



INSTITUT FÜR ENERGIE-
UND UMWELTFORSCHUNG
HEIDELBERG

Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the German market

Supplement to Comparative Life Cycle Assessment of Tetra Pak® carton
packages and alternative packaging systems for beverages and liquid food on
the European market

commissioned by Tetra Pak

Heidelberg, September 8th 2021





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Heidelberg, September 8th 2021



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Abbreviations

ACE	Alliance for Beverage Cartons and the Environment
BC	Beverage carton
CML	Centrum voor Milieukunde (Center of Environmental Science), Leiden University, Netherlands
DHP	Düsseldorfer Halbpalette (D. half-pallet)
EA	European Aluminium
EEA	European Environment Agency
EU27+2	European Union & Switzerland and Norway
FEFCO	Fédération Européenne des Fabricants de Carton Ondulé (Brussels)
FU	Functional unit
GWP	Global Warming Potential
HBEFA	Handbuch für Emissionsfaktoren (Handbook for Emission Factors)
ifeu	Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JNSD	Juice, nectars and still drinks
LCA	Life cycle assessment
LCI	Life cycle inventory
LDPE	Low density polyethylene
LPB	Liquid packaging board
MSWI	Municipal solid waste incineration
pc	packs
PEF	Product environmental footprint
PET	Polyethylene terephthalate
PP	Polypropylene
rPET	recycled PET
SBM	Stretch blow moulding
TB	Tetra Brik
TBA	Tetra Brik Aseptic

TiO₂	Titanium dioxide
TPA	Tetra Prisma Aseptic
TR	Tetra Rex
TSA	Tetra Stelo Aseptic
TT	Tetra Top
TTAD	Tetra Top Ambient Distribution
TWA	Tetra Wedge Aseptic
UBA	Umweltbundesamt (German Federal Environmental Agency)
UE	Ultra Edge

1 Goal and scope

1.1 Background and objectives

As one of the world's leading suppliers, Tetra Pak provides complete processing and carton packaging systems and machines for beverages, dairy products and food. Currently, the range of packaging systems comprises eleven alternatives, e.g. Tetra Brik, Tetra Rex, Tetra Top [Tetra Pak 2020]. Tetra Pak is part of the Tetra Laval Group, which was formed in January 1993. The three industry groups Tetra Pak, DeLaval and Sidel are currently included in the group.

An integral part of Tetra Pak's business strategy and activities is the systematic work on the efficient use of resources and energy. The 2020 environmental targets of Tetra Pak focus on the use of sustainable materials to continuously improve the entire value chain and the increase of recycling to further reduce the impact on the environment. All paperboard sourced by Tetra Pak comes from wood from Forest Stewardship Council™ (FSC™)-certified forests and other controlled sources.

Tetra Pak has recently finalised LCA studies for several packaging formats including plant-based alternatives in several European markets. However, the results are only valid for the indicated geographic scope and cannot be assumed to be valid in other geographic regions, even for the same packaging systems.

In February 2020 a European baseline study has been finalised [ifeu 2020a]. That study is conducted as a fully ISO 14040/14044 compliant LCA study for the European market. It uses average European parameters like production data and end-of-life rates.

This baseline study is complemented by local supplement studies for specific countries. These are country specific studies for single country markets for specific locally relevant packaging solutions with a specific interest on Climate Change. In order to practically cover many local markets, these local supplementary studies focus on only one environmental impact category, Climate Change. Tetra Pak considers Climate Change as the main environmental concern. Also impacts on Climate Change depend strongly on local settings like end of life processes or the local electricity mix. For other environmental impact categories, please refer to the European baseline study.

This report is the local supplement study for the German market regarding the segments dairy (ambient and chilled), Juice, Nectars and still drinks (JNSD) (ambient), flavoured and unflavoured water (ambient) and liquid food (ambient).

The goal of this study is to deliver the performance regarding Climate Change of Tetra Pak's beverage and liquid food carton systems compared to alternative beverage and liquid food packaging systems on the German market. This assessment is done following the rules of life cycle assessment (i.e. ISO 14040/14044), but without assessing further impact categories apart from Climate Change.

