Environmental impacts of alcoholic beverages
as distributed by the Nordic Alcohol Monopolies 2014

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Preface

This report has been prepared by Bo P. Weidema, Marie de Saxcé, and Ivan Muñoz of 2.-0 LCA consultants, Denmark, for the Nordic Alcohol Monopolies (Alko in Finland represented by Virpi Valtonen and Kirsi Erme, Systembolaget in Sweden represented by Lena Rogeman and Maria Hagström, and Vinmonopolet in Norway represented by Frank Lein). The study was undertaken in 2015-2016. The data relates to the turnover of the Nordic Alcohol Monopolies in year 2014. Some data have been removed for confidentiality reasons.

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Background and objectives

The Nordic Alcohol Monopolies (Alko in Finland, Systembolaget in Sweden, and Vinmonopolet in Norway) have social responsibility policies that include the environmental impact related to their activities. As part of this, the Nordic Alcohol Monopolies seek to identify the most important of their environmental impacts and options for reducing them. This study is a contribution to this aim.

The purpose of the study is to document the total environmental impact of the product portfolio of the Nordic Alcohol Monopolies, expressing the environmental impacts in monetary units, in addition to the underlying physical units. The results will be used to focus the environmental strategy of the Nordic Alcohol Monopolies and may be used in various communications e.g., with suppliers.

Modelling approach and system boundaries

The current study has been commissioned as a so-called environmental profit and loss account (E P&L), which is an organisational LCA with full monetarisation of the environmental impacts. The study is carried out using the consequential modelling approach following the requirements of the ISO standards 14040:2006 and ISO 14044:2006, which are the latest versions of the international standards on LCA.

As background database the study uses the EXIOBASE v.3.3.5, a global multi-regional input-output database based on the national and international statistical accounting of trade between industries and between countries. This ensures a complete coverage of the global economy and thus overcomes some of the problems of cut-offs and incompleteness often found in traditional LCA databases.

The biodiversity impacts and CO_2 emissions from indirect land use changes (iLUC) are included with Schmidt's accelerated denaturalisation model.

We have added more detailed data for the most relevant activities in the most relevant countries of origin of the beverages, as well as for international transport and consumption activities.

Functional unit

The functional unit of this study is the total amount of alcoholic beverages sold by the Nordic Alcohol Monopolies in Finland, Sweden and Norway in year 2014, covering the product groups beer, distilled beverages and wine. Packaging is included as a complementary product.

Data sources and data collection

To provide the total life cycle inventory, detailed sales and packaging data from the Nordic Alcohol Monopolies were combined with data from the background database, additional literature data as well as primary data collected from selected important producers of grapes, wine, vodka and whisky.

Results

The total monetarised life cycle impacts amount to 320 million Euros, which is approximately 7% of the overall before-tax sales value of the of the alcoholic beverages sold by the Nordic Alcohol Monopolies in 2014.

The following three impact categories were identified as the most significant contributors:

- Respiratory inorganics (air emissions: particulates, ammonia, NO_x, SO_2)
- Global Warming (CO_2, CH_4, N_2O)
- Nature occupation (loss of biodiversity from indirect land use changes)

The two first impacts are mainly caused by the burning of fuels for energy production.

The largest contributing life cycle stages, contributing more than half of the total impacts, are packaging manufacture and agriculture (including upstream activities and indirect land use changes).

Packaging contributes with 35% and 44% of the overall impact for wine and beer, respectively and 17% for distilled beverages. More than 45% of the overall impact from packaging is from glass manufacture, approximately 18% from aluminium, 16% from plastics and around 16% from paper. Some of the global warming impact from packaging production is alleviated through recycling, most for beer with 46%, over 30% for wine to 19% for distilled beverages.

The second largest contribution comes from agriculture (26% of the overall impact, when adding the 6% contribution from indirect land use impacts). Another 15% of the impacts come from the emissions from fuel use at the beverage industry itself. Another 14% come from other inputs to the beverage industry, which is dominated by electricity and upstream transport.

For respiratory inorganics, the contribution from the different life cycle stages follows the same pattern as for global warming, although agriculture and international sea transport have relatively larger contributions and the contributions from the packaging and beverage industry are relatively lower. These relative differences are related to differences in the fuel types and combustion efficiencies of the respective industries.

For nature occupation, 33% of contributions come from wine, 45% from distilled beverages, and 22% from beer.

Interpretation and conclusions

We have checked the applied data and impact assessment methods against other data sources, and we are confident in the validity of the above-identified major impact categories, the proportions between life cycle stages and the identified major areas for improvement. But the variation in the underlying data means that the specific percentages should not be taken as exact. Also, the country averages should not be taken as representative of individual producers within each country. The potential differences between producers are likely to be more important than differences between countries.

The largest impact categories, the largest contributing life cycle stages, and those with the largest variation, appear as natural focus areas for improvements:

- *Agricultural fuel use and emissions, especially for inputs to distilled beverages and wine:* The variation in fuel use and emissions appears very large, and a larger focus on managing fuel use and emissions should be considered.

- *Agricultural yields are particularly low in some countries, implying a larger nature occupation:* Some of the difference in yields can be explained by natural conditions, and for grapes also local regulations for the quality labels. Due to the perceived relationship between quality and yield, this is an area where it may be difficult to agree on improvements. Nevertheless, there should be a natural interest of the producers to consider which improvements in yields that could be obtained without compromising product quality. Raising the issue would be a first step.
- *Energy use in distilleries and breweries:* A very large observed variation in fuel and electricity use between producers, as well as the differences in emission factors, point to potentials for improvement. An example of an improvement made by a supplier is the co-location of distillery and animal production, whereby the distillery by-products are used directly as animal feed without prior drying, implying a substantial energy saving.
- *Packaging:* The most important improvement option for packaging is the choice of packaging material, and especially the reduction of one-way glass packaging in situations where this is not essential for the product quality. Secondly, the large variation in the weight of individual packaging for the same purpose show that reduction in packaging weight is an important improvement option. As long as glass is used, this is obviously especially important for glass bottles, but also PET bottles, aluminium cans, and Bag-in-Box show large variations in weight for the same volumes. Lastly, the variation in fuel use, combustion efficiency and emissions for packaging production is an area where large variation is found, which again points to a substantial improvement potential.
- *Communication and cooperation in the supply chain:* To reduce the environmental impacts, it is important to focus on the large impacts first, because all problems cannot be solved at the same time. It is easy for producers and consumers to become distracted by the changing impacts that are in focus in the daily media debates, but the big problems are still be there to be solved. We recommend that the Nordic Alcohol Monopolies support the producers in focussing on the important impacts, and in communicating these priorities to consumers and local interest-groups. If producers and retailers could agree on a standardised, comparable way of informing the consumers on the important issues, this could make it easier for consumers to send strong signals to the producers that improvements on these issues will be appreciated and supported. As noted several times above, differences in fuel efficiency and emissions is the cause of large differences in environmental impact. A general pattern can be seen that the farther away from the Nordic countries that a beverage is produced, the more environmental impact it is likely to cause. This can be used to focus the efforts for reducing environmental impacts on the locations where the largest improvements can be expected. However, it is important to be aware that the general pattern is not necessarily true for individual products. This means that a specific product from the Nordic countries can still have more environmental impact than a specific, comparable product from further abroad.

List of abbreviations

Units

Gg	Giga gram
Mg	Mega gram
kg	Kilo gram

Countries and regions

FI	Finland
NO	Norway
ROW	Rest-of-World
SE	Sweden
USA	United States of America

Other abbreviations

BAHY	Biodiversity Adjusted Hectare Years (unit for biodiversity impacts on ecosystems)
Bev.	Beverage
Carc.	Carcinogens
CH_4	Methane
CO_2	Carbon dioxide
DALY	Disability Adjusted Life Years (unit for impacts on human health, adding years of life lost and years lived with a disability, where the latter years are weighted with the severity of the disability)
EF	Emission Factors
EP&L	Environmental Profit and Loss account
eq.	Equivalents
GHG	Green House Gas
GWP	Global Warming Potential
iLUC	indirect Land Use Changes (transformation of unused (natural) land into productive land and intensification of production on already transformed land, as a result of land use elsewhere in the product life cycle)
IO	Input-Output
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
n.e.c.	Non elsewhere classified
n.r.	Not relevant
N_2O	Dinitrogen monoxide
NAM	Nordic Alcohol Monopolies
Non-carc.	Non-carcinogens
OEF	Organization Environmental Footprint
OLCA	Organizational Life Cycle Assessment
PDF	Potential Disappeared Fraction of species
PM2.5	Particulate Matter with a diameter of 2.5µm or less
ppm	parts-per million
QALY	Quality Adjusted Life Years (unit for impacts on human wellbeing, adding years of life lost and years lived with less than full wellbeing, where the latter years are weighted with the severity of the condition)
SEK	Swedish kroner (currency)
SUT	Supply and Use Tables
TEG	Triethylene Glycol
UES	Area of Unprotected Ecosystems
Vegetat.	Vegetation

1 Introduction

The Nordic Alcohol Monopolies are the exclusive retailers of alcoholic beverages in Finland, Norway and Sweden. The monopolies have been created to seek to reduce the damages caused by alcohol-consumption. This is done partly by reducing the retail accessibility of alcoholic beverages, partly through advocacy and research activities to increase awareness of the damages related to alcohol-consumption.

The three monopolies (Alko in Finland, Systembolaget in Sweden, and Vinmonopolet in Norway) are independent companies but cooperate on issues of common interest, including environmental issues.

The Nordic Alcohol Monopolies have social responsibility policies that include the environmental impact related to their activities. As part of this, the Nordic Alcohol Monopolies seek to identify the most important of their environmental impacts and options for reducing them. This study is a contribution to this aim.

This study has been commissioned as an Environmental Profit & Loss Account (EP&L), but the focus has been on the environmental impacts in the life cycle of the three main product groups distributed by the Nordic Alcohol Monopolies: Beer, distilled beverages, and wine.

1.1 Environmental Profit & Loss Accounts, Organisational LCA, and Product LCAs

The current study has been commissioned as a so-called environmental profit and loss account (E P&L). In 2011, PUMA launched the first acknowledged E P&L (PUMA 2011), a practice that was followed by several others, including Novo Nordisk (Høst-madsen et al. 2014a), the Danish Fashion Industry (Høst-Madsen et al. 2014b) and an E P&L on the Sollentuna municipality in Sweden (Wendin et al. 2014).

An E P&L can be described as "a means of placing a monetary value on the environmental impacts along the entire supply chain of a given business." (PUMA 2011, p 2). A life cycle approach is used to cover the entire supply chain. Generally, 'environmental impact' is defined broadly, not intended to exclude any impact. The intention is to complement the company's normal Profit & Loss account (the financial statement of the pecuniary income and expenditure) with an account of the monetarised external benefits and costs related to the life cycle of the product portfolio of the company (Weidema 2015b). Since the costs of externalities are not included in traditional economic accounts, the aim of the valuation/monetarisation is to give a better picture of the "true" costs. An E P&L can thus be defined as a "product portfolio environmental life cycle assessment with monetary valuation of impacts".

An E P&L is generally equivalent to what the European Commission calls an Organisation Environmental Footprint (OEF) (European Commissions 2013), and what the UNEP/SETAC Life Cycle Initiative calls an Organizational Life Cycle Assessment (OLCA) (UNEP/SETAC 2015). The only difference is that E P&L uses monetarisation as weighting in the life cycle impact assessment, which is commonly not done in LCAs and OEF/OLCA.

The functional unit of an E P&L is the entire activities of an organisation in a given year, including upstream and downstream activities. The calculation has an organisational focus rather than the product focus that is used in life cycle assessment (LCA). However, the only difference between an organisational LCA and a product LCA is that the organisational LCA is a sum of several product LCAs adding up the organisation's product portfolio.

In the case of this study, the main focus has been on the life cycles of three main product groups distributed by the Nordic Alcohol Monopolies (beer, distilled beverages, and wine), while the remaining activities (advocacy, retail) have not been given particular attention. The study can therefore be said to be somewhere in between a full EP&L and an LCA for a specific product portfolio.

The LCA is carried out in accordance with the latest versions of the ISO standards on LCA (ISO 14040:2006 and ISO 14044:2006).

2 Definition of goal and scope

2.1 Purpose of the study

The purpose of the study is to document the total environmental impact of the product portfolio of the Nordic Alcohol Monopolies (Alko in Finland, Systembolaget in Sweden, and Vinmonopolet in Norway), expressing the environmental impacts in monetary units, in addition to the underlying physical units. The results will be used to focus the environmental strategy of the Nordic Alcohol Monopolies and may be used in various communications e.g., with suppliers.

The results are presented per impact category (covering all relevant environmental impacts), both in physical units and monetarised, per product group.

2.2 Functional unit

The functional unit is a quantified performance of a product system for use as a reference unit (ISO 14040).

The functional unit of this study is the total amount of alcoholic beverages sold by the Nordic Alcohol Monopolies in Finland, Sweden and Norway in year 2014, covering the product groups beer, distilled beverages and wine. Packaging is included as a complementary product. Quantitative amounts are specified in Section 2.3 below.

For comparative purposes, some data will be presented per product group, per litres of product, per litres of alcohol and per country of origin. Some data for packaging may be presented per 1000 kg of packaging. Whenever data and results are presented, the functional reference is explicitly stated.

2.3 The product portfolio of the Nordic Alcohol Monopolies

The total volumes of the product groups wine, beer and distilled beverages sold by the Nordic Alcohol Monopolies in year 2014 are given in Table 1. This is the functional unit of the study. Distilled beverages are given in pure alcohol, since in general the environmental impacts are better correlated to the alcohol content than to the wet volume. The actual volume of the distilled beverages is 53 million litres with a mass of 50 Gg and an average alcohol content by volume of 33.4%.

Table 1: Sales volumes for the Nordic Alcohol Monopolies in year 2014

Beverage type	1000 L
Wine	314,240
Beer etc.	218,122
Distilled beverages, by pure alcohol	17,529

The countries of origin for these products are shown in Table 2. With the exception of Chile and Argentina, for which we use South American average data, we use country specific data for the countries specified in Table 2, i.e. for more than 90% of the total sales of each product group. For the other countries, an average for the Rest-of-World is applied.

Table 2: Countries of origin for the products in the three product groups.

Country	Wine	Beer etc.	Distilled beverages, by pure alcohol
Sweden		76.3%	4.1%
Italy	25.7%		
France	11.8%		11.5%
South Africa	11.2%		
Spain	10.5%		
Chile	10.3%		
Australia	8.3%		
Germany	5.1%	2.7%	2.6%
USA	5.0%		1.5%
Czech Republic		5.7%	
Argentina	3.7%		
Finland		3.9%	34.5%
United Kingdom		2.5%	20.4%
Norway			6.8%
Canada			4.1%
Poland			3.0%
Ireland			3.1%
Other	*8.5%*	*8.9%*	*8.3%*
Total	**100%**	**100%**	**100%**

It should be noted that the beer included in this study is mainly that sold by Systembolaget in Sweden, due to the difference in legislation between the three countries: In Finland and Norway, beverages with an alcohol content up to 4.7% by volume can be sold in normal supermarkets, which means that the share of beer sold through the alcohol monopolies is very limited. In Sweden, the same limit is only 3.5%, which explains that more beer is sold via the Swedish monopoly.

Packaging

Detailed data for packaging weight per specific product was available for Sweden. For Finland, the packaging material and packaging volume per sales unit was available per specific product. For Norway, only the packaging material per specific product was available.

From the Swedish data, a relation between packaging weight and volume of the sales unit was derived per packaging material. Table 3 shows only the average values per packaging material. Table 4 shows the average values for glass bottles for different types of beverages, reflecting mainly that heavier bottles are used for distilled beverages and sparkling wines.

Table 3: Primary packaging amounts and average weight per volume.

	Packaging mass, Sweden 2014 [1000 kg]	Sales volume, Sweden 2014 [1000 litres]	g package/L (Sweden)	g package/L (FI+NO+SE)
Packaging material	**a**	**b**	**a/b**	
Aluminium can	6,284	161,587	39	38
Bag-In-Box	6,005	102,397	59	58
Glass	90,408*	128,948	701*	716*
PET	279	2,788	100	78
Carton	447	11,902	38	38

* For glass bottles the weight does not include closures (corks, caps), see Table 5.

Table 4: Weight of glass bottle per volume of beverage for different types of alcoholic beverages (data from Sweden).

Type of alcohol beverage	g package/L
Wine, white	638
Wine, red	677
Beer	680
Distilled beverages	746
Wine, other	859

The relations from the Swedish packaging were applied to the data from Finland and Norway to arrive at an average value for all the countries (last column of Table 3) which was then applied to the total beverage volumes for the calculations on packaging production, transport and disposal.

Secondary packaging (cardboard boxes, shrink plastic) has been modelled with data from ecoVeritas (2015). Tertiary packaging (pallets, etc.) and closures (caps, corks) have been modelled with data from a previous study by BioIntelligenceService (2010) combined with pallet configuration data. Summary of the included secondary and tertiary packaging can be found in Table 5. Except for glass bottles and PET, closures are included in the weight of the primary packaging and therefore not specified here.

Table 5: Amounts of secondary and tertiary packaging, closures and labels in amounts per L of beverage.

