Systembolaget – Vinmonopolet

Nordic Life Cycle Assessment

Wine Package Study

Executive Summary

August 2010

Bio Intelligence Service - Scaling sustainable development
Industrial Ecology - Nutritional Health

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Results presented here are based on circumstances and assumptions that were considered during the study. If these facts, circumstances and assumptions come to change, results may differ.

It is strongly recommended to consider results from a global perspective keeping in mind assumptions taken rather than specific conclusions out of context.

Contents

1. Context

Systembolaget and Vinmonopolet are the Swedish and the Norwegian alcohol retail monopolies. Their aim is to minimize alcohol-related problems by selling alcohol in a responsible way, without profit motive. This includes taking into account the environmental impact of the different products they sell.

Systembolaget and Vinmonopolet decided to assess various wine packaging solutions in order to identify their main impacts on the environment. Package manufacturers for each package option studied were invited to participate, sharing primary data and costs. In addition to Systembolaget and Vinmonopolet, three package manufacturers (Elopak, Smurfit Kappa Bag-in-Box/Vitop and Tetra Pak) and one importer (Oenoforos) decided to join the study. All six partners equally shared its cost.

Previous studies has shown that there is no "perfect" or "ecological" packaging in any absolute way, but in general packaging better suited than others for a given product, market, or transportation conditions...

In this context, this study provides reliable environmental data on the considered packaging systems. The data and results are specific to these products, to the Nordic market and to the transportation conditions between the winery locations and the packaging locations.

2. Objectives

The goals of this study are:

- to identify and quantify the impacts of alternative wine packaging solutions,
- to identify which stages of the life cycle give rise to the impacts,
- to understand the drivers determining the life cycle impacts,
- to identify and investigate potential improvement opportunities for each solution,
- to carry out an ISO-compliant comparative assessment of the packaging systems.

The comparative environmental assessment of the wine packaging systems is performed through Life Cycle Assessment (LCA) methodology according to ISO 14040 and ISO 14044.

In order to allow communication based on the results of this study, a critical review has been performed by three independent experts: RDC Environment (LCA expertise and head of the critical review), JF Patingre Consultant (LCA expertise), Innventia (packaging expertise and Nordic specificities expertise).

3. Systems studied

Five different types of wine packages and sixteen volumes commercialised in Sweden and Norway are considered. For detailed analyses, the most current volumes according to professionals have been considered **as reference scenarios.** These volumes are marked in **bold** in the following list.

- PET bottle: **75 cl** and 37.5 cl,
- Glass bottle: **75 cl** and 37.5 cl,
- Bag in Box[1] (BiB): 10 l, 5 l, **3 l**, 2 l and 1.5 l,
- Stand up Pouch[2] (SuP): 3 l, **1.5 l** and 1 l,
- Beverage carton: **1 l**, 75 cl, 50 cl and 25 cl.

[1] 10 l and 5 l BiBs are not intended for households in Sweden and Norway.

[2] Some sizes not commercialised for wine in the studied countries

Note that in order to present the average environmental profile of beverage cartons, data from the two sponsors have been averaged for all formats except for the 25 cl format because one of the two does not have any cap.

Similarly, two types of bags in BiB systems have been averaged since two types of film coexist to make the bag: metallised polyester laminated to polyethylene and clear coextruded polyethylene/ethylene vinyl alcohol (EVOH)/polyethylene.

Presentation of the primary packaging reference scenarios

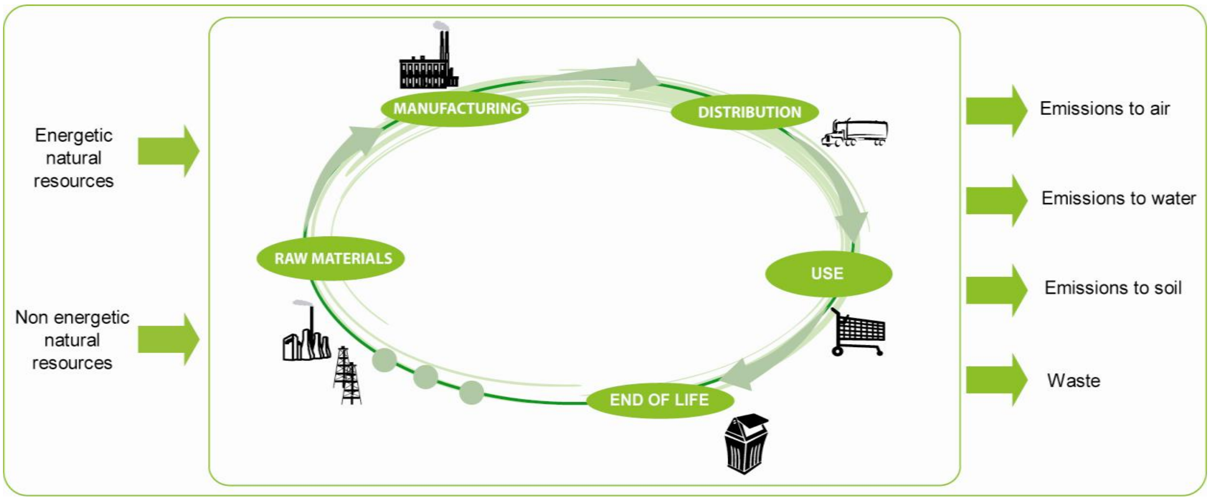
System	General description	Closure type studied	Tot. Weight including closure
PET bottle 75 cl	The package is blown PET (Polyethylene terephthalate — a thermoplastic polymer resin of the polyester family) with a plastic screw cap closure and paper labels. Various oxygen barrier enhancements can be used to extend product shelf life.	LDPE screw cap	54.4 g
Glass bottle 75 cl	Raw materials (primarily silica) are melted and formed into glass wine bottles. Paper labels are glued on the bottle or are self-adhesive. A closure (made out of natural cork, plastic or aluminum) is added to the package.	Aluminium screw cap	479.5 g
Bag in Box 3 l	A flexible plastic bag (composed of an outer barrier film and an inner polyethylene film, equipped with a tap for pouring) placed in a cardboard box. The outer barrier film contains either a thin layer of EVOH or aluminum to protect the wine against oxygen.	Tap and gland	179 g
Stand up Pouch 1.5 l	A sealed plastic bag that is designed to stand upright and made of a multilayer laminate film with a layer of aluminium foil to protect against oxygen. A tap is fitted to the pouch.	Tap and gland	34.8 g
Beverage carton 1 l	The beverage cartons analyzed in this study are primarily made of paperboard laminated with a thin aluminum foil and polymer layers. The aluminum foil functions as an oxygen barrier. There are different shapes of beverage cartons and various closures can be applied to the carton.	Top: a base with neck and separable lid	38.1 g

PET bottle 75 cl	Glass bottle 75 cl	Bag in Box 3 l	Stand up Pouch 1.5 l	Beverage carton 1 l
				

4. Methodology

General overview of the LCA methodology

A Life Cycle Assessment (LCA) aims at assessing the quantifiable environmental impacts of a service or product from the extraction of the materials contained within the components involved, to the treatment of these materials at the end-of-life stage.



This "cradle-to-grave" methodology has been standardised at the international level through ISO 14040 and ISO 14044. The methodology consists in carrying out exhaustive assessments of natural resources consumption, energy consumption and emissions into the environment (waste, emissions to air, water and ground), for each and every studied process.

All the incoming and outgoing flows of materials and energy are inventoried for each life cycle phase and then aggregated to quantify environmental impact indicators. LCA is a multi-criterion approach whose results are presented through several indicators of environmental impacts.

Compliance with the PAS2050:2008 framework

The PAS2050 is a Publicly Available Specification which has been developed for assessing the life cycle greenhouse gas emissions (GHG) of goods and services. In order to meet the requirements imposed by the PAS 2050, the GHG emissions portion of this LCA has been made as compliant as possible to the 2008 version of PAS2050.

Functional unit

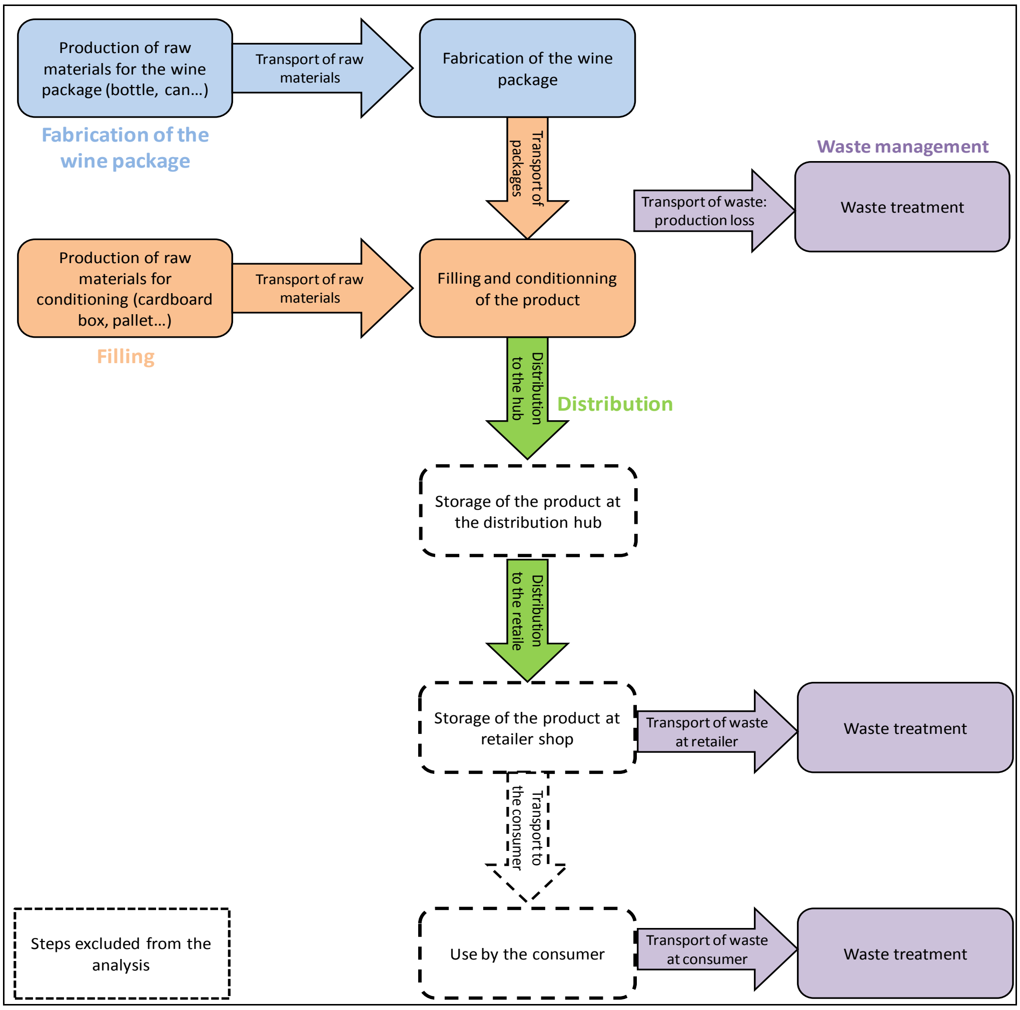
The Functional Unit must allow quantifying the service given by the packaging, which is its practical value. In this study, the functional unit chosen is:

"Packaging and distribution of 1000 litres of wine"

This functional unit is distribution oriented and does not consider the use phase.

