Update of wine packaging LCA – Final report
Alko Oy

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Content

1. Introduction

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- Alko aims to be a pioneer in product and supply chain responsibility. To achieve this goal Alko is taking actions to reduce the environmental impact of its own operations and product range. In Alko's responsibility strategy for 2020 the main goals are an environmentally friendly range of beverages, ecological packaging and reducing the environmental impact of stores.
- This report focuses on the environmental aspects related to wine packaging. As part of the environmental collaboration between the Nordic alcohol monopolies, a life cycle assessment (LCA) was conducted for wine packages during the year 2010.
- The main aim of this project was to conduct a light update of the 2010 wine packaging LCA regarding primary packaging materials
- Besides the LCA update the aim was also to provide insight about the trends in wine packaging industry and its environmental effects with a literature review.
- Results of this project support Alko and the other Nordic alcohol monopolies as a professional buyers and retailers who wish to minimize the environmental impacts of their actions.

1. Introduction

Structure of the report

- This report has three main sections:
  - The light LCA update
  - Scorecards and
  - Literature review.
- The light LCA update is described in Chapter 2 and more in detail in Appendices 1 ja 2. This section includes th description of the calculation methodology and updated results.
- Scorecards in Chapter 3 review the environmental impacts of the packaging options. The impacts are compared based on three selected indicators global warming potential, recyclability and littering. Global warming potential is based on the updated LCA. Also future possibilities and challenges for these packaging option are assessed.
- Literature review is presented in Chapter 4. In this section, emerging materials, certification, global challenges and recycling practices have been reviewed.

2. LCA update

2.1 Calculation methodology

Data:

- Update is based on the previous LCA assessment and related data that have been conducted during the year 2010[1]
  - Information from previous study have been used when available, estimations have been used for the missing information.

Calculation methodology:

- SimaPro LCA software was used for calculations (SimaPro Analyst ver. 8.5.0.0)
- Ecoinvent 3.4 data library was used
- Following environmental impact categories were assessed:
  - Global warming (kg CO2-eq.)*
  - Abiotic depletion (kg Sb-eq.)*
  - Cumulative energy demand (MJ)**
  - Water consumption (m3)***

[1] Bio Intelligence Service, 2010: Nordic life cycle assessment wine package study.

Calculated according CML IA (version 3.05) methodology (methodology developed by the Center of Environmental Science of Leiden Univeristy of The Netherlands. More information about the methodology: http://cml.leiden.edu/software/data-cmlia.html)

** Cumulative energy demand (version 1.10)

***Based on inventory data

2.2 Comparability of the results

- The purpose of the calculation was to give an insight on the changes during the past years and their contribution to the environmental impacts of the production

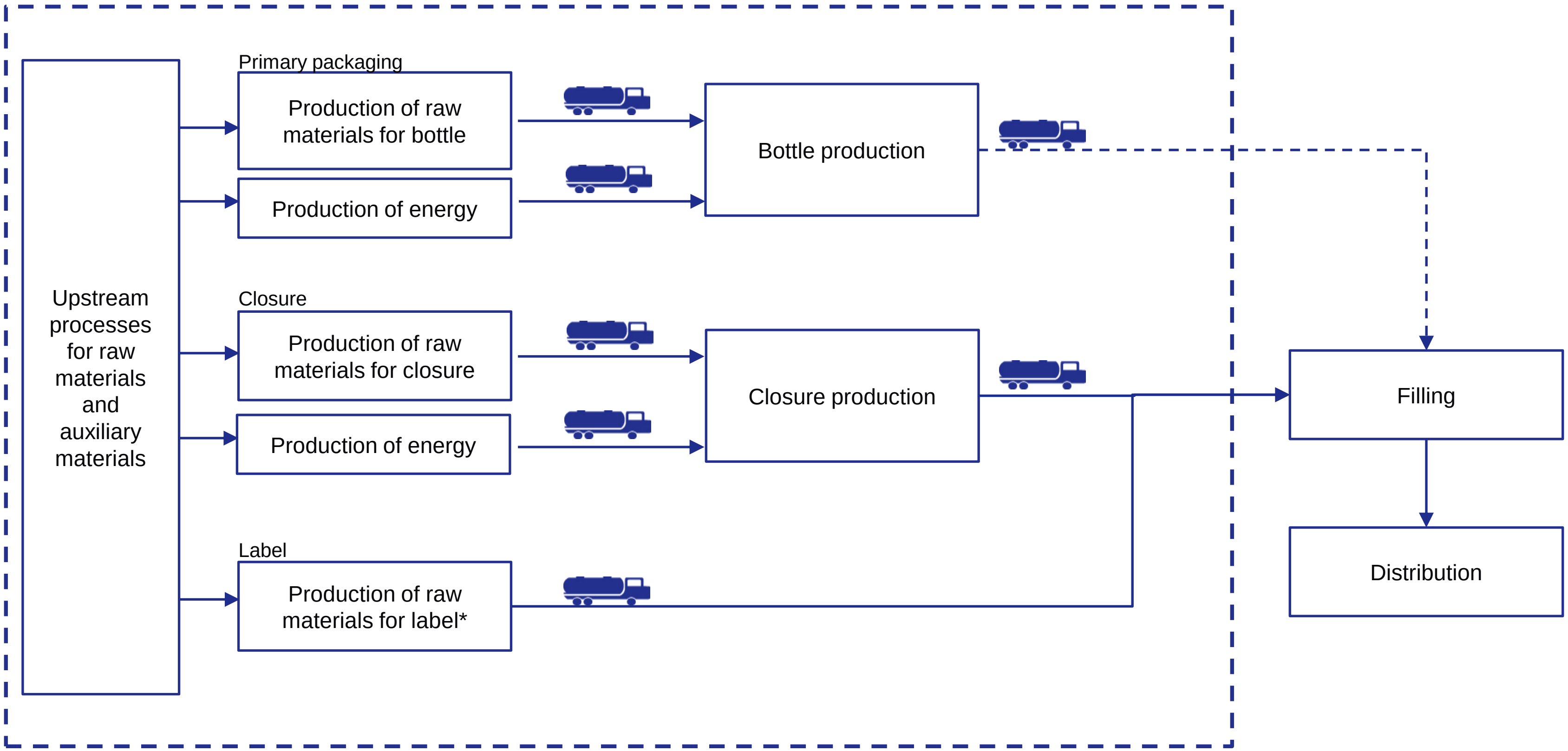
- Updates and changes in calculation methodologies and inventory data:
  - Changes in secondary databases
    - Methological changes have especially influenced the water inventory databases. Previous version of database (Ecoinvent 2.0) covered only water withdrawal (input water), not water consumption (input water – output water). This have been changed in newer (Ecoinvent 3.0) database inventories.
  - Changes in calculation methodologies of environmental impacts
    - Especially, the methodology regarding abiotic depletion have gone through significant changes. At the time the original study was conducted, abiotic depletion potential covered all the unrenewable materials (including fossil fuels), but updated methodology excludes the impacts caused by the fossil fuels.
  - Other updates cause minor changes to the calculations and methodology

- Contradictions and insufficient information of assumptions made in the original LCA, e.g. :
  - Glass: it is unclear how recycled content was taken account in original study
  - Production energy and water consumption information are not available from the original data
  - Assumptions are not necessarily in line with the original study

It should be noted, that due to methodological and database changes the results are not comparable with the original study conducted during the year 2010.

