Case Study on the Water Footprint of Stora Enso's Skoghall Mill

Report to the Alliance for Beverage Cartons and the Environment (ACE) and WWF.

Stora Enso

www.storaenso.com

Stora Enso is the global rethinker of the packaging, paper and wood products industry. We always rethink the old and expand to the new to offer our customers innovative solutions based on renewable materials. Stora Enso employs some 26 000 people worldwide, and our sales in 2010 amounted to EUR 10.3 billion. Stora Enso shares are listed on NASDAQ OMX Helsinki (STEAV, STERV) and Stockholm (STE A, STE R). In addition, the shares are traded in the USA as ADRs (SEOAY) in the International OTCQX over-the-counter market.

ACE, the Alliance for Beverage Cartons & the Environment

www.beveragecarton.eu

ACE provides a European platform for beverage carton manufacturers and their paperboard suppliers to benchmark and profile cartons as renewable, recyclable and low carbon packaging solutions. Engaging with stakeholders and partners seeking high environmental stewardship, it contributes expertise to EU policy, legislation and standard-setting.

ACE members include beverage carton producers Tetra Pak, SIG Combibloc and Elopak; they develop, manufacture and market systems for the processing, packaging and distribution of food, and produce packaging material at 20 plants in Europe. About 98% of the paperboard used by ACE members in beverage cartons in Europe is produced by Stora Enso in Skoghall (Sweden) and Imatra (Finland), and Korsnäs in Gävle and Frövi (Sweden), who are also members of ACE. These paper mills and the beverage carton manufacturers in ACE together employ close to 30,000 people worldwide.

WWF

www.wwf.eu

Why we are here: To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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1 Anticipated results of the pilot project

Access to fresh water is an issue of increasing attention and concern, both for society in general and not the least for the food industry. Worldwide, it is estimated that one billion people lack access to safe drinking water and more than two billion lack adequate water for sanitation[1]. This lack of water will increase pressure on industry and all other water users to decrease their use, especially in areas where fresh water is scarce. Being a supplier of packaging material to the food industry, Stora Enso recognizes that further understanding of our business's and products' impact on water footprint, water scarcity and related issues is needed. This pilot project was initiated to:

- Increase understanding of the water footprint concept
- Measure our products' blue, green and grey water footprint
- Estimate the impact of our products' blue, green and grey water footprint
- Identify where in our products' life cycle (Cradle-to-Gate) the biggest impact of water consumption occurs, and what possibly can be done to reduce this impact
- Identify possible methodological challenges in water footprint of fibre based products
- Increase understanding of forestry and forest based products role in the water cycle and in water footprint

Based on the results of the pilot study different actions may be developed like; information to stakeholders on our products' water footprint, strategy for choosing suppliers of purchased pulps and other raw materials, technology development in terms of increasing water efficiency at our production sites and benchmarking with other packaging materials and possibly also packed goods. Fresh water is a vital component in the manufacture of pulp and board, and access to it is hence of outmost importance, not the least in the manufacture of grades which are intended for food contact. Access to fresh water is not only important at the site of board, but equally important at the sites of suppliers of purchased pulps and chemical additives. Still, awareness of water consumption throughout the value chain of our products can contribute to reduce water use and consumption, especially where the consumption has a significant impact on the surrounding society and environment.

2 Conclusions

This pilot study reaches its targets in terms of estimating the blue, green and grey water footprint of Liquid Packaging Board produced at the Stora Enso Skoghall mill, and increasing the understanding of water footprinting of fibre based materials. It also estimates the impact of the LPB's water footprint based on the Water Stress Index. This study shows that none of the LPB production sub-processes take place in areas where water currently is scarce. Therefore the use of impact assessment does not alter the sub-process assigned with the greatest water footprint: Green water footprint of forestry (both production of fibre and bio-fuel). It can however be discussed whether evapotranspiration from a forest should be regarded as a consumptive water use and thereby be included in the green water footprint. Perhaps the water footprint methodology needs to be further refined to distinguish between possible regional differences in forestry (boreal, tropical etc.), or at least distinguish between changes in green water evapotranspiration induced by land use change. This area of development would hence be important for the forest product industry to further understand and get involved in. This is further discussed in chapter 8.2.

To reduce the impacts of LPB's water footprint it would be tempting to first address the sub-processes with the largest contribution: Evapotranspiration or green water in forestry. To reduce evapotranspiration as such is not possible without changing vegetation in the forests. Other options to reduce the green water footprint would be to:

- Further intensify the forestry to reduce the area needed. This however may be in conflict with legislation, forest certification and preservation of biodiversity.
- Further increase the wood resource efficiency of the LPB, which already is highly prioritized in product R&D.