5. System boundaries

The LCA takes into account all the impacts generated by the product over its life cycle, "from cradle to grave" as presented in the following overview of the system.



Thus, for each wine packaging system studied, the generic life cycle includes the following steps:

- extraction of raw materials and manufacturing of materials used in the composition of each packaging level: primary (body & closure), secondary, tertiary
- filling and packaging of beverages
- end-of-life of the various types of packaging (primary, secondary, tertiary) by retailer and consumer
- transportations between each of these life-cycle steps

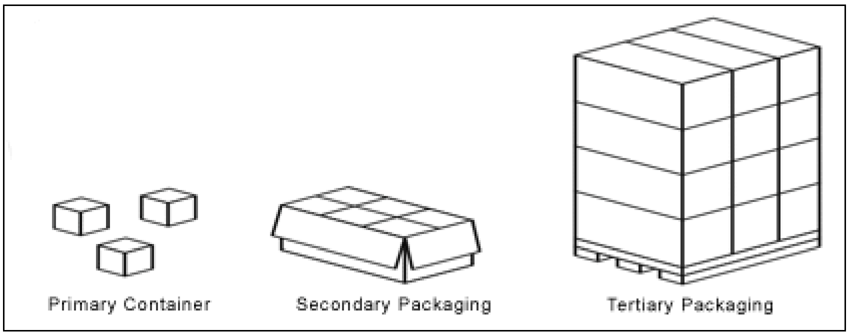
Some stages of the life cycle are not taken into account, either because they do not fit with the purpose of the study (e.g. the wine production) or because they are very difficult to estimate (the environmental impacts of the transportation of customers, estimated per kg or litre of packaging, for instance), and would not provide any insight for the eco-design of packaging.

Time perspective

In this study, a time horizon of 100 years has been chosen. Although being arbitrary, the time scale of 100 years is commonly chosen in LCA. This choice is also consistent with the PAS 2050 requirements.

Packaging levels

For each packaging solution, the system boundaries include the 3 types of packaging: primary, secondary and tertiary packaging as shown in the next figure.



6. Environmental impact/inventory indicators

Environmental impact indicators

The study of the environmental impacts has been carried out using characterisation factors from CML2 spreadsheet 3.3 (Institute of Environmental Sciences, Leiden University, NL), 2008. These indicators are scientifically and technically valid. They are among the most consensual ones according to the international community of LCA experts.

The complete list of impact indicators considered in the study is given in the next table.

Table 1: Environmental impact indicators and inventory indicators considered in the study

Impact category	Unit	Reliability	Source
Abiotic resources depletion potential	kg Sb eq	++	CML 2001 (ADP)
Global warming potential	kg CO_2 eq	+++	IPCC 2007
Ozone layer depletion potential	kg CFC-11 eq	+	CML 2001 (ODP)
Photochemical oxidation potential	kg C_2H_4 eq	+	CML 2001 (POCP)
Air acidification potential	kg SO_2 eq	++	CML 2001 (AP)
Eutrophication potential	kg PO_4^{3-} eq	++	CML 2001 (EP)
Human toxicity potential	kg 1,4-DB eq	???	CML 2001 (USES-LCA-100 years)
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	???	
Sedimental ecotoxicity potential	kg 1,4-DB eq	???	
Terrestrial ecotoxicity potential	kg 1,4-DB eq	???	
Water consumption*	m^3	+	Ecoinvent, Cumulative water consumption
Primary energy*	MJ primary	++	Ecoinvent, Cumulative Energy demand
*Inventory indicators			

Note that the water use does not consider water scarcity/water stress. The data includes feed water, groundwater, river water, sea water, well water with river silt and unspecified water, water uses for hydroelectricity and power plants cooling are not taken into account.

7. Sources of data

Primary packages data collection

Regarding primary packages, data collection has been carried out firstly through information provided by the sponsors involved in the study for their specific product. The glass system is mostly based on secondary data because glass manufacturers solicited chose not to participate in the study and not to furnish primary data.

The table below summarises the sources of data for primary package for each system.

Systems	Data source for primary package	Country
Glass bottle	Systembolaget Bibliography and inventories data	Europe
PET bottle	Manufacturer of equipment for PET bottles production	France
Bag in Box	Smurfit Kappa Bag-in-Box and Vitop	France
Stand up Pouch	Smurfit Kappa Bag-in-Box and Vitop	France
Beverage carton	Elopak (sponsor)	Norway
	Tetra Pak (sponsor)	Sweden

Data collection for filling stage, secondary packaging and tertiary packaging

For the filling stage processes (filling and conditioning), data have been provided by the sponsors and professionals directly or by one of their client. Data also covers aspects regarding the secondary and tertiary packages since the filler conditions the products before sending them to the retailing groups.

The next table summarises the sources of data for the filling stage of each system.

System	Data source for filling stage	Country
Glass bottle	JeanJean	France
PET bottle	Manufacturer of equipment for PET bottles production	France
Bag in Box	JeanJean	France
Stand up Pouch	JeanJean	France
Beverage carton	Elopak (sponsor)	Norway
	Tetra Pak (sponsor)	Sweden

Distribution and end-of-life routes

Distribution scenarios have been decided with Systembolaget and Vinmonopolet. All systems have been considered to be transported from the producer factory to the South of France to be filled. Then a common distribution hub hypothetically located in Arvika (Värmland County, Sweden) was considered.

End-of-life routes for packages after consumer use in Sweden and Norway have been taken from national statistics and adpated when necessary. Systembolaget and Vinmonopolet have provided data about end-of-life of secondary and tertiary packaging for their respective retailers network.

Data from life cycle inventories

Whenever available, specific life cycle inventories from international federations have been used (EAA, PlasticsEurope). For other data, the inventory of flows was mainly carried out with the Ecoinvent v2.0 database, recognised by the international experts as one of the best LCA databases. Lastly, as for some end-of-life processes, inventories were not available; WISARD 4.2 has been used to complete missing LCI.

8. Limitations

Concerning the glass system, the production phase only considers raw material production and the bottle formation process from fusion glass is not included in the life cycle inventory. Even though the bottle formation stage is not covered in the LCA data, associated impacts are estimated to be low compared to the impacts of melting glass which are included.

In this study, the following steps have been neglected as they were not considered relevant to achieve the purpose of this study:

- operations of research and development that have permitted the creation of the current wine packages,
- transport of finished goods between the retail outlet and the consumption place,
- consumption of energy to store the finished goods in the outlet or at the consumer's place,
- cleaning products used at production sites,
- glues used to stick labels, inks used for advertising on labels and packaging systems,
- II^{ary} and III^{ary} packaging systems used to transport raw materials have not been considered.

The production of the wine has been excluded as it does not offer differentiation between the different systems due to a lack of reliable data. For the end-of-life of the systems, the emptying rate has been considered to be of 100% i.e. no remnants have been considered inside the packages for end-of-life. Aside from the points listed above, no general cut-off criteria were applied. All available data were used.

9. Complementary/sensitivity analysis performed

In addition to the study of the reference scenarios and comparative assessments, several analyses were conducted in order to have a better understanding of impact drivers.

- Complementary analysis on transport of filled packages

In this analysis, the impacts associated with the weight of the wine are taken into account during transportation steps of filled packages from filler to distribution hub and from distribution hub to retailer.

- Sensitivity analysis on carbon sequestration

As required by the PAS 2050, carbon sequestration is accounted for in the baseline model. In this analysis, results of the reference volumes with and without considering carbon sequestration are compared.

- Sensitivity analysis on allocation procedures for recycling

In this analysis, different allocation procedures are compared in order to assess how methodological choices regarding recycling may impact the comparison results.

- Complementary analysis on glass bottle

Data used in the present report for glass bottle production are somehow outdated. For that reason, an analysis was performed. It is based on the assumption that environmental improvements in the production phase of glass life cycle should not exceed a 30% reduction of the impacts we measured.

- Complementary analysis on packaging and content: taking into account wine losses

For each packaging system, wine losses can occur throughout its life cycle. These losses can be due to distribution steps, consumer behaviour, packaging characteristics. In order to evaluate the uncertainties due to potential wine loss throughout the life cycle of the packages, a specific analysis was performed on global warming indicator assuming a similar wine loss rate of 2% for all systems.

10. Results obtained for the reference scenarios

Description of the life cycle steps

For the purpose of the study, the life cycles of the five systems have been divided into 4 main stages and 12 stages.

