Ecodesign of electronic devices

UNIT 6: Lifecycle of electronic devices

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Chapter summary:

- Lifecycle analysis
- Lifecycle of ecodesigned electronic devices
- Methods of evaluating lifecycle

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6.1. Lifecycle

Fast technological development of electronics has lead to the fast-growing trend of new electronic devices with improved functionalities and integration. New devices weight less, are smaller and have more functionalities and options for use. All this gives higher advantages in the use phase and increases user interest. With growing complexity of devices and increased functionalities, the device lifetime is shortened. The use of hazardous and potentially hazardous substances presents a great threat to humans, as well as the environment that we live in. Due to this, manufacturers of electronic devices and their suppliers will have to confront a series of important challenges in the near future that will have an effect on their business. These are, amongst others, the new directives by the European Union that implement guidelines on design and production in an environmentally and profitable way. On the other hand, we need to confront the requirements and expectations of customers and society. But it is not enough that they face the expectations of the near environment. We need to focus on the whole product lifecycle and the stakeholders (the customers), including the success of the final product.

Ecodesign of electronic devices is intended for development of electronic products in a way that we decrease environmental effects through the whole lifecycle. This means that ecodesign is based on the evaluation of the device lifecycle. The effect that the device has on the environment has to be studied and decreased in all lifecycle phases. These phases include the gathering of resources, production, marketing, distribution, use and final disposal of the product, as shown in image 1.

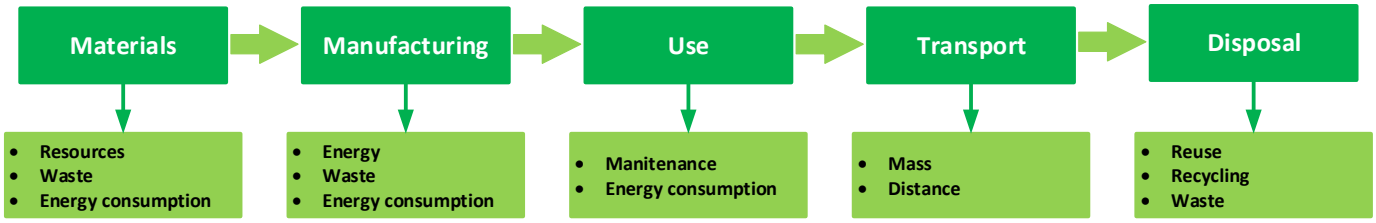

IMAGE 1: THE MOST IMPORTANT PHASES OF ELECTRONIC DEVICE LIFECYCLE

Environmental effects in each phase are:

- **Input:** used energy, resources.
- **Output:** Emissions to earth and air.
- **Production of solid waste.**
- **Issues with occupational diseases and safety.**

The method of evaluating lifecycle highlights the main areas of environmental effects that may have been invisible in the phase of production, transport, and disposal.

Ecodesign includes design processes that decrease use of materials and energy and at the same time increase the probability of reuse and recycling. With a detailed understanding of materials that are used in products, we can avoid using potentially hazardous substances.

6.2. Ecodesign and lifecycle evaluation

Ecodesign can be presented in multiple ways. Each company has a different environmental problem, related to their products and services. The company can come closer to ecodesign by using different strategies and considering laws and directives. For example, external factors, such as compliance with the newest environmental laws. These can define a strategic agenda for environmentally suitable design. Internal factors, such as energy use also have the leading role in determining the priority tasks for environmentally suitable design. The company is responsible for studying the processes and materials that are present in their specific system and which strategies to use. Use of the correct strategy will enable the company to include all their requirements in the design process. For designing an ecological electronic product. The following general strategies can be used:

- **New development concept.**
- **Physical optimization.**
- **Choice of material.**
- **Product optimization.**
- **Optimizing operations.**
- **Disposal and recycling of the product.**

Implementation of only one strategy from the above mentioned will not lead to an ecological product. For such product, it is necessary to implement most of the mentioned strategies.

