Systembolaget – Vinmonopolet

Nordic Life Cycle Assessment

Wine Package Study

Final report – ISO Compliant

August 2010

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Industrial Ecology - Nutritional Health

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Nordic Life Cycle Assessment Wine Package Study

Critical Review on final report August 2010

Final Statement, August 2010

Object

The report « *Nordic Life Cycle Assessment - Wine Package Study* » made by BioIS (Clément Tostivint, Adrien Beton, Florence Massari and Yannick Le Guern) on request of Systembolaget and Vinmonopolet has been critically reviewed by the Critical Review Panel (CRP), composed by :

- Jean-François Patingre, LCA expert,
- Ann Lorentzon, Innventia AB, Packaging, Media and Material, Sustainability and Foresight, for a specific analysis of Scandinavian market situation and Forestry-related issues
- Bernard De Caevel, LCA expert, Director of RDC-Environment, author of 150 LCA studies.

The goal is to analyse the conformity of the study with the ISO 14040:2006 and ISO 14044:2006 International Standards, in order to allow communication based on the results of this study, including comparative assertions.

Validity of the CRP (Critical Review Panel)

ISO 14044:2006 (chapter 6.1) states : "*In order to decrease the likelihood of misunderstandings or negative effects on external interested parties, a panel of interested parties shall conduct critical reviews on LCA studies where the results are intended to be used to support a comparative assertion intended to be disclosed to the public* ".
Chapter 6.3 states : " *A critical review may be carried out as a review by interested parties. In such a case, an external independent expert should be selected by the original study commissioner to act as chairperson of a review panel of at least three members. Based on the goal and scope of the study, the chairperson should select other, independent qualified reviewers. This panel <u>may</u> include other interested parties affected by the conclusions drawn from the LCA, such as government agencies, non-governmental groups, competitors and affected industries.*
For LCIA, the expertise of reviewers in the scientific disciplines relevant to the important impact categories of the study, in addition to other expertise and interest, shall be considered. The review statement and review panel report, as well as comments of the expert and any responses to recommendations made by the reviewer or by the panel, shall be included in the LCA report."

The CRP is composed only of LCA and packaging experts. The need to include interested parties was not considered crucial as interested parties were already largely represented in the sponsor group. It should be pointed out that the glass industry and the non-governmental groups were not represented.

The CRP considers enough expertise has been used by the CRP and sponsor group to ensure a quality review of the study.

Peer review process

The stages of the Peer review process are :

August 6, 2009: **Reception by email of the draft report version 1 (incomplete)**
Remarks, questions and answers in Annex 1

August 14, 2009: First comments by Bernard De Caevel

August 21, 2009: First comments by Ann Lorentzon

September 4, 2009: First comments by Jean-François Patingre

January 13, 2010: Reception by email of Comments by project sponsors on the draft full report

January 19, 2010: **Reception by email of the draft full report and data (version 2)**
Remarks, questions and answers in Annex 2

January 27, 2010: Comments by Jean-François Patingre

January 28, 2010: Comments by Ann Lorentzon

February 8, 2010: Comments by Bernard De Caevel

February 10, 2010: Meeting (Ann Lorentzon and Bernard De Caevel) with Authors and project sponsors (in Sweden)

February 12, 2010: Letter from sponsors to authors to announce decision to include comparative assertions

February 17, 2010: Additional comments by Bernard De Caevel

March 3, 2010: Short comment of CRP on the way comparative results are presented

March 11, 2010: Questions from Authors to CRP about CRP comments
Remarks, questions and answers in Annex 3

March 15,16,22, 2010: Answer CRP to Authors' questions (Annex 2)

April 1, 2010: **Reception by email of the revised draft full report and data (version 3)**
Remarks, questions and answers in Annex 4

April 12, 2010: Comment by Ann Lorentzon

April 14, 2010: Comment by Jean-François Patingre

April 16, 2010: Reception by email of Comments by project sponsors on the draft full report version 3

April 22, 2010: Comments by Bernard De Caevel

April 29, 2010: Meeting (complete CRP) with Authors and project sponsors (in Paris)

May 3, 2010:	Reception from Author of the so-called "action plan" Remarks, questions and answers in Annex 5
May 4, 2010:	Comments by Bernard De Caevel on the so-called "action plan"
May 10, 2010:	Reception from Author of a proposal for sensitivity analysis format Remarks, questions and answers in Annex 6
May 25, 2010:	Comments by Bernard De Caevel on proposal for sensitivity analysis format
June 7, 2010:	**Reception by email of the full report version 4, including aluminium packaging** Remarks, questions and answers in Annex 7
June 11, 2010:	Reception by email of Comments by project sponsors on the draft full report version 4
June 18, 2010:	Email from sponsors to authors to announce decision to exclude aluminium packaging from the scope due to lack of robust data
July 5, 2010:	Comments by the CR Panel, ignoring all parts concerning aluminium cans
July 15, 2010:	Reception by email of the final report. Remaining remarks only refer to the final version.

General Statement

The Critical Review Panel acknowledges to have analysed draft and final reports based on ISO 14040:2006 and 14044:2006 standards. Data was checked and validated. Assumptions and models are reasonable and justified.

Based on some partial checks, calculations are right (results are in line with expectations based on input data).

Interpretation of results and conclusions are justified for the base case model but the Critical Review Panel regrets the **uncertainty was not more deeply analysed and discussed**.

Differences between systems are well explained by technical differences (Table 24 and similar ones).

This study is conform to ISO 14040:2006 and ISO 14044:2006 standards.

Comments

Assumptions are explicit and sources are clearly stated. Globally the Authors took well into account the comments made by the Critical Review Panel and also answered the questions.

Comments in annexes 1 to 7 concern previous versions of the report and are not applicable to the final version, unless explicitly mentioned. They are given for information.

The main changes in the report based on comments by the Critical Review Panel are :

- Aluminium cans have been removed from the scope
- Comparative assertions are included
- Sensitivity analysis is based on multiple variations and those variations are not always the same in proportion for all materials
- Impact categories were added.
- Inclusion of infrastructure has been made coherent
- Transport model was improved (additional transport lead to additional impacts)
- Allocation method for recycling was improved
- Goal was better defined
- Better analysis of effects of wine spillage

Made in Brussels on August 6, 2010

Bernard De Caevel   Jean-François Patingre   Ann Lorentzon

Annexes :

1. Comments draft report version 1, August 6, 2009 (incomplete)
2. Comments of February 2010 on the draft full report and data of December, 2009
3. Questions and answers March 2010
4. Comments of April 2010 on the draft full report and data of April 1, 2010 (version 3)
5. Comments of May 4, 2010 on the 3action Plan" of May 3, 2010
6. Comments of May 25, 2010 on the proposal for sensitivity analysis of May 5, 2010
7. Comments of July 2010 on the draft full report and data of May 2010 (version 4)

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.

CONTEXT AND OBJECTIVES OF THE STUDY

1. CONTEXT AND OBJECTIVES OF THE STUDY

1.1 CONTEXT

Systembolaget and Vinmonopolet are the Swedish and the Norwegian alcohol retail monopolies. They have been created after the abolition of rationing of alcohol in Sweden and Norway in 1955 and 1922. Today, they are still the only companies allowed to sell alcohol containing beverages (higher than 3.5% and 4.7%) in those countries.

They represent many different brands of beer, wine and spirits from different countries. Indeed, Systembolaget's product range is among the most extensive in the world, with a regular range of around 3000 brands of beer, wine and spirits from around 40 countries and the company represents about 413 stores, 540 agents, 7000 items (900 new products are introduced every year) and 4500 employees. Vinmonopolet sells around 10600 different products while being represented by about 250 stores and 1600 sales assistants.

Their aim is to minimize alcohol-related problems by selling alcohol in a responsible way, without profit motive. As a matter of fact, such monopolies (which also exist in Finland, Iceland, Canada and several states in the USA) are based on the principle that there should be no private profit motive in the sale of alcohol: without any private profit, there is no reason to try to persuade customers to buy as much as possible, and no reason to sell to people less than 20 years old. This responsible way includes taking into account the environmental impact of the different products they sell. In 2001, Systembolaget carried out a general environmental review of its operations which resulted in the adoption of an environmental policy.

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. Thus, the different project sponsors include the monopolies, but also different packaging manufacturers and a wine importer as it can be seen in the following table.

Table 1: Project sponsors

Sponsor	Country	Activity
Elopak Norway	Norway	Packaging manufacturer
Oenoforos	Sweden	Wine importer
Vinmonopolet	Norway	Alcohol retailer (Norwegian monopoly)
Systembolaget	Sweden	Alcohol retailer (Swedish monopoly)
Smurfit Kappa Bag-in-Box and Vitop	France	Packaging manufacturer
Tetra Pak	Sweden	Packaging manufacturer

Many studies have been conducted at the request of institutions, manufacturers of packaging or professional federations, providing insights into the environmental strengths and weaknesses of various packaging systems, according to the packaged beverage.

One can mention:

- The **UBA studies** (German Environmental Federal Agency, 2000/2002) focusing on different packaging systems per market, in the German law context.
- **"LCA sensitivity and eco-efficiency analyses of beverage packaging systems"**: this study, lead by TNO for the APEAL in 2002 was based on one of the UBA study. It gives ranges of variation for the environmental impacts of different materials, but it also reveals the influence of parameters such as weight of primary packaging and transport distances on the balance sheets of each material.
- **"Comparative life cycle assessment of beverage cartons and disposable PET bottles"**: this study lead by the IFEU institute for the FKN (German association for carton packaging for liquid food) in 2006 concludes that bricks are more environmentally-friendly than PET bottles for packaging of fruit juice for all volumes.
- **"ACV d'emballages en plastique de différentes origines"** (LCA of packaging systems made of plastics of various origins): this study lead in 2007 by BIOIS for Eco-Emballages (the private company accredited by the French public authorities to install, organise and optimise sorting and selective collection of household packaging in France) compares various materials e.g. made from renewable resources or from fossil resins, to make bottles, films, pots, trays in order to understand the strengths and weaknesses of these new materials.
- **"ACV comparative de différents emballages pour boissons"** (Comparative LCA of various packaging systems for beverage): the objective of this study lead by BIOIS for Eco-Emballages in 2008 is to highlight, for various use modes, the benefits and drawbacks of different packaging systems for beverages, in an overall perspective of optimization of the source of environmental packaging.

Many other studies — some of them being confidential — exist, comparing packaging systems on behalf of packaging manufacturers wanting to ensure the validity of a given modification in the design of a packaging or to have insight on the environmental impacts of their products in comparison to other products.

Finally, experience and studies show 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, the aim of this study is to provide Systembolaget, Vinmonopolet and their sponsors with reliable environmental data on the packaging systems they manufacture or distribute. 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.

1.2 OBJECTIVES OF THE STUDY

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.

1.3 CRITICAL REVIEW PROCEDURE

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).

DEFINITION OF THE SCOPE OF THE STUDY

2. DEFINITION OF THE SCOPE OF THE STUDY

2.1 SYSTEMS STUDIED

Five different types of wine packages and sixteen volumes commercialised in Sweden and Norway are considered in this study[1]:

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

The main characteristics of these different packaging systems are presented in the next table.

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.

Note:

Some of the packaging types —e.g. different sizes of SuPs— **are not commercialised for wine** in the studied countries. The larger sizes of BiBs, 10 l and 5 l are not intended for households in Sweden and Norway.

In order to perform detailed analyses, the most current volumes according to professionals have been considered as **reference scenarios**.

- PET bottle: 75 cl — most sold volume in Sweden and Norway
- Glass bottle: 75 cl — most sold volume in Sweden and Norway
- Bag in Box: 3 l — most sold volume in Sweden and Norway
- Stand up Pouch: 1.5 l — best available data set for this volume
- Beverage carton: 1 l — most sold volume in Sweden and Norway

[1] Originally the study also included aluminium cans but this package type was eliminated because of lack of reliable data for part of its life cycle

Table 2: Presentation of the primary packaging reference scenarios

System	General description	Closure type studied	Tot. Weight including closure	Picture
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	

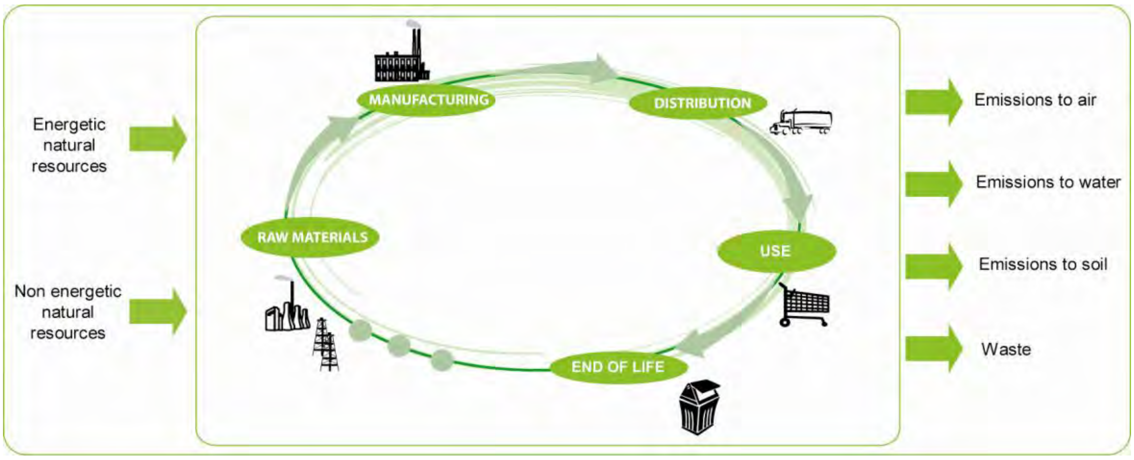
System	General description	Closure type studied	Tot. Weight including closure	Picture
Stand up Pouch 1.5 l	A sealed plastic bag that is designed to stand upright and made of a multilayer laminate film with a layer of aluminium foil to protect against oxygen. A tap is fitted to the pouch.	Tap and gland	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[2]	

[2] Data from the two sponsors have been averaged

2.2 METHODOLOGY

2.2.1. 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. This study will be carried out following the methodological regulations developed in the ISO 14's standards.

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.

Firstly, all the incoming and outgoing flows are inventoried for each life cycle phase. Flows of materials and energy, both extracted from the environment and released into it, at each phase are then aggregated to quantify environmental impact indicators.

The LCA approach allows to compare situations and to identify pollution transfers from one compartment of the natural environment to another or from a life cycle stage to another, between two different scenarios for the same system, or between two different systems. The LCA can thus be used within a "design for the environment" approach or at the time of decision-making.

The LCA is a multi-criterion approach: no global environmental mark is given. The results of the study are presented through several indicators of environmental impacts.

"Cradle-to-grave" and "Cradle to cradle" LCA

The terms "Cradle to grave" and "Cradle to cradle" both relate to the product life cycle from the raw materials (cradle) to disposal (grave).

"Cradle-to-grave" is the full Life Cycle Assessment from manufacture (cradle) to use phase and disposal phase (grave). Other LCA variants such as "Cradle to gate" (from the manufacturing process to the "gate" of the factory) or "Gate to gate" (assessment of a process, from the gate through which the materials enter the process to the gate where the products leave) are partial LCA.

"Cradle to cradle" refers to a model of industrial system powered by renewable energy, in which materials flow in safe, regenerative, closed-loop cycles. The "Cradle to cradle" concept was popularised by German chemist Michael Braungart and U.S. architect William McDonough in their 2002 book "Cradle to Cradle: Remaking the Way We Make Things". Based on this concept, they have developed a proprietary system of certification called "C2C Certification" which is a protected term of MBDC consultants.

Within the framework of LCA, "Cradle-to-cradle" is a specific kind of "Cradle-to-grave" assessment generally implying that products are recycled in closed-loop or reused instead of being disposed. Note that the "cradle-to-grave" LCA methodology employed in the present study has been standardised at the international level through ISO 14040 and ISO 14044 whereas no mention of "Cradle-to-cradle" is made in these documents.

2.2.2. APPLYING THE LCA METHODOLOGY TO PACKAGING

Applying the LCA methodology to packaging solutions consists in quantifying the impacts onto the environment of all the activities that are related to them: extraction of raw materials necessary for their production, transportation of the raw materials, production of the packaging, production of the secondary and tertiary packaging, and so on till their end-of-life: collection, recycling, energy recovery, landfilling, etc.

The potential impacts of wine production are not within the scope of the study. The environmental consequence of this choice regarding the relative performance of the packaging systems has however been assessed (see section 6.3.1).

2.2.3. AN LCA COMPLIANT 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. However, one should keep in mind that the PAS is designed to quantify the impacts of product/packaging couples, a scope that is therefore different from the one chosen in this study. Additionally, this study is rooted in a Nordic context with some products that are not yet available in the market, hence limiting strict application of PAS guidance regarding for instance data collection. In this context, the PAS was therefore considered as a general framework that was followed as closely as possible as long as it was in accordance with the original aims of the study.

Among the requirements of the PAS2050, this study particularly focuses on:

- Greenhouse gases (GHG)

The list of GHG provided by the PAS2050 and their related Global Warming Potentials has been taken into account into the GHG emissions indicator (see annex 1). These emission factors are those provided by the latest[3] report from the Intergovernmental Panel on Climate Change (IPCC) for a 100 year time perspective.

- Data requirement

PAS2050 requirements on the employment of primary and secondary data have been respected:

Chapter 7 of PAS2050:2008 gives recommendations on data quality rules, as well as e.g. on when primary data shall be collected, and when secondary data can be used.

In this study, the data used in the life cycle of the different wine packages are mainly primary data collected directly from the partners of the study. On products not produced by any partner, data considered were mainly collected from contacts of the partners or from bibliography. Every time secondary data have been used, they have been documented precisely in this report.

- Accounting for recycling credits

In order to take into account recycling credits in the analysis, a general and coherent framework consistent with state of the art methodologies and ISO requirements has been set to deal with all materials and packaging.

Note that in the baseline scenario, the PAS2050 requirements on how to take into account recycling and the use of recycled materials have not been followed as the PAS does not define a consistent framework that could be applied for all materials. The only PAS2050 formula given for closed-loop recycling has been studied in sensitivity analyses (see section 6.3.2).

Details on how recycling has been considered in the LCA model are given in section 4.2.2.

- Time perspective

In accordance with the PAS2050 requirements, a 100 year perspective has been considered in the study.

- Stored biogenic carbon

In accordance with the PAS2050, biogenic carbon in paper products that are landfilled and that is not reemitted in the atmosphere within the 100-years assessment period has been considered as stored carbon. More details on carbon sequestration following landfilling are presented in section 4.1.2.4.

According to the PAS2050, carbon storage in products should be accounted if more than 50% of the mass of biogenic carbon remains removed from the atmosphere for one year or more following production of the product (PAS2050:2008, 5.4.1). In this study this would

[3] IPCC(2007), Fourth Assessment Report, Working Group I: The Physical Science Basis, Chapter 2: Changes in Atmospheric Constituents and in Radiative Forcing

potentially apply to cardboard based packaging. However, considering the short lifetime of the packaging products, this potential storage has been disregarded.

- Weighting factors and life time of products.

According to PAS2050, where all GHG emissions arising from the use phase or from final disposal occur within one year following the formation of the product, those emissions shall be treated as a single release of emissions at the beginning of the 100-year assessment period. Where emissions arising from the use phase or from final disposal occur over more than one year, a factor shall be applied to represent the weighted average time the emissions are present in the atmosphere during the 100-year assessment period. Similarly, the impact of carbon storage shall be determined from the weighted average of the biogenic carbon taken up by a product, and not re-emitted to the atmosphere over the 100-year assessment period.

In this study, the use phase is not an emitting life cycle stage. Considering the short lifetime of packaging products, this rule has not been applied in the case of incineration, which has been considered as a single release of emissions at the beginning of the 100 years assessment period[4].

In the case of cardboard/paper products, complex continuous decay and emission patterns occurs after the landfilling of products, what is consequently also true for stored biogenic carbon in landfills. Due to high uncertainties in the emission patterns and without precise guidelines in the PAS in order to deal with this issue, these weighting factors have not been considered[5].

[4] Applying the formula provided by the PAS would give a weighting factor of 0.97-0.99 for a lifetime of 1 to 3 years.

[5] To a first approximation, assuming a rapid decomposition (between 1 and 3 years) of cardboard based products landfilled after 1 to 3 years following product formation and that carbon is released evenly over the decomposition years would give a weighting factor of 0.6-0.96.

2.3 FUNCTIONAL UNIT

To allow comparison between different scenarios and to present the results in an easy to understand way, a common reference is defined. This common reference is used to assess the bill of materials and energy of each system studied. This common reference is the Functional Unit of the environmental assessment.

The functional unit must allow quantification of the service given by the packaging, which is its practical value.

To perform a LCA for a packaging, the environmental impacts generated by the service given by the packaging must be calculated over its entire lifespan. The environmental impacts computed over this life cycle are then returned to the functional unit: each flow involved over the life cycle (e.g. material flow, energy flow) is transposed to this reference flow.

In this study, the functional unit chosen is:

"Packaging and distribution of 1000 litres of wine"

As the study focuses on packaging impacts, the functional unit is distribution oriented and does not consider the use phase.

Excluding wine of the scope has potential implications which are explored in the report (see section 6.3). It should be kept in mind that in general up to 90% of the environmental impact comes from the product and just 10 % from the packaging[6]. To perform its function the packaging should therefore minimize spillage or spoilage of products during its whole life cycle. Spillage could arise during transport and distribution (physical stresses, shocks, temperature stresses etc.) but also when consuming the wine. Different packaging systems made of different material and in different sizes could produce different amount of spillage.

[6] Environmental Impacts of Products (EIPRO), Analysis of the Life Cycle environmental impacts related to the final consumption of the EU25 , 2006

2.4 SYSTEM BOUNDARIES

2.4.1. GENERAL PRESENTATION

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.

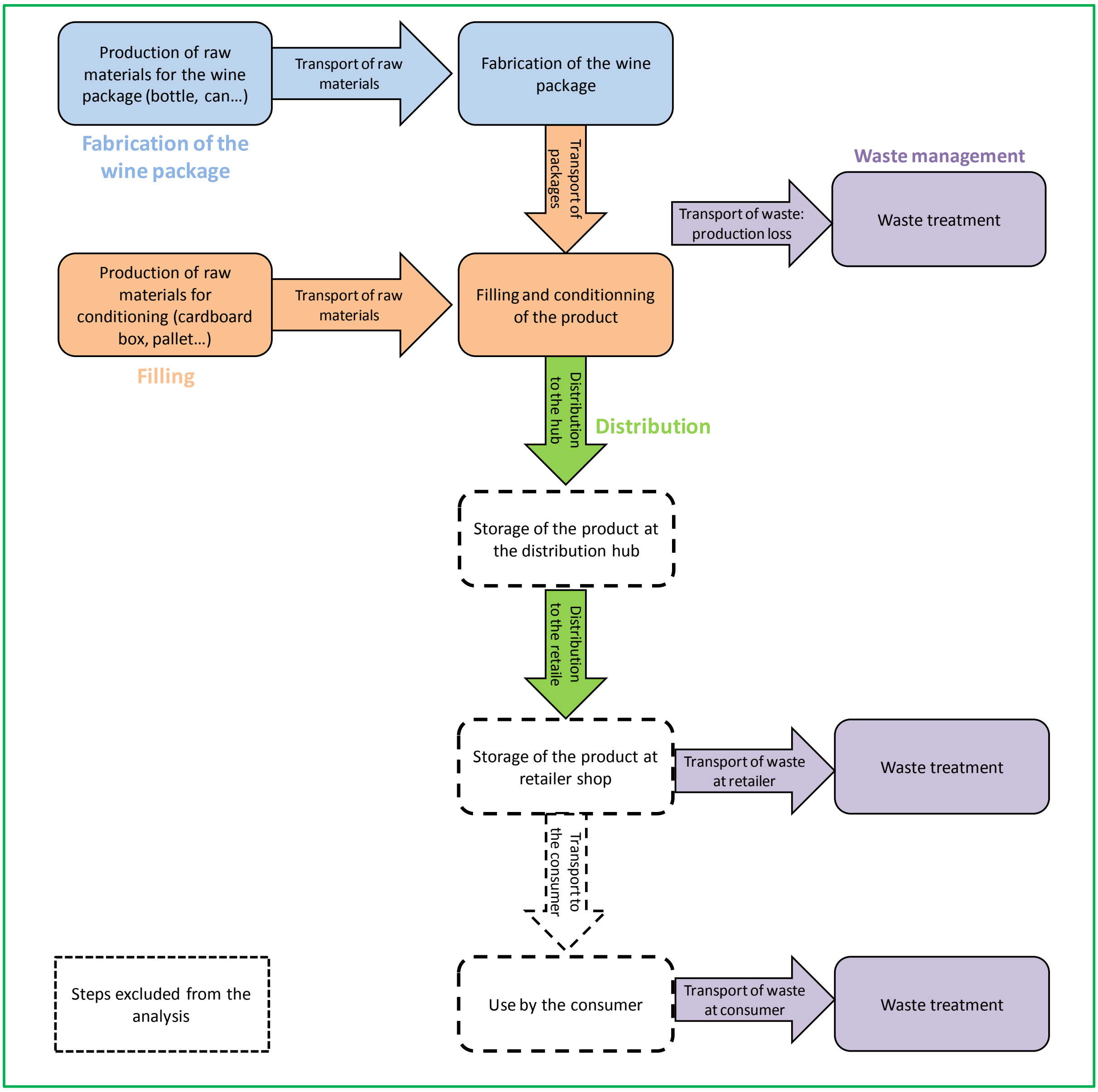


Figure 1: System boundaries

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:
    - Transport of raw materials to manufacturing and assembly plants for each packaging part
    - Transport of the packaging parts to the winery location (filling centre)
    - Supply of raw materials for closures and packaging materials
    - Transport of the packaged wine to the store (may include several steps, e.g. through a distribution platform) including impacts due to the weight of the wine
    - Transport of waste generated at three stages of the package life cycle: production wastes from the manufacturer, wastes from the retail outlet and wastes from the consumer's place. These wastes are transported to recovery or disposal sites.

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.

2.4.2. 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.

This has the following consequences:

- The life cycle impact assessment methodology has been set in order to use 100 years characterisation factors;
- Long terms emissions of landfilling have been disregarded;
- Biogenic carbon contained in landfilled materials that does not disintegrate after the hundred years assessment period is considered to be sequestered and accounted as an environmental credit (see section 2.2.3)

2.4.3. PACKAGING LEVELS

For each packaging solution, the system boundaries include the 3 types of packaging:

- **Primary packaging**: the material that first envelops the product and holds it. This usually is the smallest unit of distribution or use and is the package which is in direct contact with the content (the wine in our case). This will be the one eliminated by the consumer / end-user.

  For each system, the primary packaging includes one of the five types of wine packaging considered in the scope of the study (PET bottle, Glass bottle, Bag in Box, Stand up Pouch and Beverage carton,) including the closures and labels carried by the packaging body.
- **Secondary packaging**: the material used to group primary packages together till the shop shelves. Its end-of-life will be taken care of by the retailer.

- **Tertiary packaging**: the material used for bulk handling, warehouse storage and transport shipping. The most common form is a palletized unit load that packs tightly into containers. It may comprise pallets, films, stickers, corner pieces, etc.

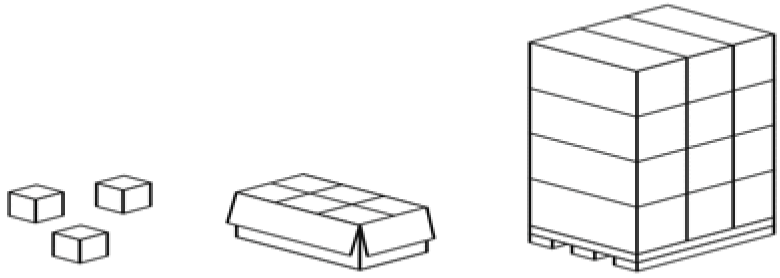


Figure 2: Primary, secondary and tertiary packaging

3. FLOWS AND INDICATORS OF ENVIRONMENTAL IMPACTS

3.1 INVENTORY FLOWS

The environmental assessment of a given system, considered through life cycle thinking, is based on the listing and quantification of all flows coming in and getting out of the system considered.

These incoming and outgoing flows are used to quantify:

- raw material consumption (e.g. water, ore),
- consumption of energy,
- atmospheric emissions (e.g. fossil CO_2, CH_4, CO, VOC (Volatile Organic Compounds), dust, metals),
- emissions to water (e.g. COD (Chemical Oxygen Demand), heavy metals),
- emissions to ground (e.g. heavy metals).

The inventory of these flows for a given system is split up into two steps:

- quantifying all the flows involved in each life cycle phase considered in the study;
- summing up these flows, which requires linking all the steps to the reference flow i.e. the chosen functional unit. In this study, the aggregated flows are related to packaging and distribution of 1000 litres of wine.

This aggregation then allows a multicriterial analysis through the study of the environmental impact indicators.

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[7] has been used to complete missing LCI.

3.2 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. Furthermore, they are relevant from the environmental point of view and provide a multi-criterion approach to the environmental issues. They are among the most consensual ones according to the international community of LCA experts. A 100 year perspective has been considered in the study, which is in accordance with the PAS 2050 regarding the assessment of greenhouse gases emissions.

The CML impact assessment method for global warming (100 years) was modified in order to exclude positive and negative contributions to global warming caused by biogenic flows of carbon dioxide (CO_2). This corresponds to a model of the biogenic carbon balance where the fixation of CO_2 in growing forests and emissions due to incineration or digestion are set to zero[8]. Characterisation factors were chosen in order to match the latest global warming potentials given by the IPCC. This dataset is PAS 2050 compliant. The complete list of characterisation factors is given in annex 1.

In addition to the characterisation results, primary energy and water consumptions are considered. Both are based on life cycle inventory data. 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] PriceWaterHouseCoopers (2008): Waste-Integrated Systems for Assessment of Recovery and Disposal, https://www.ecobilan.com/uk_wisard.php

[8] Guinée J.B. and Heijungs R. (2009), A greenhouse gas indicator for bioenergy: some theoretical issues with practical implications, Int. J. of Life Cycle Assessment 14 pp. 328–339.

Water consumption in LCA

The use of a water consumption indicator when performing a LCA study presents various methodological limits, detailed hereafter:

First of all, it is not an indicator of environmental impact, contrary to the other indicators (e.g. climate change, air acidification), which assess a potential damage for the environment (water used in a process and rejected into the environment without pollutions might be considered “neutral”, from an environmental point of view). Thus, it is not included in the list of the indicators of environmental impacts of neither CML or Impact 2002+ of which we use the factors of characterization to evaluate our indicators of impacts.

Secondly, “consumed” water (taken in the environment) can be rejected into the environment, after treatment. Our databases of life cycle inventories do not provide information on the water rejected into the environment for the production of the paperboard, plastic, glass, etc. In fact, it is not possible to evaluate the “clear” water consumption for the production of the various materials, which would be a more relevant concept. The fact that rejected water can be polluted by other elements (COD, AOX, etc.), is however taken in other indicators.

Lastly, the impact of water consumption is highly dependent on local conditions since locations with abundant water resources can cope with withdrawal of big volumes of water while regions subject to water scarcity are sensitive when relatively small volumes of water are withdrawn. In the present methodology, the locations where water consumption occurs are not taken into consideration.

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

The robustness of each of them has been classified from “???” (low) to “+++” (high). These reliability indicators are qualitative and based on our own expert judgment, they aim both at strengthening the results credibility and stressing on the necessary precautions that need to be taken when interpreting results.

Table 3: 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[9])
Global warming potential	kg CO_2 eq	+++	IPCC 2007[10]
Ozone layer depletion potential	kg CFC-11 eq	+	CML 2001 (ODP[11])
Photochemical oxidation potential	kg C_2H_4 eq	+	CML 2001 (POCP[12,13])
Air acidification potential	kg SO_2 eq	++	CML 2001 (AP[14])
Eutrophication potential	kg PO_4^{3-} eq	++	CML 2001 (EP[14])
Human toxicity potential	kg 1,4-DB eq	???	CML 2001 (USES-LCA[15, 16]-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			

9 Guinée J.B. (ed.), 2001. Life Cycle Assessment an operational guide to the ISO standard. Volume I, II, III

10 IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change. [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

11 WMO (World Meteorological Organisation), 2003: Scientific assessment of ozone depletion: 2003. Global Ozone Research and Monitoring Project - Report no. XX. Geneva.

12 Jenkin, M.E. & G.D. Hayman, 1999: Photochemical ozone creation potentials for oxygenated volatile organic compounds: sensitivity to variations in kinetic and mechanistic parameters. Atmospheric Environment 33: 1775-1293.

13 Derwent, R.G., M.E. Jenkin, S.M. Saunders & M.J. Pilling, 1998. Photochemical ozone creation potentials for organic compounds in Northwest Europe calculated with a master chemcal mechanism. Atmosperic Environment, 32. p 2429-2441.

14 Huijbregts, M., 1999: Life cycle impact assessment of acidifying and eutrophying air pollutants. Calculation of equivalency factors with RAINS-LCA. Interfaculty Department of Environmental Science, Faculty of Environmental Science, University of Amsterdam, The Netherlands.

15 Huijbregts, M., 1999: Priority assessment of toxic substances in LCA. Development and application of the multi-media fate, exposure and effect model USES-LCA. IVAM environmental research, University of Amsterdam, Amsterdam.

16 Huijbregts, M., 2000. Priority Assessment of Toxic Substances in the frame of LCA. Time horizon dependency of toxicity potentials calculated with the multi-media fate, exposure and effects model USES-LCA. Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Amsterdam, The Netherlands. (http://www.leidenuniv.nl/interfac/cml/lca2/).

3.3 NORMALISATION: EXPRESSION OF IMPACTS PER INHABITANT EQUIVALENT

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).

Table 4 : Normalisation values considered in the study

Indicator of Potential Impact	Unit per European/year	Normalisation Value
Abiotic depletion	kg Sb eq	37
Water consumption*	m^3	59
Primary energy**	MJ primary	170 000
Global warming potential	kg CO_2 eq	11 515
Ozone layer depletion	kg CFC-11 eq	0.023
Photochemical oxidation	kg C_2H_4 eq	6
Acidification	kg SO_2 eq	37
Eutrophication	kg PO_4^{3-} eq	41
Human toxicity	kg 1,4-DB eq	22 270
Freshwater aquatic ecotoxicity	kg 1,4-DB eq	1130
Freshwater sedimental ecotoxicity	kg 1,4-DB eq	2260
Terrestrial ecotoxicity	kg 1,4-DB eq	257

Source: EU25+3, 2000 (Wegener Sleeswijk et al., 2008), except * and ** (BIO IS, 2006)

DATA USED TO ESTABLISH THE LIFE CYCLE INVENTORIES

4. Systems studied and data used to establish the Life Cycle Inventories

4.1 DATA COLLECTION AND DATA MANAGEMENT

4.1.1. Data collection

To ensure the quality of the systems studied, data have been collected from professionals as far as it was possible.

4.1.1.1. 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. Thus, Elopak Norway and Tetra Pak Sweden have imparted data for beverage carton. Smurfit Kappa and Vitop have provided data for both Bag in Box and Stand up Pouch.

For the other systems, data collection has been carried out from professionals as far as possible and otherwise from bibliography and inventories data.

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

Table 5: Data source for primary package

Systems	Sources	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

Concerning primary package, the glass system is thus mostly based on secondary data. For all other packages, primary data have been used concerning the weight and composition of the primary packaging.

4.1.1.2. 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. The filling questionnaires also covers aspects regarding the secondary and tertiary packages since the filler conditions the products before sending them to the retailing groups. When no contacts have been found, bibliography and inventories data have been used.

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

Table 6: Data source for filling stage

System	Source	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

4.1.1.3. Distribution and end-of-life data collection

Distribution scenarios have been decided with Systembolaget and Vinmonopolet and the two companies agreed on considering a common distribution hub hypothetically located in Arvika (Värmland County, Sweden).

End-of-life routes for packages after consumer use in Sweden and Norway have been taken from national statistics.

Systembolaget and Vinmonopolet have provided data about end-of-life of secondary and tertiary packaging for their respective retailers network.

4.1.2. DATA FROM DATABASE

4.1.2.1. Life cycle inventory for energy production

In this study, the electricity mix chosen is the average one of the country in which the process takes place unless a specific mix (contract-specific electricity) is subscribed.

The following life cycle inventories have therefore been considered:

Table 7: Life cycle inventories for electricity

Location	Description of the inventory	Source	Representativeness
Electricity, low voltage, at grid inventories			
France	Electricity, low voltage, at grid/FR	Ecoinvent 2.0	France / 2004
Italy	Electricity, low voltage, at grid/IT	Ecoinvent 2.0	Italy / 2004
Netherlands	Electricity, low voltage, at grid/NL	Ecoinvent 2.0	Netherlands/2004
Norway	Electricity, low voltage, at grid/NO	Ecoinvent 2.0	Norway / 2004
Sweden	Electricity, low voltage, at grid/SE	Ecoinvent 2.0	Sweden / 2004
Europe	Electricity, low voltage, at grid/UCTE*	Ecoinvent 2.0	UCTE /2004
Green electricity mix (Germany)	Electricity, hydropower, at power plant/DE	Ecoinvent 2.0	Germany/2000
Green electricity mix (Netherlands)	90% Electricity, hydropower, at power plant/NL 10% Electricity, at wind power plant /RER	Ecoinvent 2.0	Netherlands /2000
*Union for the Co-ordination of Transmission of Electricity			

Electricity generation mix for each country is presented in annex 2.

The greenhouse gas emissions associated with these energy mixes are given in the next table.

Table 8 : Greenhouse gas emissions associated with each electricity mix

Electricity mix	Global warming potential ($g\ CO_2$ eq./kWh)
France	99
Italy	626
Netherlands	713
Norway	36
Sweden	96
Europe	582
Green electricity mix (Germany)	5
Green electricity mix (Netherlands)	4

Other electricity mixes

Data from European federation have been used to model the impacts of the production of plastics and aluminium:

- Concerning plastic materials (PP, LDPE, HDPE, PET, nylon), data from Plastics Europe have been considered. In these datasets, a specific energy mix weighted by plastic production sites is used.
- Concerning aluminium, data from the European Aluminium Association (EAA) are used. In these data, a model has been developed in order to take into account the energy mixes[17] of primary aluminium production sites including European production and imported aluminium. The reference year for this model is 2005. Other aluminium processes consider a EU25 average energy mix.

Production of electricity is already included in these datasets.

4.1.2.2. Life cycle inventories of materials

Table 9: Life cycle inventories of materials

Material	Description of the inventory	Source	Representativeness
Primary packaging – main container materials			
Cardboard for beverage carton	Liquid packaging board production, at plant	Ecoinvent 2.0	Europe / 2003
EVA	Ethylene vinyl acetate copolymer, at plant	Ecoinvent 2.0	Europe / 2007
EVOH	Ethylene vinyl acetate copolymer, at plant	Ecoinvent 2.0	Europe / 2007
HDPE	HDPE granulates	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005
LDPE	LDPE granulates	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005

[17] Hydropower: 58%, Nuclear: 15%, Fossil: 27%.

Material	Description of the inventory	Source	Representativeness
Nylon	Nylon 6	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005
PET	PET granulates bottle grade	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005
PP	PP granulates	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005
Glass	Glass virgin	Ecoinvent 1.3	Europe / 2003
Primary packaging – closures and labels materials			
Aluminium	Primary aluminium	EAA	Europe / 2005
HDPE	HDPE granulates	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005
LDPE	LDPE granulates	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005
Paper	Paper, woodfree, coated, at regional storage	Ecoinvent 2.0	Europe / 2003
PP	PP granulates	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005
Secondary&Tertiary packaging materials			
Cardboard	Corrugated board, fresh fibre single wall, at plant	Ecoinvent 2.0	Europe / 2003
Wood (palet)	EUR-flat pallet	Ecoinvent 2.0	Europe / 2003
Paper	Kraft paper, unbleached, at plant	Ecoinvent 2.0	Europe / 2003
HDPE	PEHD granulates	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005

4.1.2.3. Life cycle inventories of materials transformations

When raw materials are first transformed outside of the packaging producer or when specific data for the fabrication have not been provided by professionals, the following bibliographical data have been used.

Table 10: Life cycle inventories of materials transformations

Materials	Description of the inventory	Yield	Source*	Representativeness
Primary packaging, main container materials				
Aluminium foil	Aluminium foil	0.995	EAA[18]	Europe / 2005
Beverage carton	Transformation considered in the fabrication process			
Cardboard	Transformation considered in the fabrication process			
EVA	No transformation considered			
EVOH	No transformation considered			
Extruded plastics	LDPE plastic film — LDPE granulates**	0.976	Plastics Europe (Ecoinvent 2.0)	Europe / 2005
PET	Transformation considered in the fabrication process			
Glass	No transformation considered			
Primary packaging, closures and labels materials				
Aluminium foil	Aluminium foil	0.993	EAA	Europe / 2005
Aluminium screw cap	Aluminium sheet	0.995	EAA	Europe / 2005
Cardboard	Production of carton board boxes, offset printing, at plant	1	Ecoinvent 2.0	Europe / 2003
Injected moulded plastics	PP injection moulding — PP resin**	0.994	Plastics Europe (Ecoinvent 2.0)	Europe / 2005
Extruded plastics	LDPE plastic film — LDPE granulates**	0.976	PlasticsEurope (Ecoinvent 2.0)	Europe / 2005
Paper	No transformation considered			
Secondary&Tertiary packaging materials				
Wood (palet)	Transformation included to the life cycle inventory of the material			
Cardboard (secondary packaging)	Production of carton board boxes, offset printing, at plant	1	Ecoinvent 2.0	Europe / 2003
Cardboard (tertiary packaging)	No transformation considered			
Paper	No transformation considered			
Plastic film	LDPE plastic film — LDPE granulates**	0.976	Plastics Europe (Ecoinvent 2.0)	Europe / 2005

*Apart from the yields taken from Ecoinvent 2.0.

**The inventory of the process has been calculated by the deduction of the inventory of the unprocessed material from the inventory of the processed material.

4.1.2.4. Life cycle inventories of end-of-life treatments

- Waste disposal treatment

[18] European Aluminium Association

Table 11: Incineration and landfill life cycle inventories

Materials	Description of the inventory	Waste elec (MJ/kg) *	Waste heat (MJ/kg) **	Waste elec (MJ/kg)	Waste heat (MJ/kg)	Waste elec (MJ/kg)	Waste heat (MJ/kg)
Incineration		**Norway*****		**Sweden*****		**Europe*****	
Aluminium	Disposal, aluminium, 0% water, to municipal incineration/CH S with recuperation of clinkers[19] (90% recycling, 10% landfill)	–	–	–	–	–	–
Aluminium (<50µm)	Disposal, aluminium, 0% water, to municipal incineration/CH S	0.76	7.63	1.01	7.38	2.74	5.65
Cardboard	Disposal, packaging cardboard, 19.6% water, to municipal incineration/CH S	0.43	4.35	0.57	4.21	1.55	3.23
Glass	Disposal, glass, 0% water, to municipal incineration/CH S	–	–			–	–
Mixed plastics	Plastics mixture incineration with recovery in Europe	0.96	9.55	1.26	9.25	3.48	7.03
Paper	Disposal, paper, 11.2% water, to municipal incineration/CH S	0.37	3.72	0.49	3.6	1.32	2.77
PE	Disposal, polyethylene, 0.4% water, to municipal incineration/CH S	1.37	13.65	1.80	13.22	5	10.02
PET	Disposal, polyethylene terephtalate, 0.2% water, to municipal incineration/CH S	0.68	6.81	0.9	6.59	2.46	5.03
PP	Disposal, polypropylene, 15.9% water, to municipal incineration/CH S	1.03	10.25	1.35	9.93	3.74	7.54
Wood	Disposal, wood untreated, 20% water, to municipal incineration/CH S	0.37	3.67	0.48	3.56	1.3	2.74
Municipal solid waste	Disposal, municipal solid waste, 22.9% water, to municipal incineration/CH S	0.29	2.88	0.38	2.79	1.01	2.16
Landfill		**Ecoinvent 2.0 Switzerland / 2005**					
Aluminium	Disposal, aluminium, 0% water, to sanitary landfill/CH S						
Cardboard	Disposal, packaging cardboard, 19.6% water, to sanitary landfill/CH S						
Glass	Disposal, glass, 0% water, to inert material landfill/CH S						
Mix. plast.	Disposal, plastics, mixture, 15.3% water, to sanitary landfill/CH S						
Paper	Disposal, paper, 11.2% water, to sanitary landfill/CH S						
PE	Disposal, polyethylene, 0.4% water, to sanitary landfill/CH S						
PET	Disposal, polyethylene terephtalate, 0.2% water, to sanitary landfill/CH S						
PP	Disposal, polypropylene, 15.9% water, to sanitary landfill/CH S						
Wood	Disposal, wood untreated, 20% water, to sanitary landfill/CH S						

* Waste electric energy produced (MJ/kg): electricity mix inventories are used to calculate avoided impacts coming from waste electric energy produced through incineration with energy recovery

** Waste thermal energy produced (MJ/kg): gaz heat inventories are used to calculate avoided impacts coming from waste thermal energy produced through incineration with energy recovery

*** Representativeness

>Europe: Ecoinvent 2.0, Switzerland / 2005 (due to lack of more specific data, Swiss inventories have been used for end-of-life treatments)

>Sweden/Norway: Ecoinvent 2.0, Switzerland 2005 with electric/thermal repartition adapted to Nordic context. Electric/thermal repartition from Energi från avfall ur ett internationellt perspektiv RAPPORT 2008:13

[19] "ACV comparative de différents emballages pour boissons" (Comparative LCA of various packaging systems for beverage), BIOIS, Eco-Emballages, 2008

Note that aluminium foil thinner than 50 µm is deemed combustible and has a lower heating value of 25MJ/kg according to EN 13431:2004[20].

- Biogenic carbon storage

For cardboard and paper, biogenic carbon storage has been considered. The assumptions come from the Ecoinvent life cycle inventories metadata and are as follows:

Table 12: Carbon sequestration data for paper and cardboard materials[21]

Inventory	Carbon content (%)	Carbon emitted (%)	Carbon stored (%)	Carbon stored (kg CO_2 eq/kg)
Calculation	***(a) % of total weight***	***(b) % of carbon weight***	***(c) = (a) x [1 - (b)] % of total weight***	***(d) = (c) x 44/12***
Disposal, packaging cardboard, 19.6% water, to sanitary landfill/CH U	43.33%	32.44%	29.27%	**1.07**
Disposal, paper, 11.2% water, to sanitary landfill/CH S	40.40%	26.99%	29.50%	**1.08**

- Recycling life cycle inventories

The table below presents the inventories used to calculate the recycling credits.

It has thus been considered the recycled potential of each packaging provided by each professional.

Table 13: Life cycle inventories for recycling

Materials	Recycling credits (E_r-E_v)*	Sources	Representativeness **
Primary packaging – main container materials			
Cardboard	Corrugated board, **recycling fibre**, single wall, at plant **-** Corrugated board, **fresh fibre**, single wall, at plant	Ecoinvent 2.0	Europe/2005
PET	Mechanical recycling (PET bottle grade → amorphous PET): see Table 14	USEPA, Ecoinvent	Global/2006
Glass	Glass →Dead leaves***	Wisard	France/2000
Primary packaging – closures and labels materials			
Aluminium screw cap	Recycled aluminium - Aluminium Primary	EAA	Europe/2005
Plastics	Mechanical recycling : see Table 14	USEPA, Ecoinvent	Global/2006
Paper	Corrugated board, **recycling fibre**, single wall, at plant **-** Corrugated board, **fresh fibre**, single wall, at plant	Ecoinvent 2.0	Europe/2005
Secondary&Tertiary packaging materials			
Wood (pallet)			Reuse****

[20] EN 13431:2004, Packaging. Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value

[21] Doka G. (2007) Life Cycle Inventories of Waste Treatment Services, ecoinvent report No13, Swiss Centre for Life Cycle Inventories, Dubendorf, December 2007.

Materials	Recycling credits (E_r-E_v)*	Sources	Representativeness **
Cardboard	Corrugated board, **recycling fibre**, single wall, at plant **-** Corrugated board, **fresh fibre**, single wall, at plant	Ecoinvent 2.0	Europe/2005
Paper	Corrugated board, **recycling fibre**, single wall, at plant **-** Corrugated board, **fresh fibre**, single wall, at plant	Ecoinvent 2.0	Europe/2005
Plastics	Mechanical recycling: see Table 14	USEPA, Ecoinvent	Global/2006

*See section 4.2.2 for explanations on the term (E_r-E_v)

**Due to lack of more specific data, European or French inventories have been used to model recycling credits

***Dead leaf green colour glass

****Reuse: Environmental impact neglected (mainly pallet transport)

Plastics recycling

It is considered that recycled plastics are sorted and mechanically recycled and that losses are incinerated with energy recovery.

The impacts of mechanical recycling have been modeled using the following data:

Table 14 : Impacts of mechanical recycling

Data	Value	Sources
Energy consumption	0.5 kWh/kg	Ecoinvent
Loss rate during reprocessing	14%	USEPA 2006[22]

Mechanically recycled plastics substitute to virgin plastic whose production impacts have been calculated with PlasticsEurope LCIs. This approach has been chosen in order to be fully consistent with the choosing of PlasticsEurope LCIs for modeling virgin material production, in the absence of better data.

Environmental benefits generated by mechanical recycling of plastics are therefore in the form of:

$$\text{Environmental credits/unit} = EC \times E_{elec} - (1\text{-}LR) \times E_v$$

With:

EC = Energy consumption

LR = Loss rate during reprocessing

E_{elec} = impacts arising from electricity production, per kWh

E_V = impacts arising from virgin plastic input, per unit of material.

[22] This value is based on a rough weight (including impurities) not on strict plastic input. Therefore, this value tends to be overestimated.

4.2 GENERAL ASSUMPTIONS AND METHODOLOGY

4.2.1. INFRASTRUCTURES

The construction/manufacturing, maintenance and end-of-life of infrastructures and capital equipment (e.g. buildings, machines, roads, and transport vessels) are excluded from the study.

For primary data, those data have been neglected. Indeed, this assumption, usually made in the LCA studies, is based on the fact that the environmental impacts involved can be neglected when brought back to the functional unit and compared to the other impacts, because of the lifespan of such infrastructure and equipment.

4.2.2. TAKING INTO ACCOUNT RECYCLING

General principles

Recycling provides two environmental benefits:

- First, recycling avoids a conventional disposal route such as landfilling or incineration;
- Second, recycling avoids the need to extract virgin materials. This procures **environmental benefits** because for most materials recycling processes are less impacting than virgin material production processes.

These benefits occur at the interface of an upstream system — the one **providing** recycled materials — and a downstream system — the one **using** recycled material — . Both systems are essential and some rules are therefore needed to allocate these benefits.

Recycling makes possible both saving of material production and waste elimination and both savings need to be allocated as a whole. Partitioning of benefits needs to be made between recyclable waste delivery and recycled material incorporation.

Allocation rules of environmental benefits generated by recycling are in the form of:

Environmental credits/unit = F(RC, RR) (Er-Ev - Ed)

With:

RC = recycled content,

RR = recycling rate,

F(RC,RR) is a function of RC and RR

E_R = impacts arising from recycled material input, per unit of material,

E_V = impacts arising from virgin material input, per unit of material,

E_d = impacts arising from disposal of waste material, per unit of material.

The “(E_r-E_v)” term, can be understood as the recycling benefits thanks to avoided use of virgin material, whereas “-E_d” represent the benefits associated with the avoidance of a conventional disposal route.

Allocation factors

Allocation procedures factors have been chosen considering the recycling market in order to stimulate it:

- For aluminium, glass, cardboard/paper and bottle grade PET for which the demand of recycled material is high, it is important to stimulate the recycling rate, hence the benefits are given to the orientation to recycling.

  F(RR,RC) = RR

- For other plastics and non bottle PET, both the use of recycling material and the orientation to recycling needs to be encouraged.

  F(RR, RC) = ½ x RR + ½ x RC

This set of rules is consistent with latest recommendations from the French ADEME/AFNOR platform on environmental labelling.

As a summary, the following rules have been considered in the baseline scenario:

For paper/cardboard, aluminium, glass and bottle grade PET

Environmental credits/unit = RR x (E_r-E_v - E_{dd})

E_{dd} represents downstream conventional disposal that is avoided thanks to recycling.

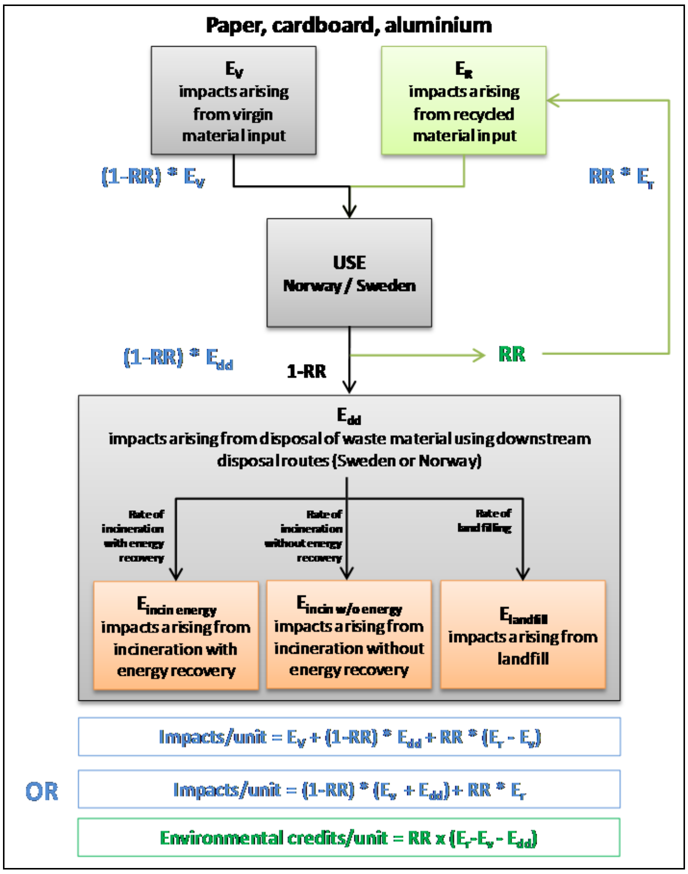


Figure 3: Taking into account recycling for paper, cardboard and aluminium

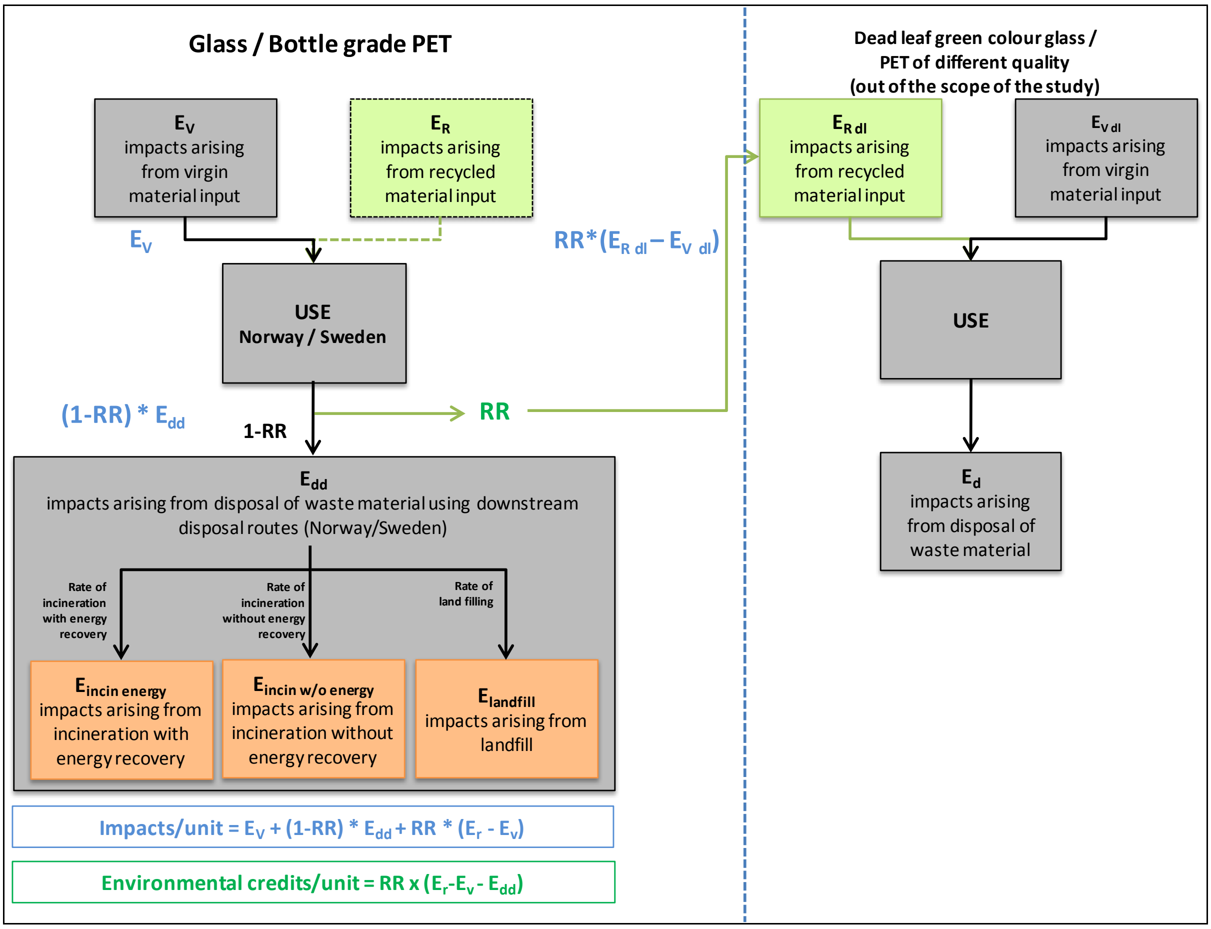


Figure 4: Taking into account recycling for glass and bottle grade PET

For other plastics (including non bottle PET)

Environmental credits/unit = ½ RR x (E_r-E_v - E_{du}) + ½ RC x (E_r-E_v - E_{dd})

E_{du} represents upstream conventional disposal that is avoided thanks to recycling, and E_{dd} downstream conventional disposal.

