained by the concept of Ecodesign so far are focused on product design and product development. A critical attribute of Ecodesign is that the products still stand in the forefront. This means that businesses create value through the sale of products. The more products are made and sold the higher the turnover. Value creation and material use is tightly coupled.

The concept of sustainable Product Service Systems (PSS) focuses on the use of the product. The production and sale of products no longer stands in the forefront, rather the use for the consumer. It is based on the idea that the use of the product has to satisfy consumers' demands and needs and raise life quality and life comfort. In many cases the consumers are not necessarily interested in the product itself (e.g. washing machine), but rather in its services and functions (washing of dirty clothes and drying the clean clothes). This transition from the sale of a product to the offer of Product Service Systems can be a contribution on the way to sustainable development.

A "sustainable service" takes into account consumers' behaviour changes and the acceptance of products. Sustainable services try to include environmental, social and economical aspects of sustainable development.

In this lesson it is aimed to further enhance the idea of Ecodesign which is a product design orientated concept to product services which is a consumer and product use orientated approach. Various examples will help to clarify this approach.

At the end of this lesson you will get familiar with the concept of sustainable Product Service Systems. You will have an idea of how Ecodesign can be enhanced and how and which consumer needs can be the main focus of product development and services.

The development of Product Service Systems will be demonstrated using S-curves, see Fig. 14.1. An office chair will be taken as a case study.

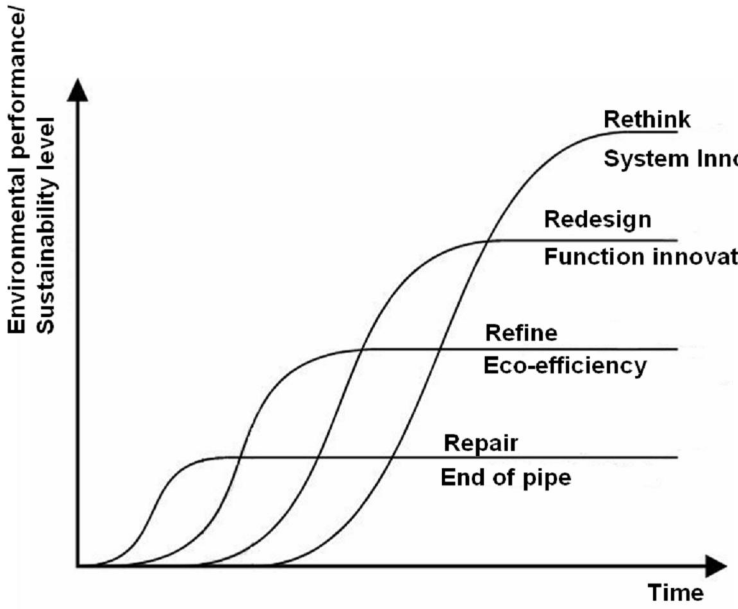

Fig.14.1: S-curves of the four R-levels

The environmental responsibility within companies grows over time in a pattern which can be illustrated as an S-curve. The S-curve can be divided into three phases:

1. Initial phase: this phase is limited by the effectiveness of a certain technology
2. Growth phase: the environmental performance is improved gradually
3. Limitation phase: the environmental performance can not be improved further due to technical limitations

Once technological limits are reached, new radical innovations are needed to obtain an improved environmental performance which involves fundamentally different ways of doing business. A radical innovation can be shown as a switch to higher level S-curve, representing alternative and competing technologies. This jump to a higher level of a S-curve will be explained using the office chair example.

Tab.14.1: Characteristics of the 4-R levels (Ölundh, 2006)

In the following table the S-curves characteristics of the four R-levels namely Repair, Refine, Redesign, Rethink are described in detail.