The new development concept is a common strategy for the development of newer ecologically suitable devices. This means implementation of innovative strategies, such as non-materialization, dematerialization, lifecycle design and development of new services in new product design. At the same time, it is necessary to guarantee that the device fulfills all consumer needs. Non-materialization is the replacement of physical with non-physical product or service. Dematerialization contrary is the use of less or new resources for the production of the same products. Dematerialization can cause reshaping of the product in order for certain materials to be recycled. With this, we get the possibility of reuse of materials in new products and ,therefore, decrease use of resources. Each designer has to perform an analysis of consumer needs to recognize the trends and functionalities, meaning they are evaluated and become the key in the development of new devices. The designer must not only designer “green” products that are ecological when in use, but the design has to be lead

in a way that included the whole device lifecycle. This means that the concept “from cradle to grave” or “from cradle to cradle” have to be considered. The concept “from cradle to cradle” is suitable for devices that can be recycled. The new development concept can also include common use. This means that the product will not be only in possession of one owner, but it will be available for use to multiple users. The typical devices are copy machine, printers, dishwashers and washing machines, etc.

Physical optimization is a strategy of product design with the intention to increase reliability and improve functions that would improve the ecological profile of the device. In order to achieve this, we need to research the following areas:

- **The increase of lifetime and product reliability.** Prolongation of product lifetime can directly decrease environmental impacts. Products with longer lifetime save resources and create less waste as they are not replaced by similar devices for a longer period. Prolongation of lifetime also means prolongation of operational period. Product lifetime can be measured by a number how many times has the product been used, length of use or even complete lifetime including the time when the product is disposed. The lifetime can be prolonged with modular product design. The modular devices enable constant adjustments or serve multiple functions. The adjustable structure enables improved technical or esthetical product appearance. The product can also follow the changing needs of the end consumer. The modular structure enables that the new technologies are included in older products. Consequently, the modular product can be upgraded during the lifecycle which decreases the need for purchasing a new device. Also, the products with interchangeable parts are suitable for the modular structure of the device.

  The main characteristic of a reliable product is its resistance to wear or environmental degradation. But there need to be used materials that guarantee sustainability if needed. The designer should not choose permanent materials for shorter functions unless they want to use them after the lifecycle. Prolonged sustainability and reliability can be a part of a wider marketing and sales strategy. Environmental impacts are closely related to product reliability. Unreliable products are quickly discarded, which causes more environmental effects and increases costs. Reliability has to be assured in the initial design with a decreased number of parts or simplified design.

- **Optimization and integration of functions.** With the integration of multiple functions in one device that uses the same components, we save on the used materials, as well as decrease device sizing. The typical examples are multifunctional devices that include printing, copying, and functions for sending messages. Functional integration and optimization

can cause new environmental design ideas, which also increases the added value of the product and opens new markets.

- **Simple maintenance and repairing**. Product maintenance included periodical and preventive maintenance work and repair of errors. Suitable maintenance will maintain and enable a longer lifetime. The designer needs to have a tendency to develop products that can be easily maintained with relatively unqualified users. These users need to be given access to all needed parts and components. The maintenance processes have to simplify. Some useful information also needs to be clearly stated, such as maintenance frequency, processes for troubleshooting, disassembly, needed tools and expected lifetime of the components. The designer has to design a product that can be repaired when needed - the lifetime will prolong if the device is based on interchangeable and standard parts. The product repair has to be cheap. Easy maintenance and repair not only decrease environmental impact but also decreases costs of use.

  Choice of suitable materials in ecodesign can decrease environmental effects related to depletion of resources and lifetime management. The key goals of this strategy are prolongation of lifetime, reduction of material consumption and general use of materials with smaller environmental effects. Choice of material characterizes the product characteristics and its lifetime. Lifecycle evaluation is an approach that can inspect alternative scenarios. This way we can examine the choice of different materials and different possibilities for disposal or recycling. In most cases, we can find substitutions that prolong lifecycle without problems and that are not in opposition to the requirements regarding costs and efficiency. Replacement of materials can be done for processing materials, such as solvents and catalysts. Reformulation of processing material can be a less drastic alternative for replacement of all materials. Instead of completely replacing one material with another one, we can change its composition and achieve the same result and environmental conditions.

