LCI as a tool in the environmentally oriented product development of paper products

Author Anna Leinonen and **Catharina Hohenthal-Joutsimo**

Corresponding authors Minna Forsell, Eero Hiltunen and Helena Wessman

KCL Science and Consulting, P.O.Box 70 FIN-02151 Espoo, Finland
Email: Catharina.hohenthal-joutsimo@kcl.fi
Phone: +358 20 7477273

Content

Summary

This paper presents a new procedure developed for environmentally oriented product development, especially for paper and board products. The procedure aims to transform qualitative expert information to an explicit form suitable for industrial decision-making. This goal is achieved by using LCI as a tool in the product design. The paper presents results from a case study and elaborates applicability of LCI in the product design procedure.

In the field of product development various approaches such as design for environment (DfE), ecodesign or environmentally oriented product design, include also life cycle thinking. These approaches aim usually at efficient material use; minimized energy consumption; improved recyclability; optimized product life time; and minimized use of environmentally harmful substances. From the paper industry's point of view, many of these approaches are unfeasible because they are developed for parceled goods. As paper and board are bulk products, which are used as raw materials for other goods, they cannot be developed without affecting the production process. Therefore, an objective of an ecodesign approach should be to define the effects of planned product development actions on the emissions from the production process. For this purpose a new procedure was developed. This paper presents the developed procedure and results from a case study on paperboard packaging, emphasizing the way LCI can be used as a tool. The case study was carried out by filling customer requirements for a folding box board package. We studied how the improved printability was received and how that change affected the environment.

The environmental burden caused by the planned development action was determined by using Life cycle inventory (balance) as the calculation method. The calculations were done with the KCL-ECO 4.0 software using data based on literature and KCL EcoData database.

The Ecodesign procedure for paper products and case study

New approach to product development in paper and board industry

A survey on product development among the Finnish board manufacturers revealed that, even if the market information is considered an important factor in guiding the product development decisions, it is not necessarily gathered systematically. The respondents also agreed that the market information should be utilized better in product development (1).

According to this we developed a new procedure for environmentally oriented product development suitable for paper products. The developed procedure (1) combines principles of ecodesign and customer oriented product design.

Definition of customer requirements

The first step of the procedure is to collect customer requirements. This is done in a structured workshop with the customers or end users of the product, such as brand owners and retailers. The workshop produces a list of desired product properties and prioritizes them. Also, interviews or other survey methods can be used to collect the customer requirements.

Specification of product properties to be improved

In the second stage the customer's qualitative voice is transformed to quantitative form using QFD (*Quality Function Development*) (2) method. In this stage, the product properties that respond to the customers' needs are defined, and the unit operations of the production process affecting the critical product properties are specified. The information for the ecodesign procedure is collected and analyzed using two matrices:
From the *Customers' needs* to the *Product properties* of board.
From the *Product properties* of the board to the *Unit processes* of the board manufacturing processes.

Definition of development actions and their consequences

The development actions are defined based on the results from the QFD matrix. Next stage of the product development procedure is to determine the environmental burden caused by the planned development actions. The method in this stage is *Life Cycle Inventory* (balance) calculation. The case study that was carried out to develop the ecodesign procedure concentrated on energy and raw material consumption and air emissions. The calculations were based on data from literature and KCL EcoData (3).

Assessment of the results in decision making

The effects of the product development actions can be compared using two functional units. In other words, the changes are calculated either per ton of board or per number of packages. These two approaches lead to different results, which is discussed later.

Results from a case study

In the case study one customer requirement was that the print quality needed some improvement. As the reference board was assumed to be uncoated, the product development action to be examined was to replace the uncoated board with a coated one . The coating layer is added only for better printability and it does not have any effect on the strength properties of the board. Therefore , the grammage (i.e. weight per area) of the board cannot remain on the original level when the coating layer is added. Table 1 below sums up the first step of the calculation which defines how the planned product development action affects energy consumption and raw material demand.

Table 1. Steps of the calculations

Customer requirement	Better print quality
Development action	Uncoated board is replaced with coated board
Assumptions	The coating does not have an effect on the strength properties of the board => the grammage of the board increases when coating is added

Reference board	Uncoated folding box board of 250g/m^2; surface layer of hardwood kraft pulp (birch) and middle layer of GW pulp (spruce, mechanical); Process heat consumption is 5.5 GJ/ton and electricity consumption 1.47 MWh/ton
Analysis	1) The effect on energy consumption (increase due to the drying of coating) 2) The effect of raw material consumption (increase due to the added coating layer)