To get an indication of how the packaging systems examined in this study perform in other environmental impact categories like for example Acidification or Eutrophication one can also refer to the result of the European baseline study [ifeu 2020a]. Of course the packaging systems examined in the present study are not exactly identical to the ones in the European baseline study. Also, some background parameters are different due to the different geographical scopes. For this reason, the results of the European baseline study can only be of indicative nature regarding the full set of environmental impact categories.¹

Competing packaging systems on the German market include:

- PET bottles
- Refillable glass bottles
- Steel cans (made from tinplate)
- Single use glass jars
- Pouches

All analysed packaging systems are divided into the segments

- 'Family Packs' with volumes of 1000 mL
- 'Portion Packs' with volumes from 200 mL to 500 mL.

The analysed packaging systems are divided into the following beverage and food segments:

- DAIRY products like milk or milk drinks
 - Chilled family packs with the volume of 1000 mL
 - Ambient family packs with the volume of 1000 mL
- Juice, Nectars and still drinks (JNSD)
 - Ambient family packs with the volume of 1000 mL
 - Ambient portion packs with the volume of 200 mL to 330 mL
- Liquid food
 - Ambient portion packs with the volume of 270 mL to 390 mL
- Water (flavoured)
 - Ambient family packs with the volume of 1000 mL
- Water (unflavoured)
 - Ambient portion packs with the volume of 500 mL

In order to address the goal of the project, the main objectives of the study are:

- (1) to provide knowledge of the strengths and weaknesses regarding Climate Change of carton packaging systems that also use a degree of plant-based materials in the described segments and markets.

¹ Please note the European baseline study does not show results for refillable bottles as these were not in the scope for the European market. For an indication how refillable bottles perform in environmental impacts categories besides Climate Change, a recent LCA for the German market exists [ifeu 2020b] that includes refillable bottles that can be requested at the German Association of Cardboard Packaging for Liquid Foods (FKN). Please note this report is currently only available in German language (<https://www.getraenkekarton.de/>).

- (2) to compare the performance regarding Climate Change of these cartons with those of the competing packaging systems with high market relevance on the German market.

The results of this study are to be used for internal and external communication. The comparative results of this study are intended to be used by the commissioner (Tetra Pak). Further they shall serve for information purposes of Tetra Pak's customers, e.g. fillers and retail customers. Therefore, the study and/or its results are intended to be disclosed.

The study is critically reviewed by an independent expert panel (see 1.3).

1.2 Organisation of the study

This study was commissioned by Tetra Pak in 2020. It is being conducted by the Institute for Energy and Environmental Research Heidelberg GmbH (ifeu).

The members of the project panel are:

- **Tetra Pak:** Dina Epifanova, Martin Gehlen, Caroline Babendererde
- **ifeu:** Samuel Schlecht, Frank Wellenreuther, Saskia Grünwasser

The modelling of the Life Cycle Assessment was done with the software UMBERTO 5.5.

1.3 Use of the study and target audience

The comparative results of this study are intended to be used by the commissioner (Tetra Pak). Further they shall serve for information purposes of Tetra Pak's customers, e.g. fillers and retail customers. The study and/or its results are therefore intended to be disclosed.

Although this present study is not a full LCA because it only focuses on Climate Change and no other environmental impact categories, it is intended to be consistent with the ISO standards on LCA [ISO 14040 and 14044 (2006)] except of the choice of impact categories. Therefore, a critical review process is undertaken by an independent panel of three LCA experts, from which one was also part of the critical review panel of the European baseline study [ifeu 2020a].

The members of the independent panel are

- Guido Sonnemann (chair), France
- Leigh Holloway, eco3 Design Ltd., UK
- Dr. Harald Käß, narocon – InnovationConsulting, Germany

Additional to the critical review panel, no other interested parties were part in the conduction of the study.

1.4 Functional unit

The function examined in this LCA study is the packaging of beverages or liquid food for retail. The functional unit (FU) for this study is the provision of 1000 L packaging volume for ambient and chilled beverage or liquid food at the point of sale. The packaging of the beverages or liquid food is provided for the required shelf life of the product.

For all packaging systems no packaging type specific differences in shelf life can be observed.

The primary packages examined are technically equivalent regarding the mechanical protection of the packaged beverage or liquid food during transport, the storage at the point-of-sale and the use phase as described in the following section.

The reference flow of the product system assessed here, refers to the actual filled volume of the containers and includes all packaging elements, e.g. beverage carton and closures as well as the transport packaging (corrugated cardboard trays and shrink wrap, pallets), which are necessary for the packaging, filling and delivery of 1000 L beverage or liquid food.