2.3 Scope of the work

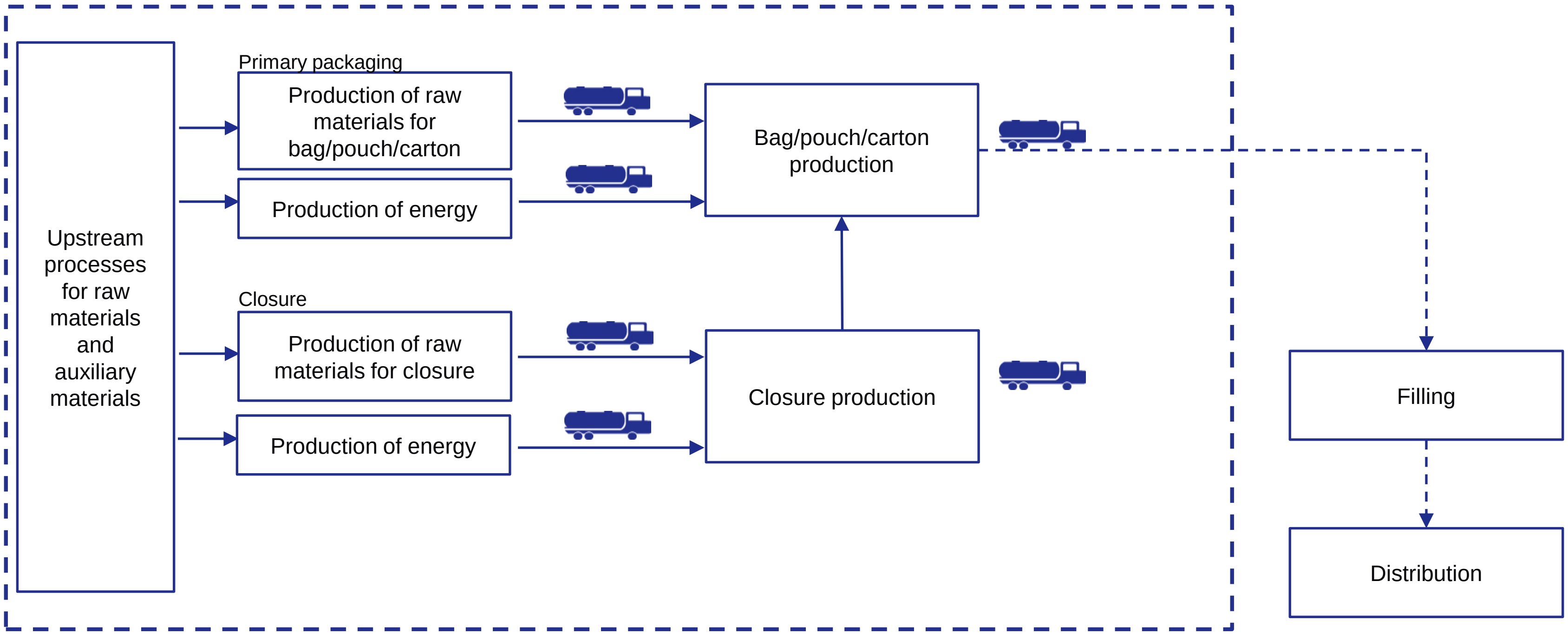
System boundary for PET and glass bottle*



*System boundary is based on definitions of primary packaging in the 2010 LCA. For PET and glass bottle the system boundary includes production and raw materials supply for primary packaging, closure and label. For primary packaging transportation to bottle production is included and for closure and label transportation to filling stage is included. Filling and distribution are not included.

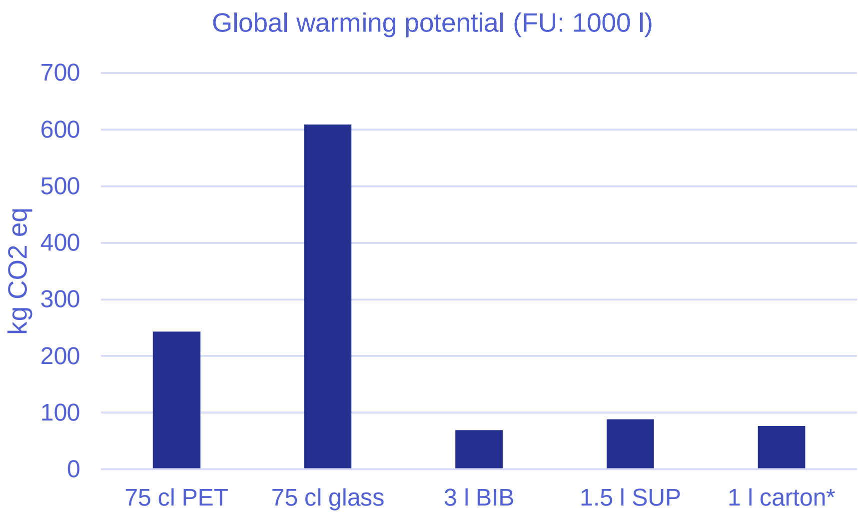
2.3 Scope of the work

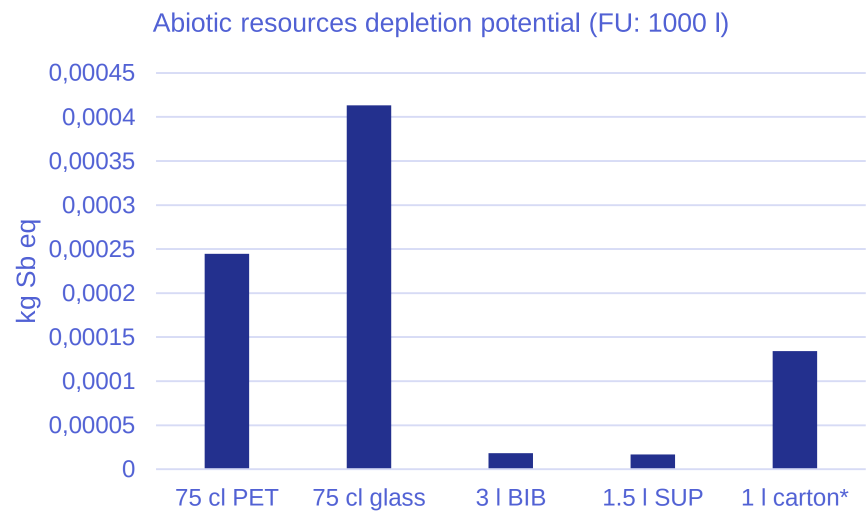
System boundary for BIB, SUP and beverage carton*