	Secondary packaging		Tertiary packaging			Closures and labels				
Primary packaging	Cardboard [g/L]	Plastic [g/L]	Cardboard [g/L]	Plastic [g/L]	Pallet [g/L]	Cork [g/L]	Plastic [g/L]	Steel [g/L]	Aluminium [g/L]	Paper [g/L]
Aluminium can	5	1	2	1	1					
Bag-In-Box		5	2	1	1					
Glass, for wine	45		4	2	1	3.6	1.1		2.5	3
Glass, for beer	28*		4	2	1			2		
Glass, for spirits	45*		4	2	1		1		2.5	3
PET, wine & spirits	13	4	2	1	1				2	3
PET, beer	13	4	2	1	1		1.6			3
Carton	19		3	1	1					

* Our estimate, based on the ecoVeritas (2015) data for glass bottles for wine, with and without dividers

2.4 LCA modelling approach

In order to calculate the life cycle emissions, life cycle assessment (LCA) is used. LCA is a method where all emissions and resources from all activities in a product system are added. Based on these life cycle emissions and resources, the life cycle impact results can be calculated.

When calculating the life cycle emissions and resources, two different approaches for LCA are commonly used: the consequential approach and the attributional approach. The **box** briefly explains the different focus of the two approaches. *This study uses the consequential approach.* The consequential approach follows the requirements in ISO 14040:2006 and 14044:2006. The modelling principles are comprehensively described in Weidema et al. (2009) and Weidema (2003).

Two LCA modelling approaches, two sets of results, giving answers to two different questions (UNEP 2011):
The consequential approach is a system modelling approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change *as a consequence of a change in demand* for the functional unit. Thus, the purpose of consequential modelling is *decision support*.
The attributional approach is a system modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system *according to a normative rule*.
Thus, the purpose of attributional modelling is to trace a specific aspect of the product (as determined by the normative allocation rule) back to its contributing unit processes.

Box. Consequential and attributional modelling in LCA.

2.5 Data collection

For the initial screening, we use the EXIOBASE v.3 as background database. EXIOBASE is a global multi-regional input-output database based on the national and international statistical accounting of trade between industries and between countries. This ensures a complete coverage of the global economy and thus overcomes some of the problems of cut-offs and incompleteness often found in traditional LCA databases. The database includes 33 mineral and non-renewable resources, land occupation, 49 emissions to air, 3 emissions to water, and 9 emissions to soil.

EXIOBASE v.3 is a multi-regional IO-model, which links together 44 countries and 5 rest-of-world regions by international trade. For this project, we aggregated this to a model where the global economy has been divided in only 18 countries and regions, namely those in which the majority of the beverages for the Nordic countries are produced; see Table 2.

The first version of EXIOBASE (version 1) was created as part of the EU FP6 project EXIOPOL, finalised in 2010 (http://www.feem-project.net/exiopol/). This database was representing the flows between industries in monetary units only. A follow-up project, EU FP7 CREEA (http://creea.eu/), published a second version of the database in 2014. As part of this project, a physical supply-use tables in units of dry mass and energy were created in addition to the monetary tables. Especially, the physical mass tables used an advanced approach to establish mass balances of inputs and outputs of products in the global economy as well as mass balance for the inputs of resources, products and wastes to industries and outputs of emissions, products and wastes for all industries. This means that all physical mass flows in the global economy was accounted for, in a balanced and comprehensive way. A hybrid model was created by combining the monetary supply-use tables with the physical tables. Without going too much in detail with the procedures for creating these tables, Figure 1 illustrates how rows from each of the tables are combined in a hybrid model. The approach to establish the physical tables was developed in the EU FP6 project FORWAST, which was finalised in 2010 (http://forwast.brgm.fr/).

Version 3 of EXIOBASE, which is used in the current project, was developed as part of the EU FP7 project DESIRE (http://fp7desire.eu/). EXIOBASE v3 is still not publically available. But version 2 is available for free at: http://www.exiobase.eu/.

The most recent year for which primary data are available in the database is year 2011, which is therefore the year we use as base-year for the emission calculations.

Since the EXIOBASE is based on average data for each industry, it does not have a lot of product detail. We have added more detail for the most relevant activities in the countries mentioned in Table 2 (except for Chile and Argentina). Based on more detailed LCA data from the literature and statistical data on production volumes we have been able to subdivide the average data on the beverage industry into specific datasets for production of beer, distilled beverages and wine (as well as cider, bottled water and soft drinks). We have also added more specific data on grape production for wine.

The EXIOBASE v.3 does not include a model for indirect land use and the models for water abstraction and electricity mixes are not very sophisticated. We have therefore added a model for indirect land use (see Section 2.7) and improved the modelling of water abstraction (see Section 2.8). For direct inputs of electricity for grape production, for the beverage industry, and for the consumption stage, we used specific consequential electricity mixes as available from 2.-0 LCA consultants Energy Club (http://lca-net.com/clubs/energy/).

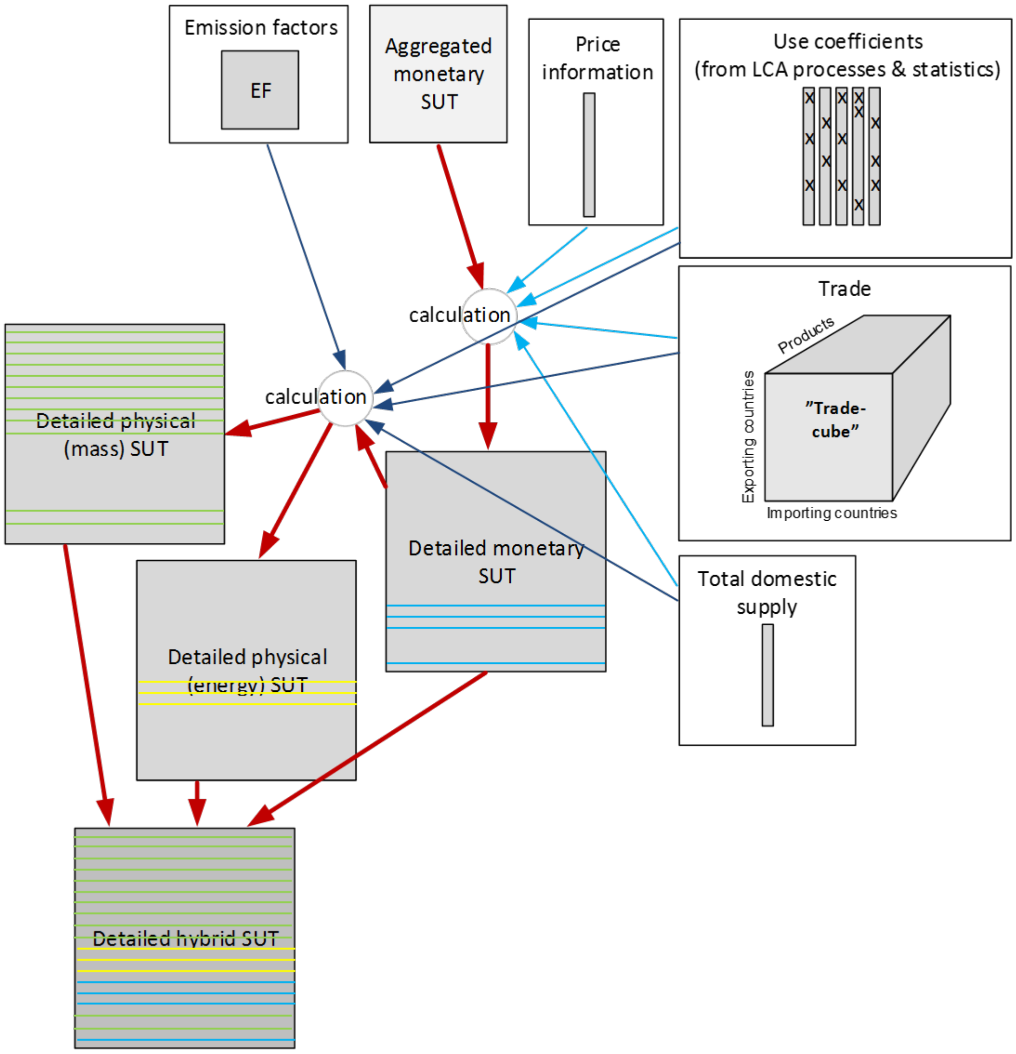

Figure 1: Overview of the procedures to produce the supply-use tables that for the basis of the hybrid version of EXIOBASE v3.

Additional data were collected for the consumption stage, packaging end-of-life, and other activities identified to be important. This data collection is reported in Chapter 3.

2.6 System boundary: Life cycle stages and included processes

The life cycle stages specified for the purpose of data presentation are:

- Agriculture and upstream,
- Indirect land use change,
- Packaging production,
- Other upstream inputs to the beverage industry,
- Beverage industry,
- International transport of beverage,
- Retail activities,
- Consumer stage,
- End-of-life of packaging, incl. recycling.

Figure 2 gives a schematic representation of the analysed system. Due to the use of EXIOBASE as a background database, no cut-offs have been applied. The system boundary is therefore that of the global economy.

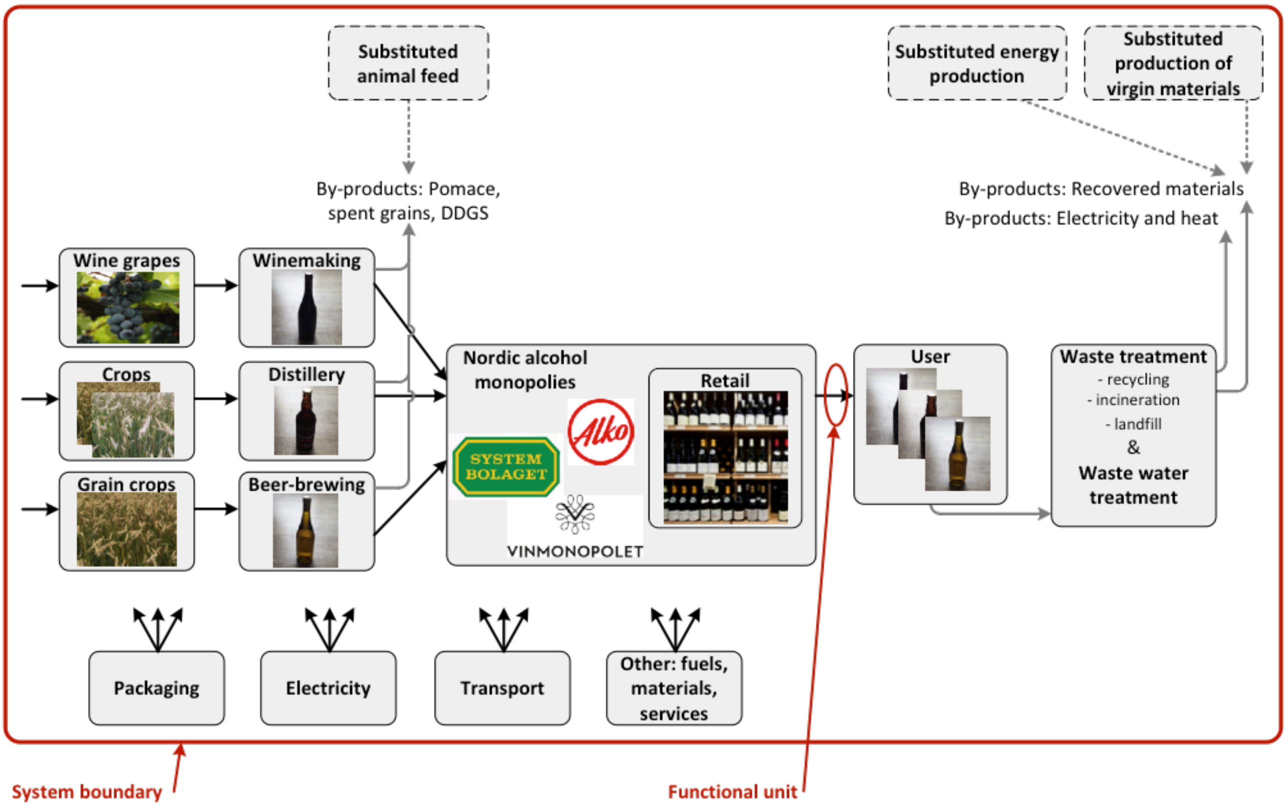

Figure 2: Schematic representation of the analysed system.

2.7 Indirect land use changes (iLUC)

The investigated beverages are produced on the basis of agricultural crops. This life cycle study takes into account that the use of land contributes to the global demand for productive land and thereby to the transformation of unproductive (natural) land into productive land, and the intensification of production on already transformed land. This most often take place in other regions of the world than where the actual crop is grown. The geographical location of the affected natural areas can be determined from the FAO forestry statistics, which shows the trends in forestry area over the period 2010-2015, see Figure 3. The transformation of land from forest to agricultural land (deforestation) implies a change in the biodiversity hosted on the land (loss of forest ecosystem species) as well as a change in the carbon stock of the land, which in turn leads to CO_2 emissions. This contribution to biodiversity impacts and CO_2 emissions is referred to as indirect land use changes (iLUC).

Indirect land use effects are modelled as accelerated denaturalisation as described in Schmidt et al. (2015). The data used for populating the model framework are documented in Schmidt and Muñoz (2014). The model is developed through a larger project supported by more than 20 industries (e.g., Unilever, DuPont, TetraPak, Arla Foods, DONG Energy, United Plantations), universities (e.g., Swedish University of Agriculture Sciences, Aalborg University, Aarhus University and Copenhagen University) and other research related organisations (e.g., The Sustainability Consortium, the ecoinvent LCA database, RSPO and the Japanese National Agricultural Research Center). More information on the iLUC-project can be found here: http://lca-net.com/clubs/iluc/. The version of the model applied is version 4.3.

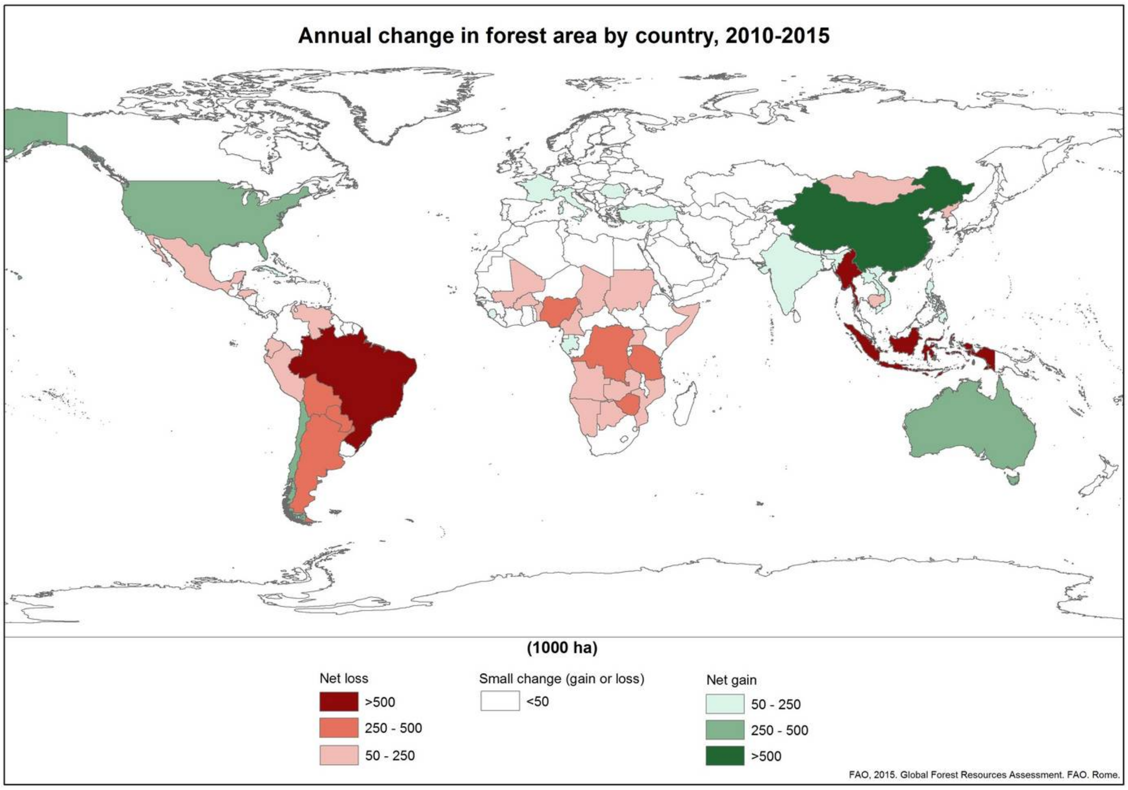

Figure 3. Annual change in forest area 2010-2015. From FAO (2015).

The accelerated denaturalisation model has several key characteristics that make it superior to many other available iLUC models:

- It is applicable to all crops (also forest, range, build etc.) in all regions in the world
- It overcomes the arbitrary allocation/amortisation of transformation impacts
- It includes both intensification of agricultural land and transformation of forest to agricultural land
- It is based on modelling assumptions that follow cause-effect relationships and standard modelling that is consistent with any other LCA-processes

It is acknowledged that the iLUC model referred to above is one among many other models and that there currently is no consensus in the LCA community how to model iLUC. In the context of viticulture, it may furthermore be questioned whether there is an excess availability of specific "viticulture soils", which would mean that occupation of such soils would not have indirect impacts on the general market for arable land. For these reasons, the contributions to results from iLUC are reported separately.