Characteristics	Repair	Refine	Redesign	Rethink
Environmental ambition	Solve urgent problems in products	Improve eco-efficiency	Needs to be set at a business level at an early stage in the project.	Dematerialization is the aim; the focus is on the whole life cycle of the total solution. The ambition needs to be set at a business level at an early stage in both service and product development.
Solution elements	Product	Product	Product	Products or new business concepts which are the elements in an integrated solution involving services, products and delivery of services.
Organisational units	Mostly product developer	Mostly product developer	All functions related to product development process also including business planners, product planners and industrial designers	All functions related to developing services, products and delivery systems during the product's life cycle, including business planners, service developers, product planners, product developers.
Innovation ambition and potential	End of pipe solutions, solve urgent problems	Improve the eco-efficiency of an existing product	Improve functions of the product, focus on the life cycle of a product.	System innovation in regard to services, infrastructure, products and user behaviour.
Process characteristics	Mostly performed in late product development stages. Environmental checklists and guidelines.	Mostly performed in late product development stages. Environmental checklists and guidelines.	Process is exploratory, iterative, and innovative. Focus is on the early stages of product development.	Business development level. Both service and product development affected; Innovative, collaboration of several levels in the company for the product's life cycle is needed early on.
Example: Office Chair	Recycling of the chair	Changing the materials of the base component	Designing a multifunctional chair for a long lifetime	Providing a chair in a Product Service System

EXAMPLE: OFFICE CHAIR

"Repair": The producer of the office chair is doing business as usual and is not aware of the environmental effects of the product. The profit of his business depends on the amount of products sold. The environmental responsibility of the producer is limited to "repairing" and end of pipe solutions, which, in this case means that the product is produced and sold first and afterwards environmental impacts are taken into consideration.

In case of the office chair, the first R-level means that the chair could be collected and recycled instead of dumped on landfill sights when reaching its end of life stage.

"Refine": In the next level the producer is not only thinking in terms of end of pipe solutions but is also considering eco-efficient products which are both environmental friendly and economical. In our example the energy efficiency of the component "base" of the office chair can be reduced to 1/6 by changing anodized aluminium to painted steel. This factor is also displayed in the costs for raw materials and manufacture of the base.

"Redesign": At this level the company's strategy to improve the environmental performance of the product lies in the redesign of the product. Strategies for environmental improvement of products have to be shifted into the early stages of product development. One strategy in this case could be to design a chair for a long life time. To achieve this goal, the office chair has to provide the possibility to be upgraded. For example the office chair can be upgraded with arm rests; also the seat can be upgraded from a fixed one to an adjustable one.

"Rethink": To reach the 4^{th} level a radical innovation is needed. This is realized by changing the whole system into a Product Service System. The production and sale of products no longer stands in the forefront, rather the provision of the use for the consumer. The Product Service System is based on the idea that the use of the product has to satisfy consumers' demands. The consumer is not necessarily interested in the office chair, but likes to sit comfortably. The producer leases or rents the office chairs to the customer and is responsible for the maintenance. The producer takes back the products for maintenance in case the office chairs become defect, need new functions or are out of fashion. Then the products are dismantled, repaired, upgraded with new functions or just covered with new textiles and brought back to the customer. Therefore it is very important that the product is designed for disassembly as shown in Fig. 14.2.

