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# Life Cycle Based Design and Product Development: Application of LCA to Lithuanian Industry

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The paper is based on some of the results of the project "Implementation of Green Product Development in the Baltic Sea Region and Establishment of Green Company Clusters in Latvia, Lithuania and Russia with Strong Links to Sweden". Life cycle assessment (LCA), as a tool for environmental evaluation of the product system has never been used before in Lithuanian industry. The main goal of this study has been to make an attempt of introducing LCA to the product development process. In the first phase LCA is applied to a selected group of products in different industry sectors. In the second phase the LCA results are used for readjusting the product, its eco-design or its environmental performance declaration development. Despite the limited capacity and lack of incentives, the companies have been satisfied with the project results in terms of the acquired knowledge, particularly in respect to the opportunities for cleaner production innovations.

The paper presents a new calculation model used in LCA research, a LCA model of an environmental impact of electricity production in Lithuanian national electricity grid and discusses the experience gained in successful implementation of LCA tools in Lithuanian industry

Key words: *Life cycle assessment; Eco-design; Cleaner production; Environmental Performance declaration; Lithuania.*

## 1. Introduction

Product life cycle thinking is essential for the path to sustainability because the focus extension from production to the entire product life cycle facilitates the links between economic and environmental dimensions within a company. Life cycle thinking deals with the widening of views and expands a traditional focus on manufacturing processes by incorporating various aspects associated with a product over its entire life cycle [24].

In recent years a number of companies in Lithuania have become aware of the fact that proactive policies and preventive measures are economically and environmentally far more attractive than the end-of-pipe technologies as they encourage greater efficiency, reduction in material use and reduction or elimination of toxic substances [1][12].

This research aims at assessing the environmental impact of selected products and at promoting the life cycle thinking as a viable tool that could be used when handling all environmental issues. The other objectives are to find the most significant environmental aspects in a product life cycle and to acquire basic knowledge about cleaner product development. LCA is applied to a group of selected products produced in different sectors of Lithuanian industry. The LCA case presented in this paper studies a solar sensor for passenger cars (used to control the interior climate in medium-sized passenger cars), a buckle switch for passenger cars and a domestic refrigerator.

The companies have been satisfied with both the results of the project in terms of the knowledge acquired and the particular recommendations for cleaner product development (analysis of production processes, "hot spot" analysis and significant aspects' evaluation). On the basis of the results the products can be redesigned to minimize their environmental impact in the product's life cycle from raw material extraction to manufacturing, and even to consumption and disposal.

## 2. LCA as a tool for environmental product development

Environmental Product Development or Eco-design as a tool of extended producer responsibility (EPR) is based on a life cycle thinking approach. Eco-design refers to the systematic incorporation of environmental factors into the product design and development with an aim to reduce an environmental impact of products throughout their whole life cycle [25].

The process of Eco-design does not essentially differ from the conventional product planning; nevertheless its intention is to integrate environmental aspects into the existing planning process wherever it is meaningful and possible. Designers often do not have sufficient information about environmental characteristics of a product. In addition, they often lack an insight into how to improve the product's environmental aspects. To ensure designers' capability to generate environmental improvement ideas easily, specific environmental aspects of the product and its corresponding Eco-design strategies are to be furnished to them simultaneously. [8][15]

The first steps in application of tools to the environmental product development are definition of the main project objectives and full product environmental assessment, with a view to evaluating its main environmental aspects and identifying "hot-spots" over the whole product system. In the environmental analysis a study of physical product without incorporating the whole product system (auxiliary products, consumables, etc.) needed to ensure the proper functioning of the product over its total lifetime will be insufficient. The product system (depending on its scope) has to cover the phases of its life cycle, including supply of materials, components and production, factory production, distribution, use or utilization, end of life system / final disposal of the product.[23]

The analysis stage involves identification, quantification, evaluation and prioritization of environmentally harmful issues in relation to product, product system, service or even a concept. Analysis is to be completed depending on the planning constrains (time, personnel, financing).

This may involve a very thorough analysis: for example, drawing up LCA including the goal and scope definition, inventory, impact assessment and evaluation steps. The factors of a negative impact on the environment are ascertained first, and then their importance is determined on the basis of their effect on the more fundamental environmental criteria. [9][14]

Various qualitative and quantitative methods of the environmental analysis, tools for product development and design are developed for both the environmental analysis of a product and setting environmental priorities. [10][11][13]

LCA is collection and evaluation of the data about the product system, its inputs, outputs and its potential impact on the environment throughout the life cycle [22][27][20]. LCA performed in accordance with the international series of standards EN ISO 14040- 14043 is to include the definition of the goal and scope, inventory analysis, impact assessment and result interpretation.