1.5 System boundaries

The study is designed as a 'cradle-to-grave' LCA without the use phase, in other words it includes the extraction and production of raw materials, converting processes, all transports and the final disposal or recycling of the packaging system.

In general, the study covers the following steps:

- Production, converting, recycling and final disposal of the primary base materials used in the primary packaging elements from the studied systems including closures and labels.
- Production, converting, recycling and final disposal of primary packaging elements and related transports
- Production, recycling and final disposal of transport packaging (stretch foil, pallets, cardboard trays)
- Production and disposal of process chemicals, as far as not excluded by the cut-off criteria (see below)
- Transports of packaging material from producers to converters and fillers
- Cleaning (only for refillable bottles) and filling processes, which are fully assigned to the packaging system
- Transport from fillers to potential central warehouses and final distribution to the point of sale
- Climate change related effects of cooling during transport where relevant (chilled dairy products).

Not included are:

- The production and disposal of the infrastructure (machines, transport media, roads, etc.) and their maintenance (spare parts, heating of production halls) as no significant impact is expected. To determine if infrastructure can be excluded the authors apply two criteria by Reinout Heijungs [Heijungs et al. 1992] and Rolf Frischknecht [Frischknecht et al. 2007]: Capital goods should be included if the costs of maintenance and depreciation are a substantial part of the product and if environmental hot spots within the supply chain can be identified. Considering relevant information about the supply chain from producers and retailers, both criteria are considered to remain unfulfilled. An inclusion of capital goods might also lead to data asymmetries as data on infrastructure is not available for many production data sets.
- Production of beverage and liquid food and transport to fillers as no relevant differences between the systems under examination are to be expected
- Distribution of beverage and liquid food from the filler to the point-of-sale (distribution of packages is included).
- Environmental effects from accidents like breakages during transportation.
- Losses of beverage and liquid food at different points in the supply and consumption chain, which might occur for instance in the filling process, during handling and storage, etc. as they are considered to be roughly the same for all examined packaging systems. Significant differences in the amount of lost beverage and liquid food between the assessed packaging systems might be conceivable only if non-intended uses or product treatments are considered as for example in regard to different break resistance of packages or potentially different amount of residues left in an emptied package due to the design of the package/closure. Further possible losses are directly related to the handling of the consumer in the use phase, which is not part of this study as handling behaviours are very different and difficult to assess. Some data about beverage and liquid food losses in households is available, these losses though cannot be allocated to the different beverage and liquid food packaging systems. Further, no data is available for losses at the point of sale. Therefore, possible beverage and liquid food loss differences are not quantifiable. In consequence, a sensitivity analysis regarding beverage and liquid food losses would be highly speculative and is not part of this study. This is indeed not only true for the availability of reliable data, but also uncertainties in inventory modelling methodology of regular and accidental processes and the allocation of potential beverage and liquid food waste treatment aspects.
- Activities at the points of sale, as no relevant differences between the systems under examination are to be expected. This includes that also further cooling at the points of sale is excluded as in the regarded chilled segments all packages are being cooled at the points of sales.
- Transport of filled packages from the point of sale to the consumer as no relevant differences between the systems under examination are to be expected and the implementation would be highly speculative as no reliable data is available.
- Use phase of packages at the consumers as no relevant differences between the systems under examination are to be expected (for example in regard to cleaning

before disposal or chilling at home) and the implementation would be highly speculative as no reliable data is available.

- Future technologies (e.g. chemical recycling, solvent based recycling). As they are not implemented in a relevant scale on the market yet, such technologies are not considered in this study.

The following simplified flow charts shall illustrate the system boundaries considered for the packaging systems beverage and liquid food carton (Figure 1), PET bottle (Figure 2), refillable glass bottle / single use glass jar (Figure 3), steel can (Figure 4) and pouches (Figure 5). In case recycled material is used as recycled content in a closed loop, the flow charts show a connection between the recycling process and the material supply phase. Specific percentages of end of life streams are shown in chapter 2.3. As there are no refillable bottles established on the Portuguese market, only single use packaging systems are included in this study.