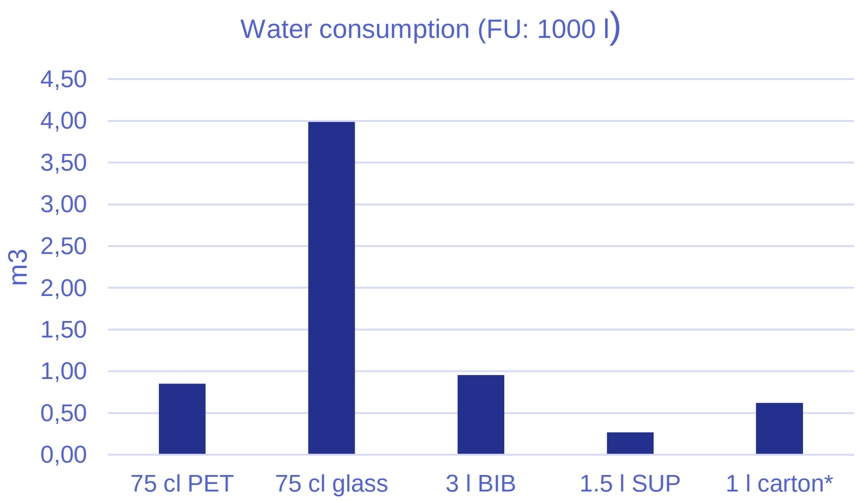


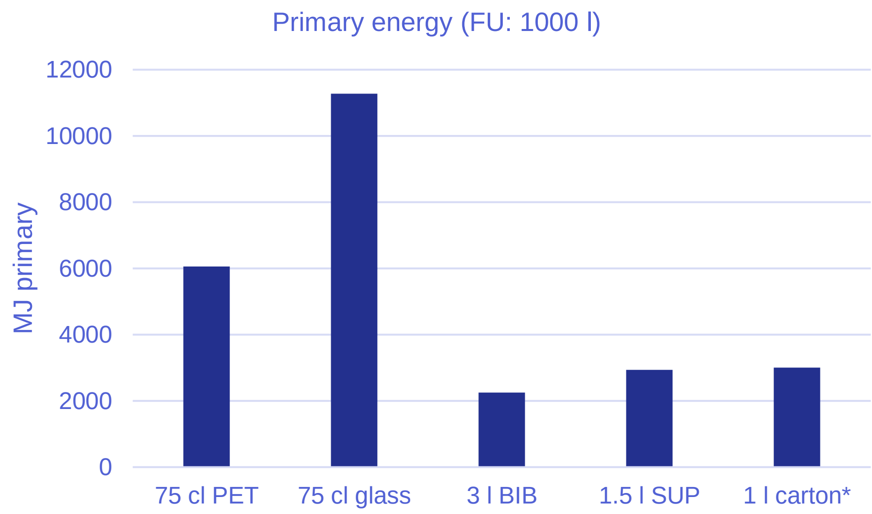
*System boundary is based on definitions of primary packaging in the 2010 LCA. For BIB, SUP and beverage carton the system boundary includes production and raw materials supply for primary packaging and closure. For primary packaging and closure transportation to bottle production is included. Transportation to filling and filling stage and distribution are not included.

2.4 LCA results



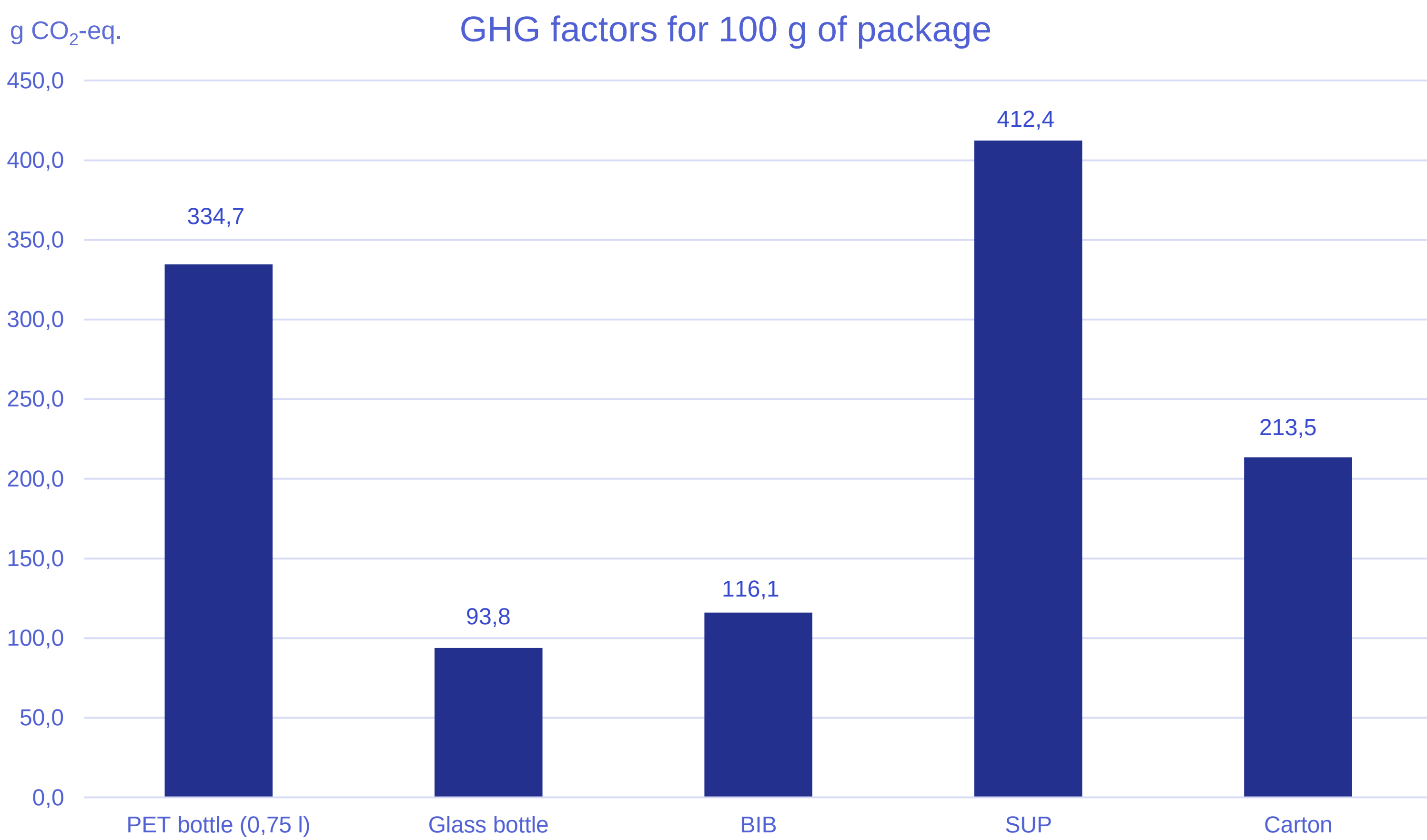






*Results from two suppliers data have been averaged.

2.5 GHG factors for different packaging types per 100 g of package*



*These results are based on the updated LCA results that have been modified to calculate the results per 100g of package. In addition, electricity factor used in this calculation is formed according to the weighted average of electricity generation emission factors according to the amount of wine imported from the main wine producing countries.

2.6 Key findings

- The production of raw materials has the major impact on the results
- Packaging forming and related energy consumption and transportation have minor impact on overall results
- In order to decrease environmental impacts of packages, the main improvement potential can be achieved by selecting lighter packaging options and by favoring recycled materials
- However, it should be remembered that e.g. water and energy consumption are very supplier specific and may vary a lot between different suppliers

3. Scorecards

3.1 Scorecard definitions

- 75 cl glass bottle’s, 75 cl PET bottle’s, 3 l BIB’s, 1,5 l SUP’s and 1 l beverage carton’s impacts are compared based on three selected indicators: global warming potential, recyclability and littering.
- Global warming potential
  - Comparison is based on the updated LCA results
- Recyclability
  - Assessed based on the typical Nordic recycling practices and recyclability of materials
- Littering
  - Assessed according to the potential environmental impacts if package do not end up to the existing recycling or waste management systems.
- Comparison is conducted between the packaging options included in the study
- Future possibilities and challenges were evaluated by expert analysis, based on weak signals and recent news of different experiments

Color code	Description
	Not relevant or not possible to define impact
	Impact is positive compared to other options
	No remarkable advantages or disadvantages compared to other options
	Impact is negative compared to other options