Table 2: Description of the life cycle steps

Life Cycle "main stages"	Life Cycle stages	Life Cycle sub-stages	Definitions
Packaging production	**Primary packaging**	Primary packaging raw materials production & supply	Extraction, production and transport of the raw materials to the primary packaging* producer
		Packaging Formation	Energy, water and raw materials used in the process of formation of the primary packaging production, supply and combustion
	Closures	Closures raw materials production & supply	Extraction, production and transport of the raw materials to the closure producer
		Closures formation	Energy, water and raw materials used in the process of formation of closures production, supply and combustion
	Labels	_	Extraction, production and transport of the raw materials of the label to the filling company
Filling	**Primary packaging supply**	_	Transport of the primary packaging (and closure when applicable) from the primary packaging producer to the filling company
	Closures supply	_	Transport of the closures from the closure producer to the filling company (when applicable)
	Secondary & tertiary packaging production & supply	_	Extraction, production and transport of the raw materials of the secondary and tertiary packaging to the filling company
	Filling and conditioning	_	Energy, water and raw materials used in the processes of filling and conditioning production, supply and combustion
Distribution	**Distribution from filling station to distribution hub**	_	Transport of the products from the filling company to the distribution hub in Arvika (excluding the wine when the transport scenario deals with filled products)
	Distribution from hub to retailer	_	Transport of the products from the distribution hub in Arvika to the retailer (excluding the wine when the transport scenario deals with filled products)
Waste Management	**Waste: production losses**	_	Waste treatment of materials lost during production stages (primary packaging and closures production and filling and conditioning) and their transport to waste treatment centres
	Waste at consumer	_	Waste treatment of primary packages and their transport to waste treatment centres
	Waste at retailer	_	Waste treatment of secondary and tertiary packages and their transport to waste treatment centres

*In this table, primary packaging consists in the main container of the packaging, excluding the closure and the label

For the five systems the results of the reference scenario are given in separated tables for Norway and Sweden. Each table shows the breakdown of the environmental impacts of the system per life cycle "**main stages**". The contribution of each main stage is presented as a percentage of total impacts even if the contribution of the phase is negative (environmental benefits). For each indicator, the percentage adds up to 100%.

75 cl PET bottle results

The next tables present the breakdown of the environmental impacts of the PET system per life cycle stage for Norway and Sweden.

Breakdown of the environmental impacts of the 75 cl PET bottle consumed in Sweden (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**1,85**	143%	24%	10%	-76%
Water consumption	m3	**1,51**	90%	100%	2%	-92%
Primary energy	MJ primary	**5016**	133%	43%	8%	-84%
Global warming potential	kg CO2 eq	**267**	88%	24%	10%	-22%
Ozone layer depletion potential	kg CFC-11 eq	**1,87E-05**	56%	41%	23%	-20%
Photochemical oxidation potential	kg C2H4 eq	**4,21E-02**	110%	40%	10%	-60%
Air acidification potential	kg SO2 eq	**0,974**	88%	34%	15%	-37%
Eutrophication potential	kg PO4 eq	**0,185**	109%	40%	18%	-68%
Human toxicity potential	kg 1,4-DB eq	**30,3**	130%	28%	5%	-62%
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	**1,18**	54%	38%	13%	-4%
Sedimental ecotoxicity potential	kg 1,4-DB eq	**2,65**	52%	37%	14%	-3%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	**5,27E-02**	80%	61%	4%	-45%

Water consumption indicator in LCA study presents various methodological limits

Breakdown of the environmental impacts of the 75 cl PET bottle consumed in Norway (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**1,77**	149%	25%	10%	-84%
Water consumption	m3	**1,51**	89%	100%	2%	-92%
Primary energy	MJ primary	**4885**	136%	45%	8%	-89%
Global warming potential	kg CO2 eq	**259**	90%	24%	11%	-26%
Ozone layer depletion potential	kg CFC-11 eq	**1,85E-05**	57%	42%	23%	-22%
Photochemical oxidation potential	kg C2H4 eq	**4,11E-02**	113%	41%	10%	-64%
Air acidification potential	kg SO2 eq	**0,957**	89%	35%	16%	-40%
Eutrophication potential	kg PO4 eq	**0,178**	114%	42%	19%	-75%
Human toxicity potential	kg 1,4-DB eq	**28,9**	136%	29%	5%	-70%
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	**1,15**	55%	39%	13%	-7%
Sedimental ecotoxicity potential	kg 1,4-DB eq	**2,58**	53%	38%	15%	-6%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	**5,15E-02**	82%	63%	4%	-49%

Water consumption indicator in LCA study presents various methodological limits

Distribution of the environmental impacts over the life cycle of the PET bottle shows similar trends in both scenarios. Indeed, they only differ for the end-of-life phase, where disposal routes are slightly different between Norway and Sweden.

The production of the packaging itself is the main contributor for all environmental indicators considered except water consumption.

Filling is the largest contributor for water consumption. Filling is also significant (≥ 40%) in terms of primary energy, ozone layer depletion, photochemical oxidation, eutrophication, and terrestrial ecotoxicity indicator. Note that the impacts of this stage are mostly due to secondary packaging and not to the filling and conditioning processes themselves.

The distribution phase is never the most contributing phase.

Recycling and energy recovery provide environmental benefits on all indicators.

As a conclusion, most of the environmental impacts of the PET system are explained by the impacts associated with the production of the raw materials, be it for primary or secondary packaging.

75 cl glass bottle results

The next tables present the breakdown of the environmental impacts of the glass bottle packaging system per life cycle phase for bottles consumed in Norway and Sweden.

This packaging system has an aluminium screw cap. Note that an inconsistency was detected in EAA inventory of aluminium recycling and primary aluminium production. Indeed, the orders of magnitude of the polycyclic aromatic hydrocarbon (PAH) emissions are not consistent between both inventories. Considering the important impact of this flow on toxicity related indicators, these indicators are not presented for this system.

Breakdown of the environmental impacts of the 75 cl glass bottle consumed in Sweden (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**4,54**	102%	16%	16%	-35%
Water consumption	m3	**7,65**	104%	26%	2%	-32%
Primary energy	MJ primary	**11760**	106%	26%	14%	-47%
Global warming potential	kg CO2 eq	**885**	109%	12%	13%	-34%
Ozone layer depletion potential	kg CFC-11 eq	**6,19E-05**	125%	21%	29%	-75%
Photochemical oxidation potential	kg C2H4 eq	**2,41E-01**	113%	10%	7%	-31%
Air acidification potential	kg SO2 eq	**7,161**	106%	8%	9%	-22%
Eutrophication potential	kg PO4 eq	**0,671**	76%	18%	21%	-15%

Water consumption indicator in LCA study presents various methodological limits

Breakdown of the environmental impacts of the 75 cl glass bottle consumed in Norway (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**4,48**	104%	16%	16%	-36%
Water consumption	m3	**7,60**	105%	27%	2%	-33%
Primary energy	MJ primary	**11646**	107%	27%	14%	-49%
Global warming potential	kg CO2 eq	**875**	110%	12%	13%	-35%
Ozone layer depletion potential	kg CFC-11 eq	**6,02E-05**	128%	22%	29%	-79%
Photochemical oxidation potential	kg C2H4 eq	**2,38E-01**	114%	11%	7%	-32%
Air acidification potential	kg SO2 eq	**7,109**	106%	8%	9%	-23%
Eutrophication potential	kg PO4 eq	**0,667**	76%	18%	21%	-16%

Water consumption indicator in LCA study presents various methodological limits

Distribution of the environmental impacts over the life cycle of the glass bottle show similar trends in Norway and Sweden. Indeed, they only differ for the end-of-life phase, where disposal routes are slightly different.

The production of the packaging itself is the main contributor for all indicators. Filling has a moderate impact (all indicators under 27%) for both systems. Note that most of the impacts of this phase are due to secondary packaging or primary packaging supply and not the filling and conditioning processes. Distribution also appears as a moderate contributor (all indicators under 29%) for both systems.

Lastly, important benefits are observed in the end-of-life phase thanks to recycling. These benefits correspond to the recycling of post consumer waste.

As a conclusion, most of the environmental impacts of the glass system are explained by the impacts associated with the production of the raw materials, be it for primary or secondary packaging.

3 l BiB results

The next tables present the breakdown of the environmental impacts of the BiB system per life cycle phase for Norway and Sweden.

Breakdown of the environmental impacts of the 3 l Bag in Box consumed in Sweden (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**1,09**	79%	18%	10%	-6%
Water consumption	m3	**1,71**	150%	51%	1%	-102%
Primary energy	MJ primary	**3175**	114%	35%	8%	-58%
Global warming potential	kg CO2 eq	**159**	55%	15%	11%	19%
Ozone layer depletion potential	kg CFC-11 eq	**1,60E-05**	64%	18%	16%	2%
Photochemical oxidation potential	kg C2H4 eq	**2,64E-02**	96%	29%	10%	-34%
Air acidification potential	kg SO2 eq	**0,522**	81%	24%	18%	-23%
Eutrophication potential	kg PO4 eq	**0,102**	73%	26%	20%	-20%
Human toxicity potential	kg 1,4-DB eq	**18,1**	65%	22%	5%	8%
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	**0,88**	51%	21%	11%	17%
Sedimental ecotoxicity potential	kg 1,4-DB eq	**1,91**	51%	21%	12%	16%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	**5,81E-02**	85%	29%	2%	-16%

Water consumption indicator in LCA study presents various methodological limits

Breakdown of the environmental impacts of the 3 l Bag in Box consumed in Norway (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**1,15**	75%	17%	10%	-1%
Water consumption	m3	**1,40**	183%	62%	1%	-146%
Primary energy	MJ primary	**3054**	119%	37%	8%	-64%
Global warming potential	kg CO2 eq	**157**	56%	15%	11%	18%
Ozone layer depletion potential	kg CFC-11 eq	**1,71E-05**	60%	17%	15%	8%
Photochemical oxidation potential	kg C2H4 eq	**2,53E-02**	100%	30%	10%	-40%
Air acidification potential	kg SO2 eq	**0,502**	84%	25%	18%	-28%
Eutrophication potential	kg PO4 eq	**0,098**	77%	27%	21%	-25%
Human toxicity potential	kg 1,4-DB eq	**18,9**	62%	22%	5%	12%
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	**0,82**	54%	23%	12%	11%
Sedimental ecotoxicity potential	kg 1,4-DB eq	**1,82**	54%	22%	13%	12%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	**5,63E-02**	88%	30%	2%	-20%

Water consumption indicator in LCA study presents various methodological limits

The distribution of the environmental impacts over the life cycle of the BiB shows similar trends for both scenarios.