2.8 Water abstraction

To supplement the EXIOBASE data on water, we have added data from Aquastat (1994-2012):

- EXIOBASE v.3 data for municipal water supply ("collection, purification and distribution of water") are given in MEUR. We used the corresponding physical data on Municipal water withdrawal in m^3 from Aquastat to calculate the use of municipal water by each industry.
- The Aquastat data for water abstracted directly by manufacturing industries were distributed over the EXIOBASE industries in proportion to the fuel consumption of these activities, considering that water use is mainly used for heating and cooling, which are also the most energy-intensive processes.

- Aquastat data for wastewater generation data were subtracted from the abstracted municipal and industry water to provide the apparent consumption.
- Water abstraction for irrigation was distributed over the crops following the percentages of irrigated area used by each crop, based on Aquastat's irrigation calendars (Aquastat 2011).
- Water used for animal production was calculated as the difference between the agricultural water abstraction and the irrigation water abstraction plus the irrigation water used for pasture and fodder crops. The resulting amount was distributed over the animal production activities in proportion to their dry mass output.

The data used for water use for cereals for countries producing beer or distilled beverages are given in Table 6. For irrigation of grapes, more specific data were used for some countries, see Table 8 in Section 3.2.

Table 6: Irrigation water per kg cereals (wet weight). Calculated from the % of national irrigated area used for cereal (Aquastat 2011), the national water abstraction for irrigation (Aquastat 1994-2012), and the 2007 national crop supply (EXIOBASE) corrected to wet weight.

Country of origin	Cereals [L water / kg]
Canada	86
Check Republic	0
Finland	1.5
Ireland	0
Norway	115
Poland	0.1
Sweden	0
United Kingdom	0.2
France	52
Germany	3
USA	101
Rest-of-World	289

2.9 Life cycle impact assessment (LCIA) method

Impact categories

The method used for LCIA in this study is the Stepwise 2006 method, version 1.5, with updates of the Global Warming potential to the values of IPCC (2013) and updates to the Nature Occupation impact category to make it consistent with the new modelling of indirect land use changes described in Section 2.7. The version 1.5 method is described and documented in Annex II in Weidema et al. (2008) and in Weidema (2009) and the specific updates for this project are reported in Annex 1. The latest software files are available at http://lca-net.com/services-and-solutions/impact-assessment-option-full-monetarisation/

In the first steps of LCIA, the emissions are classified into impact categories and multiplied by characterisation factors to arrive at impact scores per impact category in physical units. To obtain a comprehensive understanding of the environmental impacts, the exchanges are classified in following environmental impact categories:

- Acidification
- Ecotoxicity (aquatic and terrestrial)
- Eutrophication
- Global warming
- Human toxicity (carcinogenic and non-carcinogenic)

- Nature occupation (biodiversity)
- Photochemical ozone formation
- Resource use (energy, water and minerals)
- Respiratory effects

All life cycle impacts are included, i.e. Scope 1, 2 and 3 (direct from the emissions of the Nordic Alcohol Monopolies, indirect from their energy use, and other indirect emissions). The vast majority of impacts are related to indirect emissions, i.e. scope 3.

Biogenic carbon

For global warming, biogenic CO_2 uptake and emissions have been eliminated, except for land use change emissions where emissions of biogenic CO_2 contribute. According to Schmidt et al. (2015), net CO_2 emissions from land use changes are zero – only the timing of the emissions is affected. The effect of timing of CO_2 emissions is modelled consistent with the GWP100 method (IPCC 2013). For further details, see Schmidt et al. (2015).

End-point evaluation / monetarisation

In this step, the characterised results are multiplied with a factor representing the importance of the impact category relative to the other impact categories. By doing so, the magnitude of the different impact categories can directly be compared, and it is possible to point out the most significant impact categories. Monetarisation can be seen as a specific form of weighting where the weights represent the relative willingness-to-pay for a marginal change in the impacts.

The Stepwise valuation method is documented in Weidema (2009). Stepwise provides impact pathways for the following three safeguard subjects: Human wellbeing, Ecosystems, Resource productivity (Weidema 2009; Weidema et al. 2007). Figure 4 illustrates how the impact pathways from particulates to human wellbeing and from greenhouse gases to ecosystem impacts both end in the same monetary value, thus making the different quantities of these two emissions comparable.

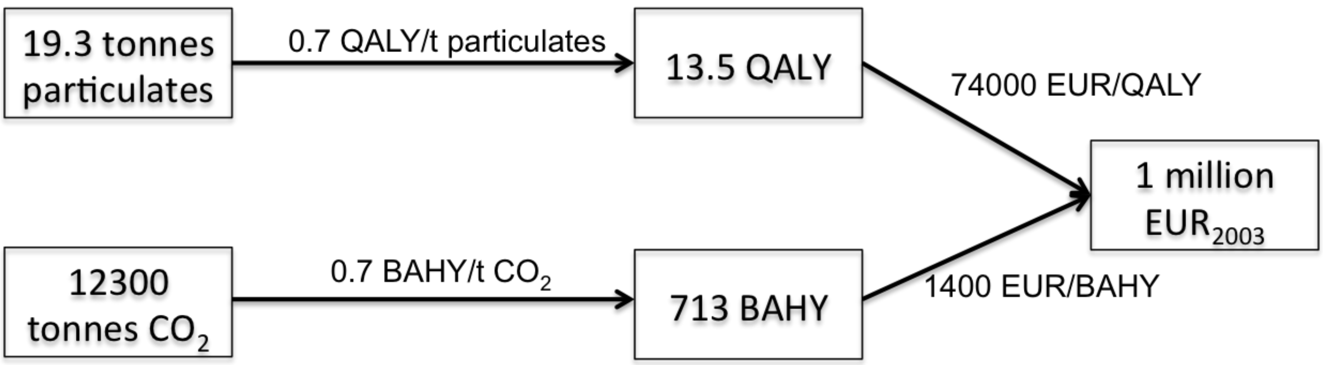

Figure 4: Illustration of the impact pathway from emissions of particulates and CO_2 (left) to impacts on Quality-Adjusted Life-Years (QALYs) of human wellbeing and Biodiversity-Adjusted Hectare-Years (BAHYs) of ecosystems to the monetary value of these impacts, showing how the different quantities of emissions and impacts have the same monetary value and thus becomes directly comparable. The conversion factors shown on the arrows correspond to the factors provided in Annex 1, which includes all monetarised impacts per unit of mid-point impact in the Stepwise method.

The first step of the calculation of monetarised impacts in the stepwise method is to relate each of the mid-point characterised results in life cycle impact assessment (LCIA) to the three safeguard subjects mentioned above. The impact categories are defined so that they can be measured in terms of Quality Adjusted Life Years (QALYs) for impacts on human wellbeing, Biodiversity Adjusted Hectare Years (BAHYs) for impacts on ecosystems, and monetary units for impacts on resource productivity. This preparation of mid-point characterisation model for monetarisation is documented in Weidema et al. (2007). QALYs are identical to the concept of disability-adjusted life years, DALY (just with opposite sign). All individuals are given equal weight irrespectively of socio-economic status (Weidema 2009). Resource productivity is expressed as the additional cost for future extraction as a result of current dissipation.

The second step of the calculation of monetarised impacts in the stepwise method is to estimate the value of one QALY as the potential average annual income per capita. This is based on the budget constraint approach (Weidema 2009). Since a QALY by definition is a life-year lived at full wellbeing, the budget constraint can be determined as the potential annual economic production per capita at full wellbeing. An average annual income is the maximum an average person can pay for an additional life year at full wellbeing. The monetary value of a QALY is determined as 74,000 EUR_{2003} with an uncertainty estimate of 62,000 to 84,000 EUR_{2003}.

The third step is to determine the relative value of ecosystems (measured in BAHY) compared to human wellbeing (QALY). 1 BAHY refers to 1 ha*year with a land use type that does not allow any species to grow, e.g., sealed land. Weidema (2009) explores different options for arriving at this value and finally settles for a proxy value corresponding to valuing the current global ecosystem impacts at 2% of the value of a QALY, i.e. 2% of the potential income, noting that the current environmental protection expenditures in developed countries are at 1–2% of GDP. Using a normalisation value for the current global ecosystem impacts of 50% of the terrestrial area ($13 \cdot 10^9$ ha), corresponding to 1.05 ha*years per person, this gives a value of 1400 EUR_{2003}/BAHY (74,000 EUR_{2003} * 2% / 1.05 BAHY) with an uncertainty estimate of 350 to 3500 EUR_{2003}. Weidema (2009) notes that the proxy value is close to the value of 1500 EUR_{2003}/BAHY derived from the only available choice modelling study that had explored this issue.

Since the impact of resource extraction is already measured in monetary value, there is no need for further valuating this.

Annex 1 includes a table with all the monetarised impacts per unit of mid-point impact in the Stepwise method.

The most prominent advantages of the Stepwise method for monetarisation are that:

- The valuations of all impacts are based on the same basic approach, which makes the method very consistent and reduces the uncertainties compared to other valuation methods.
- It is based on mid-point impacts to which thousands of emissions are related via dose-response models in existing life cycle impact assessment methods, which makes it very complete in terms of included pollutants.

It should be noted that the Stepwise method currently does not include discounting.

2.10 Critical review

This study has been reviewed internally by Jannick Schmidt, but has not been subjected to external critical review.

3 Life cycle inventory

For the life cycle inventory, EXIOBASE v3 has been used as background database, as described in Section 2.5. This section describes the additional assumptions and inventory data used.

3.1 Electricity

The present average mix of electricity generating technologies in EXIOBASE does not represent the actual affected technologies related to a change in demand, and thus does not comply with modelling principles of the current study (see Section 2.4). For direct inputs of electricity for grape production, for the beverage industry, and for the consumption stage, we therefore instead apply the marginal sources of electricity for all relevant regions for electricity generation in the current study, as identified by the "Consequential future" scenario (based on data for 2012-2020) described in Schmidt et al. (2011) and Muñoz et al. (2015): First, the electricity generation in 2020 is identified by use of energy plans/outlooks and then the affected technologies are identified as the proportion of each technology in the growth of supply during the period 2012-2020. The inventory data for electricity include emissions from production and burning of fuels and other related inputs (ancillary materials etc.) as well as capital goods (buildings, boilers, turbines, grid infrastructure etc.). The consequential electricity mix for Chile, modelled with data from EXIOBASE, was used to represent electricity consumption in both Argentina and Chile.

3.2 Viticulture

A literature review of existing life cycle assessments on wine turned up 12 studies with 17 numerical datasets, from Australia, Canada, Italy, New Zealand, Portugal, and Spain (Amienyo et al. 2014, Aranda et al. 2005, Ardente et al. 2006, Barry 2011, Benedetto 2013, Bosco et al. 2011, Carta 2009, Gazulla et al. 2010, Neto et al. 2013, Point et al. 2012, Vázquez-Rowe et al. 2012 & 2013). In general, these data are not very complete and show a large variation. The datasets represent quite small samples, often only one producer, and can therefore not be said to be representative of their respective national productions.

Considering the importance of the viticulture for the overall life cycle impacts, we performed additional data collection from 3 large suppliers to the Nordic Alcohol Monopolies. The data from the producers confirms the large variation in the literature values both for fertiliser use (for nitrogen ranging from 0.003 kg N to 0.03 kg N per kg grapes), for energy use (fuel use ranging from 0.2 MJ to 0.9 MJ per kg grapes in the data from producers and from 0.2 MJ to 4 MJ in the literature data), and for trellis materials (from no trellis to 0.04 kg wood poles or 0.017 kg steel stakes per kg grapes). The corresponding values for "Cultivation of vegetables, fruits and nuts" in the background database also show large variation between country averages, but this is exacerbated by differences in crop composition between countries. For trellis and energy use, we therefore apply the same values for all countries (0.009 kg wood poles, 0.007 kg steel stakes, and 0.55 MJ diesel per kg grapes based on the average from the surveyed producers and 0.07 kWh electricity per kg grapes based on the average of the literature values). The emissions from combustion were modified proportional to the change in fuel consumption. For fertilisers, we retain the variation in the country averages from the background database.

The yield is often seen as a quality factor, with lower yields associated with wines with more concentrated flavours. However, the relationship between quality and yield is disputed. While it is acknowledged that very high yields are linked to unfavourable leaf to fruit ratios and consequent insufficient ripening of the grapes, the relationship is less clear for moderate yields, where good canopy management appears to be of larger importance. In general, white wine is seen as less sensitive to high yields. There is a general difference in yields between different viticulture regions, which cannot be explained by differences in soil quality and climate alone, but rather in the grape varieties chosen and the style of viticulture and vinification. We therefore apply the arable land requirement for grapes based on the average yields per country as given by FAOSTAT; see Table 7. National wine yields were corrected for the yields of table and raisin grapes. For USA, this yield was available from USDA Fruit and Tree Nuts Yearbook. For the other countries, the subtracted yields of table and raisin grapes are estimated as exported grapes only, using FAOSTAT export data.

Table 7: Grape and wine yields per country (year 2011) from FAOSTAT. Grape yields are exclusive of table and raisin grapes.

	National grape yield for wine [Gg]	Grape yield per area [kg/ha]	Wine yield [L/kg grape]	Wine yield [L/ha]
Argentina	2,833	13,200	0.54	7,128
Australia	1,728	10,500	0.64	6,720
Chile	2,296	15,600	0.66	10,296
France	6,624	8,700	0.77	6,699
Germany	1,214	12,500	0.75	9,375
Italy	6,946	10,300	0.67	6,901
South Africa	1,436	14,600	0.68	9,928
Spain	5,668	6,000	0.59	3,540
USA	5,900	17,400	0.45	7,830
Rest-of-World	14,214	9,600	0.46	4,416

The data from the producers confirms the large difference in yields between countries shown in Table 7, but also the large variation between different grapes and soils. Even for the same producer in the same country and year, we found variations from 55 – 125% of the average yields. The explanation is typically that higher quality wines and organic agricultural practices imply a lower yield. Variations in yields between years depend on the variability of the climate, and can be from +/- 15% to +/- 70%. In dry regions this is also influenced by the options for irrigation. Water use obviously also depends crucially on the extent of irrigation, with 2 L/kg grape for unirrigated crops to 100-400 L/kg grape for irrigated crops. The average values applied are given in Table 8.

Table 8: Irrigation water per kg grapes (wet weight).

Country of origin	Grapes [L/kg]	Data sources and assumptions
Australia	369	Australian national statistics on irrigation (NPSI, 2012)
Chile/Argentina	251	Average from surveyed Chilean producers (own data collection)
Italy	210	Aquastat % of irrigated area in Italy used for grapes*total Irrigation water for Italy
Spain	356	Aquastat % of irrigated area in Spain used for grapes*total Irrigation water for Spain
France	40	Average from Beaujolais and Languedoc Roussillon from 2005 to 2009 (ADEME 2015)
Germany	0	Aquastat (2011) reports no irrigated area for grapes in Germany
USA	369	Extrapolated from Australia in place of missing data (worst-case-assumption)
South Africa	167	Average from surveyed South African producers (own data collection)
Rest-of-World	180	% of the ROW irrigated area used for grapes*Total irrigation (Aquastat)/ROW grape supply

3.3 Packaging

As a starting point, the amount of packaging as described in Section 2.3 can be assumed to be produced in the country of origin of the respective beverage products. However, an increasing share of the low-priced wines are shipped in bulk and bottled closer to the point of consumption (Fickling 2013). According to the global wine statistics of OIV (2013), the total volume of bulk wine is growing and reached 38% of all exported wine in 2012.

There are three major wine tapping facilities in the Nordic countries: Nordic Sea Winery in Simrishamn in Sweden, Arcus in Norway and Altia in Finland. Nordic Sea Winery has a capacity of 40 million litres per year (Rundberg s.d.) and currently taps 25 million litres of imported wine per year (Eriksson 2014). By comparing the brands of Nordic Sea Winery (http://oenoforos.se/Producent.aspx?producerID=48) to those sold by

Systembolaget we find that 19 million litres are sold via Systembolaget, with 82.5% of these tapped in Bag-In-Box and the rest in glass bottles; see Table 9.

Table 9: Origin and packaging of wines tapped in Sweden.

Country of origin	Quantity [1000 L/year]	Packaging type	Packaging [1000 kg]
Italy	7,900	Bag-In-Box	622
South Africa	7,700	Bag-In-Box	642
Italy	2,400	Glass	1,575
Australia	650	Glass	384
Spain	230	Glass	148
France	75	Bag-In-Box	5
Argentina	45	Glass	35
Total	**19,000**		

What may be surprising is that only 44% of the wines tapped in Sweden are from outside of Europe, although this is where the saving in transport costs would be the largest.

For Finland, Altia (2015) informs that they tap 20 million litres of imported wine per year, of which 70% (14,000 L) are in Bag-In-Box, 24 % in glass (4,800 L) and 6 % (1,200 L) are in PET.

We have not been able to retrieve information on the amount of wine tapped at Arcus, Norway, but the largest volume is Bag-In-Box (Arcus 2015), like in the other countries. Considering that the locally tapped wines sold in Sweden and Finland constitute 17.5% of the total wine sales, it seems likely that this percentage is also applicable to Norway, from which we can estimate an approximate amount of 10 million litres tapped by Arcus, which we assume are mainly from Italy, Australia, U.S.A and South Africa; see Table 10.