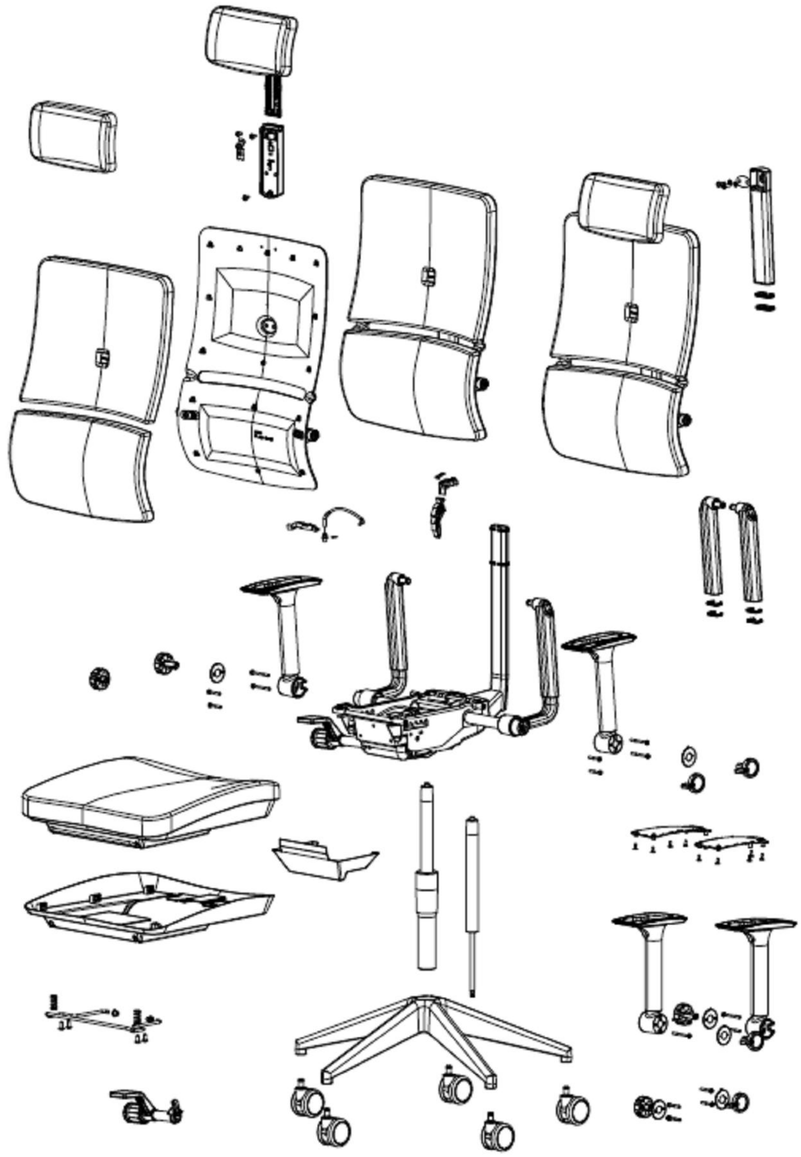

Fig. 14.2 Dismantled office chair

Each customer has individual demands which are directly communicated to the producer and taken into consideration during the product development process. This response to the customer's demand helps to become manifest in market position.

In the concept of sustainable Product Service Systems the focus of thinking is shifted from a production and sales orientated approach of products to the provision of use for the consumer. This focus implies the satisfaction of consumers' demands.

Sustainable services try to address all three dimensions of sustainable development, namely social, economic and environmental parameters. In the following Tab. 14.2 some statements of the product orientated approach and the service orientated approach are compared.

Tab.14.2: Comparison of product orientated and service orientated approach

Product orientated approach	Service orientated approach
Thinking in products	Thinking in solutions
Value creation by sales of units of product	Value creation by sales of units of use
Product sales price	Value of use over lifetime of product
Owing product	Consuming without owing
Material flows	Services
Garbage society	Repair society

A Product Service System is a system of products and services including supporting infrastructure that is designed to be competitive and to be able to satisfy customers' needs. These systems do not contribute as much to environmental impact as traditional business models. A Product Service System can be offered by one company or by an association of companies. It can include products with additionally services or services with additionally products.

Product Service Systems can help to make the use of products more optimal, effective, intensive and long-term.