Using the insights gained in the LCA analysis phase as a starting point, the next step is to develop the ideas and proposals how to improve a particular product, how to develop a new environmentally sound idea, or an Eco-efficient service to satisfy customer needs (Fig. 1). Nevertheless, the previously defined design criteria and requirements and design specifications have to be taken into account. Generated ideas are to be evaluated (according to environmental, technical and financial perspectives) and the concept of a new product is to be developed. At the same stage the product needs environmental assessment. It has to be evaluated and compared to the former product verifying its environmental performance and project benefits in its marketing. [18][19] Having verified the product concept and specified it, the project is to be evaluated and prepared for its recommendations for the future development of its eco-design in the company. This step ensures that the knowledge gained in implementation of the current project will be transferred to the new product development and the application of eco-design methodology will become a continuous process in the company. [12] [16]

LCA data obtained from Lithuanian companies have been applied to construct a calculation model of a manufacturing process using life cycle inventory software KCL-ECO version 3.1 [2]. This software is based on a mass balance. Research has been carried out in co-operation with the partners from Swedish Environmental Research Institute (IVL). The processes in software are described by modules which link input and output parameters by first-order equations to a local functional unit for each module. For example, functional unit may be the quantity of a product or a commodity. Parameters are raw material consumption, emissions, products, waste and intermediate flows. The module estimates the consequences of producing a given number of the product or the commodity in question. The modules are connected to each other by mass or energy flows. The flows are also used to define the application of transport.

In each process model an overall functional unit is defined as a basis of calculation. In all cases, a functional unit is one unit of a product. Necessary quantities of raw materials, energy and additional materials are taken from the equations and calculated in the modules describing the manufacturing line. Calculated quantities are then translated to environmental impacts in the modules describing the procurement of raw materials and other commodities.

Like the most LCA software, KCL-ECO has a function to characterize the models built into it. Tables with weighting factors are stored and used to calculate directly the values of impact categories (for example, global warming potential) from the primary calculation results.

The process model is divided by assigning the codes to particular modules. Results may be presented either in an aggregated form, as inputs and outputs of the entire system, or separately for different process stages.