Table 10: Estimated origin and packaging of wines tapped in Norway.

Country of origin	Quantity [1000 L/year]	Packaging type	Packaging [1000 kg]
Italy	3500	Bag-In-Box	205
South Africa	1000	Bag-In-Box	58
Australia	2600	Bag-In-Box	152
Australia	800	Glass	573
USA	1800	Bag-In-Box	105
USA	300	Glass	215
Total	**10,000**		

The 49 million litres of wine imported in bulk (19 million to Sweden, 20 million to Finland and 10 million to Norway) are transported either in 26,000 litres ISO tanks or 24,000 litres flexitanks. We have assumed the latter, which involves that the wine is filled into a 24,000 litres bladder of 80 kg plastic, i.e. 3.33 g/L wine. The flexitank bladder is typically made from multiple layers of different plastics.

Table 11 summarizes the total amount of primary packaging by country of production and beverage type. The amounts from Table 11, as well as the corresponding amounts of secondary and tertiary packaging, closures and labels from Table 5, are matched with the respective country-specific life cycle data for packaging production in the background database, more specifically the country-specific average industry data for:

- "Manufacture of glass and glass products" for glass bottles for each country, except for South America, Czech Republic and Ireland, for which we applied the global production-volume-weighted average, excluding data outliers.
- "Plastics, basic" for each country, with a fixed absolute addition for the manufacturing of PET bottles, plastic in Bag-In-Box, flexibags, and plastic closures. Bag-In-Box is represented with 75% board and 25%

plastic (Smurfit Kappa 2015). The fixed absolute addition to account for the manufacturing of bottles/bags etc. from basic plastics was calculated as the EXIOBASE production-volume-weighted average of the "Manufacture of rubber and plastic products" in all countries, excluding data outliers.

- "Paper" for cartons, carton in Bag-In-Box, and labels.
- "Manufacture of Aluminium products" for aluminium cans, which was modelled by removing all metal inputs except Aluminium from the original activity "Manufacture of fabricated metal products, except machinery and equipment"
- "Manufacture of fabricated metal products, except machinery and equipment" for metal closures.
- "Manufacture of wood and of products of wood and cork, except furniture" for wood pallets and cork closures.

Table 11: Primary packaging (in 1000 kg) for the functional unit by country of origin and beverage type. *Negative numbers in brackets indicate packaging used for wine in Sweden, Finland or Norway, which should therefore not be included in the country of origin of the wine.

Country	Beverage type	Aluminium can	Bag-In-Box	Flexibag	Glass	PET	Carton
Sweden	Beer	5,477			12,228	57	
Sweden	Distilled beverages				1,358		
Sweden	Wine*		1269		2,142		
Italy	Wine	1	2513(-826)	46	26,996(-1,914)	28	94
France	Wine		724(-5)	11	15,680(-3,100)	111	9
France	Distilled beverages				2,095	49	
South Africa	Wine		1775(-700)	31	4,450	74(-43)	37
Spain	Wine		623	1	12,876(-148)	29	134
Chile	Wine		954		9,143	49	82
Australia	Wine		677(-576)	48	6,496(-957)	25	98(-76)
Germany	Wine		438		5,089	19	16
Germany	Beer	91			2,579		
Germany	Distilled beverages				1,178	3	
USA	Wine		559(-285)	26	3,293(-1,515)	48(-23)	20
USA	Distilled beverages				485	4	
Czech Republic	Beer	508			4,572		
Argentina	Wine		306	1	3,437(-35)	16(-16)	61
Finland	Beer	151			1,238	25	
Finland	Distilled beverages	131			2,943	966	
Finland	Wine*		604		4,740	83	76
United Kingdom	Beer	45			3,145		
United Kingdom	Distilled beverages	5			6,054	70	
Norway	Distilled beverages		2		1,745	60	
Norway	Wine*		520		787		
Canada	Distilled beverages				1237	5	
Poland	Distilled beverages		1		858	17	
Ireland	Distilled beverages				1,295	12	
Other countries	Beer	138			10,604		
Other countries	Distilled beverages	1	1		3,749	16	
Other countries	Wine		556		9,862	144	96
Total		**6,548**	**9,131**	**164**	**154,683**	**1,826**	**571**

It should be noted that we have not included information on tapping of wine in other countries than the Nordic countries and the countries of origin. This means that, e.g., a wine of Australian origin exported in bulk to United Kingdom, tapped there and exported in bottle to Sweden would appear in our data as wine being bottled in Australia.

3.4 Beverage industry

A literature review of existing life cycle assessments on alcoholic beverages turned up 12 studies for vinification (the same as for viticulture, see Section 3.2), 6 studies on beer production (Amienyo 2012, Climate Conservancy 2008, Cordella et al. 2008, Hospido et al. 2005, Koroneos et al. 2005, Novozymes 2009) giving rise to 5 numerical datasets (one study only covered the production of wort, but could be used to complement some of the other studies that did not include this production step), and 1 study on whisky (Amienyo 2012). Furthermore, 2 studies on bottled water and soft drinks (Amienyo 2012, Quantis 2010; from U.K. and USA) were consulted in order to match all product groups in the aggregated beverage industry data. In general, the datasets from the literature are not very complete and show a large variation. The datasets represent quite small samples, often only one producer, and can therefore not be said to be representative of their respective national productions.

For water and overall energy use, more representative values are provided by the Beverage Industry Environmental Roundtable (BIER 2015), unfortunately neither specifying electricity separately, not how electricity enters into the overall energy value.

We furthermore collected data from 4 large wineries and 3 large distilleries that supply the Nordic Alcohol Monopolies. We filled data gaps in the collected data to make them comparable, e.g., adding a missing malting step using data from Novozymes (2009) and adding the water for diluting a distilled beverage to its sales concentration.

Considering the quality of the different data sources, we have created specific datasets representing winery, brewery and distillery for each country, to replace the average country datasets for “Manufacture of beverages” in the background database.

For the winery datasets, the inputs of “vegetables, fruit, nuts” in the average datasets were replaced with the country-specific inputs of grapes using the national yields from Table 7. For the brewery and distillery datasets, the cereal grains and other crops inputs were modified according to the average data from literature and the surveyed producers (0.22 kg grain and 0.0009 kg crops n.e.c. per L beer, and 1.54 kg grain per L distilled beverage). Variation is large (+/-60%).

For energy use, we have applied the averages of the data from the surveyed wineries and distilleries; see Table 12. For breweries, we subdivided the energy data from BIER (2015) using the proportions between fuel and electricity from the litterature; see Table 12.

We use the water data from BIER (2015) directly (see Table 12), considering that the water use of the surveyed wineries closely matches the industry average as reported by BIER (2015), although noting that the large distilleries surveyed have lower water use (between 17% and 50% of the industry average).

Table 12: Average use of electricity, fuel and water by the beverage activities. The applied values are highlighted in ***bold italics***.

Manufacturing of beverage activity	Electricity	Fuel	Average and range from BIER (2015)	
Unit/ flow/activity	[kWh/L]	[MJ_{fuel}/L]	[$MJ_{(el+fuel)}$/L]	[L water/L]
Winery, average from surveyed producers	***0.32*** (0.04-0.57)	***0.60*** (0.33-1.13)		
Winery, from BIER (2015)			1.67 (0.72 – 28)	***4.09*** (1.86 – 43.3)
Brewery, average from literature	0.31	1.6		
Brewery, adjusted to sum to average from BIER (2015)	***0.08****	***0.42***	1.23 (0.92 – 2.3)	***3.65*** (3.01 – 6.27)
Distillery, average from surveyed producers	***0.53*** (0.22-0.76)	***7.3*** (0.23-17)		
Distillery, adjusted to sum to average from BIER (2015)			12.6 (5 – 32)	***37.8*** (8.8 – 168)

*An energy conversion efficiency of 36% has been assumed, giving a conversion factor of 10 between electricity in kWh and MJ fuel input.

Inputs of packaging and treatment of food waste in the datasets from the background database were not included in the specific datasets for winery, brewery and distillery, since we model packaging and the treatment of the food by-products separately (see Section 3.3. and last paragraph of the current section, respectively). Also inputs of vegetable oils, dairy products, rice, sugar, and other food products and chemicals in the background database were not carried over into the specific datasets for winery, brewery and distillery, based on the assumption that these inputs to the average beverage industry represents mainly inputs to the production of non-alcoholic beverages. Instead, specific inputs of sugar and dairy products to lower alcohol content distilled beverages (liqueurs; with less than 35% alcohol by volume) were modelled based on more specific recipes. As the most consumed liqueur in the Nordic countries is whisky cream, we have used its sugar content of 0.2 kg/L (Terra 2016) as representative for the sugar content in all liqueurs in this study. We have furthermore used the content of 0.33 kg milk cream per litre (Terra 2016) as representative of the content of dairy products in all cream liqueurs, which are estimated to constitute 70% of all liqueurs in this study. The resulting amount of sugar and dairy product per L distilled beverage is 0.06 kg/L and 0.07 kg/L, respectively. For the high-alcohol content distilled beverages, the producers' data show that the average energy and water use masks that whisky generally has a larger energy and water use than vodka. For whisky, it should be noted that the data from the producers, which we have used directly, do not include the product losses in cask ageing (>2% per year of ageing).

For the wineries, the producers' have supplied data on the material in barrels, amounting to an average of 0.0007 kg steel and 0.0029 kg wood per L wine. The data collected for distilled beverages were not sufficient to estimate a specific input for barrels in distilleries.

The by-products from the beverage industry activities are modelled as used for animal feed with the consequential protein/energy feed displacement model of Schmidt (2015). In other terms, when by-products are used as animal feed, it is taken into account that this substitutes a combination of the marginal source of protein animal feed (soybean meal) and energy feed (barley). The relevant co-products that are utilised as animal feed are listed in Table 13. The inventory data for the barley and soy systems are comprehensively described in Schmidt and Dalgaard (2012, p 85) and Dalgaard and Schmidt (2012).

Table 13: Estimated amounts of by-products from beverage industry modelled for use as animal feed, per L of beverage.

Manufacturing of beverage activity	Unit	Wine	Beer	Distilled beverages
By-products		Pomace, lees, stems (for 1.46 kg wet weight grape input)	Spent grains and hops, surplus yeast, trub	DDGS and similar starch fodder
Mass	Kg dry mass	0.29	0.14	0.52
Protein content	kg crude protein	0.047	0.0082	0.19
Net energy content	MJ	2.3	0.80	4.0

While the by-products from breweries and distilleries are practically always used as fodder, some of the surveyed wineries indicate that the by-products are instead used as fertiliser or incinerated for energy recovery. In Section 5.1 we therefore compare the environmental consequences of such alternative uses of the winery by-products to the use as animal feed.

By law, whisky produced in Scotland, Canada and Ireland shall be aged at least 3 years in wood casks. This means that roughly half of all distilled beverages sold by the Nordic Alcohol Monopolies are being aged 3 years in wood casks, involving a product loss >2% per year of ageing. To account for this, the emissions from distilleries and activities upstream were multiplied by a factor 1.03.

3.5 International transport of beverages

Transport is already included with average values in the background database. However, since we have more specific data on the country of origin, we can calculate the international part of the transport with more precision than in the background database.

For the international transport, the weight of beverages (Tables 1 and 2) and the weight of packaging (Table 11) are combined and multiplied with the distances from each country to Gothenburg, the largest port of entry in Scandinavia, see Table 14. The transport to and from seaports is already included in the national data of the background database.

For wine losses during transport and handling we use the data from Lee (2007): For wine imported in flexitanks, 50 litres of wine is left in the bottom of when emptied (10 litres if ISO tanks are used instead) and 0.3% of wine is lost during the filling stage. Bottle losses during the shipping of cased wine (bottled at source) make up 0.15% (Lee 2007).

Table 14: Shipping distances between countries of origin and Scandinavia.

Country of origin	Distance [km]
Argentina	13,000
Australia	22,000
Canada	6,000
Chile	15,000
Czech Republic	400*
France	2,000
Germany	400
Ireland	1,700
Italy	5,000
Poland	600
South Africa	12,000
Spain	3,300
USA	16,000
United Kingdom	900
Rest-of-World	7,500

* Sea port distance from Rostock to Göteborg.
Transport by truck is included in the national data.

The EXIOBASE activities "Sea and coastal water transport" for each specific country have been applied. These activities are given per EUR_{2011}. We have applied a value of 0.0043 EUR/tonne-km to convert the transport work in tonne-km to its EUR_{2011} cost, based on the total value of the worldwide sea transport in EXIOBASE

(294,265 $MEUR_{2011}$) and the 6.8E13 tonne-km total global transport work for sea transport in 2011 according to Figure 1.4 in UNCTAD (2014).

3.6 Retail activities

The retail and advocacy activities of the Nordic Alcohol Monopolies are not in focus in this report. We therefore only illustrate the relative importance of average retail activities for average products, i.e. assuming that retailing of alcohol has the same impacts per EUR of sales as the average retail product in the three countries.

We include retailing in the overall result based on the following retail trade margins, taken from the 2014 accounts of the Monopolies: Finland 204 million EUR_{2014}, Norway 196 million EUR_{2014} (using a conversion rate of 8.35 NOK/EUR), Sweden 371 million EUR_{2014} (using a conversion rate of 9.105 SEK/EUR). The 2014 values were converted to EUR_{2011} of the background database with the value of 0.955 EUR_{2011}/EUR_{2014}. The distribution of the retail trade margins over beverage types has been done proportional to the price data obtained from Systembolaget and Alko, i.e. using a fixed retail margin across all beverage types.

In the retail dataset, sea transport was excluded, since this is already accounted for separately under the heading “International transport” (see Section 3.5).

Transport from retail to home is not included, since it is assumed that alcoholic beverages are purchased together with other products, and that only products with a low shelf life trigger separate shopping trips.

3.7 Consumer stage

Beer is generally consumed at less than ambient (indoor) temperature, typically 5 degrees Celcius. Also white wine, rosé wine and sparkling wine (effectively all wine that is not red wine) are typically consumed at 8-10 degrees Celcius. This implies that these product groups require refrigeration before consumption. Likewise, distilled beverages are often served chilled, although the chilling is usually done by adding ice rather than pre-cooling the beverage.

The electricity use for refrigeration has been calculated as 0.40 kWh/L beverage, which is an average for all products stored in a refrigerator, based on the 2005 electricity use for refrigeration in European households of 117,000 GWh (Bertoldi et al. 2012, p 18) and 292 million tonne food and beverages needing refrigeration (60% of the FAOSTAT food balance sheets total consumption in EU27). With the same amount of electricity, 2 kg of ice can be produced per litre of distilled beverage, assuming an efficiency of 0.2 kWh/kg ice. We therefore apply the 0.4 kWh/L to the full volume of beverages, with the exception of red wine; see Table 15.

Table 15: 2014 sales volumes and volumes for household refrigeration (all alcoholic beverages with the exception of red wine) and electricity for household refrigeration.

	Total volume [1000 L]	Volume for cooling [1000 L]	Electricity for cooling [MWh]
Finland	96,700	71,000	28,400
Norway	80,700	39,000	15,600
Sweden	407,500	306,000	122,400
Total	**584,900**	**416,000**	**166,400**

In principle, also dishwashing can be regarded as a part of the life cycle of beverages, but its importance is less than that of refrigeration, and it is unclear if additional consumption of alcoholic beverages affects the amount of dishwashing required in the households.

After ingestion, beverages are metabolized by the human body and excreted, mainly as urine. This has been taken into account with the model developed by Muñoz et al. (2008), which includes a detailed mass balancing in the human body.

To apply this model, we obtained the nutritional composition of wine and beer from the USDA Food database (USDA 2016), namely the datasets '14084, Alcoholic beverage, wine, table, all' and '14003, Alcoholic beverage, beer, regular, all'. The composition of spirits was obtained as a weighted average of the USDA dataset '14037, Alcoholic beverage, distilled, all (gin, rum, vodka, whiskey) 80 proof' and the composition of whisky cream (Baileys 2016), see Table 17. For the overall calculation, we used 71% of the high-alcohol composition (40% alcohol by volume) and 29% of the low alcohol composition (17% alcohol by volume), corresponding to a weighted average composition of 33.36% alcohol by volume with an average density of 0.953 kg/L.

It should be noted that the nutritional composition is calculated by weight rather than by volume. Because the density of alcohol is lower than that of water, the alcohol-content by weight is lower than that by volume, as can be seen in Table 16, where, for example, the beverages with alcohol content of 40% by volume have only 33.3% alcohol content when weight is used instead.

Table 16: Nutritional composition of alcoholic beverages.

Contents	Wine	Beer	Distilled beverage (40% alcohol by volume)	Distilled beverage (17% alcohol by volume)
Water	86.6%	92.0%	66.6%	45.4%
Protein	0.1%	0.5%		3.0%
Fat				13.0%
Carbohydrate	2.7%	3.6%		25.0%
Fibre				
Alcohol	10.5%*	3.5%*	33.3%*	13.5%
Other	0.1%	0.6%	0.1%	0.1%
Total	**100%**	**100%**	**100%**	**100%**

* Not originally reported by USDA; calculated as difference to 100%.