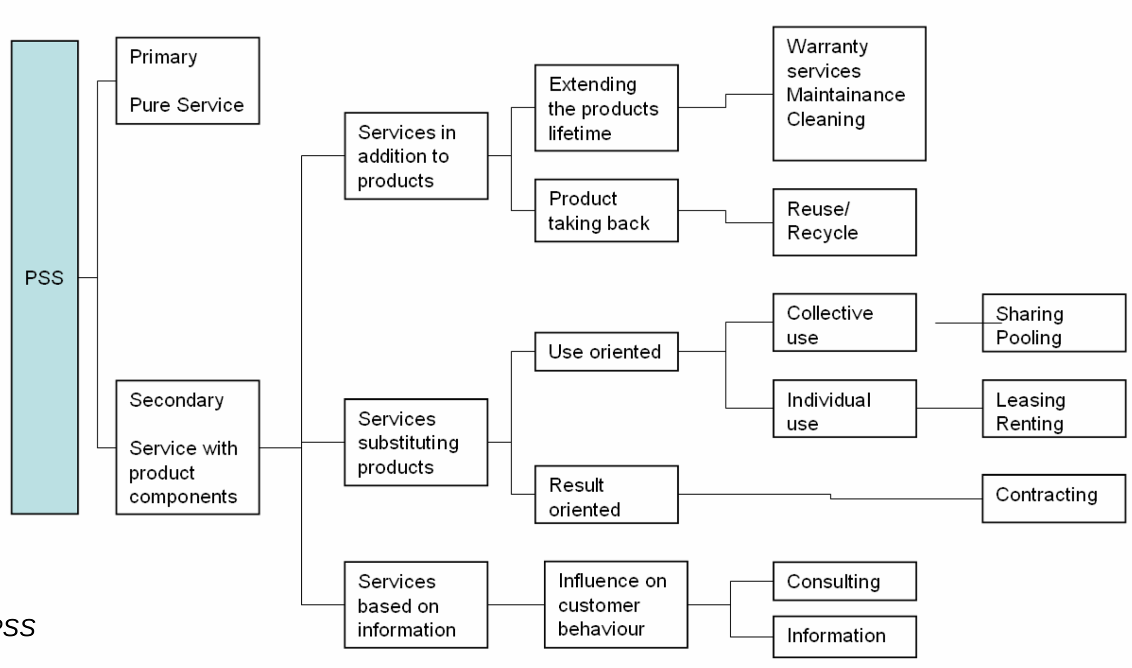

Fig.14.3: Classification of PSS

Focusing on Product Service Systems two different approaches can be defined: primary services which are pure services and secondary services which are services with product components. Different to primary Product Service Systems the main focus for the productive industry lies on secondary Product Service Systems as shown in Fig. 14.3. The service can either be added to the product or the service can substitute the product completely.

What do you think are the main profits for companies providing a Product Service System? What do you think are the main advantages for consumers using a Product Service System?

Services in addition to products such as maintenance, upgrading or warranty services aim at extending the product life time and are covered by various concepts of Ecodesign. More promising approaches of Product Service Systems are services substituting products: the producer remains the owner of a product and sells the function.

Result oriented services provide the result to the consumer. The customer may need heat to warm his house. Contracting solutions for heating systems may be the appropriate result oriented service here fore.

Use oriented services focus on the use intenseness of products through selling units of use. This can be distinguished between individual use (leasing, renting) and collective use (sharing, pooling).

By looking at the market closely it is sometimes not easy to find the difference between products and services. In practice there are a lot of examples which are neither a pure product nor a pure service. Products include some services (e.g. delivery), and services require the use of some products (e.g. concierge service).

In the following, examples of “mainly” products, products with more or less services and examples of primary services are for the demand “living” is listed (Jasch 2006):

Mainly product:

- Common rooms
- Insulation of buildings
- Use of rain water

Services in addition to products:

- Deliveries, Food on demand
- Labels for materials, colours, cleaning

Use-oriented:

- Car sharing
- Wash saloons with pay per wash

Result oriented:

- Energy, water and waste contracting

Mainly service:

- Consulting on environmental and energy issues
- Concierge service
- Neighbourhood-based concepts: Barter shop, resident-to-resident services

PRODUCT EXAMPLES

In Tab.14.3 some examples for Product Service Systems in different fields are listed and described to show which Product Service Systems already exist.

Tab.14.3: Examples for Product Service Systems

Field	Example for a Product Service System
Mobility	Car-Sharing City Bike
Information and communication	Single use camera Leasing of copiers
Cleaning	Laundry services, pay per wash cycle
Clothing	Leasing of clothing for work, textiles
Living	Energy contracting

Car-Sharing

Do you know the dilemma: you need a car for a certain time or just on weekends but you don't want to buy or owe a car because it is too expensive and it causes too many expenses for maintaining (e.g. fuel or insurance)?