- **Material recycling.** Recycling can be a very efficient solution for resource management. However, recycling plan is not the final strategy for reduction of all product's environmental effects. Use of materials that can be recycled can decrease the amount of waste on landfill, however effects of recycling on the environment also have to be examined. Here are some ecodesign principles that improve the recycling process:

  a) The product is easy to disassemble.

b) Material identification is guaranteed.
c) Simplified product parts.
d) The possibility to choose the material and compatibility check.

The quality of processed material has an important role in efficient recycling. There is no need for the use of materials of low quality because such materials cannot be recycled. A quality recyclable material can be incorporated in devices in a way that they can be separated easily or simply disassembled with mechanical or chemical processes. Ecodesigning should include as many recyclable materials as possible, for example, steel, aluminum, paper, cardboard, plastic, gum, and glass.

- **Renewable materials.** Renewable materials are those that can easily regenerate themselves in the environment. Such examples are materials made of plants of animal resources. When thinking about using renewable materials the effects through the whole lifecycle need to be examined. For example, a plastic bag can be a better solution than paper. The plastic bag production causes less air, water, and solid particles pollution than production of paper bags. Since plastic weights less than paper, less energy is used for transportation and less space is used in landfills. Even in many modern landfills with biodegradable materials, such as paper decompose very slowly. By all means, the plastic is far from a perfect material. Unlike paper, plastic is made of non-renewable resource-oil and is not biodegradable.

- **Use of less material.** Designers should in ecodesign strive for reduced use of resources in the development of new products. Reduced use of resources and energy sources means lower production costs and less waste that needs to be recycled or disposed after product lifecycle. The designer needs to guarantee that volume and weight of used materials are optimized, in order to use less energy for production, transport and storing. Reduced quantities of packaging materials will also decrease the total material content of the product. Furthermore, when the product and its packaging decrease in size and volume, more products can be transported with the same vehicle.

- **Materials with lower energy value.** This strategy refers to the use of materials that are produced with minimal energy for extraction, processing, and purification. This quantity of energy is named “embodied energy”. Whenever it is possible, the most energy efficient suppliers should be included in the material supply plan and material use plan. Materials, produced with higher quantities of energy, will, in general, be more expensive.

- **Use of materials with lower environmental effects.** Hazardous materials can directly or indirectly cause a larger problem during their use or when the device is treated as waste. For example, hazardous materials can cause poisoning, breathing problems and other illnesses.

Production processes need to be optimized to decrease use of materials, energy consumption and waste production. This can be achieved by reshaping the existing processes or removal of unnecessary production steps. Important steps in process optimization are:

- **Alternative production processes.** Processes that cause extensive environmental effects need to be replaced by alternatives. However, the effects of these changed on costs and performance need to be evaluated beforehand. Designer has to be notified on the best available technologies and equipment for completion of the processing process, preparation of alternatives need to be evaluated within lifecycle in order to provide a reduction of all effects. Engineers and designer need to consider also chemical, biological and mechanical alternatives.
- **Fewer production steps.** Process optimization includes reduction of production steps and improves the production process and its efficiency. Reduction of production steps is often linked to the introduction of new technological solutions and processes. Also, with the implementation of new technologies, new processes need to be evaluated from the financial and ecological perspective.
- **Controlling production process.** Control systems are integral parts of planning processes. Well designed process control can decrease pollution and save the resources. Production of products that are in the same area can cause the creation of large quantities of waste. Determination of suitable deviations improves precision and directly decreases environmental effects. Improvement of regulation compliance will decrease the probability of environmental fines and decrease costs. Simple approaches can significantly decrease environmental effects and energy consumption, for example with the installation of control devices that turn the device or process off when it is not in use.
- **Production with low energy consumption.** Energy consumption can be decreased with process planning. For example, waste heat can be used for preheating of process flows. Furthermore, the energy for pumping can be decreased with use of larger diameter tubes which decreases losses caused by friction. We can save with energy with the use of more efficient processing equipment, for example with highly efficient engines and fans that are highly efficient. Appropriate maintenance and equipment use can also significantly influence energy consumption.