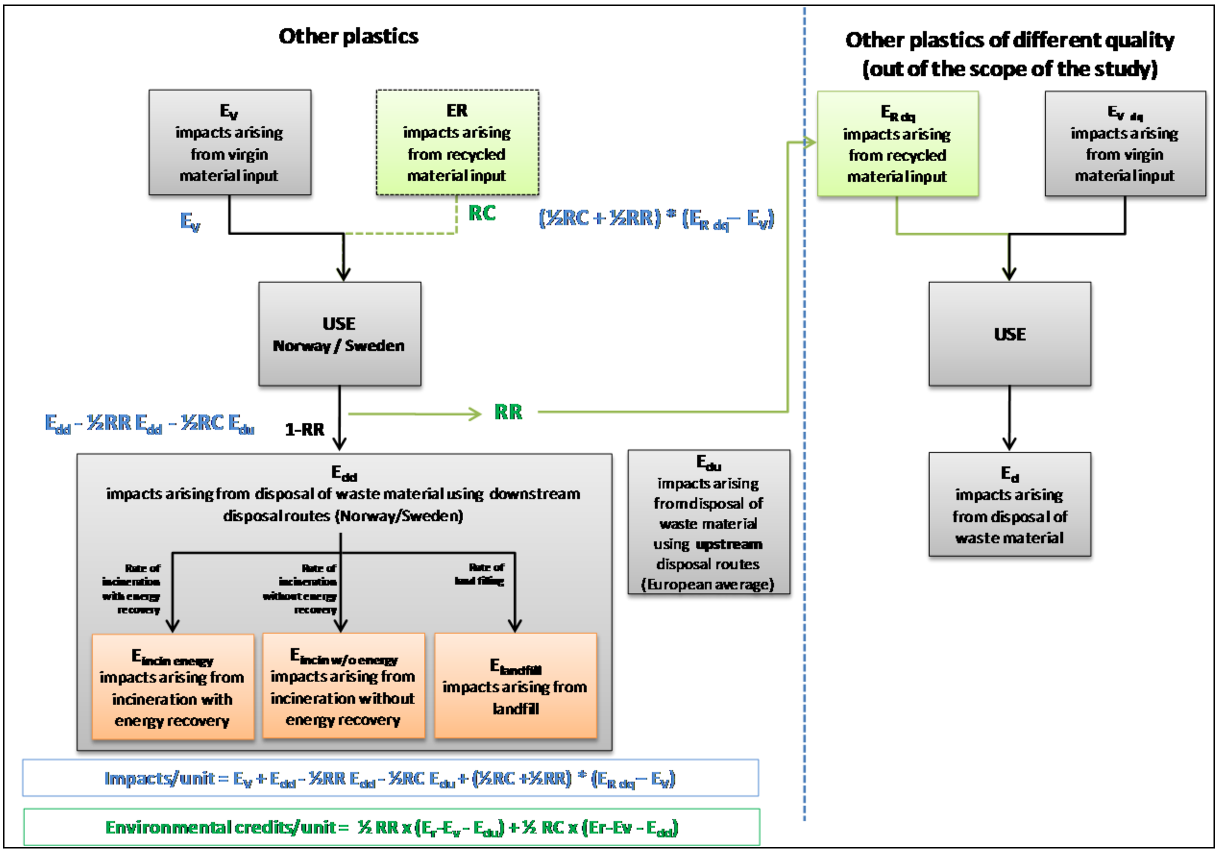


Figure 5: Taking into account recycling for other plastics

PAS2050 formula for paper and cardboard products

PAS2050 defines a unique formula paper and cardboard materials recycled in closed loop:

Environmental credits/unit = RC x (E_r-E_v) - RR x E_{du}

This formula has not been chosen in the baseline scenario as it does not allocate benefits as a whole. The formula has however been considered in sensitivity analyses in section 6.3.2.

Avoided routes

In the LCA model, it is considered that without recycling, materials would have followed the same route than residual waste. There are two cases:

- When conventional disposal is avoided thanks **to diversion to recycling (RR).** It is considered that the avoided routes are those that would have been followed in the country where waste is diverted to recycling (downstream conventional disposal).

- When conventional disposal is avoided thanks **to incorporation of recycled material (RC).** It is considered that the avoided routes are the average repartition between landfill and incineration in Europe (upstream conventional disposal). This is due to the fact that the recycling market is European and that the exact upstream source of recycled material can not be traced back.

Table 15: Residual waste disposal routes in Norway, Sweden and Europe

Disposal route	Norway	Sweden	Europe
Landfill	32%	6%	63%
Incineration without energy recovery	0%	0%	0%
Energy recovery	68%	94%	37%
Source >Europe: EUROSTAT >National statistics : see Table 19: End-of-life routes			

The next table summarises the recycled content of materials that are considered in the study.

Table 16 Recycled content of materials used in each system

Material	PET bottle	Glass bottle	Bag In Box	Stand up Pouch	Beverage carton
Glass	N/A	- Primary packaging *(75%)*	N/A	N/A	N/A
Paper	- PET bottle label *(49%)*	- glass bottle label *(49%)*	N/A	Tertiary packaging paper sheets *(49%)*	N/A
Cardboard	- Secondary packaging cardboard box *(82%)* - Tertiary packaging cardboard for bottom of pallet (82%)	- Secondary packaging cardboard box *(82%)* - Tertiary packaging cardboard for bottom of pallet (82%)	- Primary packaging *(82%)* - Secondary packaging cardboard box *(82%)* - Tertiary packaging cardboard for bottom of pallet (82%)	- Secondary packaging cardboard box *(82%)*	- Secondary packaging cardboard box *(82%)* *(100% Elopak, 82% Tetra Pak)* - Tertiary packaging cardboard for bottom of pallet (82%)

The next table presents the materials for which one of the end-of-life routes is recycling. The following assumptions have been made:

- Paper labels are not recycled, as they are removed from primary packaging at recycling centre and then sent to incineration or landfill;

- Internal coating in PET bottle is recycled with the PET, as those materials are not separated from the PET and is recycled in mass with the pool of bottles.

Table 17 Recycled materials used in each system*

Systems	PET bottle	Glass bottle	Bag In Box	Stand up Pouch	Beverage carton
Primary packaging					
Principal materials					
PET	Recycled	N/A	N/A	N/A	N/A
Nylon	Recycled with PET	N/A	N/A	N/A	N/A
Glass	N/A	Recycled	N/A	N/A	N/A
Cardboard	N/A	N/A	Recycled	N/A	N/A
Extruded PET	N/A	N/A	Not recycled	Not recycled	N/A
Aluminium foil	N/A	N/A	Not recycled	Not recycled	Not recycled
Extruded LDPE	N/A	N/A	Not recycled	Not recycled	Not recycled
EVOH	N/A	N/A	Not recycled	N/A	N/A
Extruded LLDPE	N/A	N/A	Not recycled	Not recycled	Not recycled
Liquid carton board	N/A	N/A	N/A	N/A	Recycled
EAA	N/A	N/A	N/A	N/A	Not recycled
Label					
Paper	Not recycled	Not recycled	N/A	N/A	N/A
Closure					
Aluminium sheet	N/A	Recycled	N/A	N/A	N/A
PP	N/A	N/A	Not recycled	Not recycled	N/A
HDPE	N/A	N/A	Not recycled	Not recycled	Recycled
Elastomer (PET)	N/A	N/A	Not recycled	Not recycled	N/A
LDPE	N/A	N/A	Not recycled	Not recycled	N/A
Secondary packaging					
Cardboard box	Recycled	Recycled	Recycled	Recycled	Recycled
HDPE film	N/A	N/A	N/A	N/A	Recycled
Tertiary packaging					
Cardboard for bottom of pallet	Recycled	N/A	Recycled	N/A	Recycled
Paper sheets	N/A	N/A	N/A	Recycled	N/A
Wrapping film	Recycled	Recycled	Recycled	Recycled	Recycled

*Recycling rate for each materials are given in Table 19: End-of-life routes

4.2.3. TRANSPORT

4.2.3.1. Transport stages

The transport stages considered in the study are:

1. Transport of raw materials to packaging production plants for each packaging part;
2. Transport of the empty packages to the winery location (filling centre);
3. Supply of raw materials for closures and secondary and tertiary packaging materials;
4. Transport of the filled packaging to a distribution hub;
5. Transport of the filled packaging from the distribution hub to the retailer;
6. Transport of waste from the manufacturer, from the retailer and from the consumer to their sites of recovery or disposal.

The transports are estimated based on the concept of tonne-kilometre (tkm) of transport, which is the total weight of the material/component/product that is transported (the material/product + its packaging) multiplied by the distribution distance, per mean of transportation involved.

Quantifying these impacts requires the life cycle inventories (LCIs) for each mean of transportation involved (given for 1 tkm).

A specific road transport model has been used for modelling road distribution of empty packaging to the filler and of filled packaging to the retailers (stages 2, 4 and 5) in order to take into account both weight and volume of transported items. Due to a lack of detailed information on other transportation stages (payload, haul), generic LCIs from Ecoinvent have been used for other transport (see Table 18: Life cycle inventories used for transport "fleet average" inventories).

4.2.3.2. Specific road transport model description

The objective of this model is to take into account both weight and volume of the shipment when computing the impacts of transporting goods.

The model is adapted from ADEME Bilan Carbone® v5[23] methodology and takes into account truck loading factors, haul and impacts of empty and loaded trucks. The main concept behind the transport model is that heavier is the load, higher are the impacts as fuel consumption will increase. This approach is also consistent with the French AFNOR norm NFP01-010 on Environmental Product Declaration of building products.

Whereas the Bilan Carbone® methodology only considers carbon dioxide emissions related to fuel consumption, emission factors of fully and empty loaded trucks have been replaced by Ecoinvent life cycle inventories of fully and empty loaded trucks (see Table 18: Life cycle inventories used for transport).

[23] ADEME 2007, Bilan Carbone® V5.0 Entreprises et collectivités, Guide des facteurs d'émissions

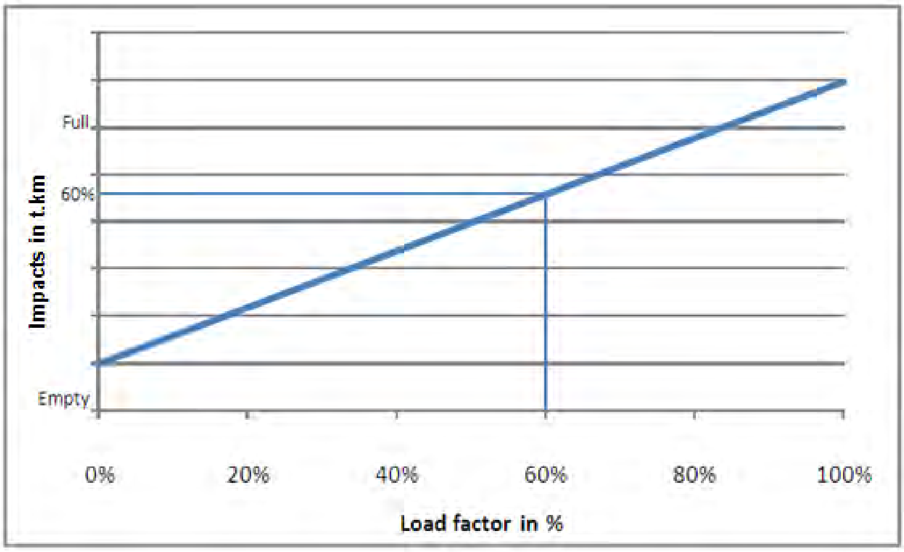


Figure 6: Influence of the load factor on truck life cycle inventory

Presentation of the model

The model is as follows:

$$\text{Impacts} = \frac{\text{Impacts}_{\text{empty}} + (\text{Impacts}_{\text{full}} - \text{Impacts}_{\text{empty}}) \times \tau_{\text{load}} + \tau_{\text{empty}} \times \text{Impacts}_{\text{empty}}}{\tau_{\text{load}} \times \text{PL}}$$

With:

Impacts = Impacts per t.km of a truck loaded with a given loading factor τ_{load}

Impacts_{empty}= Impacts per km of an empty truck

Impacts_{full} = Impacts per km of a fully loaded truck

τ_{load} is the loading factor (load/payload)

τ_{empty}: represents the percentage of the haul with an empty truck. This parameter is set to 21% for transportation steps from packaging producer to filling station and from filling station to distribution hub (transportation stages 2 and 4). For transportation from distribution hub to retailer, the parameter is set to 18% (transportation stage 5)[24].

PL is the payload. This parameter is set to 25 t for transportation steps from packaging producer to filling station and from filling station to distribution hub (transportation stages 2 and 4). For transportation from distribution hub to retailer, the parameter is set to 10 t (transportation stage 5)[25].

[24] Values taken from the ADEME Bilan Carbone® v5 methodology.

[25] Based on figures provided by international transport companies.

<u>**Effects of the parameters of the model**</u>

The first part of the equation $\text{Impacts}_{\text{empty}} + (\text{Impacts}_{\text{full}} - \text{Impacts}_{\text{empty}}) \times \tau_{\text{load}}$ represents the impacts of the truck when the items are being transported (truck loaded with a given loading factor).

The second part of equation $\tau_{\text{empty}} \times \text{Impacts}_{\text{empty}}$ is used for modelling the impacts of the empty truck haul.

Volume and weight of the shipment are taken into account through the loading factor. Indeed, τ_{load} is the ratio between the load and the payload and may be computed with the following equation:

$$\tau_{\text{load}} = \frac{\text{load}}{\text{PL}} \qquad \tau_{\text{load}} = \frac{1}{\text{PL}} \times \text{mass of one item} \times \text{number of items that fits in the truck}$$

$$\tau_{\text{load}} = \frac{1}{\text{PL}} \times \text{mass of one item} \times \frac{\text{usable truck volume}}{\text{volume of one item}}$$

One item being the package **and** its content for phase of transport of the filled packages.

On the one hand, when τ_{load} increases, the term $(\text{Impacts}_{\text{full}} - \text{Impacts}_{\text{empty}}) \times \tau_{\text{load}}$ of the equation increases in order to take into account the fact that heavier is the load, higher are the impacts; on the other hand the denominator increases $\tau_{\text{load}} \times PL$ which tends to reduce the impacts in order to take into account that from an environmental point of view it is better to use fully loaded trucks.

4.2.3.3. Transported item

Two stages have been considered in order to assess the impacts of distributing the wine packages:

- Transporting empty packages (from packaging producer to filler);
- Transporting filled packages (from filler to distribution hub and from distribution hub to retailers).

The weight of 1 litre of wine has been estimated as 1kg and is used to calculate **loading rates** that were incorporated in the road transport model. In this model, only the weight of the **packaging** is taken into account when calculating the overall impacts of the transport of filled packages. In section 6.3.1, the impacts of the weight of the wine during transport of filled packages are investigated.

In all scenarios, the model therefore consists in filling the truck and calculating the impact down to the proportion of 1000 litres (1 functional unit).

Thus for each system specific data have been collected (number of empty packages per pallet, number of pallet of empty packages per truck, number of filled packages per pallet, number of pallet of filled packages per truck) to calculate the load of the truck during distribution. When those data were no available, assumptions where made according to the average transport load rate of the professional or bibliography.

Table 18: Life cycle inventories used for transport

Transportation mean	Description of the inventory	Source
Truck (3.5-20t)	Operation, lorry 3.5-20t, empty, fleet average	Ecoinvent 2.0
	Operation, lorry 3.5-20t, full, fleet average	Ecoinvent 2.0
	Transport, lorry 3.5-20t, fleet average without operation	Ecoinvent 2.0
Truck (>28t)	Operation, lorry >28t, empty, fleet average	Ecoinvent 2.0
	Operation, lorry >28t, full, fleet average	Ecoinvent 2.0
	Transport, lorry >28t, fleet average without operation	Ecoinvent 2.0
Train	Transport, freight, rail	Ecoinvent 2.0
Boat	Transport, transoceanic freight ship	Ecoinvent 2.0

For the distribution from the packaging producer to the filler and then to the distribution hub, a truck >28t have been used according to the data given by the producers. For the distribution from the distribution hub to the retailers, a truck 3.5-20t has been considered as an assumption.

Transport scenarios

As different systems and volumes have been studied, among which some are not yet distributed by Systembolaget and Vinmonopolet, a transport scenario has been defined to be able to take into account the specific data of each producers and at the same time to assume a common filling centre.

Thus, all systems have been considered to be transported from the producer factory to the South of France to be filled. For the beverage carton, the Bag in Box and the Stand up Pouch systems, real distances from the manufacturing stage to the filling station have been considered. For glass and PET, a distance of 800 kilometres has been assumed.

Then a common distribution hub has been defined by Systembolaget and Vinmonopolet in Arvika, Sweden.

The distance considered from the location of the filler in France to this distribution hub is 2 411 km. Products are then transported to the retailers, assumed to be at 150 km.

Why French wine is chosen in this study?

Both Sweden and Norway import from a filling centre in the Languedoc-Roussillon region in France. This region was chosen because it supplies a great deal of wine to the Nordic countries.

Furthermore, in compliance with PAS 2050 it is recommended that a real filling centre be selected rather than a theoretical geographical calculation point. JeanJean was selected because they fill several types of wine packages and were fully willing to collaborate.

This choice lent an additional degree of realism to the project.

Supply of raw materials

Without precisions from producers and filler, an average truck load of 80% has been considered for the supply of raw materials.

When the transport distance was not available, an average distance of 250 km is used.

Transport of waste

For transport of waste from the manufacturer, from the retailer and from the consumer to their sites of recovery or disposal, the following assumptions have been set:

- An average distance of 50 km to landfill and incineration;
- An average distance of 400 km to recycling;
- An average load of the truck of 50% (due to low compaction of waste).

4.2.4. END-OF-LIFE ROUTES

Waste treatment occurs at three stages of the package life cycle:

- Waste from manufacture: during production as materials are lost alongside the processes;
- Waste from secondary and tertiary packaging : at the retail outlet where secondary and tertiary packaging are discarded;
- Waste from primary packaging: at the consumer's place where primary packaging is discarded;

- Waste from manufacture/production losses

During production processes, losses end-of-life routes given by each producer have been considered. When no data were available, those waste have been considered recycled.

- Waste at the retail outlet

According to data provided by Systembolaget and Vinmonopolet, wastes at their retailers are recycled (plastics and corrugated board).

The pallet has been considered to be reused 30 times[26].

- Waste at the consumer's place

When the country where waste management occurred was not known, general data about waste end-of-life routes in Europe have been used. The end-of-life route for those wastes is 67% to landfill and 33% to incineration (considered as incineration with energy recovery) according to EUROSTATS[27]. This occurs for instance when the benefits of integrating recycled material are computed.

[26] Développement de la réutilisation des emballages industriels – Etat des lieux en 2008 en France (Development of reuse of industrial packaging – France 2008 overview) ADEME, 2008

[27] Eurostat, Households waste data for 2007

Recycling rates in 2008 in Norway and Sweden have been taken from national statistics in order to model consumer disposal of primary packaging.

In order to determine the actual waste data for Norway for the particular packaging systems of the study, it was necessary to combine public available data from a number of sources. These sources are the Green Dot Norway (Grønt Punkt Norge AS), Norwegian Pollution Authority (SFT) and Norwegian Statistics (SSB). The data have been adjusted to be compatible with the LCA methodology and at the same time reflect the actual waste structure of Norway. All figures are from 2008 and 2009.

Table 19: End-of-life routes

		Recycling rate*	Incineration with energy recovery rate	Incineration without energy recovery rate	Landfill rate
Glass					
	Norway	98%	0%	0%	2%
	Sweden	94%	5.7%	0%	0.3%
Plastics (not PET)					
	Norway	13.4 %	86.4	0%	0%
	Sweden	31%	65%	0%	4%
Plastics (PET bottles)					
	Norway	90%	10%	0%	0%
	Sweden	84%	15.1%	0%	0.9%
Paper and cardboard					
	Norway	95%	2.5%	0%	2.5%
	Sweden	74%	24.5%	0%	1.5%
Metal					
	Norway	68%	28%	0%	4%
	Sweden	67%	31.1%	0%	1.9%
Liquid carton board					
	Norway	62.6%	37.4%	0%	0%
	Sweden	43.9% **	52.8%	0%	3.3%
Residual waste					
	Norway	0%	68%	0%	32%
	Sweden	0%	94%	0%	6%

*Sources:

>Sweden (2008)

- Samla in och återvinn 2008 statistik, Swedish Environmental Protection Agency
- Fördpacknings & Tidnings Insamlingen (2008), www.ftiab.se

>Norway (2008)

- Grønt Punkt Norge, www.grontpunkt.no
- Norwegian Pollution Authority (Klima og forunensings direktoratet), www.sft.no
- Norwegian Statistics (Statistisk Sentralbyra), www.ssb.no

** FTI 2008 (Förpacknings- och Tidningsinsamlingen) data communicated to Tetra Pak

4.3 LIMITATIONS

4.3.1. QUALITY OF DATA FOR GLASS BOTTLE

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. Data that were used are based on IPPC 2001 BREF document and are somehow outdated. These were the best available data when the calculations of the present study were performed. In May 2010, the European Container Glass Federation[28] has published a LCA study that provides an updated outlook of the impacts associated with glass production in Europe.

4.3.2. LIMITS

In any Life Cycle Assessment, assumptions are taken and some categories of operations are excluded as their contribution to the global impact is considered as minor. In this study, the following steps have been neglected as they were not considered relevant to achieve the purpose of this study:

- The operations of research and development that have permitted the creation of the current wine packages.
- The transport of finished goods between the retail outlet and the consumption place. As the functional unit of the study is distribution oriented and so does not include the consumption phase, this stage of transport between the Systembolaget and Vinmonopolet stores and the consumption place has been excluded.
- The consumption of energy to store the finished goods in the outlet or at the consumer's place. These consumptions can be neglected as Systembolaget and Vinmonopolet do not refrigerate wine products. Additionally, as these consumptions would not differ from one packaging system to the other, excluding this stage does not impair the relative performance of packaging systems.
- As data were not available for all packaging systems and formats, cleaning products used at production sites have been disregarded.
- Glues used to stick labels, inks used for advertising on labels, primary, secondary and tertiary packaging systems have not been considered. Secondary and tertiary packaging systems used to transport raw materials have not been considered. Scaled to the functional unit, impacts of these materials are assumed to be negligible.

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% which means that no remnants have been considered inside the packages for end-of-life. Note however that in section 6.3.4.2, the uncertainties due to the impacts of wine assuming a 2% loss for each packaging are investigated for greenhouse gases emissions. Aside from the points listed above, no general cut-off criteria were applied. All available data were used.

[28] www.feve.org

RESULTS

5. OPTIMISATION OF PACKAGING

5.1 PRESENTATION FORMAT

5.1.1. DESCRIPTION OF THE SYSTEMS

For each system studied, this section describes the data considered in this report.

5.1.2. 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 20: 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)

Life Cycle "main stages"	Life Cycle stages	Life Cycle sub-stages	Definitions
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 for Norway and Sweden. Two types of results are presented:

- a table showing the breakdown of the environmental impacts of the system per life cycle "**main stages**". In the table, 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%.

- a graph showing the breakdown of the environmental impact per life cycle **stages**. There are 12 life cycle stages. On the graph, the contribution of each stage is presented as a percentage of total impacts even if the contribution of the phase is negative (environmental benefits). The length of the bars may vary from an indicator to another but the percentage adds up to 100% for each indicator.

5.1.3. NORMALISATION

For each system, 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.

5.1.4. SENSITIVITY ANALYSIS

For each system, three sensitivity analyses have been performed in order to assess the influence of different parameters.

- Weight of the primary packaging

This analysis tests the influence on the life cycle impacts of the packaging systems for weight varying between -10% and +20%.

- Distribution distance

In this analysis, the length of the transportation chain is reduced by 20%, 40% and 50%, in order to test the influence of this parameter on the life cycle results. Note that this reduction applies to all distances from the packaging production sites to the retailers.

- Post consumer recycling rate

Apart for the pouch system, which cannot be recycled, this analysis tests the influence of increasing the recycling rate. Note that the post consumer recycling rate for glass bottles is very high in both Norway and Sweden. For that reason, no analysis was performed for these systems.

5.2 PET BOTTLE

5.2.1. DESCRIPTION OF THE SYSTEM

The following scheme represents the different steps of the life cycle of the PET bottles considered in this study.

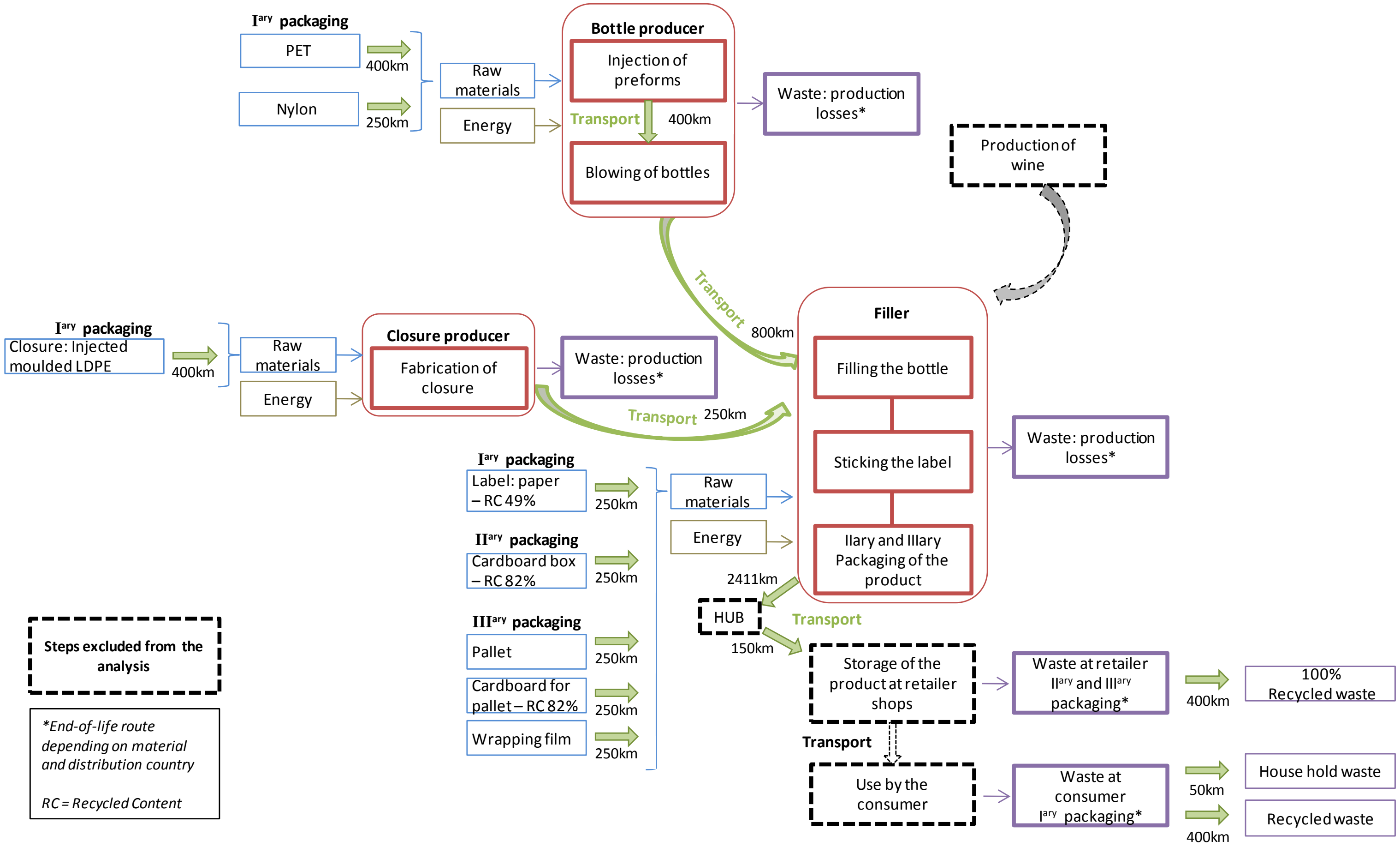


Figure 7: Steps of the life cycle of the PET bottles considered in this study

Table 21 Volumes studied

	Unit	PET Bottle 75 cl	PET Bottle 37.5 cl
Volume	[cl]	**75**	37.5
Total weight	[g]	**54.4**	32.1

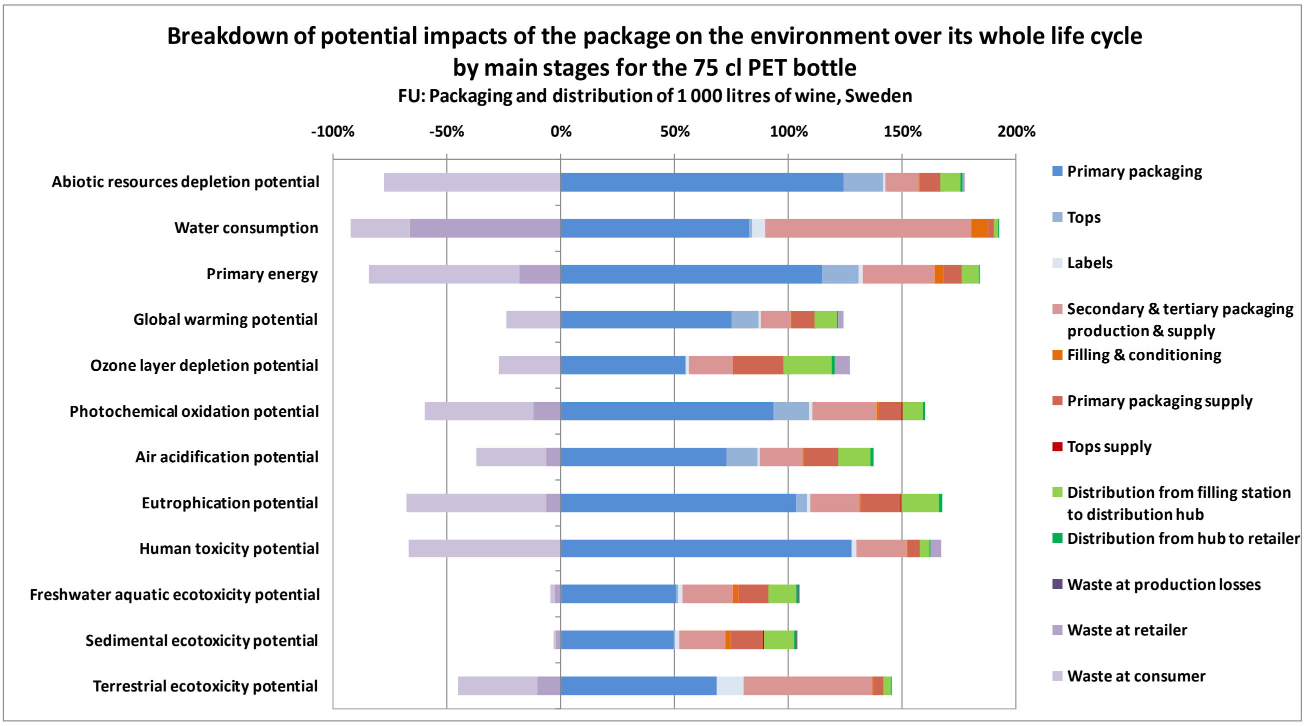
5.2.2. Results of the reference scenario

The 75 cl PET bottle has been chosen in the reference scenario. The next tables present the breakdown of the environmental impacts of the PET system per life cycle stage for Norway and Sweden.

Table 22: 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, see text box in section 3.2.



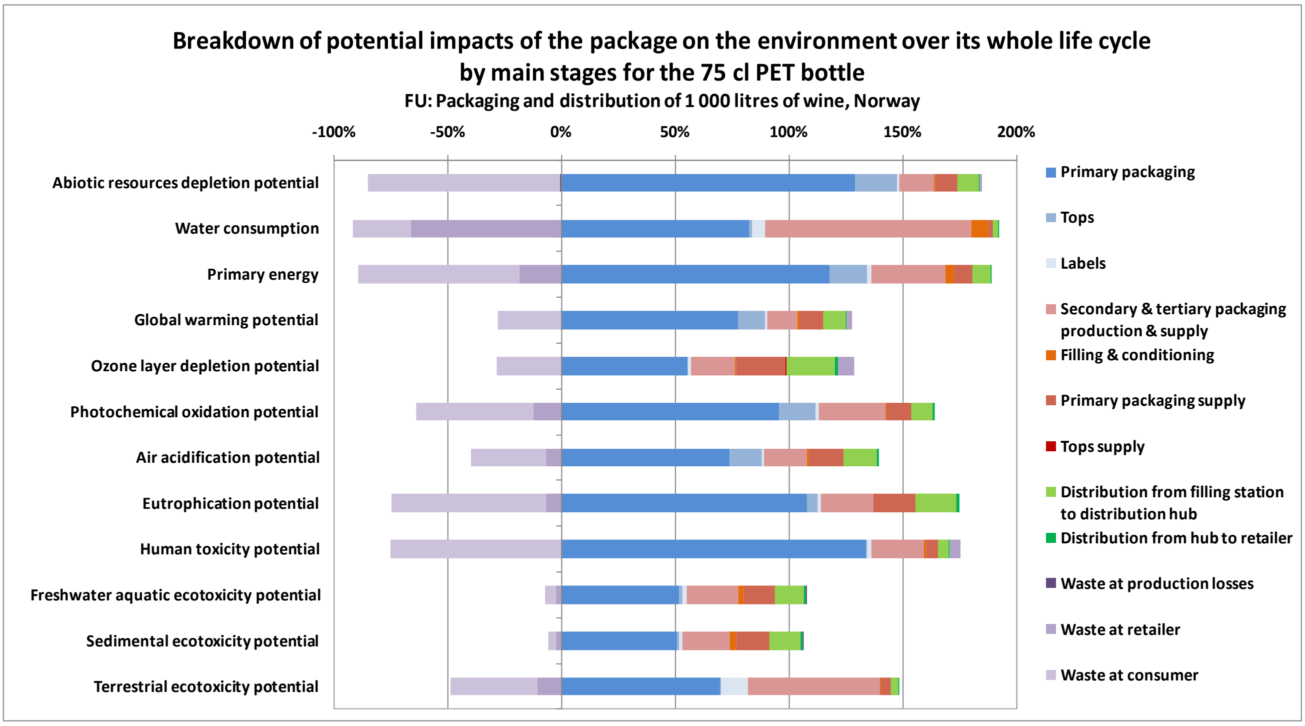
Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 8: Detailed breakdown of the environmental impacts of the 75 cl PET bottle for Sweden

Table 23: 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, see text box in section 3.2.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 9: Detailed breakdown of the environmental impacts of the 75 cl PET bottle for Norway

It can be seen that the 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 (see section 4.2.4).

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

Filling is one of the 4 life cycle "main stages"[29] and the largest contributor for water consumption.

[29] "Filling" includes: 1/primary packaging supply 2/closures supply 3/secondary & tertiary packaging production & supply 4/Filling and conditioning (see Table 20)

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.

The important contributions/emissions of the life cycle stages of the 75 cl PET bottle are presented in the next table. The table presents for each indicator and life cycle step, the flow that contributes the most to the impacts and the sub-step during which it is emitted (or consumed). The shaded life cycle stages contribute to less than 10% to the indicator in question. Environmental credits appear in green.

Table 24: Important contributions/emissions of the life cycle stages of the 75 cl PET bottle

	Packaging production	Filling	Distribution	Waste management (Sweden)	Waste management (Norway)
Abiotic resources depletion potential	Primary packaging raw materials production [Oil, crude, in ground]	Secondary packaging raw materials production [Oil, crude, in ground]		Recycling benefits Waste at consumer [Oil, crude, in ground]	Recycling benefits Waste at consumer [Oil, crude, in ground]
Water consumption	Primary packaging raw materials production [Water, river]	Secondary packaging raw materials production [Water, river]		Recycling benefits Waste at consumer [Water, river]	Recycling benefits Waste at consumer [Water, river]
Primary energy	Primary packaging raw materials production [Oil, crude, in ground]	Secondary packaging raw materials production [Energy, gross calorific value, in biomass]		Recycling benefits Waste at consumer [Oil, crude, in ground]	Recycling benefits Waste at consumer [Oil, crude, in ground]
Global warming potential	Raw materials production [Carbon dioxide, fossil]	Secondary packaging raw materials production [Carbon dioxide, fossil]	Distribution from filling station to distribution hub [Carbon dioxide, fossil]	Recycling benefits Waste at consumer [Carbon dioxide fossil]	Recycling benefits Waste at consumer [Carbon dioxide fossil]
Ozone layer depletion potential	Primary packaging raw materials production [Methane, bromochlorodifluoro-, Halon 1211]	Primary packaging supply [Methane, bromotrifluoro-, Halon 1301]	Distribution from filling station to distribution hub [Methane, bromotrifluoro-, Halon 1301]	Recycling benefits Waste at consumer [Methane, bromochlorodifluoro-, Halon 1211]	Recycling benefits Waste at consumer [Methane, bromochlorodifluoro-, Halon 1211]
Photochemical oxidation potential	Primary packaging raw materials production [Sulfur dioxide]	Secondary packaging raw materials production [Carbon monoxide, fossil]	Distribution from filling station to distribution hub [Carbon monoxide, fossil]	Recycling benefits Waste at consumer [Sulfur dioxide]	Recycling benefits Waste at consumer [Sulfur dioxide]
Air acidification potential	Primary packaging raw materials production [Sulfur dioxide]	Supply of primary packaging [Sulfur dioxide]	Distribution from filling station to distribution hub [Nitrogen oxides]	Recycling benefits Waste at consumer [Sulfur dioxide]	Recycling benefits Waste at consumer [Sulfur dioxide]
Eutrophication potential	Primary packaging raw materials production [COD, Chemical Oxygen Demand]	Secondary packaging raw materials production [COD, Chemical Oxygen Demand]	Distribution from filling station to distribution hub [Nitrogen oxides]	Recycling benefits Waste at consumer [COD, Chemical Oxygen Demand]	Recycling benefits Waste at consumer [COD, Chemical Oxygen Demand]
Human toxicity potential	Primary packaging raw materials production [Nickel]	Secondary packaging raw materials production [Nickel]		Recycling benefits Waste at consumer [Nickel]	Recycling benefits Waste at consumer [Nickel]
Freshwater aquatic ecotoxicity potential	Primary packaging raw materials production [Vanadium]	Secondary packaging raw materials production [Nickel]	Distribution from filling station to distribution hub [Barium]		
Sedimental ecotoxicity potential	Primary packaging raw materials production [Vanadium]	Supply of primary packaging [PAH, polycyclic aromatic hydrocarbons]	Distribution from filling station to distribution hub [Barium]		
Terrestrial ecotoxicity potential	Primary packaging raw materials production [Vanadium]	Secondary packaging raw materials production [Cypermethrin]		Recycling benefits Waste at consumer [Vanadium]	Recycling benefits Waste at consumer [Vanadium]

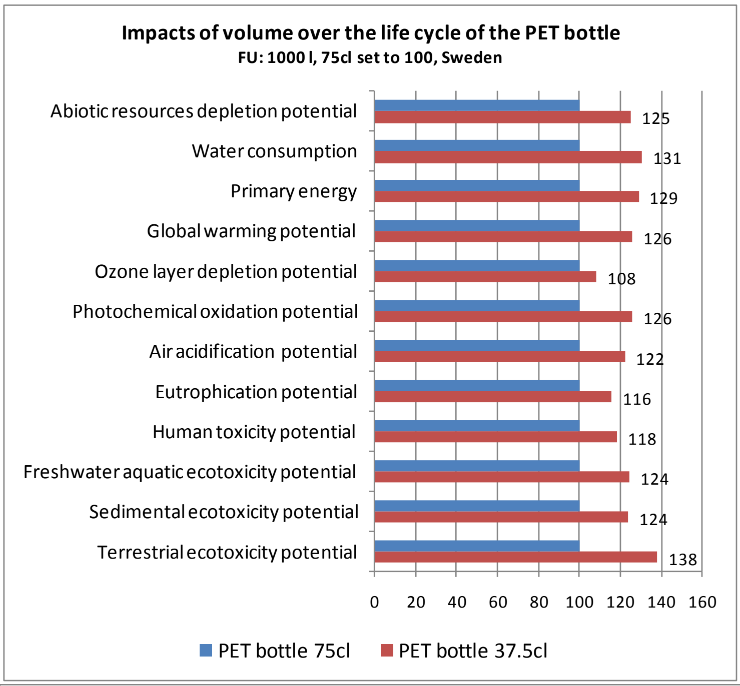
Most of the environmental impacts of the PET system are explained by the impacts associated with the production of the raw materials, be it for primary or secondary packaging.

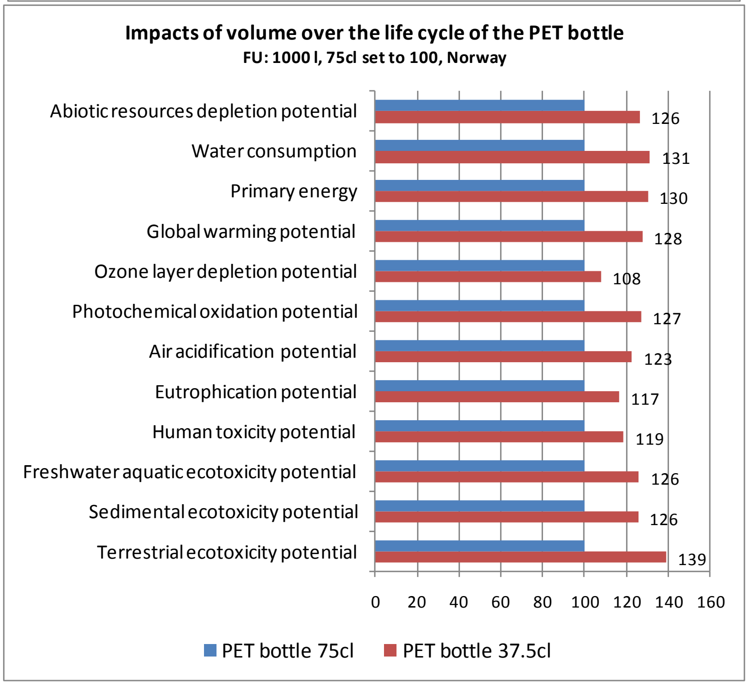
Concerning plastic compounds, whose production is energy intensive and tightly linked to the life cycles of fossil fuels; important contributions are observed with respect to indicators such as global warming, abiotic depletion, photochemical oxidation and air acidification due to combustion emissions. The production of secondary packaging (cardboard) also appears as a significant source of impact, explaining most of the contribution related to the filling stage.

The contributions of the distribution phase on most indicators are explained by emissions related to fuel consumption, such as nitrogen oxides (acidification, eutrophication) or trace metals that are associated to important characterisation factors in toxicity related indicators.

As for the end-of-life phase, the recycling benefits are significant for most of the indicators. Logically, the main avoided flows are the ones found being the most impacting during the production phase.

5.2.3. COMPARISON OF THE PACKAGING FORMAT





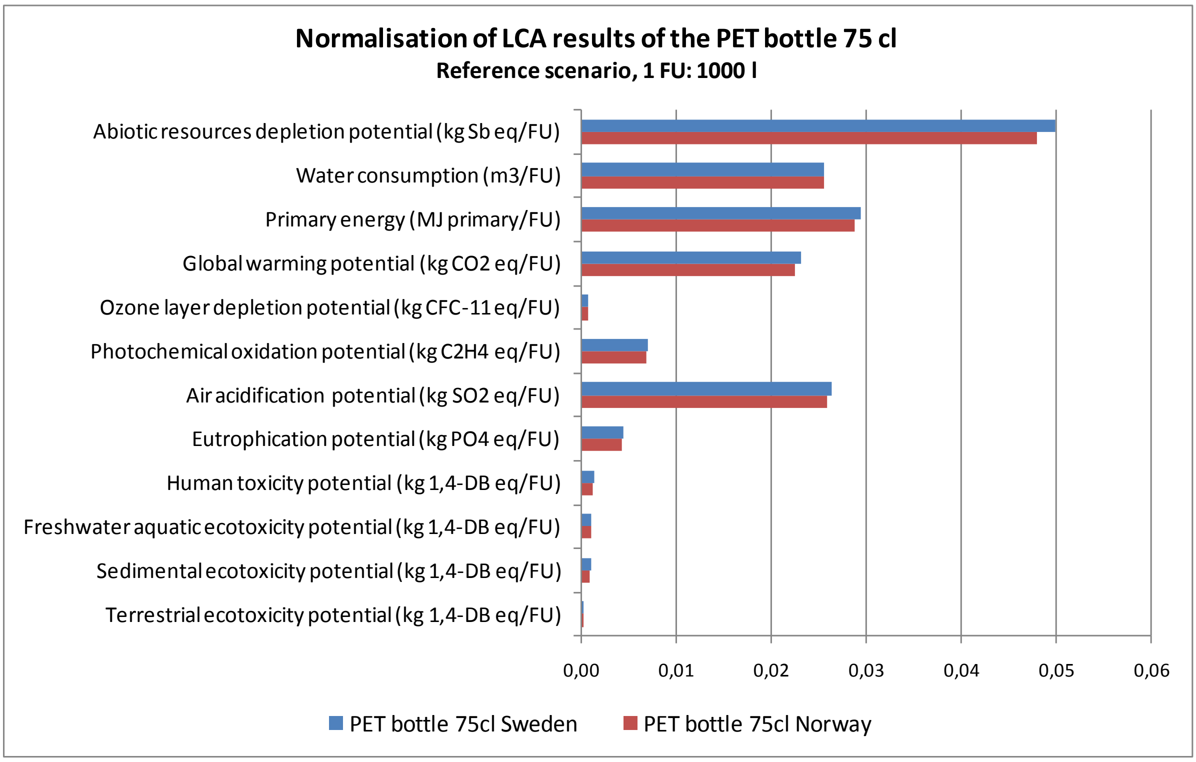
Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 10: Impact of the packaging format on the life cycle of the PET bottle in Sweden and Norway (FU: 1000 l, 75 cl set to 100)

Larger formats are less impacting than smaller ones. Indeed, in order to deliver 1000 l of product, less material is initially required when using the 75 cl format compared to the 37.5 cl one, this having an effect on all life cycle stages. The 37.5 cl bottle is more impacting than the 75 cl format from 8% to 39%.

5.2.4. Normalisation

To facilitate the comprehension of the significance of the LCA results for the 12 indicators, the total impact value for each indicator are normalised by dividing it by the standardisation value (see section 3.3). The Figure 11 presents the impacts of 1 functional unit (i.e. 1000 l of wine) normalised by the impacts generated by one European inhabitant over 1 year.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 11: Normalisation of LCA results for the 75 cl PET bottle

How to interpret this figure?

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 PET bottles of 75 cl are equivalent to the total impacts on abiotic depletion of about 5 European inhabitants over 1 year.

According to these results, one can identify:

- 5 major impacts (ratio > 0.02): abiotic depletion, water consumption, primary energy consumption, global warming potential and air acidification,
- 2 medium impacts (ratio 0.004–0.007): photochemical oxidation and eutrophication,
- 5 minor impacts (ratio ≤ 0.001): ozone layer depletion, human toxicity, freshwater aquatic ecotoxicity, sedimental ecotoxicity and terrestrial ecotoxicity.

It should be noted that the classification into major/medium/minor impacts is relative to the results for the other impact indicators in this study. They do not indicate the absolute significance of the impacts of the functional unit.

5.2.5. SENSITIVITY ANALYSIS

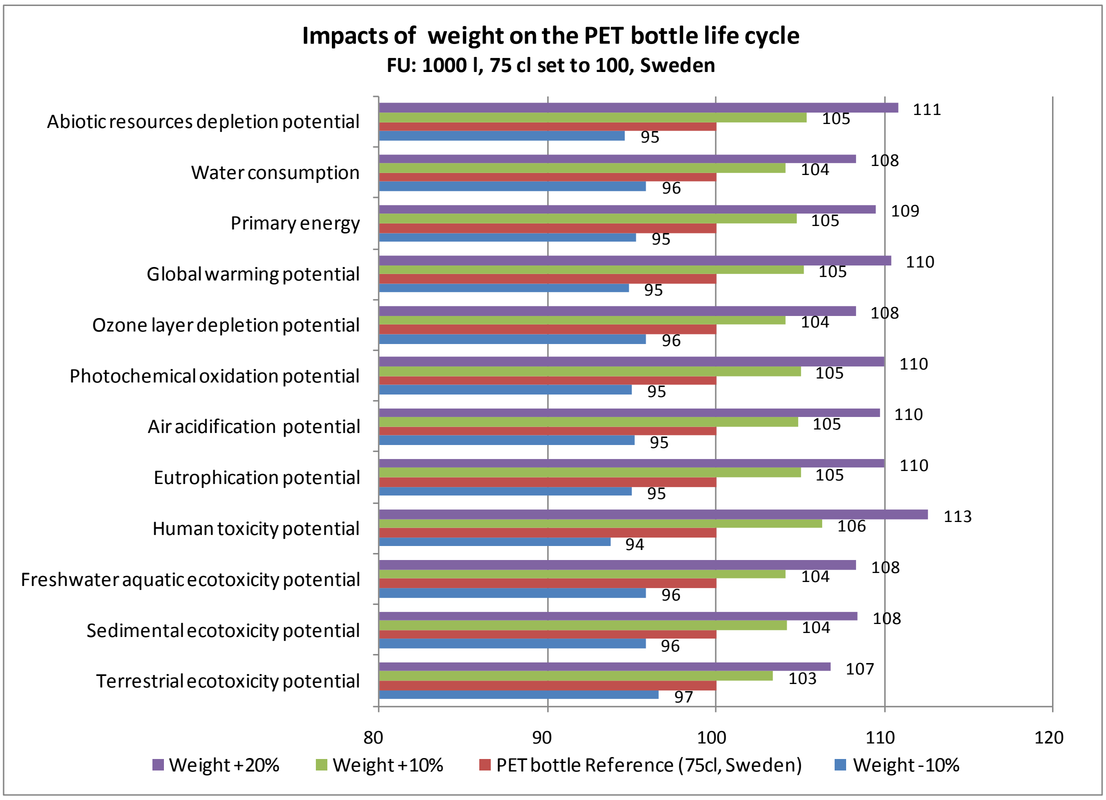
Sweden has been chosen as the reference scenario in order to perform the sensitivity analysis.

5.2.5.1. Weight sensitivity

The main parameters of this analysis are summarised in the next table.

Table 25: Parameters for the sensitivity analysis

	Reference scenario	Weight-10%	Weight+10%	Weight+20%
Weight of the primary packaging (without closure)	47.7	42.9g	52.5g	57.2g



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 12: Influence of the weight of the primary packaging on the PET bottle life cycle (FU: 1000 l, 75 cl bottle consumed in Sweden set as the reference scenario)

For all indicators, heavier packaging is logically associated with larger environmental impacts.

5.2.5.2. Distribution distance sensitivity

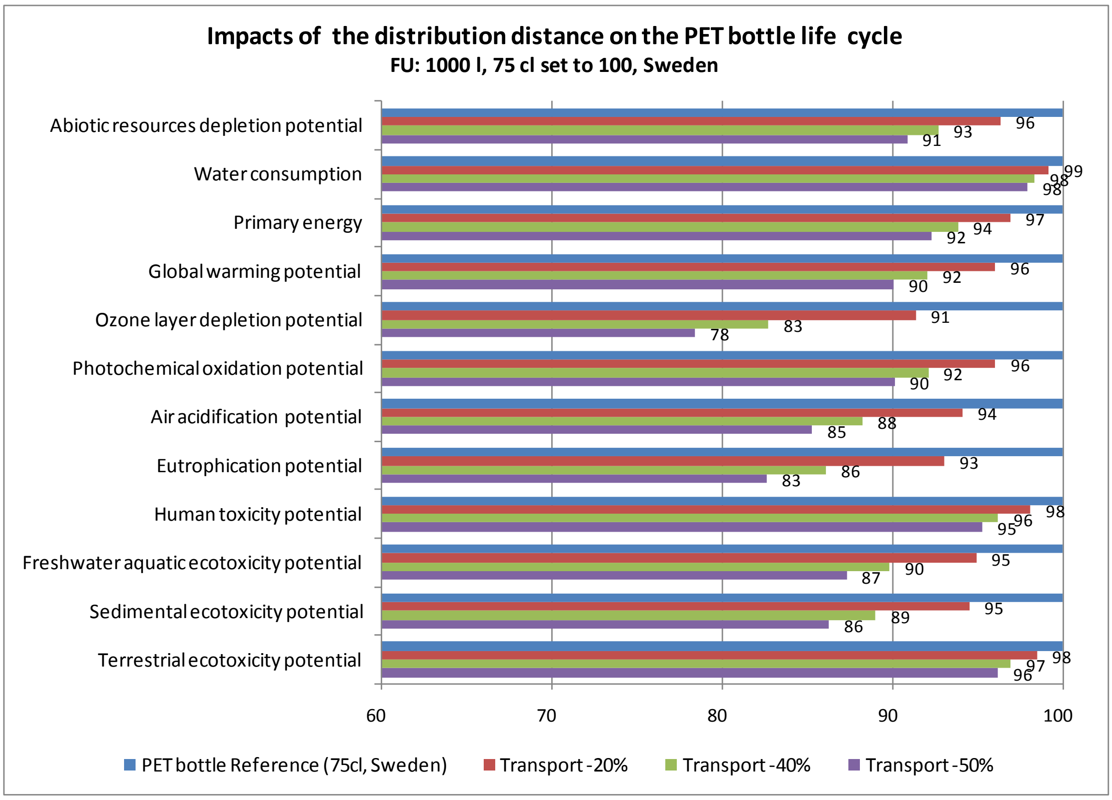
The influence of the distance between the packaging production sites, the filling station, the distribution hub and the retailer is investigated in this section.

The main parameters of this analysis are summarised in the next table.

Table 26: Parameters for the sensitivity analysis

	Reference scenario	Transport -20%	Transport -40%	Transport -50%
Distance for supply of primary packaging (without closure) up to the filling station	800 km	640 km	480 km	400 km
Distance from the filling station to the distribution hub	2411 km	1928.8 km	1446.6 km	1205.5 km
Distance from the distribution hub to retailer	150 km	120 km	90 km	75 km

Next figure presents the variations observed for the reference scenario, when the distribution distance is reduced by 20%, 40% and 50%.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 13: Influence of length of the supply chain on the PET bottle life cycle (FU: 1000 l, 75 cl bottle consumed in Sweden set as the reference scenario)

Eutrophication and ozone layer depletion are the two indicators showing the highest sensitivity to the transport distance, with reduction by 17-22% for a 50% reduction in the transport distance. As analysed in section 5.2.2, this effect is closely related to reduction in halon 1301 used in fire extinction equipment linked to the production of fuel and thus indirectly associated to the production of fuel used for trucks and nitrogen oxides emissions which are associated to the combustion during fuel consumption.

Freshwater aquatic ecotoxicity, sedimental ecotoxicity and air acidification are quite sensitive to the transport distance, being reduced by 13% to 14% for a 50% decrease in the length of the supply chain. Concerning ecotoxicity indicators, reduction in trace metals emissions associated with fuel consumption explain the observed variations. For air acidification, nitrogen is the key elementary flow associated with the fuel life cycle that explains the observed patterns.

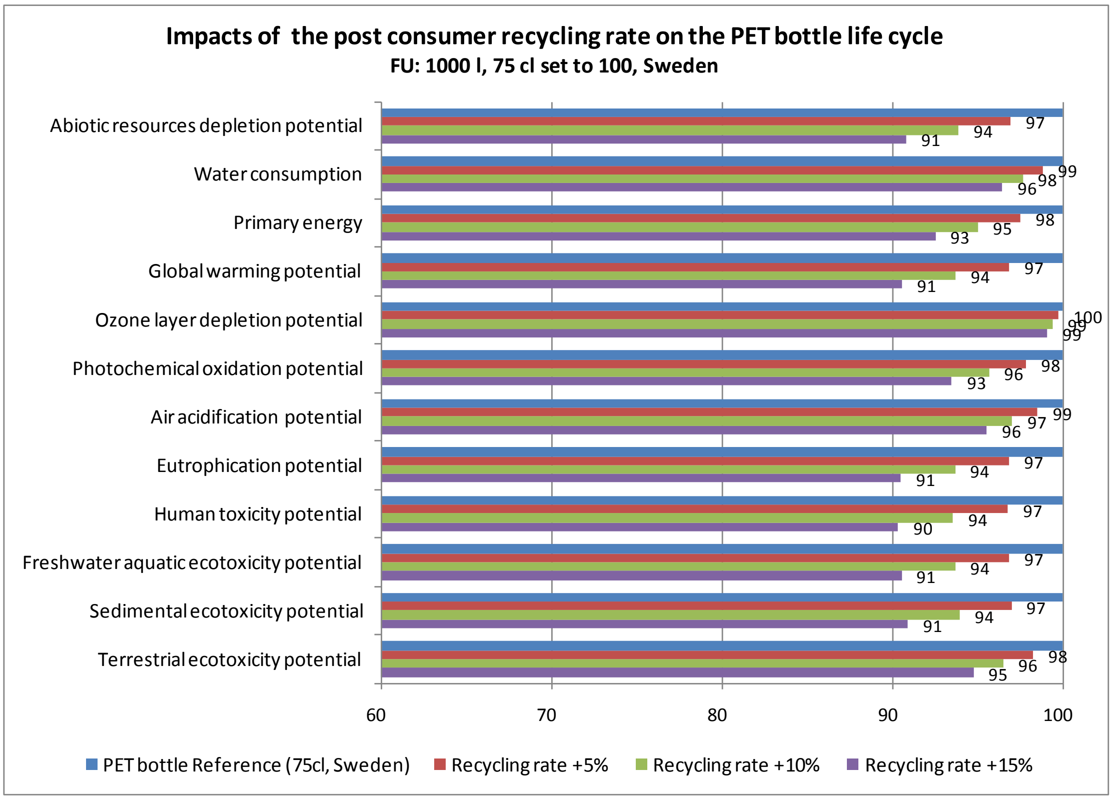
Apart from water consumption and terrestrial ecotoxicity, all the other indicators also show sensitivity with reduction by 8-10% for a 50% reduction in the transport distance.