The alternative for using a car is sharing a car with other people. Car-sharing is a service of using a car without owning it. By paying a annual fee you can rent cars or vans whenever you need it and you only pay for the service you really use. You can book the car via call centre or via online reservation of the car you need. For the booking a special card is needed. This card is also the key for opening the car. The key for driving and the papers are inside the car. After using the car can be parked at one of 200 parking areas around Austria. The fuel use and the driven kilometres are calculated together with insurance and motorway fees and have to be paid monthly.

The benefits for the user are clear: you have a car whenever you need one, you only pay for the period when you use the car and you don't have continuous expenses. Another benefit is that, depending on what you want to do, you can rent different cars: small ones, luxurious ones, vans or cross-country vehicles can be named amongst others. In combination with public transportation you can be mobile without owning a car.

Link: http://www.mobility.ch

Leasing of copiers

A widespread example for Product Service Systems is the leasing of copiers. A lot of copy shops as well as other users (offices, bureaus...) do not owe the machines; they rent or lease it from the producer. The producers are responsible for maintaining the machines. To be able to maintain the machines and to ensure a long life time the product is designed for recycling and reusing. Requirements from Xerox company's design department on their products are for example: easy to disassemble, small amount of parts used in the product, modularity, etc. At Xerox the reuse and recycling rate is between 70 and 90%. The copy machine is installed where to customer likes it to. He also benefits from the maintenance services. The producer benefits from a closer relation to his customers and has the possibility to respond immediately to the customers' demands. The environmental profits follow from the long lifetime of the product and the optimized use of the product.

http://www.xerox.com

City Bike

Another example of Product Service Systems is the free available CityBike of Vienna. To become a Citybiker you need to register with your credit card or you can apply for a special CityBike card to access the bikes..

The target of the new transportation system is to ease the switch for e.g. car to bicycle. Short trips can easily be done by bicycle. Studies show that 50% of our daily routes lay within 5 km. Therefore a bicycle can be used effectively to cover these routes. Several City Bike stations guarantee that the system works well. In Vienna there are 50 stations and in every station about 10-20 bicycles parked.

http://www.citybikewien.at

Leasing of clothing for work, textiles

Mewa provides textile services which allow customers a continuous supply of clean textiles (owned and maintained by Mewa). The customer does not need to buy, clean or dispose them.

The service concept is eco-efficient in several ways: First, by using returnable textiles which can be reused up to 40 times as opposed to one-way paper towels the company contributes to saving primary resources and reducing the amount of wastes. Second, by optimising the washing technology (e.g. cascading, water treatment facilities) and recovering waste oils from the textiles for use in internal energy production the concept creates an additional benefit for the environment. Last but not least, the client profits from the fact that the need to dispose hazardous waste (the polluted textiles) is completely shifted to the service provider which thereby save costs for disposal.

http://www.mewa-service.com/

Single-use camera

Single-use cameras which are also known as 'recyclable,' 'disposable,' and 'throw-away' cameras are cameras which are sold with the film built-in. After you take your photos, you can bring the whole unit to your photo processor, who opens the camera with special tools, develops your pictures and returns the camera to the recycler of e.g. Kodak. The recycler dismantles the camera, tests it, changes the damaged parts, puts a new film inside, packs it and sends it back to the market.

Actually you do not buy a product, you buy a service of "taking and developing pictures" with a nice looking camera.

Single-use cameras are designed to be easily reused and recycled. Kodak claims 77 percent recycling and reuse rate by collecting 100 millions of Single-use cameras.

Single-use cameras are not expensive, readily available, easy to use, and some even have special features such as a wide-angle lens or are waterproof for underwater photography. .

The ecological footprint of a single-use camera is 50 times better than the ecological footprint of a reflex camera. (Schmidt-Bleek, 2004).

www.kodak.com

Laundry service

Laundries are a typical example for using a product without owning it. In a laundry washing and drying machines are provided mostly over 24 hours a day. The service in a launderette is a use-oriented service where units of use are sold. The ecological advantage is that in a launderette effective washing machines for intensive use are provided and therefore less water and less wash detergent is needed. But on the other hand it is very important where the laundry service takes place, in the customer's apartment house or in the neighbourhood and also which means of transportation are taken. By taking a car the rebound effect is quite high. This means the ecological advantages are eliminated, or are even negative.

