Ergo Energies and Resources for Sustainability Governance

Product Environmental Footprint Report

Life Cycle Assessment (LCA) of the environmental footprint (PEF) of Tuborg ® beer distributed in Denmark in different stock keeping units

Carlsberg Group

Products:

Carlsberg Tuborg – Steel keg 25 liter (returnable)		
Carlsberg Tuborg – DraughtMaster Modular 20 PET keg 20 l		
Carlsberg Tuborg – 0,33 l green glass bottle (returnable and one way)		
Carlsberg Tuborg – 0,33 l one-way aluminium can		

Product classification:	C11.0.5 - Manufacture of beer
Company:	Carlsberg A/S, Vesterfælledvej, Copenhagen, Denmark
Date of publication:	28 January 2020
Version:	2.1
Geographic validity:	Denmark
Reference PEFCR:	PEFCR for beer – Final version (June 2018)
Compliance with the PEF method	Ref. section 4.1
Conformance to other documents	Ref. section 4.1
Additional to the PEF method	Ref. section 4.1
Name and affiliation of the verifier	Marisa Vieira, Principal consultant at PRé Consultants BV

Author: Matteo Donelli – Ergo s.r.l

1 Summary

1.1 Description of the content of the study

The goal of this LCA study is to perform a comparative LCA study (according to the PEF methodology) of the beer produced and distributed in steel and PET (DM) kegs, as well as in aluminium cans and glass bottles (returnable and non returnable), in Denmark. The brewery where the beer is produced is located in Fredericia, Denmark, and it is property of Carlsberg A/S ("Carlsberg Denmark" from here onwards).
The study has been carried out for the whole life cycle of a specific beer type (one single recipe, Tuborg® brand) packed and distributed in 5 different SKUs:

- 25 l returnable steel keg;
- 20 l DraughtMaster PET keg (one way);
- 0,33 l aluminium can (one way);
- 0,33 l returnable glass bottle;
- 0,33 l non returnable glass bottle.

According to the PEFCR for beer, the functional unit (unit of analysis) is the consumption of 1 hectoliter (hl).

The study is not intended for comparison against the benchmark beer included in the PEFCR Product Environmental Footprint Category Rules for Beer (Final version – June 2018). The study is intended for internal comparison, as an input for Carlsberg A/S internal management for future actions for sustainability, mainly focused on packaging solutions. Therefore, the main target audience will be Carlsberg A/S internal management, which is also the commissioner of the study.
This study does not use the default datasets tendered by the European Commission, since these datasets are not available in Sima Pro software format yet as of this report's date. For the same reason, as specified in the next chapter, the study is not intended for comparison against the Beer Pilot Benchmark.

The current study is aligned with the requirements of the the PEFCR "Product Environmental Footprint Category Rules for Beer Final version – June 2018", with the exceptions reported in the validation statement.

1.2 System boundaries

In accordance with the PEFCR for beer (section 4.4), for all the SKUs considered, the life cycle stages and processes of the product system (system boundaries) are reported in the following figure:

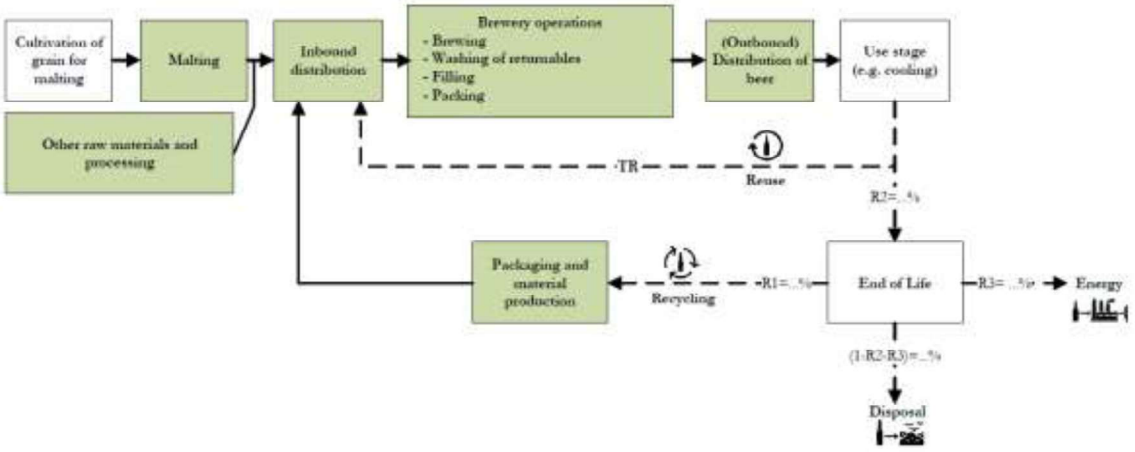


Figure 1.2-1: SKUs life cycle system boundaries- The green life cycle stages require company-specific data shall be used. Secondary data may be used for white boxes.