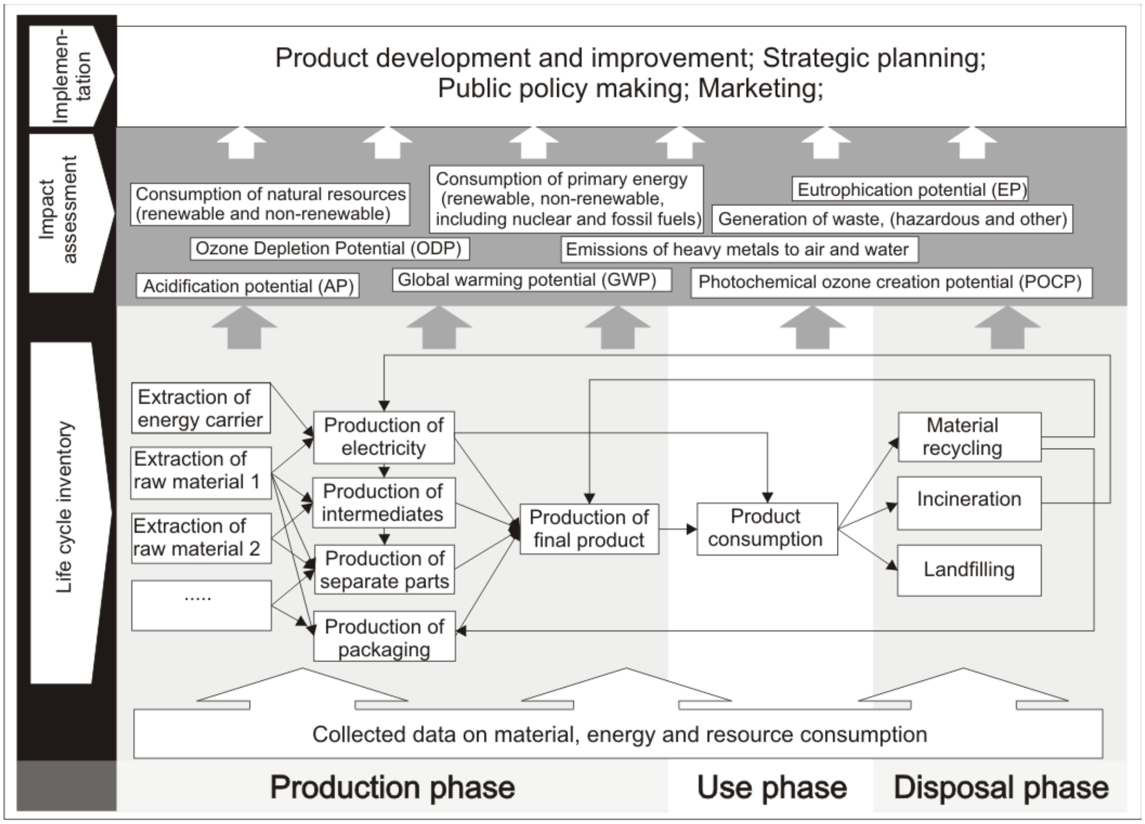

*Fig.1. Calculation model used in LCA research*

***Electricity impact analysis***

Electricity is a major concern in LCA of most products since it is a required input for production or use of almost all goods. The largest life cycle inventory (LCI) databases contain the data mainly for an impact of electricity production in West European countries and North America, while the values of environmental impact caused by local electricity production used in LCA calculations are of particular importance. Since LCA has never been applied in a number of various countries, the impact of the local energy production system on the environment has never been analyzed. The lack of significant information needed for LCA has determined the analysis of a potential impact on the environment caused by energy production in Lithuania. The experience gained in this sphere can be applied in the countries which have not started research into this issue.

The first step was to update the amount of each type of electricity contributing to the current composition of electricity in Lithuanian national grid according to the latest available data. Data are taken from the International Energy Association (IEA) [3] (Fig. 2) [28][21].

The second step was to develop a LCA model for evaluating an environmental impact made by electric power generation based on the identified energy production composition.

To describe the environmental impact of generating nuclear power and hydroelectric power, the average European data derived from the data of the UCTPE [4] and the ETH [5] were used.

To describe electricity generation from gas, oil and coal, the environmental data for heat generation from the SimaPro database [6] were recalculated using efficiency of 58% for natural gas fuelled, 56% for oil fuelled and 44% for coal fuelled combined heat and power plant (CHPP).

To describe electricity generation from bio fuels, environmental data for heat generation from bio fuels (wood) were recalculated using efficiency of 42 % for wood fuelled CHPP. The environmental impact of heat generation from wood is described by the data from Swedish company Vattenfall (1996) as cited by S. Uppenberg et al. (2001) [7].

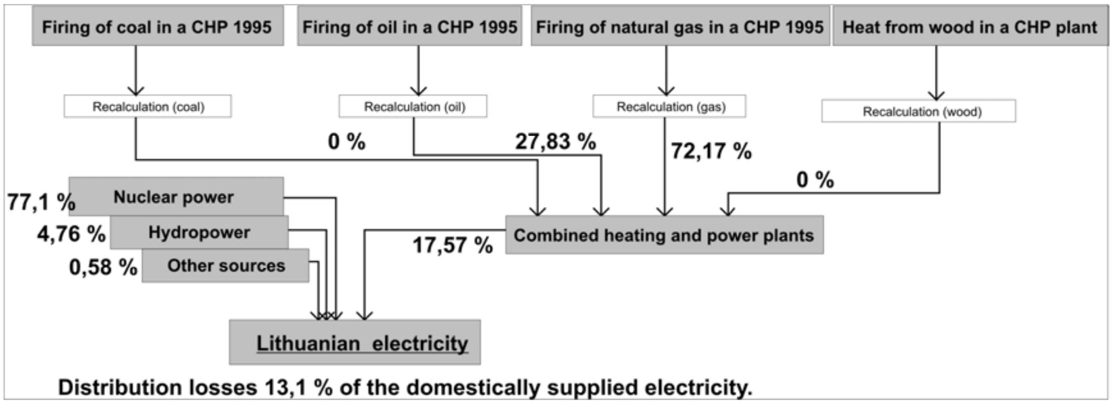

*Fig. 2. LCA model for Lithuanian national electricity grid*

***Impact categories, characterisation factors***

To estimate a potential environmental impact of production, the following impact categories have been selected as indicators:

- Consumption of natural resources (renewable and non-renewable);
- Consumption of primary energy (renewable, non-renewable, including nuclear and fossil fuels);
- Global warming potential (GWP);
- Ozone Depletion Potential (ODP);
- Acidification potential (AP);
- Eutrophication potential (EP);
- Photochemical ozone creation potential (POCP);
- Emissions of heavy metals to air and water;
- Generation of waste, (hazardous and the other).

The parameters (resource consumption and emissions) of the initial life cycle inventory are grouped (classified) into the impact categories they belong to. For each category a single impact quantity is calculated as a sum of weighted contributions from the contributing parameters (characterisation) [26].

The impact category "Consumption of natural resources" is calculated as a sum of consumed natural resources in kg. The impact category "Consumption of energy" is calculated as a sum of consumed fuel in kWh.

Waste is summed up in kg. The impact category "Emissions of heavy metals" is calculated as a sum of the emissions to air and water of specified metals or by summing up the parameters "heavy metals" in kg.

## 3. Application of LCA results to product development

### *Solar sensor and buckle switch*

Solar sensors are used to control the interior climate in medium-sized passenger cars. They consist of a printed circuit board enclosed in a casing of makrolon (a polycarbonate). Buckle switches are used in a seat-belt control system in medium-sized passenger cars. Five buckle switches are used in production of a car.