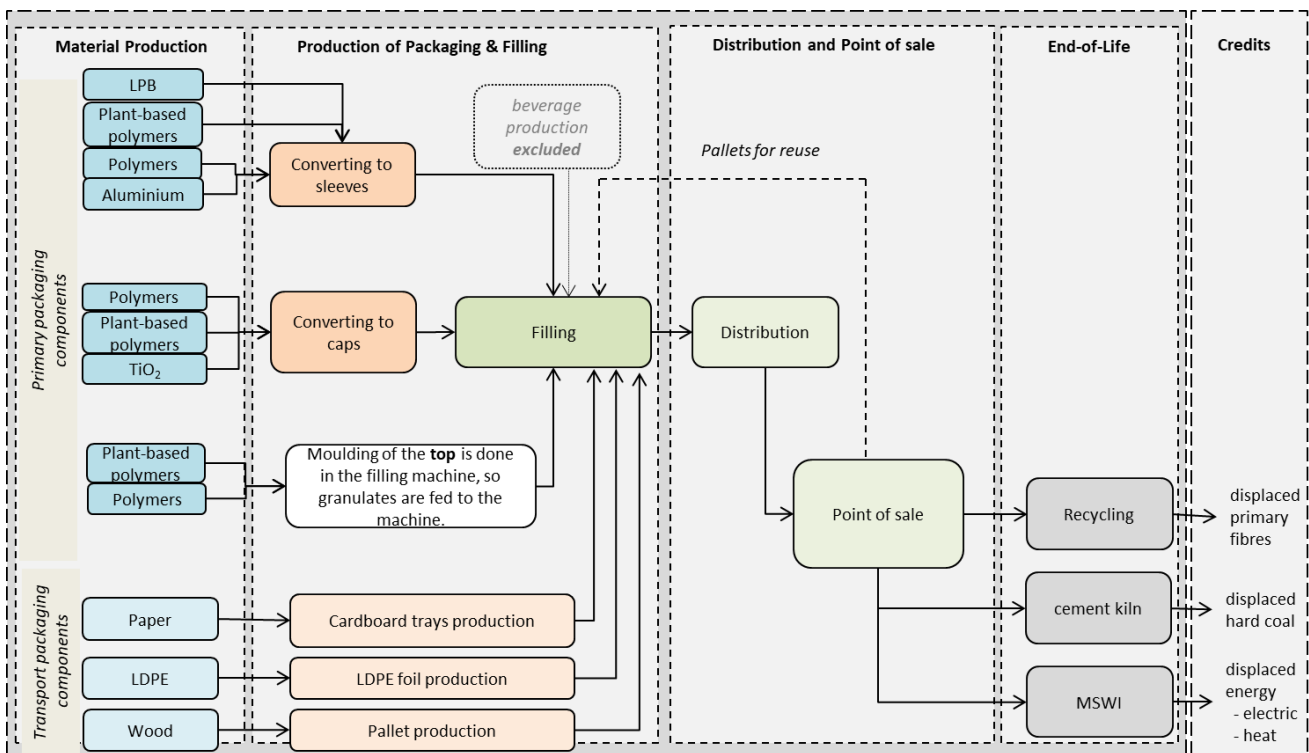


Figure 1: System boundaries of beverage and liquid food cartons

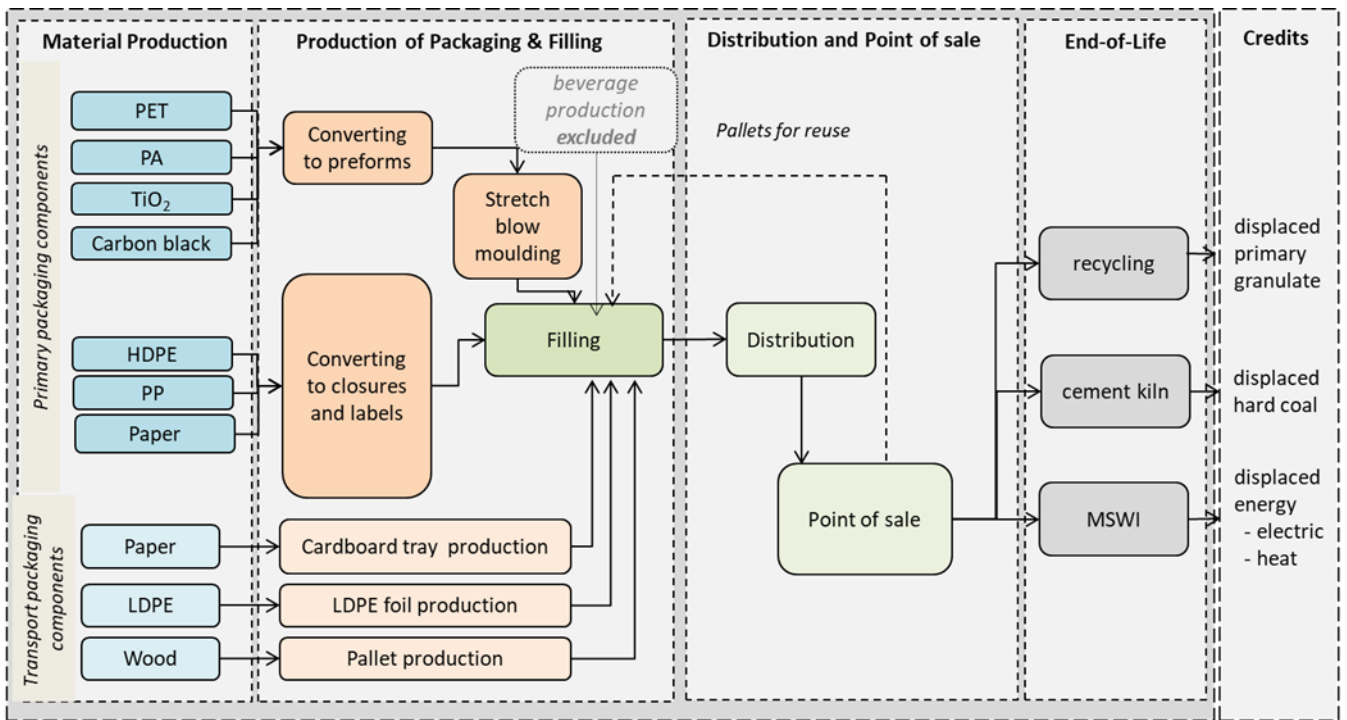