Energy contracting

Energy contracting stands for a contractual relation between an energy service company and a client which is mainly aimed at the reduction of the client's energy costs.

In case of energy contracting two forms can be differed:

- Performance-Contracting

The contractor takes measures intended to reduce the energy need and to enhance the efficiency of the customer's plants. It therefore consists of modernisation and optimisation methods, which are limited in scope compared to plant-contracting. The measures are usually planned, financed and conducted by the contractor. Measures taken are for example isolation of tubes, change of light bulbs, installation and optimization of control systems e.g. for lightning. The refinancing normally results from the guaranteed saving of energy costs. Performance-Contracting can be applied to fields such as lighting plants and system controls or pumps.

- Plant- / Operation-Contracting

The contractor plans, finances and constructs the technical plant designed for energy supply, and operates and services it when needed. The customer pays for the used energy a defined prize in €/kWh. With this amount all the costs of the contractor e.g. financing, maintenance, and administration are covered. On the basis of the high specialization of the contractor and of the cheaper purchase costs the contractor can make a prize for a energy unit which is below the costs the customer would have achieved by his own initiative.

OUTLOOK

What are the chances of Product Service Systems?

Sustainable Products and Services are the possible and promising answer to future challenges of a sustainable development of our society. This is due to the care of both the production side as well as the consumption side.

Prospects and challenges for the company

In many cases the development of sustainable products and services is not easy and requires radical innovations which include a change in the way of thinking.

Prospects and advantages for the service providers are:

- Innovations open up the chance to develop new business fields or define new markets. Innovations secure the long-term success of companies.
- To provide Product Service Systems you have to know the needs, expectations and use behaviours of the consumers. By including the consumer's requirements in the product development process you have a competitive advantage.
- Product Service Systems go beyond the point of sale. This means a long-term relation to the consumers beyond the products lifetime. Companies should intensify the quality of consumer relations and consumer loyalty.
- Economic growth is decoupled from the resource input. Thus resource productivity can be increased and the dependence on non-renewable resources can be reduced.
- The design of Product Service Systems means to take the responsibility of products in terms of impacts on the environment and the society. This means future law-requirements in context to product liability and product take back (like in the electronic sector) can be neglected due to foresighted acting. Prevention is better than cure.
- Different product design due to growing the importance of take-back, disassembly, refurbishment, reuse, etc.

Advantages for the consumer

For a successful implementation of a Product Service System acceptance of the consumers is necessary.

- Product Service Systems raise the consumer's acceptance. The consumer gets special solutions for his problems and not only a product.
- In many cases the consumer does not need a product; he is interested in the function of it. Additionally the function should be obtained comfortable, cheap and very long lasting.
- By using Product Service Systems the consumer acts like a partner of the company. The consumer feels good attended, consulted and his requirements are taken seriously.
- Product Service Systems transform the customer to a consumer and not to an owner of the product. Thus the consumer does not have to make big investments.
- The consumer is not owning a product and therefore much more flexible.

There are a lot of advantages for the consumer but one should be aware of the differences between business-to-consumer (b2c) where a product is sold to private consumers and business-to-business (b2b) where a product is sold to an enterprise or business consumer. In the private sector factors such as symbolic status effect of a product or the reputation of having a product still plays an important role.

