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# Evolution of the Total Environmental Impact of the Barley Malt Beer Chain in Finland

**Total life cycle environmental impact assessment of Finnish beer was updated and analysed for changes over a six-year period, from 2002 to 2008, in order to identify the main factors behind the ecological evolution of the chain. This information is potentially useful for planning future improvements in the brewing industry. Environmental impacts were assessed based on life cycle analysis (LCA), and total environmental impact was assessed by weighting impact of different impact categories. The impact categories included in and analysed for the total environmental impact were: primary energy consumption, climate change, acidification, formation of tropospheric ozone, and aquatic eutrophication. The data were regenerated from up-to-date site-specific production figures for the input-output models of the key processes of the chain. The results showed that total environmental impact (Eco-Benchmark value) was reduced by 7 %. Many trade-offs contribute to this general trend, both for various categories of environmental impacts and for different activity-sectors of the chain. Total environmental impact decreased for fertilizer and lime production, malting and starch barley production on farms, malting and brewing, as well as for the transportation of intermediate products. Together these activity sectors brought about a 12 % reduction in the total environmental impact. The biggest reduction was for brewing. Total environmental impact increased for beer logistics, sales and consumption, and for barley starch production. Together the contribution of these sectors was +5 %. According to the results of the analysis, evolution in the brewing chain has been favourable from the environmental point of view.**

Descriptors: LCA, environmental impact, barley, malting, brewing

## 1 Introduction

Life cycle thinking is one of the key issues of the Integrated Product Policy strategy adopted by the European Commission. It means that in order to find out how the environmental performance of a product can be improved most cost-effectively the environmental impact of that product must be considered throughout its whole life cycle from production to end-of-life ('from the cradle to the grave').

Relatively large volumes of beer are drunk in Finland, its share being 46 % of the total alcohol consumption in 2010 [1]. Rather little was known, however, about the life cycle environmental impacts of beer when the first life cycle assessment (LCA) study was carried out on Finnish beer. There was a single published LCA [2] when the study was started in 2004. Two other LCA studies on beer [3, 4] were conducted in parallel with the Finnish study. Since then a few other studies were made [5, 6], the later ones including life cycle phases from agricultural production to the consumer. The consumer phase was excluded from two earlier studies [2, 3]. Production of malting barley, as well as malting itself, was excluded from one study [4]. The environmental impact categories considered varied among the studies, but climate change, acidification and eutrophication

were included in all studies. Other impact categories included human toxicity and ecotoxicity [3, 4, 5], smog formation [2, 4], ozone depletion [4, 5], land use [5, 6], and fossil energy usage [3, 5, 6].

Due to particular features of raw material production circumstances and logistics in Finland, foreign studies have not been able to illustrate accurately the environmental impact of the Finnish beer chain. Broader, more focused and more up-to-date information was needed, and the stakeholders of the Finnish barley-malt-beer chain therefore decided to invest in the targeted assessment and analysis of the life cycle environmental impacts of the chain. The aim was to establish the current state of the environmental performance of the chain, and to seek simultaneous economic and ecological, eco-efficient improvements. The life cycle study on the basic Finnish lager beer chain was the first step in a bigger project that aimed to produce a practical new tool for environmental life cycle management of the entire barley-malt-beer chain. The LCA involved nearly all companies in the Finnish barley-malt-beer chain and was completed at the end of 2005. Below we refer to this study as the base study. The main purpose of the base study was to compile reliable environmental impact data for all phases of the barley-malt-beer chain from the production of farm inputs to retail stores including the packaging logistics between retails and breweries, to assess the total environmental impact, and to identify the contributions of different processes and life cycle phases to the total environmental impact in order to enable focusing of ecological improvements effectively in the chain.

In 2010, the stakeholders of the Finnish barley-malt-beer chain found that there was a need to update the results of the base study

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because major changes had taken place in the Finnish beer chain. For example, two breweries were closed and the market share for aluminium cans substantially increased. In this paper we introduce updated results of the Finnish barley-malt-beer chain. We compare the results with the base study results, and discuss the reasons behind the changes in the environmental impacts of the chain.