Reducing the impacts of the other sub-process's water footprint would only have very minor benefits.

1 Bertram, J. Improving on haves and have-nots. Nature 452 (7185), 283-284.

Communication of water footprint is challenging. Informing just a single volumetric number would be potentially misleading, especially if a supply chain includes water consumption in both water scarce and water rich areas. Impact assessment methodologies are currently developing quickly within the water footprint community. These will help assessing social and environmental impacts of water consumption and thereby be a support for organizations to manage their water consumption more sustainably. Different methods will likely be needed depending on the scope of a study. So far no major brand owners or retailers promote product water footprint declarations or labelling.

3 Definitions

3.1 Blue, green and grey water

According to the Water Footprint Network[2] water footprint consists of three components: the blue, green and grey water footprint. The blue water footprint is the volume of freshwater that evaporated from the global blue water resources (surface water and ground water) to produce the goods and services consumed by the individual or community. The green water footprint is the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture). The grey water footprint is the volume of polluted water that associates with the production of all goods and services for the individual or community. The latter can be estimated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains at or above agreed water quality standards.

Definitions[3]:

$WF_{proc,\ blue}$ = blueWaterEvaporation + blueWaterIncorporation + LostReturnflow

$WF_{proc,\ green}$ = greenWaterEvaporation + greenWaterIncorporation

$WF_{proc,\ grey} = \frac{L}{c_{max}\ \ c_{nat}}$, where L is the pollutant load [mass/time] and c_{max} is the maximum acceptable concentration [mass/volume] and c_{nat} is the natural concentration in the receiving water [mass/volume]

For blue and green water, distinguishing between surface water, renewable groundwater and fossil groundwater is of importance to assess the impact of the water consumption.

3.2 Water use vs. water consumption

In water footprinting only fresh water consumption is accounted for. Consumption is here defined as loss of water from the available ground or surface water body in a catchment area, which happens when water evaporates, returns to another catchment area, or to the sea or is incorporated into a product.

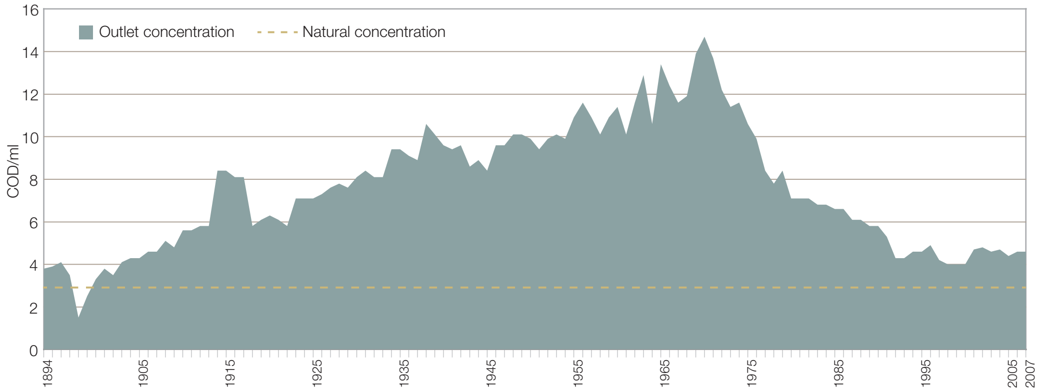
However, the gross amount of water use is more relevant when estimating the risk that lack of water may have on the possibility to run a business at a certain location. Water use can be linked to environmental permits, allocation (if two or more users compete for the same water source), water fees etc.

4 Lake Vänern

Skoghall mill is located on the shore to Lake Vänern, which serves both as water source and receiving water. Lake Vänern is one of Europe's largest lakes with an area of 565 000 ha and a volume of 153 billion m^3. The water quality in Lake Vänern has significantly improved the last 20-30 years, as presented in the figure below. This is mainly due to introduction and improved performance of waste water treatment facilities both in municipalities and industry, closures of industries, improved agricultural practice etc. Today, the COD concentration is back to pre-industrialization levels (4,7 mg COD/ml in 2007) and not far from what is perceived to be the natural concentration (3,0 mg COD/ml).

2 www.waterfootprint.org
3 Water Footprint Manual, State of the Art 2009: http://www.waterfootprint.org/downloads/WaterFootprintManual2009.pdf

Figure 1: Histogram showing the COD concentration measured at the outlet of the Lake Vänern.