A solar sensor and a buckle switch are assembled in a series of operations performed in a clean room. The process appears on the graphical interface of the software used for the LCA-calculations. Each solid module in the scheme represents a real manufacturing process or describes the material composition of a component or a waste. Open modules represent calculation procedures in the model. The open modules containing the word "delivered" represent quality inspections. They calculate the effect of rejecting a certain percentage of delivered components. The result of rejections is an increased consumption of components and an increased amount of waste. The quality inspection modules calculate the demand for components and the amount and composition of waste resulting from a given rejection ratio. Upstream from quality inspection modules the open modules calculate the amount of material transported to the factory, and also, where the data are available, the environmental impact of manufacturing the component, while accounting for rejections.

The open module "clean room operations" calculates the demand for heat, electricity, consumables, and those direct emissions from the manufacturing process which are allocated to the solar sensor.

The functional unit in both cases is one unit of the product ready for delivery at the factory gate, i.e. these LCA cases are "cradle-to-gate" ones.

As far as it is practically possible, the system boundaries are framed by the required natural resources at the starting point of production processes and the factory gate at the other end. Solar sensor and buckle switch are merely little parts of the entire product system (passenger car) which has a wider scope, therefore in total use and disposal phases of passenger cars the environmental impact of the analyzed components is not weighty and cannot be influenced by their producers. That was the main reason of a decision to choose for the study a "cradle-to-gate" concept. The composition of the production waste, including rejected components and rejected products, is calculated, whereas the waste treatment is excluded.

The potential environmental impact of the selected steps of the product life cycle defined by the product matrix has been calculated from the LCA model. The results of the entire product, i.e. from the extraction of natural resources to the final product, are illustrated in Figure 3 (solar sensor) and in Figure 4 (buckle switch) as percentage distributions of each impact category in particular process steps.

According to Figures 3 and 4, the use of electricity and heat at the factory and the extraction of raw materials for making the components are the most important environmental aspects in the production of solar sensor and buckle switch. Which one of these aspects is the most important depends on the impact category.

The absolute values of a selected potential environmental impact caused by the manufacture of solar sensor and buckle switch are given in Tables 1 and 2.

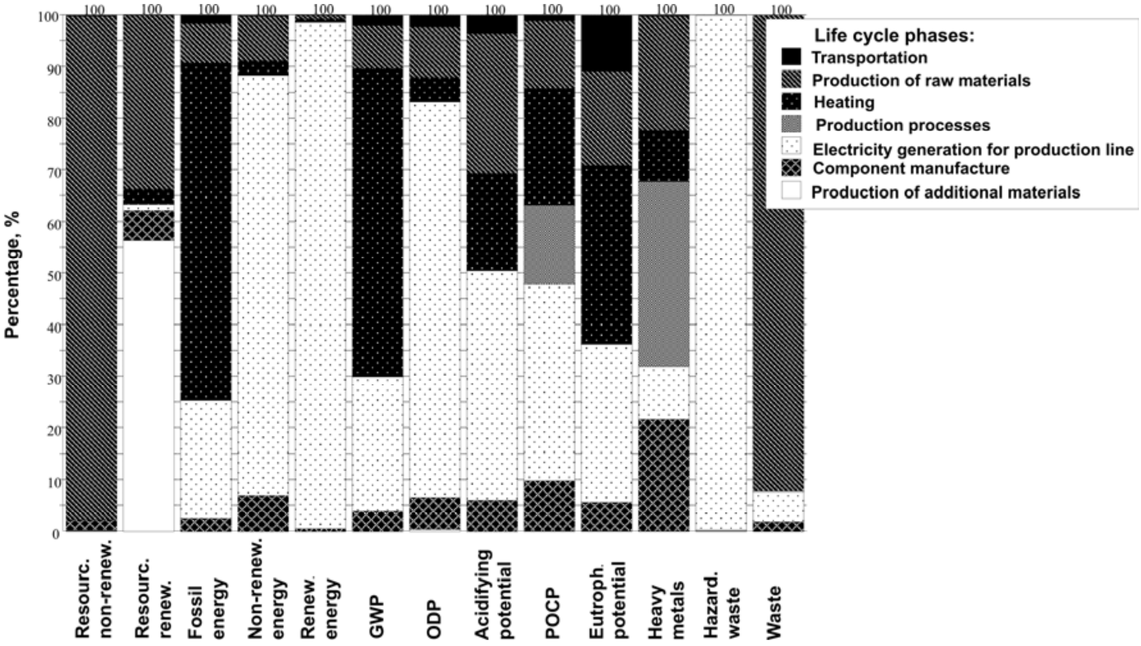

*Fig. 3.* *Production of one solar sensor ready for delivery. Relative contribution from different life cycle steps to selected impact categories, % of the total contribution*