5.2.5.3. Post consumer recycling rate sensitivity

The influence of the post consumer recycling rate on the PET bottle life cycle is presented hereafter for increase in the recycling rate of 5, 10 and 15%.

Table 27: Parameters for the sensitivity analysis

	Reference scenario	Recycling rate+5%	Recycling rate+10%	Recycling rate+15%
Recycling rate	84%	88%	92%	97%



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 14: Influence of the post consumer recycling rate on the PET bottle life cycle (FU: 1000 l, 75 cl bottle consumed in Sweden set as the reference scenario)

As the post consumer recycling rate increase, increased environmental benefits are observed. However, water consumption and ozone layer depletion show limited variation to the recycling rate, even for a 15% increased performance.

5.3 GLASS BOTTLE

5.3.1. Description of the system

The following scheme represents the different steps of the life cycle of the glass bottles considered in this study.

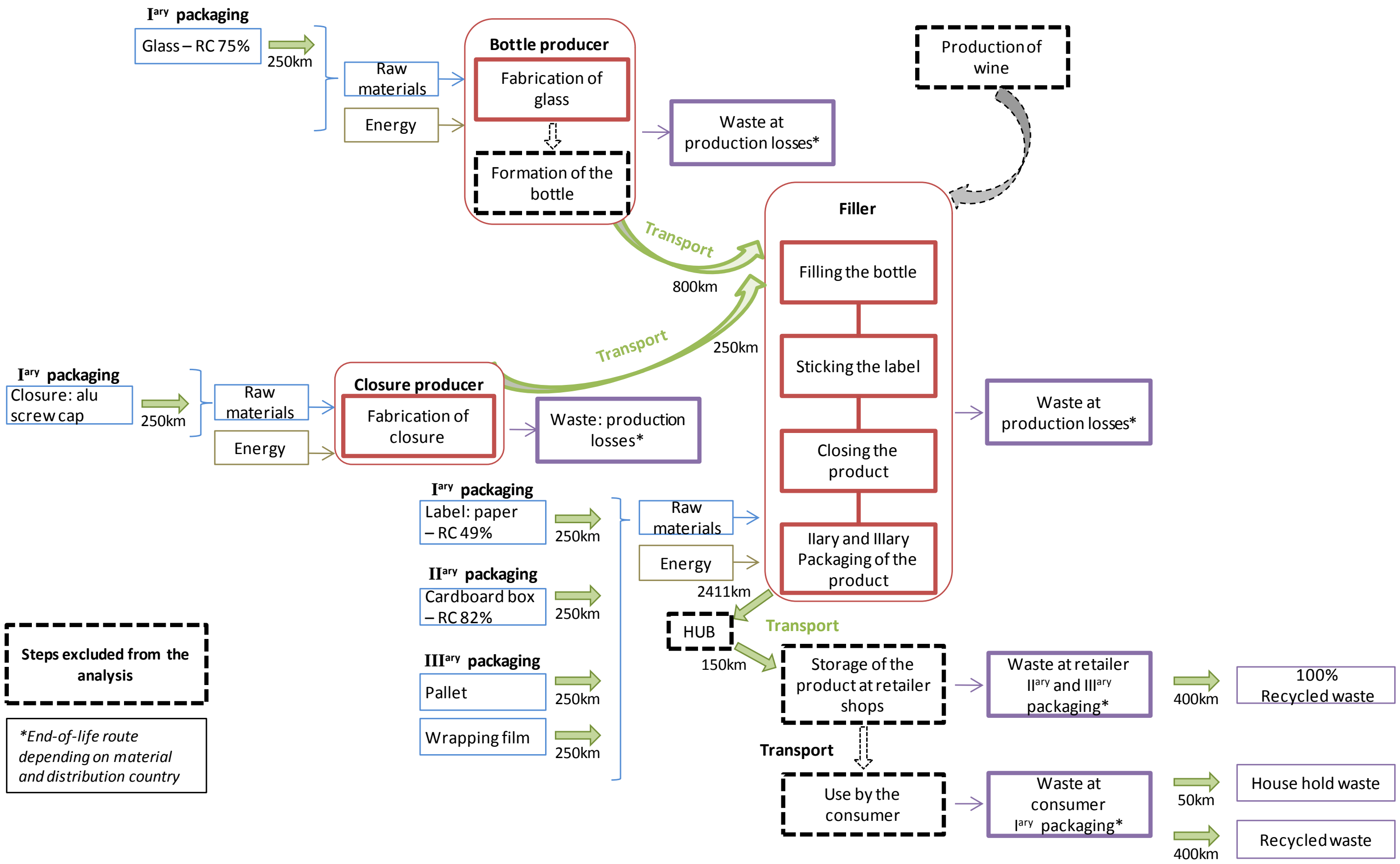


Figure 15: Steps of the life cycle of the glass bottles considered in this study

Table 28: Glass bottle — volumes studied

	Unit	Glass bottle 75 cl	Glass bottle 37.5 cl
Volume	[cl]	**75**	37.5
Total weight	[g]	**479.5**	309.3

5.3.2. Results of the reference scenario

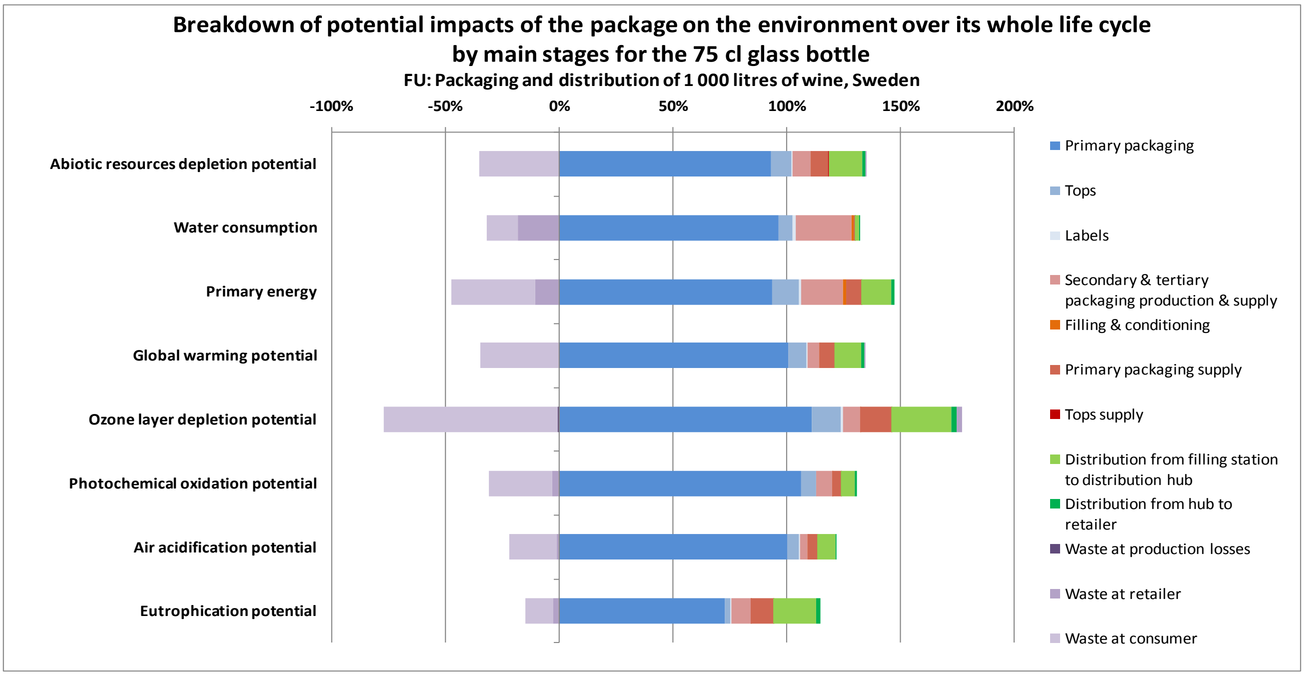
The 75 cl format for the glass bottle has been chosen as the reference. The next tables present the breakdown of the environmental impacts of the glass bottle packaging system per life cycle phase for bottles consumed in Norway and Sweden.

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 in this section.

Table 29: 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, see text box in section 3.2.



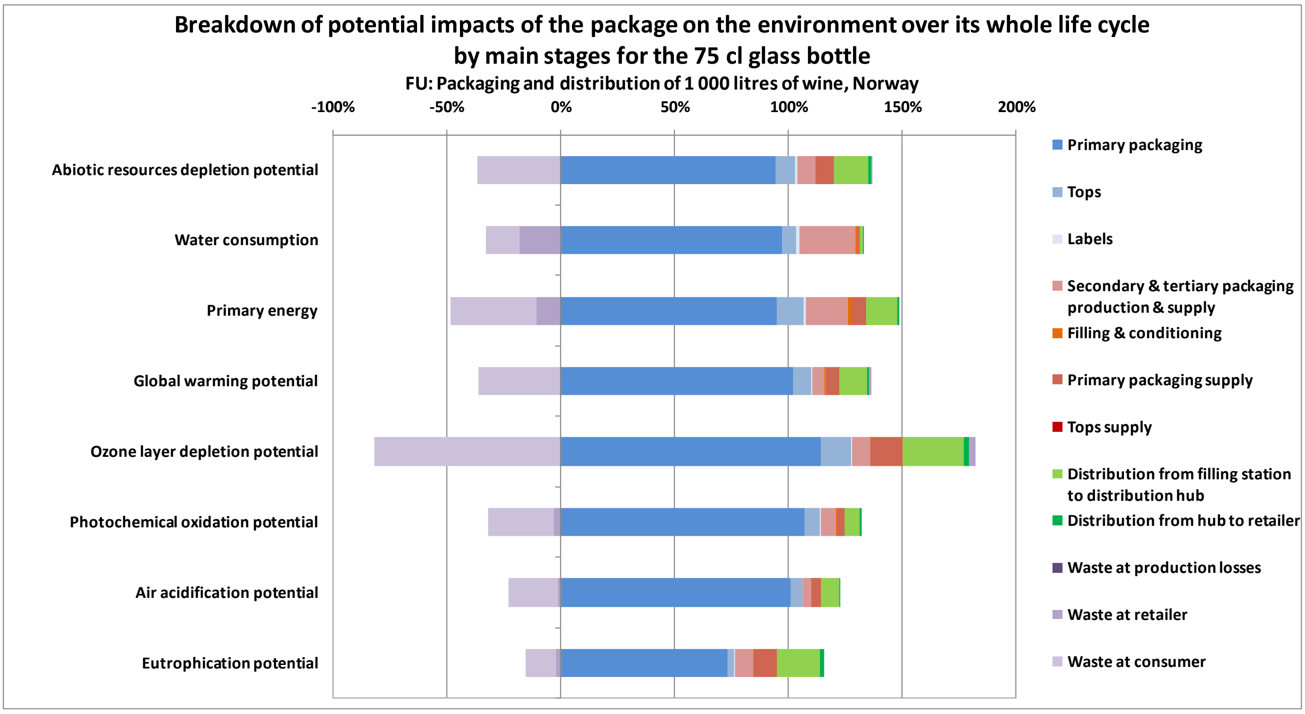
Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 16: Detailed breakdown of the environmental impacts of the 75 cl glass bottle for Sweden

Table 30: 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, see text box in section 3.2.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 17: Detailed breakdown of the environmental impacts of the 75 cl glass bottle for Norway

The distribution of the environmental impacts over the life cycle of the glass bottle shows similar trends in Norway and Sweden. Indeed, they only differ for the end-of-life phase, where disposal routes are slightly different (see section 4.2.4).

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.

The important contributions/emissions of the life cycle stages of the 75 cl glass bottles are presented in the next table. The table presents for each indicator and life cycle step, the flow that contributes the most to the impacts and the sub-step during which it is emitted (or consumed). The shaded life cycle stages contribute to less than 10% to the indicator in question.

Table 31: Important contributions/emissions of the life cycle stages of the 75 cl glass bottle

	Packaging production	Filling	Distribution	Waste management (Sweden)	Waste management (Norway)
Abiotic resources depletion potential	Primary packaging raw materials production [Oil, crude, in ground]	Secondary packaging raw materials production [Oil, crude, in ground]	Distribution from filling station to distribution hub [Oil crude, in ground]	Recycling benefits Waste at consumer [Coal, hard, unspecified, in ground]	Recycling benefits Waste at consumer [Coal, hard, unspecified, in ground]
Water consumption	Primary packaging raw materials production [Water, unspecified natural origin]	Secondary packaging raw materials production [Water, river]		Recycling benefits Waste at consumer [Water, river]	Recycling benefits Waste at consumer [Water, river]
Primary energy	Primary packaging raw materials production [Oil, crude, in ground]	Primary packaging supply [Oil, crude in ground]	Distribution from filling station to distribution hub [Oil crude, in ground]	Recycling benefits Waste at consumer [Oil crude, in ground]	Recycling benefits Waste at consumer [Oil crude, in ground]
Global warming potential	Primary packaging raw materials production [Carbon dioxide, fossil]	Primary packaging supply [Carbon dioxide, fossil]	Distribution from filling station to distribution hub [Carbon dioxide, fossil]	Recycling benefits Waste at consumer [Carbon dioxide, fossil]	Recycling benefits Waste at consumer [Carbon dioxide, fossil]
Ozone layer depletion potential	Primary packaging raw materials production [Methane, bromotrifluoro-, Halon 1301]	Secondary packaging raw materials production [Methane, bromotrifluoro-, Halon 1301]	Distribution from filling station to distribution hub [Methane, bromotrifluoro-, Halon 1301]	Recycling benefits Waste at consumer [Methane, bromotrifluoro-, Halon 1301]	Recycling benefits Waste at consumer [Methane, bromotrifluoro-, Halon 1301]
Photochemical oxidation potential	Primary packaging raw materials production [Sulfure dioxide]	Secondary packaging raw materials production [Carbon monoxide, fossil]	Distribution from filling station to distribution hub [Carbon monoxide, fossil]	Recycling benefits Waste at consumer [Sulfure dioxide]	Recycling benefits Waste at consumer [Sulfure dioxide]
Air acidification potential	Primary packaging raw materials production [Sulfure dioxide]	Secondary packaging raw materials production [Sulfur dioxide]	Distribution from filling station to distribution hub [Nitrogen oxides]	Recycling benefits Waste at consumer [Sulfur dioxide]	Recycling benefits Waste at consumer [Sulfur dioxide]
Eutrophication potential	Primary packaging raw materials production [Nitrogen oxides]	Secondary packaging raw materials production [Nitrogen oxides]	Distribution from filling station to distribution hub [Nitrogen dioxide]	Recycling benefits Waste at consumer [Nitrogen oxides]	Recycling benefits Waste at consumer [Nitrogen oxides]

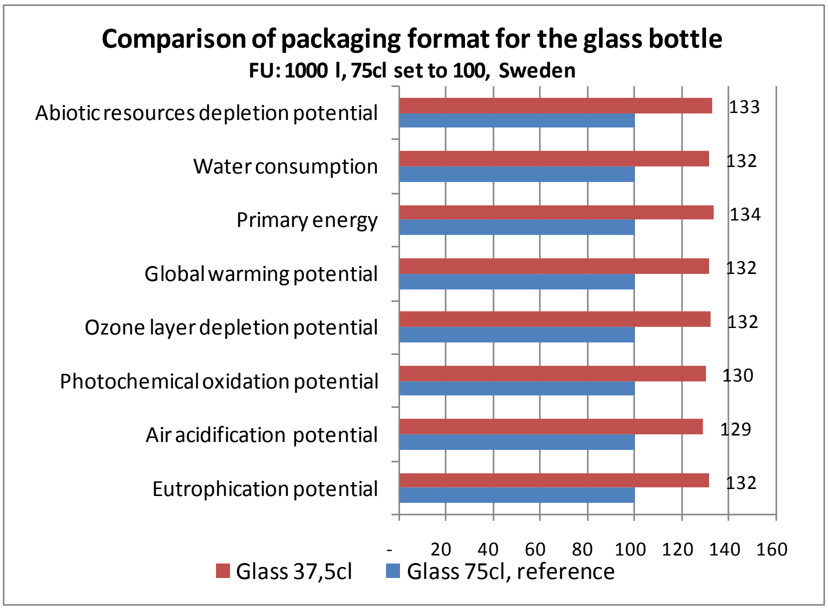
Most of the environmental impacts of the glass system are explained by the impacts associated with the production of the raw materials, be it for primary or secondary packaging.

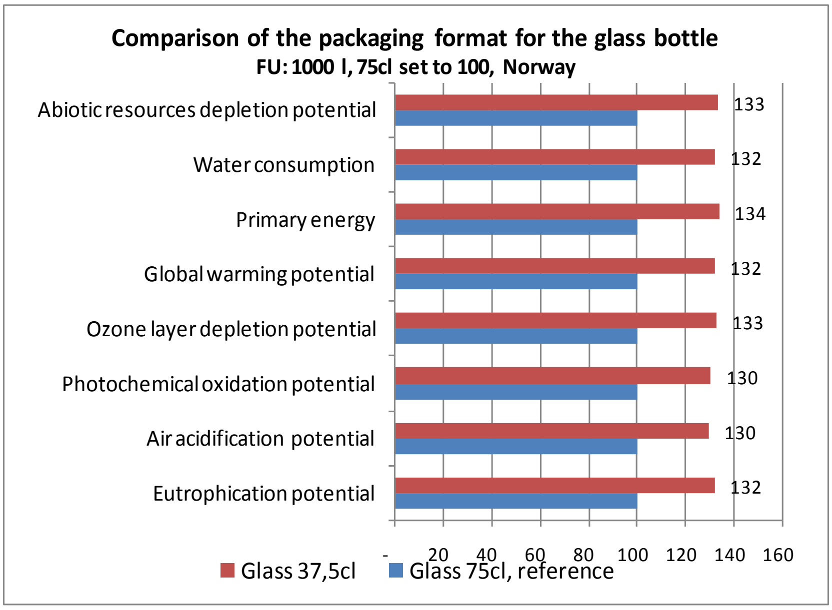
Energy consumption required to produce glass bottles is the main contributor to the environmental indicators. Important contributions are observed with respect to indicators such as global warming, abiotic depletion, photochemical oxidation and air acidification due to combustion emissions.

The contributions of the distribution phase on most indicators are explained by emissions related to fuel consumption, such as nitrogen oxides (air acidification, eutrophication).

As for the end-of-life of the glass bottle, recycling provides important benefits. Indeed, compared to melting a batch of sand, soda ash and limestone, using cullets for producing recycled glass requires less energy, and reduces carbon dioxide emissions as the reduction of the batch is an important CO_2 emitting stage.

5.3.3. COMPARISON OF THE PACKAGING FORMAT



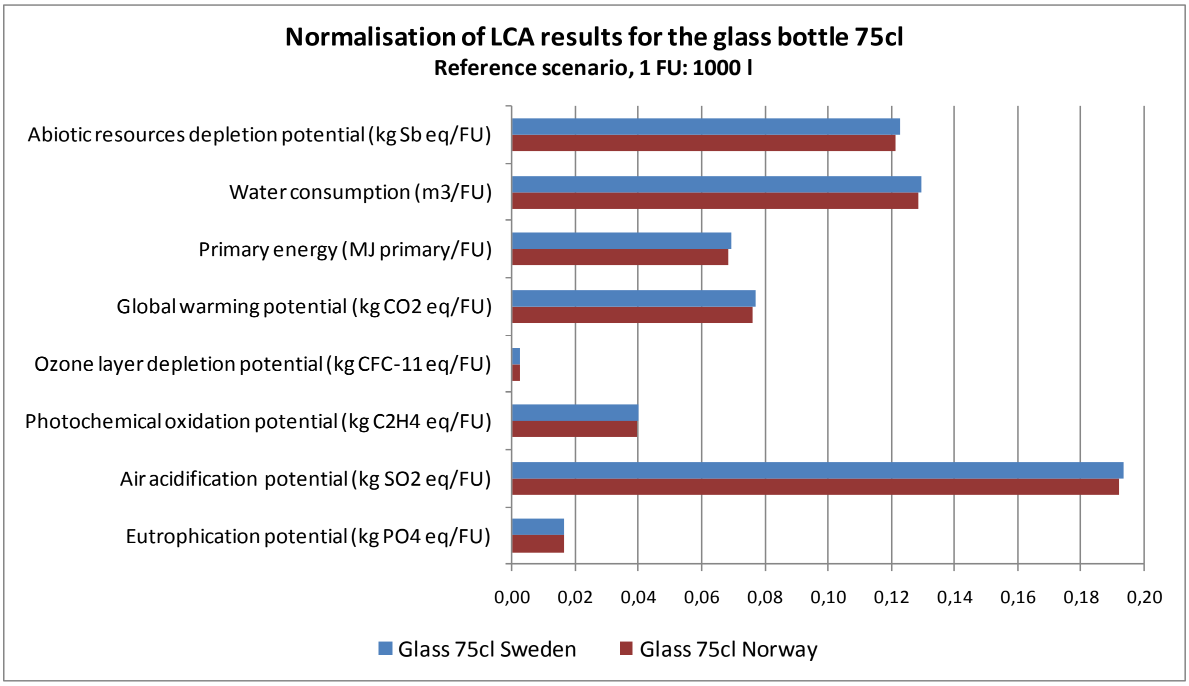


Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 18: Impact of the packaging format on the life cycle of the glass bottle in Sweden and Norway (FU: 1000 l, 75 cl set to 100)

Larger volumes are associated with smaller environmental impacts as less packaging are required to provide the same service (providing 1000 l of wine). Be it in Norway or Sweden, the half glass bottle format is approximately 30% more impacting that the 75 cl format for all indicators.

5.3.4. NORMALISATION



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 19: Normalisation of LCA results for the 75 cl glass bottle

How to interpret this figure?

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 glass bottles of 75 cl are equivalent to the total impacts on abiotic depletion of about 12 European inhabitants over 1 year.

According to these results, one can identify:

- 5 major impacts (ratio > 0.06): abiotic depletion, water consumption, primary energy consumption, global warming potential and air acidification,
- 2 medium impacts (ratio 0.01–0.04): photochemical oxidation and eutrophication,
- 1 minor impact (ratio <0.01): ozone layer depletion.

5.3.5. SENSITIVITY ANALYSIS

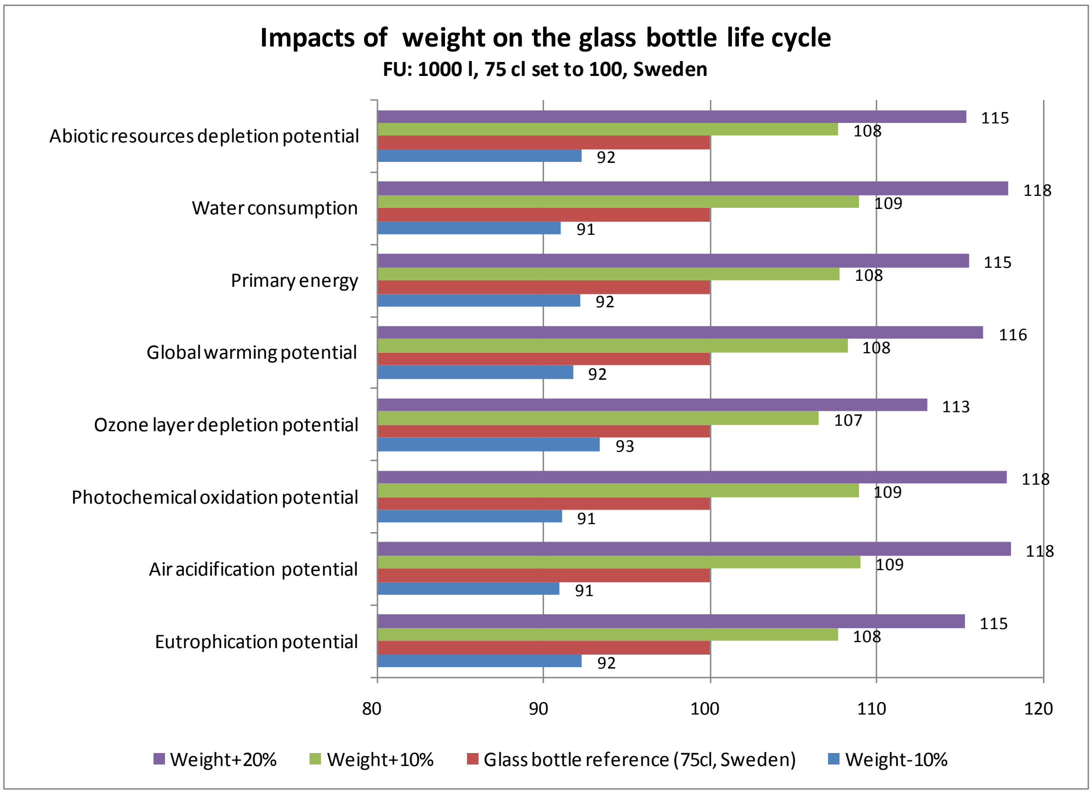
Sweden has been chosen as the reference scenario in order to perform the sensitivity analysis.

5.3.5.1. Weight sensitivity

The main parameters of this analysis are summarised in the next table.

Table 32: Parameters for the sensitivity analysis

	Reference scenario	Weight-10%	Weight+10%	Weight+20%
Weight of the primary packaging (without closure)	479.5g	432.3g	526.7g	573.9g



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 20: Influence of the weight of the primary packaging on the glass bottle life cycle (FU: 1000 l, 75 cl bottle consumed in Sweden set as the reference scenario)

This sensitivity analysis confirms the important contribution of the impacts of the production of the primary packaging on the glass bottle life cycle. Almost all indicators show a variation close to a 1 to 1 ratio with the packaging weight, a 10% increase in the weight of the bottle being associated with an increase of almost 10% for all indicators.

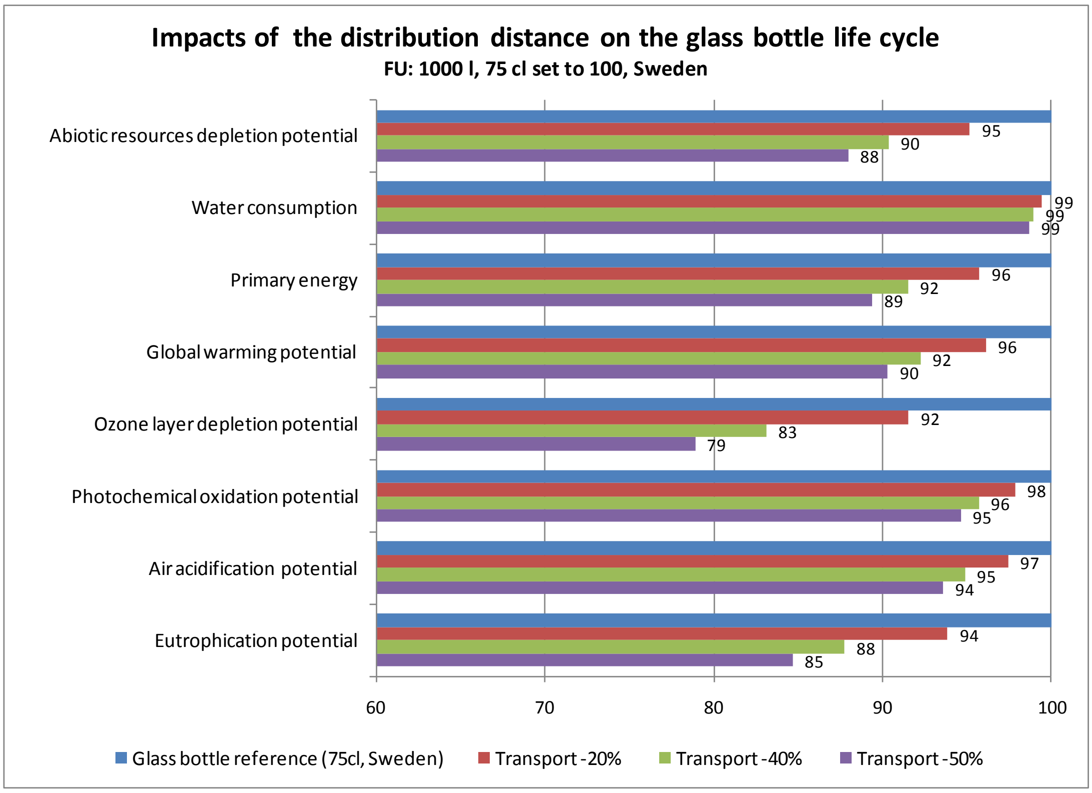
5.3.5.2. Distribution distance sensitivity

The influence of the distance between the packaging production sites, the filling station, the distribution hub and the retailer is investigated in this section. Parameters are summarised hereafter:

Table 33: Parameters for the sensitivity analysis

	Reference scenario	Transport -20%	Transport -40%	Transport -50%
Distance for supply of primary packaging (without closure) up to the filling station	800 km	640 km	4800 km	400 km
Distance from the filling station to the distribution hub	2411 km	1928.8 km	1446.6 km	1205.5 km
Distance from the distribution hub to retailer	150 km	120 km	90 km	75 km

The next figure presents the variations observed for the reference scenario, when the distribution distance is reduced by 20%, 40% and 50%.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 21: Influence of length of the supply chain on the glass bottle life cycle (FU: 1000 l, 75 cl bottle consumed in Sweden set as the reference scenario)

Ozone layer depletion appears as the indicator showing the highest sensitivity to the transport distance, with reduction by 21% for a 50% reduction in the transport distance. As analysed in section 5.3.2, this effect is closely related to reduction in halon 1301 used in fire extinction equipment linked to the production of fuel and thus indirectly associated to the production of fuel used for trucks and nitrogen oxides emissions which are associated to the combustion during fuel consumption.

Variation in fuel consumption also explains the variability observed for indicators related to resource depletion (abiotic depletion, primary energy).

5.3.5.3. Post consumer recycling rate sensitivity

The post consumer recycling rate on the glass bottle is very high in both Norway and Sweden with 98% and 94% respectively. Therefore, it was not considered as relevant to investigate the effect of an increase in the recycling rate.

5.4 BAG IN BOX

5.4.1. DESCRIPTION OF THE SYSTEM

The following scheme represents the different steps of the life cycle of the Bag in Boxes considered in this study.

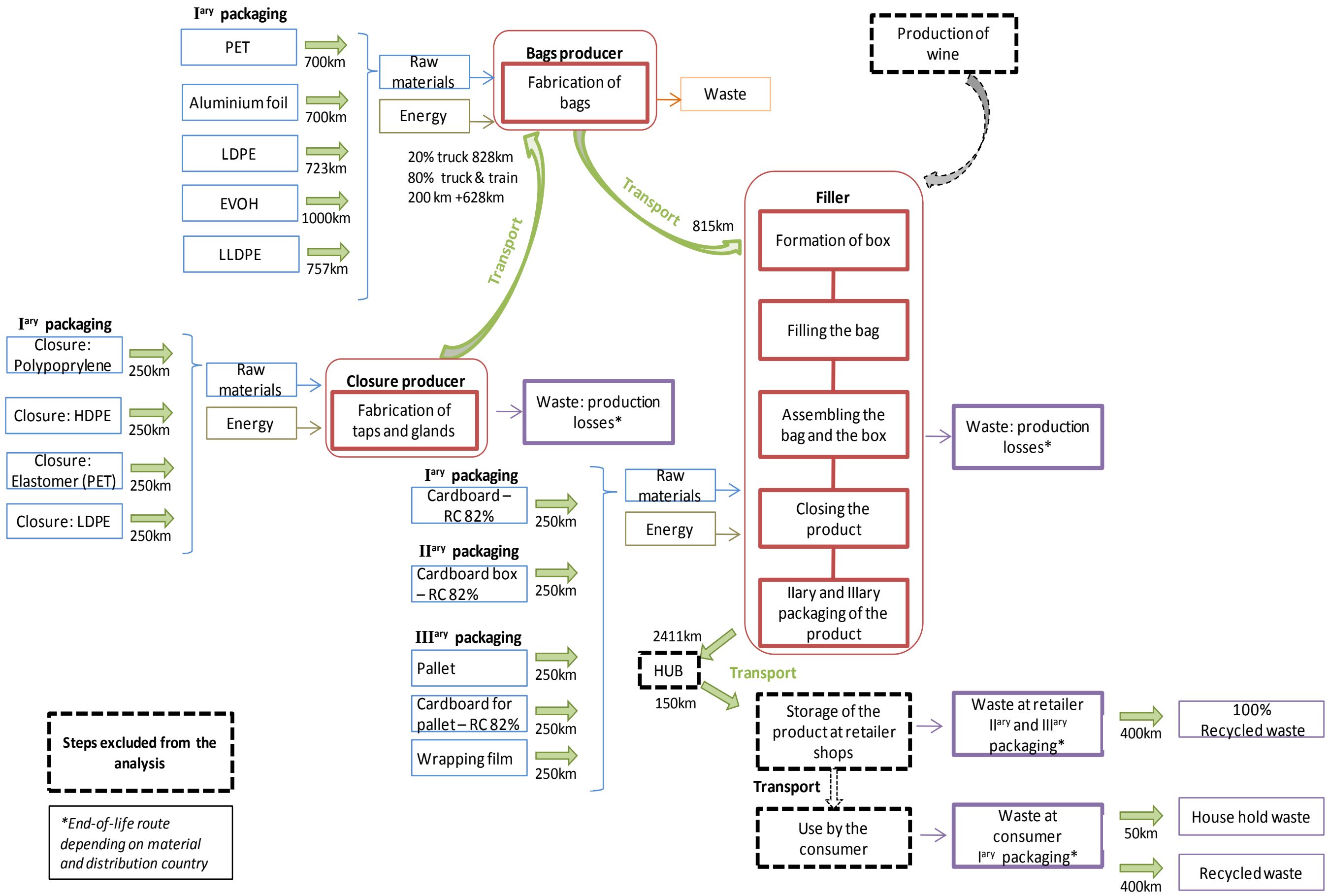


Figure 22: Steps of the life cycle of the Bag in Boxes considered in this study

Table 34: Bag in Box — volumes studied

	Unit	BiB 1 .5 l	BiB 2 l	BiB 3 l	BiB 5 l	BiB 10 l
Volume	[cl]	150	200	**300**	500	1000
Total weight	[g]	117	142	**179**	233	500

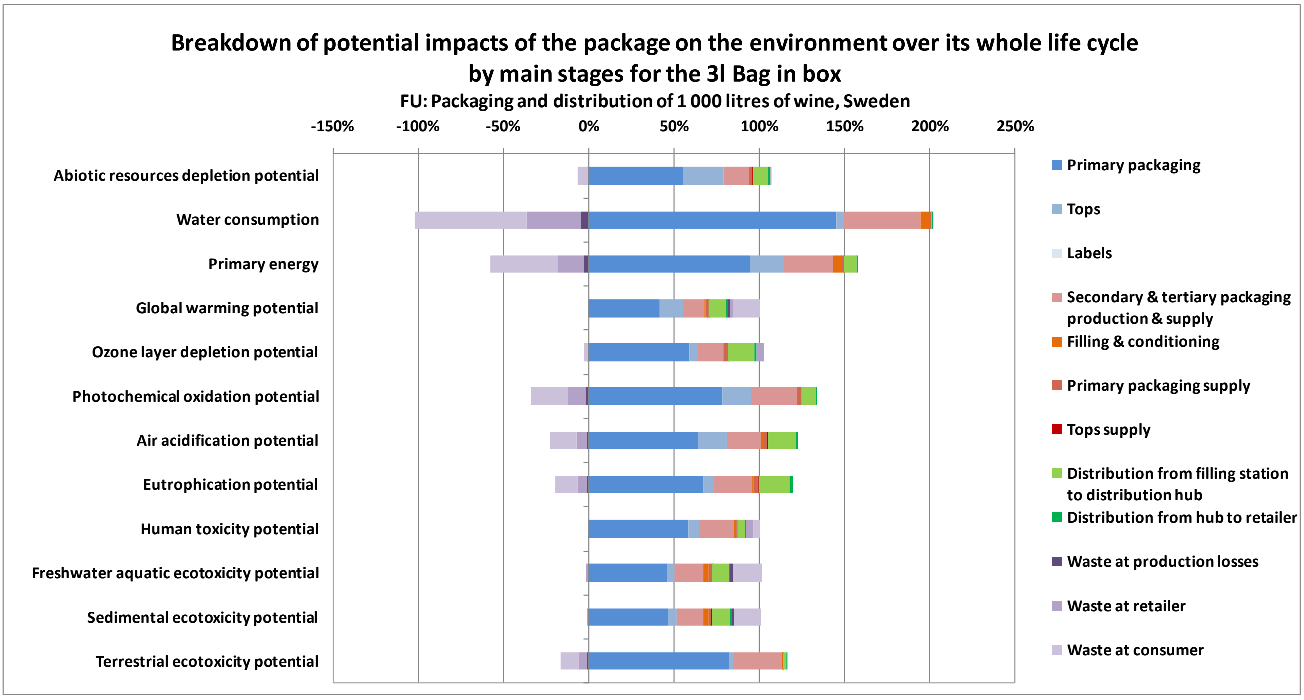
5.4.2. Results of the reference scenario

The 3 l Bag in Box (BiB) has been chosen in the reference scenario. The next tables present the breakdown of the environmental impacts of the BiB system per life cycle phase for Norway and Sweden.

Table 35: 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, see text box in section 3.2.



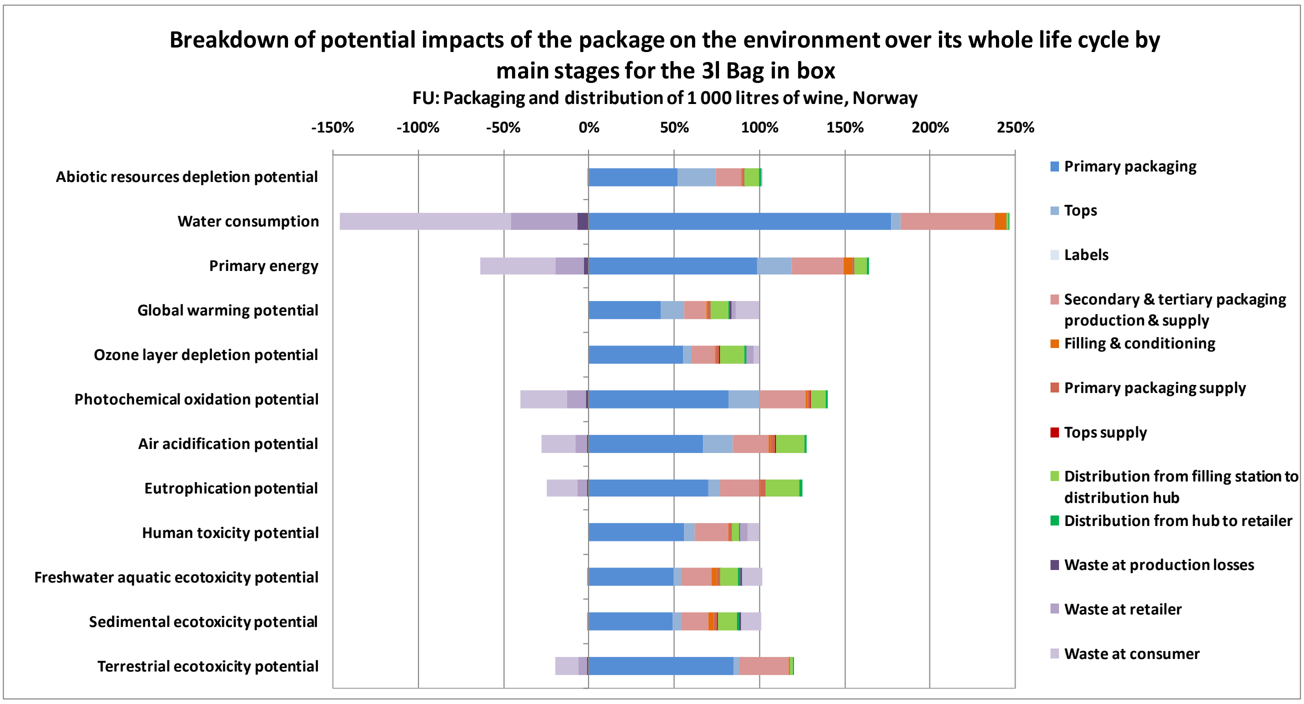
Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 23: Detailed breakdown of the environmental impacts of the 3 l Bag in Box for Sweden

Table 36: 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, see text box in section 3.2.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 24: Detailed breakdown of the environmental impacts of the 3 l Bag in Box for Norway

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 reminder, at end-of-life, the box is recycled considering the recycling rate of the country of disposal whereas the bag follows the same route than municipal solid waste. Norway and Sweden have distinct recycling rate for cardboard (95% and 74% respectively). When not recycled incineration of cardboard with energy recovery is a preferred option in Sweden. This explains why differences in environmental benefits are observed if comparing the Norwegian and Swedish scenarios.

The important contributions/emissions of the life cycle stages of the 3 l Bag in Box are presented in the next table. This table presents for each indicator and life cycle step, the flow that contributes the most to the impacts and the sub-step during which it is emitted (or consumed). The shaded life cycle stages contribute to less than 10% to the indicator in question. Environmental credits appear in green.

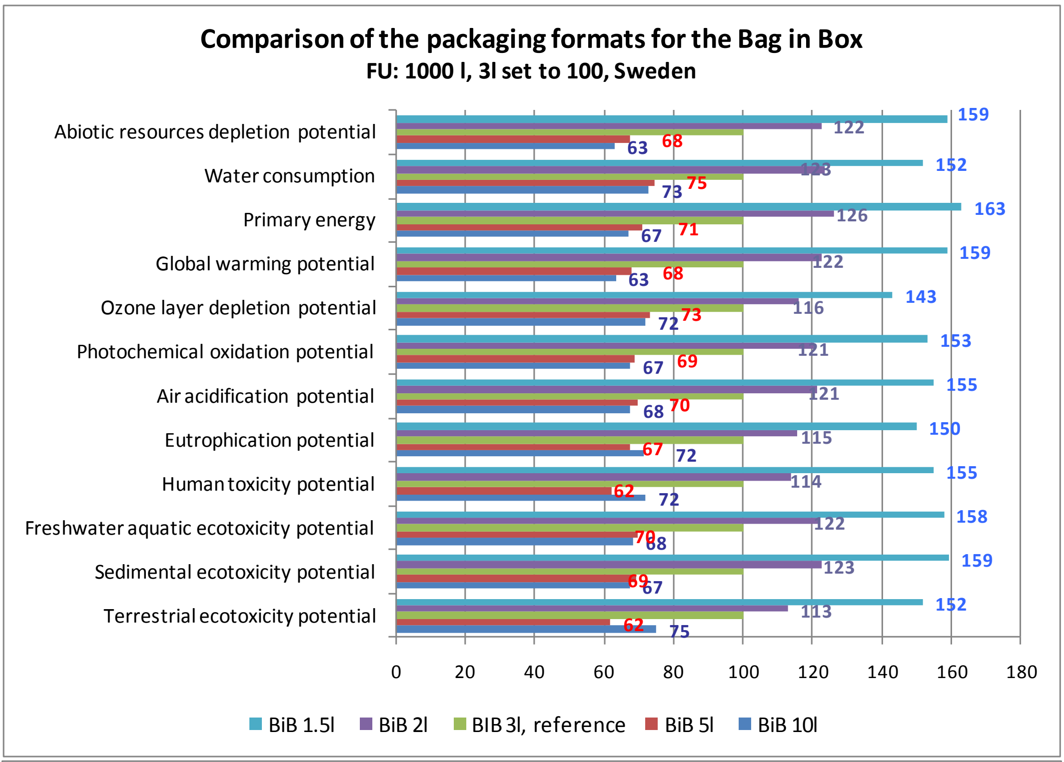
Table 37: Important contributions/emissions of the life cycle stages of the 3 l Bag in Box

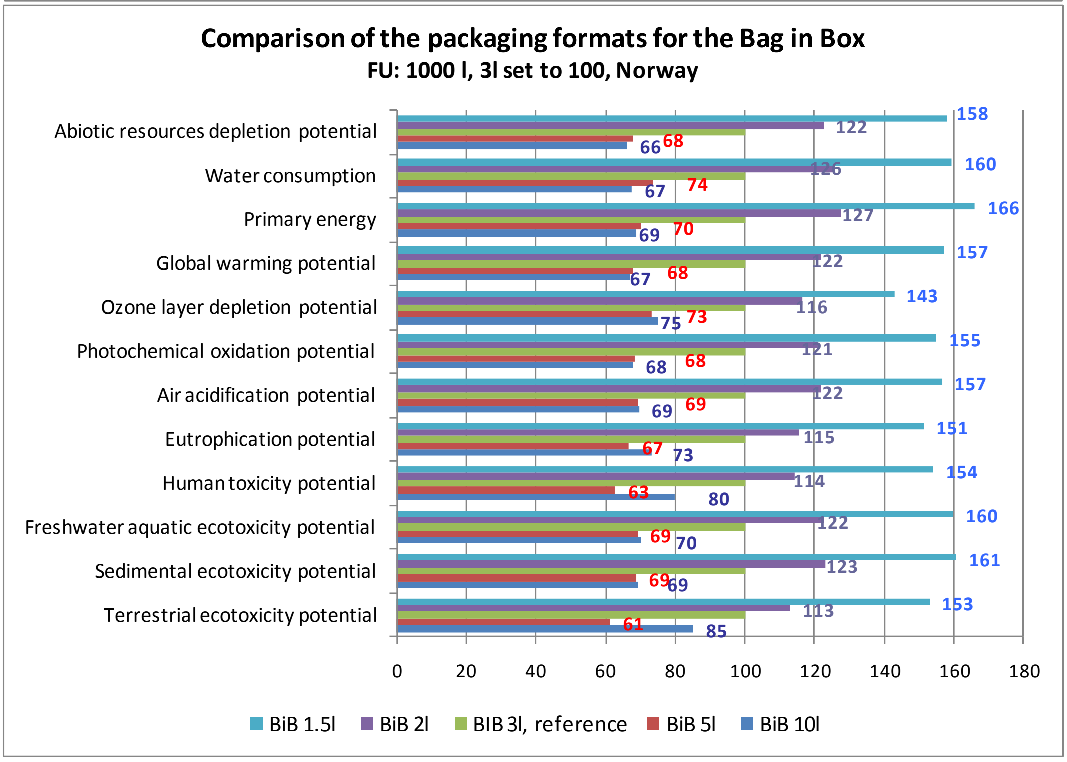
	Packaging production	Filling	Distribution	Waste management (Sweden)	Waste management (Norway)
Abiotic resources depletion potential	Primary packaging raw materials production (cardboard) [Oil, crude, in ground]	Secondary packaging raw materials production [Oil, crude, in ground]	Distribution from filling station to distribution hub [Oil, crude, in ground]		
Water consumption	Primary packaging raw materials production (cardboard) [Water, river]	Secondary packaging raw materials production [Water, river]		Waste management benefits (Waste at consumer) [Water, river]	Waste management benefits (Waste at consumer) [Water, river]
Primary energy	Primary packaging raw materials production (cardboard) [Energy, gross calorific value, in biomass]	Secondary packaging raw materials production [Energy, gross calorific value, in biomass]		Waste management benefits (Waste at consumer) [Energy, gross calorific value, in biomass]	Waste management benefits (Waste at consumer) [Energy, gross calorific value, in biomass]
Global warming potential	Primary packaging raw materials production (cardboard) [Carbon dioxide, fossil]	Secondary packaging raw materials production [Carbon dioxide, fossil]	Distribution from filling station to distribution hub [Carbon dioxide, fossil]	Energy recovery Waste at consumer [Carbon dioxide fossil]	Energy recovery Waste at consumer [Carbon dioxide fossil]
Ozone layer depletion potential	Primary packaging raw materials production (cardboard) [Methane, dichlorodifluoro-, CFC-12]	Secondary packaging raw materials production [Methane, dichlorodifluoro-, CFC-12]	Distribution from filling station to distribution hub [Methane, bromotrifluoro-, Halon 1301]		
Photochemical oxidation potential	Primary packaging raw materials production (cardboard) [Sulfur dioxide]	Secondary packaging raw materials production [Carbon monoxide, fossil]		Waste management benefits Waste at consumer [Sulfur dioxide]	Waste management benefits Waste at consumer [Sulfur dioxide]
Air acidification potential	Primary packaging raw materials production (cardboard) [Sulfur dioxide]	Secondary packaging raw materials production [Sulfur dioxide]	Distribution from filling station to distribution hub [Nitrogen oxides]	Waste management benefits Waste at consumer [Sulfur dioxide]	Waste management benefits Waste at consumer [Sulfur dioxide]
Eutrophication potential	Primary packaging raw materials production (cardboard) [COD, Chemical Oxygen Demand]	Secondary packaging raw materials production [COD, Chemical Oxygen Demand]	Distribution from filling station to distribution hub [Nitrogen oxides]	Waste management benefits Waste at consumer [COD, Chemical Oxygen Demand]	Waste management benefits Waste at consumer [COD, Chemical Oxygen Demand]
Human toxicity potential	Primary packaging raw materials production (cardboard) [Nickel]	Secondary packaging raw materials production [Nickel]			Waste at consumer [Chromium VI]
Freshwater aquatic ecotoxicity potential	Primary packaging raw materials production (cardboard) [Copper, ion]	Secondary packaging raw materials production [Copper, ion]	Distribution from filling station to distribution hub [Barium]	Waste at consumer [Vanadium, ion]	Waste at consumer [Vanadium, ion]
Sedimental ecotoxicity potential	Primary packaging raw materials production (cardboard) [Copper, ion]	Secondary packaging raw materials production [Copper, ion]	Distribution from filling station to distribution hub [Barium]	Waste at consumer [Vanadium, ion]	Waste at consumer [Vanadium, ion]
Terrestrial ecotoxicity potential	Primary packaging raw materials production [Cypermethrin]	Secondary packaging raw materials production [Cypermethrin]		Waste management benefits Waste at consumer [Vanadium]	Waste management benefits Waste at consumer [Vanadium]

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.

Regarding End-of-life, energy recovery of waste BiB avoids conventional energy production (both electricity and heat) and thus associated impacts. However, energy recovery is at the origin of vanadium emissions which are contributing to toxicological risks as well as carbon dioxide due to the combustion of the plastic parts of the BiB (LLDPE).

5.4.3. COMPARISON OF THE PACKAGING FORMAT





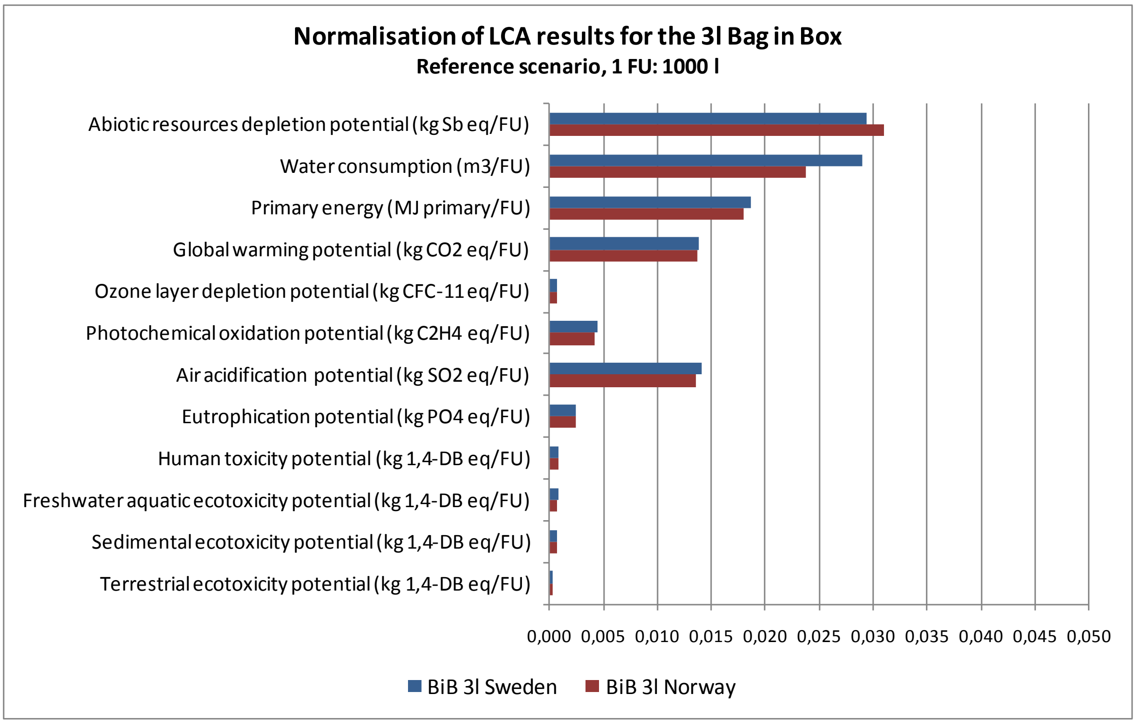
Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 25: Impact of the packaging format on the life cycle of the Bag in Box in Sweden and Norway (FU: 1000 l, 3 l set to 100)

For volumes between 1.5 l and 5 l, Bag in Boxes with lower capacity have higher environmental impacts. Indeed, for these volumes less packaging units are necessary to provide the same service (providing 1000 l of wine).

Interestingly, the 10 l Bag in Box does not strictly follow this rule, being as impacting as the 5 l for most indicators and even more impacting on some indicators. This is due to additional tertiary packaging that is only required for this format. Indeed, during the distribution stage from the filling station to the distribution hub, 3 paper sheets per pallet are used in order to stack the boxes.

5.4.4. NORMALISATION



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 26: Normalisation of LCA results for the 3 l Bag in Box

How to interpret this figure?

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 BiB of 3l are equivalent to the total impacts on abiotic depletion of about 3 European inhabitants over 1 year.

According to these results, one can identify:

- 5 major impacts (ratio > 0.01): abiotic depletion, water consumption, primary energy consumption, global warming potential and air acidification,
- 2 medium impacts (ratio 0.002–0.004): photochemical oxidation and eutrophication,
- 5 minor impacts (ratio <0.001): ozone layer depletion, human toxicity, freshwater aquatic ecotoxicity, sedimental ecotoxicity and terrestrial ecotoxicity.

5.4.5. Sensitivity analysis

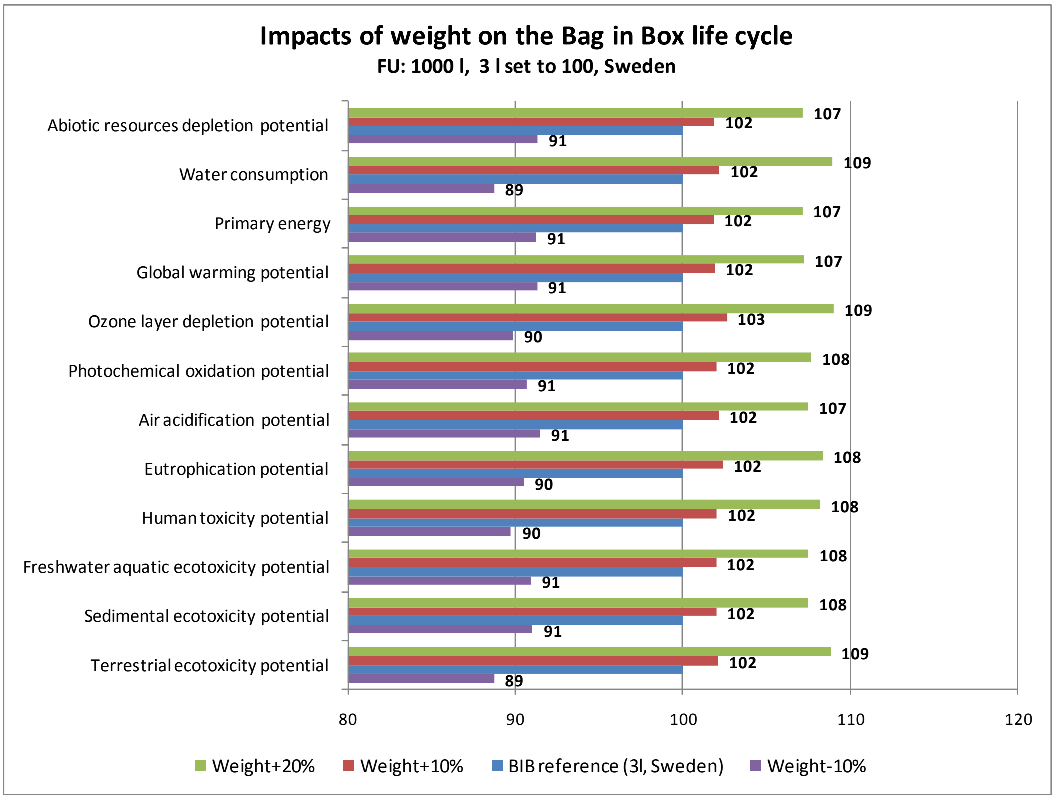
Sweden has been chosen as the reference scenario in order to perform the sensitivity analysis.

5.4.5.1. Weight sensitivity

Parameters of this sensitivity analysis are summarised in the next table.

Table 38: Parameters for the sensitivity analysis

	Reference scenario	Weight-10%	Weight+10%	Weight+20%
Weight of the primary packaging (without closure)	162.4g	146.2g	178.7g	194.9g



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 27: Influence of the weight of the primary packaging on the 3 l Bag in Box life cycle (FU: 1000 l, 3 l Bag in Box consumed in Sweden set as the reference scenario)

The weight of the bag in box has a moderate influence on the overall environmental performance of the bag in box system with variations encompassed between 7 and 9% for a 20% augmentation of the packaging weight.