4.1 Lake Vänern Society for Water Conservation

The Lake Vänern Society for Water Conservation[4] is a non-profit organization. Among the members are local authorities, county councils, other government bodies, companies engaged in the private sector, pressure groups and others interested in water conservancy.

The Society's objects are to promote the conservation of Lake Vänern's natural environment by e.g.:

- Functioning as a forum for the discussion of environmental issues affecting Lake Vänern and the dissemination of information about the lake
- Carrying out surveys of the lake and its waters
- Reporting and evaluating the results of environmental monitoring
- Formulating environmental objectives and proposing measures to be taken where these are needed; and also, where necessary, initiating further surveys
- Disseminating information about environmental conditions affecting the lake and about current environmental issues
- Producing information about the lake that is easily accessible

The Society publishes an annual report on the status of Lake Vänern. In the 2009 report[5] (Swedish only) has listed a number of indicators for Lake Vänern:

- Water quality

  This year's lake bottom oxygen levels were as usually very good. The lowest measures were at all three locations just under 10 mg O_2/litre. The total level of phosphorus is since the mid 1990's close to the estimated natural level of 4,5 – 6,5 µg P/litre, while the total level of nitrogen are still about 3 times the natural level of 200 – 300 µg N/litre. The high levels of nitrogen are considered to origin from leakage from agriculture in the southern parts of Lake Vänern. The TOC level has since the end of the 1990's remained on a stable level, slightly higher than the lowest levels measured in the first half of the 1990's. The ecological status for Lake Vänern is assessed to be high regarding total phosphorus, visible depth and chlorophyll levels. No immediate actions to improve the water quality of Lake Vänern are needed, but an investigation will be conducted to map the origin of nitrogen and phosphorus and options to further reduce these.

- Phytoplankton

  The level of total biomass in Lake Vänern was the lowest since the mid 1990's. Silicon algae are the dominating species in spring, while Recoiling algae dominate in the summer. The ecological status is assessed to be high regarding total biomass in august and good regarding trophic phytoplankton. Furthermore the status regarding chlorophyll level is high. No immediate actions are needed to further improve the phytoplankton situation in Lake Vänern.

4 www.lansstyrelsen.se/vastragotaland/Projektwebbar/Vanern/English
5 http://www.lansstyrelsen.se/NR/rdonlyres/9E0C745A-217F-4A36-932D-7D53D672C2AB/158003/Vanern_arsrapport_2009.pdf

- Metals and persistent organic compounds

  Maximum measured level of mercury in Pike was 0,42 mg/kg, which is significantly less than the maximum allowed level given in the EU directive 1881/2006[6] setting maximum levels for certain contaminants in foodstuffs (1,0 mg/kg). The corresponding level for Perch was 0,31 mg/kg (max allowed 0,5 mg/kg). The maximum level of PCB and PCB-like substances in Perch was 0,98 ng/kg, which was significantly less than the maximum allowed level in the EU directive 1881/2006 (100 ng/kg). Also the levels of PCBs in Trout were lower than the allowed level. The maximum level of dioxins in Perch was 0,13 ng/kg, which was significantly less than the maximum allowed level in the EU directive 1881/2006 (4 ng/kg). Also the levels of dioxins in Trout were lower than the allowed level. The levels of Cupper, Zink, Arsenic, Cadmium, Chrome, Lead and Nickel in fish are regularly monitored and were found to be stable or slightly decreasing (Cadmium). In Trout, the levels of Lead and Cadmium were even below detection limit, but the level of Mercury exceeded the EU directive 1881/2006 (maximum level: 0,51 µg/kg, limit: 0,5 µg/kg). No changes to the monitoring program are planned.

- No immediate actions are needed to further improve the situation for zooplankton, species living on the bottom of Lake Vänern or fish (Smelt and Vendace).

The report also identifies five issues of special attention for Lake Vänern. This issues are; sea level regulation, action plans for certain eutrophic bays and inlets to Lake Vänern, map and decontaminate certain catchment areas, keep meadows, beaches and islands clear from overgrowth, and protect important areas for the future. For each of these issues a list of actions is available. For the eutrophic bays and inlets, decreased nitrogen and phosphorus emissions from municipal waste water, industrial waste water and single house waste water is an action that affects Skoghall mill's operations.

4.2 The EU water framework directive

The EU water framework directive[7] is implemented in Swedish law and 5 five River Basin District Authorities have been established. Water discharges from the Skoghall mill are released into Värmlandssjön (a part of Lake Vänern) and the subsequent water bodies, all belonging to the Skagerrak and Kattegat river basin district. Värmlandssjön is characterized as follows below.