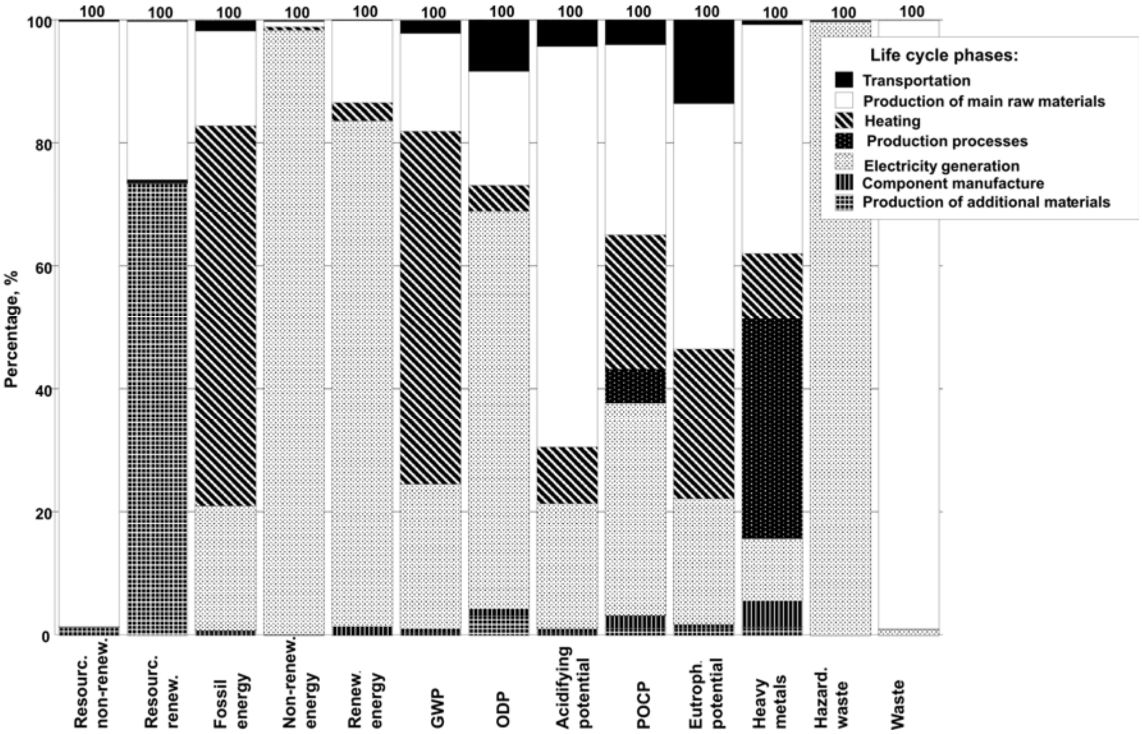

*Fig. 4.* *Production of buckle switch ready for delivery. Relative contribution from different life cycle steps to selected impact categories, % of the total contribution*

*Table 1. Product matrix of solar sensor. Absolute values expressing a potential environmental impact caused by manufacturing a solar sensor*

| | Extract. raw materials | Compon. manufact. | Manufact. ancillary materials | Electr. generat. factory | Heat use factory | Factory operations | Transports | Total prod. |
|---|---|---|---|---|---|---|---|---|
| Natural resources, non-renewable, kg | 0.018 | 0.00035 | $7.0 * 10^{-5}$ | 0 | 0 | 0 | $1.4 * 10^{-6}$ | 0.018 |
| Natural resources, renewable, kg | 0.00063 | 0.00011 | 0.0011 | $2.2 * 10^{-5}$ | $5.3 * 10^{-5}$ | 0 | 0 | 0.0019 |
| Primary energy use, renewable, MJ | 0.098 | 0.080 | $7.1 * 10^{-5}$ | 0.92 | 0.031 | 0 | 0 | 1.1 |
| Primary energy use, non-renewable, MJ | 0.30 | 0.27 | 0.0025 | 45 | 0.25 | 0 | 0 | 46 |
| Primary energy use, fossil, MJ | 1.4 | 0.45 | 0.017 | 4.1 | 12 | 0 | 0.27 | 18 |
| GWP, kg $CO_2$-equiv. | 0.086 | 0.040 | 0.00070 | 0.27 | 0.62 | 0 | 0.019 | 1.0 |
| ODP, kg CFC-11 equiv. | $9.5 * 10^{-9}$ | $6.1 * 10^{-9}$ | $3.9 * 10^{-10}$ | $7.5 * 10^{-8}$ | $4.6 * 10^{-9}$ | 0 | $2.1 * 10^{-9}$ | $9.7 * 10^{-8}$ |
| AP, mol $H^+$ | 0.035 | 0.0076 | 0.00016 | 0.057 | 0.024 | 0 | 0.0044 | 0.13 |
| POCP, kg ethylene equiv. | $4.3 * 10^{-5}$ | $3.2 * 10^{-5}$ | $7.8 * 10^{-7}$ | 0.00013 | $7.4 * 10^{-5}$ | $5.0 * 10^{-5}$ | $3.3 * 10^{-6}$ | 0.00033 |
| EP, kg oxygen | 0.0019 | 0.00057 | $2.1 * 10^{-5}$ | 0.0032 | 0.0036 | 0 | 0.0011 | 0.010 |
| Heavy metals, kg | $2.2 * 10^{-5}$ | $2.2 * 10^{-5}$ | $1.5 * 10^{-7}$ | $1.0 * 10^{-5}$ | $1.0 * 10^{-5}$ | $3.6 * 10^{-5}$ | $1.3 * 10^{-7}$ | 0.00010 |
| Hazardous wastes, kg | 0.00014 | 0.00098 | $1.8 * 10^{-6}$ | 0.26 | 0 | 0 | 0 | 0.26 |
| Wastes, other, kg | 0.30 | 0.0060 | $5.4 * 10^{-6}$ | 0.019 | 0 | 0.00070 | $4.8 * 10^{-7}$ | 0.32 |