For wastewater treatment (see Table 17), the EXIOBASE dataset has been applied. This dataset has a reference flow of kg dry matter contained in wastewater, which for our beverages corresponds to 7.8 g faecal matter (faeces plus urea in dry matter) per L ingested beverages, or 4,560 tonnes per functional unit.

Table 17: Wastewater calculated with the human metabolism model.

Activity	Beers	Wines	Spirits	Total of average
Wastewater to treatment, g dry matter per L ingested beverage	3.7	10	23	7.8
Wastewater to treatment, Mg dry matter per functional unit	1,160	2,190	1,210	4,560

The electricity and other inputs to the households is split geographically according to the volume of beverages consumed in each country, as given in Table 15.

3.8 Packaging end-of-life, incl. recycling

The total amount of packaging as indicated in Table 11 is disposed of in the countries where the beverages are sold, as discerned in Table 18, which also gives the data per product type.

Table 18: Primary packaging (in 1000 kg) for the functional unit by country of use and product group.

	Aluminium can	Bag-In-Box	Flexibags	Glass	PET	Carton
Finland						
- Beer	118			2966	25	
- Distilled beverages	136			6697	991	
- Wine		1048	67	24595	323	112
Norway						
- Beer	8			1347		
- Distilled beverages	1	4		6105	175	
- Wine	1	2074	33	22523	33	12
Sweden						
- Beer	6284			30052	57	
- Distilled beverages				10194	35	
- Wine		6004	64	50204	187	447
Total	**6,548**	**9,130**	**164**	**154,683**	**1,826**	**571**

Table 19 shows the distribution over disposal routes. For Norway, the applied recycling rates were obtained from Miljødirektoratet (2015) and the relative landfill/incineration rates from SBB (2015). For Sweden, we obtained the recycling rates from the Swedish statistics on packaging recycling (Allerup & Fråne 2015) and subtracted the refillable glass bottles for beer (10% of the total amount of beer sold in glass bottles). The relative landfill/incineration rates for Sweden were taken from the Swedish waste statistics (Avfall Sverige 2015). For Finland, the recycling rates were found on the webpages of the recycling agents: www.palpa.fi, www.rinkiin.fi and www.ekopullo.fi and a landfill/incineration rate of 70/30 was applied.

Table 19: Primary packaging (in 1000 kg) for the functional unit by country of use and disposal route.

	Aluminium can	Bag-In-Box	Flexibags	Glass	PET	Carton
Finland						
- Refilling				1,160		
- Remanufacture	246			28,703	1,122	
- Incineration	2	314	20	1,318	65	34
- Landfill	5	734	47	3,076	152	78
Norway						
- Refilling						
- Remanufacture	7			26,469	84	5
- Incineration		1,941	31	659	123	6
- Landfill	3	137	2	2,848	1	0
Sweden						
- Refilling				3,005		
- Remanufacture	5,844			83,072	231	353
- Incineration	433	5,914	63	4,307	47	93
- Landfill	7	90	1	66	1	1
Total	**6,547**	**9,130**	**163**	**154,683**	**1,826**	**570**

The data from Table 19 are matched with the life cycle data for disposal in the background database, more specifically the country-specific average industry data for the respective packaging industries (refilling implies a reduced need for the output from these industries, while remanufacturing implies a reduce need for the raw material and energy inputs to these industries) and the country-specific data for incineration and landfilling (with country-specific efficiencies of energy recovery, etc.). The particular datasets used, together with the total amount of material treated is shown in Table 20.

Table 20: Inventory of packaging waste and disposal route. Includes secondary and tertiary packaging.

Waste fraction	Disposal datasets {SE} {FI} {NO}	Amount disposed [1000 kg]
Aluminium cans	Re-processing of secondary aluminium into new aluminium	5,600
Glass, closures, aluminium cans	Incineration of waste: Metals and Inert materials	9,334
Glass, closures, aluminium cans	Landfill of waste: Inert/metal/hazardous	13,223
PET bottles, secondary and tertiary packaging, closures	Re-processing of secondary plastic into new plastic	2,930
PET bottles, secondary and tertiary packaging, closures	Incineration of waste: Plastic	3,069
PET bottles, secondary and tertiary packaging, closures	Landfill of waste: Plastic	718
Carton bricks, secondary and tertiary packaging, labels	Re-processing of secondary paper into new pulp	265
Carton bricks, secondary and tertiary packaging, labels	Incineration of waste: Paper	16,782
Carton bricks, secondary and tertiary packaging, labels	Landfill of waste: Paper	3,784
Glass bottles	Recycling of bottles by direct reuse	4,165
Glass bottles	Re-processing of secondary glass into new glass	136,495
Pallets	Incineration of waste: Wood	1198
Pallets	Landfill of waste: Wood	154

4 Life cycle impact assessment (LCIA)

In this section the results of the LCA calculations are presented.

4.1 Characterised results

The environmental impacts from the functional unit, characterised by impact category, are shown in Table 21. Mid-point results are also shown for water use but this is not related to any impacts in the Stepwise method. All positive numbers indicate a negative (i.e. bad) impact.

The contribution to each of impact categories from different life cycle stages and emissions are described in Section 4.2.

Table 21: The environmental impacts from the functional unit, characterised by impact category.

Impact category	Unit	Amount	Comment
Acidification	ha UES	13,165	Expressed in hectares of unprotected ecosystem
Ecotoxicity, aquatic	Gg TEG-eq w	17,949	Equivalents of triethylene glycol emissions to water
Ecotoxicity, terrestrial	Gg TEG-eq s	14,052	Equivalents of triethylene glycol emissions to soil
Eutrophication, aquatic	Mg NO_3-eq	5,548	Expressed in nitrate-equivalents
Eutrophication, terrestrial	ha UES	28,441	Expressed in hectares of unprotected ecosystem
Global warming, fossil	Gg CO_2-eq	1,073	Expressed in CO_2-equivalents (GWP100)
Human toxicity, carcinogens	Mg C_2H_3Cl-eq	73,628	Expressed in vinyl chloride equivalents
Human toxicity, non-carcinogens	Mg C_2H_3Cl-eq	163,036	Expressed in vinyl chloride equivalents
Mineral extraction	MJ extra	6,941	Expressed in MJ additional energy required for future extraction
Nature occupation (biodiversity)	BAHY	5,305	Expressed in Biodiversity-Adjusted Hectare-Years
Non-renewable energy	TJ primary	1,005,334	Expressed in total primary non-renewable energy
Photochemical ozone, vegetation	ha*ppm*hours	1,018,299	Expressed in hectare-hours above 60 ppm threshold
Respiratory inorganics	Mg PM2.5-eq	1,637	Expressed as equivalents of Particulate Matter below 2.5μm
Respiratory organics	pers*ppm*h	988,232	Expressed in person-hours above 40 ppm threshold
Additional indicator not related to any impacts			
Water use	Mm^3	152	Expressed in million cubic meters gross water input

Table 22 shows the percentages per product group for each impact category.

Table 22: The environmental impacts from the functional unit specified in percentages for each product group

Impact category	Total (%)	Wine (%)	Beer (%)	Distilled beverage (%)
Acidification	100	47.5	22.8	29.7
Ecotoxicity, aquatic	100	60.0	26.4	13.6
Ecotoxicity, terrestrial	100	63.2	23.6	13.2
Eutrophication, aquatic	100	19.2	12.2	68.6
Eutrophication, terrestrial	100	36.5	17.7	45.7
Global warming, fossil	100	51.4	20.2	28.4
Human toxicity, carcinogens	100	65.8	20.3	13.9
Human toxicity, non-carcinogens	100	66.6	22.1	11.3
Mineral extraction	100	31.3	62.2	6.5
Nature occupation (biodiversity)	100	33.0	22.2	44.8
Non-renewable energy	100	65.2	24.7	10.1
Photochemical ozone, vegetation	100	52.0	24.1	24.0
Respiratory inorganics	100	51.7	24.2	24.1
Respiratory organics	100	51.4	24.7	23.9
Additional indicator not related to any impacts				
Water use	100	86.6	6.9	6.55
Product volume for comparison				
Product volume	100	53.7	37.3	9.0

Because the characterised results are not expressed in the same or comparable units, the amounts should not be added or otherwise compared across impact categories. For comparisons across impact categories, it is more appropriate to use the monetarised results in Section 4.2.

4.2 Monetarised results

The monetarised results are shown in Figure 5 and Figure 6. The unit is $MEUR_{2014}$, i.e. million Euros.

The contributions to Human toxicity are not included, as these results are dominated by high contributions from dioxins from waste incineration and benzo(a)pyrene from diesel combustion that we find unlikely to be correct. To counter the concern that we hereby also eliminate the impact from pesticides, we separately calculated the potential contribution to human toxicity from pesticides for grape growing. For the total wine production for the Nordic Alcohol monopolies we calculate this to be 2.4 MEUR2014, which is less than 1% of the overall life cycle impacts. The calculation is based on Fantke et al. (2012)'s estimate of the total health impact from pesticides on European grape production of 724 DALY as well as specific pesticide application data for California for year 2012 from the PAN pesticides database (PAN, 2012). The calculation was done with the more recent USETOX method (Rosenbaum et al. 2008) that covers a larger number of specific pesticides, and the DALY (=QALY) values from Huijbregts et al. (2005). The volume of wine for the Nordic Alcohol monopolies is 1/60 of the European volume, thus giving a value of 12 QALY. Adding another 6 QALY as a high estimate for worker and bystander exposure, which is not included in the model of Fantke et al (2012), gives a total of 18 DALY or 2.4 MEUR2014.

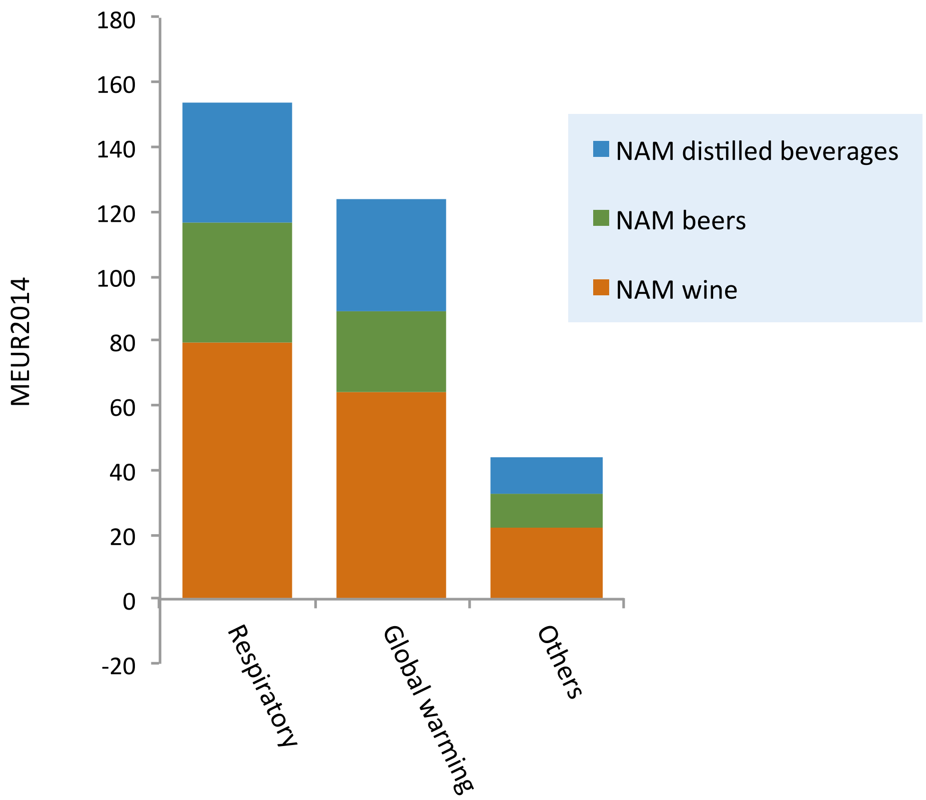

Figure 5: Monetarised environmental impacts related to the life cycle of Nordic Alcohol Monopolies (NAM) 2014 sales of wine, beer, and distilled beverages. The unit is $MEUR_{2014}$, i.e. million Euros.

The total life cycle impacts amount to 320 $MEUR_{2014}$, excluding the human toxicity values (90 $MEUR_{2014}$). This total value can be compared to the overall sales value of the alcoholic beverages sold by the Nordic Alcohol Monopolies in 2014, which is approximately 4800 $MEUR_{2014}$, excluding taxes. This means that the environmental externalities (life cycle impacts) are approximately 7% of the product value.

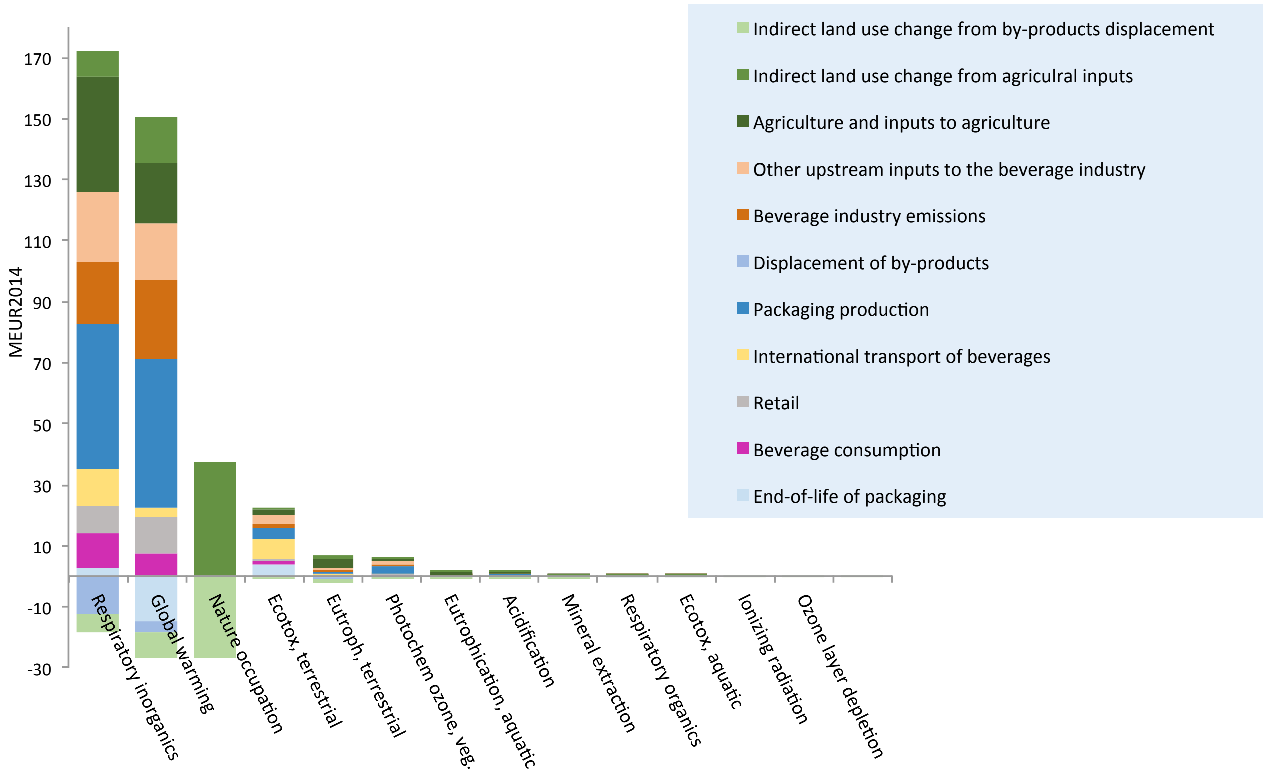

Figure 6: Monetarised environmental impacts related to the life cycle of Nordic Alcohol Monopolies 2014 sales of alcoholic beverages. The unit is $MEUR_{2014}$, i.e. million Euros. Negative contributions are due to recycling benefits.

It appears from Figure 5 and 6 that the contributions of two impacts categories are significantly higher than the rest, namely respiratory inorganics, global warming. These two impact categories together account for 86% of the total monetarised impact excluding human toxicity. Nature occupation, terrestrial ecotoxicity, terrestrial eutrophication and photochemical ozone impacts on vegetation are the next impact categories of interest. The contributions to terrestrial ecotoxicity is mainly from copper and other metals emitted to air, which is to a large extent an artefact of the impact assessment method, which do not account adequately for the long-term reduction in bioavailability of these substances (Plouffe et al. 2012).

The average monetarised LCA results per litre beverage are shown in Figure 7.