Figure 2: Skoghall mill's receiving water Värmlandssjön (marked in darker blue), which is a part of Lake Vänern.

6 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:364:0005:0024:EN:PDF
7 Directive 2000/60/EC

Table 1: Characterization of Värmlandssjön.

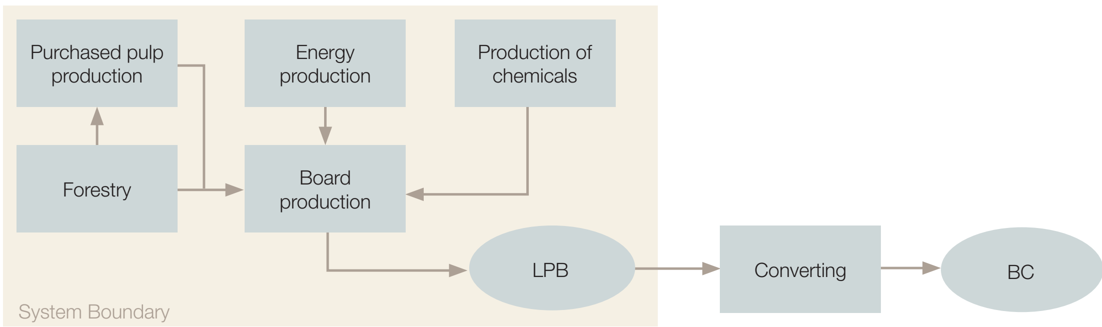
ECOLOGICAL STATUS	
Biological quality elements	Good regarding phytoplankton High regarding benthic invertebrates
Physico-chemical quality elements	Good regarding general conditions
CHEMICAL STATUS	
Lead and its components	Good
Cadmium and its components	Good
Mercury and its components	Failing to achieve good*, level of mercury in pike > 22mg/kg
Nickel and its components	Good
Pentachloro-phenol	Good
ENVIRONMENTAL ISSUES	
Acidification	No
Eutrophication	No
Environmental pollutants	Yes, mercury
Environmental pollutants except mercury	No
Alien species	Yes, signal crayfish
ASSESSMENT OF RISK	
Ecological risk	Not at risk
Chemical risk	At risk, mercury
Chemical risk except mercury	Not at risk

*All lakes in Sweden fail due to high levels of mercury.

5 Water footprint calculations

Not all input data for the calculations of the Water Footprint can be given due to confidentiality reasons. Instead the full set of data is presented in Appendix 1, which can be presented to a limited audience. The system boundaries of this pilot project are presented in the figure below.

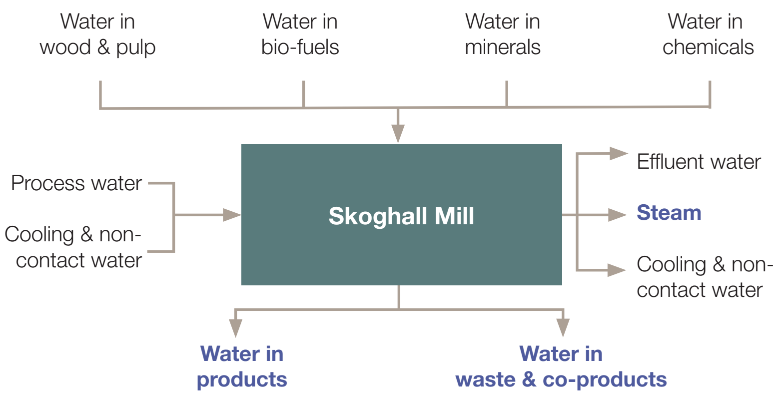
Figure 3: Included processes in the pilot study.



5.1 Skoghall mill

Skoghall mill is an integrated mill with both pulp and board production. Some pulp is also purchased from external producers. Because of the abundance of fresh water close to the mill site and lack of regulation, the amount of water used for cooling is not measured. Neither evaporated water (in form of steam) is measured, but can be estimated by the mill's energy experts. A water mass balance for 2009 was therefore used to estimate the mill's flows.

Figure 4: Water mass balance for Skoghall mill, where contributions to blue water footprint is marked in blue.



Blue WF

The Skoghall mill's blue water footprint is the sum of steam, water in products and water in waste & co-products: 1 128 000 + 50 000 + 150 000 = 1 328 000 m^3/year or *1,9 m^3/ton board*. Both effluent water and cooling & non-contact water are returned to the same water body as it was taken from, thus no lost return flows occur.