- **Less waste.** Optimization of processes decreases waste production. This way we can achieve more efficient use of materials which results in less waste on landfill.
- **Incorporation of renewable resources.** Solar and heat systems can be used in heating processes in lower and middle-temperature range. With these measures, the use of fossil energy sources can positively influence the environment. Unlike conventional energy system, the use of solar energy, in the beginning, requires relatively high investment. But it consequently leads to decrease in costs during its use. Current prices of energy sources in demand can lead to longer payment terms, but we need also consider reduction of emissions and that the removal of uncertain markets brings a more reliable business environment. Wind energy is another great example of alternative resources for production of electrical energy with significantly lower environmental effects.

Optimization of product distribution with the use of more efficient transport systems and packaging can also decrease costs and reduces environmental effects.

- **Packaging:** Products need to be packaged in a way that enables simple transport without any damage. To guarantee this, the following strategies are used:
    a) Packaging reduction.
    b) Some products can be distributed without packaging.
    c) Use of products suitable for recycling or reuse.
    d) Replacement of materials with less hazardous ones, materials that are easier to handle and degradable materials.
- **Transport:** Product transport can be optimized with the following strategies:
    a) Use of efficient energy transport.
    b) Maintenance of transportation vehicles.
    c) Optimized vehicle capacities.
    d) Providing appropriate management of hazardous substances.
    e) Optimization of transportation routes to decrease distance traveled.
    f) Decreasing product sizing.

High consumption of energy and other consumer materials during device lifetime greatly contributes to its general environmental efficiency. Optimization of energy efficiency and a consequential decrease of large consumption will lower the emissions and waste production. Here are a few techniques for product optimization:

- **Cleaner energy sources.** Use of renewable energy sources will decrease use of fossil fuels which leads to lower emissions. Rechargeable batteries can be used where this is suitable. For industrial products or machines, it is also a suitable use of cleaner energy, such as natural gas or sources with lowe sulfur content. Where there are no possibilities for other energy sources, an increase of device efficiency is the only possible solution.
- **Lower energy consumption.** Energy efficiency decreases use of electrical energy or fossil fuels and decreases emissions, especially for energy-intensive products. Energy consumption became a marketing tool for manufacturers of household

appliances, such as refrigerators or washing machines. Energy used in devices when in standby mode is also an important indicator of its efficiency. Insulation improvements in heating and cooling devices can decrease energy consumption and contribute to lowering of emissions.

- **Cleaner consumer materials.** Consumer materials have to be designed for reuse, processing or recycling. One example are batteries that need to be managed correctly at the end of their lifetime. Removal of filters and battery cartridges should also be reduced. The manufacturers have to provide consumers the data on disposal of consumer materials.
- **Reduction of consumer materials.** Reduction or efficient use of consumer materials can be achieved with the following ways:
    a) By designing products.
    b) By providing and following the guidelines on appropriate device use.
    c) By providing and following the information on appropriate maintenance.
- **Waste reduction**. When reuse or recycling is not possible, the device designer first has to guarantee that the quantity of waste that needs to be disposed at landfills drastically decreases.

Environmentally friendly alternatives for managing product and materials at the end of a lifetime include product processing for reuse or reproduction, material recycling or responsible disposal. The product management technique is influenced by several factors. These vary depending on the recycling process technology, material disposal techniques, processing, and economic justification. The techniques have to be evaluated depending on the environmental effects, as well as on sustainability. The environmentally designed product is the main factor in the implementation of environmentally friendly strategy at the end of product lifecycle.

- **Reuse**. Products have to be designed in a way that enables quick and easy to disassemble. Separate components should be suitable for reuse in the production of other product. Such products are faster to make because they are made of the original parts. Consequently, the company's profit is increased. Designing for reuse is not only good for the environment but also for reduction of production costs.
- **Rebuilding.** Rebuilding includes collecting of products by sorts and types, then follows cleaning and examination for repairs and reuse. Rebuilt products are assembled using the reused and new parts, where needed.
- **Designing for disassembly.** Designing for disassembly guarantees that the product and its parts can be reused, rebuilt or recycled after the lifetime. The following strategies are in use:
    a) Use of materials that can be easily recycled processed or reused.
    b) Use of fasteners and attachments that enable easy and quick disassembling.
    c) Designing product structure that can be disassembled quickly and cheap without damaging other parts.