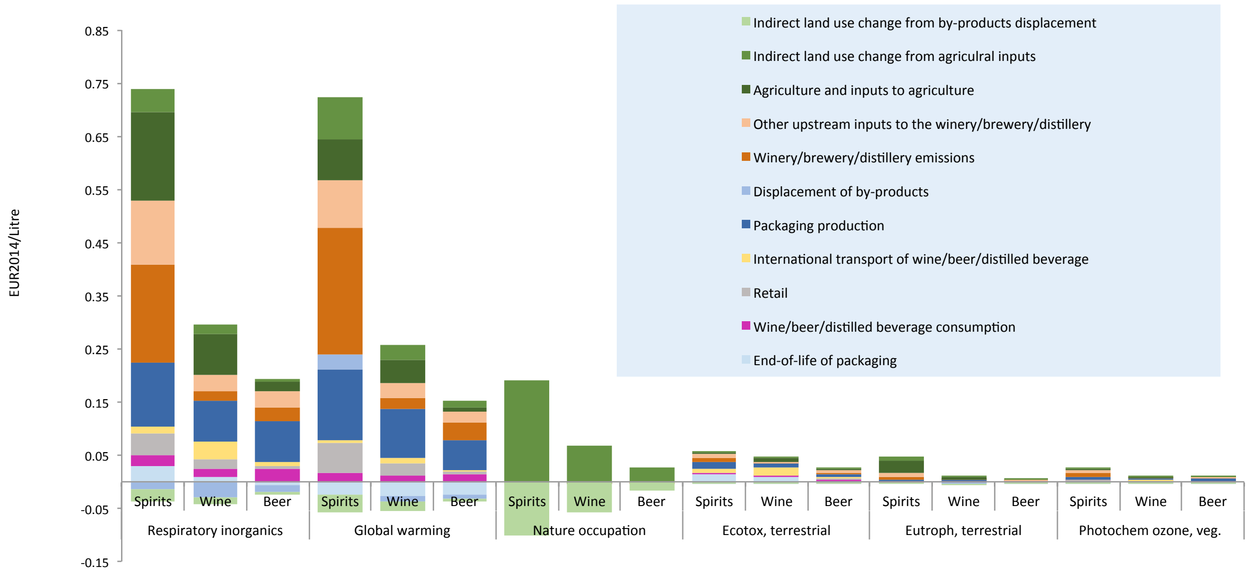

Figure 7: Monetarised LCA results per litre beverage as averages over the different alcohol types

The packaging impacts per litre are the highest for spirits and the smallest for beers. The high percentage of beers sold in cans explains the lower impact of beer packaging.

The distillery direct emissions are a major contributor to respiratory inorganics compared to the direct emissions from brewery and winery. The direct emissions from distilleries are directly proportional to the fuel energy use per litre beverage, which is much higher in distilleries than in breweries and wineries (11 MJ fuel per litre distilled beverage versus 0.2-0.4 MJ fuel per litre beer or wine).

The displacement of by-products from the beverage industry leads to a reduction of nature occupation and respiratory inorganics impacts, which can be seen from the negative values in Figure 6 and 7. The similar effect on global warming impacts, which can be seen for wine and beer in Figure 7, is lower and caused exclusively by the displacement of energy feed. The displacement of protein feed actually has the opposite effect on global warming, because the protein feed displaces soy meal, which reduces the amount of its by-product soy oil, which in turn leads to an increase in the production of palm oil, which has a high global warming impact. Since the energy/protein ratio of distillery by-products is low, the displacement effects of these by-products are dominated by the displacement of protein, leading to a net increase in global warming impact from the distillery by-product displacement.

The impact from retail per litre beverage appears higher for distilled beverages than for wine and beer, which is due to differences in the average database emission factors for retail activities combined with the differences in the proportions of the three product groups in the three countries (more distilled beverages are sold in Finland and most of the beer is sold in Sweden).

The impact from consumption per litre beverage is higher for beer because all beers are refrigerated while red wines are not.

It should be noted that the data presented in Figure 7 are averages per litre beverage, averaged over the different alcohol percentages within each beverage type.

In the following the contribution of the different life cycle stages to the global warming, respiratory inorganics, and nature occupation impacts will be described in more detail. Also the contribution of the different life cycle stages to water use is presented.

4.3 Contribution analysis

Global warming

More than 99.9% of the contribution to global warming in the current study is caused by carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O).

Table 23 shows the contribution of the different life cycle stages to the global warming impact.

Packaging production contributes with 46-49% of the overall global warming impact for wine and beer, and 20% for distilled beverages. More than 44% of the overall global warming impact from packaging production is from glass manufacture, approximately 18% from aluminium cans, 16% from plastics and around 16% from paper. Some of the global warming impact from packaging production is alleviated through recycling, most for beer with 46%, over 30% for wine to 19% for distilled beverages.

Table 23: Contribution analysis: Global warming impact for an average amount of alcoholic beverage sold by the Nordic Alcohol Monopolies in year 2014

Life cycle stages	Total	Beer	Wine	Distilled beverages
Indirect land use changes (iLUC)	5.40%	5.48%	4.65%	6.71%
Agriculture and upstream (excl. iLUC)	16.02%	7.88%	21.61%	11.67%
Packaging production	39.48%	49.25%	46.36%	20.10%
Other upstream inputs to the beverage industry	15.07%	17.44%	15.01%	13.50%
Beverage industry	21.31%	30.00%	9.78%	35.99%
Displacement of by-products	-2.92%	-6.23%	-5.49%	4.10%
International transport of beverage	2.73%	1.69%	4.35%	0.55%
Retail activities	9.72%	5.76%	11.99%	8.43%
Consumer stage	5.94%	11.57%	5.53%	2.69%
End-of-life of packaging	-12.77%	-22.85%	-13.79%	-3.75%
Total	**100%**	**100%**	**100%**	**100%**

The second largest contribution to global warming comes from agriculture (21% of the overall impact, when adding the 5% contribution from indirect land use impacts). The contributions from indirect land use changes are proportional to the amount of marginal arable land required to grow the agricultural inputs.

Another 21% of the global warming impacts come from the emissions from fuel use at the beverage industry itself. Another 15% come from other inputs to the beverage industry, which is dominated by electricity and upstream transport.

Respiratory inorganics

Table 24 shows the contribution of the different life cycle stages to the impacts of respiratory inorganic substances (mainly ammonia, nitrogen oxides, particulates, and sulfur dioxide). The major sources of ammonia are field emissions from crop cultivation, including the intensification effect of indirect land use. Nitrogen oxide emissions originate from combustion of diesel in agricultural machinery, field emissions, and transport. Particulates and sulfur dioxide originate mainly from combustion of fuels in agricultural machinery, transport vehicles and power plants.

Table 24: Contribution analysis: Impacts of respiratory inorganics for an average amount of alcoholic beverage sold by the Nordic Alcohol Monopolies in year 2014

Life cycle stages	Total	Beer	Wine	Distilled beverages
Indirect land use changes (iLUC)	1.6%	1.4%	1.1%	3.0%
Agriculture and upstream (excl. iLUC)	24.7%	11.2%	31.4%	23.8%
Packaging production	31.0%	45.1%	30.7%	17.3%
Other upstream inputs to the beverage industry	14.8%	18.2%	12.1%	17.3%
Beverage industry	13.4%	14.8%	6.9%	26.1%
Displacement of by-products	-8.1%	-6.9%	-11.4%	-2.1%
International transport of beverage	8.0%	4.2%	12.6%	1.9%
Retail activities	6.1%	3.3%	7.5%	5.8%
Consumer stage	7.4%	14.4%	6.3%	2.8%
End-of-life of packaging	1.0%	-5.6%	2.6%	4.1%
Total	**100%**	**100%**	**100%**	**100%**

The contribution from the different life cycle stages follows the same pattern as for global warming, although agriculture and international sea transport have relatively larger contributions and the contributions from the packaging and beverage industry are relatively lower. These differences are related to differences in the fuel types and combustion efficiencies of the respective industries.

Nature occupation

The impacts on nature occupation (biodiversity) occur exclusively as accelerated denaturalisation via indirect land use, as explained in Section 2.7. 33% of nature occupation contributions come from wine, 22% from distilled beverages and 45% from beer. A breakdown by crops and by country is provided Table 25. As already discussed for wine in Section 3.2, indirect land use is practically exclusively caused by agricultural activities and is therefore closely related to the raw material requirements for the beverages and their yields per area. However, a large part of this effect is counter-balanced by the by-products from winery, brewery and distillery, which are used for fodder, and which therefore displace the growing of dedicated fodder crops.

Table 25: Main contributing activities to indirect land use (nature occupation), breakdown by crops and by country. This reflects the geographical origin of the beverages supplied to the Nordic Alcohol Monopolies, as well as the average yields in these countries. The unit is Biodiversity-Adjusted Hectare-Years (BAHY).

Main contributors to Nature occupation	Agriculture and upstream inputs (BAHY)	Displaced fodder production due to by-products from beverage industry (BAHY)	Total BAHY
Distilled beverages, Finland	2,064	-1,003	1,061
Wine, Spain	2,042	-1,040	1,003
Beer, Sweden	2,334	-1,523	812
Wine, France	1,416	-897	520
Distilled beverages, Rest of the World	589	-241	348
Wine, Italy	2,562	-2,244	318
Distilled beverages, Norway	472	-197	275
Wine, Rest of the world	1,321	-1,082	239
Distilled beverages, United Kingdom	796	-594	202
Distilled beverages, Poland	233	-87	146
Distilled beverages, Sweden	229	-119	109
Wine, Australia	849	-759	90
Sum of the above (>95% of total)	*14,908*	*-9,785*	*5,123*

As can be seen in Figure 8, for some countries where the wine yields per hectare are high, this may even result in a net negative use of land (i.e. reduction of land use), because the displaced fodder crops, especially soybeans, have a relatively lower yield per hectare. It should be noted that the indirect impacts are typically *not* occurring in the same countries as the cultivation.

Water use

81% of water use is consumed in agriculture, 76% from growing grapes for wine and 5% from growing cereals for distilled beverages and beers. 7% of water use is consumed for the manufacturing of packaging and 6.5% is used at the consumption stage. A breakdown by crops and life cycle stages of beverage types is provided in Table 26. The tables 6 and 8 should be referred to for the identification of the most water consuming agriculture type per country.

Table 26: Main contributors to water use, per life cycle stage and beverage type. This reflects the geographical origin of the beverages supplied to the Nordic Alcohol Monopolies, as well as the water use per litre beverage in these countries.

Main contributors to Water use	Beverage type	Total
Cultivation of grapes Italy	Wine	17.50%
Cultivation of grapes Spain	Wine	13.50%
Cultivation of grapes Chile and Argentina	Wine	11.70%
Cultivation of grapes Australia	Wine	10.20%
Cultivation of grapes United States of America	Wine	8.88%
Cultivation of grapes Rest of the world	Wine	7.14%
Cultivation of grapes South Africa	Wine	6.10%
Cultivation of grapes France	Wine	1.45%
Other upstream inputs for wine	Wine	1.48%
Packaging of wine	Wine	5.21%
Consumption of wine	Wine	3.21%
Packaging end of life of wine	Wine	-1.90%
Agricultural inputs for beer	Beer	1.30%
Packaging of beer	Beer	1.74%
Consumption of beer	Beer	3.29%
Agricultural inputs for distilled beverages	Spirit	3.19%
Retail of beverages	Beverage	1.79%
Upstream inputs for beverages, other	Beverage	2.40%
Total		**98%**

Transport contributions

The Table 27 shows the impacts from the different transport industries over the life cycle of the analysed beverage types separately. As explained in Section 3.5, the international part of the transport by ship was modelled with more precision than the transports to and from seaports (originally included as averages within the database). From Table 27, it appears that the most contributing transport industry is the costal and seawater transport industry. Land transport only ranks second in order of contributing importance to the global impact, accounting for 6 to 8% of total transport contributions to global impact. Global warming is only a minor contributor to the total impacts from transport.

Table 27: Percentage contributions from the transport industries to the overall monetarised life cycle Impacts.

Transport industries	Wine		Beer		Distilled beverage	
	All impacts	- of which Global warming	All impacts	- of which Global warming	All impacts	- of which Global warming
Sea and costal water transport	13.4	1.31	9.8	1.0	2.6	0.2
Inland water transport	0.12	0.02	0.53	0.07	0.45	0.11
Air transport	0.23	0.11	0.27	0.12	0.05	0.02
Transport via railways	0.12	0.05	0.06	0.02	0.05	0.02
Road transport	0.83	0.31	0.94	0.28	0.23	0.08
Supporting and auxiliary transport activities	0.40	0.16	4.2	1.0	0.31	0.12
Total transport contribution to life cycle impacts	15.1	2.0	15.8	2.5	3.7	0.6

4.4 Country variation

In this section, we compare the environmental impacts per unit of product between the different supplying countries.

Wine

The cradle to gate impacts for 1 L wine sourced from the different countries are presented in Figure 8.

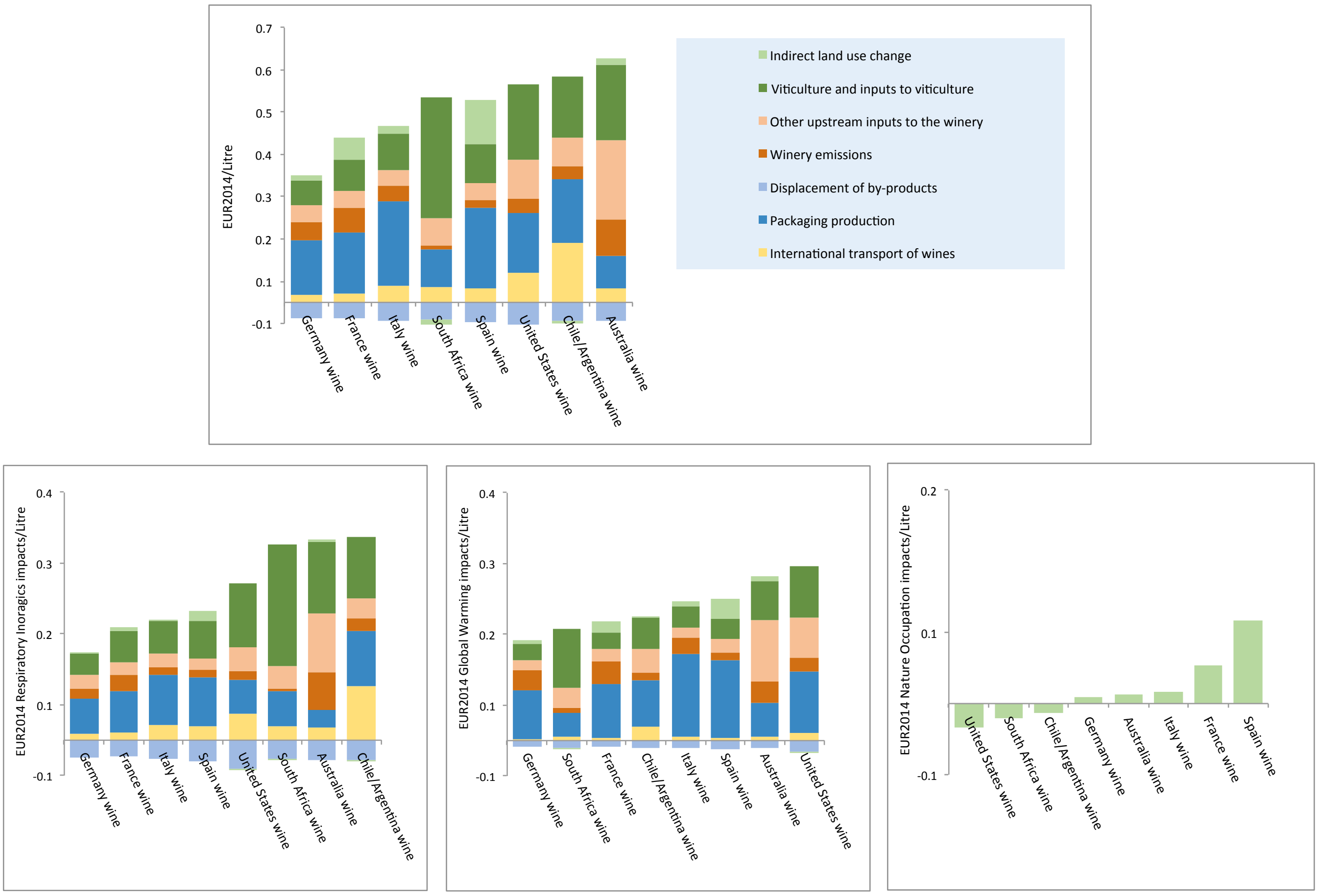

Figure 8: Monetarised cradle to gate impact of 1L wine per sourcing country. The unit is EUR2014. The top graph show the total of all environmental monetarised impacts, and the three graphs below show the monetarised impacts of the three main impact categories (from left to right): respiratory Inorganics, global warming, and nature occupation. Negative contributions are due to the use of by-products (biomass waste) as animal feed.

The large differences in viticulture contributions (in dark green) are caused by differences in the fuel combustion emission factors, which are particularly high in Australia, Chile/Argentina, the USA and South Africa.

The large differences in "Other upstream inputs to the beverage industry" (light brown) are mainly due to the different marginal electricity mixes. The contributions from packaging production (blue) are largely determined by the country-specific emission factors for glass manufacturing. The international transport contributions (yellow) are higher for the countries with larger transport distance to the Nordic countries, as would be expected, although lower bottle weights and bulk transport reduces the impact, especially for Australian and South African wines. The nature occupation impacts are proportional to the average country yields provided in Table 7, with France and Spain having the lowest viticulture yields, and therefore the largest iLUC contributions.

Beer

The cradle to gate impacts for 1 L beer sourced from the different countries are presented in Figure 9.