3.2 Scorecards 1/3

Packaging type	Impacts to selected indicators		Future possibilities	Future challenges
75 cl PET bottle	Global warming potential	• Energy intensive raw material production • Fossil non-renewable material	• Closed loop recycling of bioplastic bottles • RFID tags or other traceability of individual packages • Full recycling of PET bottles back to quality PET bottles by using enzymes	• Ban of plastic bottles in national, EU or global level • Consumer movement against fossil-based plastics • Sustainability requirements for biomass based materials (bioplastics)
	Recyclability	• Recycling is possible but only a small amount is closed-loop recycled back to bottles • Quality of the plastic is decreased during the recycling process and typically downcycled to other products.		
	Littering	• Outside the recycling or waste management system, package contributes to plastic pollution via plastic degradation		
75 cl glass bottle	Global warming potential	• Energy and material intensive production if only primary material is used • Heavy packaging causes more emissions from transportation per unit	• Revival of the glass packages compared to plastics • ”Toxic-free” packaging for organic wines etc	• Dead-end in the development of logistics of heavy glass bottles • Glass is heavy material and the weight of the glass bottle cannot be reduced endlessly
	Recyclability	• Recycling system is in place and recycling rate of glass bottles is high • No material degradation during the recycling process		
	Littering	• No degradation in nature		

3.2 Scorecards 2/3

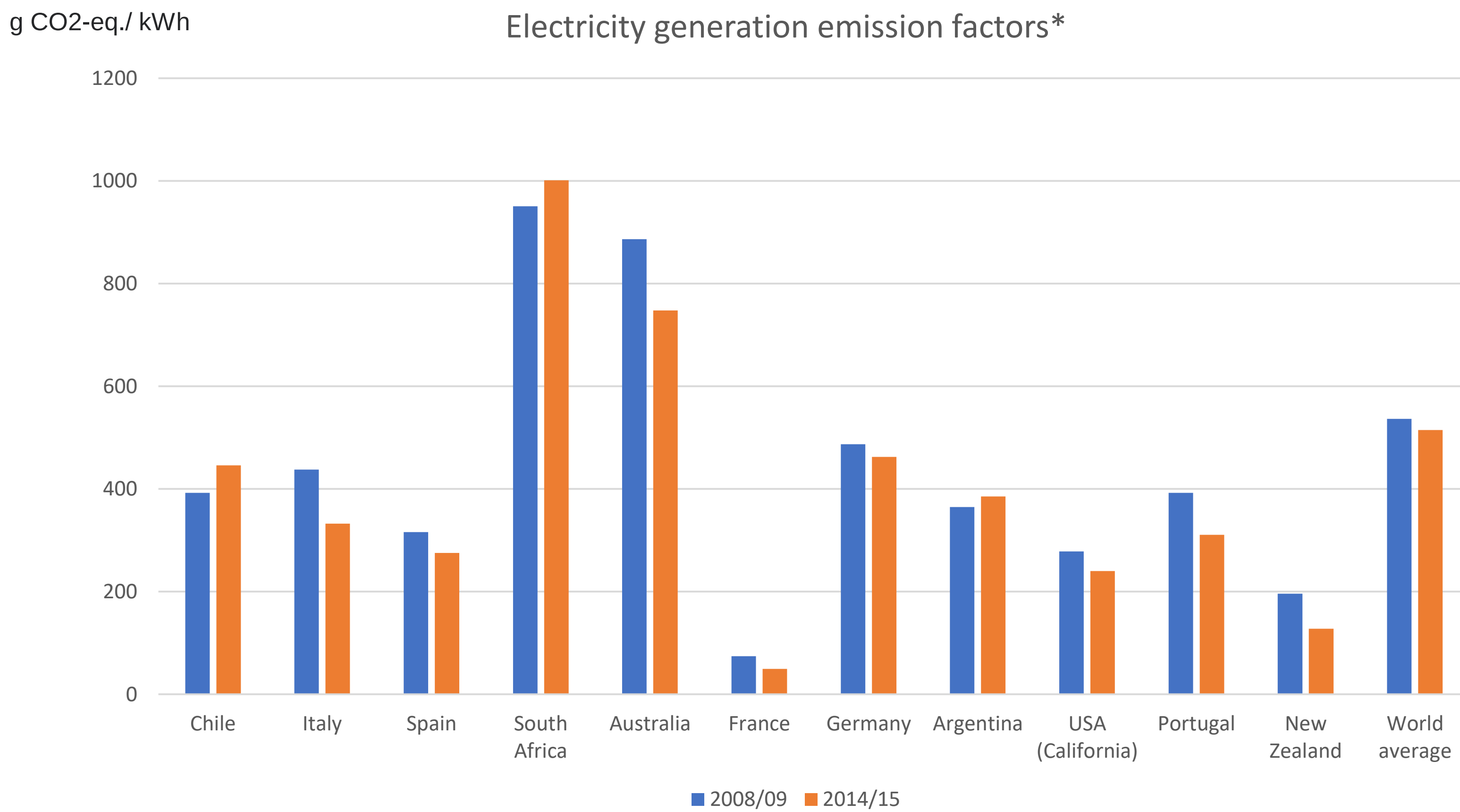
Packaging type	Impacts to selected indicators		Future possibilities	Future challenges
3 l Bag in box	Global warming potential	• Larger package has smaller impact per unit • Light packaging reduces emissions from transportation per unit	• Development of bags from multilayer bags to single layer bags, which could be recycled using current methods • Recycling of multilayer materials back to oil and metal • Upcycling of the bags as material for other products	• Sustainability requirements for biomass based materials (cardboard, bioplastics) • Development of new emerging recycling methods into large-scale methods
	Recyclability	• Cardboard is recyclable and recycling system exists • Multilayer plastic film and aluminium foil are not easily separated • Plastics are still often used for energy recovery instead of recycling		
	Littering	• Outside the recycling system, bag can contribute to plastic pollution via plastic degradation		
1,5 l Stand up Pouch	Global warming potential	• Light packaging reduces emissions from transportation per unit • Energy intensive raw material production • Fossil non-renewable material	• Development of bags from multilayer bags to single layer bags, which could be recycled using current methods • Recycling of multilayer materials back to oil and metal	• Development of new emerging recycling methods into large-scale methods
	Recyclability	• Multilayer plastic film and aluminium foil are not easily separated • No existing recycling system • Often material is used for energy recovery instead of recycling		
	Littering	• Outside the recycling or waste management system pouch can contribute to plastic pollution via plastic degradation		

3.2 Scorecards 3/3

Packaging type	Impacts to selected indicators		Future possibilities	Future challenges
1 l Beverage carton	Global warming potential	• Light packaging reduces emissions from transportation per unit	• Use of biodegradable plastics in cartons • Depending of plastic type recycle by enzyme or to oil and use again	• Sustainability requirements for biomass based materials (cardboard)
	Recyclability	• Carton, aluminium and plastic can be separated in the recycling process. • Carton is recycled as material • Aluminium and plastic can be separated from carton and are recyclable • Often plastics are used for energy recovery instead of recycling		
	Littering	• Outside the recycling system plastic in beverage can contribute to plastic pollution via plastic degradation • Amount of plastic is smaller than in other packaging options containing plastic		

4. Literature review

4.1 Changes in electricity production GHG emission levels



Data sources: International Energy Association, World energy Energy Balances, (2017 ed.), IEA, Paris.