Grey WF

The production at Skoghall mill operates under an environmental permit given by the local authorities. The permit for waste water is set with regards taken to the environmental quality of the receiving water (Lake Vänern) in accordance with the IPPC directive[8] and the water framework directive[9]. The table below gives the environmental permit (June 10, 2005) for water emissions for the Skoghall mill and the emission levels for 2009. The water quality of the receiving water is described in chapter 4 ovan. Note: The new permit referred to below is dated April 3, 2009, but has not yet been enforced.

Table 2: Environmental permit and emissions to water for Skoghall mill in 2009.

PARAMETER	UNIT	PERMIT	NEW PERMIT	EMISSION	TYPE
AOX	kg/day	150	150	41,8	Limit
Suspended solids	ton/day	-	3	2,3	Limit
Chelating agents	kg/ton board	1,6	0,8	0,33	Limit
TOC	ton/day	14,5	10	7,3	Target
Chlorate	kg/day	200	200	17,9	Target
N-tot	kg/day	500	280	206	Target
P-tot	kg/day	50	30	17,7	Target

5.2 Scandinavian forestry

About 90% of the fibres used in Skoghall mill's board origins from Sweden and Norway. For this reason Scandinavian forestry is a good estimate for this project, when combined with the inclusion of pulp produced in South America.

8 Directive 2008/1/EC concerning integrated pollution prevention and control: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:024:0008:0029:EN:PDF

9 Directive 2000/60/EC establishing a framework for the Community action in the field of water policy: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF

Blue WF

No irrigation or other consumption of blue water is accounted for in the Scandinavian forestry.

Green WF

Based on the evapotranspiration in Sweden, given by FAO 2006[10], the average wood consumption (excluding purchased pulps) and the wood yield in the forest, the Green WF is *1 668 m^3 water/ton board*.

In the green water footprint, also water incorporated in the product leaving the forest is accounted for. The round wood and sawmill chips delivered to the Skoghall mill adds another *1,4 m^3 water/ton board*.

The total green water footprint in the Scandinavian forest is thus: *1 669 m^3 water/ton board*.

Grey WF

Due to forestry operations like transporting of logs in the forest, local water recipients can be affected. A number of activities within the forest management practice aim at minimizing the effect on local waters. These actions include avoiding logging near waters, not harvesting when the soil is too wet, constructing temporary bridges over creeks, introducing new vehicles with less ground pressure etc.

The potential grey water footprint of forestry would be affected by how forest management is conducted, time of year for harvesting and the prevailing weather, the sensitivity of a local water body etc. To draw any conclusions based on this in a general study like this would be very difficult and not meaningful.

10 http://www.fao.org/docrep/008/a0400e/a0400e00.htm

5.3 Purchased pulp and related forestry

15-20% of the fibres used at Skoghall mill comes from purchased pulps. About half of this pulp is produced in South America. As an approximation for the South American pulp, we have chosen to look into the Veracel pulp and the eucalypt plantations close in southern Bahia.

Blue WF

The blue water footprint of purchased pulp is the sum of evaporated water from the mill (steam), the water in products and co-products, and the water in wastes, all related to the consumption of purchased pulps. The Blue WF is estimated to *0,3 m^3 water/ton board* (according to appendix 1)

No irrigation or other consumption of blue water occurs in the forestry for the purchased pulp.

Green WF

The Green WF is based on the evapotranspiration in the Veracel area (FAO 2006), the wood consumption for eucalypt pulp, the wood yield in the forest and the purchased pulp consumption at Skoghall mill. This gives: *94,6 m^3 water/ton board.*

In the green water footprint, also water incorporated in the product leaving the forest should be accounted for: *0,2 m^3 water/ton board*.

The total green water footprint of purchased pulp is thus: 95 m^3 water/ton board.

Grey WF

No grey WF can be estimated, see chapter 5.2 Scandinavian forestry above.

5.4 Chemicals

Not all chemicals used in the board production are included here. Instead focus is on an agricultural product: Potato starch. Water consumption in starch production is estimated using EcoInvent[11] data. These EcoInvent datasets do not indicate if a water resource corresponds to blue or green water footprint. Instead this has been estimated by the author of this report.

11 www.ecoinvent.org

Table 3: Water consumption for starch production. Source: EcoInvent, 2009.