- **Material recycling.** Recycling is the process of gathering the materials that can be reused in new products. Separation of different materials increases the value of recycled materials if we remove the contaminants and hazardous materials. The components can be separated manually or automatically.
- **Safe disposal.** If disposal is the only possibility that the consumer has, the designer has to do the following:
    a) Avoids the use of toxic or dangerous substances.
    b) Provides instructions on safe disposal.
    c) Uses biodegradable materials where this is possible.

6.3. Methods of evaluating device lifecycle

Since environmental awareness of consumers is increasing, the companies have started evaluating how their activities and production affect the environment. The society became concerned regarding the depletion of natural resources and degradation of the environment. Many companies have responded to these issues by guarantees on ecological characteristics of their products and use of ecological production processes. Ecological efficiency of products and processes has become the key question, and for this, the companies are examining ways of reducing their environmental impact. Many societies have benefited from examining how to achieve compliance with the strategies for preventing pollution and use environmental management systems for improving their environmental efficiency. A useful tool for evaluating device's impact on the environment is a method of lifecycle evaluation. This approach examines the complete product lifecycle (LCA – Life Cycle Assesment). The LCA process analyzes the device from the design start to decomposition, recycling or disposal at the landfill.

Society of Environmental Toxicology and Chemistry evaluates LCA as an excellent way of evaluating environmental impacts related to the complete product or service lifecycle. The "from cradle to grave" approach begins with the gathering of raw materials for product production and ends when the materials are returned to the soil. The LCA methodology evaluates all lifetime phases in terms of interdependence meaning one operation leads to another and so on.

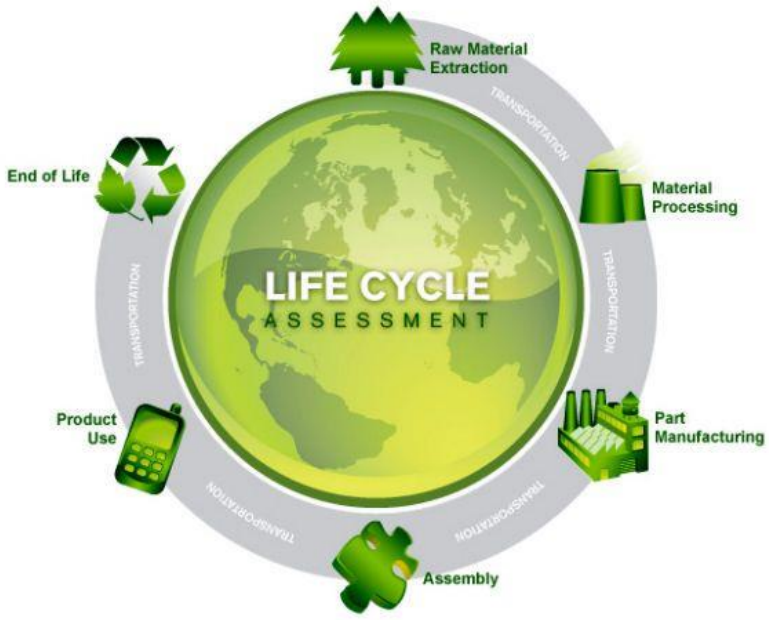

IMAGE 2: LIFECYCLE OF ELECTRONIC DEVICES

LCA enables evaluation of cumulative environmental effects that originate from all phases of the product lifecycle. Often the evaluation is given including the effects that are not considered in more traditional analyses, such as extraction of resources, material transportation, final product disposal, etc. By considering the effects through the whole product lifecycle, LCA provides a complete overview of an environmental characteristic of a product or process. We also gain a clearer view of actual environmental compromises in product selection.