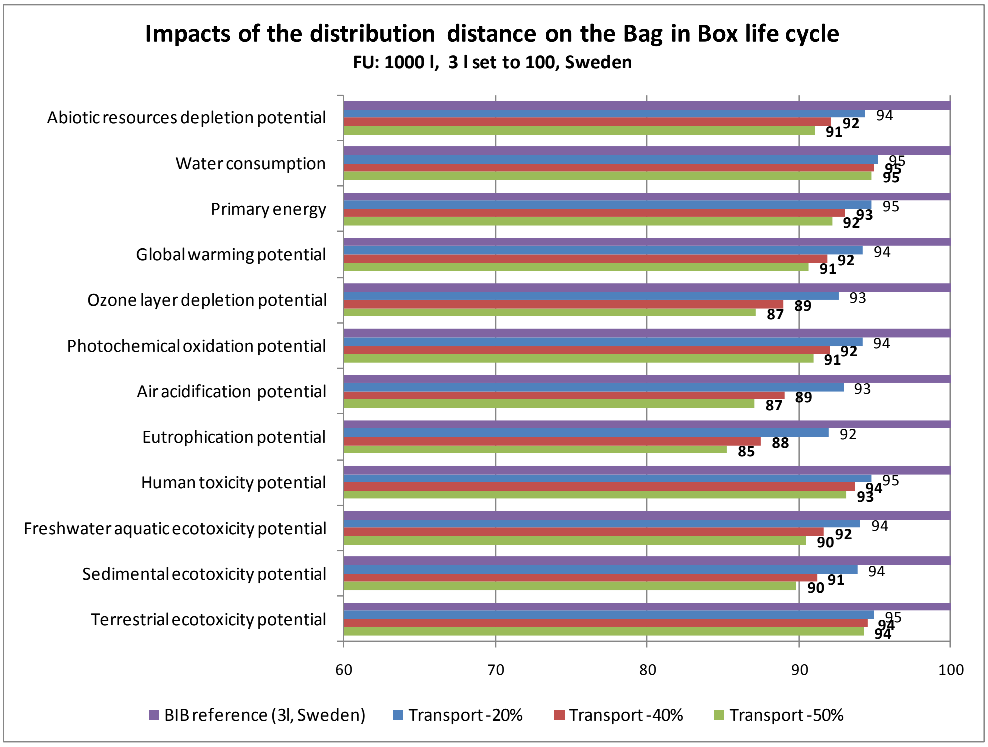
5.4.5.2. Distribution distance sensitivity

The influence of the distance between the packaging production sites, the filling station, the distribution hub and the retailer is investigated in this section. The corresponding parameters are given in the next table.

Table 39: Parameters for the sensitivity analysis

	Reference scenario	Transport -20%	Transport -40%	Transport -50%
Distance for primary packaging supply	815 km	652 km	489 km	407.5 km
Distance from the filling station to the distribution hub	2411 km	1928.8 km	1446.6 km	1205.5 km
Distance from the distribution hub to retailer	150 km	120 km	90 km	75 km

The next figure presents the variations observed for the reference scenario, when the distribution distance is reduced by 20%, 40% and 50%.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 28: Influence of the length of the supply chain on the 3 l Bag in Box life cycle (FU: 1000 l, 3 l Bag in Box consumed in Sweden set as the reference scenario)

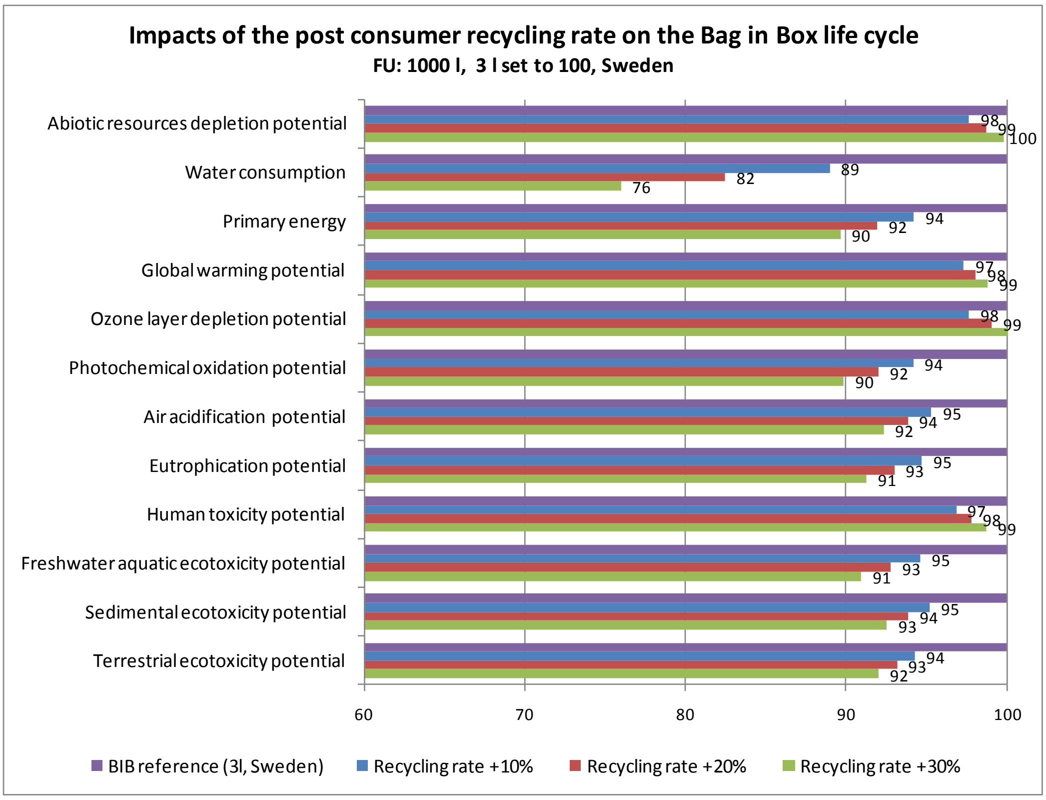
Ozone layer depletion, air acidification, and eutrophication are the most sensitive indicators to the distribution distance. Indeed, these indicators are affected by air emissions during fuel consumption or indirectly by emissions associated with the life cycle of fuel in the case of ozone layer depletion (halon 1301 which is the main ozone depleting substance of the system is used in fire equipment). Aside from water consumption and terrestrial ecotoxicity, other indicators are also sensitive to the distribution distance.

5.4.5.3. Post consumer recycling rate sensitivity

The influence of the post consumer recycling rate on the bag in box life cycle is presented hereafter for an increase in the recycling rate of 10, 20 and 30%.

Table 40: Parameters for the sensitivity analysis

	Reference scenario	Recycling rate+10%	Recycling rate+20%	Recycling rate+30%
Recycling rate	74%	81%	89%	96%



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 29: Influence of the post consumer recycling rate on the 3 l Bag in Box life cycle (FU: 1000 l, 3 l Bag in Box consumed in Sweden set as the reference scenario)

Increasing the post consumer recycling rate of the BiB has very limited impact on the overall environmental performance of the system apart for water consumption. This observation is due to different factors, first, only the box is recycled and it is already done at a high rate in the reference model, what tends to limit the contribution of increasing recycling on the overall environmental impacts of the BiB packaging system.

In addition, cardboard recycling is an energy intensive process and in the LCA model with the corresponding assumptions, energy recovery appears more environmentally friendly than recycling on some categories. The environmental impacts of cardboard recycling are subject to important discussions and are highly dependent on assumptions taken[30]. Specific studies in the Nordic context would be necessary in order to increase the robustness of these conclusions.

[30] See for instance WRAP 2006, Environmental benefits of recycling, an international review of life cycle comparisons for key materials in the UK recycling sector

5.5 STAND UP POUCH

5.5.1. DESCRIPTION OF THE SYSTEM

The following scheme represents the different steps of the life cycle of the Stand up Pouches considered in this study.

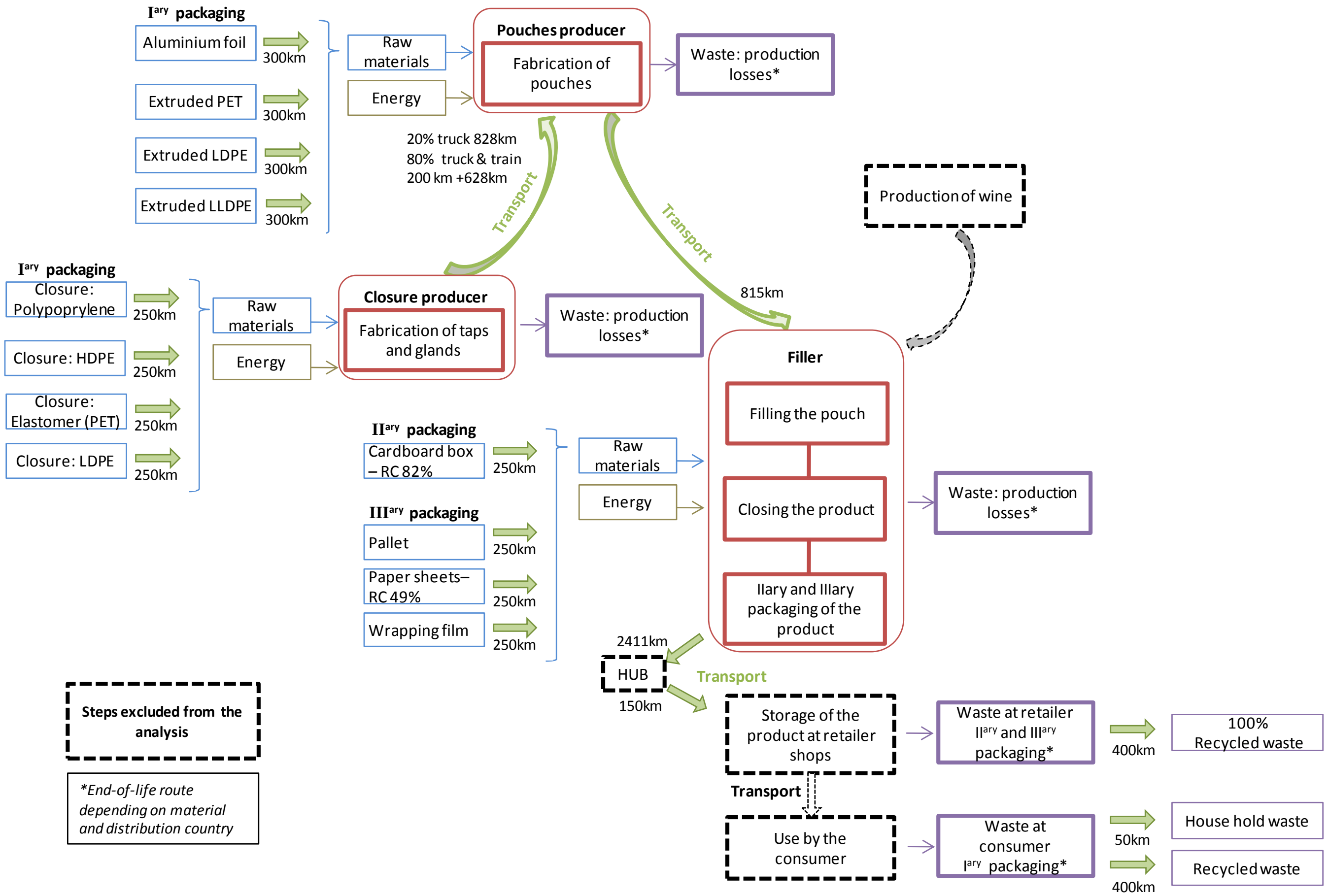


Figure 30: Steps of the life cycle of the Stand up Pouches considered in this study

Table 41: Stand up Pouch — volumes studied

	Unit	SuP 3 l	SuP 1 .5 l	SuP 1 l
Volume	[cl]	300	**150**	100
Total weight	[g]	62	**34.8**	32

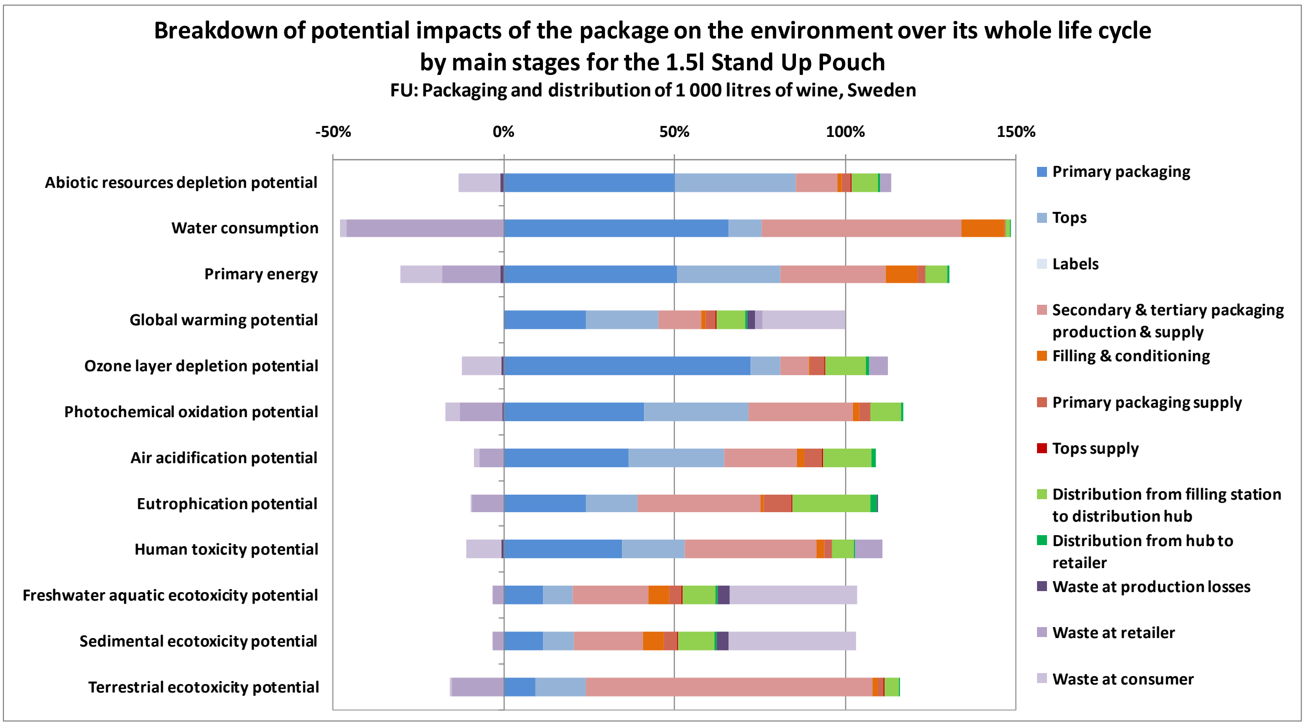
5.5.2. Results of the reference scenario

The 1.5 l Stand up Pouch (SuP) has been chosen in the reference scenario. The next tables present the breakdown of the environmental impacts of the SuP system per life cycle phase for Norway and Sweden.

Table 42: Breakdown of the environmental impacts of the 1.5 l Stand up Pouch 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, see text box in section 3.2.



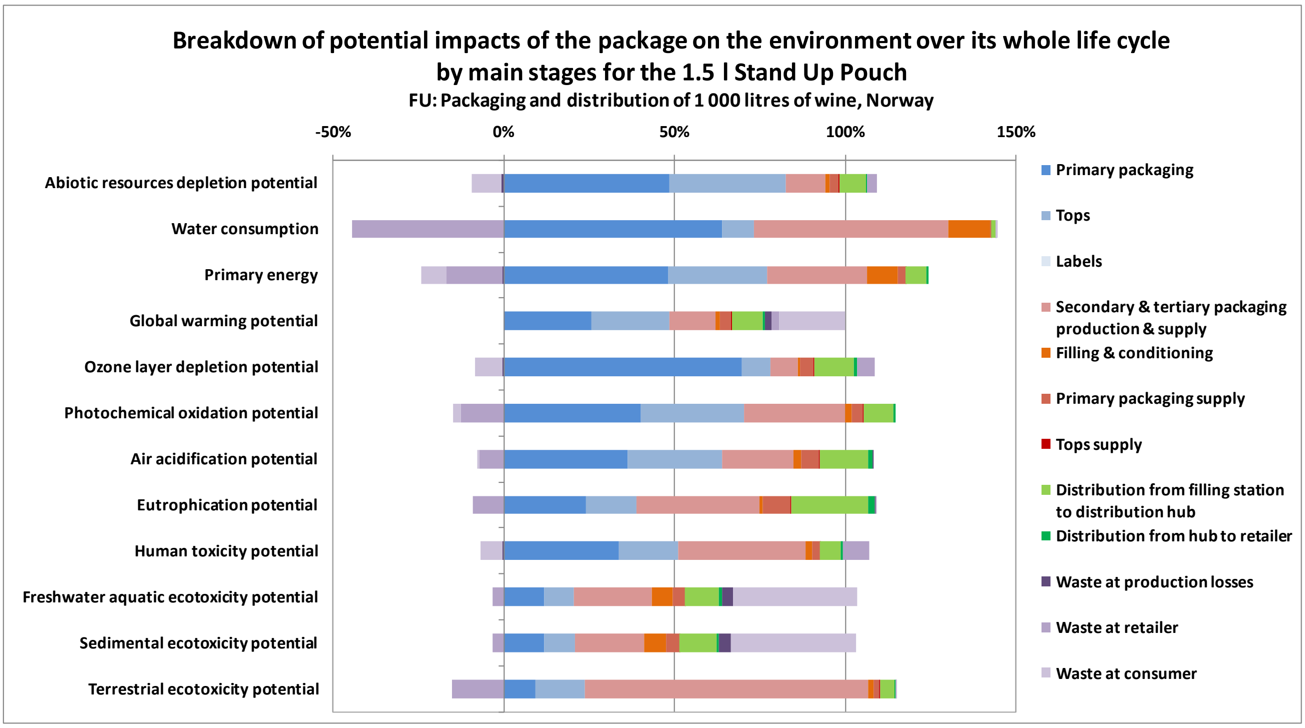
Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 31: Detailed breakdown of the environmental impacts of the 1.5 l Stand up Pouch for Sweden

Table 43: Breakdown of the environmental impacts of the 1.5 l Stand up Pouch 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, see text box in section 3.2.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 32: Detailed breakdown of the environmental impacts of the 1.5 l Stand up Pouch for Norway

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.

In terms of abiotic depletion, water consumption, primary energy, global warming, photochemical oxidation, air acidification, human toxicity and ozone layer depletion, the production of the raw materials entering in the composition of the SuP is the most impacting stage.

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

In Sweden, the impacts related to waste management have a significant (29% to 38%) contribution in terms of global warming, freshwater ecotoxicity and sedimental ecotoxicity. Waste management brings benefits to other impacts.

In Norway, the impacts related to waste management have a slightly lower (24% to 37%) contribution in terms of global warming, freshwater ecotoxicity and sedimental ecotoxicity. However, the waste management benefits on other impacts are lower too, human toxicity becoming impact.

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. This explains the higher contribution in terms of global warming for the end-of-life stage in Sweden, incineration of plastic compounds being a green house gases emitting process. These different practices have little effect in terms of freshwater and sedimental ecotoxicity, and in terms of air acidification and eutrophication, both routes having close impacts on these indicators. For the other indicators, energy recovery is associated with environmental credits that explain lower contribution of the end-of-life in Sweden. Energy recovery during incineration thus explains the mitigated impacts in terms of primary energy, abiotic depletion, ozone layer depletion or human toxicity.

The important contributions/emissions of the life cycle stages of the 1.5 l SuP are presented in the next table. The table presents for each indicator and life cycle step, the flow that contributes the most to the impacts and the sub-step during which it is emitted (or consumed). The shaded life cycle stages contribute to less than 10% to the indicator in question. Environmental credits appear in green.

Table 44: Important contributions/emissions of the life cycle stages of the 1.5 l Stand up Pouch

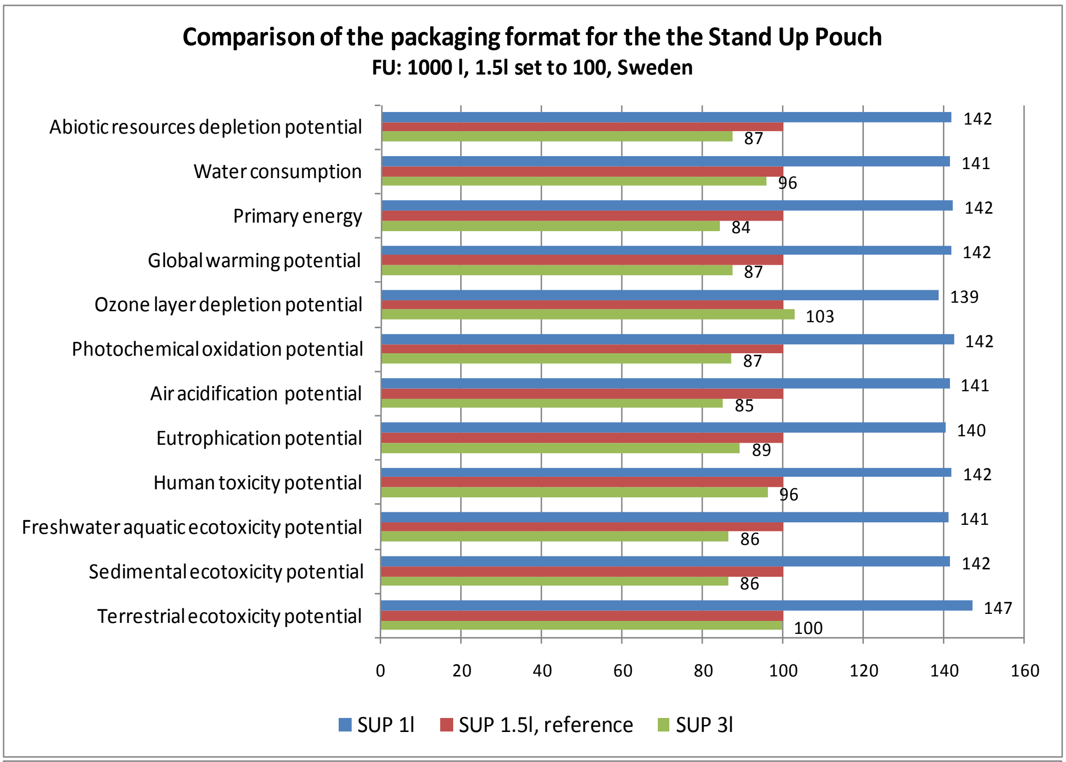
	Packaging production	Filling	Distribution	Waste management (Sweden)	Waste management (Norway)
Abiotic resources depletion potential	Primary packaging raw materials production [Oil, crude, in ground]	Secondary packaging raw materials production [Oil, crude, in ground]		Energy recovery benefits Waste at consumer [Gas, natural, in ground]	Energy recovery benefits Waste at consumer [Gas, natural, in ground]
Water consumption	Primary packaging raw materials production [Water, unspecified natural origin]	Secondary packaging raw materials production [Water, river]		Energy recovery benefits Waste at retailer [Water, river]	Energy recovery benefits Waste at retailer [Water, river]
Primary energy	Primary packaging raw materials production [Oil, crude, in ground]	Secondary packaging raw materials production Energy, gross calorific value, in biomass		Energy recovery benefits Waste at retailer [Energy, gross calorific value, in biomass]	Energy recovery benefits Waste at retailer [Energy, gross calorific value, in biomass]
Global warming potential	Primary packaging raw materials production [Carbon dioxide, fossil]	Secondary packaging raw materials production [Carbon dioxide, fossil]		Waste at consumer [Carbon dioxide fossil]	Waste at consumer [Carbon dioxide fossil]
Ozone layer depletion potential	Primary packaging raw materials production [Methane, dichlorodifluoro-, CFC-12]	Secondary packaging raw materials production [Methane, bromotrifluoro-, Halon 1301]	Distribution from filling station to distribution hub [Methane, bromotrifluoro-, Halon 1301]		
Photochemical oxidation potential	Primary packaging raw materials production [Sulfur dioxide]	Secondary packaging raw materials production [Carbon monoxide, fossil]	Distribution from filling station to distribution hub [Carbon monoxide, fossil]	Energy recovery benefits Waste at retailer [Sulfur dioxide]	Energy recovery benefits Waste at retailer [Sulfur dioxide]
Air acidification potential	Primary packaging raw materials production [Sulfur dioxide]	Secondary packaging raw materials production [Sulfur dioxide]	Distribution from filling station to distribution hub [Nitrogen oxides]		
Eutrophication potential	Primary packaging raw materials production [Nitrogen oxides]	Secondary packaging raw materials production [COD, Chemical Oxygen Demand]	Distribution from filling station to distribution hub [Nitrogen oxides]		
Human toxicity potential	Primary packaging raw materials production [PAH, polycyclic aromatic hydrocarbons]	Secondary packaging raw materials production [Nickel]			
Freshwater aquatic ecotoxicity potential	Tops formation [Vanadium]	Secondary packaging raw materials production [Copper, ion]	Distribution from filling station to distribution hub [Barium]	Waste at consumer [Vanadium, ion]	Waste at consumer [Vanadium, ion]
Sedimental ecotoxicity potential	Tops formation [Vanadium]	Secondary packaging raw materials production [Copper, ion]	Distribution from filling station to distribution hub [Barium]	Waste at consumer [Vanadium, ion]	Waste at consumer [Vanadium, ion]
Terrestrial ecotoxicity potential	Tops formation [Vanadium]	Secondary packaging raw materials production [Cypermethrin]		Energy recovery benefits Waste at retailer [Vanadium]	Energy recovery benefits Waste at retailer [Vanadium]

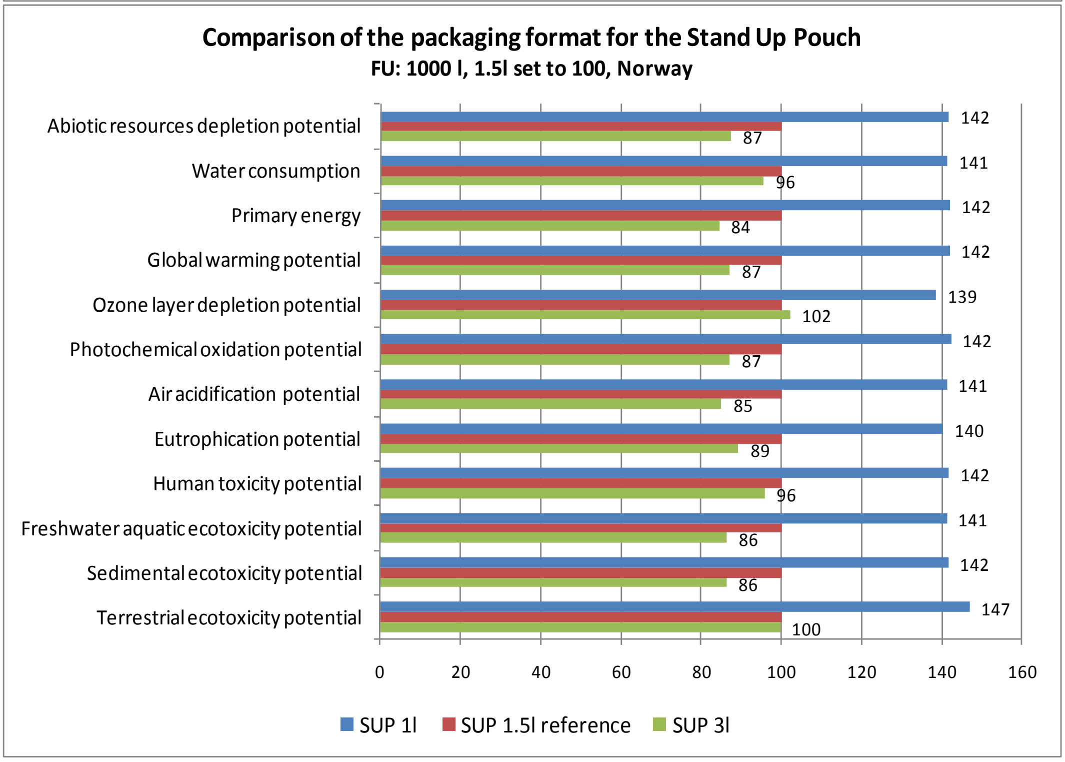
Environmental impacts of the pouch system itself are explained by the impacts associated with the production of the raw materials, be it for primary or secondary packaging.

Fossil energy used to produce raw materials, primary and secondary packaging and fuel consumed during transportation appear as a main contributor to most of the impacts causing elementary flows (crude oil, CO_2 emissions, sulfur dioxide and nitrogen oxides, polyaromatic hydrocarbons).

Energy recovery of waste avoids conventional energy production (both electricity and heat) and thus associated impacts. However, energy recovery is at the origin of carbon dioxide emissions when burning plastics, and vanadium emissions which are contributing to toxicological risks (aquatic and sedimental ecotoxicity).

5.5.3. COMPARISON OF THE PACKAGING FORMAT



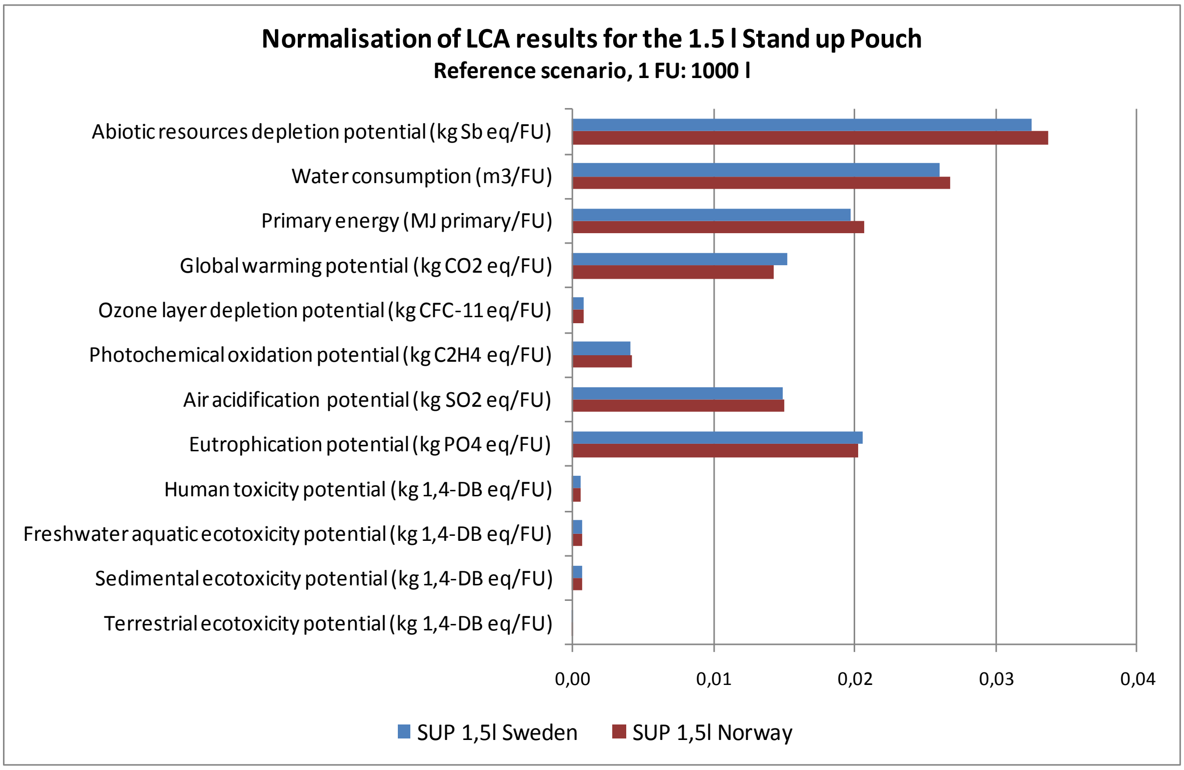


Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 33: Impact of the packaging format on the life cycle of the Stand up Pouch in Sweden and Norway (FU: 1000 l, 1.5 l set to 100)

The 1.5 l Stand up pouch has higher environmental impacts than the 3 l format. The 3 l format is around 40% more environmentally friendly than the 1.5 l. Indeed, with this volume less packaging units are necessary to provide the same service (providing 1000 l of wine).

5.5.4. Normalisation



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 34: Normalisation of LCA results for the 1.5 l Stand up Pouch

How to interpret this figure?

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 SUP of 1.5 l are equivalent to the total impacts on abiotic depletion of about 3 European inhabitants over 1 year.

According to these results, one can identify:

- 6 major impacts (ratio > 0.01): abiotic depletion, water consumption, primary energy consumption, global warming potential, air acidification and eutrophication,
- 1 medium impacts (ratio 0.004): photochemical oxidation,
- 5 minor impacts (ratio <0.001): ozone layer depletion, human toxicity, freshwater aquatic ecotoxicity, sedimental ecotoxicity and terrestrial ecotoxicity.

5.5.5. Sensitivity analysis

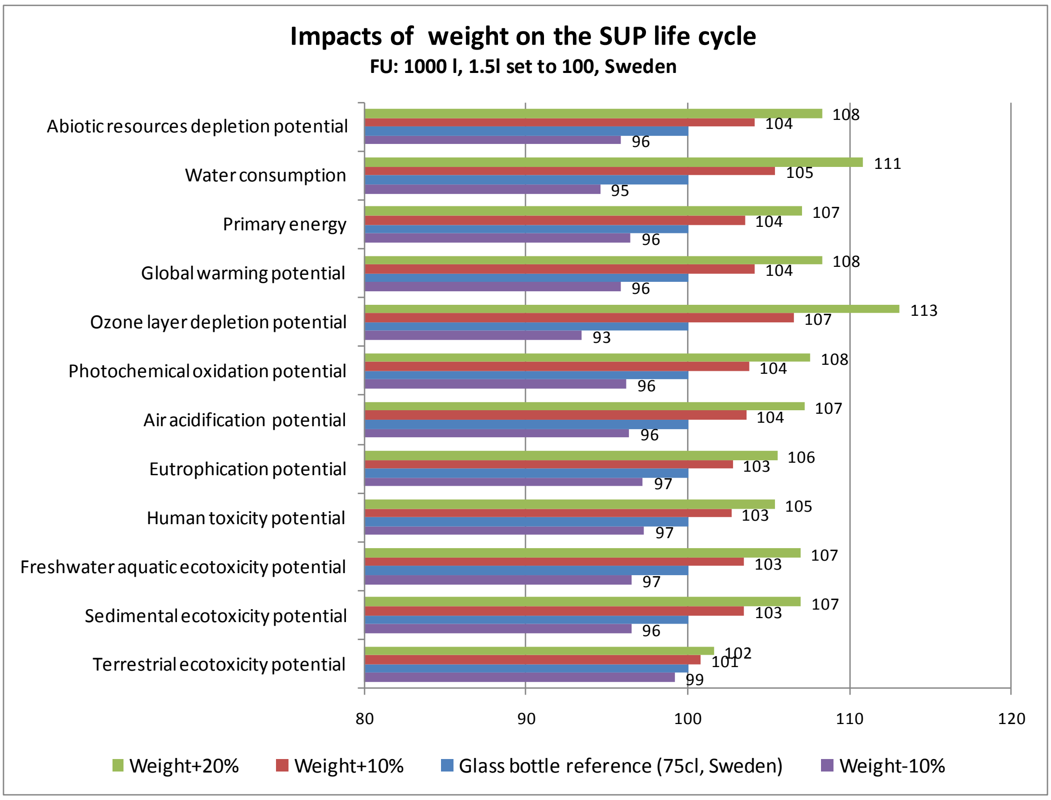
Sweden has been chosen as the reference scenario in order to perform the sensitivity analysis.

5.5.5.1. Weight sensitivity

The next table presents the parameters used in the analysis.

Table 45: Parameters for the sensitivity analysis

	Reference scenario	Weight-10%	Weight+10%	Weight+20%
Weight of the primary packaging	22.5g	20.3g	24.8g	27g



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 35: Influence of the weight of the primary packaging on the Stand up Pouch life cycle (FU: 1000 l, 1.5 l SuP consumed in Sweden set as the reference scenario)

As presented in section 4.2.4, the production of primary packaging is not as predominant as in other systems for most of the environmental impacts. In addition, some environmental credits are observed thanks to energy recovery at the end-of-life of the packaging. Overall, the SuP life cycle shows moderate sensitivity to the weight of the primary packaging for all indicators. Ozone layer depletion is the most sensitive indicator. As already presented, primary packaging production is the most impacting step for this indicator.

5.5.5.2. Distribution distance sensitivity

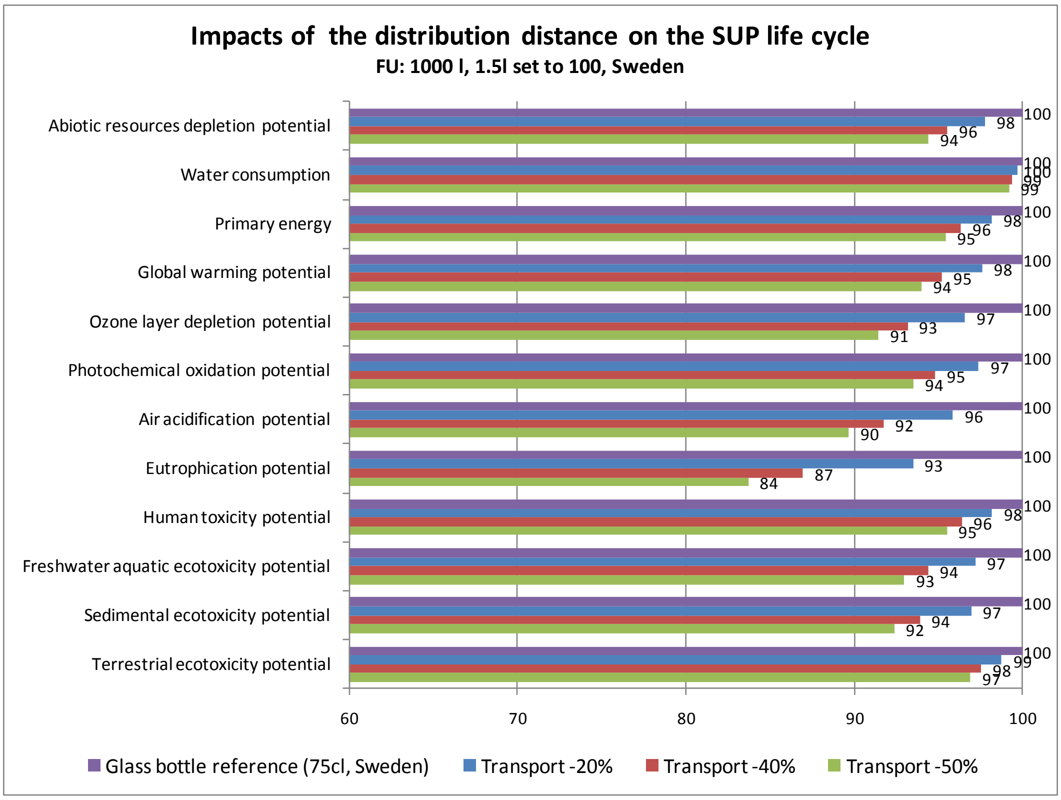
The influence of the distance between the packaging production sites, the filling station, the distribution hub and the retailer is investigated in this section. The main parameters of this analysis are summarised in the next table.

Table 46: Parameters for the sensitivity analysis

	Reference scenario	Transport -20%	Transport -40%	Transport -50%
Distance for primary packaging supply	815 km	652 km	489 km	407 km

	Reference scenario	Transport -20%	Transport -40%	Transport -50%
Distance from the filling station to the distribution hub	2411 km	1930 km	1447 km	1205 km
Distance from the distribution hub to retailer	150 km	120 km	90 km	75 km

The next figure presents the variations observed for the reference scenario, when the distribution distance is reduced by 20%, 40% and 50%.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 36: Influence of length of the supply chain on the Stand up Pouch life cycle (FU: 1000 l, 1.5 l SuP consumed in Sweden set as the reference scenario)

The environmental profile of the SuP life cycle is sensitive to the transportation distance. A 50% decrease in the length of the supply chain results in environmental benefits of 16% for eutrophication which is the most sensitive indicator.

5.6 BEVERAGE CARTON

5.6.1. DESCRIPTION OF THE SYSTEM

The 2 following schemes represent the different steps of the life cycle of the beverage cartons considered in this study.

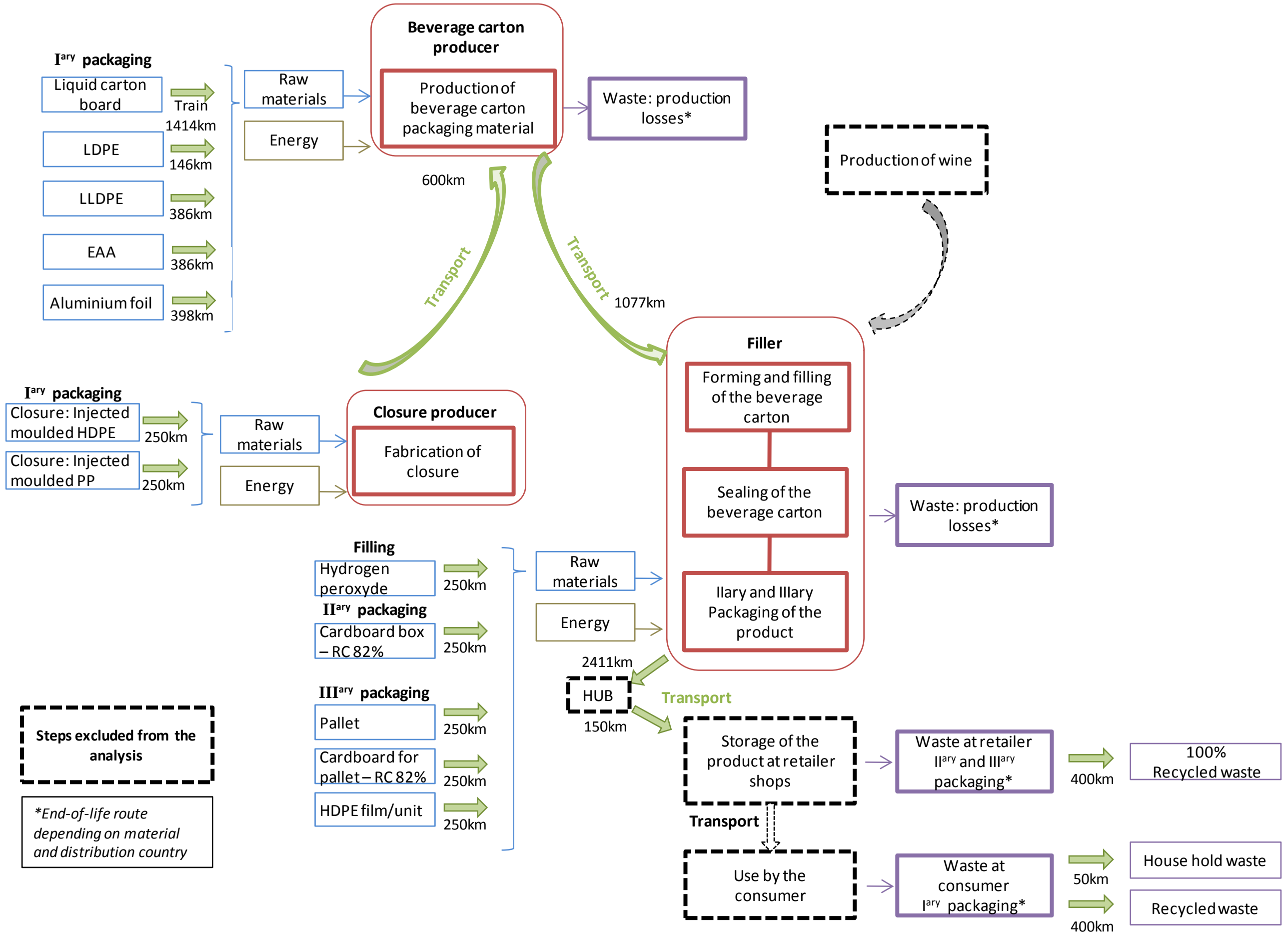


Figure 37: Steps of the life cycle of the beverage carton "SYSTEM 1" considered in this study

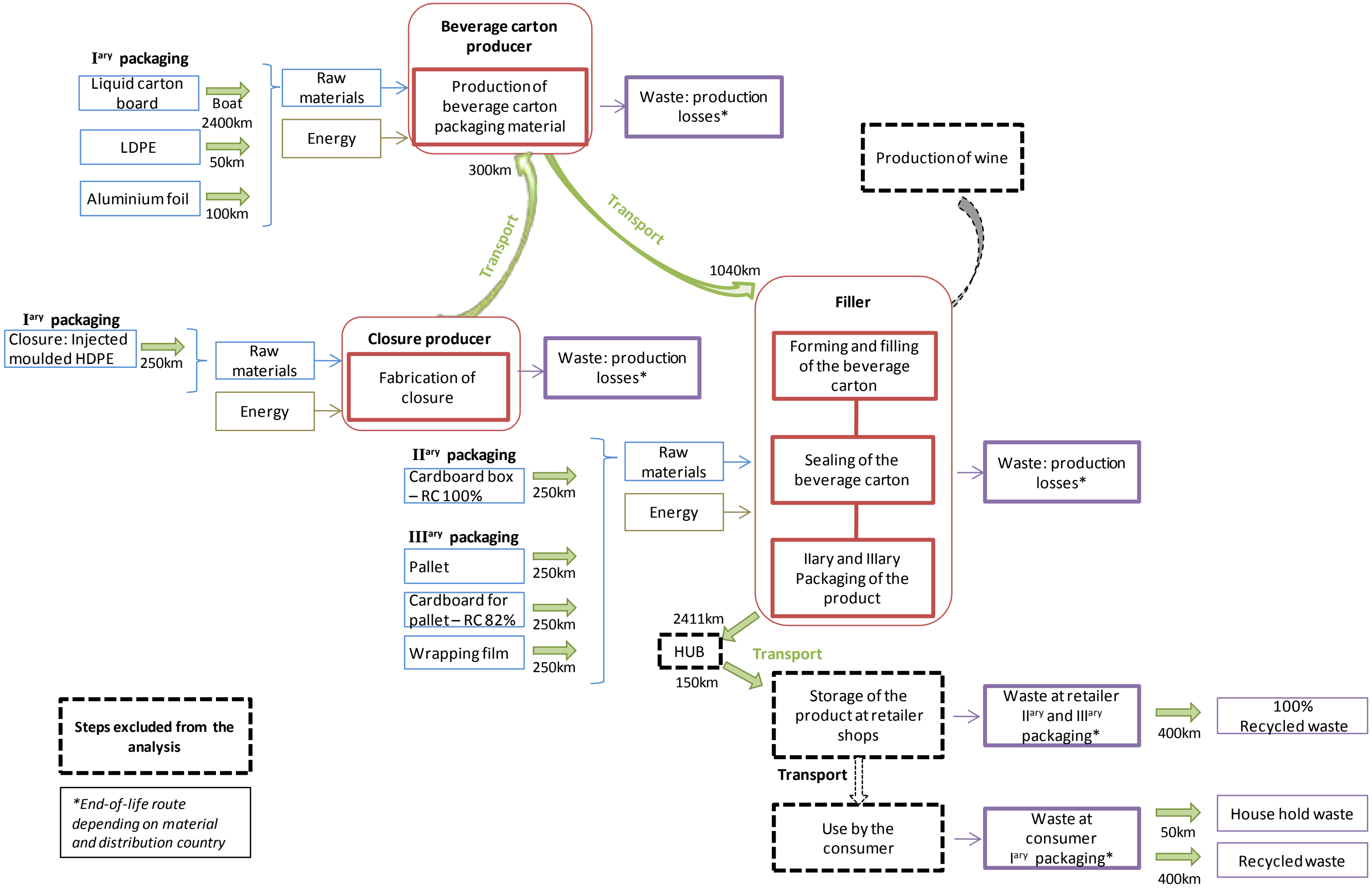


Figure 38: Steps of the life cycle of the beverage carton "SYSTEM 2" considered in this study

Table 47: Beverage carton — volumes studied

	Unit	Bev. cart. 1 l	Bev. cart. 75 cl	Bev. cart. 50 cl	Bev. cart. 25 cl*
Volume	[cl]	**100**	75	50	25
Total weight — System 1	[g]	**39.6**	33.2	22.7	9.3
Total weight — System 2	[g]	**36.6**	31.5	23.8	15.6
Averaged total weights System 1 — System 2	[g]	**38.1**	32.3	23.2	N/A
*The 25 cl beverage carton has no closure in system 1 and has one in system 2					

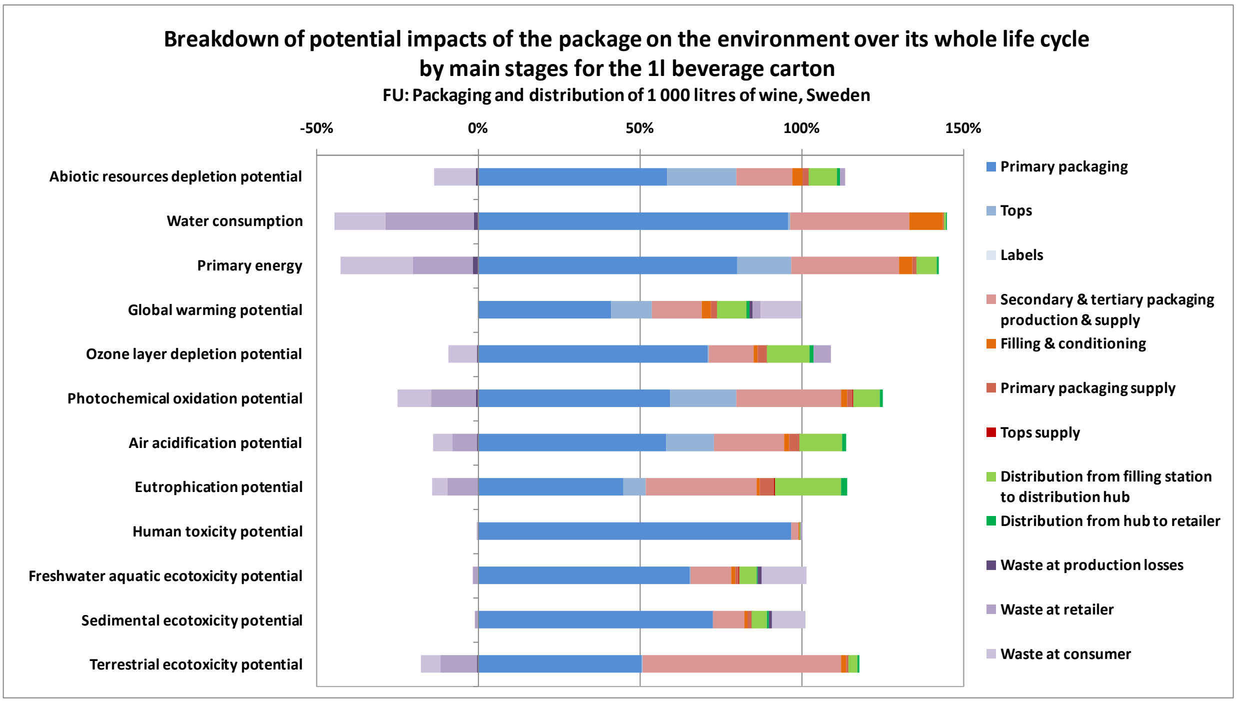
5.6.2. RESULTS OF THE REFERENCE SCENARIO

The 1 l beverage carton has been set as the reference scenario in this section. 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.

Table 48: 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, see text box in section 3.2.



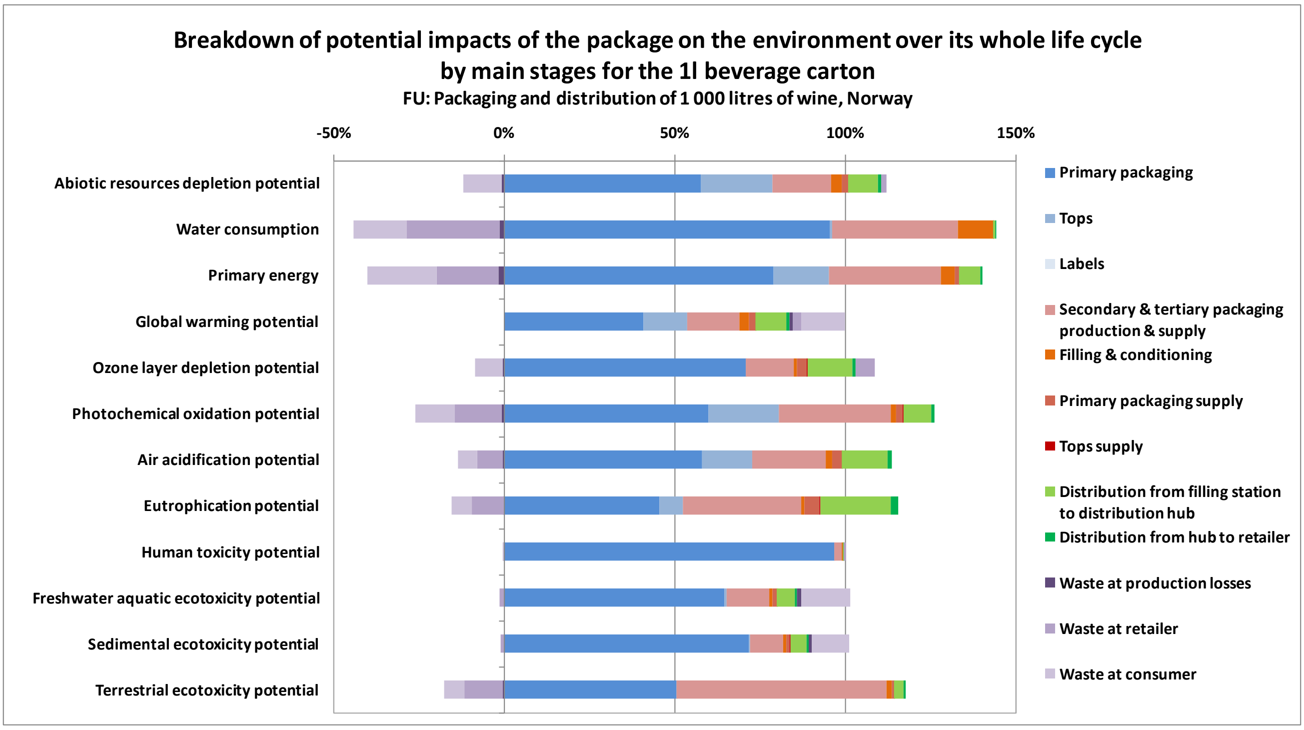
Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 39: Detailed breakdown of the environmental impacts of the 1 l beverage carton for Sweden

Table 49: 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, see text box in section 3.2.



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 40: Detailed breakdown of the environmental impacts of the 1 l beverage carton for Norway

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%.

Waste management tends to mitigate the environmental impact of the system. In both Sweden and Norway, the impacts related to waste management have a moderate (<16%) contribution in terms of global warming, freshwater ecotoxicity and sedimental ecotoxicity.

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

The important contributions/emissions of the life cycle stages of the 1 l beverage carton are presented in the next table. The table presents for each indicator and life cycle step, the flow that contributes the most to the impacts and the sub-step during which it is emitted (or consumed). The shaded life cycle stages contribute to less than 10% to the indicator in question. Environmental credits appear in green.

Table 50: Important contributions/emissions of the life cycle stages of the 1 l beverage carton

	Packaging production	Filling	Distribution	Waste management (Sweden)	Waste management (Norway)
Abiotic resources depletion potential	Primary packaging Primary packaging raw materials production [Oil, crude, in ground]	Secondary packaging raw materials production [Oil, crude, in ground]	Distribution from filling station to distribution hub [Oil crude, in ground]	Energy recovery benefits Waste at consumer [Gas, natural, in ground]	Energy recovery benefits Waste at consumer [Gas, natural, in ground]
Water consumption	Primary packaging raw materials production [Water, unspecified natural origin]	Secondary packaging raw materials production [Water, river]		Energy recovery benefits Waste at retailer [Water, river]	Energy recovery benefits Waste at retailer [Water, river]
Primary energy	Primary packaging raw materials production [Energy gross calorific value, in biomass]	Secondary packaging raw materials production [Energy gross calorific value, in biomass]		Energy recovery benefits Waste at retailer [Energy, gross calorific value, in biomass]	Energy recovery benefits Waste at retailer [Energy, gross calorific value, in biomass]
Global warming potential	Primary packaging raw materials production [Carbon dioxide, fossil]	Secondary packaging raw materials production [Carbon dioxide, fossil]	Distribution from filling station to distribution hub [Carbon dioxide, fossil]	Waste at consumer [Carbon dioxide, fossil]	Waste at consumer [Carbon dioxide, fossil]
Ozone layer depletion potential	Primary packaging raw materials production [Methane, dichlorodifluoro-, CFC-12]	Secondary packaging raw materials production [Methane, bromotrifluoro-, Halon 1301]	Distribution from filling station to distribution hub [Carbon monoxide, fossil]		
Photochemical oxidation potential	Primary packaging raw materials production [Sulfur dioxide]	Secondary packaging raw materials production [Carbon monoxide, fossil]		Energy recovery benefits Waste at retailer [Sulfur dioxide]	Energy recovery benefits Waste at retailer [Sulfur dioxide]
Air acidification potential	Primary packaging raw materials production [Sulfur dioxide]	Secondary packaging raw materials production [Sulfur dioxide]	Distribution from filling station to distribution hub [Nitrogen oxides]	Energy recovery benefits Waste at retailer [Sulfur dioxide]	Energy recovery benefits Waste at retailer [Sulfur dioxide]
Eutrophication potential	Primary packaging raw materials production [COD, Chemical Oxygen Demand]	Secondary packaging raw materials production [COD, Chemical Oxygen Demand]	Distribution from filling station to distribution hub [Nitrogen oxides]	Energy recovery benefits Waste at retailer [COD, Chemical Oxygen Demand]	Energy recovery benefits Waste at retailer [COD, Chemical Oxygen Demand]
Human toxicity potential	Primary packaging raw materials production [PAH, polycyclic aromatic hydrocarbons]				
Freshwater aquatic ecotoxicity potential	Primary packaging raw materials production [PAH, polycyclic aromatic hydrocarbons]	Secondary packaging raw materials production [Copper ion]		Waste at consumer [Vanadium, ion]	Waste at consumer [Vanadium, ion]
Sedimental ecotoxicity potential	Primary packaging raw materials production [PAH, polycyclic aromatic hydrocarbons]	Secondary packaging raw materials production [Copper, ion]		Waste at consumer [Vanadium, ion]	Waste at consumer [Vanadium, ion]
Terrestrial ecotoxicity potential	Primary packaging raw materials production [Vanadium]	Secondary packaging raw materials production [Cypermethrin]		Energy recovery benefits Waste at retailer [Vanadium]	Energy recovery benefits Waste at retailer [Vanadium]

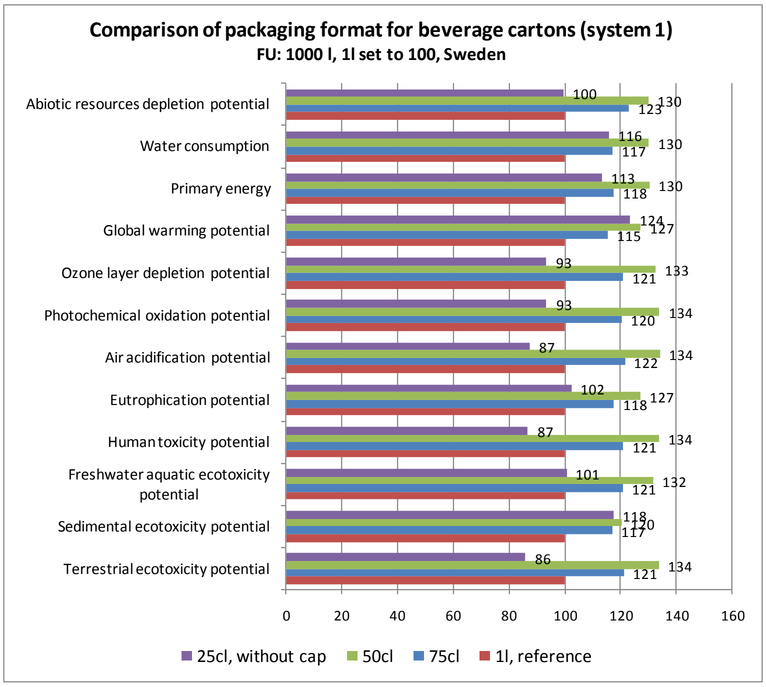
Most of the environmental impacts of the beverage carton itself are explained by the impacts associated with the production of the raw materials, be it for primary or secondary packaging. Note that impacts in terms of ecotoxicity and human toxicity are explained by PAH emissions, a substance that is emitted during aluminium production.