DESCRIPTION	ORIGIN	BLUE WF	GREEN WF	GREY WF
Cooling water	Unspecified	-	-	✓
Unspecified use	Lake	✓	-	-
Unspecified use	River	✓	-	-
Saltwater	Ocean	-	-	-
Saltwater	Sole	-	-	-
Unspecified use	Unspecified	-	✓	-
Unspecified use	Groundwater	✓	-	-
Turbine water	River	-	-	-

Note: Salt water falls out of the water footprint definition and turbine water was excluded from the blue water footprint as it is assumed be in-stream use and not affecting the river basin except for temporal variations. The grey water footprint is here estimated to correspond to the cooling water. However, it is not clear if there is a thermal pollution or not. The possible pollution caused by emissions to water has not been possible to estimate due to lack of knowledge of the environmental status of the receiving water.

Based on the EcoInvent data and the consumption of starch at the Skoghall mill (both given in appendix 1), the blue WF is 0,05 *m^3/ton board*, the green WF is *0,01 m^3/ton board* and *the grey WF is 0,04 m^3/ton board*.

5.5 Purchased electricity

The Skoghall mill is equipped with a Combined Heat and Power plant (CHP) where some of the electricity used at the mill is generated. Still about 60% of the electricity is purchased from the Swedish grid. The water consumed to generate Swedish electricity is taken from EcoInvent 2009.

Table 4: Water consumption for production of Swedish electricity mix. Source: EcoInvent, 2009.

DESCRIPTION	ORIGIN	BLUE WF	GREEN WF	GREY WF
Cooling water	Unspecified	-	-	✓
Unspecified use	Lake	✓	-	-
Unspecified use	River	✓	-	-
Unspecified use	Unspecified	-	✓	-
Unspecified use	Groundwater	✓	-	-
Saltwater	Ocean	-	-	-
Saltwater	Sole	-	-	-
Turbine water	River	-	-	-

Note: Salt water falls out of the water footprint definition and turbine water was excluded from the blue water footprint as it is assumed be in-stream use and not affecting the river basin except for temporal variations. The grey water footprint is here estimated to correspond to the cooling water. However, it is not clear if there is a thermal pollution or not. The possible pollution caused by emissions to water has not been possible to estimate due to lack of knowledge of the environmental status of the receiving water.

The use of externally purchased electricity gives *3,37 m^3/ton board blue WF, 0,09 m^3/ton board green WF and 2,37 m^3/ton board grey WF*.

5.6 Purchased bio-fuels

Blue WF

No irrigation or other consumption of blue water occurs in the production of purchased bio-fuels.

Green WF

In 2009 about 94% of the fuels used to generate heat at the Skoghall mill were bio-fuels. Most of the bio-fuels are residuals from the wood and chips used to produce board, and the water footprint of these is thereby accounted for in section 4.2 above. However, separately purchased bio-fuels were also used.

The evapotranspiration in Sweden is taken from FAO 2006 and is together with bio-fuel consumption and the annual wood yield in the forest the basis for the calculation (presented in appendix 1), which gives *422,5 m³ water/ton board*.

Additionally, the amount of water removed from the forest via bio-fuels is *0,18 m³ water/ton board*. Calculations presented in appendix 1.

The total green water footprint for bio-fuels is thus *423 m³ water/ton board*.

Grey WF

No grey water footprint is accounted for. For reasoning, see section 5.2.

6 Summary of water footprint

The water footprint for the production of 1 ton Liquid Packaging Board is summarized below, where also the blue, green and grey constituents are included for the different phases of the supply chain.

Table 5: Summary of the water footprint of Liquid Packaging Board expressed as m³ water/ton board.

	WATER FOOTPRINT [m³ water/ton board]			
	Blue	**Green**	**Grey**	**Total**
Skoghall mill	1,9	-	-	1,9
Scandinavian forestry	-	1669	-	1669
Purchased pulp and related forestry	0,3	95	-	95
Chemicals, Starch	0,05	0,01	0,04	0,1
Purchased electricity	3,4	0,1	2,37	5,8
Purchased bio-fuels	-	423	-	423
Sum	**6**	**2186**	**2**	**2194**

The vast majority (99,6%) of the LPB's water footprint is thus related to forest activities, either in Scandinavia where pulp wood and bio-fuels are sourced, or in Brazil (as exemplified here) from where wood for purchased pulp is sourced.

7 Assessing local environmental impacts of water consumption

So far this study has estimated the total consumption of water (in m³) at different parts of the supply chain of the liquid packaging board. However, estimating the impact of that water consumption will be very important to enable as correct decision making as possible. A product with a lower water footprint can actually be more damaging to society and environment than another product with a higher water footprint (in m³), depending on where the water for the two products were sources[12].To further assess the environmental impact of the water consumption in various locations, some different methods within the WBCSD's Global Water Tool[13] was used, together with the Water Stress Index.