Figure 2: System boundaries of PET bottles

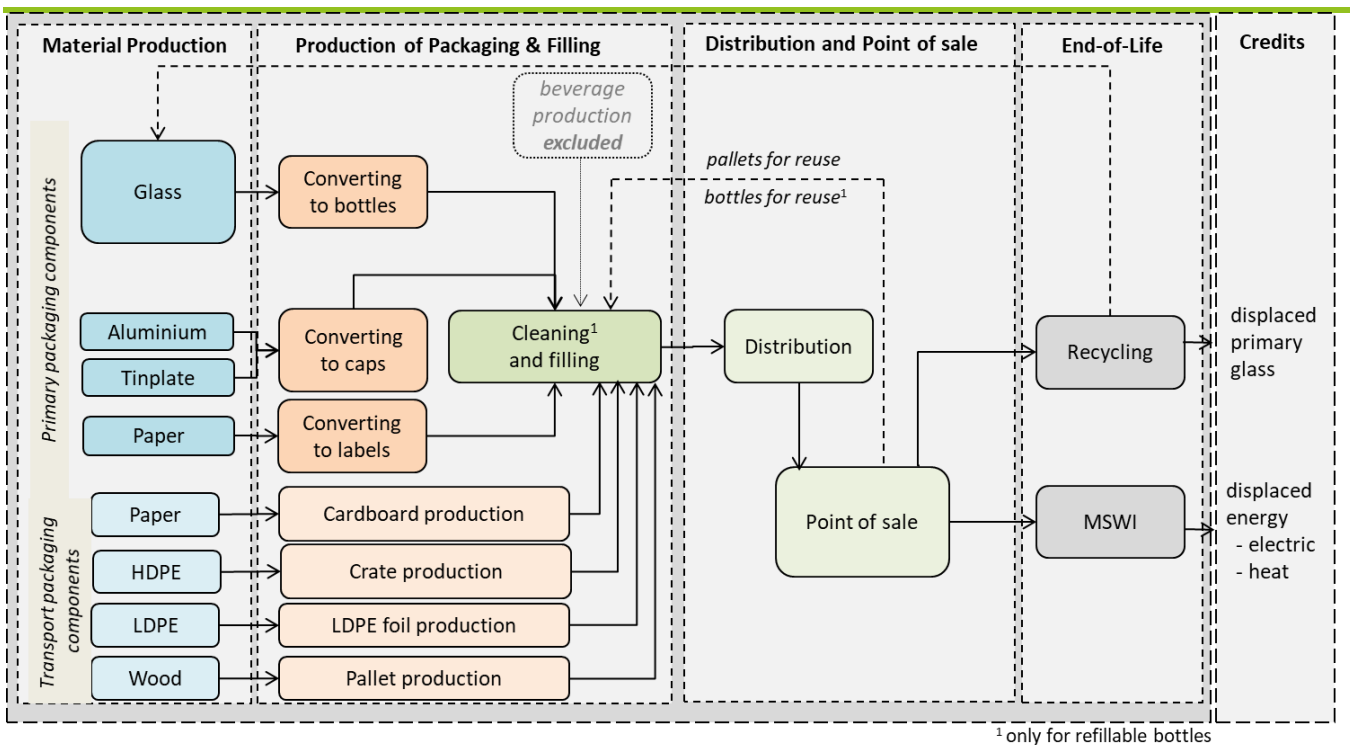


Figure 3: System boundaries of refillable glass bottles and single use glass jars