For USA California, the following information source is used: Emissions & Generation Resource Integrated Database (eGRID). eGRID databases can be downloaded here: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

*Average emission factor for two years is used. It should be noted that that in the newest IEA edition, the newest complete datasets are for the year 2015

4.2 Emerging materials and packaging types in the wine industry

gaia

Environmental impacts of new solutions (1/2)

Solution	Environmental advantages	Environmental disadvantages	Examples
PLA	• Reduced use of fossil materials • Reduced emitted green house gases • Compostable in right conditions (large-scale industrial composting)	• No existing recycling system • Biodegradable only in industrial composting conditions, not degradable in water • Consumers attitude towards plastics are changing rapidly (including bioplastics) • Bioplastics are not solution for the marine or microplastic pollution • Biomass production sustainability	• PLA wine bottle, Bodega Matarromera and Aimplas • Bioplastic closure, Tetrapak
PEF	• 100 % Biobased alternative to PET • Reduced use of fossil materials • Reduced emitted green house gases • Should not interfere in the PET recycling system	• No existing recycling system (yet) • Biodegradable only in industrial composting conditions, not degradable in water • Consumers attitude towards plastics are changing rapidly (including bioplastics) • Bioplastics are not solution for the marine or microplastic pollution • Biomass production sustainability	• Avantium
Bioplastic bottle made from juice processing wastewater	• Sustainability of biomass is not a problem as waste have been used as raw materials. • Reduced energy use and GHG emissions • Compostable in composting plants	• No existing recycling system • Not a solution for marine or microplastic pollution	• PHB Bottle

[1]Bodega Matarormera and Aimplas (https://www.aimplas.net/blog/packaging-innovation-first-pla-wine-bottle)

[2] Avantium (https://www.avantium.com/yxy/products-applications/)

[3] PHB Bottle (www.phbottle.eu/)

4.2 Emerging materials and packaging types in the wine industry

Environmental impacts of new solutions (2/2)

Solution*	Environmental advantages	Environmental disadvantages	Examples
Flax fibre composite bottle	• Lower carbon footprint • 91 % of the bottle is bio-based • Partly biodegradable	• Includes plastic film (inner lining), which may complicate recycling/ re-usability • Biomass production sustainability	• Green Gen (bottle should be available in 2018)
Single-serve wine in paper-plastic-aluminium pouch	• Made from 75 % paper, 20 % PE, 5 % aluminium => Mostly renewable material • Light packaging reduces emissions from transportation per unit	• Recyclability of multilayer packaging is generally low	• Oneglass
Aluminium can for wine	• Recyclable • Light package	• Primary aluminium production energy intensive	• Underwood can
Example of not successful packaging material (loss of profit as wine was spoiled prematurely):			
Paper pulp bottle with plastic lining (molded pulp, vacuum-formed plastics)	• Mostly bio-based renewable material • Light packaging reduces emissions from transportation per unit	• Includes plastic film (inner lining), which may complicate recycling/ usability	• Paperboy/ Green bottle

[1]Paperboy (https://www.packworld.com/article/sustainability/renewable-resources/paperboy-paper-wine-bottle-us-first)

[2]Oneglass (http://www.oneglass.com/italia/Products#sect-organicWines)

[3]Underwood can (https://unionwinecompany.com/our-wines/underwood/can/)

4.2 Emerging materials and packaging types in the wine industry

Future challenges and possibilities

- Future possibilities related to emerging materials:
  - Most emerging materials are bio-based and reduce the use of fossil materials and generally also the use of non-renewable energy.
  - Food industry sidestreams can be used to produce bioplastic
  - Good barrier properties
  - In sustainable co-production of biofuels, bioplastics and food, biofuels and –plastics can even serve as a stabilizer for food prices by providing farmers more secure markets
- Future challenges related to emerging materials:
  - Ensuring that wine is preserved long enough in packaging made from emerging materials
  - Negative impacts on global warming through direct of indirect land-use change
  - To eutrophication and acidification bioplastics usually have a higher impact than fossil plastics
  - Development of a recycling system for bioplastics
  - Clarification of the terms ”biodegradable” and ”compostable” to the consumer, as well as the fact that home composting rarely equals industrial composting conditions
- New packaging types:
  - Different single-serve packages are being developed for wines including glass, plastic with barrier technologies and small stand-up-pouch mainly from paper but with plastic and aluminium lining.
  - Future possibility related to small single-serve packages is mainly decreasing the possible waste of wine that can happen when buying bigger packages.
  - As a trend single-serve packaging tends to encourage conspicuous consumption and throw away culture

4.3 Certified raw materials' impact on selected indicators

Certificate	Relevance	Intended environmental impact	Impacts to global warming potential, recyclability and littering
Forest Stewardship Council[1]: • FCS 100%: The wood within the product comes completely from FSC-certified forests. • FSC Recycled label: All the wood or paper in the product comes from reclaimed (re-used) material. • FSC Mix: The wood within the product is from FSC-certified material, recycled material, or controlled wood.	• Bag in Box • Beverage carton	• Minimized degradation of natural forests, no conversion of forests to other land use in certified areas	• FSC Recycled label is best regarding global warming potential as it can reduce use of primary materials • The other FSC labels are also good for ensuring that no forests are converted to other land use which would cause loss of carbon sinks

ISCC PLUS[2]:
• International Sustainability and Carbon Certification: certification system covering the entire supply chain and all kinds of bio based feedstocks and renewables.
• Traceable and deforestation free supply chain
• GHG monitoring as voluntary add-on
	• Beverage carton
	• Bioplastics
		• To ensure sustainable production of biomass and biomass base products:
		  • Biomass shall not be produced on land with high biodiversity value or high carbon stock
		  • Biomass shall be produced in an environmentally responsible way
			• Positive impact on global warming potential when biomass is produced sustainably and no forests are converted to cropland

Compostability label "The Seedling" [3]: • Proves that a product is certified industrially compostable according to the European standard EN 13432	• Bioplastics	• Enabling and facilitating the proper sorting in waste collection and recovery	• Enabling composting • Reducing littering by enabling composting • Reducing use of fossil-based plastic

[1] FSC Labels (https://ic.fsc.org/en/choosing-fsc/fsc-labels)
[2] ISCC PLUS (https://www.iscc-system.org/process/certification-scopes/iscc-for-feed/iscc-for-bio-based-products/)
[3] European bioplastics (https://www.european-bioplastics.org/bioplastics/standards/labels/)

4.4 Changes since 2010 in global challenges (1/2)

Global challenge	Description	Influence on packaging industry
Plastic pollution	Significance and awareness towards plastic pollution have increased rapidly during past years. Especially ocean plastic pollution have been recognized and it is estimated that by 2050, oceans will contain more plastics than fish by weight.	• If plastics ends up outside the recycling or waste management system, they will contribute to plastic pollution • Consumers awareness towards plastics have been changed rapidly during the past years. • Bioplastics are recognized as a replacement for the fossil-based plastics; thus part of the bioplastics are degradable, they are not degradable in nature or oceans and therefore bioplastics are not solution for the plastic pollution
Climate change	Climate change have been and still is the main global challenge, which threats humanity in many different ways.	• Political pressure towards climate change mitigation action will have an impact on all industry sectors, including packaging industry. • Possibility to differentiate on market by offering low-carbon solution for consumers. • Actions to mitigate climate change accelerates development of new climate friendly materials as well as lighter packaging options.
Clean water	Availability of clean water is ranked on the second place of the Global Challenges for Humanity.	• Water scarcity and clean water availability will be on high political agenda in future in all industry sectors, including packaging industry. • Consumption of water is especially important for the bio-based materials, especially if these materials are plant-based origin requiring irrigation.