## 2 Materials and methods

Total life cycle environmental impact assessment of basic Finnish lager was updated and analysed with respect to changes over a six-year period from 2002 to 2008 in order to identify the main factors underlying ecological evolution of the chain. Total environmental impact was assessed using exactly the same methodology as in the 2005 base study reported at the 31st EBC conference in Venice in 2007 [7]. Also, the main methodological choices are represented below.

The assessment of environmental impacts was based on life-cycle analysis (LCA). The chain studied was Finnish, i.e. the beer was made in Finland of Finnish raw materials including barley, malt and starch. Data for the system models were mainly acquired from the companies of the chain, thus providing a reliable basis to analyze the sources of environmental impacts. All quantitatively significant processes and transports of materials were included in the assessment. The phases of the life cycle included in the assessment were: production of fertilizers and other agro-inputs, barley production on farms, malting, production of barley starch, brewing, packaging, distribution and sales, and beer consumption (Fig. 1). All phases included supply chains of main inputs and waste management, e.g. fuel chains and energy inputs. The phases that were not included were: energy use in consumer activities and

chains of materials used in small amounts, e.g. pesticides, growth control agents, hops and filter materials.

The data were regenerated from the up-to-date site-specific production figures for the input-output-models of the key processes of the chain, and their linked local heat and steam production, wastewater management, and transportation processes. The models for beer packaging, sales and consumption subsystems for different kinds of primary packaging (aluminium can, glass bottle, steel keg) were not updated for their input-output data, however, but only for their volume-shares of the total beer supply by each brewery. The profiles of the total beer supply by breweries and the total malt supply by malt-houses at each brewery were regenerated on the basis of the site-specific production data. The data for power supply and landfill subsystems were not updated. Allocation was avoided, wherever possible, by adding the resolution of the process analysis, i.e. in the wording of the ISO standard "by dividing the unit process to be allocated into two or more sub-processes and collecting the environmental data related to these sub-processes" [8]. Expansion of the product system to include the additional functions related to the co-products was not used. Crediting was not included for the materials and energy that were used outside the studied system by material and energy recovery processes.

The impact categories included in and analysed for the total environmental impact were: primary energy consumption, climate change, acidification, formation of tropospheric ozone, and aquatic eutrophication. Additionally, aquatic oxygen depletion, utilisation of side-streams for material recycling and for energy recovery, and disposal of wastes were inventoried. Total environmental impact was weighted impact of different impact categories. The method for weighting is termed the Eco-Benchmark, and was developed in Finland [9]. The main objective of Eco-benchmark development was to provide the consumers with the results of environmental life cycle assessments in such a form that helps to see the role of various products and consumption patterns in terms of their total environmental impacts. The Eco-Benchmark presentation is a comparison of the total environmental impact of the average daily per capita consumption of the product studied and the Eco-Benchmark reference products. In order to obtain the Eco-Benchmark value life-cycle impacts are assessed for the daily consumption, then normalized using the per capita impact rates of Finland for each impact category, and finally summed up applying Finland specific weights for each impact category to get the indicator value. Weighting factors were the same as they were in the 2005 study, i.e. primary energy consumption 18 %, climate change 30 %, acidification 16 %, formation of tropospheric ozone 10 %, and aquatic eutrophication 26 %.

The total environmental impact indicator approach and the Eco-Benchmark presentation method are effective tools for sustainability assessment and communication. They considerably increase the applicability of LCA-based data. The benchmark format offers a possibility to make sense of LCA information. On one hand, it is useful when sustainability improvements are sought and communicated. On the other hand, it can help to better assess possible sustainability effects of process, product and system development aimed at economical improvements in the supply chain of beer.