1.3 Main assumptions and limitations

The results of this LCA study are limited to the following main assumptions:

- the product is brewed and sold in Denmark;
- packaging end of life has been modelled according to recycled contents (R1) and recycling rates reported, respectively in chapter 6.3.3 and 6.3.7;
- EF compliant datasets, being the comparison against the PEFCR benchmark out of scope, have not been used. Data from the EF beer pilot screening study and Carlsberg supporting study have been used as substitute datasets whenever the PEFCR for Beer required the EF compliant datasets;
- Data Quality Requirements for Steel keg and aluminium can production do not meet PEFCR requirement, being not company specific.

As in the pilot screening LCA study, the main gaps in data relate to beer ingredients where no secondary data exist (e.g. sweeteners, enzymes, fining agents). None of the processes affected by data gaps issues are in the list of the most relevant processes included in the PEFCR for beer.

The following table summarizes the main aspects of the compared options (SKUs).

Table 1.3-1: main aspects of the compared options (SKUs)

Main aspects	Steel keg 30l (returnable)	PET keg 20l (one way)	Glass bottle 0,33l (returnable)	Glass bottle 0,33l (non returnable)	Aluminium can 0,33l (one way)
Packaging Country of production	Germany (steel)	Czech Republic (PET preform) Slovak Republic (PET base part) Denmark (cardboard)	Denmark (glass)	Denmark (glass)	Denmark (aluminium) Denmark (cardboard)
Packaging recycled content (R1)	0% for steel	0% for PET 100% for cardboard	66,01% for glass	86,15% for glass	56% for aluminium (can body) 22% for aluminium (can lid) 100% for cardboard
Packaging recycling rate (R2)	51% for steel	0% for PET 76,05% for cardboard	88% for glass	88% for glass	75% for aluminium 76,05% for cardboard
Packaging incineration rate	47,5% for steel	97% for PET 23,2% for cardboard	11,6% for glass	11,6% for glass	24,3% for aluminium 23,2% for cardboard
Packaging landfill rate	1,47% for steel	3% for PET 0,719 for cardboard	0,36% for glass	0,36% for glass	0,75% for aluminium 0,719% for cardboard
Packaging weight (kg per hl of delivered beer)	0,535 (considering 92,62 reuses for keg)	4,85	3,74 (considering 29 reuses for bottle)	69,4	4,4

1.4 PEF results

The next table shows the characterized results for all the PEF impact categories listed in chapter 5.3, for each SKU considered in the current study[1].

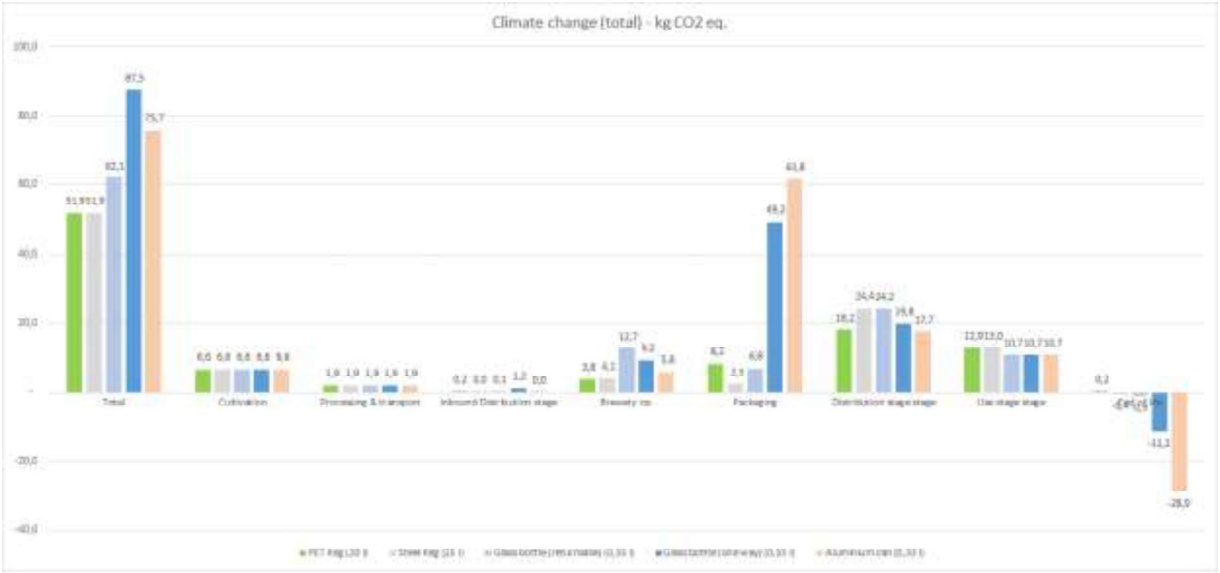
Table 1.4-1: Characterised results for each impact category for 1hl of beer, "cradle to grave" (total).