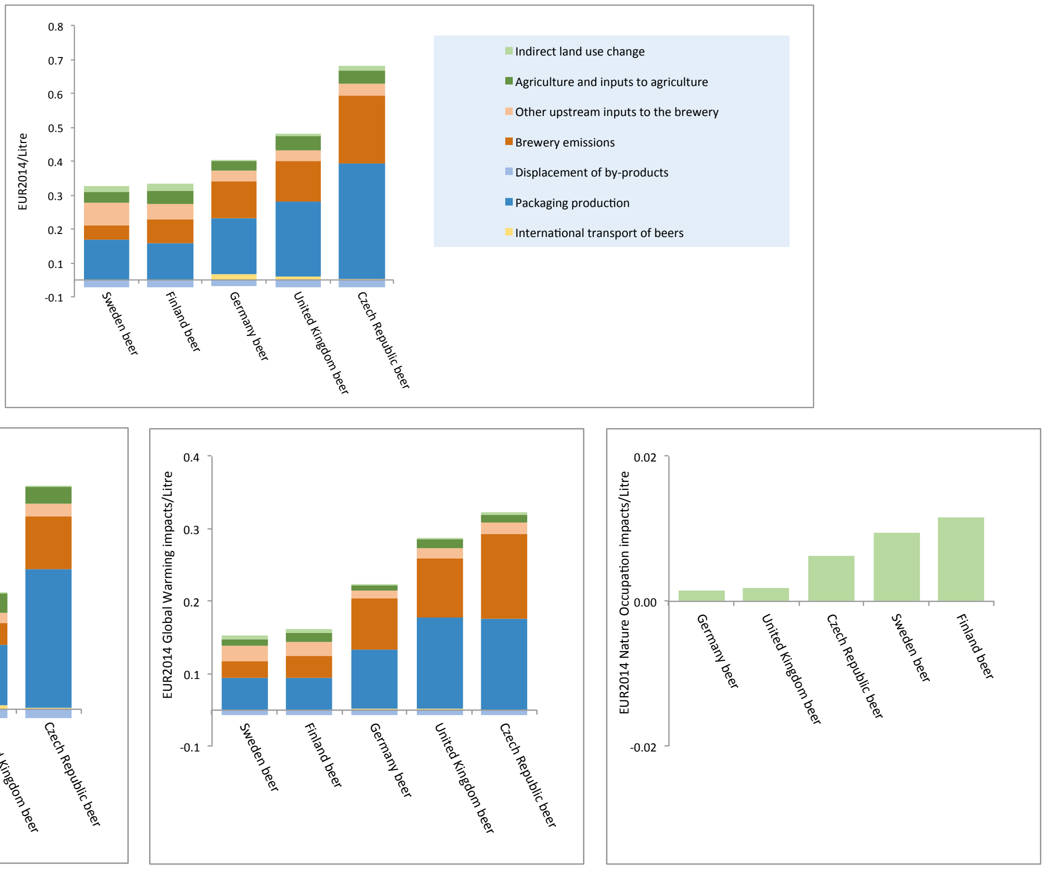

Figure 9: Monetarised LCA results relating to the cradle to gate impact of 1L beer per sourcing country. The unit is EUR_{2014}. The top graph show the total of all environmental monetarised impacts, and the three graphs below show the monetarised impacts of the three main impact categories (from left to right): respiratory Inorganics, global warming, and nature occupation. Negative contributions are due to the use of by-products (biomass waste) as animal feed.

The beers from Sweden and Finland have lower impacts compared to the beers from Germany, the UK and Czech republic. Different parameters explain these results:

- The brewery emissions are less in Sweden and Finland because the fuel combustion emission factors are lower in these countries.
- The glass bottles for tapping in Sweden and Finland have a less impacting manufacture.

- No international transports are required for beers from Sweden and Finland.

The nature occupation impacts are higher for Swedish and Finnish beers but this does not counterbalance the benefits from the glass manufacturing efficiency and low brewery emissions in Sweden and Finland.

Distilled beverages

The cradle to gate impacts for 1 L distilled beverage sourced from the different countries are presented in Figure 10.

The agriculture contributions are determined by the impacts of the cereal inputs. The impacts from growing cereals largely depend on the country specific fuel combustion emission factors, the yields and the fertiliser application. The indirect land use change impacts (nature occupation) are inversely proportional to the country specific grain yields, with the highest yields registered for Ireland and the UK.

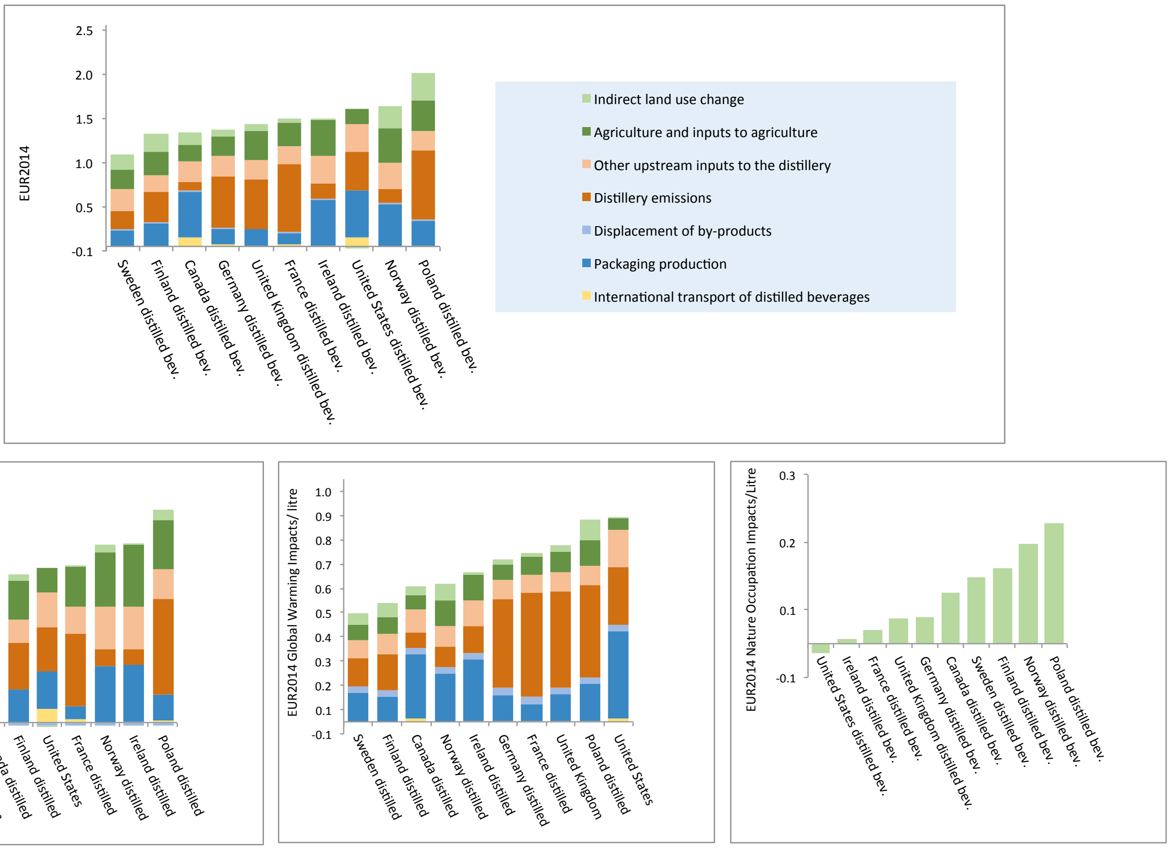

Figure 10: Monetarised LCA results relating to the cradle to gate impact of 1L distilled beverage per sourcing country. The unit is EUR_{2014}. The top graph show the total of all environmental monetarised impacts, and the three graphs below show the monetarised impacts of the three main impact categories (from left to right): respiratory Inorganics, global warming, and nature occupation. Negative contributions are due to the use of by-products (biomass waste) as animal feed.

The difference in distillery impacts is due to differences in country-specific emission factors for the beverage industry. The packaging impact is largely determined by the glass input (from 50 to 99% of the impacts), and thus by differences in the impacts from glass bottle manufacture.

5 Sensitivity, completeness and consistency checks

According to ISO 14044 (2006) an evaluation in the interpretation phase including sensitivity, completeness and consistency check must be carried out in order to establish confidence in the results of the LCA.

5.1 Sensitivity assessment

The objective of the sensitivity assessment is to assess the reliability of the results and how they are affected by uncertainties in data, assumptions and LCIA-methods (ISO 14044 2006).

Data

Throughout the study, the plausibility of the applied data has been checked by comparing several data sources. This has led to a number of adjustments, notably:

- the omission of human toxicity from the overall monetarised results, due to implausibly high data for dioxins from waste incineration and benzo(a)pyrene from diesel combustion. We do not find any reason that human toxicity should be an important impact category for alcoholic beverages;
- the elimination of implausible outliers in country-specific emission factors for plastic product manufacture and glass production;
- calculation of new data for irrigation and industry water consumption compared to those available in the background database.

We are confident that the data now applied are plausible within the context of the study, i.e. sufficiently reliable to give confidence in the results as presented in Chapter 4.

It should be noted that there is a very high degree of variability in most of the important activities in the life cycles of the investigated beverages, both in terms of variability between producers and between countries, as pointed out in Chapter 3. Such variation will tend to be reduced when averaging over many producers or many countries, so that we can have sufficient confidence in the identified proportions between life cycle stages (as shown in e.g., Figure 6) and in the identified major areas for improvement (Chapter 6). But the variation in the underlying data means that the specific percentages shown in Chapter 4 should not be taken as exact. Also, the country averages should not be taken as representative of individual producers within each country. The potential differences between producers are likely to be more important than differences between countries.

The study does not intend to distinguish the specific impacts of specific brands, nor the impact of specific agricultural practices such as organic agriculture. However, we are confident that the overall conclusions are generally relevant for all producers and production practices.

Assumptions

Assumptions are introduced in situations where specific data are missing. Compared to the ideal situation where no data were missing, the use of assumptions will increase the uncertainty of the results, either as increased stochastic uncertainty or as an over- or underestimation bias. The latter will be mentioned specifically in the following list of the assumptions made in this study:

- Due to missing data from the specific suppliers to the Nordic Alcohol monopolies, industry averages per country have been used. Individual producers can have very different environmental performance from the country averages, as described in Chapter 3.
- Due to lack of detail, the background database generally contains only aggregated industry and market averages per country, rather than data on specific products and marginal suppliers. This bias can lead to both under- and overestimations of the environmental impact, but will on average lead to

overestimations, because averages will include more complex products than the ones used in the beverage life cycles and because marginal producers will more often use modern, less polluting technologies. No systematic studies are available of the size of this aggregation bias, but we estimate that it does not affect the identified proportions between life cycle stages (as shown in e.g., Figure 6) and in the identified major areas for improvement (Chapter 6).

- In the background database, data are not available for Chile and Argentina individually, but only as part of the region Latin America. For electricity, we applied the marginal electricity data for Chile also to Argentina. The maximum error implied can be estimated by varying the Argentinian electricity mix between the one with the lowest electricity impacts (Norwegian) and the highest electricity impacts (South Africa). The maximum error estimated in this way is -7.5%/+9.6% on the impact of the life cycle of Argentinian wine at the point of entry to the Nordic countries.
- The most recent year for which primary data are available in the background database is year 2011. These data were assumed to be valid also for 2014, which may be seen as giving an overestimation of the environmental impact, since most technologies become more efficient with time.
- Due to missing data on packaging weights for beverages sold in Finland and Norway, data on packaging weight from Sweden were extrapolated to Finland and Norway. Based on the variation in packaging weights, the additional uncertainty from this extrapolation has been calculated to be +/-2.4% on the packaging weights.
- Due to missing data on secondary cardboard packaging for beer and distilled beverages in glass bottles, data on secondary cardboard packaging for wine were used, respectively without and with dividers. The impacts from secondary packaging for beers and distilled beverages are anyway negligible compared to the primary packaging, respectively 0.018% and 0.023%.
- Due to missing data on the international bulk trade in wine and the location of tapping for the specific brands, with the exception of tapping in the Nordic countries, we assumed all other wines to be tapped in the country of origin and the packaging materials to be produced there. Since the amount of tapping in Sweden and Finland is only 17.5% of the wines sold (see Section 3.3), and the international bulk wine sales are estimated at 38% of all exported wine in 2012 (OIV 2013), this may imply an overestimation of the international transport and a misrepresentation of the location of wine packaging manufacture. If 38% of the wine packaging manufacture takes place in Europe instead of 17.5%, this may change the impact contribution from packaging by +/- 34% depending on which overseas and European countries are involved, while reducing the transport work by 5% compared to the values presented in the results. Thus, the variation in impacts from packaging manufacture is more important than the potential reduction in impacts from transport.
- Winery by-products are assumed to be used as animal feed by default. This turns out to be also the most environmentally sensible use. We calculated alternative applications for the winery by-products, and found that incineration of the by-products with energy recovery would increase by 9% the life cycle impacts for respiratory inorganics, compared to the default modelling of use as animal feed, while the use as fertiliser would increase the life cycle impact from global warming by a few percent.
- In accordance with the scope of the study, the retail and advocacy activities of the Nordic Alcohol Monopolies have not been modelled in detail, and retail activities have therefore been included with the same impacts per EUR of sales as the average retail product in the three countries, to illustrate its approximate magnitude. It is assumed that alcoholic beverages are purchased together with other products, and do not trigger separate shopping trips (additional transport between home and retail).
- Due to missing data on household behaviour, all alcoholic beverages except red wine are assumed to require cooling prior to consumption with 0.40 kWh electricity use per litre beverage, corresponding to the average for all products stored in a refrigerator.

LCIA-methods

The applied LCIA method, Stepwise 2006, has been compared to other LCIA methods, namely to Ecoindicator99 and ReCiPe (Weidema 2015a) and the more recent IMPACT World+ (Bulle et al. 2014). The three impact categories that show up as most important in this study: global warming, respiratory inorganics, and nature occupation (land use impacts) are also important in the results for the other three methods. For Stepwise 2006, Ecoindicator99 and ReCiPe these three impact categories together make up between 86% and 97% of the overall global impacts in all three methods. IMPACT World+ considers additional impact categories such as marine acidification and water use impacts on human health as important, and gives higher importance to toxicity, eutrophication and acidification than the other three methodologies, differences that are currently under investigation by the IMPACT World+ to evaluate their validity.

The finding that the total monetarised life cycle impacts of the alcoholic beverages sold by the Nordic Alcohol Monopolies in 2014 amounts to approximately 7% of the overall sales value, can be compared to the total global environmental impacts amounting to 30% of the GDP, calculated with the Stepwise 2006 method (Weidema 2015a). Another possible comparison is to a similar study performed for Arla Foods (Schmidt & Flysjö 2016) showing the monetarised environmental impact from dairy products to be 46% of the value added of these products (Arla Foods revenue 2014 plus 20% retail sales margin). This implies that alcoholic beverages are relatively environmentally benign compared both to average products with the same economic value and to dairy products specifically. This result would be further emphasised if the relatively high tax on the alcoholic beverages in the Nordic countries was taken into account.

5.2 Completeness check

The objective of a completeness check is to ensure that the information provided in the difference phases of the LCA is sufficient in order to interpret the results (ISO 14044 2006).

The life cycle inventory is considered to have a high level of completeness given that it is based on IO-data, which consistently operates with a cut-off criterion at 0%. When the IO data have been too aggregated for the purpose in this LCA, they have been detailed by using other more specific data, e.g., crop yields, fertiliser inputs, energy inputs, electricity mixes etc. When this has been done, it is still within the IO-data and without loss of completeness.

Compared to process-based LCA databases, such as ecoinvent, the IO database includes fewer emissions, e.g., for pesticides, but the emissions included are those that contribute most to the global impacts, as identified in Figure 6.

5.3 Consistency check

The objective of the consistency check is to verify that assumptions, methods and data are consistent with the goal and scope. Especially the consistency regarding data quality along the product chain, regional/temporal differences, allocation rules/system boundaries and LCIA are important (ISO 14044).

In general, the model is based on a consistent and well-defined methodological framework as presented in Chapter 2. The default background data are from the Exiobase v3 database. Whenever relevant, the relatively aggregated activities in Exiobase have been detailed in order to better represent the actual activities. For example, the cultivation of wine grapes is modelled by adjusting the yields and emissions in the activity

'Vegetables, fruit, nuts'. The same approach is used when modifying the average beverage industry in Exiobase to represent beer-brewing, winemaking and distilled alcohol production.

The life cycle inventory includes indirect land use changes (iLUC). The effect on GHG emissions includes a time-shift in emissions. The applied GWP method addresses the timing of GHG emissions. The time-dependency is only included for iLUC. This inconsistency could have some effects – for example for beverage packaging where recycling benefits are achieved later than the impacts from production – especially for old wines and distilled alcohol.

6 Interpretation and conclusions

The monetarised results presented in Chapter 4 highlight three impact categories as dominating:

- Respiratory inorganics (air emissions: particulates, ammonia, NO_x, SO_2)
- Global Warming (CO_2, CH_4, N_2O)
- Nature occupation (biodiversity)

as well as some large contributing life cycle stages that appear as natural focus areas for improvements:

- Agricultural fuel use and emissions, especially for inputs to distilled beverages and wine
- Agricultural yields are particularly low in some countries, implying a larger nature occupation
- Energy use in distilleries and breweries
- Packaging

6.1 Improvement options for agriculture

The variation in fuel use and emissions appears very large, and even for producers with a lot of focus on environmental issues, the fuel use for cultivation does not appear to be in focus. While some of the variation is due to natural conditions, a larger focus on managing fuel use and emissions should be considered.