Packaging production is always the most impacting life cycle stage for all environmental indicators.

Filling has a significant impact (more than 35%) in terms of water consumption and primary energy for both systems. Note that most of the impacts of this phase are due to secondary packaging and not the filling and conditioning processes.

Overall, distribution appears as a moderate contributor with all indicators having a contribution below 21%.

Waste management appear as a minor impacting stage in this system in terms of global warming potential, ozone depletion, human, freshwater and sedimental ecotoxicity. Waste management brings benefits on other indicators.

As a conclusion, most of the environmental impacts of the BiB system itself are explained by the impacts associated with the production of the raw materials, and particularly from the production of cardboard, be it for primary or secondary packaging.

1.5 l SuP results

The next tables present the breakdown of the environmental impacts of the SuP system per life cycle phase for Norway and Sweden.

Breakdown of the environmental impacts of the 1.5 l SuP consumed in Sweden (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**1,20**	85%	16%	8%	-10%
Water consumption	m3	**1,53**	75%	72%	1%	-48%
Primary energy	MJ primary	**3353**	81%	42%	7%	-30%
Global warming potential	kg CO2 eq	**176**	45%	17%	9%	29%
Ozone layer depletion potential	kg CFC-11 eq	**1,88E-05**	81%	13%	13%	-7%
Photochemical oxidation potential	kg C2H4 eq	**2,50E-02**	72%	36%	10%	-17%
Air acidification potential	kg SO2 eq	**0,550**	65%	29%	16%	-9%
Eutrophication potential	kg PO4 eq	**0,078**	39%	46%	25%	-9%
Human toxicity potential	kg 1,4-DB eq	**12,6**	53%	43%	7%	-3%
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	**0,84**	20%	32%	11%	37%
Sedimental ecotoxicity potential	kg 1,4-DB eq	**1,88**	20%	30%	11%	38%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	**2,50E-02**	24%	88%	5%	-16%

Water consumption indicator in LCA study presents various methodological limits

Breakdown of the environmental impacts of the 1.5 l SuP consumed in Norway (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**1,25**	82%	16%	8%	-6%
Water consumption	m3	**1,58**	73%	69%	1%	-44%
Primary energy	MJ primary	**3518**	77%	40%	7%	-24%
Global warming potential	kg CO2 eq	**164**	48%	18%	10%	24%
Ozone layer depletion potential	kg CFC-11 eq	**1,95E-05**	78%	13%	13%	-3%
Photochemical oxidation potential	kg C2H4 eq	**2,55E-02**	70%	35%	10%	-15%
Air acidification potential	kg SO2 eq	**0,555**	64%	28%	15%	-8%
Eutrophication potential	kg PO4 eq	**0,079**	39%	45%	24%	-9%
Human toxicity potential	kg 1,4-DB eq	**13,0**	51%	42%	7%	1%
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	**0,83**	21%	32%	11%	36%
Sedimental ecotoxicity potential	kg 1,4-DB eq	**1,86**	21%	31%	12%	37%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	**2,53E-02**	24%	86%	5%	-15%

Water consumption indicator in LCA study presents various methodological limits

The distribution of the environmental impacts over the life cycle of the SuP shows a balanced profile between each life cycle stage and the most contributing stage depends on the environmental indicator considered.

The production of the raw materials entering in the composition of the SuP is the most impacting stage for several indicators.

Filling and more specifically the production and supply of secondary packaging is the most impacting stage for terrestrial ecotoxicity and eutrophication indicators.

The differences observed between the two scenarios are due to different post-consumer waste management practices. Stand up pouches are not recycled and therefore follows the same route as municipal solid waste. In Sweden, energy recovery is preferred whereas landfilling is more common in Norway.

As a conclusion, most of the environmental impacts of the pouch system itself are explained by the impacts associated with the production of the raw materials, be it for primary or secondary packaging.

1 l beverage carton results

The next tables present the breakdown of the environmental impacts of the beverage carton system per life cycle phase for Norway and Sweden. Results for Elopak and Tetra Pak have been averaged.

Breakdown of the environmental impacts of the 1 l beverage carton in Sweden (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**0,92**	80%	22%	10%	-12%
Water consumption	m3	**2,27**	97%	47%	1%	-45%
Primary energy	MJ primary	**2914**	97%	39%	7%	-42%
Global warming potential	kg CO2 eq	**139**	54%	20%	10%	16%
Ozone layer depletion potential	kg CFC-11 eq	**1,46E-05**	71%	18%	14%	-4%
Photochemical oxidation potential	kg C2H4 eq	**2,23E-02**	80%	36%	9%	-25%
Air acidification potential	kg SO2 eq	**0,504**	73%	27%	15%	-14%
Eutrophication potential	kg PO4 eq	**0,074**	52%	40%	22%	-14%
Human toxicity potential	kg 1,4-DB eq	**183,7**	97%	3%	0%	0%
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	**1,28**	66%	15%	6%	13%
Sedimental ecotoxicity potential	kg 1,4-DB eq	**3,41**	73%	12%	5%	10%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	**3,00E-02**	51%	64%	3%	-18%

Water consumption indicator in LCA study presents various methodological limits

Breakdown of the environmental impacts of the 1 l beverage carton in Norway (FU: 1000 l)

	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**0,93**	79%	22%	9%	-10%
Water consumption	m3	**2,27**	96%	47%	1%	-44%
Primary energy	MJ primary	**2961**	95%	38%	7%	-40%
Global warming potential	kg CO2 eq	**139**	54%	20%	10%	16%
Ozone layer depletion potential	kg CFC-11 eq	**1,47E-05**	71%	18%	14%	-3%
Photochemical oxidation potential	kg C2H4 eq	**2,21E-02**	80%	37%	9%	-26%
Air acidification potential	kg SO2 eq	**0,505**	73%	26%	15%	-14%
Eutrophication potential	kg PO4 eq	**0,073**	52%	40%	23%	-15%
Human toxicity potential	kg 1,4-DB eq	**183,9**	97%	3%	0%	0%
Freshwater aquatic ecotoxicity potential	kg 1,4-DB eq	**1,29**	65%	15%	6%	14%
Sedimental ecotoxicity potential	kg 1,4-DB eq	**3,44**	72%	12%	5%	11%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	**3,00E-02**	51%	64%	3%	-18%

Water consumption indicator in LCA study presents various methodological limits

The distribution of the environmental impacts over the life cycle of the beverage carton shows similar trends for both scenarios:

Packaging production is the most impacting life cycle stage for all environmental indicators apart for terrestrial ecotoxicity where the filling stage is more impacting due to secondary packaging.

Filling has a significant impact (more than 35%) in terms of water consumption, primary energy, photochemical oxidation potential and eutrophication for both systems. Note that most of the impacts of this phase are due to secondary packaging and not the filling and conditioning processes. It is the most impacting stage in terms of terrestrial ecotoxicity.

Distribution appears as a moderate contributor with all indicators having a contribution below 23%.

The differences observed between the two scenarios are due to different post-consumer waste management practices.

As a conclusion, most of the environmental impacts of the beverage carton itself are explained by the impacts associated with the production of the raw materials, be it for primary or secondary packaging.

11. Comparative assessment

Preamble

Glass packaging system is presented in the comparative assessment but the reader should bear in mind that exhaustive and updated information on the life cycle impacts of this system would be needed to make more robust comparison with the other systems.

The comparative analysis of the five packaging systems is focused on three impact assessment and two life cycle inventory indicators:

- Global warming potential; Abiotic depletion; Air acidification;
- Water consumption; Primary energy.

These indicators have been selected for the following reasons:

- Apart for water consumption, they are among the most robust and consensual indicators in LCA;
- These indicators are the most significant for all packaging following the normalisation procedure. This explains why water consumption has been kept in the analysis despite its intrinsic caveats.

Uncertainty analysis

The baseline results for the 16 formats and the 5 indicators are presented hereafter in several bar diagrams. The reference scenarios (glass bottle 75 cl, BiB 3 l, SuP 1.5 l, PET bottle 75 cl and beverage carton 1 l) are indentified with black frames. Each bar shows an uncertainty.

The uncertainty that is presented focuses on:

- Uncertainty associated with the **raw data**. For each system, every raw data being strong determinants in the environmental impacts have been identified.

  These determinants can be:

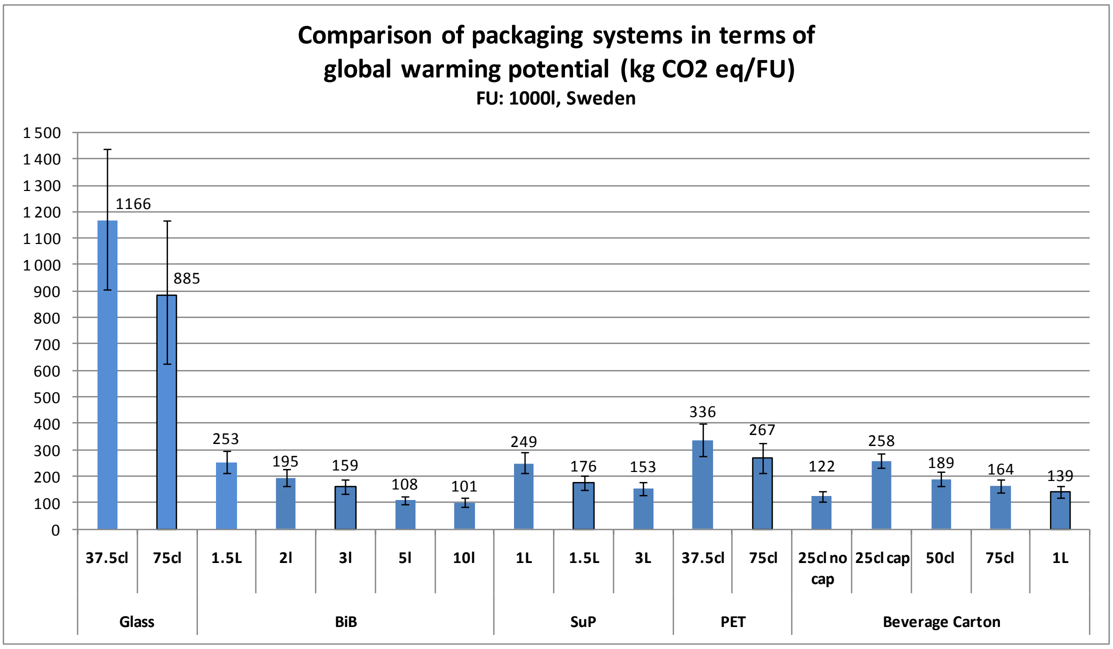
  - mass of the most impacting materials of the primary packaging
  - mass of the most impacting materials of the closure
  - amount of energy employed in the transformation process
  - amount of energy employed in the filling process
  - mass of the most impacting materials of the secondary packaging
- Uncertainty associated with **transportation scenario**. Lower and upper limits for the total length of the supply chain are assumed

For each packaging systems, the intervals presented in the results graphs are based on theoretical best case / worst case scenarios.