Sources: The millenium project (http ://107.22.164.43/millennium/challenges.html), The World Economic Forum,The Global Risk Report 2018, 13th edition, Plastic Pollution Coalition (http://www.plasticpollutioncoalition.org)

4.4 Changes since 2010 in global challenges (2/2)

Global challenge	Description	Influence on packaging industry
Food security , land use change and deforestation	Food security, indirect and direct land use change as well as deforestation are all global challenges with interlinked connections. Cultivation land is limited resource and farmland use for the non-food purposes is debated as it threats the global food security. In addition, when agricultural land is used for the biomass production it lead to indirect land use changes and deforestation since the more land need to be cleared for agricultural use.	• Bioplastic is one of the most rapidly increasing material in packaging industry. • Use of bioplastics may accelerate direct and indirect land use change as well as deforestation, but this depends largely on the used raw material (e.g use of corn vs. biowaste as raw materials) • Globally biomass industrial utilization is rapidly increasing and tension between land use for food production and biomass cultivation for industrial use is expected to increase.

Sources: The Millennium Project (http ://107.22.164.43/millennium/challenges.html)

OECD, 2018, Meeting policy challenges for a sustainable bioeconomy, OECD Publishing, Paris (http://dx.doi.org/10.1787/9789264292345-en)

4.5 Recycling practices

Major changes in recycling practices

Material	Current recycling practices	Future prospects
Glass	Glass bottles collection rate has been high and the collection system works well.	Glass bottle is fully recyclable and can be recycled endlessly. However, much depends on the collection system, in some countries great amount of glass is still landfilled. However, for example in USA (North Carolina), the value of recycled glass has decreased almost 50 % since 2011 because decreased demand for recycled cullets. Market dynamics has major influence on recycling business as well.
PET	In Europe, the PET bottles collection rate was almost 60 % and has been increased steadily during the past years. However, approximately only 11 % of PET bottles are used for production of new PET bottles and the rest of the materials are downcycled for other uses (textile fibers and sheets).	Still only small share of collected PET is recycled back to bottles. Without any economic incentive or technology development, the growth of close-loop recycling is probably going to be slow. Example of upcycling: In South Africa, schools and residentials homes have been made of recycled PET bottles.
Plastics	Recycling systems for other plastic, such as LPDE, HPDE and PE are not as efficient as for PET bottles. It is estimated that globally only • 14 % of plastics are recycled • Only 2 % is close-looped recycled. • 32 % of plastics end up to ecosystem • 40 % of collected plastics are landfilled • 14 % incinerated	Plastic recycling technologies as well as practices have been developed and collection practices improved. In Europe, in 2016 more plastics were recycled than landfilled on the first time. Increased awareness towards plastic pollution will probably accelerate new recycling innovations and development of new materials. One example about the possible future technologies are “plastic-to-oil” –technology, which enable to production of oil from the plastic waste.

Sources: Information sources used are listed in Appendix 3, p.46

5. Conclusions

- The aim of the project was to
  - conduct a light update of the 2010 wine packaging LCA regarding primary packaging materials; environmental impact categories assessed were global warming, abiotic depletion, cumulative energy demand and water consumption.
  - provide insight about the trends in wine packaging industry; also environmental factors outside LCA, like recyclability and littering, were compared in literature review
- **Main conclusions:**
  - Production of raw materials for packaging has the major impact on the results, closure, label, packaging forming and related energy consumption and transportation have only a minor impact on overall results
  - In order to decrease environmental impacts of packages, the main improvement potential can be achieved by selecting lighter packaging options and by favoring recycled materials
  - Based on the LCA results, glass bottle has more environmental impacts than other options. But when considering other factors e.g. recyclability and littering, glass bottle might perform better than a PET bottle within current, incomplete recycling systems globally. However, in the Nordic countries PET bottle recycling typically performs better than glass bottle recycling.
  - New packaging materials, like some bioplastics, do not necessarily have an existing circular economy ecosystem. On the other hand, growing markets of the new packages will catalyze the recycling innovations. Unbiodegradable but bio-based PE and PET can be recycled the same way as fossil-based PET but also have the same problems of littering via microplastics.
  - Markets are affected by the changes of regulative environment (e.g. material bans, waste taxation, quality requirements of raw materials, producers responsibility) as well as consumer trends and expectations.
  - Information is needed of both the LCA and other environmental factors of different packages for retail, shops and consumers
- Things to be noted, when using results:
  - Due to methodological and database changes, the results of the LCA are not comparable with the original study conducted during the year 2010.
  - Part of the results are based on water and energy consumption that are very supplier specific and may vary a lot between different suppliers

6. Disclaimers

- The report shall be provided based on the facts and instructions in the specific assignment considering the circumstances at the time of the assignment in accordance with the respective scope of work. We assume that all the information provided to us is accurate and complete and that you have verified the correctness of the disclosed information.
- We assume no responsibility and make no representations with respect to the accuracy or completeness of the information in this report unless otherwise stated. The report should not be regarded, or be relied upon, as a recommendation in decision making concerning any matter referred to in it.
- It should be understood that we do not assert that we have identified all matters included in these documents that may be relevant if these

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Appendix 1: Results of the LCA update

75 cl PET bottle produced in France (FU: 1000 l)		2018			
Impact category	Unit	Total	Bottle production	Closure production	Label production
Abiotic resources depletion potential	kg Sb eq	0.00024	0.00024	0.000003	0.000002
Water consumption	m3	0.85	0.66	0.05	0.14
Primary energy	MJ primary	6061	5235	706	120
Global warming potential	kg CO2 eq	243	219	21	2.7

75 cl glass bottle produced in France (FU: 1000 l)		2018			
Impact category	Unit	Total	Bottle production	Closure production	Label production
Abiotic resources depletion potential	kg Sb eq	0.00041	0.00023	0.000181	0.000005
Water consumption	m3	3.99	2.81	1.01	0.17
Primary energy	MJ primary	11280	9746	1393	141
Global warming potential	kg CO2 eq	609	520	86	3.6

3 l Bag in Box produced in France (FU: 1000 l)		2018			
Impact category	Unit	Total	Bag production	Closure production	Cardboard production
Abiotic resources depletion potential	kg Sb eq	0.00002	0.00000	0.000001	0.000012
Water consumption	m3	0.95	0.07	0.05	0.83
Primary energy	MJ primary	2256	748	556	952
Global warming potential	kg CO2 eq	69	21	17	31

1.5 l Stand up Pouch produced in France (FU: 1000 l)		2018		
Impact category	Unit	Total	Poach production	Closure production
Abiotic resources depletion potential	kg Sb eq	0.00002	0.00001	0.000003
Water consumption	m3	0.27	0.17	0.10
Primary energy	MJ primary	2938	1827	1111
Global warming potential	kg CO2 eq	88	54	34

1 l Beverage carton produced in Netherlands/Germany (FU: 1000 l)				
Impact category	Unit	Total	Beverage carton production	Closure production
Abiotic resources depletion potential	kg Sb eq	0.0	0.0	0.0
Water consumption	m3	0.6	0.6	0.0
Primary energy	MJ primary	3011.2	2591.6	419.6
Global warming potential	kg CO2 eq	76.4	64.0	12.4

Appendix 2: Calculation assumptions*

PET bottle

PET bottle (75 cl, total weight: 54,4 g)			
Raw materials	Weight [g]	Emission factor used	Calculation assumptions and other comments
PET	-**	For virgin PET: Polyethylene terephthalate, granulate, bottle grade {RER}| production | Cut-off, U For recycled PET: Polyethylene terephthalate, amorphous, recycled, {Europe without Switcherland}| production | Cut-off, U	Assumed recycled content of 10 %
Nylon	-**	Nylon 6 {RER}| production | Cut-off, U	Recycled content 0 %
Injected moulded LDPE	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U + Injection moulding {RER}| processing | Cut-off, U	Recycled content 0 % Yield for injection moulding 0,994
Paper (label)	-**	Paper, woodfree, coated {RER}| paper production, woodfree, coated, at non-integrated mill | Cut-off, U Paper, woodcontaining, lightweight coated {RER}| production, woodfree, | Cut-off, U	Recycled content 50 %
Electricity used for fabrication	-**	Electricity, low voltage {FR}| market for | Cut-off, U	
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
PET	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Nylon	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Injected moulded LDPE	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Paper (label)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study

*Calculation is based on the information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.