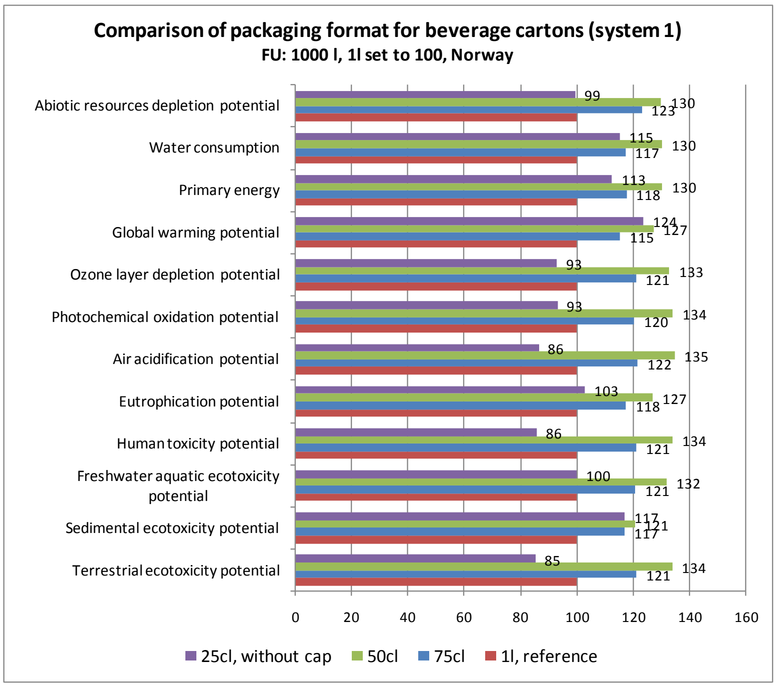
Fossil energy used to produce raw materials, primary and secondary packaging and used during transportation appears as a main contributor to most of the elementary flows which are causing impacts (crude oil, CO_2 emissions, sulfur dioxide and nitrogen oxides).

Energy recovery of waste avoids conventional energy production (both electricity and heat) and thus associated impacts. In addition, part of the aluminium found in bottom ash after incineration is ultimately recycled, hence mitigating the impacts associated with virgin aluminium production.

5.6.3. COMPARISON OF THE PACKAGING FORMAT

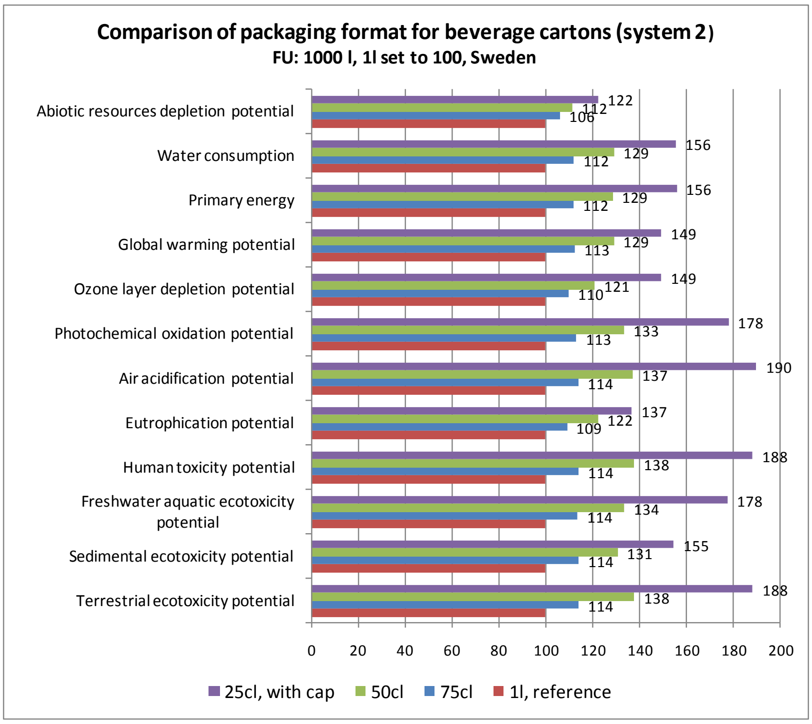
Two beverage carton producers are included in the study and therefore two slightly different systems are modelled. The 25 cl format has a cap in one system, while the other does not. Because of this difference and in order to draw meaningful conclusions without introducing mathematical bias when comparing the packaging formats, both systems are presented hereafter.

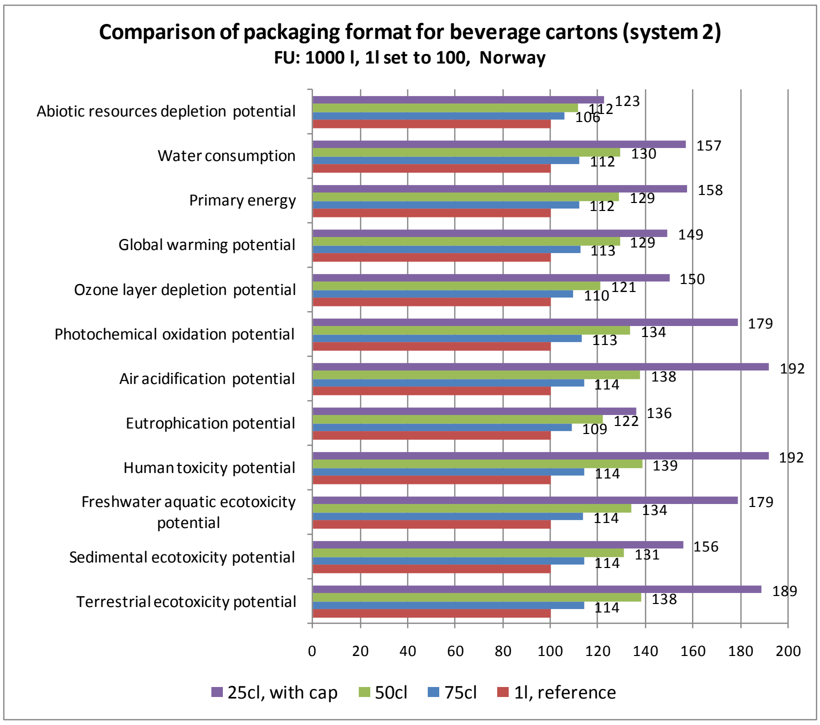




Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 41: Impact of the packaging format on the life cycle of the beverage carton in Sweden and Norway (system 1) (FU: 1000 l, 1 l set to 100)





Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

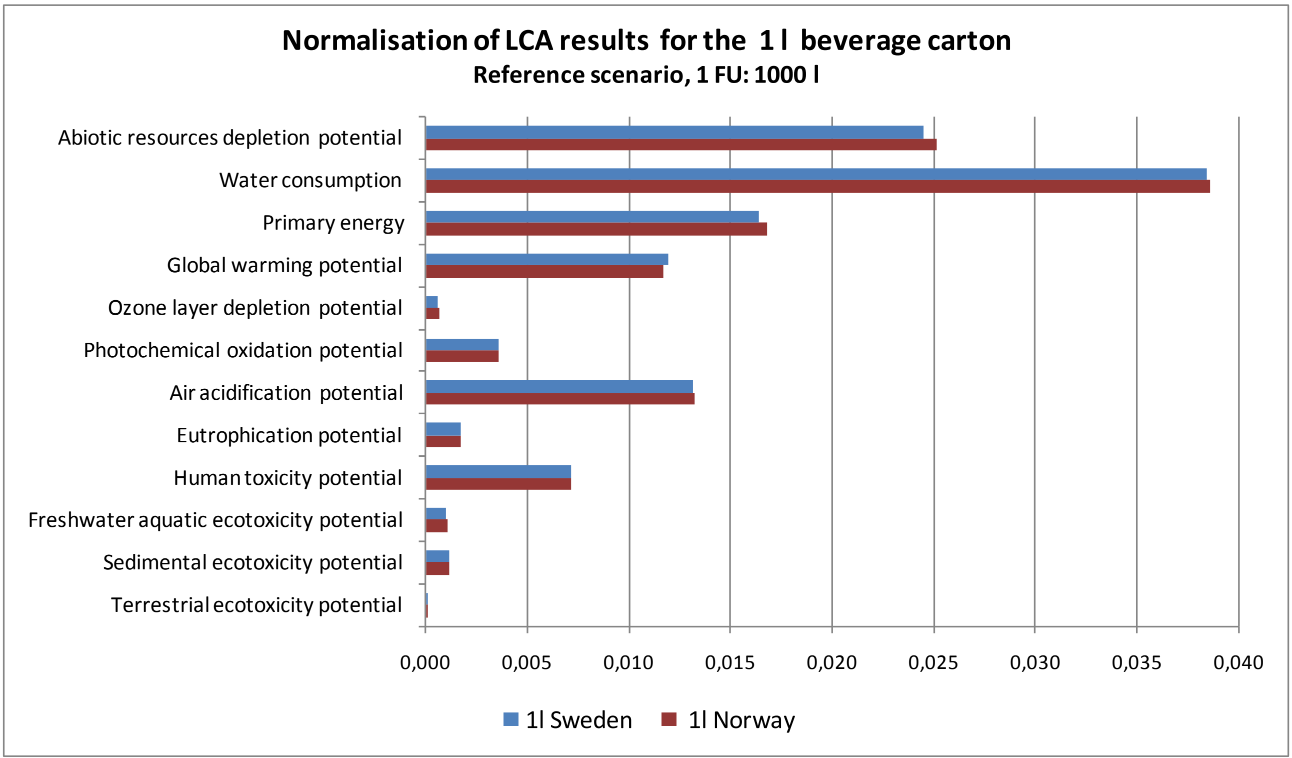
Figure 42: Impact of the packaging format on the life cycle of the beverage carton in Sweden and Norway (system 2) (FU: 1000 l, 1 l set to 100)

As a general rule, one can see that packaging with lower capacity have higher environmental impacts. This is due to the fact that less packaging units are necessary to provide the same service (i.e. providing 1000 l of wine).

Concerning the 25 cl format, in terms of characteristics, this format is close to the others in the second system as they all have a plastic closure. For all indicators, the 25 cl format is the less environmentally performing packaging in the second system.

In the first system, the 25 cl format differs from the others because it does not have any closure. Because of this intrinsic difference, this format appears as the best alternative for several indicators. This is due to reduced materials. Indeed, the life cycle impacts of the closure are avoided.

5.6.4. NORMALISATION



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 43: Normalisation of LCA results for the 1 l beverage carton

How to interpret this figure?

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.

According to these results, one can identify:

- 5 major impacts (ratio > 0.01): abiotic depletion, water consumption, primary energy consumption, global warming potential, and air acidification,
- 3 medium impacts (ratio 0.002–0.007): photochemical oxidation, eutrophication and human toxicity,
- 4 minor impacts (ratio <0.002): ozone layer depletion, freshwater aquatic ecotoxicity, sedimental ecotoxicity and terrestrial ecotoxicity.

5.6.5. SENSITIVITY ANALYSIS

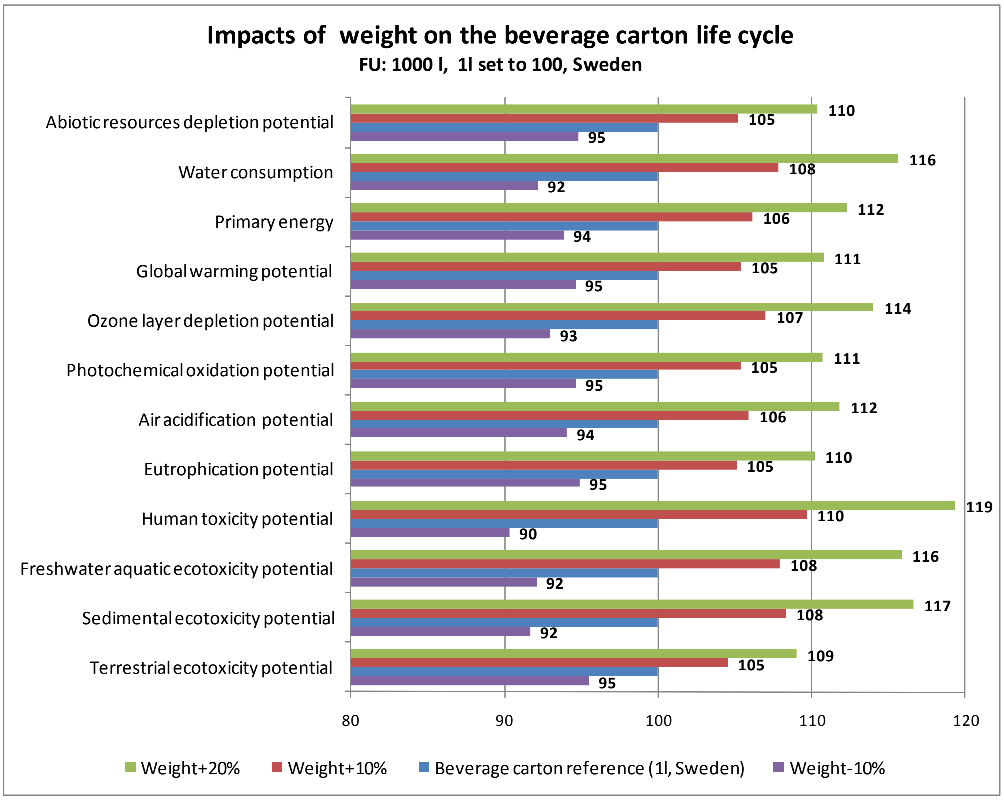
Sweden has been chosen as the reference scenario in order to perform the sensitivity analysis.

5.6.5.1. Weight sensitivity

The parameters of this sensitivity analysis are given in the next table.

Table 51: Parameters for the sensitivity analysis

	Reference scenario	Weight-10%	Weight+10%	Weight+20%
Weight of the primary packaging	33g/35g	29g/32g	36g/39g	39g/43g



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 44: Influence of the weight of the primary packaging on the beverage carton life cycle (FU: 1000 l, 1 l beverage carton consumed in Sweden set as the reference scenario)

The beverage carton life cycle system shows moderate sensitivity to the weight of the packaging with variation of 9-19% of the impacts for a 20% change of the packaging weight.

Water consumption and human toxicity appears as the most sensitive indicator. Reduction of the cardboard mass explains the sensitivity of the system in terms of water depletion, whereas for human toxicity, most of the impacts are related to the aluminium mass.

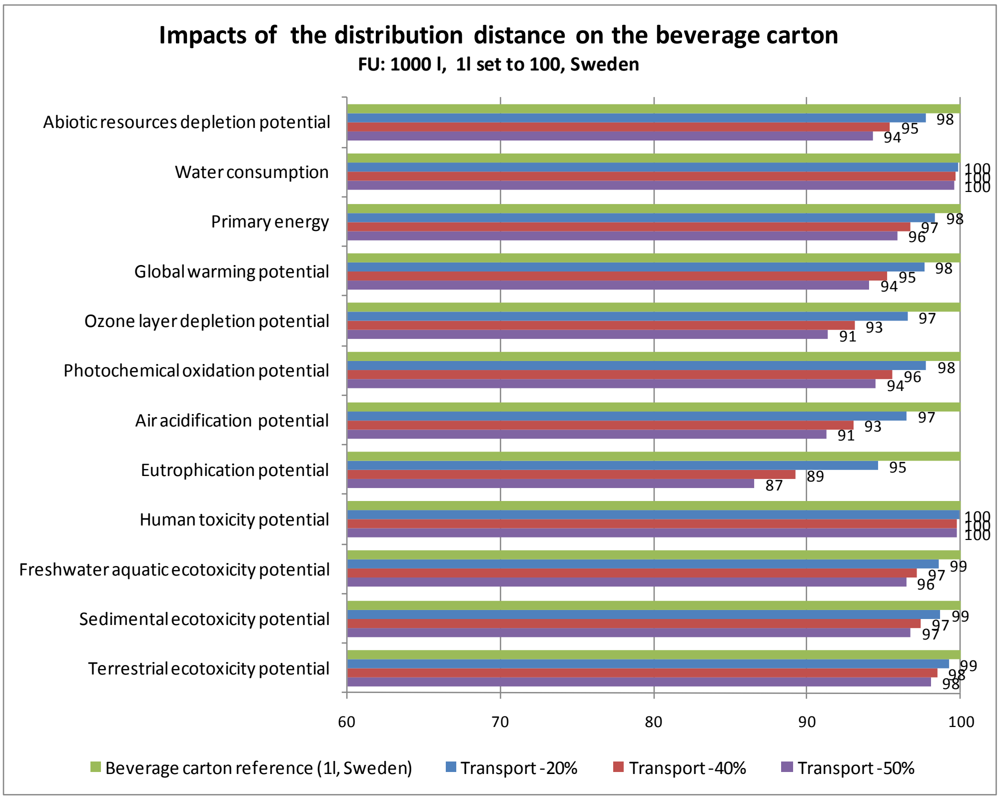
5.6.5.2. Distribution distance sensitivity

The influence of the distance between the packaging production sites, the filling station, the distribution hub and the retailer is investigated in this section.

The next figure presents the variations observed for the reference scenario, when the distribution distance is reduced by 20%, 40% and 50%, corresponding parameters are as follows:

Table 52: Parameters for the sensitivity analysis

	Reference scenario	Transport -20%	Transport -40%	Transport -50%
Distance for primary packaging supply	1040 km/1077 km	832 km/861 km	624 km/646 km	520 km/540 km
Distance from the filling station to the distribution hub	2411 km	1930 km	1447 km	1205 km
Distance from the distribution hub to retailer	150 km	120 km	90 km	75 km



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 45: Influence of length of the supply chain on the beverage carton life cycle (FU: 1000 l, 1 l beverage carton consumed in Sweden set as the reference scenario)

The beverage carton system is particularly sensitive to variation in the length of the supply chain in terms of eutrophication, air acidification and ozone layer depletion. This is mainly due to reduction in nitrogen oxides and carbon monoxide associated with fuel combustion.

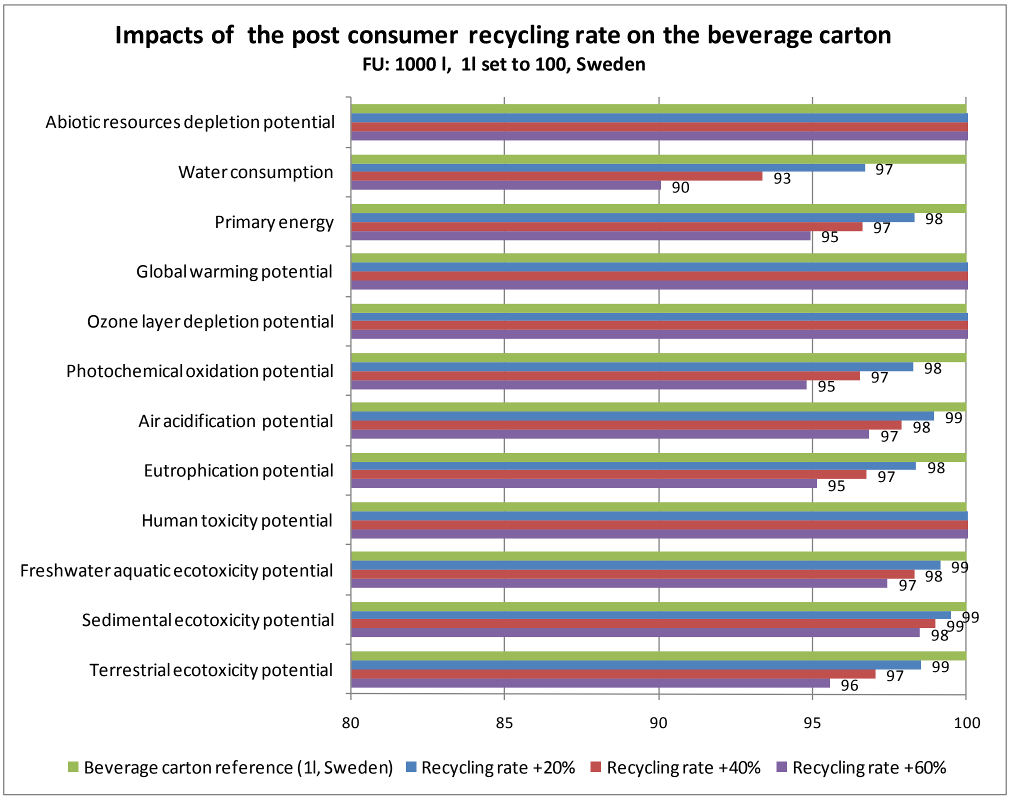
Human toxicity and water consumption are not sensitive to the reduction in the supply chain other indicators are slightly sensitive.

5.6.5.3. Post consumer recycling rate sensitivity

The influence of the post consumer recycling rate on the beverage carton life cycle is presented hereafter for increase in the recycling rate of 20, 40 and 60%.

Table 53: Parameters for the sensitivity analysis

	Reference scenario	Recycling rate+20%	Recycling rate+40%	Recycling rate+60%
Recycling rate	43.9%	53%	61%	70%



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 46: Influence of the post consumer recycling rate on the beverage carton life cycle (FU: 1000 l, 1 l beverage carton consumed in Sweden set as the reference scenario)

Increasing the post consumer recycling rate of the beverage carton has limited impact on the overall environmental performance of the system. The most sensitive indicator is water consumption with a 10% decrease with a 60% increase of the recycling rate.

This observation is due to the fact that only the cardboard of the beverage carton is recyclable in the LCA model and already recycled at a significant rate in the reference model.

6. COMPARATIVE ASSESSMENT

6.1 PREAMBLE

6.1.1. COMPARABILITY OF THE PACKAGING SYSTEMS

As presented in section 2.4, systems boundaries have been set consistently for all packaging systems. In addition, ISO 14040 requirements in terms of data management and methodology have been closely followed in order to draw meaningful comparison across the different packaging systems.

Nevertheless, the production phase for the glass system only considers raw material production. The bottle formation process from molten glass is not included in the life cycle inventory. These LCI data are based on IPPC 2001 BREF document and were the best available data when the calculations were performed. Still, it has to be mentioned that in May 2010, a new LCA study on glass has been published by the European Container Glass Federation (see section 4.3.1).

In this context**, glass packaging system** is presented in this section 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.

6.1.2. ENVIRONMENTAL INDICATORS

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;
- As it can be seen in section 5, 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.

6.1.3. UNCERTAINTY IN COMPARATIVE LCA

6.1.3.1. Uncertainty sources in LCA

In every Life Cycle Assessment, potential environmental impact indicators are calculated from the listing and quantification of all flows coming in and getting out of the system considered (Life Cycle Inventories) brought back to the chosen functional unit.

To represent it simply, one can say that life cycle inventories are obtained by multiplying standard inventory data from databases (e.g. production of 1kWh of electricity in France) by raw data collected on the system (e.g. amount of electricity required in the fabrication process of a product).

Actually, prior to multiplying the collected data by the standard inventories, these data are adapted to fit to the chosen functional unit and scope of the study. This can involve the use of arbitrary rules to deal with issues such as recycling or co-product allocation.

Therefore, two levels of uncertainty can be differentiated in LCA:

- Uncertainty associated with the **raw data** gathered or measured during the data collection phase. This uncertainty comes out from intrinsic variability between processes (e.g. different bottles weights), representativeness issues, potential measurement errors and loss of information inherent to averaging.

- Uncertainty associated with the **scenarios** chosen for the LCA, that is to say choices regarding system boundaries, allocation procedures, weighting factors.

6.1.3.2. Uncertainties evaluated in the present analysis

Presentation of the data generating uncertainty

In the present study, the uncertainty analysis focuses on:

- Uncertainty associated with the **raw data**. For each system, every raw data being strong determinants — at least 10 times higher than other elements of the same stage or sub stage of the life cycle — 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**. For all the systems, transport distances from filling to hub and hub to retailer are **assumptions**. Regarding glass, distances from fabrication to filling are also assumptions. Therefore an uncertainty analysis is also performed on the distribution phase assuming lower and upper limits for the total length of the supply chain.

Moreover, note that uncertainty analysis regarding allocation procedure to take into account recycling are not performed in this part, since a specific sensitivity analysis is already performed in section 6.3.2 in order to evaluate the effect of the various rules for allocation of recycling.

Presentation of the statistical model for uncertainty analysis

In order to determine the uncertainties on the values employed as parameters in the LCA model, statistical distributions have been defined. Depending on the source of the figure — primary data collected directly from the partners; secondary data based on bibliography and assumptions — the statistical distribution have been parameterized differently since a higher uncertainty is assumed for secondary data. Characteristics of the selected statistical distributions are presented in the next table.

Table 54: Statistical model for uncertainty analysis

Statistical distribution	Primary data	Secondary data
Mean (μ)	Figure provided by the partners	Figure found in literature or assumption
Standard deviation (σ)	10%	20%
Probability distribution	Normal distribution	
Lower bound	$\mu + 2\,\sigma$	
Upper bound	$\mu - 2\,\sigma$	
Description	If data distribution for the considered raw data is approximately normal and the assumptions made when parameterizing the distribution are reasonable then about 95 % of the values are within the interval [μ - 2σ ; μ + 2σ] which corresponds to [μ - 0.2 μ ; μ + 0.2 μ]	If data distribution for the considered raw data is approximately normal and the assumptions made when parameterizing the distribution are reasonable then about 95 % of the values are within the interval [μ - 2σ ; μ + 2σ] which corresponds to [μ - 0.4 μ ; μ + 0.4 μ]

Presentation of the worst case and best case scenarios

The next table presents the lower and upper bounds of the specific "uncertainty determinants" identified for each system. These lower/upper bounds are employed to calculate the impacts of theoretical best case / worst case scenarios.

Table 55: Presentation of the best case / worst case scenarios for each system

Type of data	Unit	PET Bottle 75 cl	PET Bottle 37,5 cl	Data source	Glass bottle 75 cl	Glass bottle 37,5 cl	Data source	Bag in Box 1,5L	Bag in Box 2L	Bag in Box 3L	Bag in Box 5L	Bag in Box 10L	Data Source	Stand Up Pouch 3L	Stand Up Pouch 1,5L	Stand Up Pouch 1L	Data Source	Beverage carton Elopak 1L	Beverage carton Elopak 75cl	Beverage carton Elopak 50cl	Beverage carton Elopak 25cl	Data source	Beverage carton Tetrapak 1L	Beverage carton Tetrapak 75cl	Beverage carton Tetrapak 50cl	Beverage carton Tetrapak 25cl	Data source
Description of primary packaging																											
Principal materials																											
Material 1																											
Name		PET	PET		Green glass	Green glass		Cardboard	Cardboard	Cardboard	Cardboard	Cardboard		LDPE extrusion	LDPE extrusion	LDPE extrusion		Cardboard	Cardboard	Cardboard	Cardboard		Cardboard	Cardboard	Cardboard	Cardboard	
Weight	**[g]**	**mean**	**mean**	**Primary**	**mean = 472**	**mean = 302**	**Primary**	**mean**	**mean**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**mean**	**Primary**
Weight - Lower bound	[g]	mean - 20%	mean - 20%	N/A	350	250	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A
Weight - Upper bound	[g]	mean + 20%	mean + 20%	N/A	600	353	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A
Material 2		N/A			N/A			Not determinant						Not determinant													
Name																		LDPE extrusion	LDPE extrusion	LDPE extrusion	LDPE extrusion		LDPE extrusion	LDPE extrusion	LDPE extrusion	LDPE extrusion	
Weight	**[g]**																	**mean**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**mean**	**Primary**
Weight - Lower bound	[g]																	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A
Weight - Upper bound	[g]																	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A
Fabrication of the primary package		Not determinant			N/A			Not determinant										Not determinant					Not determinant				
Country														France	France	France											
Electricity	**[MJ]**													**mean**	**mean**	**mean**	**Primary**										
Electricity - Lower bound	[MJ]													mean - 20%	mean - 20%	mean - 20%	N/A										
Electricity - Upper bound	[MJ]													mean + 20%	mean + 20%	mean + 20%	N/A										
Other materials																											
Tap		Not determinant			Not determinant													Not determinant					Not determinant				
Total weight	[g]							16.21	16.21	16.21	16.21	16.21	-	12.25	12.25	12.25	-										
Material 1																											
Name								PP	PP	PP	PP	PP		PP	PP	PP											
Weight	**[g]**							**mean**	**mean**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**Primary**										
Weight - Lower bound	[g]							mean - 20%	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	N/A										
Weight - Upper bound	[g]							mean + 20%	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	N/A										
Material 2																											
Name								LDPE	LDPE	LDPE	LDPE	LDPE		LDPE	LDPE	LDPE											
Weight	**[g]**							**mean**	**mean**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**Primary**										
Weight - Lower bound	[g]							mean - 20%	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	N/A										
Weight - Upper bound	[g]							mean + 20%	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	N/A										
Labels		Not determinant			Not determinant			N/A						N/A									N/A				
Filling stage																											
Filling		Not determinant			Not determinant			Not determinant						Not determinant				Not determinant					Not determinant				
Country																											
Electricity	**[MJ]**																										
Electricity - Lower bound	[MJ]																										
Electricity - Upper bound	[MJ]																										
Description of secondary packaging																											
Cardboard box											N/A	N/A											N/A				
Number of products per box		12	12	Primary	6	12	Primary	6	6	4	12	12	Primary	6	6	12	Primary	12	16	24	48	Primary					
Weight	**[g]**	**mean**	**mean**	**Primary**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**mean**	**Primary**					
Weight - Lower bound	[g]	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A					
Weight - Upper bound	[g]	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A					
Filmed cardboard box		N/A			N/A			N/A						N/A				N/A					N/A				
Number of products per box																							6	6	6	6	Primary
Cardboard box																											
Weight	**[g]**																						**mean**	**mean**	**mean**	**mean**	**Primary**
Weight - Lower bound	[g]																						mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A
Weight - Upper bound	[g]																						mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A
HDPE film																											
Weight	**[g]**																										
Weight - Lower bound	[g]																										
Weight - Upper bound	[g]																										
Transport stages																											
Fabrication of primary packaging -> filling stage																											
Truck (calculated load)	[km]																										
Distance	**[km]**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**mean**	**Primary**	**mean**	**mean**	**mean**	**mean**	**Primary**
Distance - Lower bound	[km]	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A	mean - 20%	mean - 20%	mean - 20%	mean - 20%	N/A
Distance - Upper bound	[km]	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A	mean + 20%	mean + 20%	mean + 20%	mean + 20%	N/A
Filling stage -> distribution hub																											
Truck (calculated load)	[km]																										
Distance	**[km]**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**mean**	**Secondary**
Distance - Lower bound	[km]	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	mean - 40%	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	mean - 40%	mean - 40%	N/A
Distance - Upper bound	[km]	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	mean + 40%	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	mean + 40%	mean + 40%	N/A
Distribution hub -> retailers																											
Truck (calculated load)	[km]																										
Distance	**[km]**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**mean**	**Secondary**	**mean**	**mean**	**mean**	**mean**	**Secondary**
Distance - Lower bound	[km]	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	mean - 40%	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	mean - 40%	mean - 40%	N/A	mean - 40%	mean - 40%	mean - 40%	mean - 40%	N/A
Distance - Upper bound	[km]	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	mean + 40%	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	mean + 40%	mean + 40%	N/A	mean + 40%	mean + 40%	mean + 40%	mean + 40%	N/A

6.2 COMPARISON OF PACKAGING SYSTEMS

6.2.1. PRESENTATION FORMAT

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.

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

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

Based on these uncertainty calculations, it is considered that robust conclusions can be drawn when comparing two systems A and B when their respective uncertainty intervals are not overlapping. In other words, the assertion “A has less environmental impacts than B” is robust only if A worst case scenario is below B best case scenario.

Note that in annex 4 other intervals are presented. They are based on the same theoretical best case / worst case scenarios presented in this section except for transportation distances where the reference values are employed instead. This is done to evaluate the share of variability that is not due to uncertainty on transportation distances.

6.2.2. GLOBAL WARMING POTENTIAL

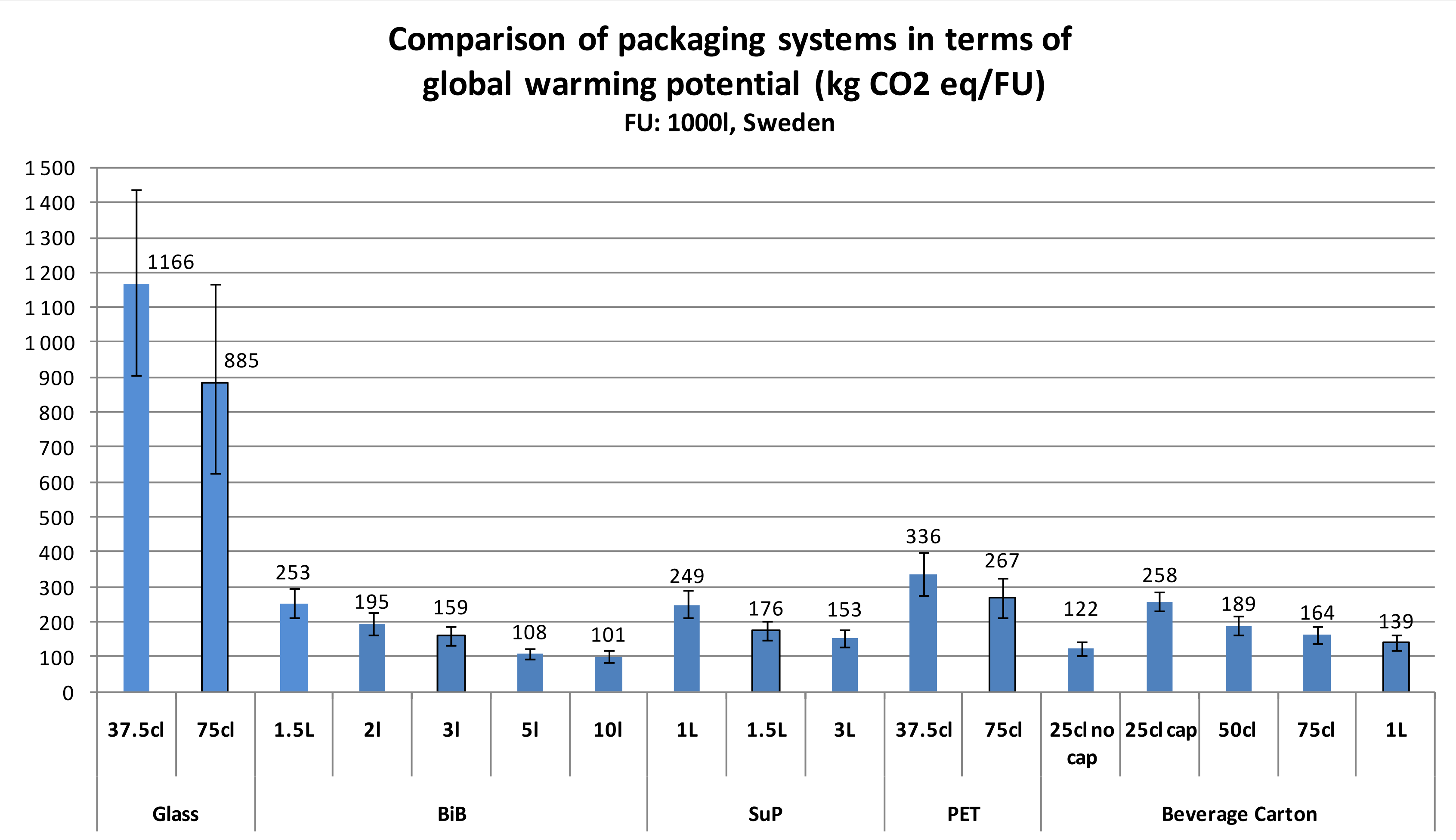


Figure 47: Comparison of packaging systems in terms of global warming potential in Sweden

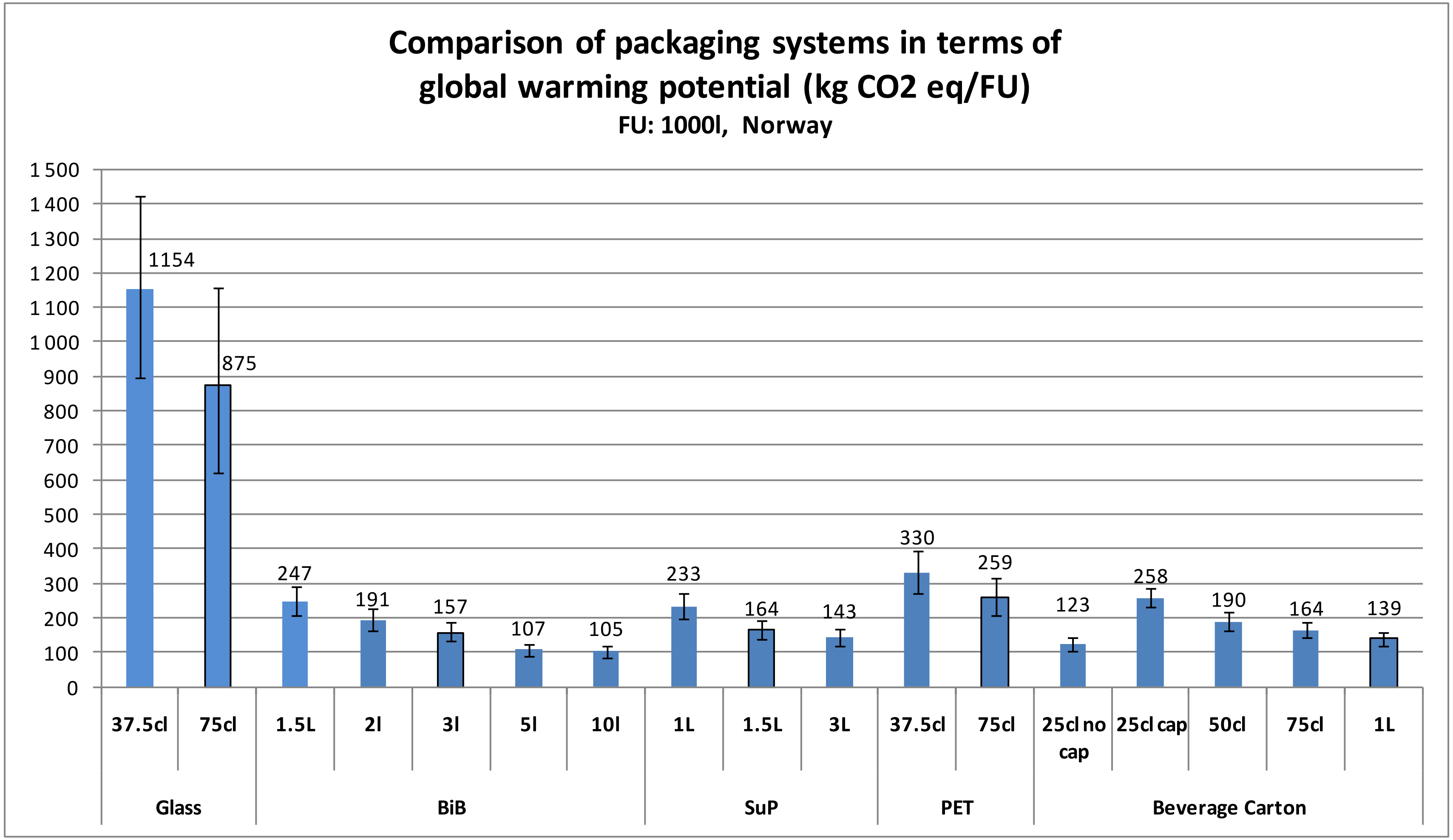


Figure 48: Comparison of packaging systems in terms of global warming potential in Norway

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 37.5 cl and 75 cl glass bottles are the most impacting packaging system. The difference of their respective performances is smaller than the uncertainty.

The 1 l pouch life cycle is more impacting than the 1 l beverage carton. This is mainly due to three factors. Firstly, the closure system is more complex and heavier in the SuP system and more secondary packaging is used, which entails more impacts at all stages. Secondly, the SuP is not recycled and additional materials are therefore even more impacting. Lastly, as fewer pallets are necessary per functional unit in the beverage carton system, the distribution stage is less impacting.

The 1 l beverage carton system performs better than the 1.5 l BiB as less material (primary and secondary packaging) is necessary in the beverage carton system per functional unit, which means that impacts over the complete life cycle are reduced. When looking at bigger volumes for the BiB, only the 5 l and 10 l BiB systems are likely to perform better than the 1 l beverage carton. For these volumes, fewer pallets are needed per functional unit and they require no secondary packaging. Note that 5 l and 10 l BiBs cannot be categorically differentiated, the difference between these two formats is smaller than the uncertainty. This is due to the fact that the amount of primary packaging and number of pallets per functional unit are almost identical in the two systems.

The packaging systems in Norway show similar trends.

6.2.3. AIR ACIDIFICATION

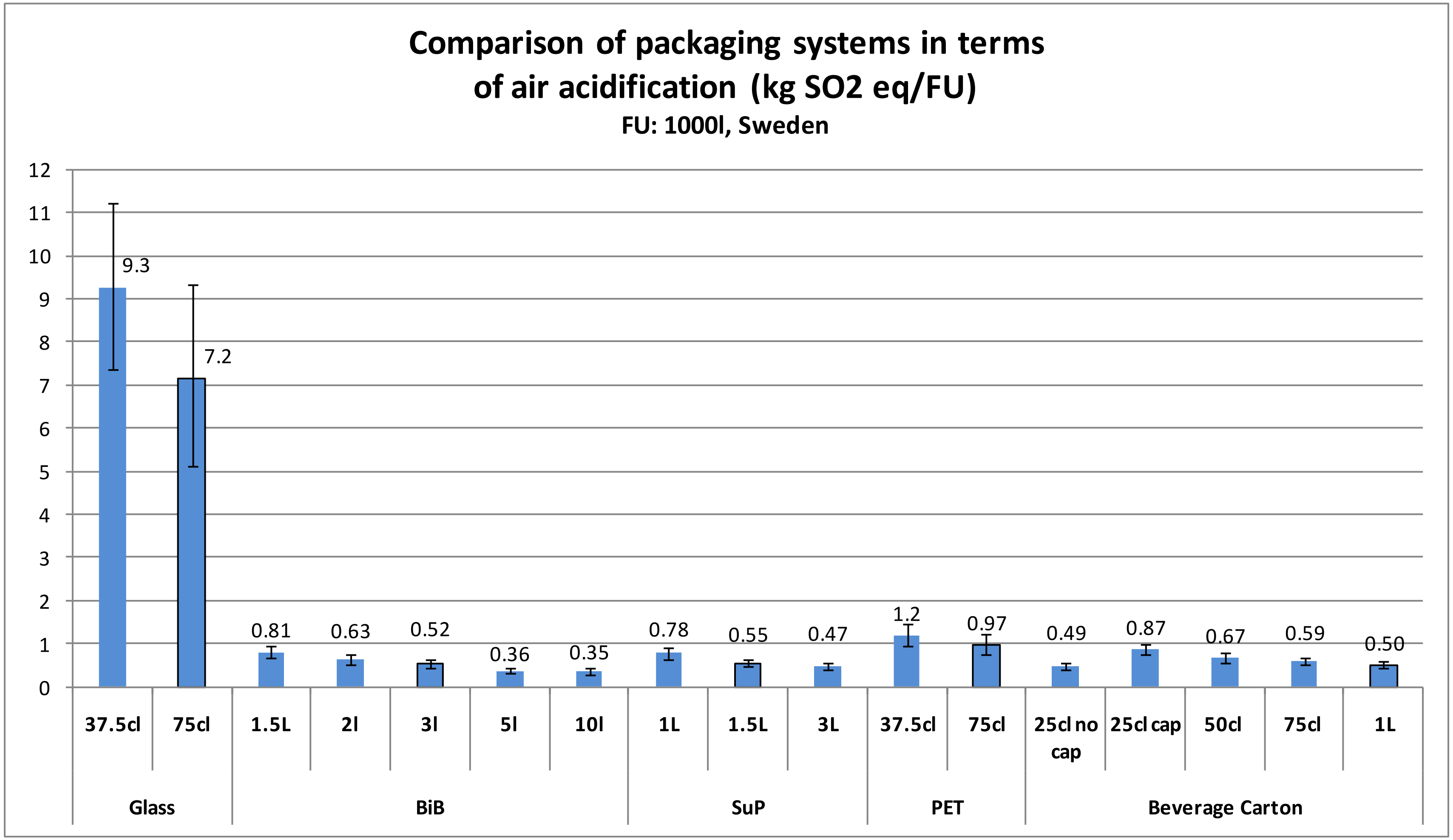


Figure 49: Comparison of packaging systems in terms of air acidification in Sweden

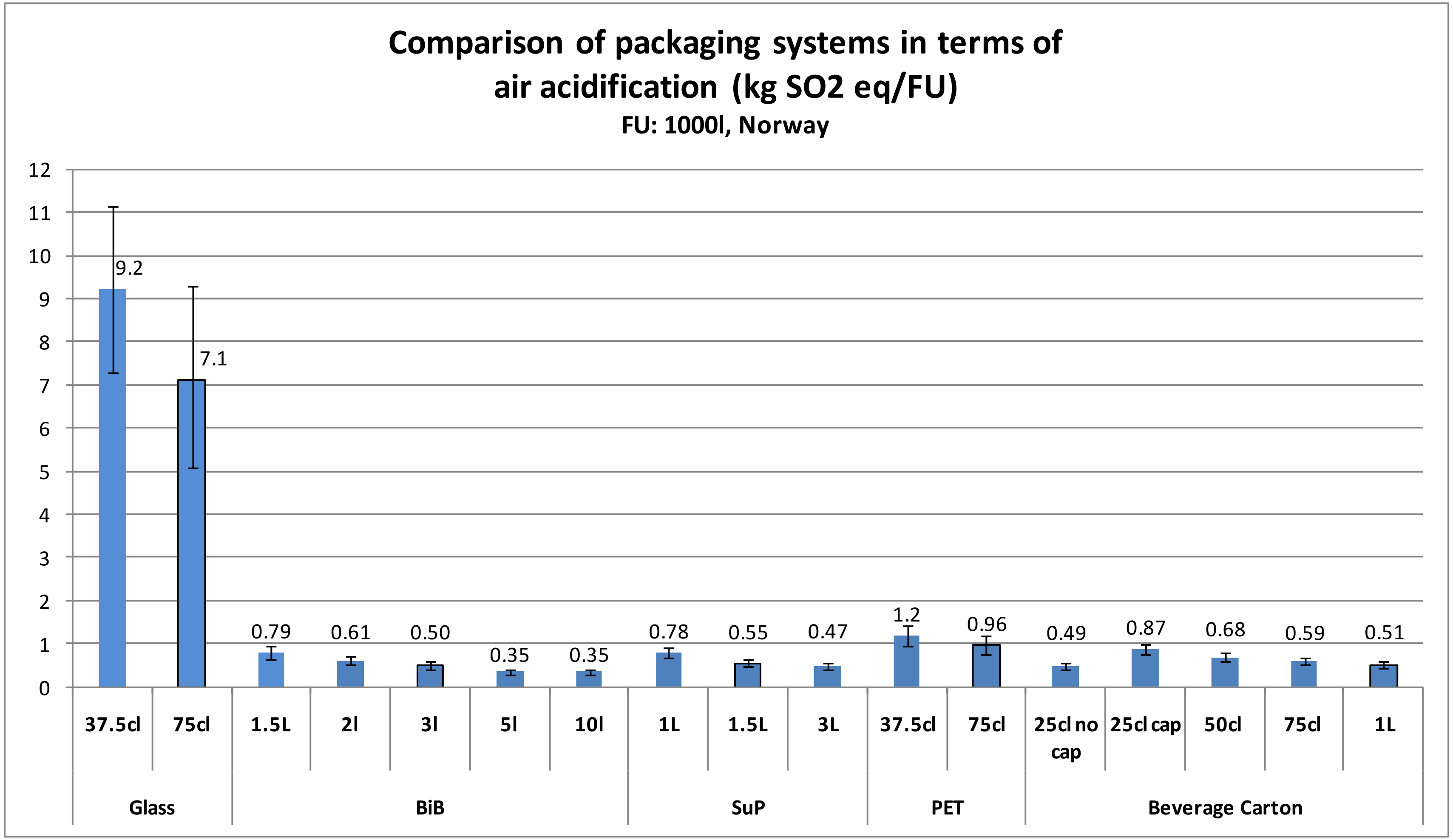


Figure 50: Comparison of packaging systems in terms of air acidification in Norway

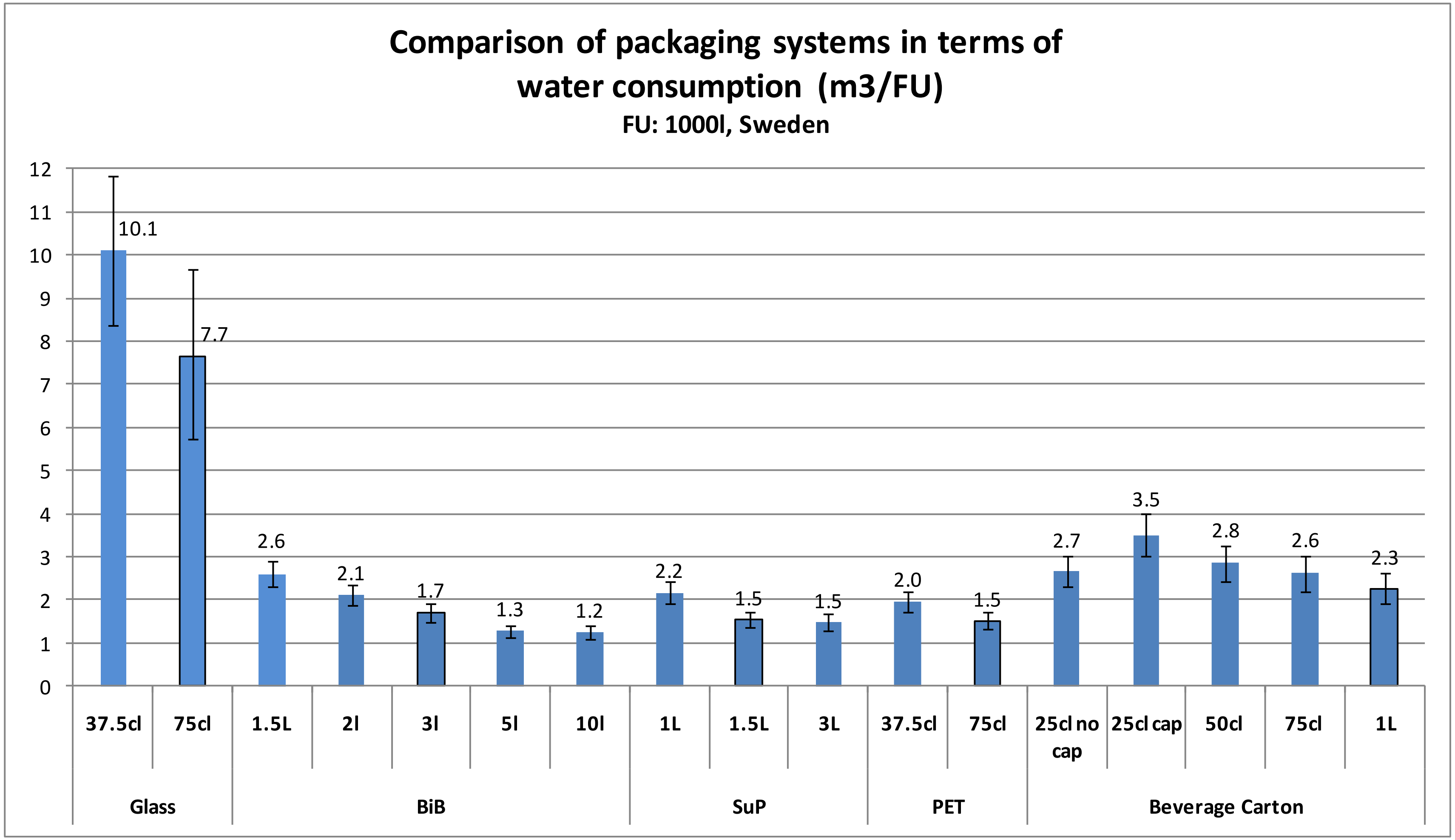
Note that for this indicator, results show less variability across the different capacity of a similar packaging system. General trend observed for global warming is still valid but the relative differences are particularly low and conclusions should be made with caution: within a same packaging system,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

The 37.5 cl and 75 cl glass bottles are the most impacting packaging system. The difference of their respective performances is smaller than the uncertainty.

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

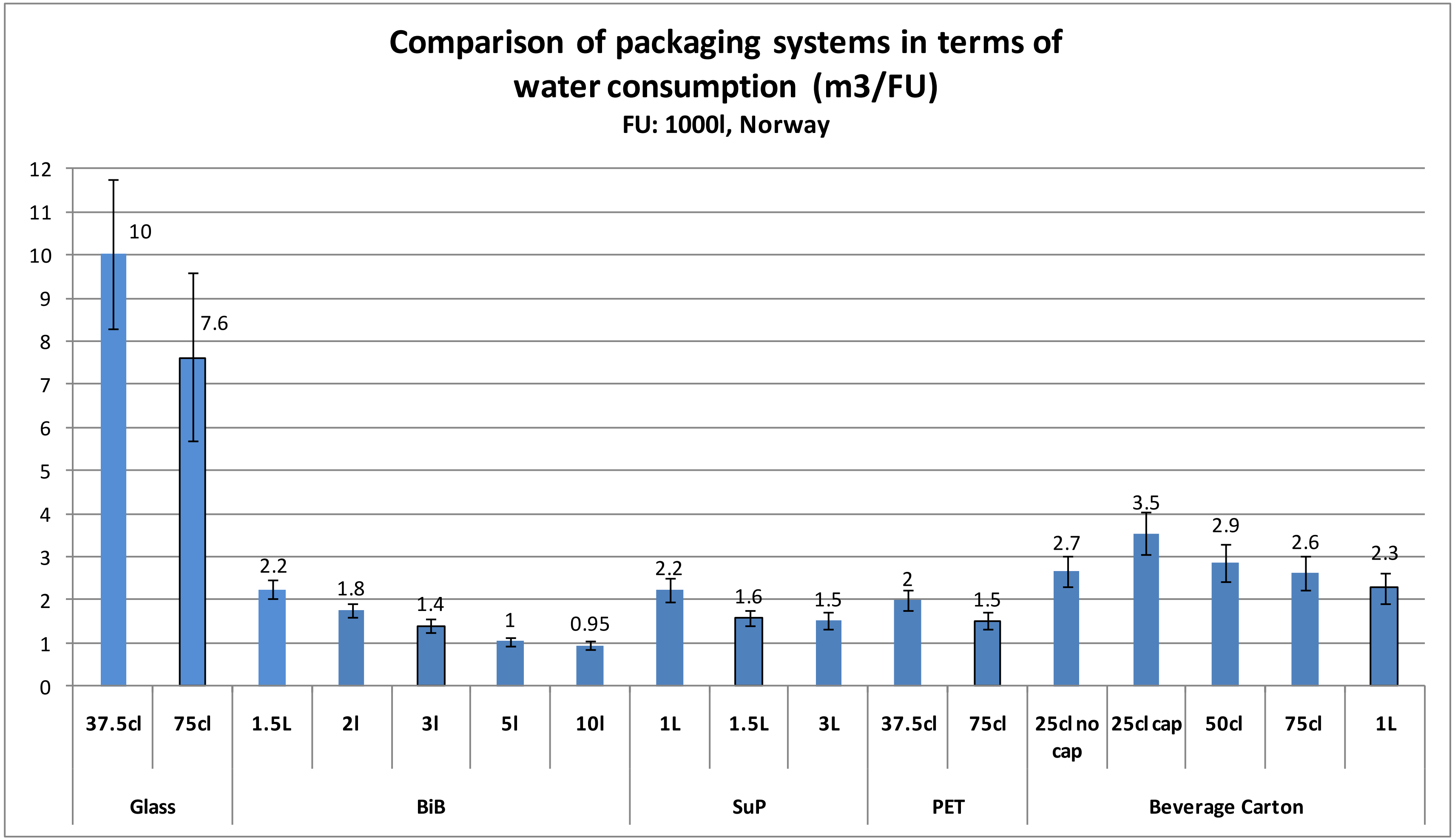
In Norway, the relative performances of the packaging systems are identical to Sweden. This is due to the important impacts of the fabrication stage on the acidification indicator (the same fabrication stage is considered for both countries).