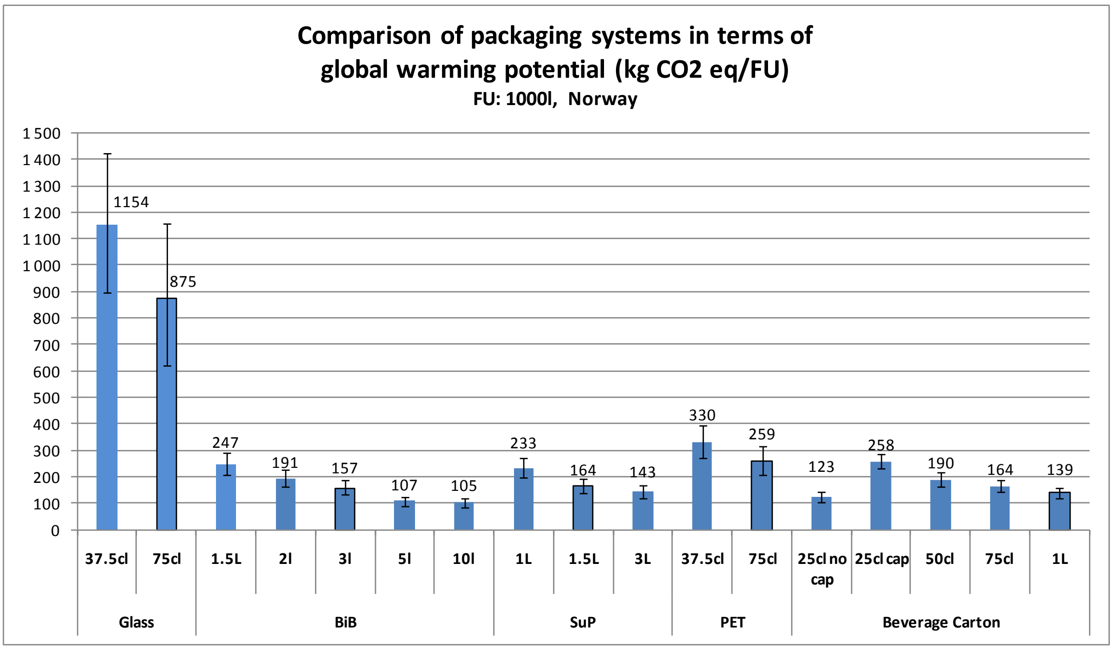
Upper/lower value on the graph for a given indicator = worst/best case scenario = impacts of the system calculated with all determinants set to the upper/lower bound.

Based on these uncertainty calculations, it is considered that the assertion “A has less environmental impacts than B” is robust only if A’s worst case scenario is below B’s best case scenario.

Global warming potential



Comparison of packaging systems in terms of global warming potential in Sweden

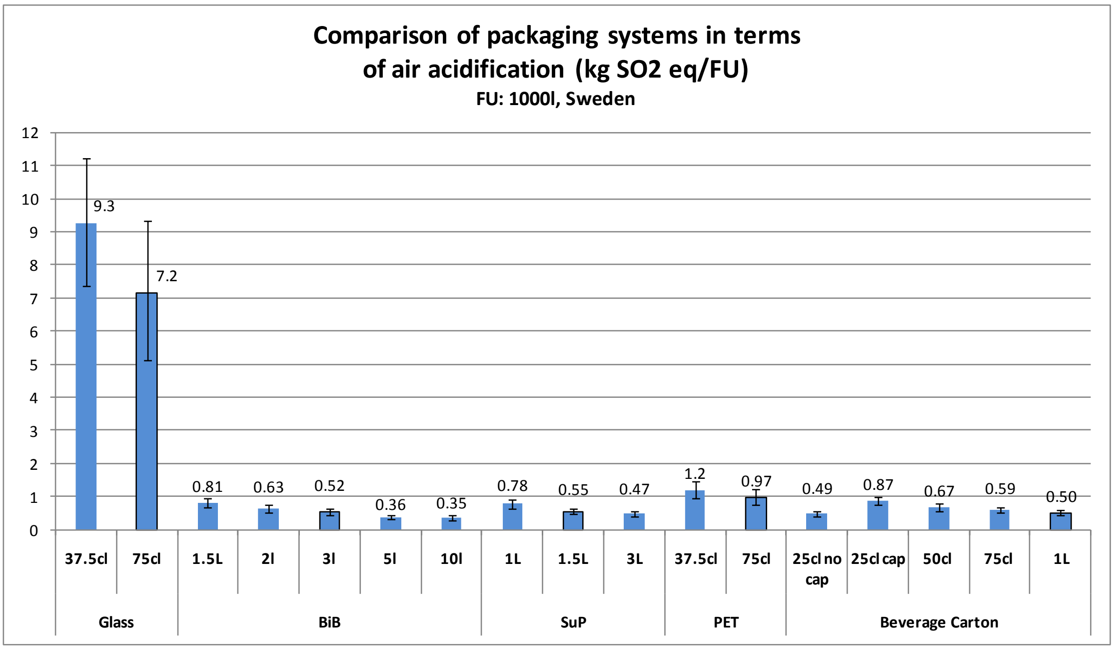


Comparison of packaging systems in terms of global warming potential in Norway

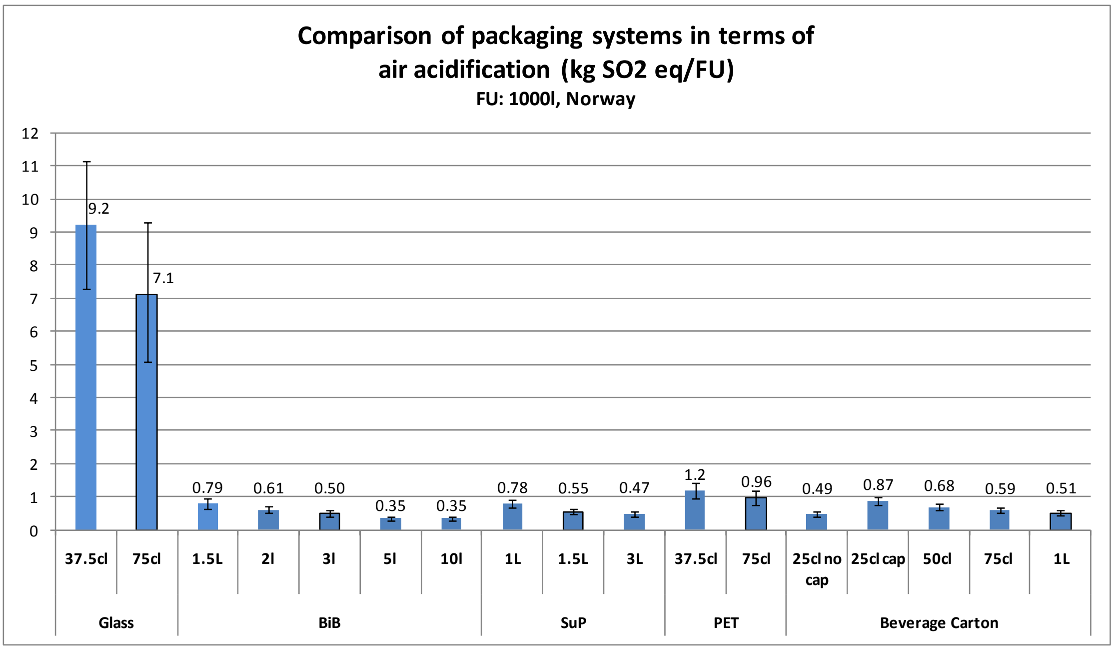
In terms of global warming potential, a general trend can be observed: within a same packaging system, products with larger capacity have a tendency to show lesser impacts. The 25 cl beverage carton without cap is an exception to this. Indeed, since most of the impacts are due to primary material production, the beverage carton without cap performs well as it is lighter.

The packaging system in Norway show similar trends.