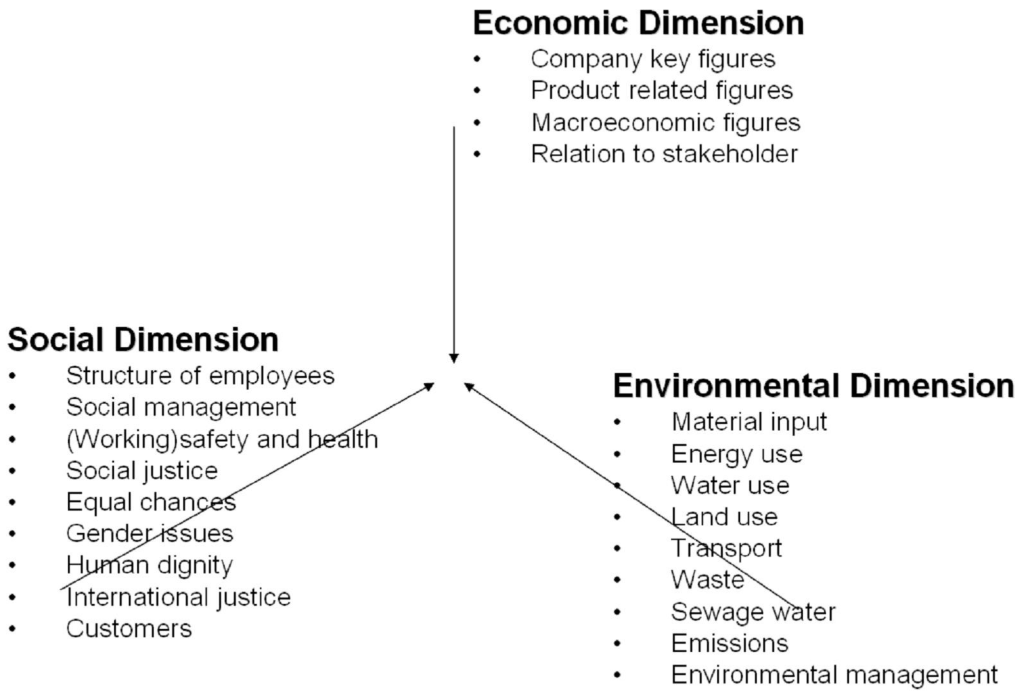

Fig.14.4: Some Criteria for the assessment of Product Service System (Jasch, 2006)

Sustainability and Product Service Systems

Companies provide a combination of services and products. Product Service Systems are able to make the use of products more optimal, intensive and long-term. However, the sustainability of the Product Service System depends on the design of the system elements. Each Product Service System represents the individual solution for the fulfilment of the consumer's needs. Therefore the sustainability profile has to be evaluated case by case. Evaluation methods should include indicators that are based on environmental, social and economic effects.

Product Service Systems are not necessarily more sustainable than pure product solutions. In fact, it depends on the basic framework conditions of the user and the product. There is also often a rebound effect, which refers to the reverse part e.g. negative impacts on the environment of the intended positive impacts on sustainability. For example if you decide to wash your clothes in a laundry, the transportation has to be taken into account. Also in case of taking a delivery service, the transportation displays a rebound effect.

SUMMARY

Looking at products and improving their environmental performance over the products' life cycle is very important but it is also important to look at the whole system; It is not enough to redesign the product based on environmental considerations, but it is necessary to rethink the whole system. Who is using the product? How often is the customer using the product? What does the consumer really need and how can his demands be fulfilled?

Therefore Product Service Systems as a combination of products and services are an appropriate approach. Product Service Systems are one possible answer to future challenges of a sustainable development in our society. Here the production and sale of products no longer stands in the forefront and economic growth is decoupled from the resource input.

However, the sustainability of Product Service Systems depends very much on the design of the system elements. Each Product Service System needs different solutions for the fulfilment of the individual needs of the customers. Therefore the sustainability has to be evaluated case by case.

It is also important to consider the rebound effect when thinking of using Product Service Systems. For example if using a delivery service of organic food the transportation has to be considered as rebound effect.

Product requirements for products within a Product Service System are different to usually sold ones. A product provided together with a take-back solution has to be designed for easy dismantling, easy repair and easy upgrade to secure reuse and to secure a long lifetime of the product.

HOME EXERCISES

1. How does a Product Service System look like for your analysed product?
   - bb. Give a short description of the system. Which infrastructure is needed? How are they linked together?
   - cc. What are the requirements to the product? Is the design of the product suitable for offering a Product Service System?

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APPENDIX 1

List of Figures

APPENDIX 2

List of Tables