**Based on the supplier specific data based on the 2010 ”Nordic life cycle assessment wine package study”. The information is not enclosed to this study, but can be derived from the original study.

Appendix 2: Calculation assumptions*

Glass Bottle

Glass bottle (75 cl, total weight 479,5 g)			
Raw materials:	Weight [g]	Emission factor used	Calculation assumptions and other comments
Glass	472	Packaging glass, green {RER w/o CH + DE}| production | Cut-off, U	Recycled content 83 %, formation included into the emission factor
Aluminium sheet (closure)	5,5	Aluminium primary, ingot {IAI area, EU27 & EFTA}|production |Cut-off, U + Metal working, average for aluminium product manufacturing {RER} | processing | Cut-off, U	Recycled content 0%
Paper (label)	2	Paper, woodfree, coated {RER}| paper production, woodfree, coated, at non-integrated mill | Cut-off, U Paper, woodcontaining, lightweight coated {RER}| production, woodfree, | Cut-off, U	Recycled content 50 %
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
Glass	0,118	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Aluminium sheet (closure)	0,001375	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Paper (label)	1	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.

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Appendix 2: Calculation assumptions*

Bag in Box 1/3

Bag in Box (3 l, total weight 179 g)			
Raw materials:	Weight [g]	Emission factor used	Calculation assumptions and other comments
Cardboard	-**	Linerboard {RER}| treatment of recovered paper to, testliner | Cut-off, U Linerboard {RER}| production, craftliner| Cut-off, U	Recycling content 70 %
Extruded PET	-**	Polyethylene terephthalate, granulate, bottle grade {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Recycled content 0 % Yield for extrusion 0,976
Aluminium foil	-**	Aluminium primary, ingot {IAI area, EU27 & EFTA}|production |Cut-off, U + Metal working, average for aluminium product manufacturing {RER} | processing | Cut-off, U	Recycled content 0%
Extruded LDPE	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Recycled content 0 % Yield for extrusion 0,976
Formation of package		Thermoforming of plastic sheets,{FR}| processing | Cut-off, U	Ecoinvent process is used as an estimate for the required production utilities, such as water and electricity as no primary data was available for calculation.
EVOH	-**	Ethylene vinyl acetate copolymer {RER}| production | Cut-off, U	
Polypropylene (closure)	-**	Polypropylene, granulate {RER}|production | Cut-off, U + Injection moulding {RER}| processing | Cut-off, U	Injection moulding assumed for fabrication of closure. Yield added for each closure material (0,994).
HDPE (closure)	-**	Polyethylene, high density, granulate {RER}| production | Cut-off, U	Yield for injection moulding 0,994

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.

**Based on the supplier specific data based on the 2010 ”Nordic life cycle assessment wine package study”. The information is not enclosed to this study, but can be derived from the original study.

Appendix 2: Calculation assumptions*

Bag in Box 2/3

Bag in Box (3 l, total weight 179 g)			
Raw materials:	Weight [g]	Emission factor used	Calculation assumptions and other comments
Elastomer (PET) (closure)	-**	Polyethylene terephthalate, granulate, bottle grade {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Yield for injection moulding 0,994
LDPE (closure)	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U	Yield for injection moulding 0,994
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
Cardboard	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	
Extruded PET	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	
Aluminium foil	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	
Extruded LDPE	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	

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**Based on the supplier specific data based on the 2010 ”Nordic life cycle assessment wine package study”. The information is not enclosed to this study, but can be derived from the original study.

Appendix 2: Calculation assumptions*

Bag in Box 3/3

Bag in Box (3 l, total weight 179 g)			
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
EVOH	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Polypropylene (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
HDPE (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Elastomer (PET) (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
LDPE (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.

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Appendix 2: Calculation assumptions*

Stand up Pouch 1/3

Stand up Pouch (1,5 l, total weight 34,8 g)			
Raw materials:	Weight [g]	Emission factor used	Calculation assumptions and other comments
Extruded PET	-**	Polyethylene terephthalate, granulate, bottle grade {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Recycled content 0 % Yield for extrusion 0,976
Aluminium foil	-**	Aluminium primary, ingot {IAI area, EU27 & EFTA}|production |Cut-off, U + Metal working, average for aluminium product manufacturing {RER} | processing | Cut-off, U	Recycled content 0%
Extruded LDPE	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Recycled content 0 % Yield for extrusion 0,976
Extruded LLDPE	-**	Polyethylene, linear low density, granulate {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Recycled content 0 % Yield for extrusion 0,976
Formation of package		Thermoforming of plastic sheets,{FR}| processing | Cut-off, U	Ecoinvent process is used as an estimate for the required production utilities, such as water and electricity as no primary data was available for calculation.
Polypropylene (closure)	-**	Polypropylene, granulate {RER}|production | Cut-off, U + Injection moulding {RER}| processing | Cut-off, U	Injection moulding assumed for fabrication of closure. Yield added for each closure material (0,994).
HDPE (closure)	-**	Polyethylene, high density, granulate {RER}| production | Cut-off, U	Yield for injection moulding 0,994

*Calculation is based on the information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.
**Based on the supplier specific data based on the 2010 "Nordic life cycle assessment wine package study". The information is not enclosed to this study, but can be derived from the original study.

Appendix 2: Calculation assumptions*

Stand up Pouch 2/3

Stand up Pouch (1,5 l, total weight 34,8 g)			
Raw materials:	Weight [g]	Emission factor used	Calculation assumptions and other comments
Elastomer (PET) (closure)	-**	Polyethylene terephthalate, granulate, bottle grade {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Yield for injection moulding 0,994
LDPE (closure)	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U	Yield for injection moulding 0,994
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
Extruded PET	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Aluminium foil	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Extruded LDPE	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Extruded LLDPE	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.

**Based on the supplier specific data based on the 2010 ”Nordic life cycle assessment wine package study”. The information is not enclosed to this study, but can be derived from the original study.

Appendix 2: Calculation assumptions*

Stand up Pouch 3/3

Stand up Pouch (1,5 l, total weight 34,8 g)			
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
Polypropylene (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
HDPE (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Elastomer (PET) (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
LDPE (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.
**Based on the supplier specific data based on the 2010 ”Nordic life cycle assessment wine package study”. The information is not enclosed to this study, but can be derived from the original study.