Impact category	Unit	Total – Steel keg	Total – PET keg	Total – Glass bottle (ret.)	Total – Glass bottle (non ret.)	Total – Aluminium can
Climate change	kg CO2 eq	**51,91**	**51,92**	**62,10**	**87,46**	**75,68**
Ozone depletion	kg CFC11 eq	**1,47E-06**	**1,38E-06**	**2,21E-06**	**3,21E-06**	**6,37E-06**
Ionising radiation, HH	kBq U-235 eq	**3,33**	**3,36**	**2,97**	**4,25**	**8,47**
Photochemical ozone formation, HH	kg NMVOC eq	**2,89E-01**	**2,59E-01**	**2,99E-01**	**4,06E-01**	**3,20E-01**
Respiratory inorganics	disease inc.	**3,43E-06**	**3,42E-06**	**3,59E-06**	**8,59E-06**	**5,16E-06**
Non-cancer human health effects	CTUh	**5,71E-05**	**5,60E-05**	**5,63E-05**	**5,85E-05**	**6,16E-05**
Cancer human health effects	CTUh	**9,38E-07**	**6,03E-07**	**6,26E-07**	**8,86E-07**	**2,05E-06**
Acidification terrestrial and freshwater	mol H+ eq	**5,84E-01**	**5,62E-01**	**5,89E-01**	**7,88E-01**	**6,84E-01**
Eutrophication freshwater	kg P eq	**1,47E-02**	**1,53E-02**	**1,17E-02**	**1,58E-02**	**2,60E-02**
Eutrophication marine	kg N eq	**2,78E-01**	**2,67E-01**	**2,79E-01**	**3,21E-01**	**2,87E-01**
Eutrophication terrestrial	mol N eq	**2,56**	**2,41**	**2,57**	**3,07**	**2,61**
Ecotoxicity freshwater	CTUe	**81,44**	**93,87**	**77,80**	**87,44**	**102,68**
Land use	Pt	**540,90**	**819,86**	**558,19**	**918,13**	**2.237,21**
Water scarcity	m3 depriv.	**323,62**	**58,11**	**69,03**	**797,18**	**2,38E+04**
Resource use, energy carriers	MJ	**656,48**	**654,52**	**816,04**	**815,95**	**945,80**
Resource use, mineral and metals	kg Sb eq	**1,02E-04**	**7,16E-05**	**6,35E-05**	**1,14E-04**	**1,31E-04**

[1] Normalized and weighted results are reported in section 7

The following figure shows the results for climate change impact category for all SKUs.

Figure 1.4-1: Overall score: SKUs comparison – Climate change total



1.5 Main findings from the analysis of the results

The default results of the study are those required by applying the PEFCR assumptions and requirements, aimed at assuring consistency and comparability. **However, some of those assumptions might differ, in some life cycle processes, from Carlsberg's measured ones**. Sensitivity analysis, which is reported in details in section 8.5, tried to assess those assumptions by using alternative data which seems to be more representative for the specific Denmark case.

From an overall life cycle perspective, it appears clearly that:

- the aluminium can and the non returnable glass bottle, due to their much higher impact of the packaging phase, show the worst environmental performance for all the main impact categories. The straightforward reason lies in the energy intensive production process for aluminium and glass materials, which is only partially counterbalanced by the credit from the avoided materials related to recycling at the end of life;

by applying the default PEFCR assumptions:

- **the comparison between PET and steel kegs shows that both PEF are substantially equal** for the majority of the main impact categories, with the exception of water scarcity and resource use, minerals and metals;
- **both PET and steel kegs show a significant advantage (higher than 10%) against bottles and can**, for some of the main impact categories: **climate change; resource use, energy carriers** while **PET only also show a significant advantage (higher than 10%) against bottles and can, for water scarcity**;