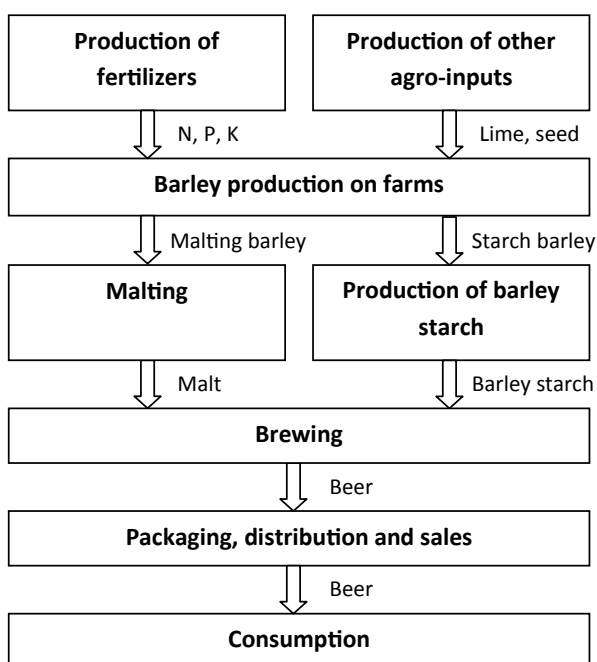


Fig. 1 Phases of the life cycle included in the environmental assessment

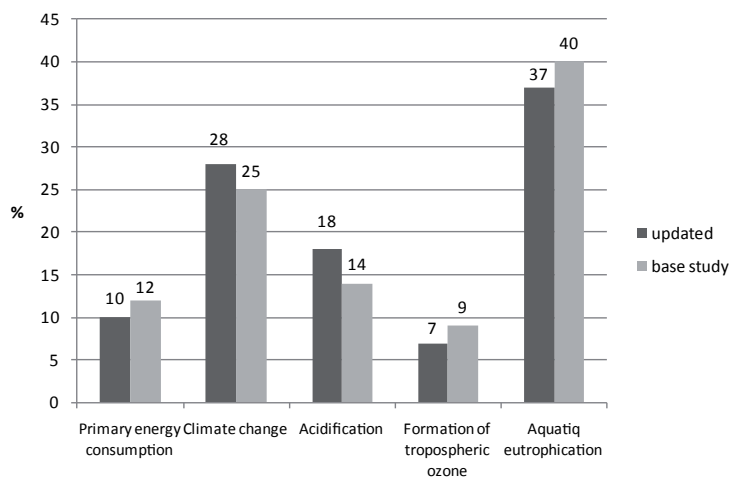
### 3 Results

#### 3.1 Total environmental impact of the Finnish beer chain

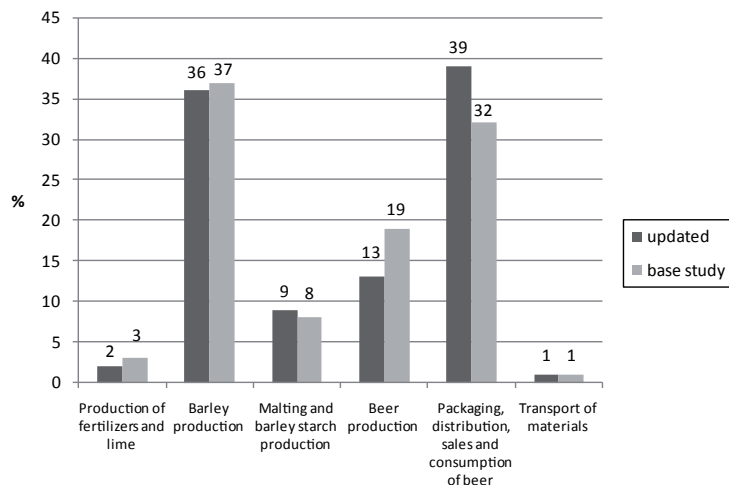
The contribution of beer consumption to the total environmental impact of the Finnish end-use appears relatively small. Daily beer consumption represented less than 0.5 % of the total daily per capita environmental impact in the base study [7]. That is approximately the same total environmental impact as a daily portion of rye bread, a traditional Finnish basic food, or half of a wash of laundry. Total environmental impact (Eco-Benchmark value) was reduced by 7 % compared with the value in the base study. There are many trade-offs underlying this general trend, both between different categories of environmental impacts and between different activity-sectors of the chain. The change in climate change impact was +3 % whereas eutrophication impact changed by -13 %. Thus the total balance of the trade-offs turned negative when acidification, formation of tropospheric ozone and primary energy consumption additionally contributed -2 % to the change in total environmental impact.