Some of the difference in agricultural yields can be explained by natural conditions, and for grapes also local regulations for the quality labels. Due to the perceived relationship between quality and yield, this is an area where it may be difficult to agree on improvements. Nevertheless, there should be a natural interest of the producers to consider which improvements in yields that could be obtained without compromising product quality. Raising the issue would be a first step.

6.2 Improvement options for fuel use in distilleries and breweries

The very large observed variation in fuel and electricity use between producers, as well as the differences in emission factors, point to potentials for improvement.

A Swedish producer of vodka informed us that due to the co-location of animal production with the distillery, the distillery by-products can be used directly as animal feed without prior drying, implying a substantial energy saving.

6.3 Improvement options for packaging

The most important improvement for packaging is the choice of packaging material, and especially the reduction of one-way glass packaging in situations where this is not essential for the product quality. The use of glass bottles is to a large extent a question of tradition and consumer preferences, that could be sought influenced by information.

Secondly, the large variation in the weight of individual packaging for the same purpose show that reduction in packaging weight is an important improvement option. As long as glass is used, this is obviously especially important for glass bottles, but also PET bottles, aluminium cans, and Bag-in-Box show large variations in weight for the same volumes.

Lastly, the variation in fuel use, combustion efficiency and emissions for packaging production is an area where large variation is found, which again points to a substantial improvement potential.

6.4 Communication and cooperation in the supply chain

To reduce the environmental impacts, it is important to focus on the large impacts first, because all problems cannot be solved at the same time. It is easy for producers and consumers to become confused by the changing impacts that are in focus in the daily media debates. Local impacts may be seen by local interest-groups as more important than more global impacts as respiratory inorganics and global warming, thus providing a bias towards solving local rather than the larger global problems. But if producers become distracted, the big problems would still be there to be solved. The Nordic Alcohol Monopolies can support producers in focussing on the important impacts, and in communicating these priorities to consumers and local interest groups. If producers and retailers could agree on a standardised, comparable way of informing the consumers of the important issues, this could make it easier for consumers to send strong signals to the producers that improvements on these issues will be appreciated and supported.

As noted several times above, differences in fuel efficiency and emissions is the cause of large differences in environmental impact. A general pattern can be seen that the farther away from the Nordic countries that a beverage is produced, the more environmental impact it is likely to cause. On average, breweries in the Nordic countries use less and cleaner energy for brewing and for packaging than breweries in the rest of Europe. Likewise, spirits produced in Norway, Sweden and Finland have on average lower global warming footprints than spirits produced elsewhere. And wines from e.g., Germany and France are likely to have less environmental impact than wines from further abroad. This can be used to focus the efforts for reducing environmental impacts on the locations where the largest improvements can be expected. However, it is important to be aware that the reason for the differences is not so much the necessary transport, but rather differences in fuel efficiency and emissions for the productive activities, and that the general pattern is not necessarily true for individual products. This means that a specific product from the Nordic countries can still have more environmental impact than a specific, comparable product from further abroad.

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Annex 1: Details of the Stepwise method

Update of the Nature conservation impact category of the Stepwise method v. 1.5

In the version 1.5 of the Stepwise method (Weidema 2009; Weidema et al. 2007), biodiversity is modelled using an average approach for including biodiversity effects from indirect land use changes. The modelling in version 1.5 implies that:

1) the effects on biodiversity are overestimated because in version 1.5, all changes in demand for land affects denaturalisation (deforestation) although intensification has no effect on Nature Occupation, and
2) the full cause effect pathway from land occupation to nature occupation (biodiversity) is inherently carried out in Stepwise (i.e. as part of the LCIA), while other effects from indirect land use changes (e.g., greenhouse gas emissions) need to be modelled in the life cycle inventory phase. This is inconsistent.

The nature occupation impact method in Stepwise v1.5 has therefore been revised. The revision makes the biodiversity impact assessment consistent with the general modelling of indirect land use changes as described in Schmidt et al. (2015) and in Section 2.7 of the main report). The revision involves splitting up the aggregated nature impact in Stepwise into direct and indirect impacts. The revision is described in the following.

In the version 1.5 of Stepwise, occupation of 1 ha*year arable land has an impact of 0.88 BAHY (Biodiversity Adjusted Hectare Years). The biodiversity adjustment is similar to the potential disappeared fraction of species (PDF), i.e. the impact is expressed in terms of the fraction of species that are affected per unit of area and time. According to Weidema et al. (2008, p 157), this is calculated as the annual global deforested area divided by the current global use of arable land (this gives a value for average deforested area per unit of land occupation), multiplied by 500 years (this is the relaxation time for biodiversity), and multiplied by 0.2 (this is the average severity – biodiversity adjustment – during the 500 years). However, this approach to establish a link between land occupation and BAHY is not compatible with more recent findings on pathway modelling from land occupation to land transformation; according to Schmidt et al. (2015), the effect of a change in demand for 1 ha*year land has the effect that denaturalisation of one hectare is moved one year closer. According to Weidema et al. (2008, p 157), arable land hosts only 20% of the species compared to the number in nature at full relaxation. Therefore, one ha*year arable land corresponds to 0.8 BAHY. Furthermore, the monetarisation in the current version of Stepwise refers to EUR/agricultural land (agricultural land equivalents is used as midpoint indicator) while the updated version uses BAHY as mid-point – therefore the updated monetarisation must refer to EUR/BAHY. This update is made by dividing the current monetarisation factor by 0.88.

The updated characterisation factors for nature occupation (indirect and direct impacts per hectare-year of land use) are listed in Table A1. In Table A1, it can be seen that the direct impact plus the indirect impact is equal to 1 when occupying sealed land (assuming that no intensification dampens the indirect effect).

Direct land use effects are normally of minor importance. As long as arable land is used for purposes that have similar direct impact on nature occupation (biodiversity) as average arable cropping, no direct land use impacts need to be added/subtracted. However, in cases where a specific land use is associated with a different direct impact than average arable cropping, this effect is included as direct effects.

Table A1: Characterisation factors for 1 ha*year land occupation and 1 ha*year indirect denaturalisation impact. The characterisation factors are all based on Stepwise (Weidema et al. 2007), the difference is that they are divided into direct and indirect here, making it compatible with the modelling of indirect land use changes in Schmidt et al. (2015). The values have been adopted from Ecoindicator99 (Goedkoop and Spriensma 2001) by maintaining the original proportion between direct impact indicator values, relative to the values for intensive agricultural and urban use of arable land. Positive numbers indicate a negative (i.e. bad) impact.

Land markets and uses	Direct marginal impact relative to marginal land use BAHY	Indirect denaturalisation impact BAHY
Arable land		
Intensive agricultural and urban use of arable land		
Occupation, accelerated denaturalisation, secondary forest to arable*	n.r.	0.8
Occupation, arable		
Occupation, pasture and meadow, intensive	0	n.r.
Occupation, urban, continuously built		
Occupation, sealed, on arable land*	0.2	
Less intensive uses of arable land		
Occupation, arable, organic	-0.04	
Occupation, forest, on arable land*	-0.7	
Occupation, industrial area, built up	-0.22	n.r.
Occupation, pasture and meadow, extensive	-0.09	
Occupation, traffic area	-0.22	
Intensive forest land		
Occupation, accelerated denaturalisation, secondary forest to intensive forest*	n.r.	0.1
Occupation, accelerated denaturalisation, primary forest to intensive forest*		0.1
Occupation, forest	0	n.r.
Occupation, sealed, on intensive forest land*	0.9	
Extensive forest land		
Occupation, accelerated denaturalisation, secondary forest to extensive forest	n.r.	0.1
Occupation, accelerated denaturalisation, primary forest to extensive forest		0.1
Occupation, forest, extensive	0	n.r.
Occupation, sealed, on extensive forest land*	0.9	
Grassland		
Occupation, accelerated denaturalisation, grassland to pasture	n.r.	0.3
Occupation, grassland	0	n.r.
Occupation, sealed, on grassland*	0.7	

Indirect land use changes include transformation and intensification (as described in Section 2.7 of the main report). Intensification has no effect on nature occupation. The effects from intensification are included via other impact pathways, e.g., biodiversity effects from terrestrial eutrophication from losses of nutrients due to increased fertiliser application. Land transformation via indirect land use changes is referred to as accelerated denaturalisation. This term is used because the effect on denaturalisation, such as deforestation from a specific land occupation (1 ha*year-equivalent), is only temporary, moving the denaturalisation of one ha*year-equivalent one year closer, see Schmidt et al. (2015), hence the term accelerated. The accelerated denaturalisation related to occupation of arable land includes transformation from secondary forest to cropland (Schmidt et al. 2015). The effect in units of biodiversity midpoint indicator (BAHY) is calculated as the difference in biodiversity-value of secondary forests and cropland. This is then multiplied by the duration, which is one year, and the area. It should be noted that since some of the indirect land use changes involve compensation of land for displaced crops via intensification, occupation of 1 ha*year-equivalent induce less than 1 ha*year-equivalent accelerated denaturalisation.

Summary of all endpoint damage factors of the Stepwise 2006 method

Table A2 shows all endpoint damage factors applied in the Stepwise 2006 method, as applied in this study and described in Section 2.9.

Table A2: Summary of damage endpoint factors for the Stepwise method (Weidema 2009; Weidema et al. 2007) including the updates for Nature occupation described in the text. EUR refers to EUR_{2003}. The final results of the LCIA of this study are shown in EUR_{2014} using a conversion rate of 1.38 EUR_{2014}/EUR_{2003}. Positive numbers indicate a negative (i.e. bad) impact.

Impact category	Units of characterised values at midpoint	Impacts on ecosystems		Impacts on human well-being		Impacts on resource productivity	All impacts aggregated
		BAHY/ characterised unit at midpoint	EUR_{2003}/ characterised unit at midpoint	QALY/ characterised unit at midpoint	EUR_{2003}/ characterised unit at midpoint	EUR_{2003}/ characterised unit at midpoint	EUR_{2003}/ characterised unit at midpoint
Acidification	m^2 year UES	5.5E-06	7.7E-03				7.7E-03
Ecotoxicity, aquatic	kg-eq. TEG water	5.0E-09	7.1E-06				7.1E-06
Ecotoxicity, terrestrial	kg-eq. TEG soil	7.9E-07	1.1E-03				1.1E-03
Eutrophication, aquatic	kg NO_3-eq.	7.2E-05	1.0E-01				1.0E-01
Eutrophication, terrestrial	m^2 UES	8.9E-06	1.3E-02				1.3E-02
Global warming	kg CO_2-eq.	5.8E-05	8.2E-02	2.1E-08	1.6E-03	-3.7E-04	8.3E-02
Human toxicity	kg C_2H_3Cl-eq.			2.8E-06	2.1E-01	6.4E-02	2.7E-01
Injuries, road/work	fatal injuries -eq.			4.3E+01	3.2E+06	9.9E+05	4.2E+06
Mineral extraction	MJ extra					4.0E-03	4.0E-03
Nature occupation	BAHY	8E-05	1.4E-01				1.4E-01
Ph. chem. ozone – veg.	m^2*ppm*h	6.6E-08	9.3E-05				
Respiratory inorganics	kgPM2.5-eq.			7.0E-04	5.2E+01	1.6E+01	6.8E+01
Respiratory organics	pers*ppm*h			2.6E-06	2.0E-01	6.1E-02	2.6E-01

References for Annex 1 are included with the references of the main report

Annex 2: Tables for monetarised results

This Annex includes three Tables with the values behind the figures in Section 4.2 of the report.

Table A3: Monetarised environmental impacts related to the life cycle of Nordic Alcohol Monopolies 2014 sales of wine, beer, and distilled beverages. The unit is $MEUR_{2014}$, i.e. million Euros. Corresponds to Figure 5 of the main report.

Impact category	Total	Wine	Beers	Distilled beverages
	$MEUR_{2014}$	$MEUR_{2014}$	$MEUR_{2014}$	$MEUR_{2014}$
Respiratory inorganics	153	80	37	37
Global warming	123	63	25	35
Others	45	22	10	12

Table A4: Monetarised environmental impacts related to the life cycle of Nordic Alcohol Monopolies 2014 sales of alcoholic beverages. The unit is $MEUR_{2014}$, i.e. million Euros. Negative contributions are due to recycling benefits. Corresponds to Figure 6 of the main report.

Impact category	Total	End-of-life of package-ing	Beverage consump-tion	Retail	Inter-national trans-port of beve-rages	Packa-ging pro-duc-tion	Displa-cement of by-product	Bever-age indu-stry emis-sions	Other up-stream inputs to the beve-rage industry	Agri-culture and inputs to agri-culture	Indirect land use change from agricul-tural inputs	Indirect land use change from by-product displace-ment
Respiratory inorganics	153	1.5	11	9.3	12	47	-12	21	23	38	8.7	-6.2
Global warming	123	-16	7.3	12	3.4	49	-3.4	26	19	20	15	-8.6
Nature occupation	10	0	-0.0064	0	0	0	0.017	0	-0.0074	-0.0022	37	-27
Ecotox, terrestrial	21	3. 8	1.3	0.62	6.2	4. 1	-0.54	0.90	2.8	2.2	0.19	-0.14
Eutrophiction, terrestrial	4. 9	-0.30	0.14	0.17	0.24	0.80	-0.87	0.49	0.92	2.9	1.5	-1.1
Photochem ozone, vegetation	5.2	-0.15	0.31	0.36	0.38	2.0	-0.31	0.96	0.81	0.84	0.055	-0.047
Eutrophication, aquatic	0.78	-0.0064	0.025	0.0091	0.0048	0.049	-0.46	0.0076	0.11	1.0	0.020	-0.016
Acidification	1.4	0.0028	0.067	0.050	0.081	0.43	-0.14	0.13	0.22	0.51	0.21	-0.15
Mineral extraction	0.039	-0.013	0.039	0.00050	6.1E-05	0.047	-0.048	0	0.018	0.0071	0.00022	-0.011
Respiratory organics	0.35	-0.013	0.021	0.022	0.020	0.15	-0.015	0.067	0.051	0.053	0.0030	-0.0028
Ecotox, aquatic	0.18	0.037	0.023	0.0054	0.069	0.029	-0.029	0.0071	0.030	0.013	0.0012	-0.0024

Table A5: Monetarised LCA results per litre beverage as averages over the different alcohol types. The unit is $MEUR_{2014}$, i.e. million Euros. Negative contributions are due to recycling benefits. Corresponds to Figure 7 of the main report. The data for Nature occupation are provided separately below in Table A6.

Impact category	Respiratory inorganics			Global warming			Ecotox, terrestrial			Eutroph, terrestrial			Photochem ozone, veg.		
	Spirits	Wine	Beer	Spirits	Wine	Beer	Spirits	Wine	Beer	Spirits	Wine	Beer	Spirits	Wine	Beer
Agriculture and inputs to agriculture	0.166	0.079	0.019	0.078	0.043	0.009	0.003	0.006	0.001	0.021	0.004	0.002	0.002	0.002	0.000
Other upstream inputs to the winery/brewery/distillery	0.121	0.031	0.031	0.090	0.030	0.020	0.007	0.003	0.007	0.010	0.001	0.001	0.005	0.001	0.001
Winery/brewery/distillery emissions	0.183	0.017	0.025	0.239	0.020	0.034	0.007	0.001	0.001	0.004	0.000	0.001	0.008	0.001	0.001
Packaging production	0.121	0.077	0.076	0.134	0.093	0.056	0.013	0.007	0.005	0.002	0.002	0.001	0.004	0.002	0.005
Displacement of by-products	-0.015	-0.029	-0.012	0.027	-0.011	-0.007	-0.001	-0.001	0.000	0.000	-0.002	-0.001	0.000	-0.001	0.000
International transport of wine/beer/distilled beverage	0.013	0.032	0.007	0.004	0.009	0.002	0.007	0.016	0.004	0.000	0.001	0.000	0.000	0.001	0.000
Retail	0.041	0.019	0.006	0.056	0.024	0.007	0.002	0.001	0.000	0.001	0.000	0.000	0.002	0.001	0.000
Wine/beer/distilled beverage consumption	0.020	0.016	0.024	0.018	0.011	0.013	0.002	0.002	0.003	0.000	0.000	0.000	0.001	0.000	0.001
End-of-life of packaging	0.029	0.007	-0.010	-0.025	-0.028	-0.026	0.013	0.008	0.002	0.000	-0.001	0.000	0.002	0.001	-0.002
Indirect land use change from agricultural inputs	0.045	0.016	0.006	0.078	0.028	0.011	0.001	0.000	0.000	0.008	0.003	0.001	0.000	0.000	0.000
Indirect land use change from by-products displacement	-0.023	-0.013	-0.004	-0.033	-0.018	-0.005	-0.001	0.000	0.000	-0.004	-0.002	-0.001	0.000	0.000	0.000

Table A6: Monetarised LCA results per litre beverage as averages over the different alcohol types. The unit is $MEUR_{2014}$, i.e. million Euros. Negative contributions are due to recycling benefits. Corresponds to the data for Nature occupation in Figure 7 of the main report.

Impact category	Nature occupation		
	Spirits	Wine	Beer
Indirect land use change from agricultural inputs	0.190	0.068	0.027
Indirect land use change from by-products displacement	-0.102	-0.057	-0.017