- on the contrary, **returnable glass bottles have a substantial advantage against PET keg in one single main impact category** (which according to weighted results, was excluded from the most relevant impact categories as shown in chapter 8.1) **resource use, minerals and metals** (due mainly to the high reuse rate);
- from the outcome of sensitivity analysis, **PET keg** could have been penalized by the mandatory PEFCR assumptions on the distribution and use phase;

by applying Carlsberg specific assumptions for Denmark (sensitivity analysis):

- sensitivity analysis shows that **PEFCR default data used for the use phase** (electricity consumption for cooling and beer losses) **might differ substantially from real measured data**. by using measured data for the use phase (energy for cooling and beer losses), in comparison to the default scenario, whenever a refrigerator is needed at the point of sale to keep the steel kegs cooled, **the PET keg shows a significant better environmental performance (>10%) than all the other SKUs for all the most relevant impact categories**, with the exception of respiratory inorganics, where the advantage is, however, approximately 9%. Being so relevant on the final results, the measured input data needs, however, to be confirmed by further samples, possibly of higher size, in order to manage the related uncertainty;
- sensitivity analysis shows that the recycling of **PET can lead to an interesting reduction of the footprint for the majority of the main impact categories** with the exception of water scarcity and resource use energy carriers (where the effect is slightly worst). However, **this sensitivity analysis is highly dependent on the recycling process and the avoided material** that will be selected. This potentiality has been assessed thanks to recent new data (June 2019) on a new technology to upcycle used kegs and obtain plastic tiles to be use as construction material, which proved that **this technology, associated with the ability of reaching high recycling rates, has the potential to reduce the majority of the main impact categories in the life cycle of the product**. The sensitivity analysis proved that the CO^2 saved emissions, with the upcycling of used kegs, ranges from 0,94 to 1,35 kg/Hl if the recycling rate ranges from 52% to 95%. Projecting these figures on the annual DraughtMaster beer production in Fredericia (198.200 hl) would mean a **total saving of approximately 185 to 267 tonnes of CO^2 eq. emissions per year**;

- by combining all the alternative scenarios based on more specific data, in comparison to some PEFCR mandatory assumptions, namely PET upcycling at the end of life, distance and transportation mean from distribution centres to final client, beer losses and electricity consumption at the use phase, it appears that
  - **whenever a refrigerator is needed, the advantage of PET kegs against all other SKUs, steel keg included, is substantial (>10%), even at lower recycling rates**;
  - in case no refrigerator is needed, the PET keg still has an advantage over the steel keg in climate change impact category, thought it never reaches +10% threshold. For the other most relevant impact categories, the advantage of the PET over the steel keg is substantial even at very low PET recycling rates. A greater (close to +10%) advantage in climate change impact category can be reached by PET against steel keg in case a higher recycling rate (from 75% upwards) is achieved in the upcycling scenario of used kegs. Since the collection of the kegs will be performed under Carlsberg control, the recycling rate of used PET would be presumably higher than the recycling rate from the municipal collection.

2 Validation statement (extract)

4. Validation statement

4.1. General information

Title of the PEF study under verification/validation, together with the exact version of the report to which the validation statement belongs to	Product Environmental Footprint Report - Life Cycle Assessment (LCA) of the environmental footprint (PEF) of Tuborg ® beer distributed in Denmark in different stock keeping units. Version 2.1 published on 28 January 2020
Commissioner of the PEF study	Carlsberg Breweries A/S Ny Carlsberg vej 100 1799 Copenhagen V Denmark
User of the PEF method	Matteo Donelli, Consultant at Ergo s.r.l
Verifier	Marisa Vieira, Principal consultant at PRé Sustainability

The verifier confirms the absence of conflicts of interest of the verifier with respect to concerned products and any involvement in previous work (where relevant, PEFCR development, Technical Secretariat membership, consultancy work carried out for the user of the PEF method during the last three years).

The verification/ validation aims at increasing the credibility and robustness of the outcomes of the comparative PEF study.

4.2. Outcome of the verification / validation

The verifier acknowledges Carlsberg and Ergo for their willingness to take account of, and incorporate, the verifier's comments. Carlsberg and Ergo performed the review meetings and the review process in an open, competent and professional manner.

The verification of the **PEF study** ensures that the PEF study is conducted in compliance with the most recent version of the PEF method or PEFCR, with the exception of the elements listed in section 4.3. The validation of information in the PEF study ensures that:

- the data and information used for the PEF study are consistent, reliable and traceable;
- the calculations performed do not include significant mistakes.