6.2.4. WATER CONSUMPTION



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 51: Comparison of packaging systems in terms of water consumption in Sweden



Water consumption indicator in LCA study presents various methodological limits, see text box in section

Figure 52: 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. The 37.5 cl glass bottle, 75 cl glass bottle are the most impacting packaging systems. The difference of their respective performances is smaller than the uncertainty.

Bag in Box, SuP and beverage carton appear to have similar impacts in term of water consumption for close formats (overlapping uncertainties are observed). This is due to the important water requirements of cardboard production.

Concerning the Bag in Box and Stand up Pouch systems, most of the impacts occur during the production stage are related to cardboard production, while less cardboard is needed for the SuP than for the BiB in terms of primary packaging, the opposite is true in terms of secondary packaging, as a consequence, both systems tends to have similar impacts. Note than in Norway, the Bag in Box system tends to perform slightly better than in Sweden due to a higher recycling rate.

PET being a material less impacting than cardboard in terms of water consumption, the PET system tends to perform better than the beverage carton, even when comparing the 37.5 cl format with the 25 cl format without a cap. The 75 cl PET bottle appears less impacting than the 1 l beverage carton, 1.5 l BiB and1 l SuP.

As a general comment regarding this indicator, one can underline that the relative performances of the packaging systems are tightly linked with the water requirements of cardboard production. Though best available LCI data were used, important variations could be seen between cardboard from integrated and non integrated mills. In the LCA model, production of liquid packaging board (used in beverage carton) requires three times more water than production of corrugated cardboard.

6.2.5. ABIOTIC DEPLETION

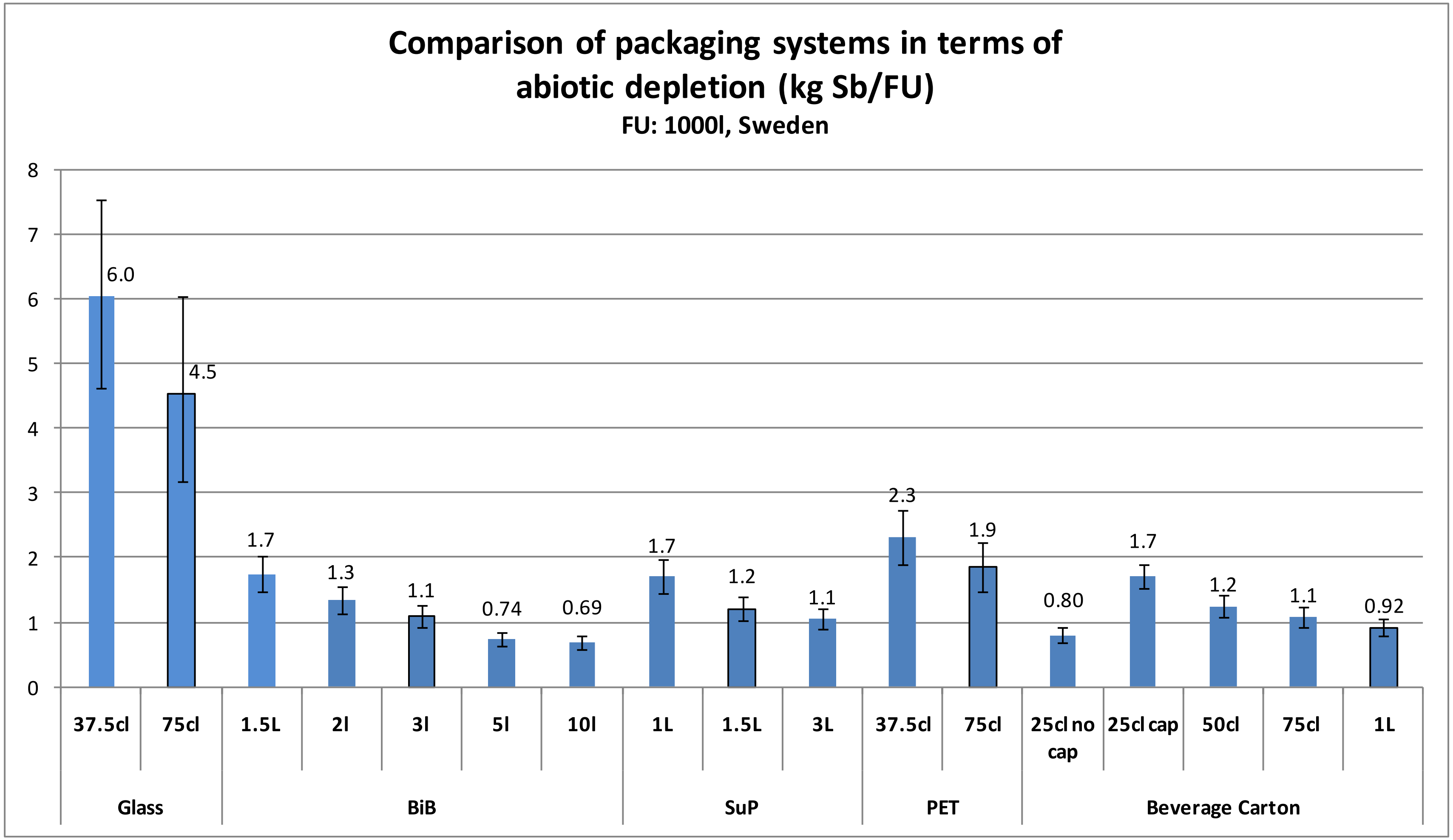


Figure 53: Comparison of packaging systems in terms of abiotic depletion in Sweden

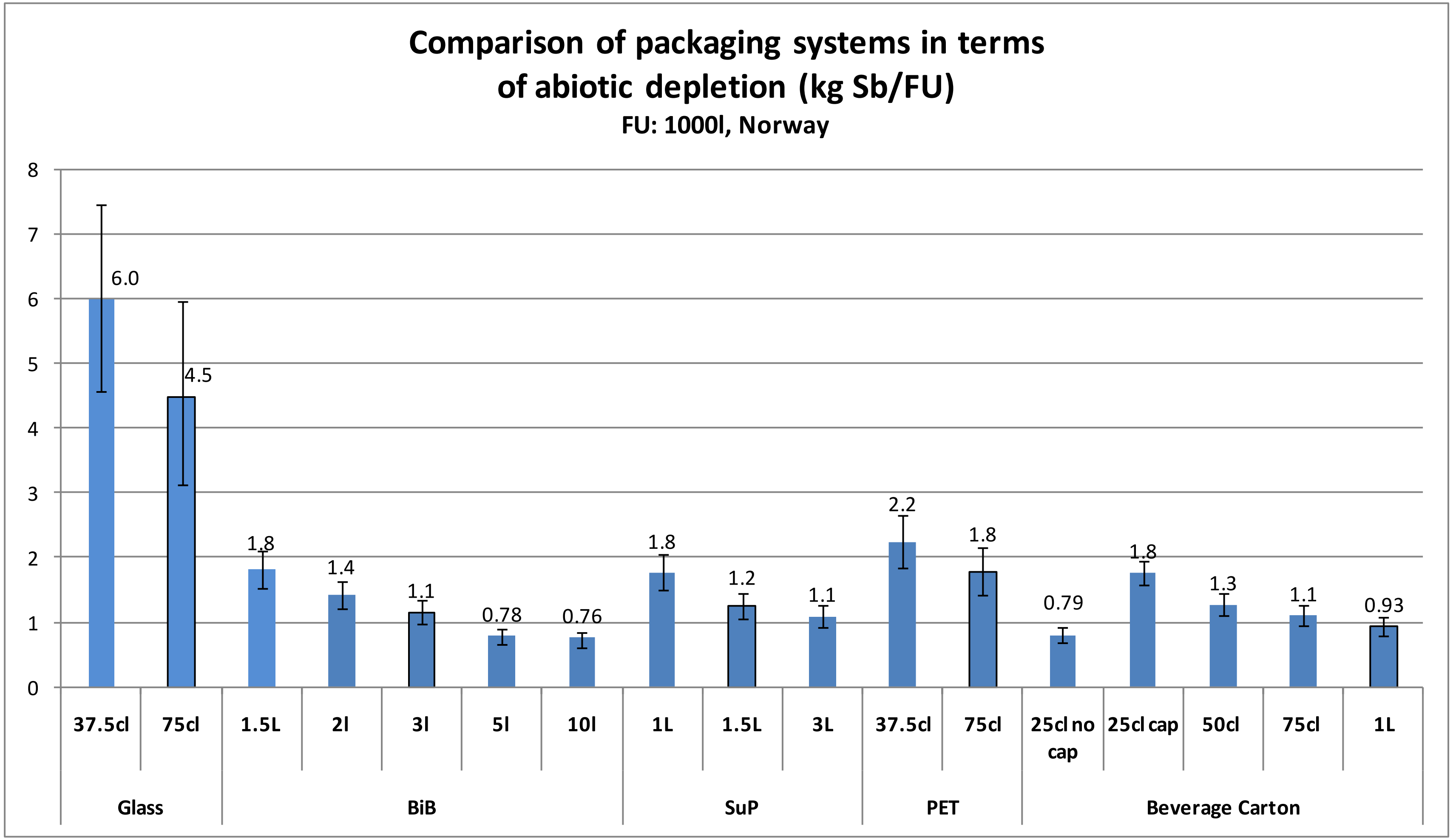


Figure 54: Comparison of packaging systems in terms of abiotic depletion in Norway

In terms of abiotic depletion, the relative performance of the packaging systems is identical in Sweden and in Norway. The 37.5 cl and 75 cl glass bottles are the most impacting packaging system. The difference of their respective performances is smaller than the uncertainty.

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 the difference of respective performances is higher than the uncertainty.

6.2.6. PRIMARY ENERGY

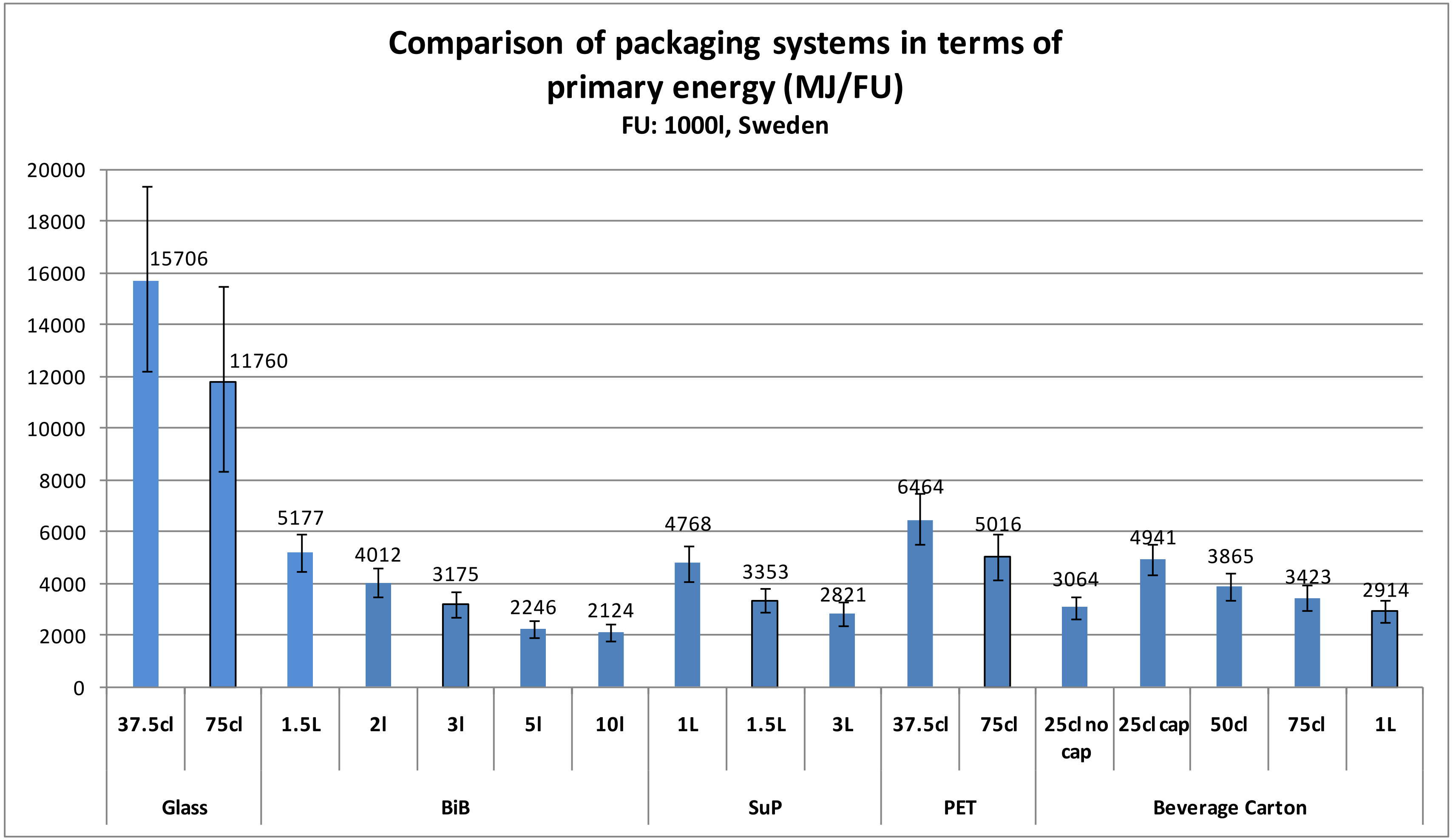


Figure 55: Comparison of packaging systems in terms of primary energy in Sweden

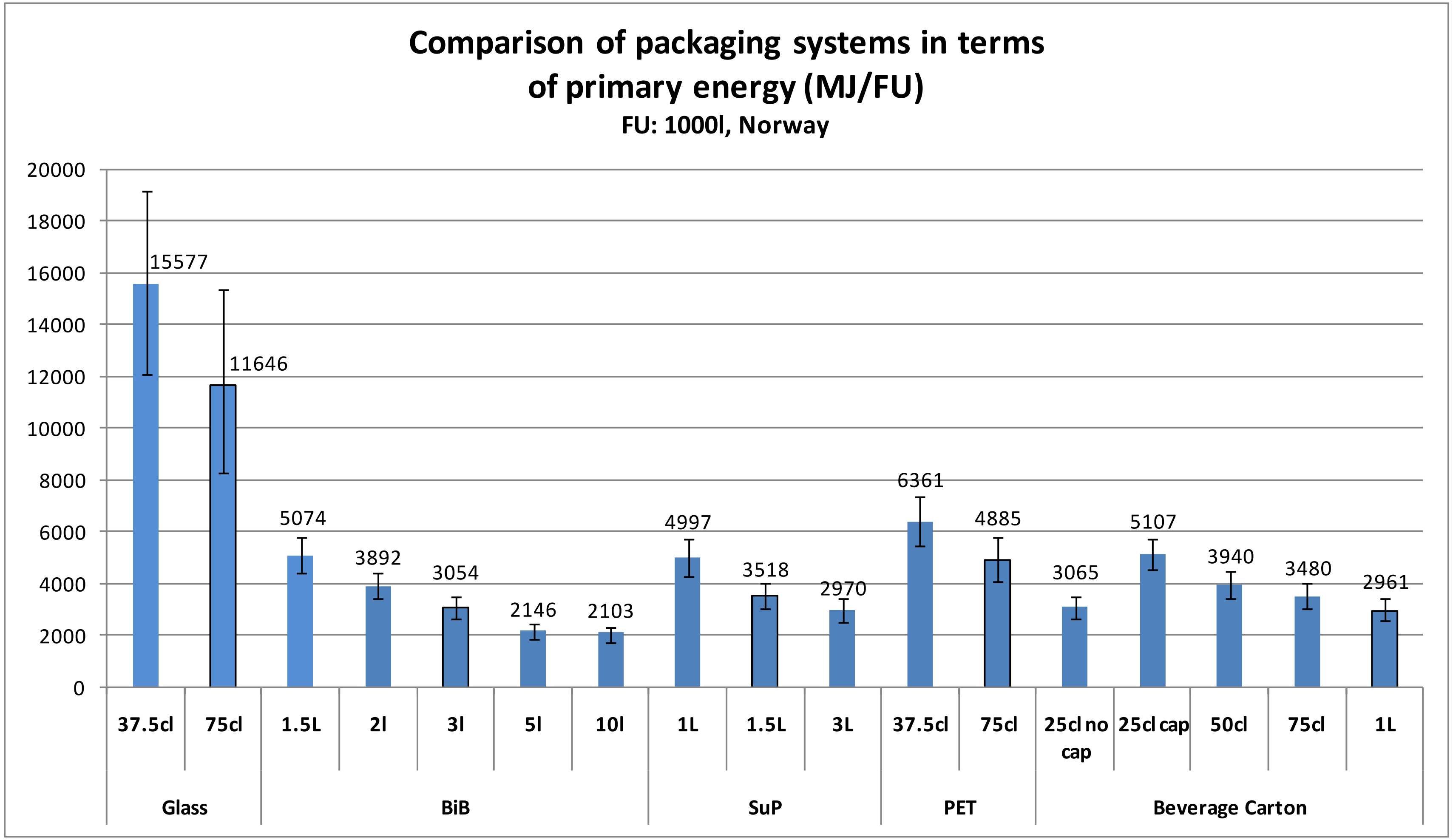


Figure 56: Comparison of packaging systems in terms of primary energy in Norway

The 37.5 cl glass bottle, 75 cl glass bottle are the most impacting packaging systems. The difference of their respective performances is smaller than the uncertainty.

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.

6.2.7. Summary

6.2.7.1. Comparison of the different packaging systems — Format with the lowest impacts set to 100

The next table summarises this comparative section. For each indicator and each country, the packaging format with the lowest impacts has been set to 100 and the other packaging scaled accordingly. Once again, one can see that the biggest format (BiB 10 l) is the less impacting one as less material per functional unit is required.

Due to the reduced impacts of larger volumes and high number of different capacities under study, general conclusions should be made with caution.

Table 56: Comparison of the different packaging system normalised to the lowest format for each country and indicator

Packaging system	Volume	Global warming potential		Air acidification potential		Abiotic resources depletion potential		Water consumption		Primary energy	
		Sweden	Norway	Sweden	Norway	Sweden	Norway	Sweden	Norway	Sweden	Norway
Glass	37.5cl	1158	1097	2629	2642	882	787	809	1059	740	741
	75cl	**878**	**831**	**2031**	**2040**	**662**	**590**	**613**	**802**	**554**	**554**
Bag-in-box	1.5l	251	235	230	226	253	239	208	236	244	241
	2l	194	182	180	175	195	185	170	186	189	185
	3l	**158**	**149**	**148**	**144**	**159**	**151**	**137**	**148**	**149**	**145**
	5l	107	101	103	100	107	103	103	109	106	102
	10l	100	100	100	100	100	100	100	100	100	100
Stand-up-pouch	1l	247	221	220	225	249	232	174	236	225	238
	1.5l	**174**	**156**	**156**	**159**	**176**	**164**	**123**	**167**	**158**	**167**
	3l	152	136	133	135	153	143	118	159	133	141
PET bottle	37.5cl	334	314	338	337	338	295	158	209	304	302
	75cl	**265**	**246**	**276**	**275**	**270**	**234**	**121**	**159**	**236**	**232**
Beverage carton	25cl no cap	121	117	138	140	116	105	213	281	144	146
	25cl cap	256	245	246	251	250	231	281	374	233	243
	50cl	188	180	191	194	182	167	228	302	182	187
	75cl	162	156	167	170	158	144	210	278	161	165
	1l	**138**	**132**	**143**	**145**	**134**	**122**	**182**	**240**	**137**	**141**

Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

6.2.7.1. Comparison of the different packaging systems — Normalisation of LCA results by main stages

The next charts are another summarized view of this comparative section. They show 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).

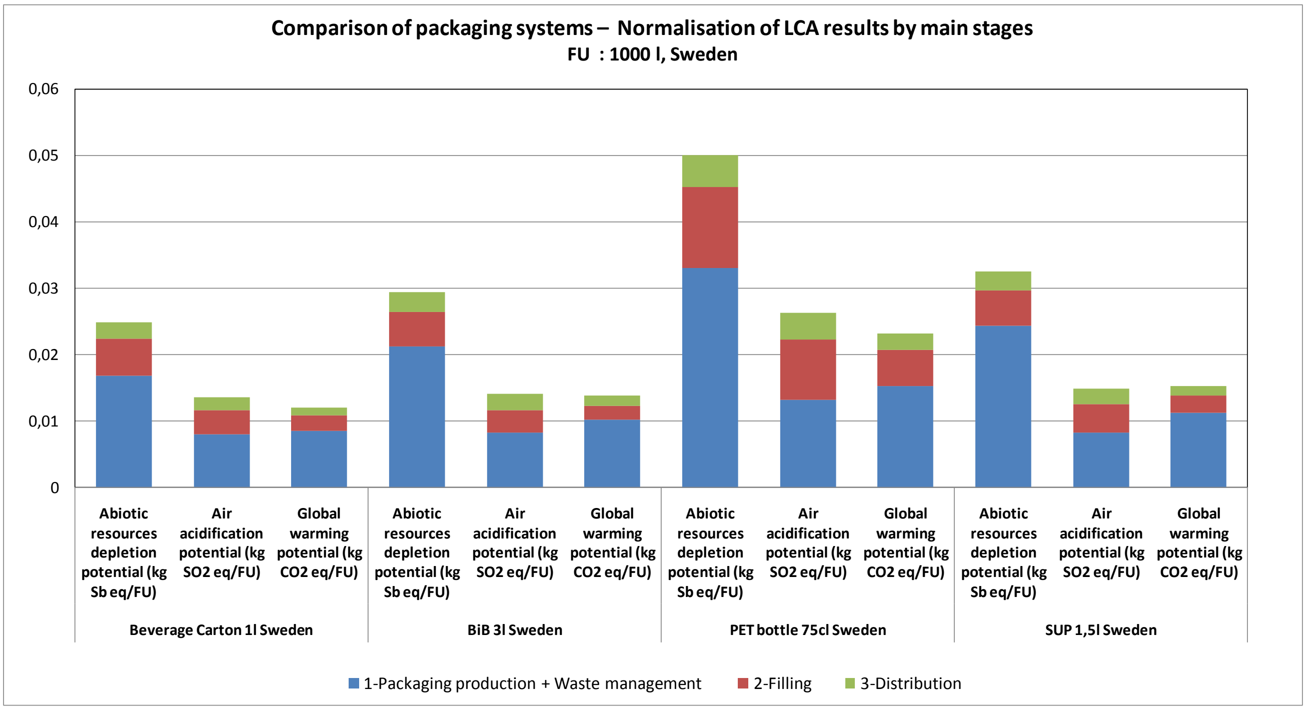


Figure 57: Comparative normalisation of LCA results by main stages, Sweden

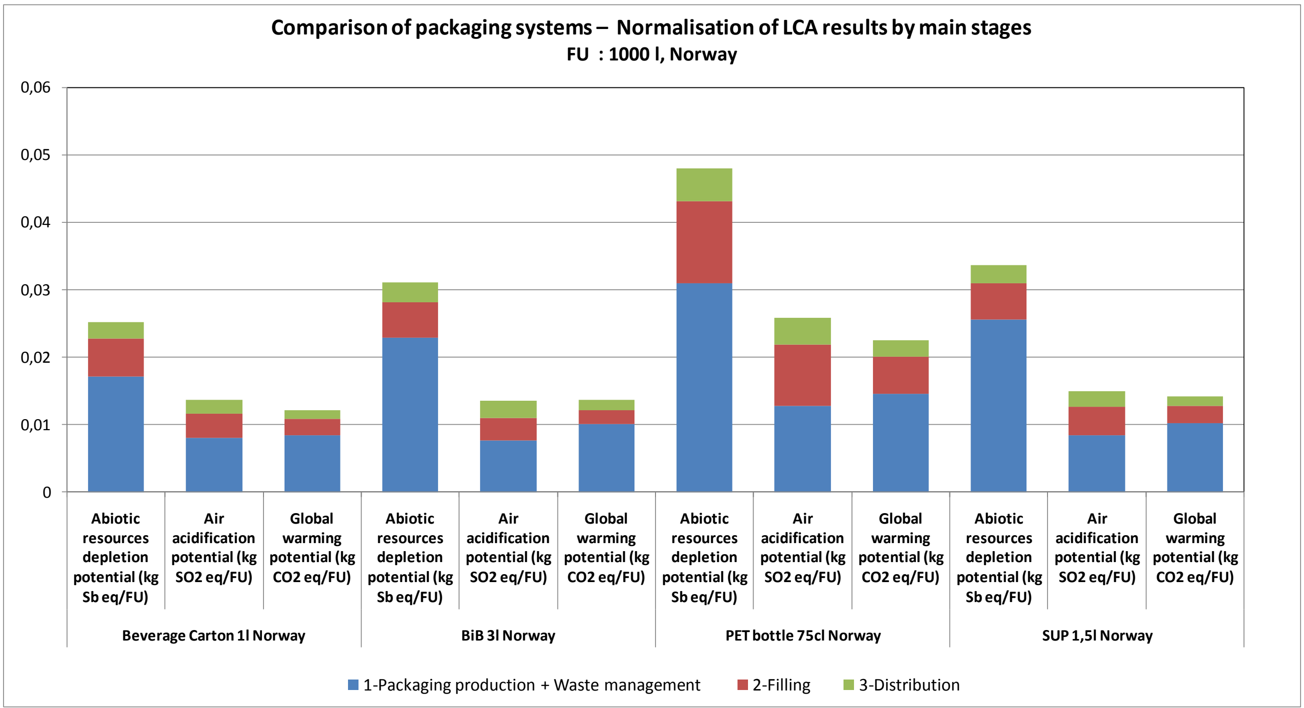


Figure 58: Comparative normalisation of LCA results by main stages, Norway

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.

6.3 COMPLEMENTARY ANALYSIS AND SENSITIVITY ANALYSIS

6.3.1. COMPLEMENTARY ANALYSIS: TRANSPORT OF FILLED PACKAGES

6.3.1.1. Presentation of the analysis

In this section 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 (stages 4 and 5 described in section 4.2.3.1).

In order to put emphasis on the variations between systems and volumes, a fixed amount corresponding to the transportation impacts of the system with the lowest transportation impacts have been withdrawn to all systems and volumes.

The system with the lowest transportation impacts is the beverage carton system 1 of 25 cl. Impacts of the transport of filled packages in the present analysis have been calculated using the following formula:

Impacts of the transport of filled packages /unit =

$$m_{system} \times d_{system} \times Impacts_{system}$$

$$-$$

$$m_{ref} \times d_{ref} \times Impacts_{ref}$$

With:

m_{system} = the mass, per functional unit, of the filled package of the considered system and format

d_{system} = distance of transportation of the considered system and format

$Impacts_{system}$ = Impacts for the considered system and format calculated with the specific road transport model presented in section 4.2.3.2.

m_{ref} = the mass, per functional unit, of wine in a beverage carton system 1 of 25 cl

d_{ref} = distance of transportation of a beverage carton system 1 of 25 cl

$Impacts_{ref}$ = Impacts for the beverage carton system 1 of 25 cl calculated with the specific road transport model presented in section 4.2.3.2.

6.3.1.2. Presentation of the results

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.

Relative results are presented with beverage carton 25 cl with no cap set to 100.

- Global warming potential

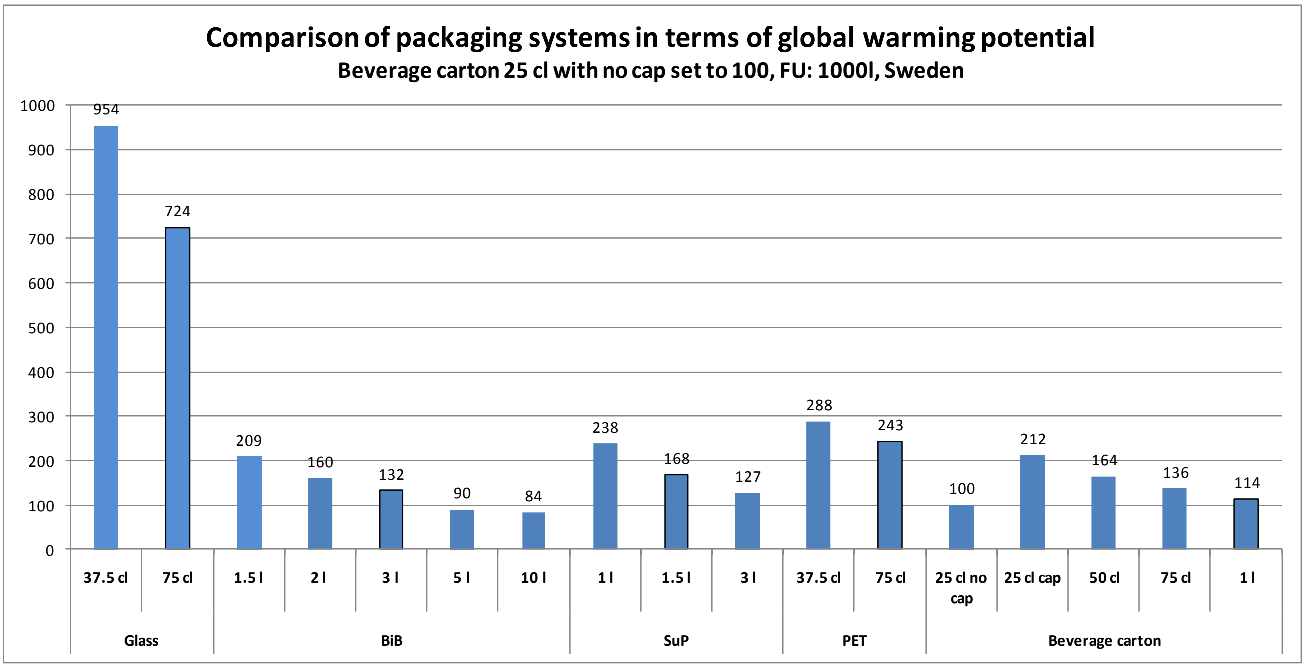


Figure 59: Comparison of packaging systems in terms of global warming potential in Sweden

— Impact of transport taken into account —

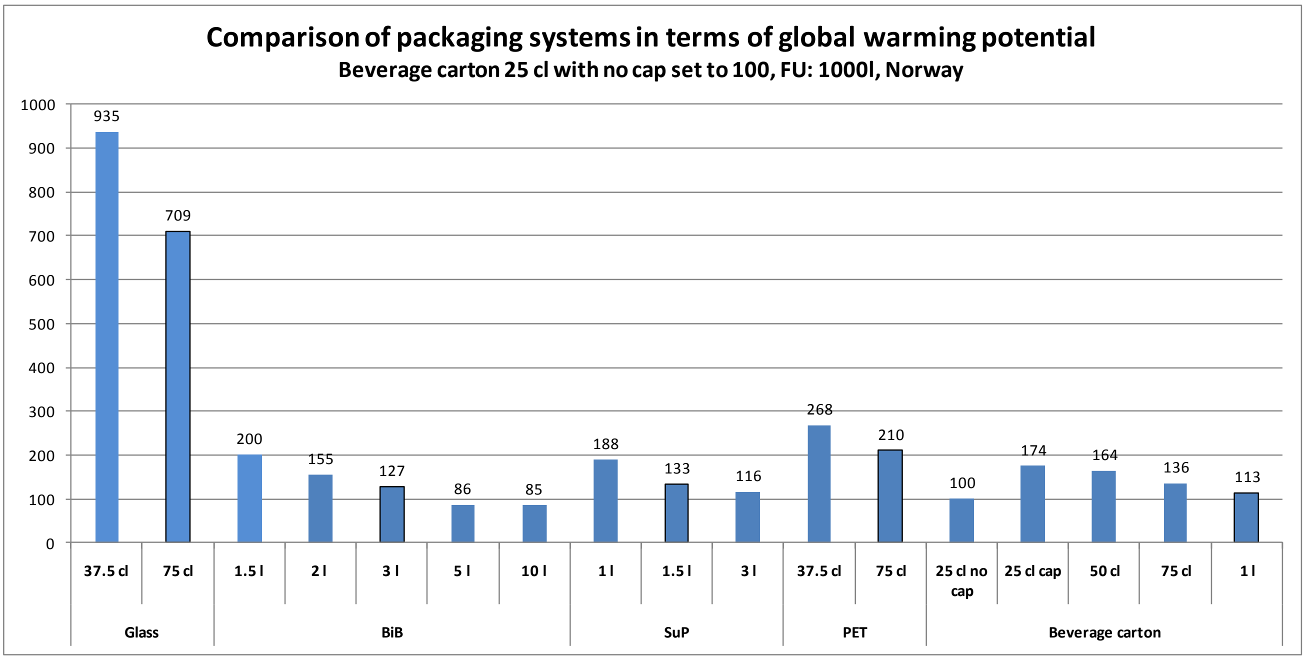


Figure 60: Comparison of packaging systems in terms of global warming potential in Norway

— Impact of transport taken into account —

- Abiotic depletion

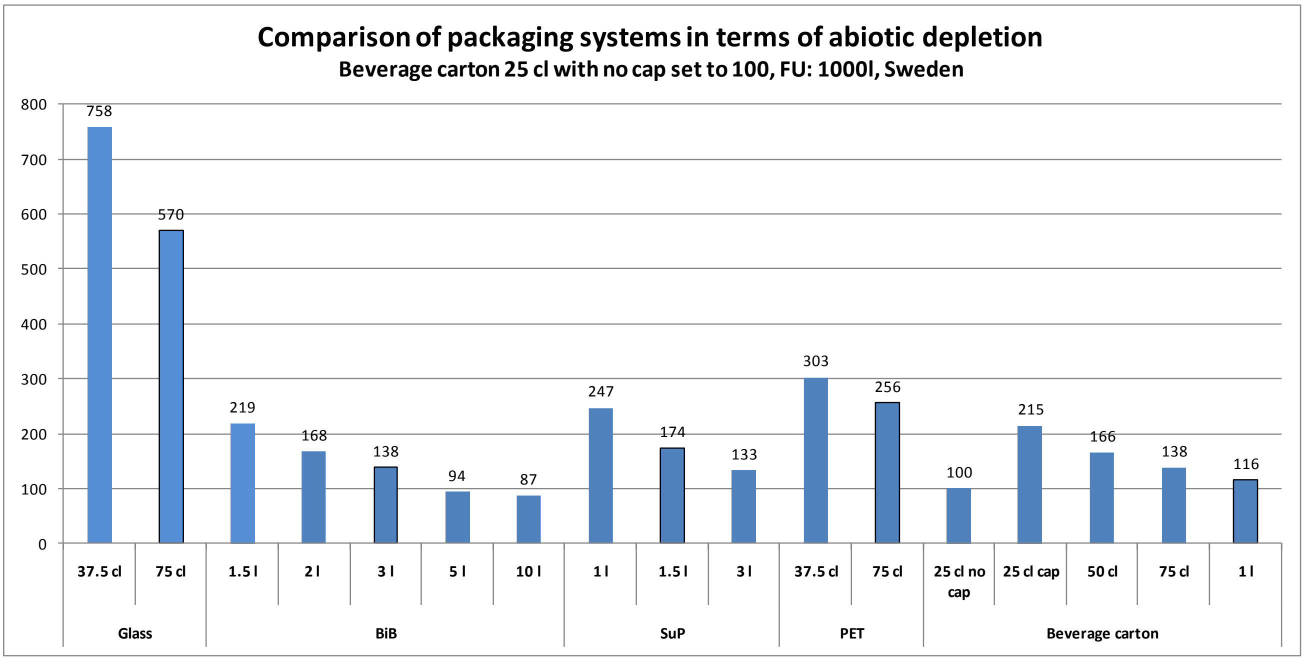


Figure 61: Comparison of packaging systems in terms of abiotic depletion in Sweden

— Impact of transport taken into account —

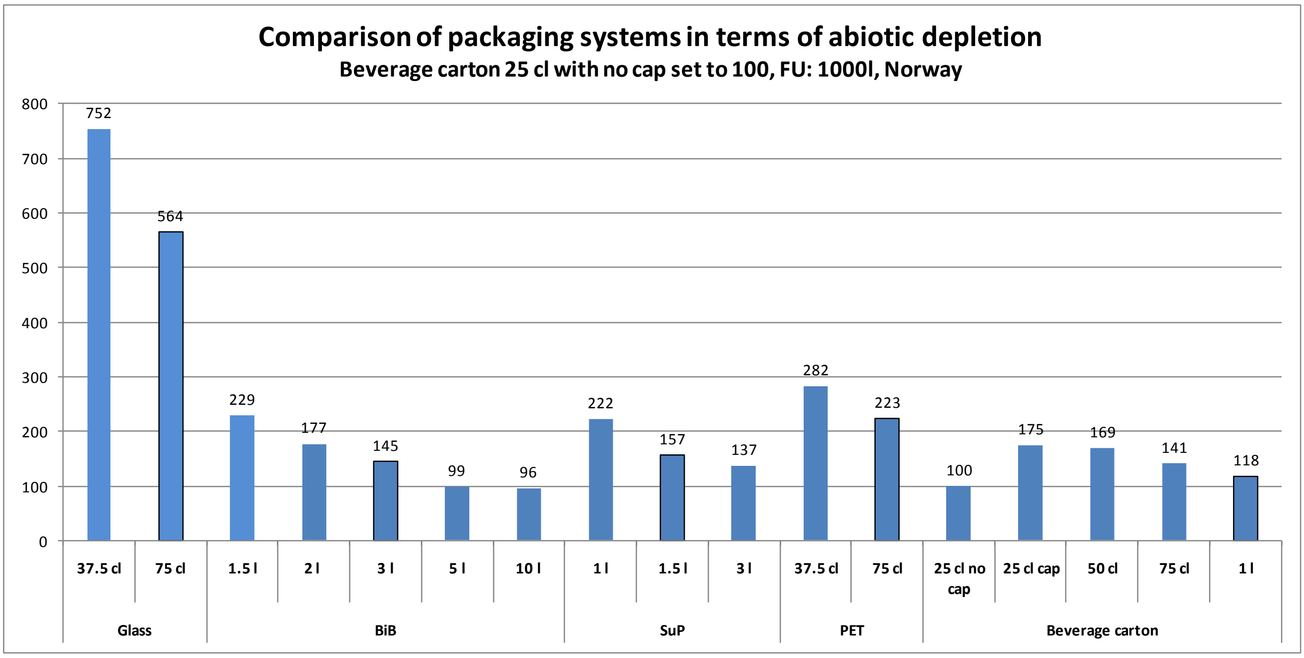


Figure 62: Comparison of packaging systems in terms of abiotic depletion in Norway

— Impact of transport taken into account —

- Air acidification

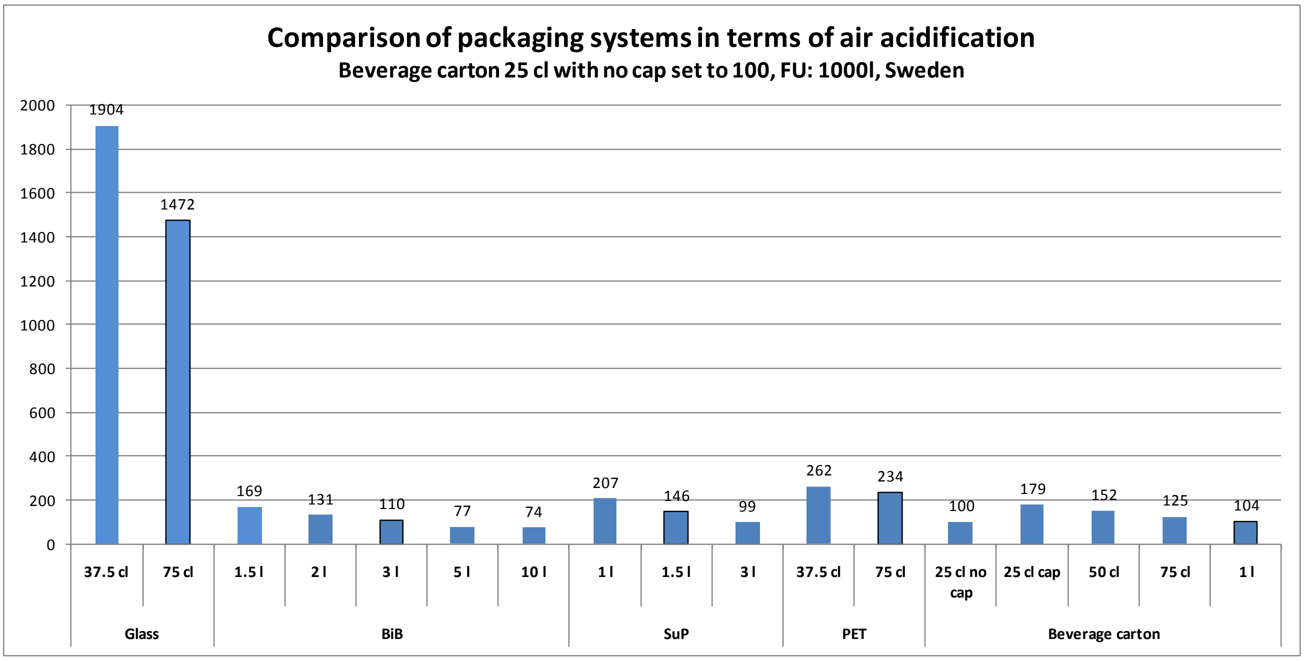


Figure 63: Comparison of packaging systems in terms of air acidification in Sweden

— Impact of transport taken into account —

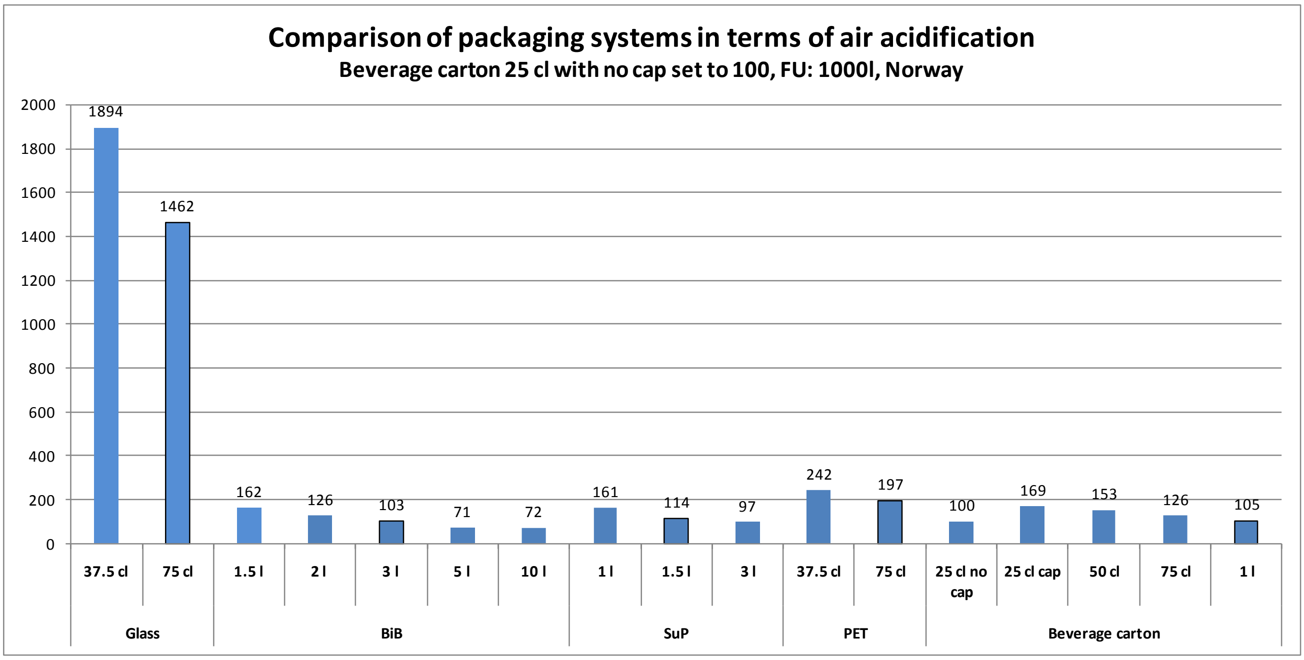
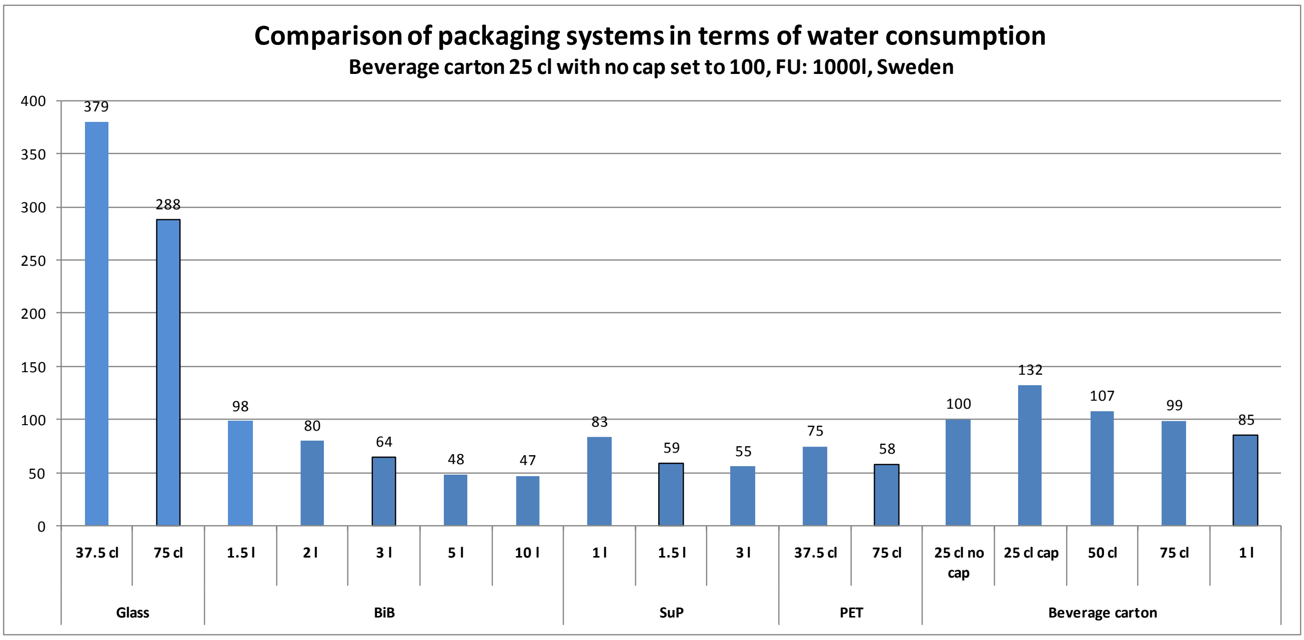


Figure 64: Comparison of packaging systems in terms of air acidification in Norway

— Impact of transport taken into account —

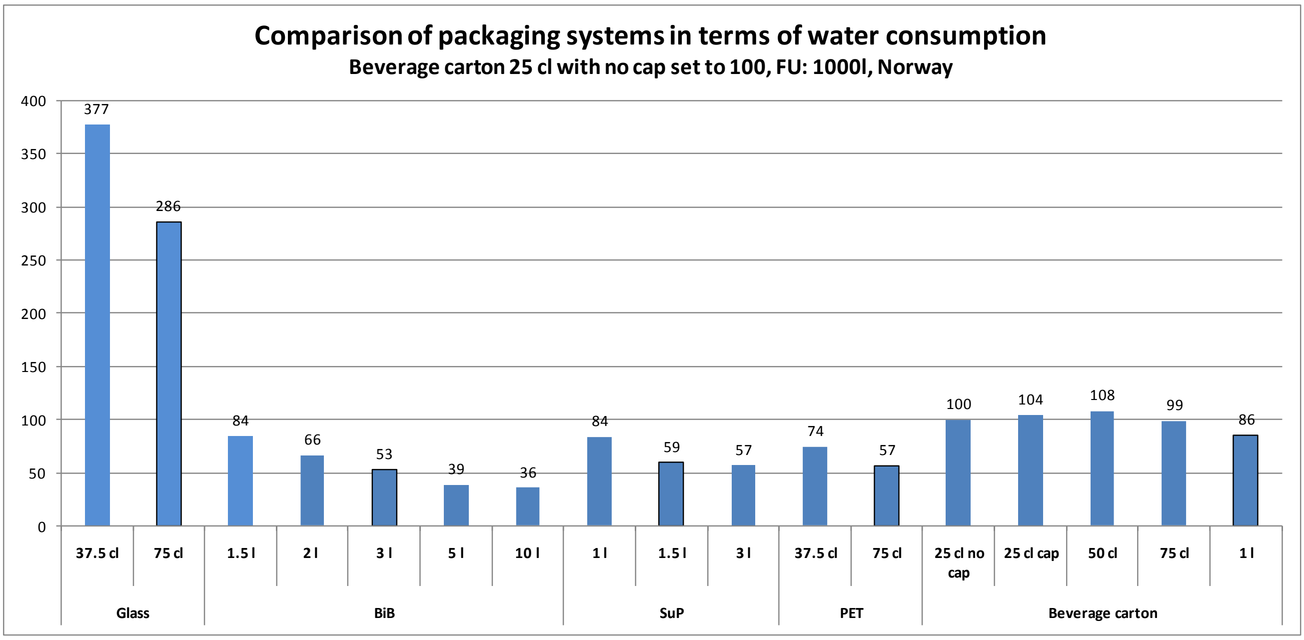
- Water consumption



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 65: Comparison of packaging systems in terms of water consumption in Sweden

— Impact of transport taken into account —



Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Figure 66: Comparison of packaging systems in terms of water consumption in Norway

— Impact of transport taken into account —

- Primary energy

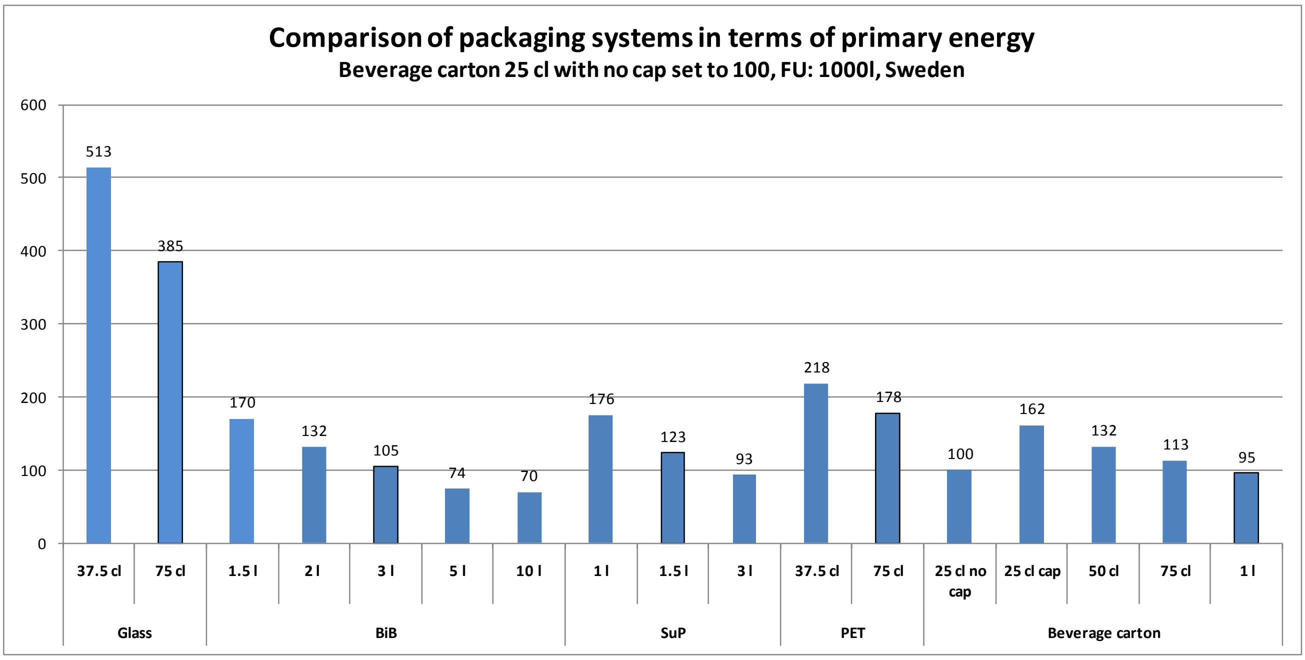


Figure 67: Comparison of packaging systems in terms of primary energy in Sweden

— Impact of transport taken into account —

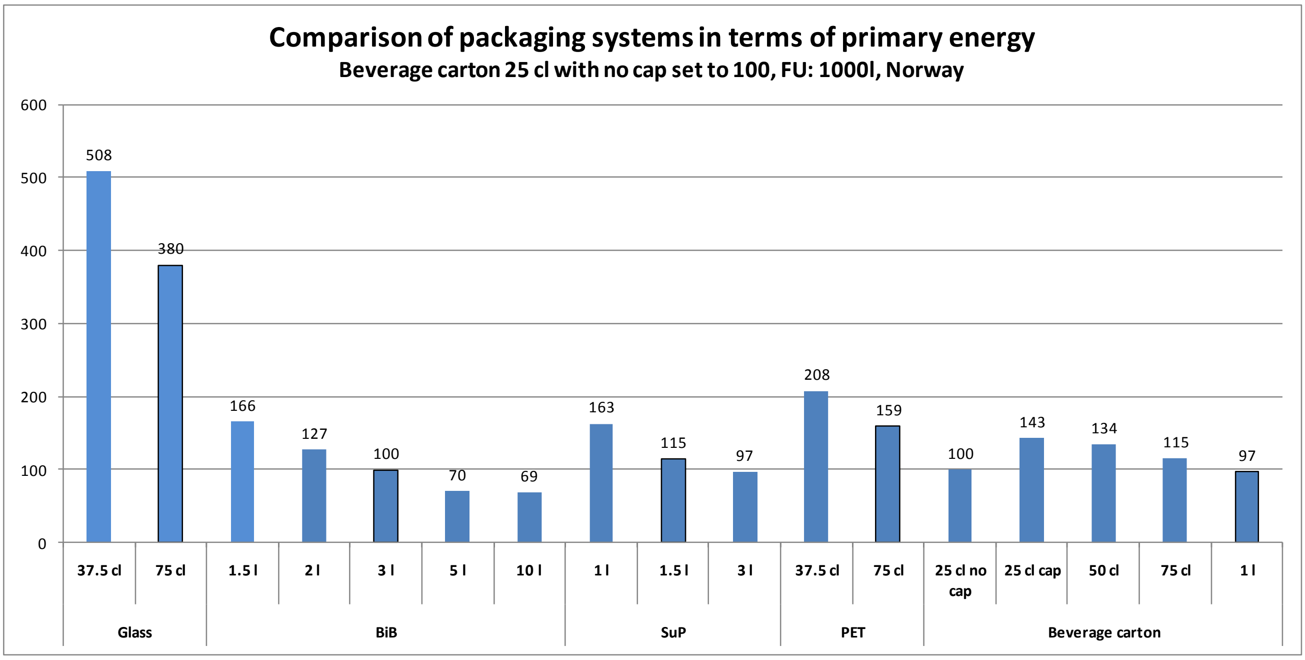


Figure 68: Comparison of packaging systems in terms of primary energy in Norway account

— Impact of transport taken into account —

On the whole, the same trends as in section 6.2 are observed. Although relative performances of packaging are not modified, some slight changes are observed regarding the magnitude of differences between systems. This is due to the palletisation characteristics of each format. This aspect becomes a stronger determinant in the impacts when the weight of the wine is taken into account.

6.3.2. SENSITIVITY ANALYSIS: ALLOCATION ISSUES

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

Four allocation procedures have been applied:

- Allocation to the recycling rate (RR)
- Allocation to the recycled content (RC)
- 50/50 allocation to the recycling rate and recycled content (50/50)
- Hybrid allocation as set in the PAS (PAS)

The next table summarises the corresponding environmental benefits (see section 4.2.2 for additional details)

Allocation procedure	Environmental credits
RR: recycling rate	Environmental credits/unit = RR x (E_r-E_v - E_{dd})
RC: recycled content	Environmental credits/unit = RC x (E_r-E_v - E_{du})
50-50	Environmental credits/unit = ½ RC (E_r-E_v - E_{du}) + ½ RR (E_r-E_v - E_{dd})
PAS	Environmental credits/unit = RC x (E_r-E_v) - RR x (E_r-E_v - E_{du})

The analysis has been performed on the reference volume for each packaging system in Sweden and in Norway.

For each packaging system, the different allocation procedures have been tested on the main primary packaging material:

- Glass, for the glass system;

PET, for the PET system. In the present analysis we assumed a 15% recycled content[31].

- Cardboard, for the BiB;
- Liquid packaging board for the beverage carton.

Note that no analysis has been performed on the SuP as it does not contain recycled material and it is not recycled.

For each sensitivity analysis, parameters of the baseline scenario have been set to 100 and results scaled accordingly.

[31] Based on figures provided by a French wine bottling company

The next table present the maximum variations and corresponding parameters for each system.