*Table 2. Product matrix of buckle switch. Absolute values expressing a potential environmental impact caused by manufacturing a buckle switch*

| | Extract. raw materials | Compon. manufact. | Manufact. ancillary materials | Electr. generat. factory | Heat use factory | Factory operations | Transports | Total prod. |
|---|---|---|---|---|---|---|---|---|
| Natural resources, non-renewable, kg | 0.025 | $3.3 * 10^{-5}$ | 0.00034 | 0 | 0 | 0 | $3.0 * 10^{-6}$ | 0.025 |
| Natural resources, renewable, kg | 0.0018 | $1.0 * 10^{-5}$ | 0.0052 | $1.1 * 10^{-5}$ | $2.7 * 10^{-5}$ | 0 | 0 | 0.0071 |
| Primary energy use, renewable, MJ | 0.071 | 0.0077 | 0.00063 | 0.44 | 0.016 | 0 | 0 | 0.54 |
| Primary energy use, non-renewable, MJ | 0.21 | 0.027 | 0.010 | 22 | 0.13 | 0 | 0 | 22 |
| Primary energy use, fossil, MJ | 1.5 | 0.043 | 0.044 | 2.0 | 5.0 | 0 | 0.16 | 9.7 |
| GWP, kg $CO_2$-equiv. | 0.088 | 0.0039 | 0.0023 | 0.13 | 0.31 | 0 | 0.011 | 0.55 |
| ODP, kg CFC-11 equiv. | $1.0 * 10^{-8}$ | $5.8 * 10^{-10}$ | $1.8 * 10^{-9}$ | $3.6 * 10^{-8}$ | $2.3 * 10^{-9}$ | 0 | $4.5 * 10^{-9}$ | $5.5 * 10^{-8}$ |
| AP, mol $H^+$ | 0.087 | 0.00073 | 0.00069 | 0.027 | 0.012 | 0 | 0.0055 | 0.13 |
| POCP, kg ethylene equiv. | $5.4 * 10^{-5}$ | $3.7 * 10^{-6}$ | $2.3 * 10^{-6}$ | $6.0 * 10^{-5}$ | $3.8 * 10^{-5}$ | $9.7 * 10^{-6}$ | $6.8 * 10^{-6}$ | 0.00017 |
| EP, kg oxygen | 0.0030 | $5.4 * 10^{-5}$ | $9.2 * 10^{-5}$ | 0.0015 | 0.0018 | 0 | 0.0010 | 0.0075 |
| Heavy metals, kg | $1.8 * 10^{-5}$ | $2.1 * 10^{-6}$ | $6.4 * 10^{-7}$ | $4.9 * 10^{-6}$ | $5.2 * 10^{-6}$ | $1.7 * 10^{-5}$ | $2.8 * 10^{-7}$ | $4.9 * 10^{-5}$ |
| Hazardous waste, kg | 0.00024 | 0.00010 | $1.6 * 10^{-6}$ | 0.12 | 0 | 0 | 0 | 0.12 |
| Waste, other, kg | 0.97 | 0.00057 | $3.0 * 10^{-5}$ | 0.0091 | 0 | 0.00081 | $1.1 * 10^{-6}$ | 0.98 |

The inspection of Figures 3 and 4 makes it possible to conclude that the use of electricity and heat at the factory and the extraction of raw materials for making components are the most important environmental aspects in the production of solar sensor and buckle switch. Which one of these aspects is of greatest importance depends on the impact category we focus on. "Hot spot" analysis may be compiled in the way illustrated in Tables 3 and 4 listing the important environmental aspects, the impact they are the most significant contributors to, and the processes causing the impact.