The verification and validation of the **PEF report**[6] ensures, with the exception of the elements listed in section 4.3, that:

- the PEF report is complete, consistent, and compliant with the PEF report template provided in the most recent version of the PEF method;
- the information and data included are consistent, reliable and traceable;
- the mandatory information and sections are included and appropriately filled in;
- all the technical information that could be used for communication purposes, independently from the communication vehicle to be used, are included in the report.

4.2.1. Evaluation of specific verification and validation requirements

In Table 1, the minimum requirements listed in section 8.4.1 of the most recent version of the PEF method (Zampori and Pant, 2019) and the verifier's evaluation thereof are shown.

Table 1 – Minimum requirements for the verification and validation of the PEF study

Requirement	Evaluation
Check if the correct version of all impact assessment methods was used. For each of the most relevant EF impact categories (ICs), at least 50% of the characterisation shall be verified, while all normalisation and weighting factors of all ICs shall be verified. In particular, the verifier shall check that the characterisation factors correspond to those included in the EF impact assessment method the study declares compliance with	VERIFIED AND IN COMPLIANCE
Cut-off applied (if any) fulfils the requirements at section 4.6.4 of the most recent version of the PEF method (Zampori and Rana, 2019)	VERIFIED AND IN COMPLIANCE
All the newly created datasets shall be checked on their EF compliance. All their underlying data (elementary flows, activity data and sub processes) shall be validated	PARTLY VERIFIED AND IN COMPLIANCE Only the methodological requirements were verified; the documentation and nomenclature requirements were not applicable since the ILCD format for newly created datasets wasn't adopted
The aggregated EF compliant dataset of the product in scope is made available to the European Commission	NOT VERIFIED Carlsberg decided not to create an aggregated EF compliant dataset for the products studied
For at least 70% of the most relevant processes (by number) in situation 2 option 2 of the DNM, 70% of the underlying numbers shall be validated. The 70% data shall include all energy and transport sub-processes for processes in situation 2 option 2	VERIFIED AND IN COMPLIANCE
For at least 60% of the most relevant processes (by number) in situation 3 of the DNM, 60% of the underlying data shall be validated	VERIFIED AND IN COMPLIANCE

[6] A PEF report consists of at least: a summary, the main report, the aggregated EF compliant dataset and an annex.

For at least 50% of the other processes (by number) in situation 1, 2 and 3 of the DNM, 50% of the underlying data shall be validated	VERIFIED AND IN COMPLIANCE
For all processes to be validated, check if the DQR satisfies the minimum DQR as specified in the PEF method	NOT POSSIBLE TO VERIFY This verification requirement was not met because the data quality of individual datasets was not assessed (added to list of limitations in section 4.3).

For the complete overview of the verification and validation topics and related decisions, please see the attached table "verification comments, answers and decisions".

The outcomes of the verification and validation of the models developed for each product life cycle in SimaPro® are the following:

- The models are very intricate, detailed and well documented;
- The models are aligned with the general EF modelling rules and with the PEFCR for beer with the exception of the limitations listed in section 4.3;
- With the secondary data available, the models attempted, whenever possible, to adapt to the specific conditions of the products under study, e.g. modification of electricity mix in the secondary data to Danish mix;
- The models adopted company-specific data except when the PEFCR prescribes the use of default or secondary data, with the exception of data for the production of aluminium cans and steel kegs (read the limitations).

4.2.2. Main improvements made resulting from verification/validation

The verification and validation process resulted in the following main improvements:

- The alignment of the PEF report with the most recent PEF report template which led to the addition of missing elements to the report.
- Alignment with most recent version of the PEF method, e.g. use of most recent default values for parameters of the circular footprint formula.
- More consistency in the LCI database used to select the secondary data; this ensures consistent modelling in the secondary data used.
- Improvement of the identification of the most relevant impact categories, life cycle stages and processes
- Awareness of all deviations and limitations of the PEF study related to compliance with the most recent PEF method and to the PEFCR for beer (listed in section 4.3).

4.3. Limitations of the verification / validation outcomes

In the PEF study verified, the verifier found a few significant deviations from the requirements of the most recent version of the PEF method and of the PEFCR for beer.

In this section, the verifier lists the main deviations and limitations of the PEF study in relation to the documents it was to comply with:

- The fact that no company-specific data is used for two out of four packaging materials, i.e. aluminium cans and steel keg, when the aim of the study is primarily to compare the various packaging materials is a main limitation of this study. For that reason, the comparative results related to these two packaging solutions should be used with caution.