Table 57: Sensitivity analysis of allocation procedures on the reference volumes

Glass 75cl	Sweden				Norway			
	min		max		min		max	
Global warming potential	100	ref (RR)	107	RC	100	ref (RR)	108	PAS
Air acidification potential	100	ref (RR)	105	RC	100	ref (RR)	104	RC
Abiotic resources depletion potential	100	ref (RR)	107	RC	100	ref (RR)	108	PAS
Primary energy	100	ref (RR)	107	RC	100	ref (RR)	107	RC
Water consumption	100	ref (RR)	107	RC	100	ref (RR)	102	PAS

Beverage carton 1L	Sweden				Norway			
	min		max		min		max	
Global warming potential	93	RC	100	ref (RR)	96	RC	100	ref (RR)
Air acidification potential	100	ref (RR)	108	RC	100	ref (RR)	108	RC
Abiotic resources depletion potential	93	RC	100	ref (RR)	95	RC	100	ref (RR)
Primary energy	100	ref (RR)	113	PAS	100	ref (RR)	114	PAS
Water consumption	100	ref (RR)	120	RC	100	ref (RR)	122	RC

BiB 3L	Sweden				Norway			
	min		max		min		max	
Global warming potential	90	RC	100	ref (RR)	98	RC	100	ref (RR)
Air acidification potential	100	ref (RR)	103	RC	100	ref (RR)	109	RC
Abiotic resources depletion potential	95	RC	100	ref (RR)	98	RC	100	ref (RR)
Primary energy	94	RC	100	ref (RR)	100	ref (RR)	109	PAS
Water consumption	98	PAS	100	ref (RR)	100	ref (RR)	126	RC

PET 75cl	Sweden				Norway			
	min		max		min		max	
Global warming potential	100	ref (RR)	156	RC	100	ref (RR)	164	RC
Air acidification potential	100	ref (RR)	126	RC	100	ref (RR)	129	RC
Abiotic resources depletion potential	100	ref (RR)	159	PAS	100	ref (RR)	167	PAS
Primary energy	100	ref (RR)	150	PAS	100	ref (RR)	155	PAS
Water consumption	100	ref (RR)	121	PAS	100	ref (RR)	126	RC

Water consumption indicator in LCA study presents various methodological limits, see text box in section 3.2.

Allocations have different effects depending on the country, the packaging system and the indicator considered. Main conclusions are as follows:

- 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;
- Similarly, when comparing the packaging system and the impacts of different allocation, the glass, BiB and beverage carton show little variation (0-10%) for global warming, air acidification and abiotic resources indicators.
- Water consumption is more sensitive to the allocation procedure for the Bag in Box and the beverage carton, varying up to 26%. This is due to the important benefits of recycling in terms of water consumption for cardboard materials and the higher recycling rate in Norway than in Sweden. Note that this reinforces the limits of this indicator that have already been discussed for cardboard materials in section 6.2.4. 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.

6.3.3. SENSITIVITY ANALYSIS: CARBON SEQUESTRATION

Carbon sequestration is subject to important uncertainty. As a reminder, and as required by the PAS 2050, carbon sequestration is accounted for in the baseline model. Biogenic carbon in landfill that is not emitted[32] during the 100 year assessment period is considered to be stored and accounted as carbon credits.

The next table present the impacts in terms of global warming potential of the reference volumes with and without considering carbon sequestration.

Table 58: Impacts of carbon sequestration on global warming potential for the reference volumes in Norway and Sweden

	Glass 75cl		Beverage carton 1l	
	Baseline	No sequestration	Baseline	No sequestration
Sweden	100	100.02	100	100.67
Norway	100	100.11	100	100.00

	BiB 3l		PET 75cl	
	Baseline	No sequestration	Baseline	No sequestration
Sweden	100	100.51	100	100.05
Norway	100	100.86	100	100.30

	SuP 1.5l	
	Baseline	No sequestration
Sweden	100	100.00
Norway	100	100.00

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.

6.3.4. COMPLEMENTARY ANALYSIS: EVALUATION OF DATA GAPS

6.3.4.1. Glass bottle

As mentioned in section 4.3.1, it is acknowledged that data used in the present report for glass bottle production — even though they were the best available data at the time of the study — are somehow outdated.

For that reason, a complementary analysis on glass bottle was performed. This analysis is based on the reasonable assumption that environmental improvements in the production phase of glass life cycle should not exceed a 30% reduction of the impacts we measured.

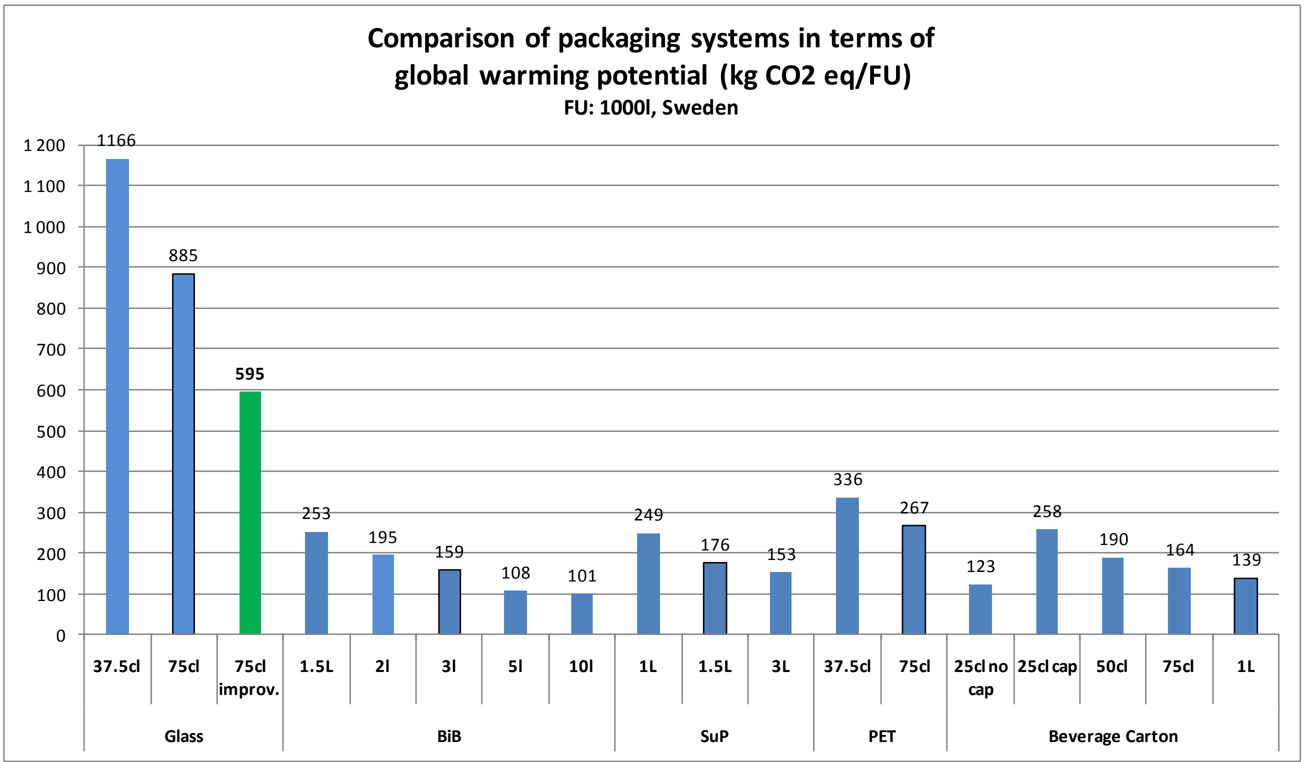
This complementary analysis is focused on three impact assessment and two life cycle inventory indicators:

- Global warming potential, abiotic depletion, air acidification;
- Water consumption, primary energy.

Note that a table showing the breakdown of the environmental impacts of the system per life cycle main stages for this improved glass system is presented in annex 5.

[32] In water through lixiviate or in air through biogas emission

- Global warming potential



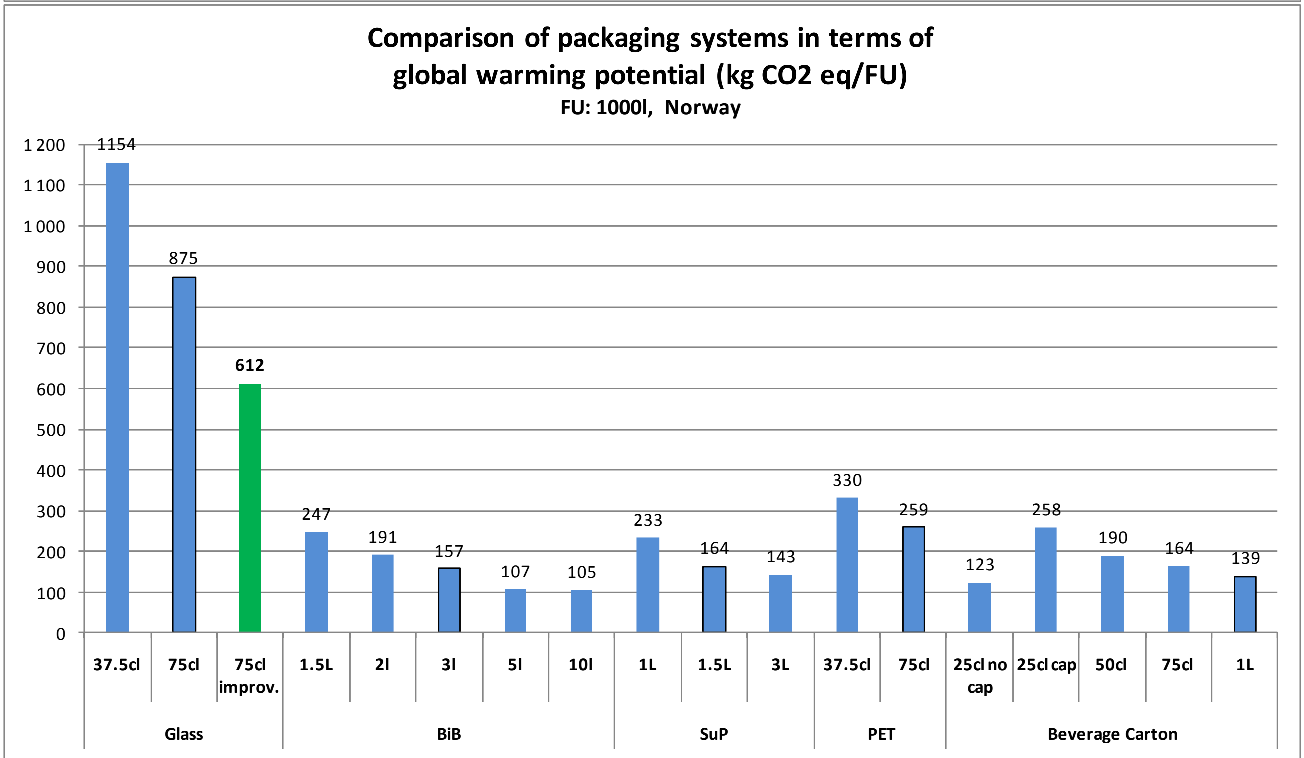


Figure 69: Estimation of environmental improvements in the production of glass in terms of global warming potential in Sweden and Norway

- Abiotic depletion

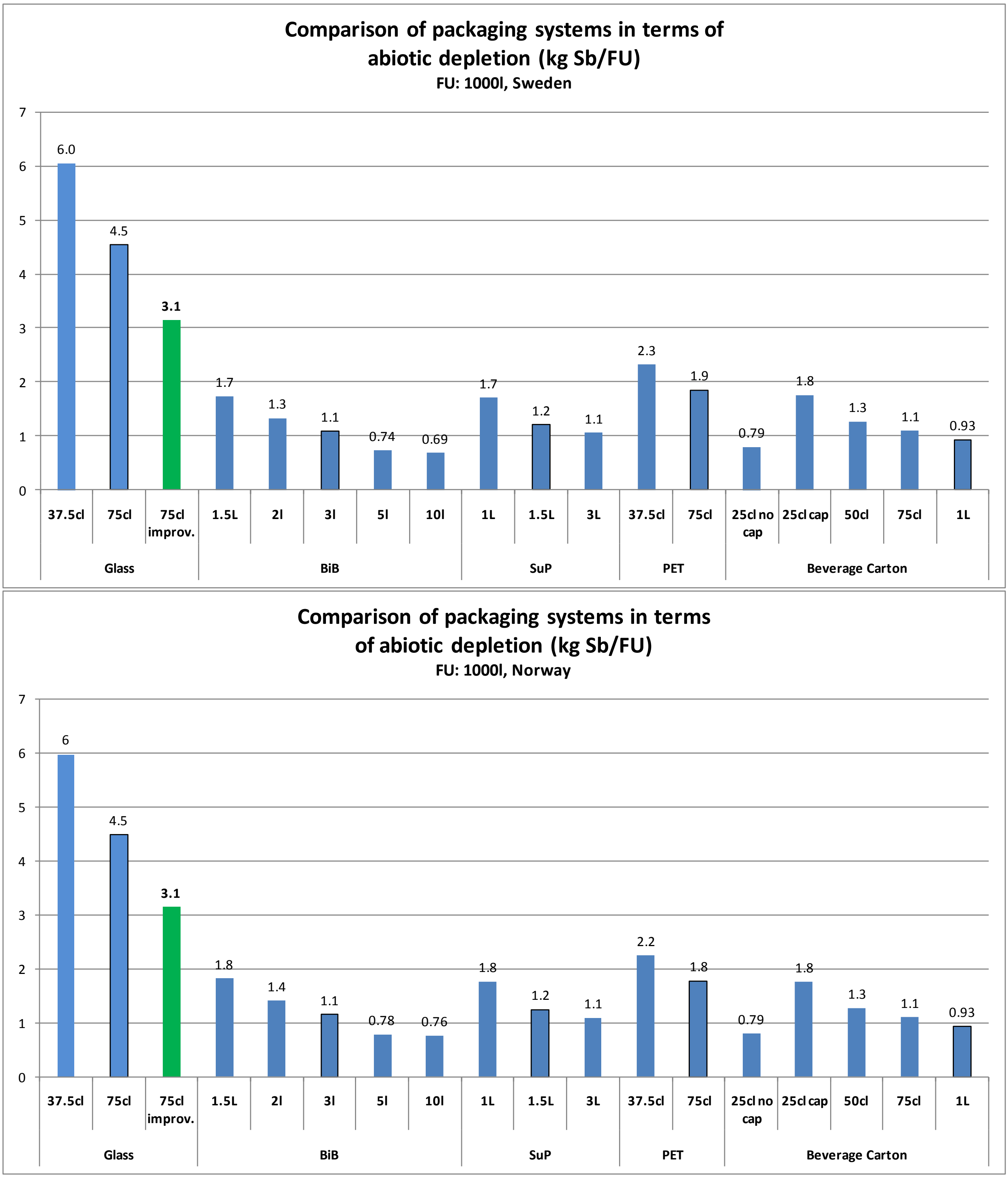


Figure 70: Estimation of environmental improvements in the production of glass in terms of abiotic depletion in Sweden and Norway

- Air acidification

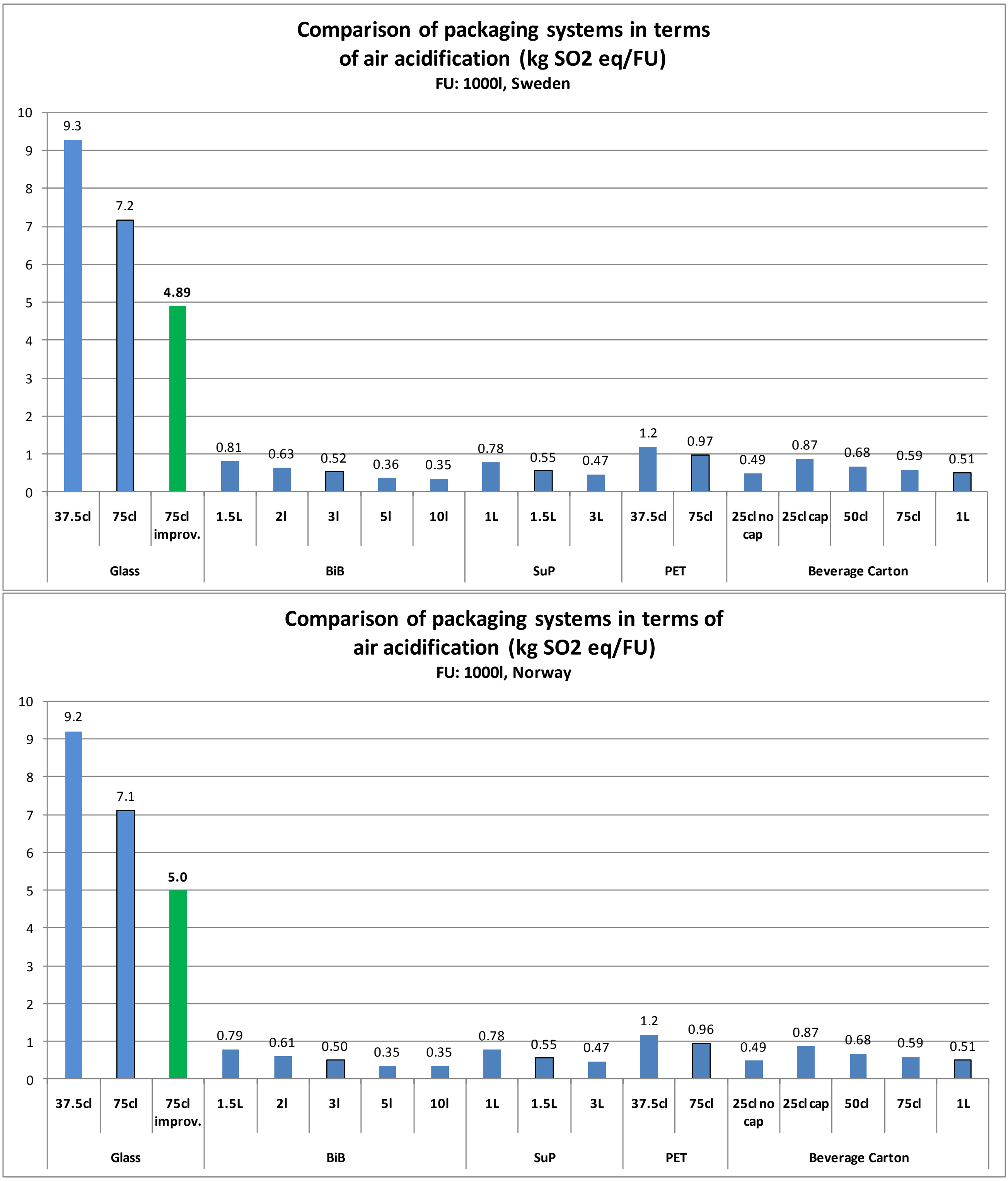
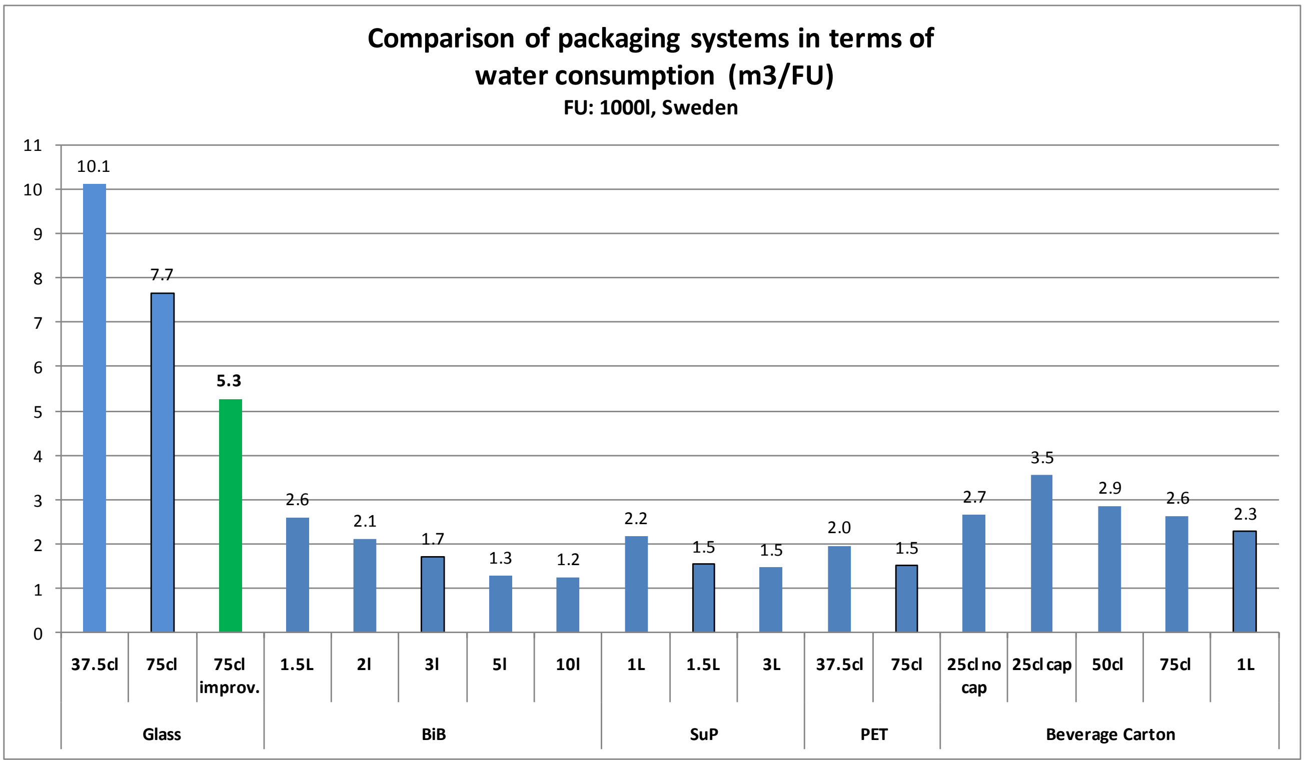


Figure 71: Estimation of environmental improvements in the production of glass in terms of air acidification in Sweden and Norway

- Water consumption



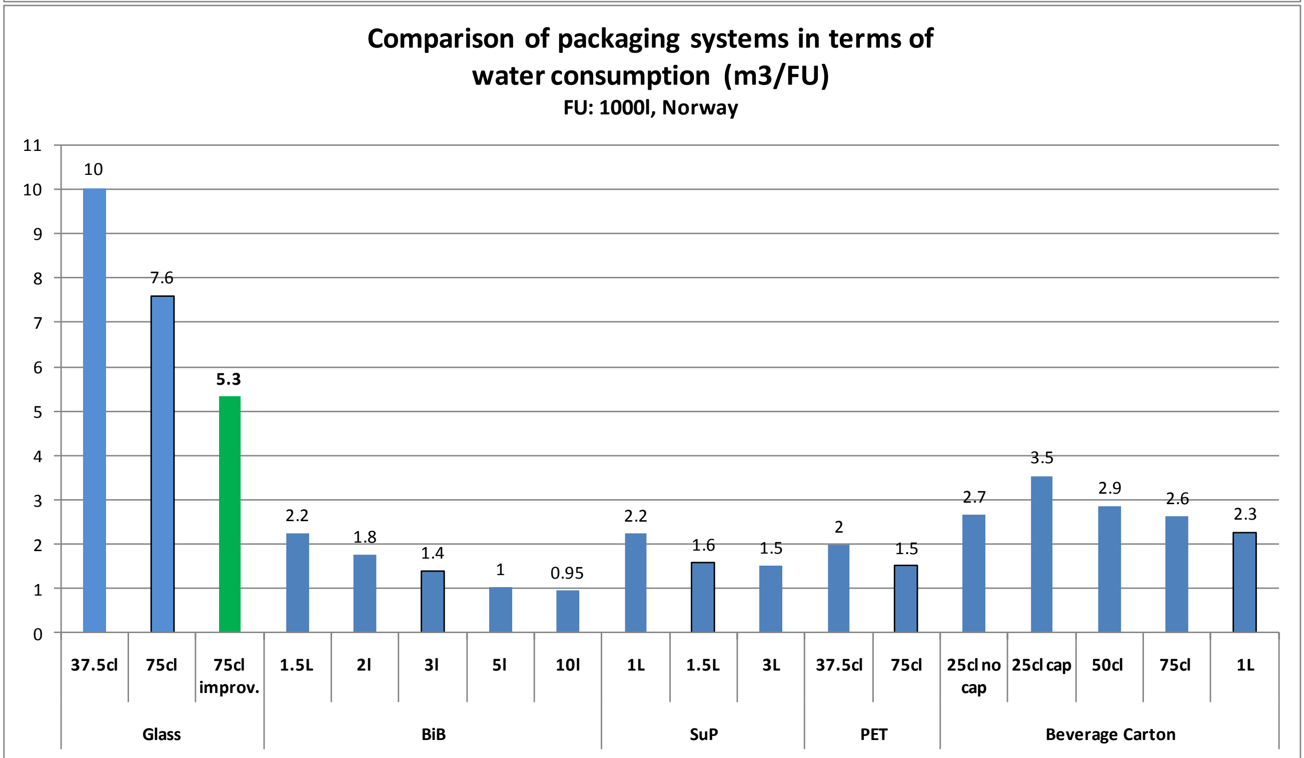
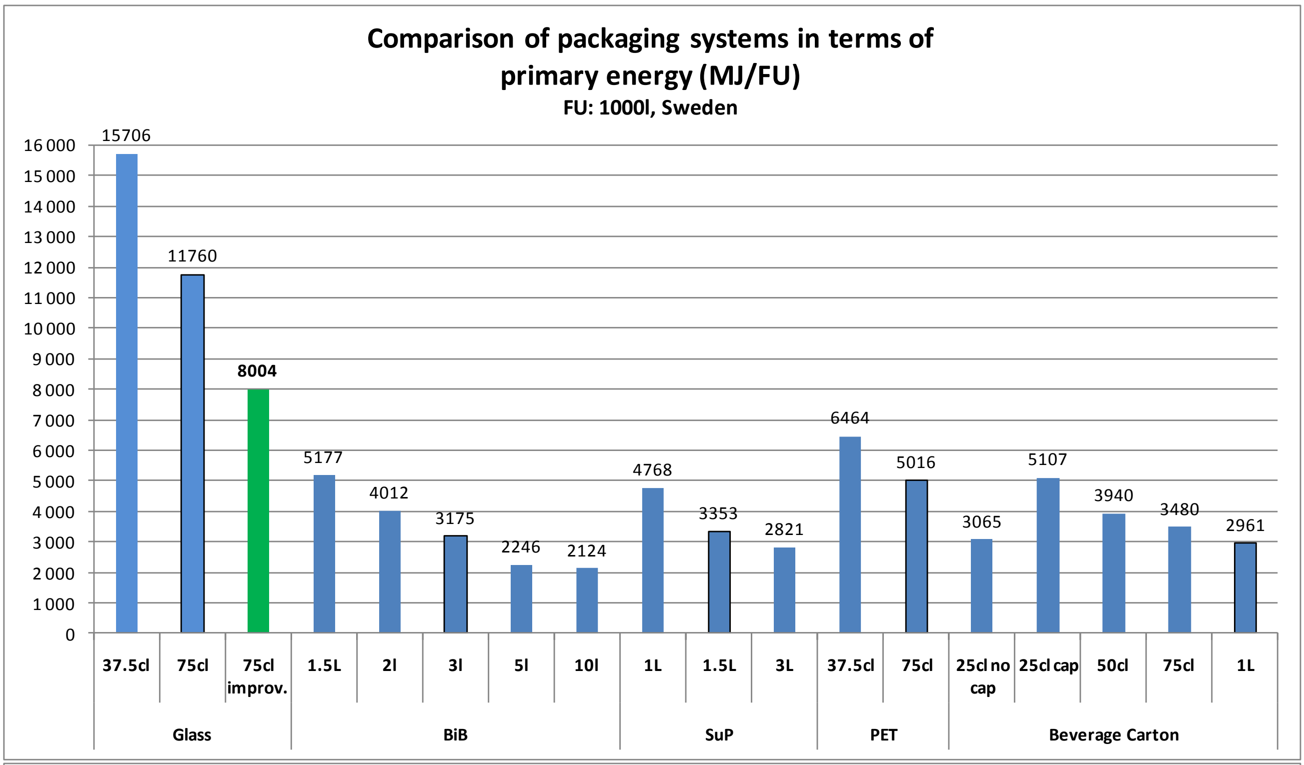


Figure 72: Estimation of environmental improvements in the production of glass in terms of water consumption in Sweden and Norway

- Primary energy



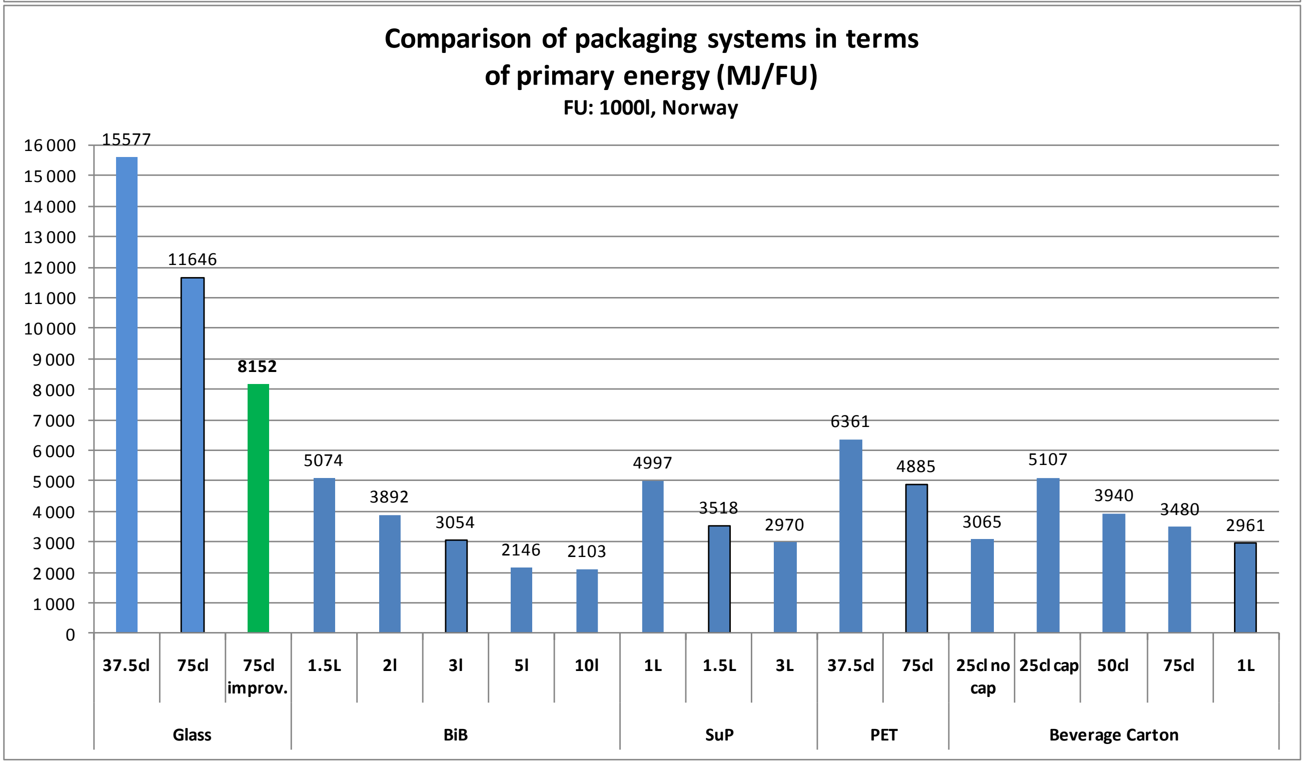


Figure 73: Estimation of environmental improvements in the production of glass in terms of primary energy in Sweden and Norway

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.

6.3.4.2. Packaging and content: taking into account wine losses

The impacts of wine production and transportation have not been considered in the reference scenarios of the present study. Note however that the impacts of wine transportation — which is tightly related to packaging performance and palletisation — have been considered in a complementary analysis presented in section 6.3.1.

As regards wine production, it is obvious that for each packaging system, wine losses can occur throughout its life cycle. These losses can be due to distribution steps, consumer behaviour, packaging characteristics. Some causes can be:

- broken packaging during distribution;
- incomplete emptying of the packaging;
- wine discarded because it was not consumed in time after opening, which is more likely to occur for large formats;
- wine thrown out because of oxidation (caused before or after opening the package) or taste contamination (e.g. "corked" taste) due to the container.

Environmental impacts related to the production of the amount wine that is lost have not been taken into account because of a significant lack of data on these aspects. In particular, there is no information on losses happening at consumption level.

Indeed, aside from the present LCA, a specific study would be needed to gather data on consumer behaviour for each packaging type and format. A beneficial outcome of such a study on wine loss (beyond allowing more accurate environmental impact calculations) is that it would allow package manufacturers to better quantify and thus minimize wine loss at the package design stage.

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.

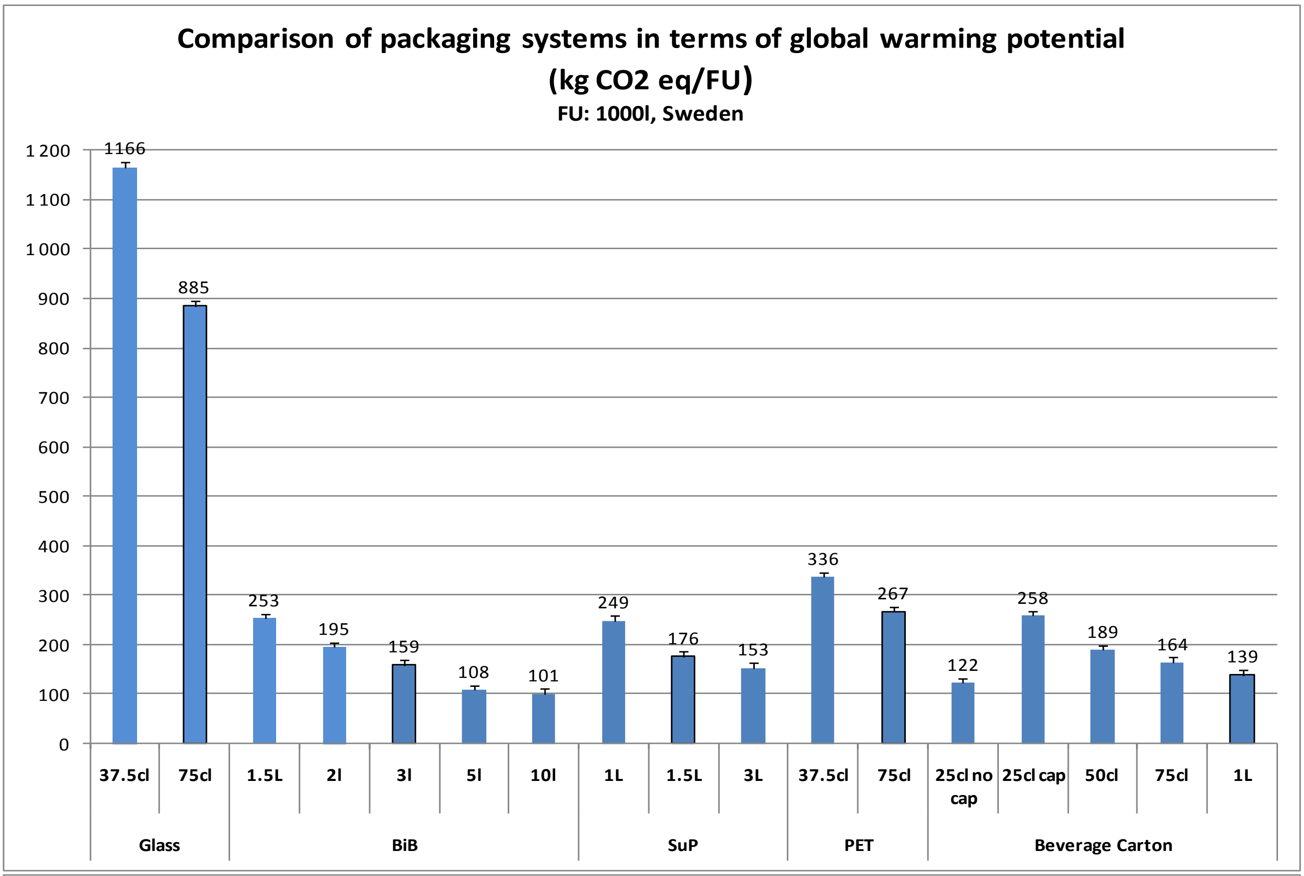
According to a 2007 study[33], the greenhouse gases emissions for wine production are as follows:

- 283.33 g CO_2 eq/75 cl for the agricultural stage;
- 102.8 g CO_2 eq/75 cl for the wine making stage.

For 1000 l (i.e. 1 functional unit), this corresponds to **515 kg CO_2 eq**.

Based on this data one can calculate uncertainties due to the impacts of wine assuming a 2% loss (20 l per FU) for each packaging in Sweden and in Norway. These uncertainties are presented in the next figure.

[33] 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



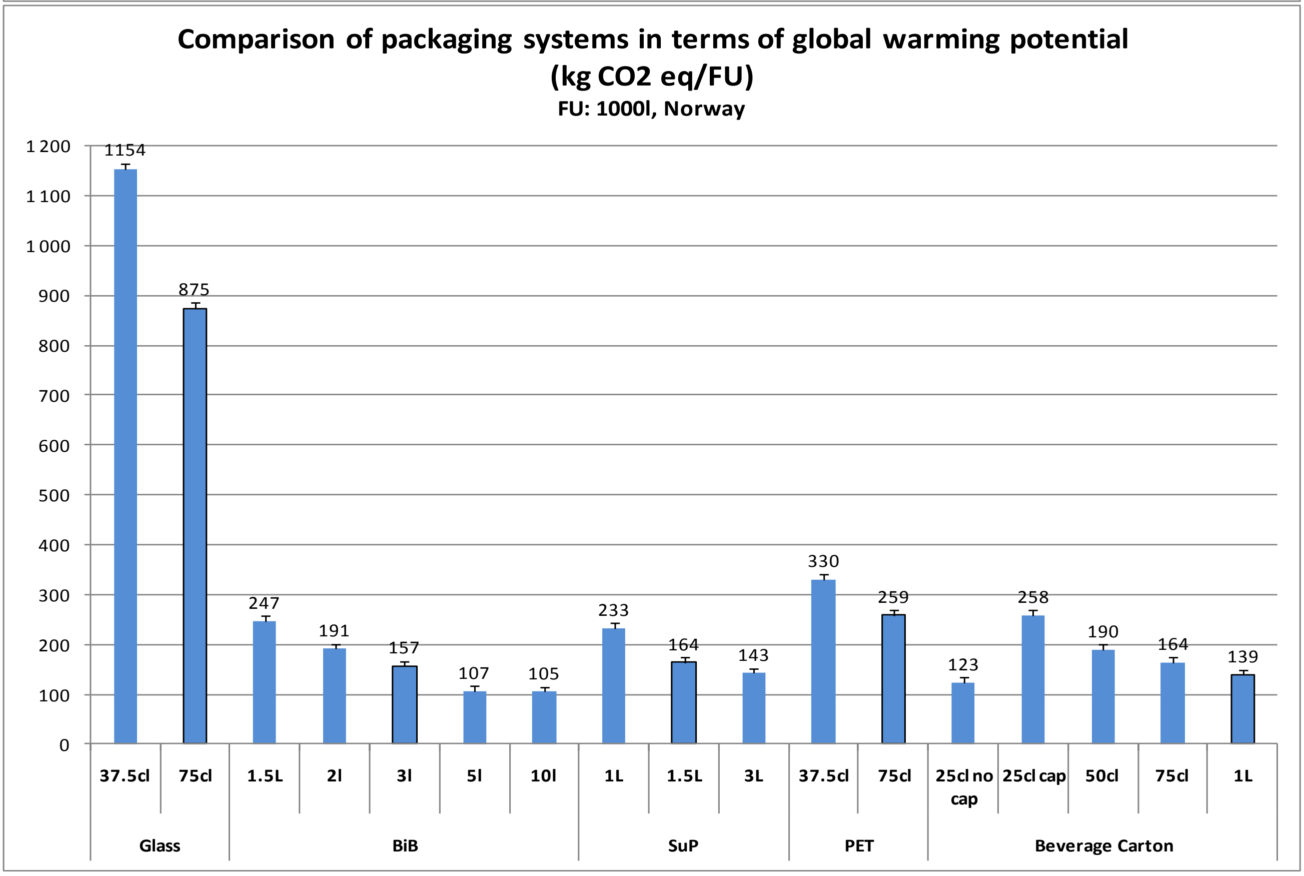


Figure 74: Estimation of the effect of wine loss in terms of greenhouse gases emissions in Sweden and Norway

This 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.

It must be underlined that 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, as shown in the next table, wine can represent up to 84 % percent of the impacts in terms of GHG emissions of the “packaged wine” system (i.e. wine + package).

Table 59: Share of wine in the impacts of “packaged wine” for global warming potential

		Glass		BiB					SuP			PET		Beverage carton				
Global Warming Potential	**Unit**	**37.5 cl**	**75 cl**	**1.5L**	**2l**	**3l**	**5l**	**10l**	**1L**	**1.5L**	**3l**	**37.5 cl**	**75cl**	**25 cl no cap**	**25cl cap**	**50cl**	**75cl**	**1L**
Packaging system	**kg CO_2 eq/FU**	1166	885	253	195	159	108	101	249	176	153	336	267	122	258	189	164	139
Wine production		515																
Packaged wine (total)		1681	1399	768	710	674	623	616	764	691	668	851	782	637	773	704	678	654
Wine	**% of total**	**31%**	**37%**	**67%**	**73%**	**76%**	**83%**	**84%**	**67%**	**75%**	**77%**	**61%**	**66%**	**81%**	**67%**	**73%**	**76%**	**79%**

This strengthens the need for accurate data on the **variability** of wine losses for the various packaging systems, be it through the distribution stage or through consumer behaviour.

Lastly, Garnett’s study only considered the impacts of wine in terms of greenhouse gases emissions. Life cycle 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 (fertilisers, pest control agents, water consumption, fuel consumption of machinery…). Additional studies would be needed because the trends observed in Figure 74 might be different for another indicator.

CONCLUSIONS

7. 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.

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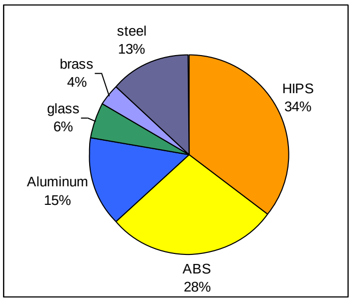
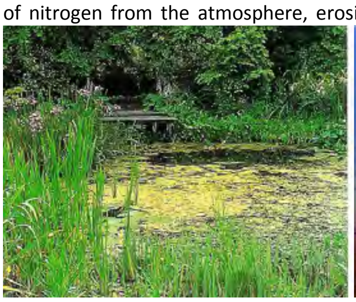
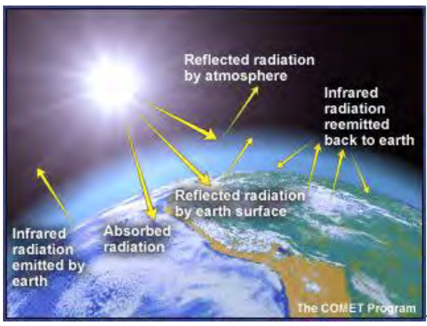
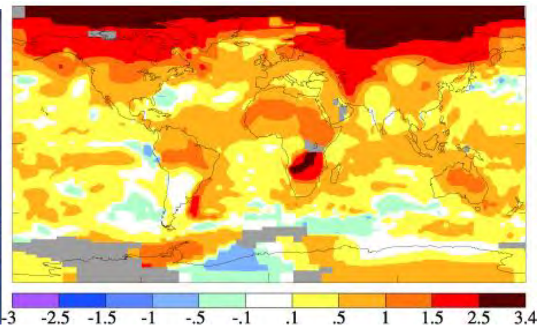
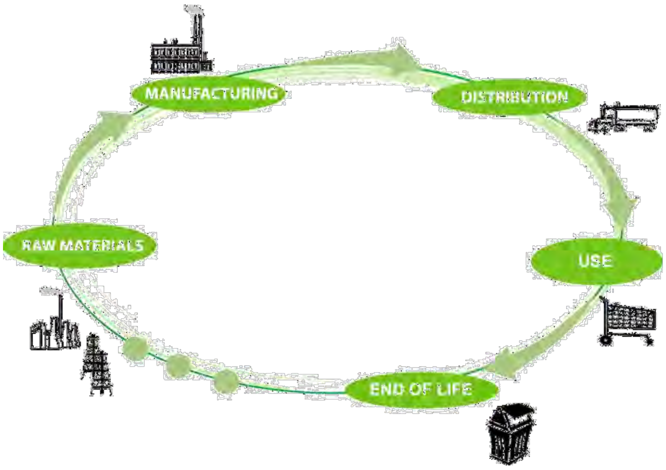
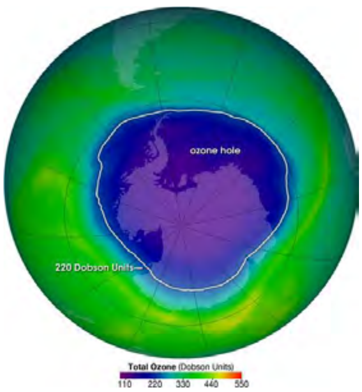
GLOSSARY

8. GLOSSARY

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>Abiotic resource depletion potential</td><td>Resource depletion can be defined as the decreasing availability of natural resources. The resources considered in this impact are fossil and mineral resources, excluding biotic resources, and associated impacts such as species extinction and loss of biodiversity.
</td></tr>
<tr><td>Acidification potential</td><td>Air acidification consists of the accumulation of acidifying substances (e.g. sulphuric acid, hydrochloric acid) in the water particles in suspension in the atmosphere. Deposited onto the ground by rains, acidifying pollutants have a wide variety of impacts on soil, groundwater, surface waters, biological organisms, ecosystems and materials (buildings).

</td></tr>
<tr><td>Bill-Of-Materials (BOM)</td><td>The BOM of a device is a list of the materials contained in this device. For each material, the BOM gives the total weight of all the parts and components made of this material within the device.

</td></tr>
<tr><td>Biogenic carbon</td><td>Carbon coming from the biosphere (animals and plants)</td></tr>
<tr><td>Eutrophication potential</td><td>Eutrophication is a process whereby water bodies, such as lakes or rivers, receive excess chemical nutrients — typically compounds containing nitrogen or phosphorus — that stimulate excessive plant growth (e.g. algae). Nutrients can come from many sources, such as fertilisers applied to agricultural fields and golf courses, deposition of nitrogen from the atmosphere, erosion of soil containing nutrients, and sewage treatment plant discharges.
 </td></tr>
</table>

Term	Definition
Freshwater aquatic ecotoxicity potential	The European Union System for the Evaluation of Substances (EUSES) quantitatively assesses the risks posed by chemicals to human health and the environment. Using toxicological benchmarks for both human and ecological effects, EUSES produces "risk characterisation ratios" that indicate when chemical releases are likely to result in toxic doses that exceed acceptable levels. Freshwater Aquatic Ecotoxicity Potential characterises health risks to a specific ecological system: fresh surface waters. 
Freshwater sedimental ecotoxicity potential	The European Union System for the Evaluation of Substances (EUSES) quantitatively assesses the risks posed by chemicals to human health and the environment. Using toxicological benchmarks for both human and ecological effects, EUSES produces "risk characterisation ratios" that indicate when chemical releases are likely to result in toxic doses that exceed acceptable levels. Freshwater Sedimental Ecotoxicity Potential characterises health risks to a specific ecological system: freshwater sediments. 
Functional Unit	Flow of reference for a LCA. The Functional Unit must allow quantifying a service given. When performing the LCA of a product, the FU quantifies its practical value.
Global warming potential	Global warming refers to the increase in the average temperature of the Earth's surface, due to an increase in the greenhouse effect, caused by anthropogenic emissions of greenhouse gases (carbon dioxide, methane, nitrous oxide, fluorocarbons (e.g. CFCs and HCFCs), and others).  

Term	Definition
Human toxicity potential	The European Union System for the Evaluation of Substances (EUSES) quantitatively assesses the risks posed by chemicals to human health and the environment. Using toxicological benchmarks for both human and ecological effects, EUSES produces "risk characterisation ratios" that indicate when chemical releases are likely to result in toxic doses that exceed acceptable levels. Human Toxicity Potential characterises health risks to humans.
ISO 14040	The core ISO standard for LCA, which standardises the principles and framework of life cycle assessment (LCA).
ISO 14044	ISO standard for LCA. ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14044:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies.
Life cycle	Succession of steps. The life cycle of a product comprises any steps in a "cradle to grave" approach: the extraction of the necessary raw materials, the manufacturing of the product (comprising material manufacturing and assembly), its distribution to the user, its use and its end-of-life (including collection and treatment: reuse, recycling, incineration with or without recovery, landfilling and so on). 
Life Cycle Assessment (LCA)	Methodology aiming to assume 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 end-of-life. This "cradle-to-grave" methodology has been standardised at the international level through ISO 14044.
Ozone layer depletion potential	The ozone layer acts as a filter, absorbing harmful short wave UV light. The thinning of the ozone layer over the Antarctic each spring can reach up to a 80-98% removal of this layer, hence the so-called "ozone hole", mainly due to the anthropogenic emission of brominated and chlorinated substances like CFCs. 

Term	Definition
Photochemical oxidation potential	This pollution results mainly from chemical reactions induced by solar light between nitrogen oxides and volatile organic compounds (VOC), commonly emitted in the combustion of fossil fuels. It provokes high levels of ozone and other chemicals toxic for humans and flora. 
Primary energy, non-renewable	Primary energy is raw energy available in nature. The main non-renewable primary energies are: oil, coal, natural gas, and nuclear energy.  
Terrestrial ecotoxicity potential	The European Union System for the Evaluation of Substances (EUSES) quantitatively assesses the risks posed by chemicals to human health and the environment. Using toxicological benchmarks for both human and ecological effects, EUSES produces "risk characterisation ratios" that indicate when chemical releases are likely to result in toxic doses that exceed acceptable levels. Terrestrial Ecotoxicity Potential characterises health risks to a specific ecological system.

ANNEX

9. ANNEX

9.1 ANNEX 1: DIRECT (EXCEPT FOR CH_4) GLOBAL WARMING POTENTIAL (GWP) RELATIVE TO CO_2[34]

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon (at date of publication)
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Substances controlled by the Montreal Protocol		
CFC-11	CCl_3F	4 750
CFC-12	CCl_2F2	10 900
CFC-13	$CClF_3$	14 400
CFC-113	CCl_2FCClF_2	6 130
CFC-114	$CClF_2FCClF_2$	10 000
CFC-115	$CClF_2CF_3$	7 370
Halon-1301	CB_rF_3	7 140
Halon-1211	CB_rClF_2	1 890
Halon-2402	$CB_rF_2CB_rF_2$	1 640
Carbon tetrachloride	CCl'_4	1 400
Methyl bromide	CH_3B_r	5
Methyl chloroform	CH_3CCl_3	146
HCFC-22	$CHClF_2$	1 810
HCFC-123	$CHCl_2CF_3$	77
HCFC-124	$CHClFCF_3$	609
HCFC-141b	CH_3CCl_2F	725
HCFC-142b	CH_3CClF_2	2 130
HCFC-225ca	$CHCl_2CF_2CF_3$	122

[34] PAS2050:2008, Specification for the assessment of the life cycle greenhouse gas emissions of goods and services, Annex A. Emissions factors based on latest published report from the Intergovernmental Panel on Climate Change at this date (AR4), IPCC 2007

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon (at date of publication)
HCFC-225cb	$CHClFCF_2CClF_2$	595
HFC-23	CHF_3	14 800
HFC-32	CH_2F_2	675
HFC-125	CHF_2CF_3	3 500
HFC-134a	CH_2FCF_3	1 430
HFC-143a	CH_3CF_3	4 470
HFC-152a	CH_3CHF_2	124
HFC-227ea	CF_3CHFCF_3	3 220
HFC-236fa	$CF_3CH_2CF_3$	9 810
HFC-245fa	$CHF_2CH_2CF_3$	1 030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1 640
Perfluorinated compounds		
Sulfur hexafluoride	SF_6	22 800
Nitrogen trifluoride	NF_3	17 200
PFC-14	CF_4	7 390
PFC-116	C_2F_6	12 200
PFC-218	C_3F_8	8 830
PFC-318	$c\text{-}C_4F_8$	10 300
PFC-3-1-10	C_4F_{10}	8 860
PFC-4-1-12	C_5F_{12}	9 160
PFC-5-1-14	C_6F_{14}	9 300
PFC-9-1-18	$C_{10}F_{18}$	>7 500
Trifluoromethyl sulfur	SF_5CF_3	17 700
Fluorinated ethers		
HFE-125	CHF_2OCF_3	14 900
HFE-134	CHF_2OCHF_2	6 320
HFE-143a	CH_3OCF_3	756
HCFE-235da2	$CHF_2OCHClCF_3$	350

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon (at date of publication)
HFE-245cb2	$CH_3OCF_2CHF_2$	708
HFE-245fa2	$CHF_2OCH_2CF_3$	659
HFE-254cb2	$CH_3OCF_2CHF_2$	359
HFE-347mcc3	$CH_3OCF_2CF_2CF_3$	575
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	580
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	110
HFE-449sl (HFE-7100)	$C_4F_9OCH_3$	297
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	59
HFE-43-10-pccc124 (H-Galden	$CHF_2OCF_2OC_2F_4OCHF_2$	1 870
HFE-236ca12 (HG-10)	$CH_2OCF_2OCHF_2$	2 800
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	1 500
Perfluoropolyethers		
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	10 300
Hydrocarbons and other compounds — direct effects		
Dimethylether	CH_3OCH_3	1
Methylene chloride	CH_2Cl_2	8.7
Methyl chloride	CH_3Cl	13

9.2 ANNEX 2: ELECTRICITY GENERATION MIX IN 2007[35]

Production from:	Coal	Oil	Gas	Biomass	Waste	Nuclear	Hydro*	Geo thermal	Solar PV	Solar thermal	Wind	Tide	Other sources	Total Prod.	Imports	Exports
France	4.95%	1.08%	3.86%	0.35%	0.62%	**77.17%**	11.17%	0.00%	0.00%	0.00%	0.71%	0.09%	0.00%	569840	10782	-67595
Italy	15.84%	11.28%	**55.00%**	1.19%	1.02%	0.00%	12.26%	1.77%	0.01%	0.00%	1.29%	0.00%	0.33%	313888	48931	-2648
Netherlands	27.57%	2.15%	**57.18%**	2.52%	2.87%	4.07%	0.10%	0.00%	0.03%	0.00%	3.33%	0.00%	0.17%	103241	23139	-5565
Norway	0.10%	0.02%	0.53%	0.23%	0.09%	0.00%	**98.24**%	0.00%	0.00%	0.00%	0.65%	0.00%	0.13%	137471	5285	-15320
Sweden	1.15%	0.72%	0.55%	5.86%	1.30%	**44.99%**	**44.47%**	0.00%	0.00%	0.00%	0.96%	0.00%	0.00%	**148849**	16052	-14736
* Includes production from pumped storage plants.																