*Table 3. Environmental aspects of the manufacture of solar sensor*

| **Environmental aspect** | **Impact category significantly contributed by environmental aspect** | **Cause of impact** |
|---|---|---|
| Generation of electricity for production line | Energy, non-renewable<br>Energy, renewable<br>Ozone Depletion Potential<br>Acidifying Potential<br>Phot. Ozone Creat. Potential<br>Eutrophying Potential<br>Hazardous waste | Nuclear power<br>Hydropower<br>Halons (fire extinguishers)<br>Oil power plants<br>Oil power plants<br>Oil power plants<br>Nuclear power plant |
| Use of heat at production line | Energy, fossil<br>Global Warming Potential<br>Eutrophying Potential | Natural gas burner |
| Extraction of raw materials for component manufacture | Natural resources, non-renew.<br>Acidifying Potential<br>Waste | <br>Copper production<br>Copper production |
| Factory operations | Heavy metal emissions | Emissions of tin from soldering |

*Table 4. Environmental aspects of the manufacture of buckle switch*

| **Environmental aspect** | **Impact category significantly contributed by environmental aspect** | **Cause of impact** |
|---|---|---|
| Electricity generation for production line | Energy, non-renewable<br>Energy, renewable<br>Ozone Depletion Potential<br>Phot. Ozone Creat. Potential<br>Hazardous waste | Nuclear power<br>Hydropower<br>Halons (fire extinguishers)<br>Oil power plants<br>Nuclear power plant |
| Extraction of raw materials for component manufacture | Natural resources, non-renew.<br>Acidifying Potential<br>Eutrophying Potential<br>Phot. Ozone Creat. Potential<br>Waste | <br>Copper production<br>Copper cable (copper, PVC)<br>PBT for connector housing<br>Copper production |
| Use of heat at production line | Energy, fossil<br>Global Warming Potential | Natural gas burner |
| Factory operations | Heavy metal emissions | Tin emissions from soldering |

***Refrigerator***

A domestic refrigerator has a freezer compartment with automatic defrosting, three adjustable safety-glass shelves, two drawers for vegetables and fruit, three trays and four door shelves.

The freezer compartment keeps storage temperature of –18 °C or lower and is equipped with a defrosting water drain. It has two drawers and one tray.

The product consists of the following materials:

**Material content, including compressor**

| | |
|---|---|
| Metals | |
| Steel | 48.3 % |
| Iron | 2.1 % |
| Copper | 1.6 % |
| Aluminium | 0.4 % |
| Plastics | |
| PUR insulation | 10.4 % |
| Other plastics, mainly polystyrene | 30.4 % |
| Glass | 5.9 % |
| Blowing agent | 0.6 % |
| Refrigerant | 0.07 % |
| Relays | 0.3 % |

*Table 5. Technical specifications of refrigerator*

| **Model** | **RF310-1503a** |
|---|---|
| Storage volume (fridge/freezer), net | 193/92 litres |
| Height | 173 cm |
| Width | 60 cm |
| Depth | 60 cm |
| Weight | 65 kg |
| Energy efficiency class | A |
| Energy consumption | 324 kWh/year |
| | 0,89 kWh/day |
| Required power supply | 90 W |
| Noise | 40 dB(A)re 1pw |
| Refrigerant | R600a (isobutene) |
| Blowing agent for PUR insulation | Cyclopentane |

Phosphatiser used for a metal cabinet contains 2.5 % nickel orthophosphate. Its main constituents are iron-zinc phosphates.

The paint used for the metal cabinet is powder coat of an epoxy-polyester type. It does not contain additives or pigments based on cadmium, chromium, lead or mercury.

The plastic contains neither cadmium nor lead nor mercury, nor any of their compounds, and no chlorinated/brominated hydrocarbons and flame retardants are used.

LCA has been divided into three phases:

The production phase:

- Manufacture of all raw materials.
- Transport of raw materials from suppliers to the factory.
- Production in the factory, where the main operations are metal working (including surface treatment and painting), polymerisation and filling with polyurethane (PUR), and assembly. Wastewater treatment from a painting line by lime precipitation, pH adjustment and ion exchange is also included.

The consumer use phase:

- Electricity consumption, disposal of packing materials and maintenance. Maintenance includes one replacement of a compressor, refilling of refrigerant and compressor oil, and disposal of waste.
- Transport of a packaged refrigerator from manufacturing plant to consumer, and transport of the waste from consumer to disposal facility.

The end-of-life phase:

- Scrapping of a refrigerator. The output of waste materials and emissions directly from the product are specified. The scrapping process itself is excluded.
- Transport of a worn-out refrigerator from a consumer to a disposal facility.

Study results of environmental performance of a refrigerator are presented in Table 6.