- The assessment of the data quality was not done. That would be desirable at least for the production and end of life modelling of the packaging materials and their inbound and outbound distribution since these are the main elements that differ between the four packaging solutions. At the moment, it is not possible to evaluate if the quality of the data is sufficient to support the study outcomes.
- The verifier did not validate company-specific data. It simply accepted the data provided by Carlsberg for this PEF study. This is listed as a deviation from the verification/validation requirements and as a limitation of the verification/validation process.
- The secondary datasets selected to use in this study are not those prescribed in the PEFCR for beer. This means that the PEF results obtained in this study cannot be compared with the benchmark results included in the PEFCR for beer.
- The secondary datasets selected to use in this study are not those prescribed in the PEFCR for beer. For that reason, it cannot be guaranteed that the outcomes would be the same if EF-compliant datasets were used.
- The secondary datasets selected to use in this study are not those prescribed in the PEFCR for beer. However, the verifier confirms that the secondary datasets used in the models were the most suitable taking into account those available to Carlsberg and Ergo at the time the study was performed.
- Results shall be reported for (i) the total life cycle, and (ii) the total life cycle excluding the use stage. However, the PEF report does not list the total life cycle excluding the use stage (though that can be easily calculated by the reader since the results of all life cycle stages are provided).
- The identification of the most relevant processes is not fully aligned with the EF rules. However, this doesn't affect the outcomes related to the objective of this study, i.e. to compare different beer packaging solutions.
- Also, since the secondary data is disaggregated, this also affects the identification of the most relevant processes. For instance, the dataset "Electricity, high voltage {DK}| heat and power co-generation, hard coal | Cut-off, U" was identified as most relevant process but this dataset wasn't directly used in the model. It is a sub-process of a secondary dataset used, i.e. "Electricity, medium voltage {DK}| market for | Cut-off, U". For that reason, it's not this dataset that should be listed but the parent dataset that was selected in the model.
- The identification of the most relevant elementary flows was not done but this doesn't affect the outcomes related to the objective of this study.
- Water scarcity results are likely to be incorrect due to lack of balance of input and output water flows for the hydropower electricity production dataset from ecoinvent used. This can affect the outcomes of the most relevant impact categories and the contribution per life cycle stage and per process for this impact category.
- The uncertainty analysis of the study was improved. Now, it is focused on the difference between the products systems under study which better relates to the objective of the study.

4.4. Final conclusion

Carlsberg Breweries A/S aims to compare the product environmental footprint performance of Tuborg® beer produced and distributed in Denmark in steel and PET (polyethylene terephthalate) kegs, aluminium cans, returnable and one-way glass bottles.

For the most relevant impact categories selected in the PEFCR for beer, the environmental impact of the different stock keeping units stock keeping units (SKUs) used for Tuborg® beer distributed in Denmark is ranked as follows:[7]

- For climate change, one-way glass bottle > aluminium can > returnable glass bottle > PET keg ≈ steel keg;
- For respiratory inorganics (particulate matter), one-way glass bottle > aluminium can > returnable glass bottle ≈ PET keg ≈ steel keg;
- For acidification, one-way glass bottle > aluminium can > returnable glass bottle > steel keg > PET keg;
- For resource use, energy carriers, aluminium can > one-way glass bottle ≈ returnable glass bottle > PET keg ≈ steel keg;
- For resource use, minerals and metals, aluminium can ≈ one-way glass bottle ≈ steel keg > PET keg ≈ returnable glass bottle;
- Water scarcity results are likely to be incorrect due to lack of balance of input and output water flows for some of the electricity production technologies. For that reason, no conclusions can be drawn regarding the comparing of the various SKUs for this impact category.

However, for proper interpretation and communication of the results, it is crucial to consider the limitations of the study as reported in section 4.3 of this report. These limitations might affect the reliability of the results.

The verifier confirms that the PEF study is compliant with the most recent version of the PEF method and with the PEFCR for beer except for the elements listed in section 4.3. Assumptions, calculations, and results are presented in a transparent and appropriate way.

Amersfoort, 29 January 2020

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[7] *> is used when the product to the left of the symbol has a larger environmental impact than the product to the right of the symbol and the difference, when considering the outcome of the uncertainty analysis, if significant (probability ≥ 90%).*
≈ is used when the difference between the impact results of two products considering the uncertainty analysis is not significant (probability < 90%).