Air acidification



Comparison of packaging systems in terms of air acidification in Sweden



Comparison of packaging systems in terms of air acidification in Norway

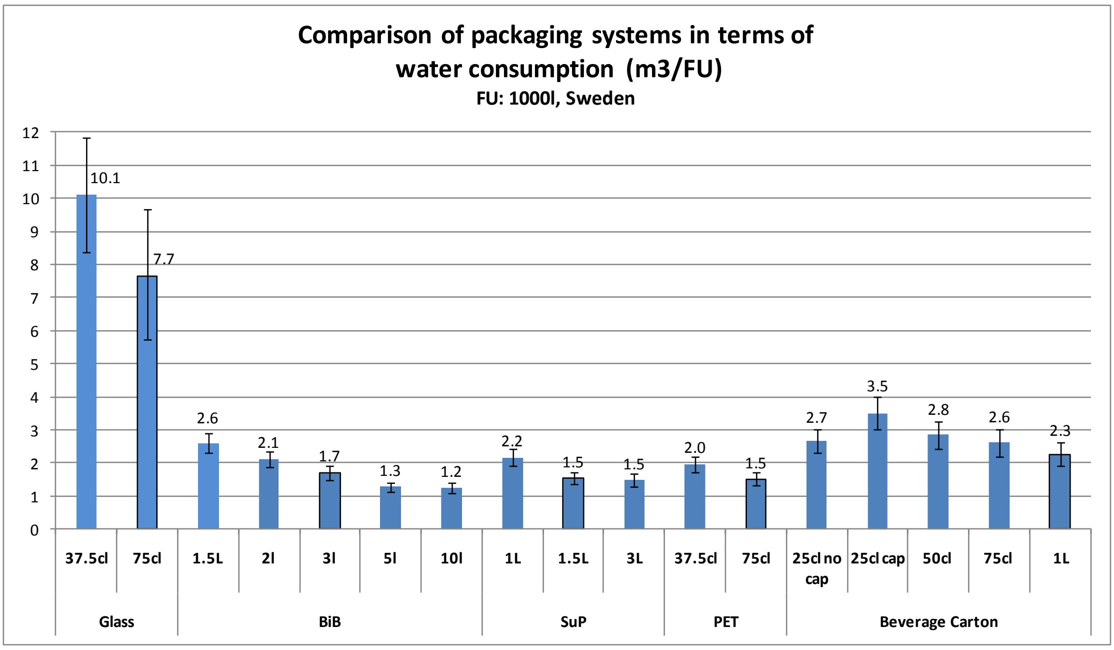
Note that for this indicator, results show less variability across the different capacity of a similar packaging system. General trend observed for global warming is still valid but the relative differences are particularly low and conclusions should be made with caution: within a same packaging system, larger formats have lesser impacts apart for the 25 cl beverage carton with no cap.

As the acidification indicator is particularly impacting on the fabrication stage, volumes that require less material tend to perform better.

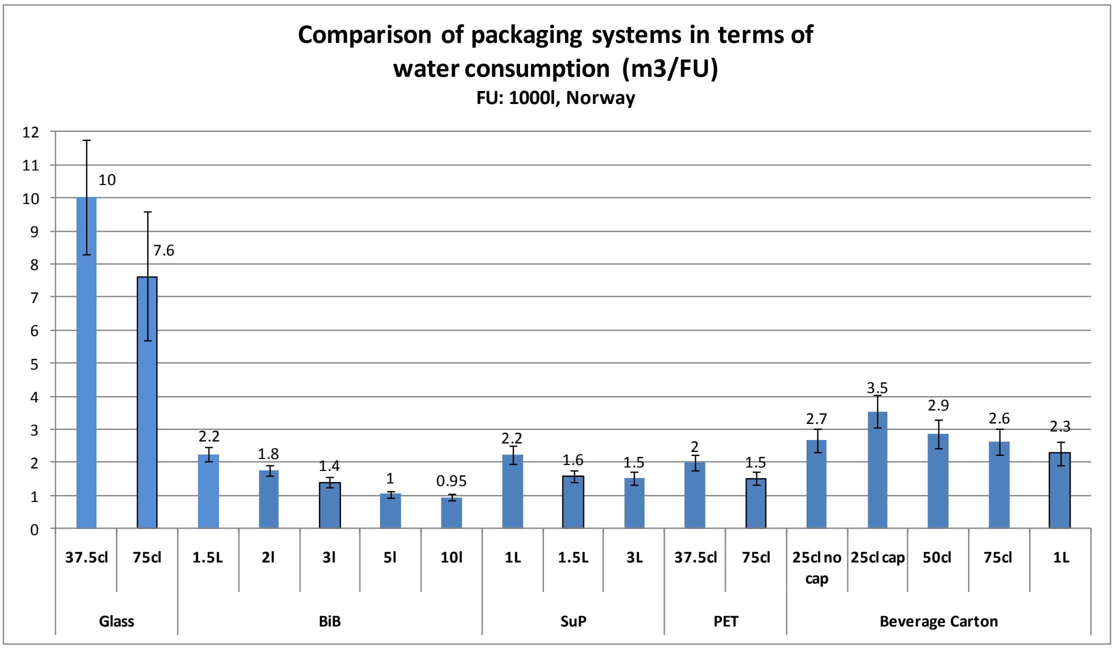
In Norway, the relative performances of the packaging systems are identical to Sweden.

Water consumption

Water consumption indicator in LCA study presents various methodological limits



Comparison of packaging systems in terms of water consumption in Sweden

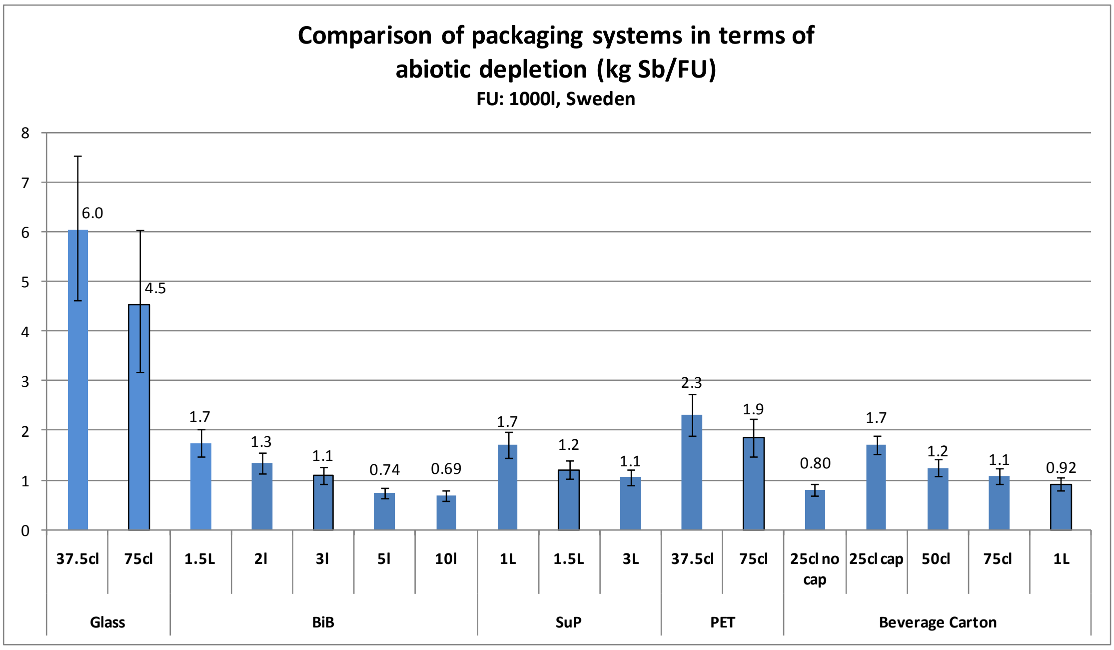


Comparison of packaging systems in terms of water consumption in Norway

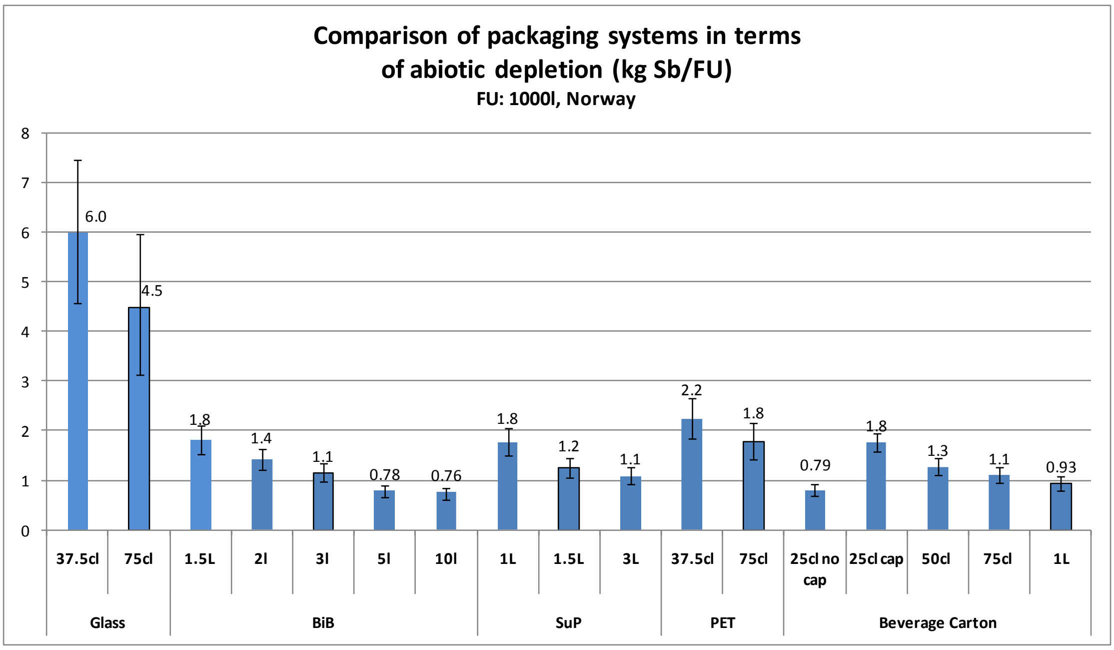
In terms of water consumption, the relative performance across the different packaging systems is identical in Norway and in Sweden.

A general comment regarding this indicator is that the relative performances of the packaging systems are tightly linked with the water requirements of cardboard production.