*Table 6. Environmental performance of refrigerator*

| | **Production** | **Consumer use** | **End of life** | **Total** |
|---|---|---|---|---|
| **Resources** | | | | |
| Non-renewable materials, kg | 120 | 19 | - | 140 |
| Renewable materials, kg | 9.3 | 0.33 | - | 9.6 |
| Energy, kWh | 1400 | 16000 | 1.8 | 17000 |
| | | | | |
| **Emissions** | | | | |
| Greenhouse gases, kg $CO_2$ equivalent | 260 | 350 | 0.46 | 610 |
| Ozone-depleting gases, kg CFC equivalent | $2.4 * 10^{-5}$ | $8.8 * 10^{-5}$ | 0 | 0.00011 |
| Acidifying gases, mol hydrogen ions | 53 | 82 | 0.092 | 130 |
| Ground-level ozone creating gases, kg ethylene equivalent | 0.13 | 0.16 | 0.11 | 0.40 |
| Oxygen consuming substances to water, kg oxygen equivalent | 4.6 | 4.5 | 0.024 | 9.1 |
| ***Waste*** | | | | |
| Hazardous waste, kg | 22 | 305 | 0.41 | 330 |
| Other waste, kg | 630 | 190 | 1 | 820 |
| ***Recyclable resources*** | | | | |
| Materials, kg | 3.4 | 15 | 70 [a)] | 88 |

*Potentially recyclable materials*

The quantity of recyclable materials given in the environmental performance declaration is that of potentially recyclable materials, namely, metals and plastics.

The product is designed for easy and efficient disassembly and recycling of materials.

## 4. Considerations and conclusions

This pilot LCA research has illustrated how the introduction of LCA to industry changes the classical product development process by initiating and giving a start for new concepts and measures (product requirements readjustment, environmental product evaluation and eco-design application). It should be also remembered that the introduction of environmental quality into product development processes is highly influenced by the company's environmental attitude, strategy or policy, in other words, the mixture of what a company can, want and must do in the environmental area. This process is influenced by environmental, competitive, financial and social considerations.

Having completed LCA in selected companies, the process of an environmentally improved product development has started. In the cases of buckle switch and solar sensor "hot-spot" identification in the product system was done and eco-design tools were applied. In the case of refrigerator, the environmental performance declaration (EPD) was developed and LCA results were used for strategic business development, policy development and education of employees [12].

This research has proved that the obvious benefit of LCA lies in its comprehensiveness: the inclusion of life cycle, and consideration of all environmental aspects in different steps of the cycle. Comparison of different ways to fulfill one function is of particular importance in this regard, and LCA is the most suitable tool for this purpose. This includes all types of analysis of life cycles that are defined in reference to the fulfillment of a specific function: spotting main problematic points in a cycle, deriving options for particular improvement, optimizing a cycle, comparing alternative cycles, etc. In some cases of this project, LCA has been used in the companies to identify improvement options in their products and production processes.

Results obtained during this research allow drawing the following conclusions:

1. Intensive and successful implementation of LCA tools in Lithuanian industry has shown outstanding results in its potential of resource conservation and pollution prevention. At the same time, understanding that sustainable industrial development cannot be achieved by technological change and process modifications alone has increased.
2. Various requirements coming from several directions have forced companies to design products that comply with the eco-efficiency practice, i.e. pollute less and consume fewer resources. For this reason the companies have been positive about the project idea and satisfied with the results in terms of the acquired knowledge and particular recommendations for cleaner product development.
3. Environmental design is a complex process and demands a huge amount of data. Ideally, designers can use the data base or a simple LCA procedure to select environmentally preferred materials. Unfortunately, in most cases such data do not exist and no simple procedure for comparing materials does.
4. Since LCA has never been applied in a number of various countries, the impact of the local energy production system (which is a major concern in LCA) on the environment has never been analyzed. Developed LCA model for evaluating an environmental impact made by electric power generation and experience gained in this sphere can be applied in the countries which have not started research into this issue.
5. The product environmental design is a proactive approach for integrating cleaner production and resource conservation strategies into the development of more environmentally and economically sustainable product systems. Implementation of continuous development of innovations (based on LCA results) makes it possible to analyze innovative ideas and decisions and to stimulate radical changes in the whole product system.

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# Gaminių projektavimas būvio ciklo požiūriu: būvio ciklo vertinimas Lietuvos pramonėje

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Pagrindinis straipsnyje aprašyto tyrimo tikslas – pateikti būvio ciklo įvertinimo (BCĮ) principą kaip vieną iš gaminių kūrimo proceso komponentų. Tyrimas atliktas dviem etapais: pirmajame etape BCĮ priemonės taikomos pasirinktų skirtingų pramonės šakų gaminių grupėms, antrajame etape BCĮ rezultatai naudojami gaminio aplinkosauginėms savybėms tobulinti, gaminio ekologinio projektavimo priemonėms taikyti arba gaminių aplinkosauginėms deklaracijoms (GAD) rengti. Straipsnyje pateikti pavyzdžiai rodo, kad įmonėms projektas buvo naudingas skatinant žinių sklaidą ir atvėrė galimybes diegti aplinkosaugines inovacijas praktikoje. Straipsnyje aprašytas naujas būvio ciklo įvertinimo modelis gali būti taikomas daugelyje pramonės įmonių.