- Based on the *Annual Renewable Water Supply* per Person[14], 4 of 6 supply chain parts included in this study were in watersheds with abundant water supply (> 4000 m³/person/year). These supply chain parts include: Skoghall mill, Scandinavian forestry, Purchased pulp and related forestry and Purchased bio-fuels. Purchased electricity was sources from a watershed with sufficient water supply (1700-

12 Ridoutt & Pfister, 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Global Environmental Change 20 (2010) 113-120.

13 See: http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?type=p&MenuId=MTc1Mg&doOpen=1&ClickMenu=LeftMenu (last visited: July 6, 2011)

14 See: http://www.wbcsd.org/web/watertool/GWT_Datasets.pdf (last visited: July 11, 2011)

4000 m³/person/year), while Chemicals, Starch was sourced from a watershed with stressed water supply (1000-1700 m³/person/year). The Annual Renewable Water Supply per Person is given for two reference years: 1995, and a projection for 2025. Both reference years gave the same results.

- Based on the *Total Renewable Water Resources*[15] (TRWR) per person, 5 of 6 supply chain parts included in this study were in watersheds with abundant water supply (> 4000 m³/person/year). Only Chemicals, Starch was sourced from a watershed with sufficient water supply (1701-4000 m³/person/year). The TRWR is given for three reference years: 2008, and projections for 2025 and 2050. All three reference years gave the same results.
- Based on the *Mean Annual Relative Water Stress Index*[15], all 6 supply chain parts included in this study were in watersheds with the lowest stress ranking (Low < 0,2).
- The *Water Stress Index*[15] gives a stress indicator between 0 (no water stress) and 1 (extreme water stress) based on the location of water consumption. The WSI was here used to be multiplied with the different components of the Liquid Packaging Board's water footprint. The WSI and the results are presented below in Table 6. It is worth noticing in Table 6 that all included areas where water is consumed have no, or low water stress.

Table 6: Summary of the Water Stress Index weighted water footprint of Liquid Packaging Board expressed as m³ water/ton board.

		WSI WEIGHTED WATER FOOTPRINT [m³ water/ton board]			
	WSI	**Blue**	**Green**	**Grey**	**Total**
Skoghall mill	0,0123	0,02	-	-	0,02
Scandinavian forestry	0,0123	-	20,5	-	20,50
Purchased pulp and related forestry	0,0121	0,00	1,10	-	1,10
Chemicals, Starch	0,11	0,01	0,00	0,00	0,01
Purchased electricity	0,015	0,05	0,00	0,04	0,09
Purchased bio-fuels	0,0123	-	5,20	-	5,20
Sum		**0,08**	**26,9**	**0,04**	**27,0**

Also the Water Footprint Network provides a method for assessing the sustainability of a product. Here it is suggested to separately assess the blue and green water scarcity, expressed as a quota between the footprint and the water availability. Quotas of 100% and above indicate an unsustainable situation. The method is interesting but difficult to apply with limited access to detailed information on water access throughout a supply chain of a complex product. Separating sustainability assessment between blue, green and grey water also adds to transparency and well informed decision making.

8 Discussion

8.1 Blue water footprint

The concept of blue water footprint is fairly straight forward and applicable to give an indication of water resource consumption in production processes. In this study, it was necessary to establish a water mass balance and to make some estimations to quantify all in- and outflows of water at the production site (Skoghall mill). For other parts of the supply chain, LCI database figures have been used. The available database figures are not intended for use in water footprint calculations which causes some difficulties in applying them. This is further discussed below.

8.2 Green water footprint

The concept of green water footprint was originally developed for agricultural activities and might work well for non-irrigated agriculture. For forest based products, the inclusion of green water evaporation might give misleading results as the evapotranspiration from a forest area would occur regardless if the forest is managed and harvested or not. The forests included in this study grow on land areas where they represent the natural vegetation.

15 Pfister et al, 2009. Assessing the environmental impacts of freshwater consumption in LCA. See: http://www.ifu.ethz.ch/staff/stpfiste/index_EN (Last visited: July 11, 2011)

If the purpose of estimating a green water footprint to assess the effects of anthropogenic water consumption the green water footprint of forestry should be left out. Support to this statement is also given in the draft ISO standard on water footprint.