Figure 2 presents distribution of the total environmental impact indicator by impact categories in 2010 and in the base study. Aquatic eutrophication represents the largest share (37 %) of the total environmental impact. At the same time, the total contribution decreased most in aquatic eutrophication (3 %-points). This is due to the improved nitrogen balances and decreased run-offs from barley production. Also the hectare-yields of barley were higher in the updated data. The contributions of formation of tropospheric ozone and primary energy consumption decreased by 2 percentage points from the base study values. Those categories in which the contribution increased were climate change and acidification.

Figure 3 shows the distribution of the individual phases to the total environmental impact for the life cycle of beer. Barley production on farms represented the largest share (37 %) in the base study, but the updated results show that packaging, logistics, sales and



**Fig. 2** Distribution of the total environmental impact indicator (Eco-Benchmark value) of Finnish barley malt beer chain by impact categories in the 2005 base study and in the 2010 updated study. Estimated confidence interval is ±2 %



**Fig. 3** Distribution of the total environmental impact indicator (Eco-Benchmark value) of Finnish barley malt beer chain by life cycle phases in the 2005 base study and in the 2010 updated study. Estimated confidence interval is ±2 %

consumption of beer currently represent the largest share (39 %). The share of barley production in farms is 36 % in the updated study, and it contributed -4 % to the total environmental impact. Brewing contributes 13 % to the total impact in the updated results, and thus represents the biggest decline (-7 %). That decline is due to the decreased specific electricity and specific heat consumption of breweries. According to data from breweries specific electricity consumption (kWh/litre beer) has been reduced through energy saving measures such as inverter controls for pump motors, reduced pumping in washing systems, better cooling technologies, and improved utilisation of the production capacity, i.e. higher production volumes at specific sites. Improved capacity utilisation and energy saving also largely explain the reduction in specific heat consumption (MJ/litre beer).

In conclusion, total environmental impact decreased in fertilizer and lime production, malting and starch barley production on farms, malting and brewing, as well as in transportation of intermediate products. Together these activity sectors brought about a 12 % reduction in the total environmental impact. Total environmental impact increased in beer logistics, sales and consumption as well as in barley starch production. Together the contribution of these sectors was +4 %, of which most derived from beer logistics, sales and consumption. Furthermore, specific energy consumption decreased in malting, even though the share of the total life cycle of beer increased because the total environmental impact decreased more. In addition, the total environmental impact of production of fertilizers and lime decreased. The reason for this is that currently in Finland nitric acid production, which is a component of fertilizer production, incorporates catalytic removal of nitrous oxide (N<sub>2</sub>O) emissions. The catalytic technology removes about 90 % of N<sub>2</sub>O emissions from fertilizer production.

#### 3.2 Barley production on farms

Changes in barley production on farms were studied with real input-output data from barley fields from 2005 to 2009. The results were compared with those of the base study, for which input-output data were available from 2001 to 2003. Differences were found in

volumes of lime products and fertilizers used, and in barley grain yields. Use of lime products decreased because of the longer times between lime applications, which decreased climate change impact. There were also changes in lime products used; use of clinker from the iron and steel industry increased from 3 % in the base study to 12 % in the updated study.

Barley yields increased in 2005–2009 by about 4 % per year as nitrogen fertilizer use decreased by about 2 kilograms per hectare. These factors have improved the nitrogen balances of fields and thereby nitrogen run-off per hectare has decreased. Also use of phosphorus fertilizer decreased and phosphorus balances have improved compared the base study. A better phosphorus balance does not, however, affect phosphorus run-off because it depends on the concentration of soluble phosphorus and total phosphorus in soil, and did not change substantially.