The method of lifecycle assessment uses device or system modeling and different databases that evaluate the environmental effects of certain materials or components. Often LCA is connected to use of complex scientific methods that demand an advanced understanding of risky natural science and technical areas, such as mathematics, chemistry, biology, and physics. For easier understanding, we will present meanings and use of the lifecycle method in the development of electronic devices.

6.3.1 Benefits of using lifecycle evaluation for electronic devices

The method of lifecycle evaluation provides many benefits and possibilities for use. The latter will be summarized in the following points:

- **Improved device design.** Method LCA can be used as help in design and redesign. Companies can use LCA for comparison of environmental effects of the device and evaluation of different design possibilities. With this evaluation, the company can see if the device has environmental benefits or weaknesses. In this case, LCA enables systematic evaluation of environmental effects related to a specific electronic product.

- **Providing environmental information.** With the increased use of lifecycle method in the whole supply chain, the companies can share their data on environmental effects of their products to others in the chain. This information can be required by the government, other manufacturers or the general public. With the use of LCA, the industry has a prepared source of data. LCA quantifies input and output data of all phases of the lifecycle of production and the device. This way we can precisely analyze each phase and determine its environmental effects.
- **Marketing.** LCA can be used as a marketing tool. It is used in product development which shows that the product is improved from the ecological perspective. Use of LCA tool could be the driving force for the consumers who want to use environmentally friendlier products.
- **Financial benefits.** As previously mentioned, LCA evaluates the product's lifecycle and determines where the main environmental effects occur. These effects can be reduced by increasing device efficiency, using suitable materials and by different production technologies. The increase of resource use efficiency will lower the quantities of used resources. Consequently, less waste will be made, and the costs will be decreased.

Method LCA can be incorporated into different environmental management and environmental labeling systems. Certain competitive and business advantages also occur:

- **Environmental management systems.** Methodology LCA can be used in environmental management systems. For example, one of the goals of the environmental policy in a company is reducing environmental effects related to their products. LCA provides means for achieving this goal because it enables evaluation of environmental effects related to the product in the whole lifecycle.
- **Environmental labeling.** All national systems of environmental labeling that operate inside EU use LCA as a basis for defining criteria that all products need to meet in order to be awarded the environmental labels.

6.3.2 Use of lifecycle evaluation method for electronic devices

LCA is a technique that evaluates the environmental effects and potential effects related to the product or service. This is an analytical method that can help the company to evaluate all inputs and outputs of their production process. LCA provides an overview of environmental effects with gradual steps.

- First is the preparation of a list of suitable energy inputs, materials and environmental outputs (for example emissions, disposal of solid waste, separation of wastewater).

- Evaluation of possible environmental effects related to the defined inputs and outputs.
- Interpretation of results as the basis for decision-making.

Main areas of LCA are:

- The examination of the problem source, related to the product or service.
- Evaluation and analysis of possibilities for product or service improvement.
- Design of new devices and possibility to compare the product with other similar products.

Environmental policy is oriented on the device production and guides the companies to use of lifecycle analysis method. By describing the product lifecycle from cradle to grave it is possible to analyze all effects, consequences, and participants in the whole life chain. This way, it is easier to accept certain solutions and determine optimal design and use of the given product. Environmental management system EMS , such as ISO 14000 or EMAS work on achieving environmental goals of the company and determine the criteria when the goals are achieved. LCA solely evaluates the consequences to the environment on all phases of device's lifetime. This way the manufacturer can meet all environmentally interested parties with incorporating LCA and EMS in all phases of device lifecycle. LCA also significantly contributes to the scientific and transparent basis for determining ecological criteria for the Europen ecological labeling. These labels can be awarded to devices that are in compliance with special ecological criteria. The criteria are determined by using the cradle to grave approach and consider all suitable environmental aspects in every lifecycle phase.

The following table presents an example of LCA use in a company.

Application	Example
Establishment of Environmental Focus	Identification of areas for improvement. Product-oriented Environmental Policy Environmental Management.
Design Choice	Concept Selection. Component Selection. Material Selection. Process Selection.
Environmental Documentation	ISO 14000 Certification. Eco-labels.

TABLE 1: EXAMPLE OF LCA USE IN A COMPANY