8.3 Grey water footprint

While the blue and green water footprint indicates a consumption of a resource, the grey water footprint is an indicator of pollution. Adding indicators of two widely separated impact indicators may give a non-relevant information, or even a redundant information as water pollution is most commonly included in LCI and LCA studies either as emission parameters (e.g. COD, AOX, N-tot or P-tot) or as impact categories (e.g. eutrophication or aquatic ecotoxicity). The study also shows that estimating the grey water footprint is difficult for several reasons:

- Not all receiving waters are as well investigated and documented as Lake Vänern. The national authorities implementing the European Water Framework Directive provide information on the status of river basins, but beyond Europe much of this service is lacking.
- It is not clear how the grey water footprint methodology handles combinations of emissions, e.g. COD potentially contributing to eutrophication and AOX potentially having a toxic effect on water living organisms.
- It is also not clear how the fact that in most cases there are more than one industrial or other activity emitting pollutants to the same recipient.
- It is not clear how to estimate the impact that thermal pollution that a waste water stream may cause on the receiving water.
- If e.g. insecticides are used in forest management, the pollution caused by these should be included in the grey water footprint, but other possible effects on water sheds e.g. increased turbidity due to operating machines close to water have not been possible to estimate here.

The definition of water footprint only includes fresh water. However it would also be relevant to include pollution of sea water in the scope of the grey water footprint as pollution of sea water may cause equally bad ecological effects as pollution of fresh water would do.

8.4 Data gaps

This study intends to cover the major parts of the production of Liquid Packaging Board supply chain. It covers board production at Skoghall mill, production of wood and chips in the Scandinavian forest, production of purchased pulp and its related forestry, generation of purchased electricity, production of purchased bio-fuels and production of starch (which was estimated to be the most water intensive chemical additive. This roughly includes the cradle-to-gate life-cycle of Liquid Packaging Board production with the following exemptions:

- Transportation was estimated to have a low water footprint. It could however be argued that e.g. electric train transports could have a significant contribution, especially in countries with high share of hydro electric power production and if turbine water should be included in the water footprint.
- Other chemical additives (than starch) which require much electric power to be produced might have a significant contribution, especially in countries with high share of hydro electric power production and if turbine water should be included in the water footprint.
- Purchased fuels are dealt with in terms of bio-fuels, both separately purchased bio-fuels and wood residuals etc. coming with the wood and chips used in the pulp production at the Skoghall mill. A minor amount of fossil fuels are still used at the Skoghall mill and the pre-chains of these fuels are excluded from this study.

Later stages of the LPB's life cycle e.g. converting to packaging, filling etc. are beyond the scope of this study.

8.5 Data availability

As already mentioned some data in this study was taken from publicly available databases. Neither of the examined databases (EcoInvent[16] and ELCD[17]) have organized the data on water in a manner that is easy to use for water footprint studies. As relying on databases for non-primary processes is needed to enable water footprint studies, these databases need to be further developed in terms of providing relevant data for water footprint calculations.

Before relevant and well documented data for water footprint calculations is made available in publicly available databases, it is difficult to conduct product related water footprints taking a life cycle perspective.

8.6 Turbine water

Water consumption in electricity generation often includes water passing through hydro electrical power plants. If included, the turbine water in electricity generation would have had the greatest share of the total water footprint in this study. It can be questioned if this water should be regarded as water consumption and hence be included in the water footprint, but as the hydro electric power generation is based on storing water in basins over time there will be a temporal impact of water availability both upstream and downstream of the power plant. It can however be argued that only a part of the turbine water causes a temporal impact on the surrounding water bodies. How large this share should be is not clear. Turbines also have an effect on living organisms passing through them. The possible harm to these organisms should be studied in detail case by case, and has not been included in this study.

8.7 Water footprint vs. water stewardship

Water scarcity is a global concern, but a local problem. The consumptive water use should therefore be mapped to where the consumption occurs (geographically) and the water stress at that location. There are already several indicators of water stress (and similar) that can be used as weighting factors depending on what the scope of the study is. Water Scarcity Index and the WBCSD Water Tool provide useful help in defining places of water consumption on maps where also the water stress level can be displayed. Just highlighting this (see the figure below) gives a quick illustration of e.g. a supply chain's hot-spots in terms of which production sites have higher water risk, and thus where risk management might be focused.

16 www.ecoinvent.org
17 http://lct.jrc.ec.europa.eu/assessment/data/

Figure 5: The location of the included parts of the LPB's supply chain mapped on the Water Scarcity Index (blue = no water scarcity, red = extreme water scarcity).