[35] Source: International Energy Agency – http://www.iea.org/stats/index.asp

![bio Intelligence Service logo]

9.3 ANNEX 3: DATA USED FOR EACH SYSTEM STUDIED[36]

9.3.1. PET BOTTLE

Type of data	Unit	PET Bottle 75 cl	PET Bottle 37,5 cl	Data source
Description of primary packaging				
Content				
Volume	[cl]	75.0	37.5	-
Total weight	[g]	54.4	32.1	-
Principal materials				
Total weight	[g]			Industry
PET				
Recycled content	[%]	0%	0%	Industry
Weight	[g]			Industry
Truck (80% load)				*assumption*
Distance	[km]			Industry
Nylon				
Recycled content	[%]	0%	0%	Industry
Weight	[g]			Industry
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Fabrication of the primary package				
Country		France	France	Industry
Electricity	[MJ]			Industry
Losses	%			Industry
Other materials				
Tap				
Total weight	[g]			Industry
Injected moulded LDPE				
Recycled content	[%]	0%	0%	Industry
Weight	[g]			Industry
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Labels				
Total weight	[g]			Industry
Paper				
Recycled content	[%]	49%	49%	*Bibliography (CEPI)*
Weight	[g]			Industry
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Filling stage				
Filling the bottle				
Country		France	France	Industry
Electricity	[MJ]			Industry
Losses	%			Industry
Labelling				
Country		France	France	Industry
Electricity	[MJ]			Industry
Secondary and tertiary conditioning				
Country		France	France	Industry
Electricity	[MJ]			Industry
Description of secondary packaging				
Cardboard box				
Number of products per box				Industry
Weight	[g]			Industry
Recycled content	[%]	82%	82%	*Bibliography (FEFCO)*
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*

36 Data source in italic are secondary data source

Type of data	Unit	PET Bottle 75 cl	PET Bottle 37,5 cl	Data source
Description of tertiary packaging				
Pallet				
Number of products per pallet				Industry
Weight	[g]	22000	22000	*Bibliography (BIOIS)*
Reused	times	30	30	*assumption*
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Cardboard for bottom of pallet				
Weight	[g]	1900	1900	*Bibliography (BIOIS)*
Recycled content	[%]	82%	82%	*Bibliography (FEFCO)*
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Wrapping film				
Weight	[g]	850	850	*Bibliography (BIOIS)*
Recycled content	[%]	0%	0%	*assumption*
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Transport stages				
Fabrication of preforms -> fabrication of primary packaging				
Truck (80% load)				*assumption*
Distance	[km]			Industry
Fabrication of primary packaging -> filling stage				
Nb of products per pallet				Industry
Nb of pallets per truck		33	33	Industry
Truck (calculated load)				
Distance	[km]	800	800	*assumption*
Fabrication of closures -> filling stage				
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Filling stage -> distribution hub				
Truck (calculated load)				
Distance	[km]	2411	2411	*assumption*
Distribution hub -> retailers				
Truck (calculated load)				
Distance	[km]	150	150	*assumption*
Transport of waste				
Household waste	[km]	50	50	*Bibliography (BIOIS)*
Recycled waste	[km]	400	400	*Bibliography (BIOIS)*
Distribution				
Country of distribution		Sweden/Norway	Sweden/Norway	*assumption*

9.3.2. GLASS BOTTLE

Type of data	Unit	Glass bottle 75 cl	Glass bottle 37,5 cl	Data source
Description of primary packaging				
Content				
Volume	[cl]	75	37.5	-
Total weight	[g]	479.5	309.3	-
Principal materials				
Total weight	[g]	472	302	-
Glass				
Recycled content	[%]	75%	75%	JeanJean
Weight	[g]	472	302	Systembolaget
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Fabrication of the primary package				
Excluded (no data available)				-
Other materials				
Closure				
Total weight	[g]	5.5	5.5	-
Aluminium sheet				
Recycled content	[%]	0	0	Systembolaget
Weight	[g]	5.5	5.5	Systembolaget
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Fabrication of the closure				
Aluminium sheet				EAA
Labels				
Total weight	[g]	2	1.8	-
Paper				
Recycled content	[%]	49%	49%	*Bibliography (CEPI)*
Weight	[g]	2	1.8	*Bibliography (BIOIS)*
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Filling stage				
Filling the bottle				
Country		France	France	JeanJean
Electricity	[MJ]			JeanJean
Sticking the label				
Country		France	France	JeanJean
Electricity	[MJ]			JeanJean
Closing the bottle				
Country		France	France	JeanJean
Electricity	[MJ]			JeanJean
Secondary conditioning				
Country		France	France	JeanJean
Electricity	[MJ]			JeanJean
Tertiary conditioning				
Country		France	France	JeanJean
Electricity	[MJ]			JeanJean

Type of data	Unit	Glass bottle 75 cl	Glass bottle 37,5 cl	Data source
Description of secondary packaging				
Cardboard box				
Number of products per box				JeanJean
Weight	[g]			JeanJean
Recycled content	[%]	82%	82%	*Bibliography (FEFCO)*
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Description of tertiary packaging				
Pallet				
Number of products per pallet				Oenoforos / JeanJean
Weight	[g]	22000	22000	*Bibliography (BIOIS)*
Reused	times	30	30	*assumption*
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Wrapping film				
Weight	[g]			JeanJean
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Transport stages				
Fabrication of primary packaging -> filling stage				
Nb of products per pallet				*assumption (as filled)*
Nb of pallets per truck		33	33	*assumption (as filled)*
Truck (calculated load)				
Distance	[km]	800	800	*assumption*
Fabrication of closures -> filling stage				
Truck (80% load)				*assumption*
Distance	[km]	250	250	*assumption*
Filling stage -> distribution hub				
Truck (calculated load)				
Distance	[km]	2411	2411	*assumption*
Distribution hub -> retailers				
Truck (calculated load)				
Distance	[km]	150	150	*assumption*
Transport of waste				
Household waste	[km]	50	50	*Bibliography (BIOIS)*
Recycled waste	[km]	400	400	*Bibliography (BIOIS)*
Distribution				
Country of distribution		Sweden/Norway	Sweden/Norway	*assumption*

9.3.3. BAG IN BOX

Type of data	Unit	Bag in Box 1,5L	Bag in Box 2L	Bag in Box 3L	Bag in Box 5L	Bag in Box 10L	Data Source
Description of primary packaging							
Content							
Volume	[cl]	150	200	300	500	1000	-
Total weight	[g]	117	142	179	233	500	-
Principal materials							
Total weight	[g]						-
Cardboard							
Recycled content	[%]	82%	82%	82%	82%	82%	*Bibliography (FEFCO)*
Weight	[g]						Smurfit Kappa/ Gustav Jonsson Berntsonvin (1,5L)
Truck (80% load)							*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
Extruded PET							
Recycled content	[%]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Weight	[g]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Truck (80% load)							*assumption*
Distance	[km]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Aluminum foil							
Recycled content	[%]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Weight	[g]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Truck (80% load)							*assumption*
Distance	[km]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Extruded LDPE							
Recycled content	[%]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Weight	[g]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Truck (80% load)							*assumption*
Distance	[km]						Smurfit Kappa (all volumes except 1,5L extrapolated)
EVOH							
Recycled content	[%]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Weight	[g]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Truck (80% load)	[km]						*assumption*
Distance	[km]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Extruded LLDPE							
Recycled content	[%]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Weight	[g]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Truck (80% load)							*assumption*
Distance	[km]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Fabrication of the primary package							
Country		France	France	France	France	France	Smurfit Kappa (all volumes except 1,5L extrapolated)
Electricity	[MJ]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Fuel oil	[MJ]						Smurfit Kappa (all volumes except 1,5L extrapolated)
Losses	%						Smurfit Kappa (all volumes except 1,5L extrapolated)

Type of data	Unit						Data Source
Other materials							
Closure							
Total weight	[g]						-
Polypropylene							
Recycled content	[%]						Vitop
Weight	[g]						Vitop
Truck (80% load)	[km]						*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
Polypropylene							
Recycled content	[%]						Vitop
Weight	[g]						Vitop
Truck (80% load)	[km]						*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
HDPE							
Recycled content	[%]						Vitop
Weight	[g]						Vitop
Truck (80% load)	[km]						*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
Elastomer (PET)							
Recycled content	[%]						Vitop
Weight	[g]						Vitop
Truck (80% load)							*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
LDPE							
Recycled content	[%]						Vitop
Weight	[g]						Vitop
Truck (80% load)							*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
Fabrication of the closure							
Country		Italy	Italy	Italy	Italy	Italy	Vitop
Electricity	[MJ]						Vitop
Fuel oil	[MJ]						Vitop
Water	[m^3]						Vitop
Losses	%						Vitop

Type of data	Unit						Data Source
Filling stage							
Formation of the box							
Country		France	France	France	France	France	JeanJean
Electricity	[MJ]						JeanJean
Filling of the bag and assembling of the bag in box							
Country		France	France	France	France	France	JeanJean
Electricity	[MJ]						JeanJean
Losses	%						JeanJean
Sticking and closing the product							
Country		France	France	France	France	France	JeanJean
Electricity	[MJ]						JeanJean
Losses	%						JeanJean
Secondary and tertiary conditioning							
Country		France	France	France	France	France	JeanJean
Electricity	[MJ]						JeanJean
Description of secondary packaging							
Cardboard box							
Number of products per box							JeanJean
Weight	[g]						JeanJean
Recycled content	[%]	82%	82%	82%	82%	82%	*Bibliography (FEFCO)*
Truck (80% load)							*assumption*
Distance	[km]	250	250	250	-	-	*assumption*
Description of tertiary packaging							
Palet							
Number of products per pallet							JeanJean / Gustav Jonsson Berntsonvin / Oenoforos
Weight	[g]	22000	22000	22000	22000	22000	*Bibliography (BIOIS)*
Reused	times	30	30	30	30	30	*assumption*
Truck (80% load)							*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
Cardboard for bottom of pallet							
Weight	[g]						JeanJean/Gustav Jonsson Berntsonvin (1,5L)
Recycled content	[%]	82%	82%	82%	82%	82%	*Bibliography (FEFCO)*
Truck (80% load)							*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
Wrapping film							
Weight	[g]						JeanJean/Gustav Jonsson Berntsonvin (1,5L)
Recycled content	[%]	0%	0%	0%	0%	0%	*assumption*
Truck (80% load)							*assumption*
Distance	[km]	250	250	250	250	250	*assumption*

Type of data	Unit						Data Source
Transport stages							
Fabrication of closures -> fabrication of primary packaging							
Truck only (80% load)							
Proportion concerned	%						Vitop / 1,5L extrapolated
Distance	[km]						Vitop / 1,5L extrapolated
Truck & train							
Proportion concerned	%						Vitop / 1,5L extrapolated
Truck only (80% load)	[km]						Vitop / 1,5L extrapolated
Train	[km]						Vitop / 1,5L extrapolated
Fabrication of bag -> filling stage							
Nb of products per pallet							Smurfit Kappa (all volumes except 1,5L extrapolated)
Nb of pallets per truck		33	33	33	33	33	*assumption*
Truck (calculated load)	[km]						
Distance	[km]	815	815	815	815	815	Smurfit Kappa (all volumes except 1,5L extrapolated)
Fabrication of box -> filling stage							
Truck only (80% load)							*assumption*
Distance	[km]	250	250	250	250	250	*assumption*
Filling stage -> distribution hub							
Truck (calculated load)	[km]						
Distance	[km]	2411	2411	2411	2411	2411	*assumption*
Distribution hub -> retailers							
Truck (calculated load)	[km]						
Distance	[km]	150	150	150	150	150	*assumption*
Transport of waste							
Household waste	[km]	50	50	50	50	50	*Bibliography (BIOIS)*
Recycled waste	[km]	400	400	400	400	400	*Bibliography (BIOIS)*
Distribution							
Country of distribution		Sweden/Norway	Sweden/Norway	Sweden/Norway	Sweden/Norway	Sweden/Norway	*assumption*

9.3.4. Stand up Pouch

Type of data	Unit	Stand Up Pouch 3L	Stand Up Pouch 1,5L	Stand Up Pouch 1L	Data Source
Description of primary packaging					
Content					
Volume	[cl]	300	150	100	-
Total weight	[g]	61.9	34.8	32.3	-
Principal materials					
Total weight	[g]				Smurfit Kappa (1,5L)/Gustav Jonsson Bernstonvin (other volumes)
Aluminum foil					
Recycled content	[%]	0%	0%	0%	Smurfit Kappa (1,5L)/other volumes extrapolated
Weight	[g]				Smurfit Kappa (1,5L)/other volumes extrapolated
Truck (80% load)					*assumption*
Distance	[km]				
Extruded PET					
Recycled content	[%]				Smurfit Kappa (1,5L)/other volumes extrapolated
Weight	[g]				Smurfit Kappa (1,5L)/other volumes extrapolated
Truck (80% load)					*assumption*
Distance	[km]				Smurfit Kappa (1,5L)/other volumes extrapolated
Extruded LDPE					
Recycled content	[%]				Smurfit Kappa (1,5L)/other volumes extrapolated
Weight	[g]				Smurfit Kappa (1,5L)/other volumes extrapolated
Truck (80% load)					*assumption*
Distance	[km]				Smurfit Kappa (1,5L)/other volumes extrapolated
Extruded LLDPE					
Recycled content	[%]				Smurfit Kappa (1,5L)/other volumes extrapolated
Weight	[g]				Smurfit Kappa (1,5L)/other volumes extrapolated
Truck (80% load)					*assumption*
Distance	[km]				Smurfit Kappa (1,5L)/other volumes extrapolated
Fabrication of the primary package					
Country		France	France	France	Smurfit Kappa (1,5L)/other volumes extrapolated
Electricity	[MJ]				Smurfit Kappa (1,5L)/other volumes extrapolated
Fuel Oil	[MJ]				Smurfit Kappa (1,5L)/other volumes extrapolated
Losses	%				Smurfit Kappa (1,5L)/other volumes extrapolated

Type of data	Unit	Stand Up Pouch 3L	Stand Up Pouch 1,5L	Stand Up Pouch 1L	Data Source
Other materials					
Closure					
Total weight	[g]				-
Polypropylene					
Recycled content	[%]				Vitop
Weight	[g]				Vitop
Truck (80% load)					*assumption*
Distance	[km]	250	250	250	*assumption*
Polypropylene					
Recycled content	[%]				Vitop
Weight	[g]				Vitop
Truck (80% load)					*assumption*
Distance	[km]	250	250	250	*assumption*
HDPE					
Recycled content	[%]				Vitop
Weight	[g]				Vitop
Truck (80% load)					*assumption*
Distance	[km]	250	250	250	*assumption*
Elastomer (PET)					
Recycled content	[%]				Vitop
Weight	[g]				Vitop
Truck (80% load)					*assumption*
Distance	[km]	250	250	250	*assumption*
LDPE					
Recycled content	[%]				Vitop
Weight	[g]				Vitop
Truck (80% load)					*assumption*
Distance	[km]	250	250	250	*assumption*

Type of data			Unit	Stand Up Pouch 3L	Stand Up Pouch 1,5L	Stand Up Pouch 1L	Data Source
	Fabrication of the closure						
		Country		Italy	Italy	Italy	Vitop
		Electricity	[MJ]				Vitop
		Fuel oil	[MJ]				Vitop
		Water	[m^3]				Vitop
		Losses	%				Vitop
Filling stage							
	Filling the bag						
		Country		France	France	France	JeanJean (1,5L)/other volumes extrapolated
		Electricity	[MJ]				JeanJean (1,5L)/other volumes extrapolated
		Losses	%				JeanJean (1,5L)/other volumes extrapolated
	Closing the bag						
		Country		France	France	France	JeanJean (1,5L)/other volumes extrapolated
		Electricity	[MJ]				JeanJean (1,5L)/other volumes extrapolated
	All other stages made by hand						JeanJean (1,5L)/other volumes extrapolated
Description of secondary packaging							
	Cardboard box						
	Number of products per box						JeanJean (1,5L)/Gustav Jonsson Bernstonvin (other volumes)
		Weight	[g]				JeanJean (1,5L)/Gustav Jonsson Bernstonvin (other volumes)
		Recycled content	[%]	82%	82%	82%	*Bibliography (FEFCO)*
		Truck (80% load)					*assumption*
		Distance	[km]	250	250	250	*assumption*
Description of tertiary packaging							
	Palet						
	Number of products per pallet						JeanJean (1,5L)/Gustav Jonsson Bernstonvin (other volumes)
		Weight	[g]	22000	22000	22000	*Bibliography (BIOIS)*
		Reused	times	30	30	30	*assumption*
		Truck (80% load)					*assumption*
		Distance	[km]	250	250	250	*assumption*
	Paper sheets						
		Weight	[g]				JeanJean (1,5L)/Gustav Jonsson Bernstonvin (other volumes)
		Recycled content	[%]	49%	49%	49%	*Bibliography (CEPI)*
		Truck (80% load)					*assumption*
		Distance	[km]	250	250	250	*assumption*
	Wrapping film						
		Weight	[g]				JeanJean (1,5L)/Gustav Jonsson Bernstonvin (other volumes)
		Recycled content	[%]	0%	0%	0%	*assumption*
		Truck (80% load)					*assumption*
		Distance	[km]	250	250	250	*assumption*

Type of data	Unit	Stand Up Pouch 3L	Stand Up Pouch 1,5L	Stand Up Pouch 1L	Data Source
Transport stages					
Fabrication of closures -> fabrication of primary packaging					
Truck only (80% load)					
Proportion concerned	%				Vitop (1,5L)/other volumes extrapolated
Distance	[km]				Vitop (1,5L)/other volumes extrapolated
Truck & train					
Proportion concerned	%				Vitop (1,5L)/other volumes extrapolated
Truck only (80% load)	[km]				Vitop (1,5L)/other volumes extrapolated
Train	[km]				Vitop (1,5L)/other volumes extrapolated
Fabrication of primary packaging -> filling stage					
Nb of products per pallet					Smurfit Kappa (1,5L)/other volumes extrapolated
Nb of pallets per truck		33,00	33,00	33,00	Smurfit Kappa (1,5L)/other volumes extrapolated
Truck (calculated load)					
Distance	[km]				Smurfit Kappa (1,5L)/other volumes extrapolated
Filling stage -> distribution hub					
Truck (calculated load)					
Distance	[km]	2411	2411	2411	*assumption*
Distribution hub -> retailers					
Truck (calculated load)					
Distance	[km]	150	150	150	*assumption*
Transport of waste					
Household waste	[km]	50	50	50	*Bibliography (BIOIS)*
Recycled waste	[km]	400	400	400	*Bibliography (BIOIS)*
Distribution					
Country of distribution	0	Sweden/Norway	Sweden/Norway	Sweden/Norway	*assumption*

9.3.5. BEVERAGE CARTON

9.3.5.1. Elopak data used for determining the average impacts of beverage carton

Type of data	Unit	Beverage carton Elopak 1L	Beverage carton Elopak 75cl	Beverage carton Elopak 50cl	Beverage carton Elopak 25cl	Data source
Description of primary packaging						
Content						
Volume	[cl]	100	75	50	25	-
Total weight	[g]	36.6	31.5	23.8	15.6	-
Principal materials						
Total weight	[g]					Elopak
Extruded LDPE						
Recycled content	[%]					Elopak
Weight	[g]					Elopak
Truck (80% load)						*assumption*
Distance	[km]					Elopak
Liquid carton board						
Recycled content	[%]					Elopak
Weight	[g]					
Boat						Elopak
Distance	[km]					Elopak
Aluminum foil						
Recycled content	[%]					Elopak
Weight	[g]					Elopak
Truck (80% load)						*assumption*
Distance	[km]					Elopak
Fabrication of the primary package						
Country		Netherlands	Netherlands	Netherlands	Netherlands	Elopak
Electricity	[MJ]					Elopak
Natural gas	[MJ]					Elopak
Water	[m^3]					Elopak
Losses	%					Elopak

Type of data	Unit	Beverage carton Elopak 1L	Beverage carton Elopak 75cl	Beverage carton Elopak 50cl	Beverage carton Elopak 25cl	Data source
Other materials						
Closure						
Total weight	[g]					Elopak
Injected moulded HDPE						
Recycled content	[%]					Elopak
Weight	[g]					Elopak
Truck (80% load)						*assumption*
Distance	[km]	250	250	250	250	*assumption*
Filling stage						
Filling/closing/conditioning						
Country		Netherlands	Netherlands	Netherlands	Netherlands	Elopak
Electricity	[MJ]					Elopak
Water	[m^3]					Elopak
Losses	%					Elopak
Description of secondary packaging						
Cardboard box						
Number of products per box						Elopak
Weight	[g]					Elopak
Recycled content	[%]					Elopak
Truck (80% load)						*assumption*
Distance	[km]	250	250	250	250	*assumption*

Type of data			Unit	Beverage carton Elopak 1L	Beverage carton Elopak 75cl	Beverage carton Elopak 50cl	Beverage carton Elopak 25cl	Data source
Description of tertiary packaging								
	Palet							
	Number of products per pallet							Elopak
		Weight	[g]	22000	22000	22000	22000	*Bibliography (BIOIS)*
		Reused	times	30	30	30	30	*assumption*
		Truck (80% load)						*assumption*
		Distance	[km]	250	250	250	250	*assumption*
	Cardboard for bottom of pallet							
		Weight	[g]	1900	1900	1900	1900	*Bibliography (BIOIS)*
		Recycled content	[%]	82%	82%	82%	82%	*Bibliography (FEFCO)*
		Truck (80% load)						*assumption*
		Distance	[km]	250	250	250	250	*assumption*
	Wrapping film							
		Weight	[g]	850	850	850	850	*Bibliography (BIOIS)*
		Recycled content	[%]	0%	0%	0%	0%	*assumption*
		Truck (80% load)						*assumption*
		Distance	[km]	250	250	250	250	*assumption*

Transport stages								
	Fabrication of primary packaging (+closure) -> filling stage							
		Nb of products per pallet						Elopak
		Nb of pallets per truck		33	33	33	33	*assumption*
		Truck (calculated payload)						
		Distance	[km]	1040	1040	1040	1040	Elopak
	Fabrication of closure -> Fabrication of primary packaging							
		Truck (80% load)						*assumption*
		Distance	[km]					Elopak
	Filling stage -> distribution hub							
		Truck (calculated payload)						
		Distance	[km]	2411	2411	2411	2411	*assumption*
	Distribution hub -> retailers							
		Truck (calculated payload)						
		Distance	[km]	150	150	150	150	*assumption*
	Transport of waste							
		Household waste	[km]	50	50	50	50	*Bibliography (BIOIS)*
		Recycled waste	[km]	400	400	400	400	*Bibliography (BIOIS)*
Distribution								
		Country of distribution	0	Sweden/Norway	Sweden/Norway	Sweden/Norway	Sweden/Norway	*assumption*

9.3.5.2. Tetra Pak data used for determining the average impacts of beverage carton

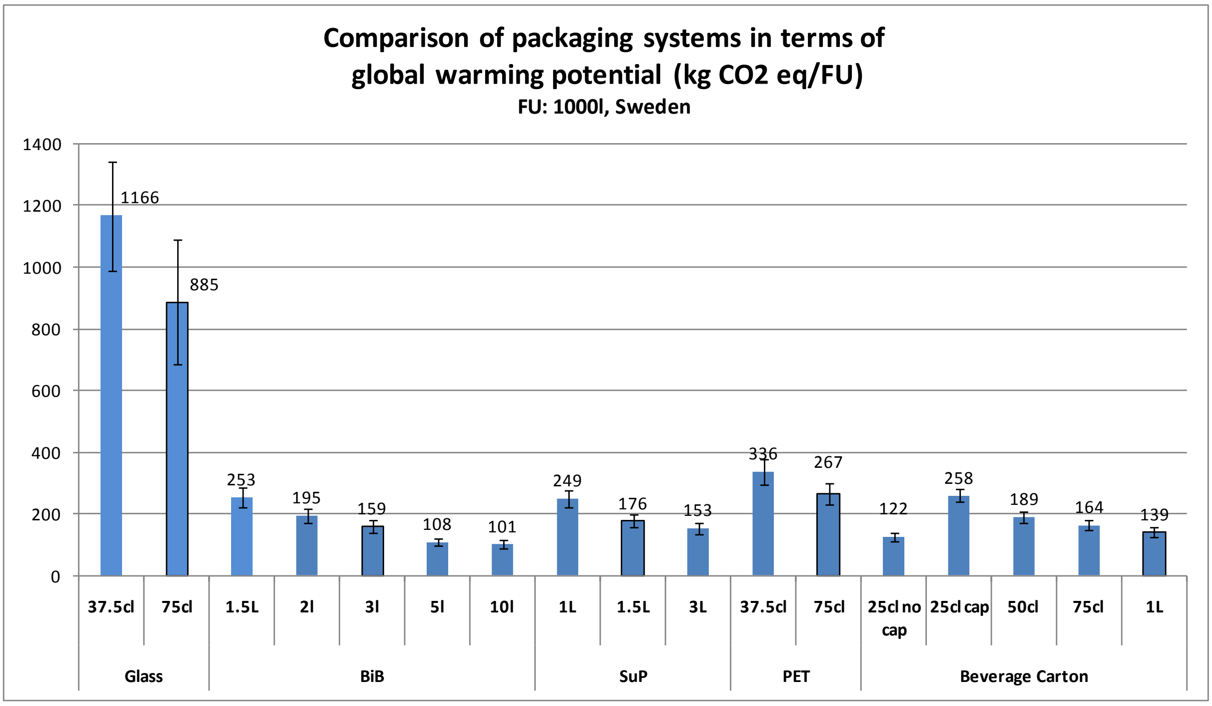
Type of data	Unit	Beverage carton Tetrapak 1L	Beverage carton Tetrapak 75cl	Beverage carton Tetrapak 50cl	Beverage carton Tetrapak 25cl	Data source
Description of primary packaging						
Content						
Volume	[cl]	100	75	50	25	-
Total weight	[g]	39,6	33,2	22,7	9,3	-
Principal materials						
Total weight	[g]					Tetrapak
Liquid carton board						
Recycled content	[%]					Tetrapak
Weight	[g]					Tetrapak
Train						
Distance	[km]					Tetrapak
Extruded LDPE						
Recycled content	[%]					Tetrapak
Weight	[g]					Tetrapak
Truck (80% load)						*assumption*
Distance	[km]					Tetrapak
Extruded LLDPE						
Recycled content	[%]					Tetrapak
Weight	[g]					Tetrapak
Truck (80% load)						*assumption*
Distance	[km]					Tetrapak
Acrylic acid						
Recycled content	[%]					Tetrapak
Weight	[g]					Tetrapak
Truck (80% load)						*assumption*
Distance	[km]					Tetrapak
Extruded EVA						
Recycled content	[%]					Tetrapak
Weight	[g]					Tetrapak
Truck (80% load)						*assumption*
Distance	[km]					Tetrapak
Aluminum foil						
Recycled content	[%]					Tetrapak
Weight	[g]					Tetrapak
Truck (80% load)						*assumption*
Distance	[km]					Tetrapak

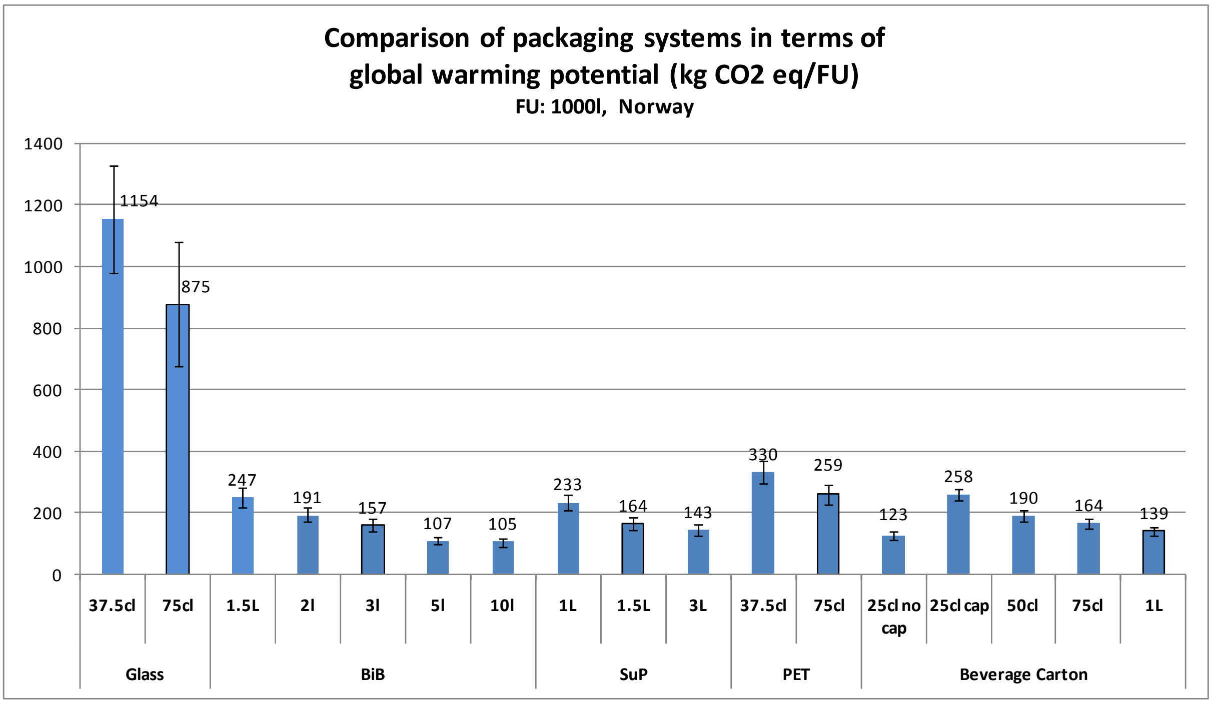
Type of data	Unit	Beverage carton Tetrapak 1L	Beverage carton Tetrapak 75cl	Beverage carton Tetrapak 50cl	Beverage carton Tetrapak 25cl	Data source
Fabrication of the primary package						
Country		Germany (green electricity)	Netherlands (green electricity)	Sweden	Sweden	Tetrapak
Electricity	[MJ]					Tetrapak
Natural gas	[MJ]					Tetrapak
Water	[m^3]					Tetrapak
Losses	%					Tetrapak
Other materials						
Closure						
Total weight	[g]					Tetrapak
Injected moulded HDPE						
Recycled content	[%]					Tetrapak
Weight	[g]					Tetrapak
Truck (80% load)						*assumption*
Distance	[km]					*assumption*
Injected moulded PP						
Recycled content	[%]					Tetrapak
Weight	[g]					Tetrapak
Truck (80% load)						*assumption*
Distance	[km]					*assumption*
Filling stage						
Hydrogen peroxide						
Quantity	[g]					Tetrapak
Truck (80% load)						*assumption*
Distance	[km]	250	250	250	250	*assumption*
Filling/closing/conditioning						
Country		France	France	France	France	Tetrapak
Electricity	[MJ]					Tetrapak
Water	[m^3]					Tetrapak
Losses	%					Tetrapak
Steam	kg					Tetrapak
Compressed air	Nl					Tetrapak

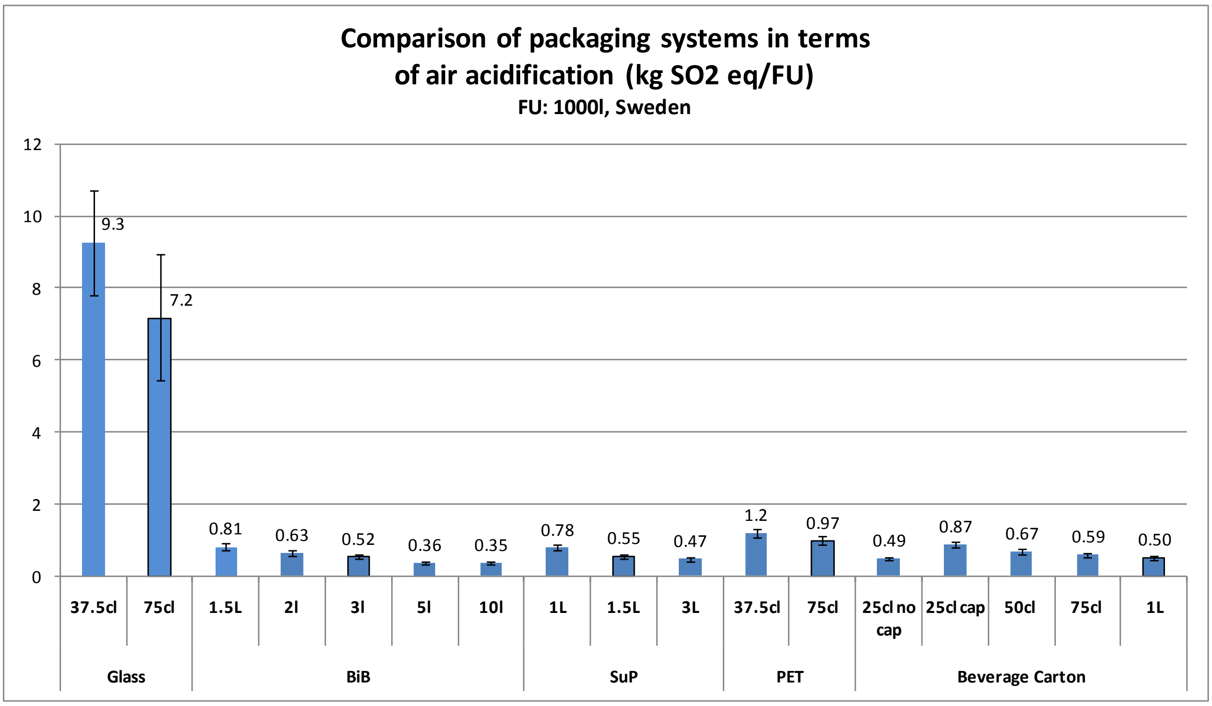
Type of data			Unit	Beverage carton Tetrapak 1L	Beverage carton Tetrapak 75cl	Beverage carton Tetrapak 50cl	Beverage carton Tetrapak 25cl	Data source
Description of secondary & tertiary packaging								
	Secondary & tertiary packaging							
	Cardboard box/unit							
		Weight	[g]					Tetrapak
		Recycled content	[%]	82%	82%	82%	82%	*Bibliography (FEFCO)*
		Truck (80% load)						*assumption*
		Distance	[km]	250	250	250	250	*assumption*
	HDPE film/unit							
		Weight	[g]					Tetrapak
		Recycled content	[%]	0%	0%	0%	0%	*assumption*
		Truck (80% load)						*assumption*
		Distance	[km]	250	250	0	0	*assumption*
	Palet							
		Number of products per pallet	0					Tetrapak
		Weight	[g]	22000	22000	22000	22000	*Bibliography (BIOIS)*
		Reused	times	30	30	30	30	*assumption*
		Truck (80% load)						*assumption*
		Distance	[km]	250	250	250	250	*assumption*
	Cardboard for bottom of pallet							
		Weight	[g]	1900	1900	1900	1900	*Bibliography (BIOIS)*
		Recycled content	[%]	82%	82%	82%	82%	*Bibliography (FEFCO)*
		Truck (80% load)						
		Distance	[km]	250	250	250	250	*assumption*
Transport stages								
	Fabrication of primary packaging -> filling stage							
		Truck (70% load)						Tetrapak
		Distance	[km]	1077	1122	1891	1891	Tetrapak
	Fabrication of closures -> filling stage							
		Truck (80% load)						*assumption*
		Distance	[km]	600	600	600	600	Tetrapak
	Filling stage -> distribution hub							
		Truck (calculated load)						
		Distance	[km]	2411	2411	2411	2411	*assumption*
	Distribution hub -> retailers							
		Truck (calculated load)						
		Distance	[km]	150	150	150	150	*assumption*
	Transport of waste							
		Household waste	[km]	50	50	50	50	*Bibliography (BIOIS)*
		Recycled waste	[km]	400	400	400	400	*Bibliography (BIOIS)*
Distribution								
		Country of distribution		Sweden/Norway	Sweden/Norway	Sweden/Norway	Sweden/Norway	*assumption*

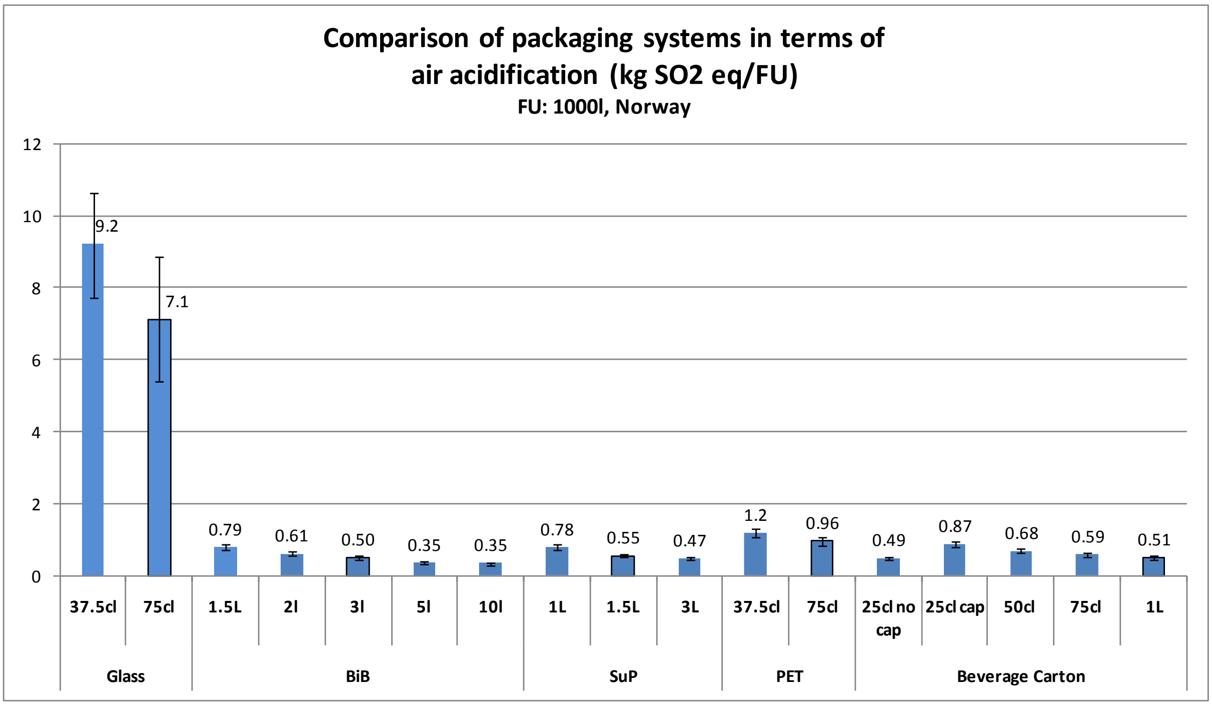
9.4 ANNEX 4: COMPARISON OF PACKAGING SYSTEMS

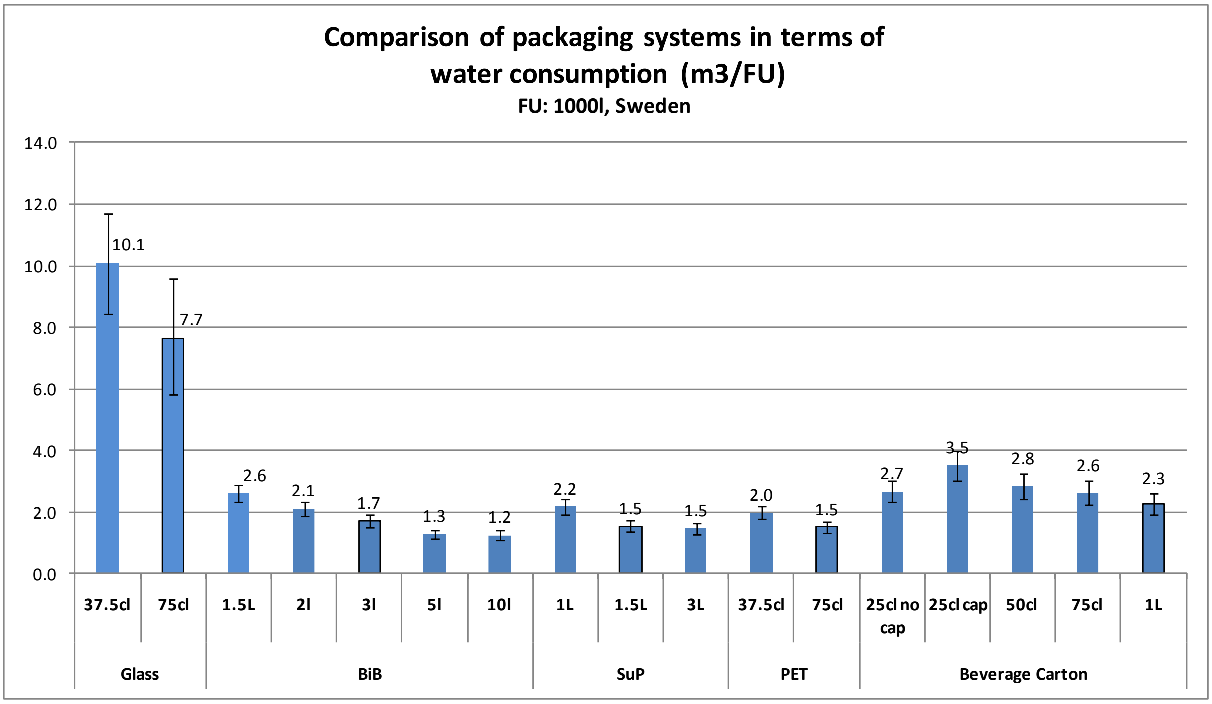
The baseline results for the five packaging systems and the five indicators are presented hereafter. They are the same as the one presented in section 6.2. However, in this annex the intervals presented in the results graphs are based on the theoretical best case / worst case scenarios presented in Table 55 except for transportation distances where the reference values are employed instead. This is done to evaluate the share of variability that is not due to uncertainty on transportation distances.

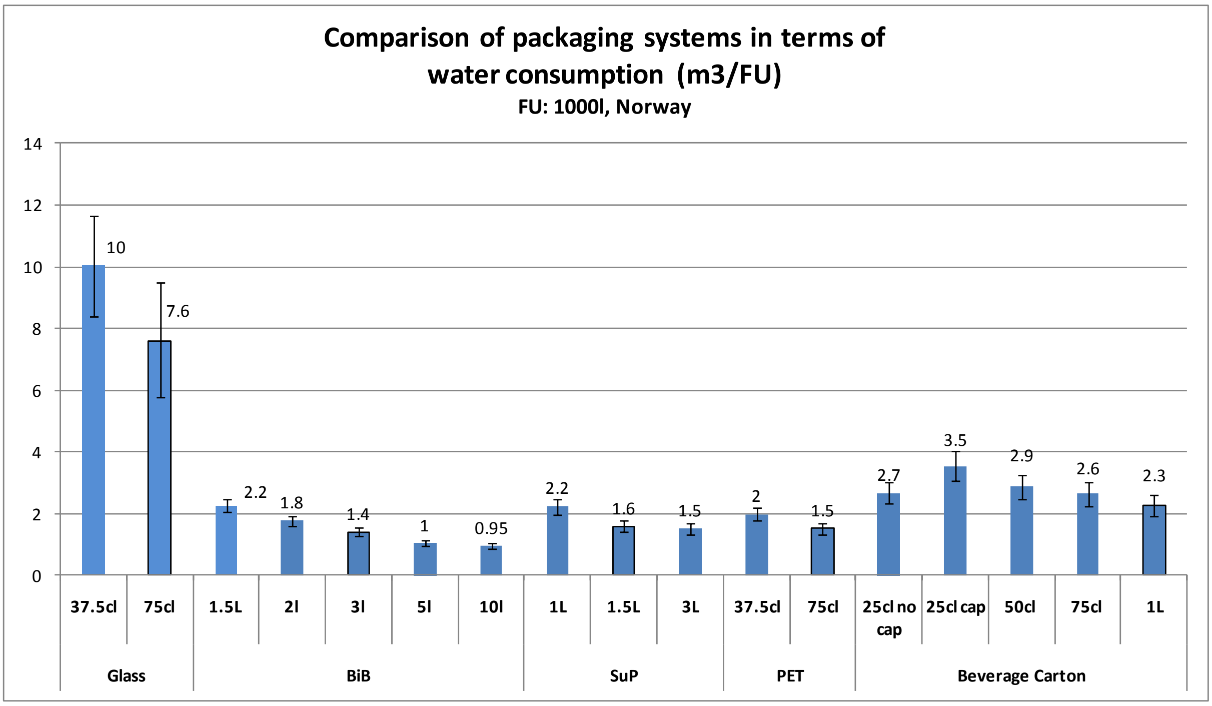


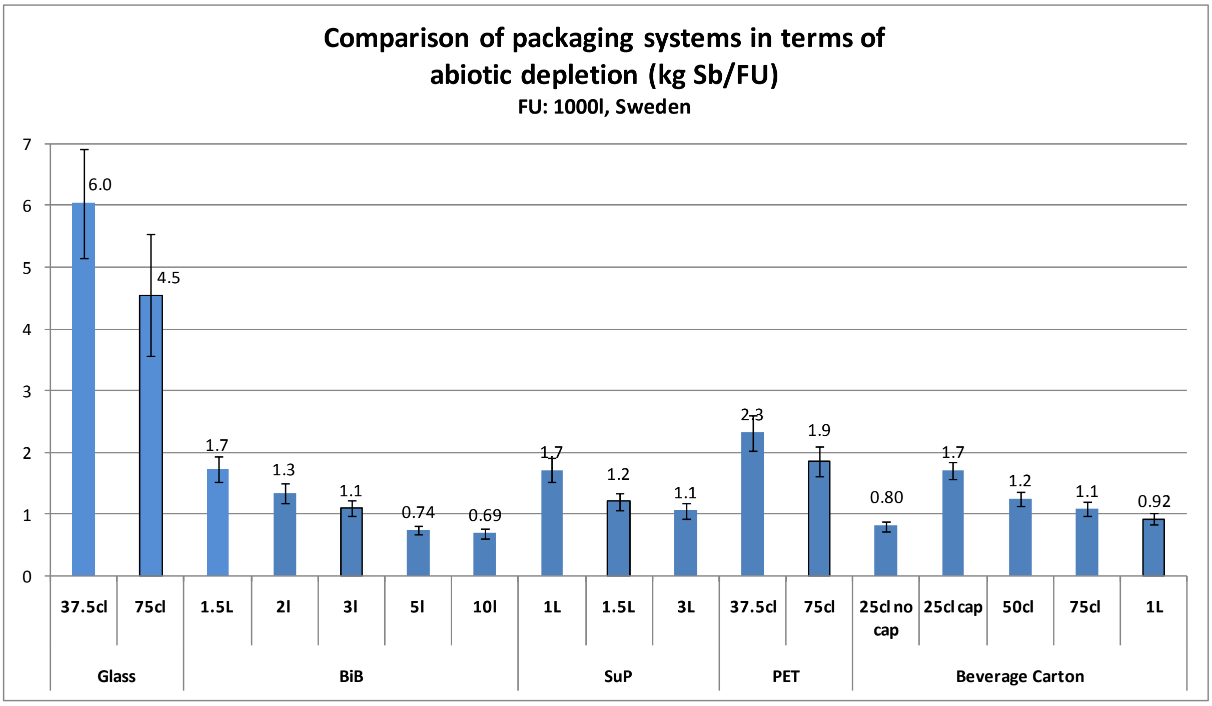



Comparison of packaging systems in terms of air acidification (kg SO2 eq/FU)
FU: 1000l, Sweden
12
10
8
6
4
2
0
9.3
7.2
0.81
0.63
0.52
0.36
0.35
0.78
0.55
0.47
1.2
0.97
0.49
0.87
0.67
0.59
0.50
37.5cl
75cl
1.5L
2l
3l
5l
10l
1L
1.5L
3L
37.5cl
75cl
25cl no cap
25cl cap
50cl
75cl
1L
Glass
BiB
SuP
PET
Beverage Carton

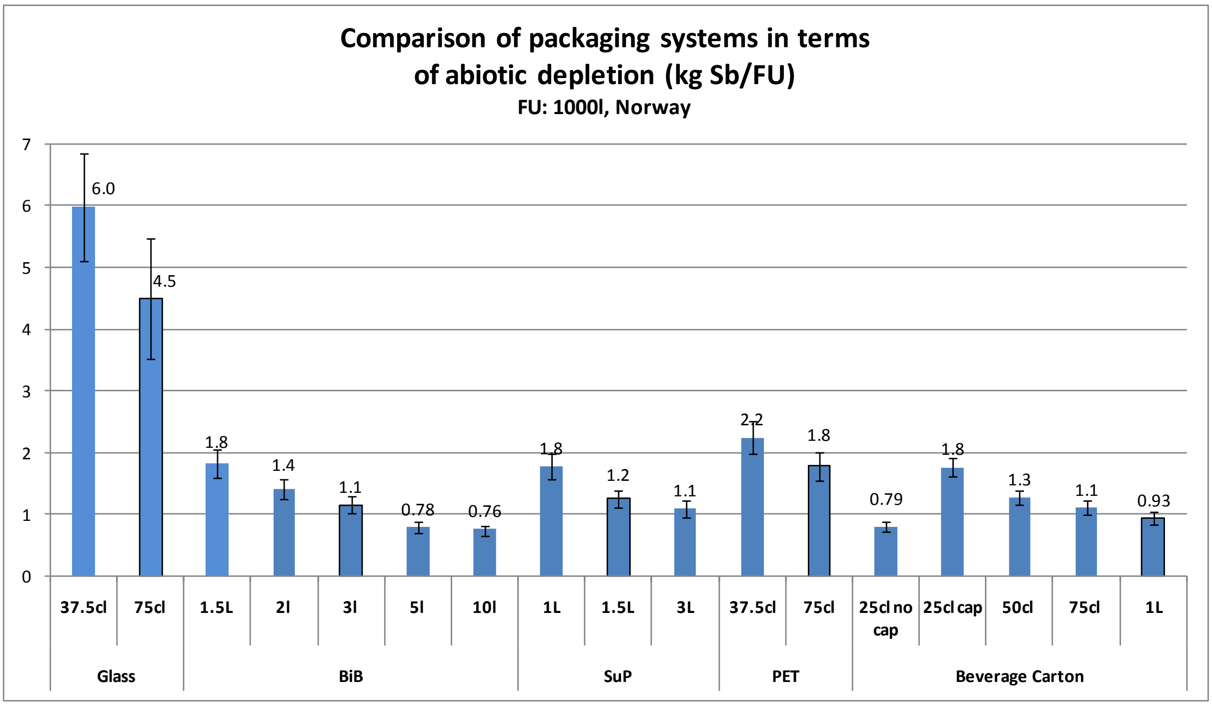

Comparison of packaging systems in terms of air acidification (kg SO2 eq/FU)
FU: 1000l, Norway
12
10
8
6
4
2
0
9.2
7.1
0.79
0.61
0.50
0.35
0.35
0.78
0.55
0.47
1.2
0.96
0.49
0.87
0.68
0.59
0.51
37.5cl
75cl
1.5L
2l
3l
5l
10l
1L
1.5L
3L
37.5cl
75cl
25cl no cap
25cl cap
50cl
75cl
1L
Glass
BiB
SuP
PET
Beverage Carton


Comparison of packaging systems in terms of water consumption (m3/FU)
FU: 1000l, Sweden
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10.1
7.7
2.6
2.1
1.7
1.3
1.2
2.2
1.5
1.5
2.0
1.5
2.7
3.5
2.8
2.6
2.3
37.5cl
75cl
1.5L
2l
3l
5l
10l
1L
1.5L
3L
37.5cl
75cl
25cl no cap
25cl cap
50cl
75cl
1L
Glass
BiB
SuP
PET
Beverage Carton

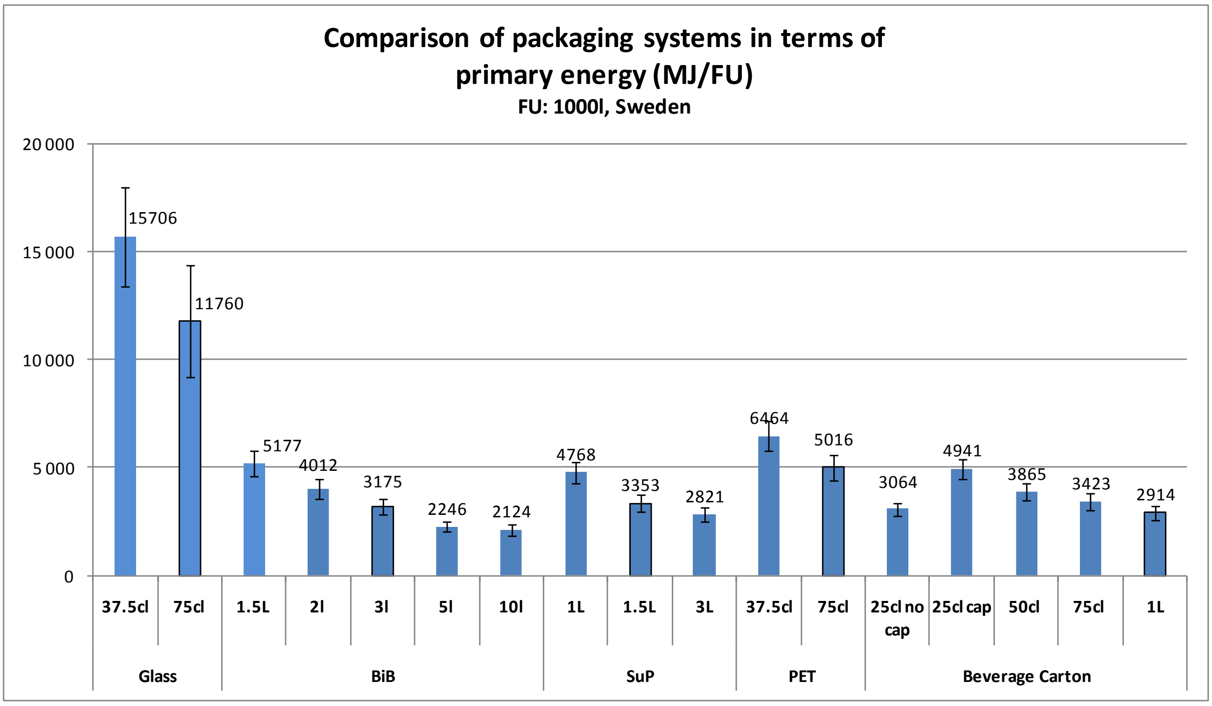

Comparison of packaging systems in terms of water consumption (m3/FU)
FU: 1000l, Norway
14
12
10
8
6
4
2
0
10
7.6
2.2
1.8
1.4
1
0.95
2.2
1.6
1.5
2
1.5
2.7
3.5
2.9
2.6
2.3
37.5cl
75cl
1.5L
2l
3l
5l
10l
1L
1.5L
3L
37.5cl
75cl
25cl no cap
25cl cap
50cl
75cl
1L
Glass
BiB
SuP
PET
Beverage Carton

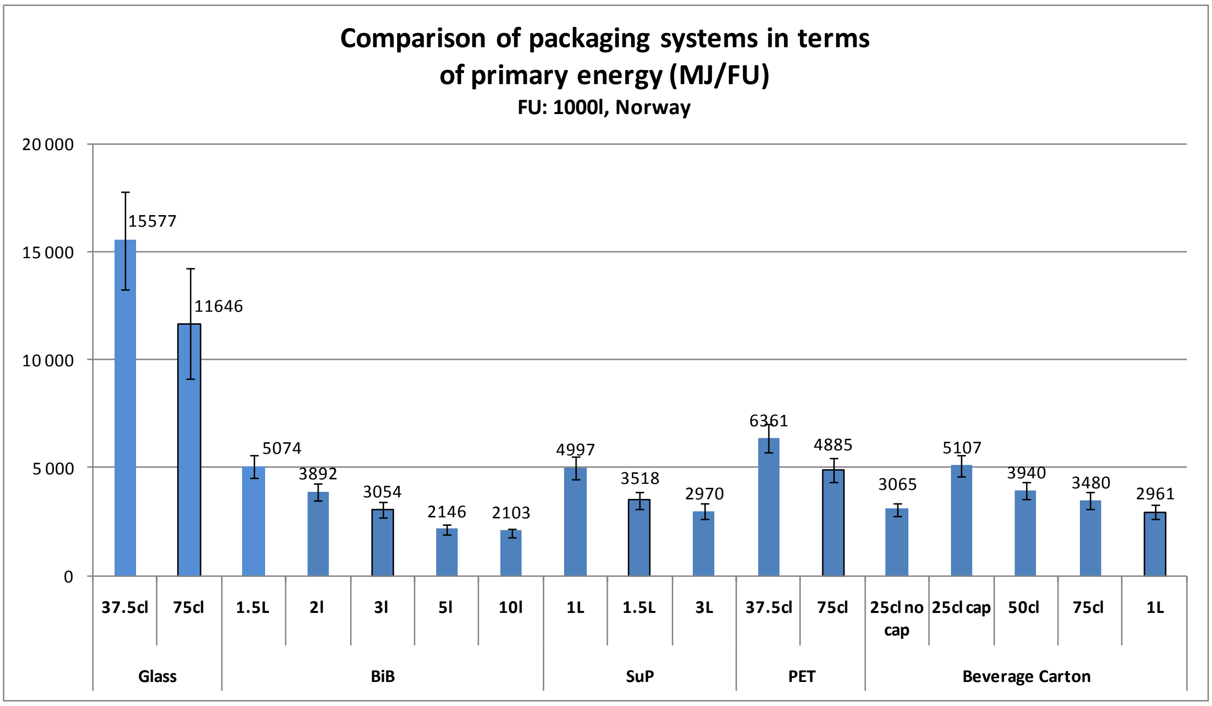


Comparison of packaging systems in terms of abiotic depletion (kg Sb/FU)
FU: 1000l, Sweden
7
6
5
4
3
2
1
0
6.0
4.5
1.7
1.3
1.1
0.74
0.69
1.7
1.2
1.1
2.3
1.9
0.80
1.7
1.2
1.1
0.92
37.5cl
75cl
1.5L
2l
3l
5l
10l
1L
1.5L
3L
37.5cl
75cl
25cl no cap
25cl cap
50cl
75cl
1L
Glass
BiB
SuP
PET
Beverage Carton



Comparison of packaging systems in terms of abiotic depletion (kg Sb/FU)
FU: 1000l, Norway
7
6
5
4
3
2
1
0
6.0
4.5
1.8
1.4
1.1
0.78
0.76
1.8
1.2
1.1
2.2
1.8
0.79
1.8
1.3
1.1
0.93
37.5cl
75cl
1.5L
2l
3l
5l
10l
1L
1.5L
3L
37.5cl
75cl
25cl no cap
25cl cap
50cl
75cl
1L
Glass
BiB
SuP
PET
Beverage Carton


Comparison of packaging systems in terms of primary energy (MJ/FU)
FU: 1000l, Sweden
20 000
15 000
10 000
5 000
0
15706
11760
5177
4012
3175
2246
2124
4768
3353
2821
6464
5016
3064
4941
3865
3423
2914
37.5cl
75cl
1.5L
2l
3l
5l
10l
1L
1.5L
3L
37.5cl
75cl
25cl no cap
25cl cap
50cl
75cl
1L
Glass
BiB
SuP
PET
Beverage Carton


Comparison of packaging systems in terms of primary energy (MJ/FU)
FU: 1000l, Norway
20 000
15 000
10 000
5 000
0
15577
11646
5074
3892
3054
2146
2103
4997
3518
2970
6361
4885
3065
5107
3940
3480
2961
37.5cl
75cl
1.5L
2l
3l
5l
10l
1L
1.5L
3L
37.5cl
75cl
25cl no cap
25cl cap
50cl
75cl
1L
Glass
BiB
SuP
PET
Beverage Carton

9.5 ANNEX 5: ESTIMATION OF ENVIRONMENTAL IMPROVEMENT FOR GLASS

Table 60: Estimation of environmental improvements (30% reduction) in the production of glass in terms of global warming potential in Sweden and Norway

SWEDEN	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**3,14**	103,6%	23,0%	23,5%	-50,1%
Water consumption	m3	**5,27**	105,6%	38,2%	2,6%	-46,4%
Primary energy	MJ primary	**8004**	109,5%	38,9%	21,1%	-69,4%
Global warming potential	kg CO2 eq	**595**	113,6%	17,5%	19,5%	-50,5%
Ozone layer depletion potential	kg CFC-11 eq	**3,88E-05**	139,2%	34,3%	45,6%	-119,1%
Photochemical oxidation potential	kg C2H4 eq	**1,59E-01**	120,0%	15,8%	10,9%	-46,6%
Air acidification potential	kg SO2 eq	**4,891**	108,3%	11,2%	12,7%	-32,2%
Eutrophication potential	kg PO4 eq	**0,519**	68,7%	23,7%	26,8%	-19,2%

NORWAY	Unit	Total	Packaging production	Filling	Distribution	Waste management
Abiotic resources depletion potential	kg Sb eq	**3,14**	103,6%	16,1%	16,5%	-36,2%
Water consumption	m3	**5,32**	104,6%	26,5%	1,8%	-32,9%
Primary energy	MJ primary	**8152**	107,5%	26,7%	14,5%	-48,7%
Global warming potential	kg CO2 eq	**612**	110,4%	11,9%	13,2%	-35,5%
Ozone layer depletion potential	kg CFC-11 eq	**4,21E-05**	128,0%	22,1%	29,4%	-79,5%
Photochemical oxidation potential	kg C2H4 eq	**1,67E-01**	114,2%	10,5%	7,3%	-32,0%
Air acidification potential	kg SO2 eq	**4,976**	106,4%	7,7%	8,7%	-22,9%
Eutrophication potential	kg PO4 eq	**0,467**	76,3%	18,5%	20,8%	-15,6%