Abiotic depletion



Comparison of packaging systems in terms of abiotic depletion in Sweden

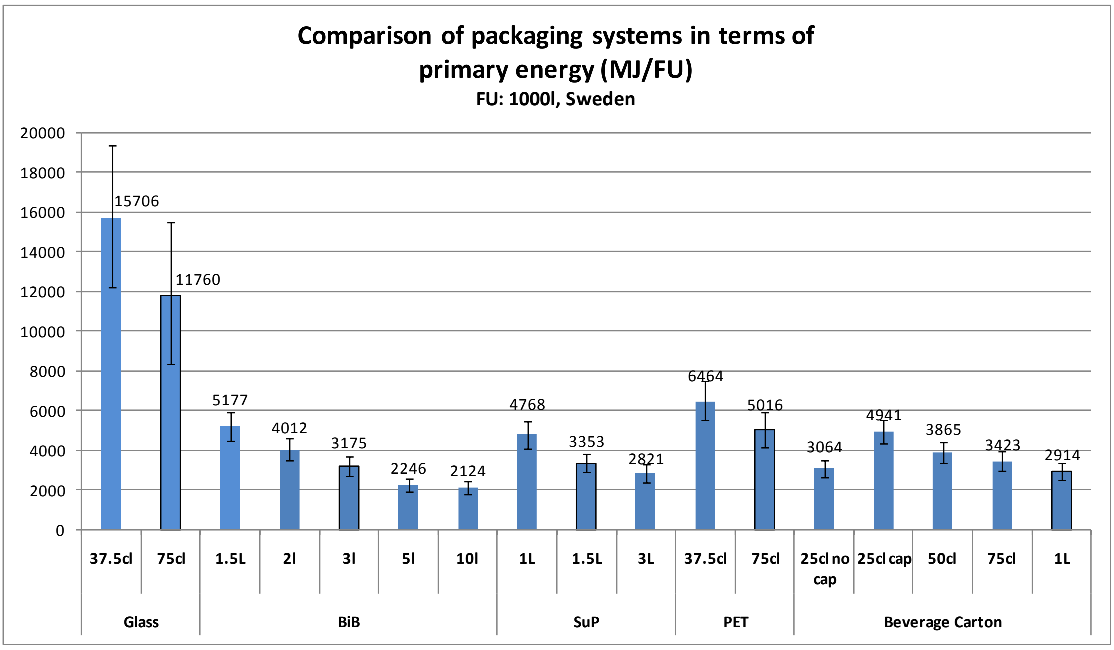


Comparison of packaging systems in terms of abiotic depletion in Norway

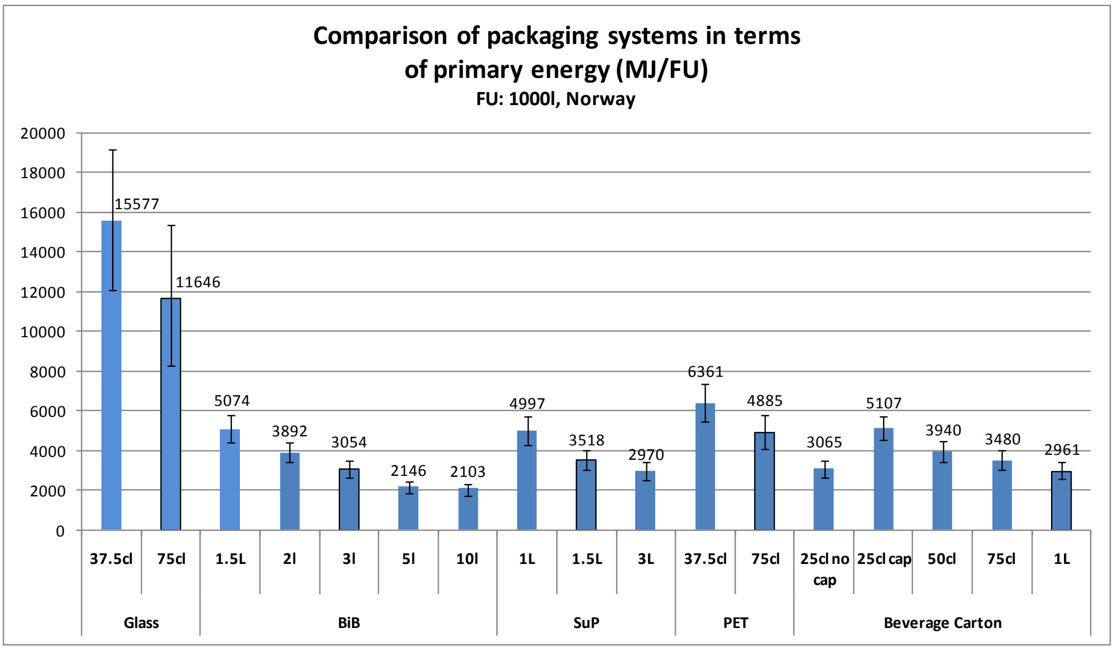
In terms of abiotic depletion, the relative performance of the packaging systems is identical in Sweden and in Norway.

The Bag in Box and the SuP systems have close performance as it can be seen on the 3 l format where the uncertainties are overlapping. PET bottles are more impacting than the beverage carton as it can be observed for the 75 cl format where respective performances are higher than the uncertainty.

Primary energy



Comparison of packaging systems in terms of primary energy in Sweden



Comparison of packaging systems in terms of primary energy in Norway

While In Sweden, the 3 l BiB is more impacting than the 3 l SuP by 11%, the difference in Norway is only 3%. The difference in waste management explains this difference, indeed SuP tend to be more incinerated with energy recovery in Sweden whereas landfilling is a more common practice in Norway, hence explaining the higher impacts of the SuP system in Norway than in Sweden.

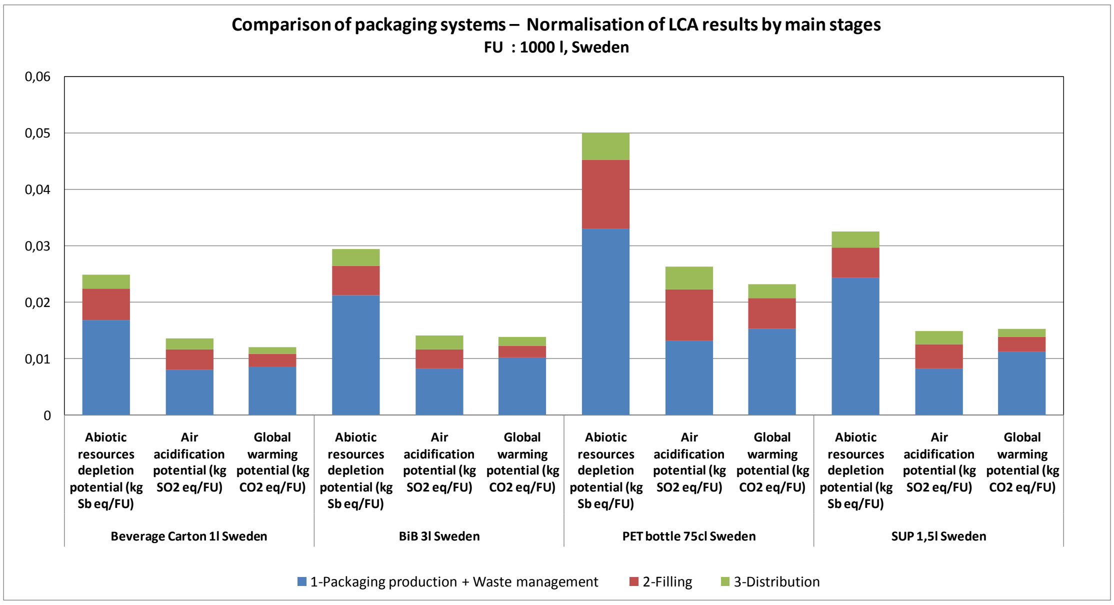
In both countries, the energy consumption of the 1 l beverage carton is lower than the 1.5 l BiB and the 1 l SuP, reduced primary and secondary packaging materials for the beverage carton explains this performance.

Normalisation of LCA results by main stages

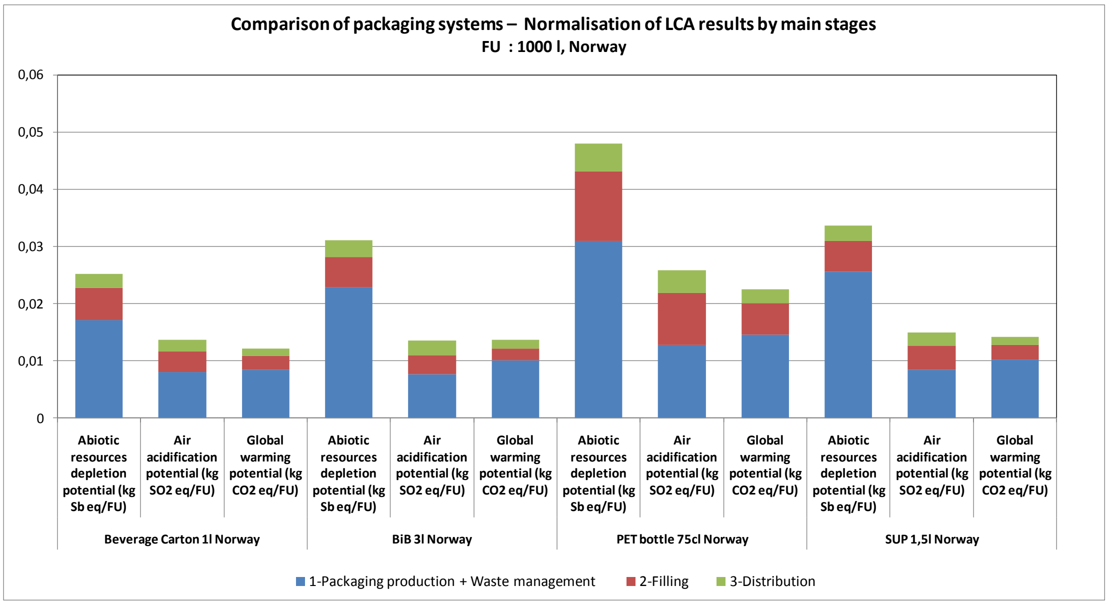
To facilitate the understanding of the magnitude of potential environmental impacts or benefits related to life cycle of the five systems studied, the environmental impacts are translated into inhabitant-equivalents, i.e. compared to the contribution of an "average" inhabitant — an EU-25+3 inhabitant — to the environmental impact indicator over one year.