The functional unit and its effects on results

When the original reference board is compared to the improved version, a functional unit for the comparison is needed. There are two optional approaches that are possible for the calculation of the energy consumption and raw material demand. The changes can be calculated either per ton of board or per constant number of packages. These two approaches lead to different results. Calculations per tone is the traditional approach in board mills and LCA calculations. Board is typically sold per weight and the emission permits of a mill is often granted per ton of product. However from the end user's perspective, the number of packages is more relevant, the number of packages is the primary need. If the board making process is changed so that the weight per package increases, then also the material as well as the environmental load increases. Table 2 below summarizes the results of the calculation. To make sure the results are comparable, we used an area equal to one ton of uncoated board for representing the number of packages. (As our ref. Board has the grammage of 250g/m^2, one ton of it has the area of 4000 m^2)

Table 2. results of comparison with two different functional units

Effect on:	Comparison/ ton	Comparison/ package
Total energy consumption	Increases (+27%)	Increases (+42%)
Electricity consumption	Decreases (-3.3%)	Increases (+1.3%)
Pulp consumption	Less pulp needed (-10%)	No change

Coating raw materials	Additional material needed	Additional material needed

The relative amount of base board in one ton of board decreases when the coating layer is added on the board surface. Therefore in comparison per ton of board, the pulp consumption decreases. Naturally, the need of energy used for drying of the base board also decreases. Also, the electricity needed for grinding of spruce for the base board middle layer decreases. This compensates the increased electricity consumption due to infrared dryers, and therefore, the total electricity consumption decreases. The total energy consumption however, increases because more heat is needed for drying the coating layer. The increase in total energy consumption is even higher when the comparison is done per constant number of packages. In order to manufacture constant area of board with equal strength properties compared to the uncoated reference board, we need as much pulp as before. Implication of this is that all the additional energy consumption caused by the drying of coating has to be added to the reference board. This is why the energy consumption increases more when the comparison is done per number of packages.

Determination of environmental load

The final step of the calculation is to determine the environmental burden caused by the changes. This is fulfilled by LCI analysis including the following life cycle stages (figure 1 Harvesting operations, transports of wood, chemical pulping process, transports of pulp, folded box board production and energy production (mill energy and electricity from the grid). The chemical pulping process was not integrated. The transport distances and vehicle types are set to certain default values. The process changes required by customers were carried out in the folding box board process. Electricity from the grid used the average Finnish fuel mix which is 32% nuclear, 21% hydro, 13% coal, 12% natural gas, 2% heavy fuel oil, 6% peat and domestic energy 14%. All data used for the calculations are from the KCL EcoData database.

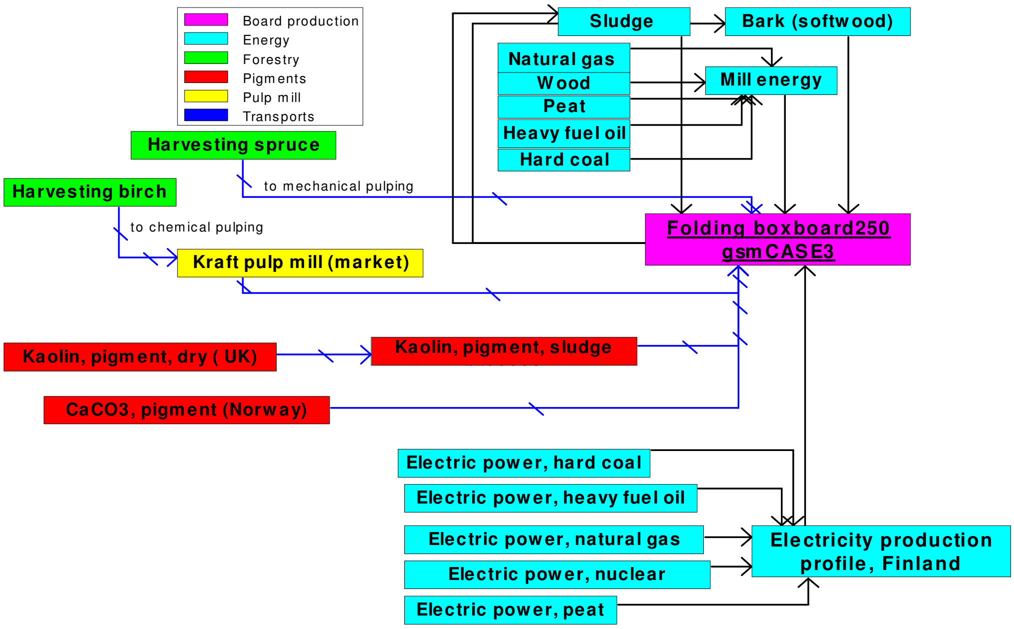

Figure 1. Life cycle stages of the LCI calculation

The objective of the case study was to calculate how the change from uncoated folded box board to coated one affects the air emissions from the product life cycle that was described above. Figures 2-4 below show the results of the calculations. The figures show which life cycle stages contribute most to the air emissions, but also the effect of the functional unit can be seen.