### 3.3 Changes in beer packaging

The models for the various kinds of primary packaging (aluminium can, glass bottle, steel keg) were not updated for their input-output data, but only for their volume-shares of the total beer supply by each brewery. In the base study the glass bottle share was biggest (76 %), whereas the aluminium can share was biggest in the updated study (70 %). The aluminium can share was only 7 % in the base study so the increase has been considerable (Fig. 4). The steel keg share was approximately the same in both studies. Changes in the primary packaging shares increased the estimated environmental impacts of the beer chain. The reason to the increase is the difference in the specific total environmental impact estimates (from the base study) used. Thus the total environmental impact indicator value per litre of beer delivered to consumers in aluminium cans was about 25 % higher than that delivered in reusable glass bottle. However, the environmental impacts of the aluminium can and glass bottle systems nowadays differ from those when the base study was conducted because aluminium can recycling has increased, and there have been some changes in glass bottle production systems. Because of this it is uncertain how changes in beer packaging volume-shares really affect the total environmental impact.

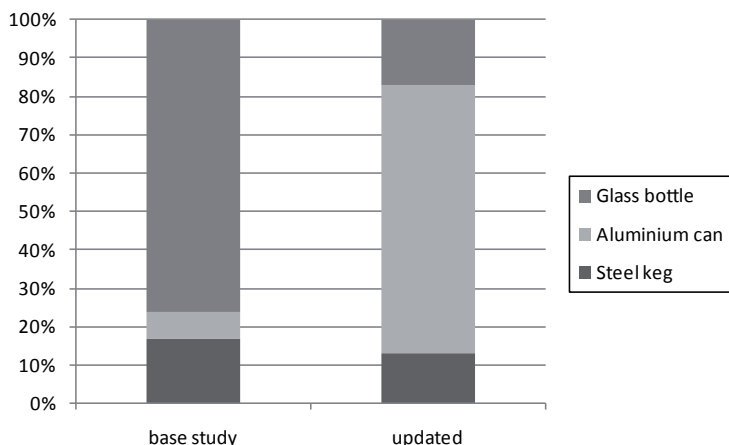


Fig. 4 Volume-shares of beer packaging in the 2005 base study and in the 2010 updated study

## 4 Conclusions

According to the results of the analysis, the evolution of the barley-malt-beer chain has been favourable from the environmental point of view. Total environmental impact (Eco-Benchmark value) was reduced by 7 % compared to base study. There are many trade-offs underlying this general trend, both between different categories of environmental impacts and between different activity-sectors of the chain. The categories in which the total impact decreased were: primary energy consumption, formation of tropospheric ozone and aquatic eutrophication. Those categories in which the impact increased were climate change and acidification. The trade-off between impacts on climate change and aquatic eutrophication on the one hand, and between impacts on acidification and formation of tropospheric ozone, and primary energy consumption on the other hand, were considered important for the reduction of the total impact.

As for activity-sectors, total environmental impact decreased in fertilizer and lime production, malting and starch barley production on farms, malting and brewing, as well as in transportation of intermediate products. Together these activity sectors brought about a 12 % reduction in the total environmental impact. The biggest reduction, –7 %, was in brewing. Barley production on farms contributed –4 %. Total environmental impact increased in beer logistics, sales and consumption as well as in barley starch production. Together the contribution of these sectors was +4 %, of which most derived from beer logistics, sales and consumption.

The changes in the Finnish beer chain that have reduced the total impact most significantly include: lower emissions from fertilizer production, decrease in lime use, improved hectare-yields of barley, better nitrogen balance and reduced run-off, and decrease in specific energy demand in malting, starch production and brewing. Nowadays in Finland nitric acid production, which is a part of fertilizer production, involves catalytic removal of nitrous oxide (N<sub>2</sub>O) emissions. Also breweries have invested in new technologies, e.g. inverter controls for pump motors, better cooling technologies, and motion and timer controlled lights, which have helped to decrease specific electricity demand. Heat demand in brewing has decreased due to the decreasing need to wash glass bottles following the decline in their use in favour of aluminium cans.

The total environmental impact decreased most in aquatic eutrophication. Reduction of aquatic eutrophication from barley production is still a very effective way to decrease the total environmental impact and to improve ecological evolution of the barley-malt-beer chain. Furthermore, a very effective way to strengthen sustainability is by making energy usage more efficient, as the example of brewing indicates. Efficient energy usage is a powerful tool to reduce total environmental impact because it affects the various environmental activity-sectors simultaneously.

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