This value is obtained by dividing the total quantity generated for a given indicator by the European Union-25+3 during 1 year by the number of inhabitants of the EU-25+3 (for the year under review).

The next charts are normalised results for the reference volumes of the partners' systems. The repartition between life cycle stages is shown within the bars. Note that packaging production and waste management stages have been combined for readability reasons (waste management stage can be negative because of environmental credits).



Comparative normalisation of LCA results by main stages, Sweden



Comparative normalisation of LCA results by main stages, Norway

How to interpret these figures?

If one takes the example of the impact of abiotic depletion: the impacts of 100 functional units (i.e. packaging and distribution of 100 000 litres of wine) with beverage cartons of 1l are equivalent to the total impacts on abiotic depletion of about 2.5 European inhabitants over 1 year.

For all systems considered, be it in Sweden or Norway, the packaging production phase — even mitigated by the waste management phase — accounts for 50 to 75% of the total impacts.

12. Findings of complementary/sensitivity analysis

Complementary analysis on transport of filled packages

On the whole, the same trends as in section 11 are observed. Although relative performances of packaging are not modified, some slight changes due to the palletisation characteristics of each format are observed regarding the magnitude of differences between systems.

Sensitivity analysis on carbon sequestration

Carbon sequestration has almost no effect on the impacts of the reference volumes. This is due to the high recycling rates of cardboard based materials of primary and secondary packaging.

Sensitivity analysis on allocation procedures for recycling

Four allocation procedures have been applied. The analysis has been performed on the main primary packaging material of the reference volume for each packaging system in Sweden and in Norway: Glass, PET, Cardboard, and Liquid packaging board. Note that no analysis has been performed on the SuP as it does not contain recycled material and it is not recycled.

Be it in Norway or in Sweden, parameters considered for the baseline scenario are conservative and tend to be on the lower range of the results for all packaging system;

PET is the most sensitive system to the allocation procedure. The results for the PET reference system can be 20%-60% higher for studied indicators when the allocation methodology of the base case is changed to another method.

Complementary analysis on glass bottle

On the whole, a 30% reduction of the impacts of the production phase would not change the relative performance of the 75 cl glass bottle when compared to the BiB, SuP, PET and beverage carton systems. These conclusions must be regarded very cautiously because of the uncertainty on the future improvements that will be achieved in the glass industry.

Complementary analysis on packaging and content: taking into account wine losses

According to a 2007 study[3], the greenhouse gases emissions for wine production are **515 kg CO_2 eq** for 1000 l (i.e. 1 functional unit). Based on this data, the analysis shows that a 2% loss of wine (10.3 kg CO_2 eq/FU) has limited – but not always negligible – impacts on the performance of the packaging systems. As a matter of fact, for 5 l and 10 l BiBs, a 2% loss of wine is equivalent to about 10% of the impacts of the package.

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[3] Garnett T. (2007), The alcohol we drink and its contribution to the UK's greenhouse gas emissions: a discussion paper, Centre for environmental strategy, University of Surrey

The present analysis is performed assuming a **similar wine loss rate** for all systems. Yet, in practice, different format and material may behave differently which could modify the relative performance of the different packaging systems.

Furthermore, impacts of wine are only considered in terms of GHG emissions whereas LCA studies on food and beverage tend to prove that agricultural production can have significant impacts on almost all impact categories due to the various inputs and associated impacts.

13. Conclusions

The present work confirms results from previous studies. Most of the environmental impacts of a packaging system are related to the following aspects: primary and secondary packaging, distribution and end-of-life.

- **Optimising packaging**

Most of the environmental impacts are related to the production of the raw materials used in the packaging systems. The most important contributor is primary packaging, but the study also shows that secondary packaging and more specifically cardboard can have a substantial weight on the overall performance of systems, especially for lightweight options.

As a general rule, when comparing a set of different capacities of the same packaging, larger volumes are associated with smaller environmental impacts. This is mostly due to the fact that less material is required to provide the same service. This rule can however be challenged if a specific format comes with different characteristics (no closure for instance) or if secondary packaging and palletisation vary significantly among the different formats.

Wine lost during distribution or because of incomplete consumption by consumers should be taken into consideration when optimising the environmental performance of the package. For instance, in terms of global warming potential, wine may possibly represent 30 to 80% of the impact of the "wine + package" system. This means that for low-impact packaging systems, high loss rates could significantly influence overall performance of the "wine + package" system. Wine could also have important impacts on other indicators as would most agricultural products. In this context, there is a need for accurate data on wine-related aspects that would confirm the necessity to design packaging systems and formats that minimise incomplete emptying and maximise conservation.

As a conclusion:

- Maximising packaging capacity (with respect to demand and consumer practices) is a key target to achieve in order to lower the environmental impacts of any packaging systems, provided that other parameters do not vary.
- Reducing material consumption is among the most effective ways to improve the environmental profile of any packaging systems.
- Minimizing wine losses should be a key objective.

- **Optimising distribution**

The distribution phase from the filling station to the distribution hub is a key step of the environmental profile of all packaging systems. Optimising supply and distribution routes and truck loads are efficient ways to improve the environmental profile of packaging.

Optimising palletisation can have significant impacts on the performance of packaging. This should however not compete with increasing break rates during transportation considering the important environmental value of wine. Additional studies on loss rates and wine impacts would however be needed in order to determine break-even points.

Optimising waste management

Encouraging consumers to properly dispose of their packaging is the most powerful leverage point in terms of waste management. Indeed, the end-of-life of secondary packaging at retailers and the waste management of production losses are less contributing. Producers, municipalities and consumers have therefore an important role to play in order to improve the environmental impacts of packaging that occur at end-of-life.

For plastics and glass, increasing recycling rate is an effective option to reduce the environmental footprint of packaging. Recycling provide environmental benefits as it avoids conventional disposal routes and avoids the extraction and production of virgin materials.

Incineration with energy recovery can also be an effective disposal route for some materials, particularly for paper based products. Landfilling is clearly the less desirable option.

Note that the benefits associated with recycling are highly dependent on local conditions, assumptions and methodology. This is particularly true for paper based products for which no clear and absolute picture can be drawn and where intense debate are observed in the LCA community. Moreover, the environmental benefits of recycling PET bottles are highly sensitive on allocation procedures. Other studies could therefore cast a different perspective on the impacts of recycling for these materials.

As a conclusion:

- Waste management of post-consumer waste is the most powerful leverage, hence implying that producers, waste collections services and consumers have an important role to play. Raising consumer awareness is therefore crucial
- In terms of disposal routes, there are clear environmental benefits for recycling glass, and plastics packaging. For cardboard products, results are highly dependent on LCA methodology and additional studies could cast a different light on the environmental benefits of recycling.

Comparative assessment of packaging systems

As the glass system is less robust than the others due to recently outdated data, this system has been included in the analysis essentially for information purpose. Data are not considered to be reliable enough to draw robust conclusions when this system is compared to the others. More recent data could significantly change the performance of the glass system.

However the uncertainty analysis that has been performed on every systems and the additional analysis on glass potential improvement shows that glass seems to be the most impacting system for all the indicators studied in the comparative analysis.

The comparative analysis has been performed on five indicators: global warming potential, air acidification, abiotic depletion, primary energy and water consumption. These indicators are the most significant for all packaging systems following the normalisation procedure. However, the water consumption is clearly less robust from a methodological point of view. Additionally, this indicator can vary significantly for cardboard/paper based material depending on LCA data.

The relative performances of the packaging systems depend on the indicators and formats that are considered. Nevertheless, comparisons made within a same packaging system show as a general rule that larger formats are associated with fewer impacts.

This rule is not respected by the 25 cl beverage carton without a cap due to reduced materials. As a matter of fact, when brought back to the functional unit (1000 l of wine), the difference in the amount of material between 25 cl BC with or without cap is due to the 4000 “avoided” caps which represents about 14 kg of high-density polyethylene (HDPE). This explains the noticeable discrepancies in environmental impacts for 25 cl BC with or without cap.

The important number of packaging formats under study renders difficult a direct comparison across the packaging types but overall it would appear as though BiBs, SuPs and beverage cartons offer lower environmental impact alternatives compared to glass bottles. PET bottles are somehow in between glass and other packaging systems but no robust conclusion can be draw for this system because of his sensitivity to the different allocation procedures for recycling.

The other conclusions are summarised by format ranges where overlapping formats are observed:

- For very large formats (>1.5 l)

Considering the 3 l format, the Stand up Pouch and the Bag in Box have very close impacts for all indicators and they cannot be differentiated considering the intrinsic uncertainties of the environmental indicators.

- For large formats (1 l-1.5 l)

The 1.5 l SuP is in between the 1.5 l Bag in Box and the 1 l beverage carton for all indicators apart for water consumption where, the SuP tends to perform better than the other packaging materials. For the one litre format, the beverage carton appears as the least impacting system, performing better than the 1.5 l BiB and the 1 l SuP, on most indicators.

- For medium formats (75 cl)

The 75 cl beverage carton appears as the least impacting format for all indicators but water consumption where the PET bottle is the least impacting. The 75 cl PET bottle is close to the 1 l SuP in terms of global warming potential, acidification, abiotic depletion and primary energy consumption.

- For small formats (<75 cl)

For small format, the 25 cl beverage carton without a cap is the least impacting packaging for all indicators but water consumption, for which the 37.5 cl PET bottle performs better.

Out of these ranges, the relative impacts of packaging of different nature and formats show important variability that also depends on the indicator and the country under consideration.

- **Improvements and limits**

These conclusions should be put in perspective with the assumptions, data used and limits of the study and generalisation should not be made. In particular, allocation procedures for recycling and specific loss rates of packaging systems are two aspects that might alter relative performances of packages.

The results of the evaluation of the potential environmental impacts are relative indicators that do not predict the effects on the final impacts per category, the exceedance of thresholds or risks. In this context, this study should not be the only source of information on the comparative performance of the studied products and complementary studies could provide additional information and fill some of the methodological gaps inherent to the LCA methodology.