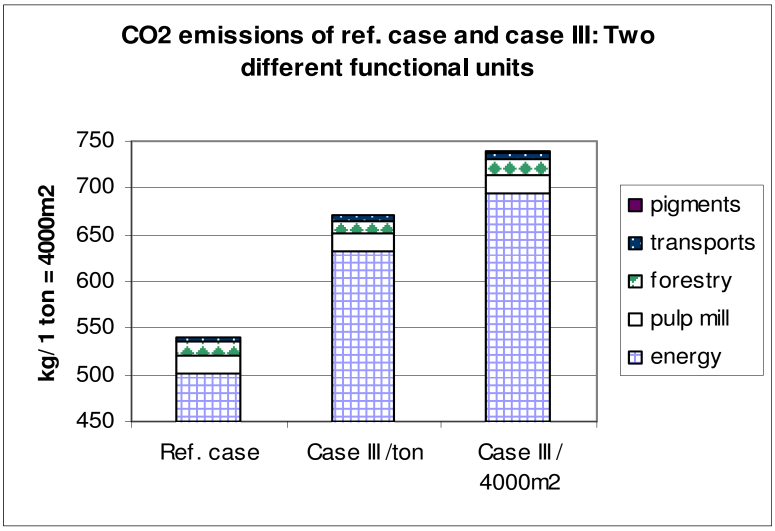

Figure 2. The change in CO_2 emissions.

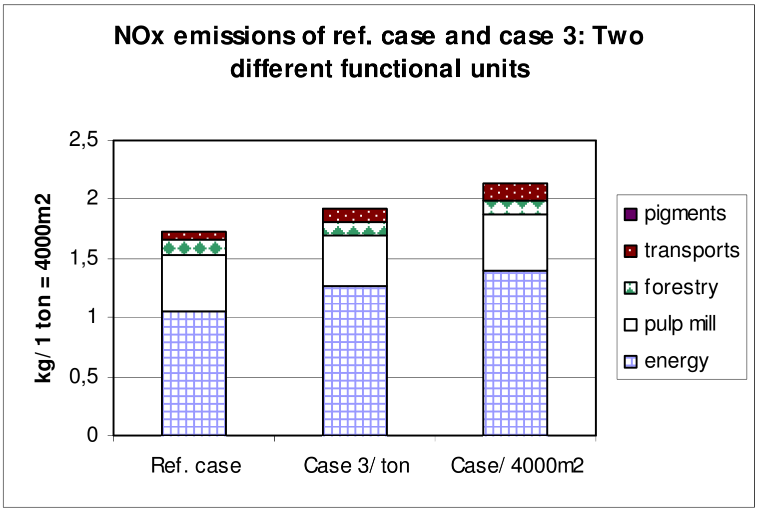

Figure 3. The change in NO_x emissions.

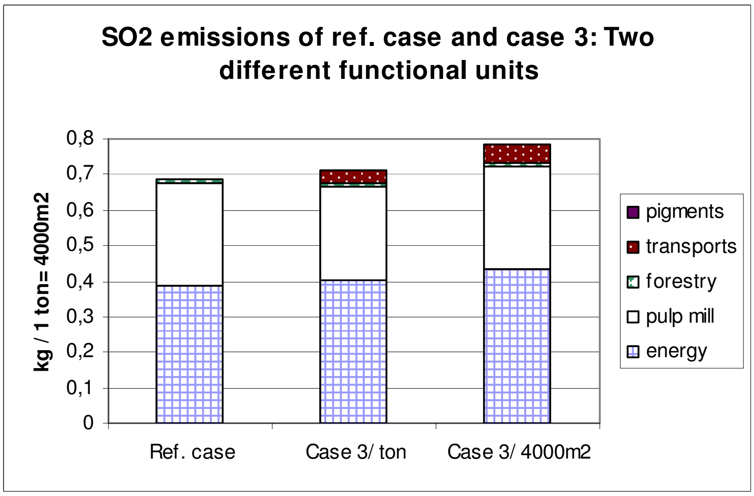

Figure 4. The changes in SO_2 emissions.

Especially, when studying CO_2 emissions he proportional share of energy production is remarkable. When studying NO_x and SO_2 emissions also the chemical pulping is a significant life cycle stage, but also emissions from transports in the coated case can be significant depending on the distance of transportation.

Table 3. The effect of the functional unit, relative change of emissions when the coated board is compared to the ref. board.

Emission	Comparison / ton	Comparison / package
CO_2	24%	37%
NO_x	12%	24%
SO_2	3%	14%

The number of packages produced is smaller in the case when the comparison has been done per ton board.

Conclusions

The case study shows that LCI balance calculation is a very good and transparent method to be implemented to the procedure of turning customer qualitative requirements into quantitative environmental loads. The case study is though a hypothetical development case and did not include real life development targets. In the future, the procedure needs to be tested in a real business case to definitely prove its applicability.

References

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(2) J. Revelle, J. Moran, and C. Cox; ”The QFD Handbook” 1998
(3) KCL ”KCL-ECO 4.0 LCA Software and EcoData database” www.kcl.fi/eco