Appendix 2: Calculation assumptions*

Beverage carton Elopak 1/2

Beverage carton Elopak (1 l, total weight 36,6 g)			
Raw materials:	Weight [g]	Emission factor used	Calculation assumptions and other comments
Liquid carton board	-**	Liquid packaging board {GLO}| production | Cut-off, U	Average production process of the main European LPB producers, recycling rate not known
Extruded LDPE	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Recycled content 0 % Yield for extrusion 0,976
Aluminium foil	-**	Aluminium primary, ingot {IAI area, EU27 & EFTA}|production |Cut-off, U + Metal working, average for aluminium product manufacturing {RER} | processing | Cut-off, U	Recycled content 0%
Injected moulded HDPE (closure)	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U + Injection moulding {RER}| processing | Cut-off, U	Yield for injection moulding 0,994
Electricity used for fabrication	0,00632 kWh	Electricity, low voltage {NL}| market for | Cut-off, U	Elopaks's environmental report is used for the estimation of electricity consumption**** as information was not available from the original study.

*Calculation is based on the information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.
**Based on the supplier specific data based on the 2010 "Nordic life cycle assessment wine package study". The information is not enclosed to this study, but can be derived from the original study.
***Source: http://www.elopak.com/resources/publications/EnvironmentalReport_2016_LR.pdf ---A

Appendix 2: Calculation assumptions*

Beverage carton Elopak 2/2

Beverage carton Elopak (1 l, total weight 36,6 g)			
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
Liquid carton board	-**	Transport, freight, sea, transoceanic ship {GLO}| processing| Cut-off, U	Same distances used as in the original study
Extruded LDPE	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Aluminium foil	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Injected moulded HDPE (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.

**Based on the supplier specific data based on the 2010 ”Nordic life cycle assessment wine package study”. The information is not enclosed to this study, but can be derived from the original study.

Appendix 2: Calculation assumptions*

Beverage carton Tetrapak 1/3

Beverage carton Tetrapak (1l, total weight: 39,6 g)			
Raw materials:	Weight [g]	Emission factor used	Calculation assumptions and other comments
Liquid carton board	-**	Liquid packaging board {GLO}| production | Cut-off, U	Average production process of the main European LPB producers, recycling rate not known
Extruded LDPE	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Recycled content 0 % Yield for extrusion 0,976
Extruded LLDPE	-**	Polyethylene, linear low density, granulate {RER}| production | Cut-off, U + Extrusion, plastic film {RER}| production | Cut-off, U	Recycled content 0 % Yield for extrusion 0,976
Acrylic acid			Not taken into account due to lack of information. Amount assumed to be insignificant
Extruded EVA	-**	Ethylene vinyl acetate copolymer {RER}| production | Cut-off, U	
Aluminium foil	-**	Aluminium primary, ingot {IAI area, EU27 & EFTA}|production |Cut-off, U + Metal working, average for aluminium product manufacturing {RER} | processing | Cut-off, U	Recycled content 0%
Electricity used for fabrication	0,00632 kWh	Electricity, low voltage {NL}| market for | Cut-off, U	Elopaks's environmental report is used for the estimation of electricity consumption**** as information was not available from the original study.

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.

**Based on the supplier specific data based on the 2010 "Nordic life cycle assessment wine package study". The information is not enclosed to this study, but can be derived from the original study.

***Source: http://www.elopak.com/resources/publications/EnvironmentalReport_2016_LR.pdf ---A

Appendix 2: Calculation assumptions*

Beverage carton Tetrapak 2/3

Beverage carton Tetrapak (1l, total weight: 39,6 g)			
Raw materials:	Weight [g]	Emission factor used	Calculation assumptions and other comments
Injected moulded HDPE (closure)	-**	Polyethylene, low density, granulate {RER}| production | Cut-off, U + Injection moulding {RER}| processing | Cut-off, U	Yield for injection moulding 0,994
Injected moulded PP (closure)	-**	Polypropylene, granulate {RER}|production | Cut-off, U + Injection moulding {RER}| processing | Cut-off, U	Yield for injection moulding 0,994
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
Liquid carton board	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Extruded LDPE	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Extruded LLDPE	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.
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Appendix 2: Calculation assumptions*

Beverage carton Tetrapak 3/3

Beverage carton Tetrapak (1l, total weight: 39,6 g)			
Transportation:	Ton-km	Emission factor used	Calculation assumptions and other comments
Extruded EVA	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Aluminium foil	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Injected moulded HDPE (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study
Injected moulded PP (closure)	-**	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Same distances used as in the original study

*Calculation is based on information derived from the original LCA-study conducted in 2010. No primary data is collected during this update. In cases original data was not available, assumption have been made.

**Based on the supplier specific data based on the 2010 ”Nordic life cycle assessment wine package study”. The information is not enclosed to this study, but can be derived from the original study.

Appendix 3: Sources (1/2)

gaia

Bio Intelligence Service, 2010: Nordic life cycle assessment wine package study.

Emerging materials:

- Bodega Matarrmera and Aimplas (https://www.aimplas.net/blog/packaging-innovation-first-pla-wine-bottle)
- Avantium (https://www.avantium.com/yxy/products-applications/)
- PHB Bottle (www.phbottle.eu/)
- Paperboy (https://www.packworld.com/article/sustainability/renewable-resources/paperboy-paper-wine-bottle-us-first)
- Oneglass (http://www.oneglass.com/italia/Products#sect-organicWines
- Underwood can (https://unionwinecompany.com/our-wines/underwood/can/)

Certificates:

- FSC Labels (https://ic.fsc.org/en/choosing-fsc/fsc-labels)
- ISCC PLUS (https://www.iscc-system.org/process/certification-scopes/iscc-for-feed/iscc-for-bio-based-products/)
- European bioplastics (https://www.european-bioplastics.org/bioplastics/standards/labels/)

Global challenges:

- The Millenium Project (http ://107.22.164.43/millennium/challenges.html),
- The World Economic Forum, 2018, The Global Risk Report 2018, 13th edition, Plastic Pollution Coalition (http://www.plasticpollutioncoalition.org)
- OECD, 2018, Meeting policy challenges for a sustainable bioeconomy, OECD Publishing, Paris (http://dx.doi.org/10.1787/9789264292345-en)

Appendix 3: Sources (2/2)

Recycling:

- FEVE – The European Container Glass Federation website. Available at: http://feve.org/
- GPI - Glass packaging institute website, available at: www.gpi.org/about-gpi
- Bloomberg news, ”Turning plastics to Oil, U.K. Startup Sees money in Saving Oceans”. 5.5.2017, available: https://www.bloomberg.com/news/articles/2017-05-05/turning-plastic-to-oil-u-k-startup-sees-money-in-saving-oceans
- News24, ”Class act: Turning plastic bottles into the building blocks of education” 28.12.2016, available: https://www.news24.com/SouthAfrica/News/class-act-turning-plastic-bottles-into-the-building-blocks-of-education-20161228
- Plastic Europe website: https://www.plasticseurope.org/en
- Plastics – the Facts 2017. An analysis of European plastics production, demand and waste data. Available: https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf
- PET Core – Press release 18.12.2017. PET Collection rate and recycling rates in Europe significantly increased in 2016. Available: https://petcore-europe.prezly.com/pet-collection-and-recycling-rates-in-europe-significantly-increased-in-2016
- Plaxx Recycling Technologies website, available: https://recyclingtechnologies.co.uk/solutions/plaxx/
- USA Today, news 20.4.2017 ”Recycling in trouble – and it might be your fault”, available: https://www.usatoday.com/story/news/politics/2017/04/20/weak-markets-make-consumers-wishful-recycling-big-problem/100654976/
- World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, The New Plastics Economy — Rethinking the future of plastics (2016, http://www.ellenmacarthurfoundation.org/publications).