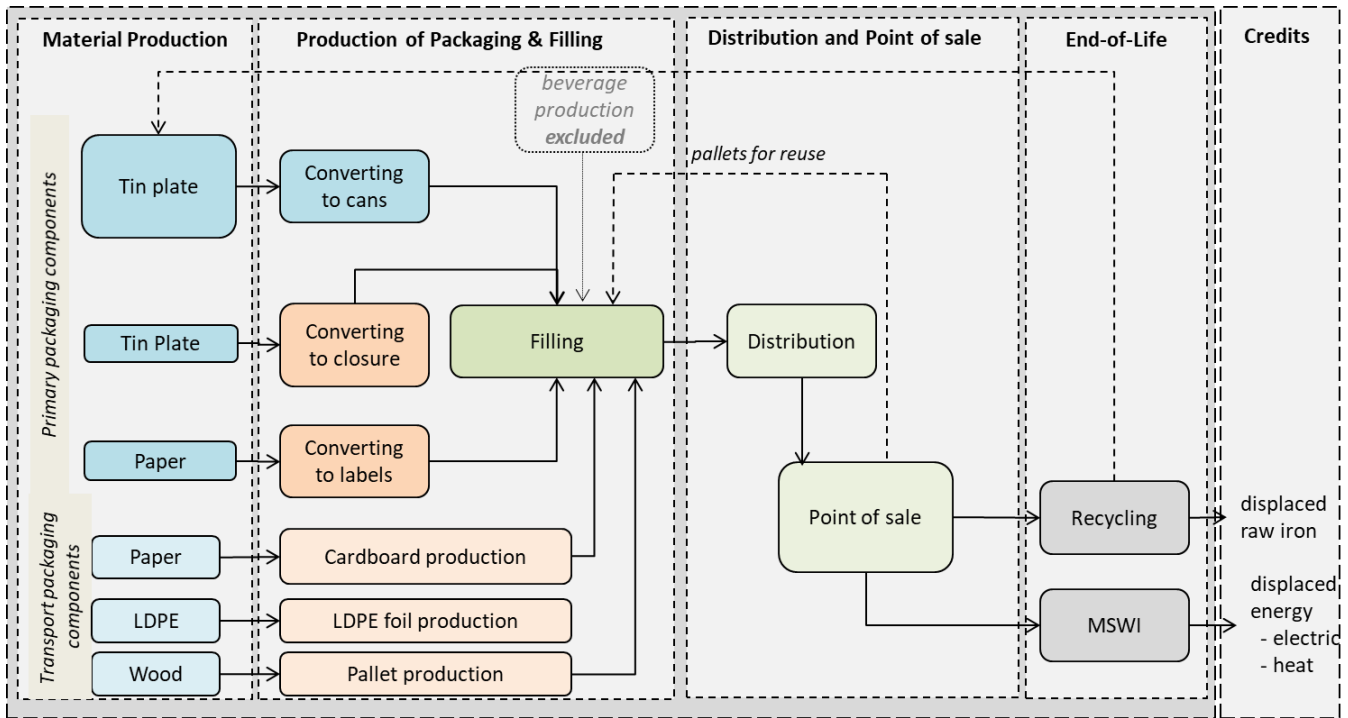


Figure 4: System boundaries steel can

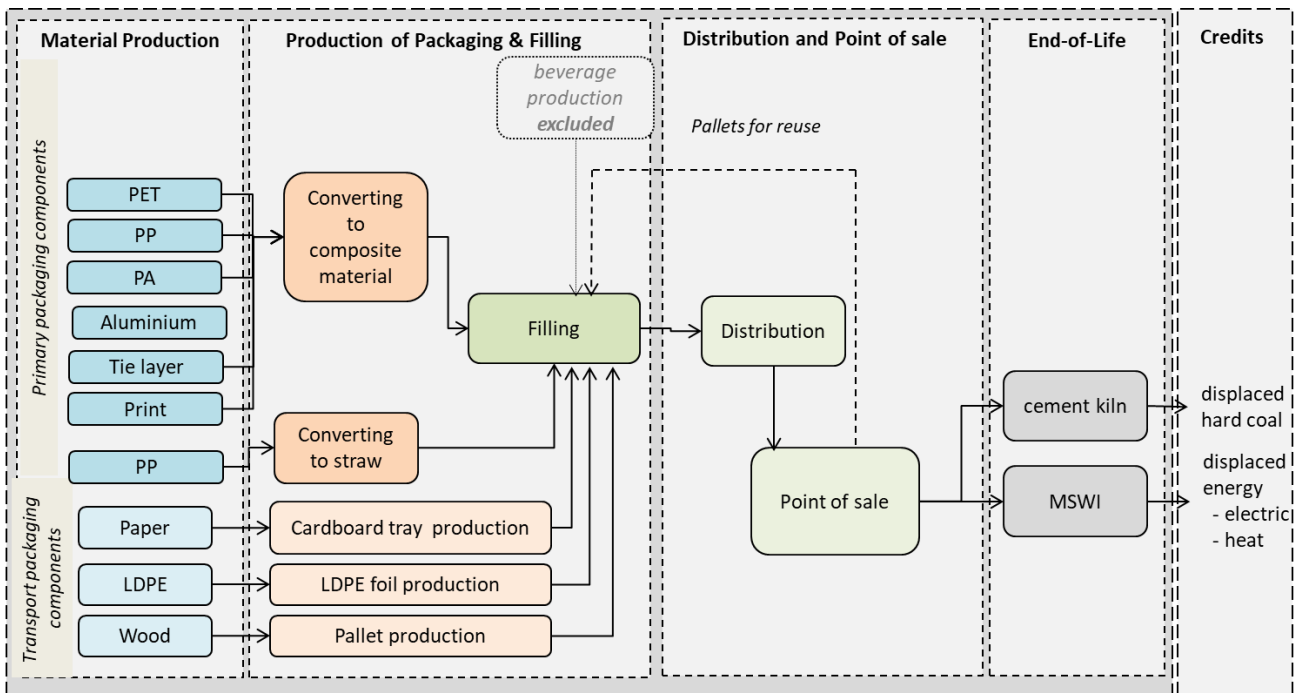


Figure 5: System boundaries pouch

Cut-off criteria

In order to ensure the symmetry of the packaging systems to be examined and to maintain the study within a feasible scope, a limitation on the detail in system modelling is necessary. So-called cut-off criteria are used for that purpose. According to ISO standard [ISO 14044], cut-off criteria shall consider mass, energy or environmental significance. Regarding mass-related cut-off, prechains from preceding systems with an input material share of less than 1% of the total mass input of a considered process were excluded from the present study. However, total cut-off is not to surpass 5% of input materials as referred to the functional unit. Based on the mass-related cut-off, the amount of printing ink used for the surface of beverage and liquid food cartons and labels of the bottles was excluded in this study. The mass of ink used per packaging never exceeds 1% of the total mass of the primary packaging for any beverage and liquid food carton examined in this study. Due to the fact that the printed surface of the labels on the bottles is smaller than the surface of a beverage and liquid food carton, the authors of the study assume, that the printing ink used for the labels will not exceed 1% of the total mass of the primary packaging as well. Environmental relevance of ink in beverage and liquid food packaging systems is low. Ruttenborg (2017) included ink in a LCA of beverage cartons. The contribution of ink to Climate Change is less than 0.2%. According to Tetra Pak, inks are not in direct food contact. In this study, ink is only considered for one packaging system (pouch 2). The ink of this pouch is more than 1% of the total mass of the packaging system. However, the requirements on inks are that they need to fulfil food safety requirements. This is also valid for all base materials included in the packages. From the toxicological point of view therefore no relevance is to be expected.

1.6 Data gathering and data quality

The datasets used in this study are described in section 3. The general requirements and characteristics regarding data gathering and data quality are summarised in the following paragraphs.

Geographic scope

In terms of the geographic scope, the LCA study focuses on the production, distribution and disposal of the packaging systems in Germany. A certain share of the raw material production for packaging systems takes place in specific European countries. For these, country-specific data is used. In other cases European average data are used. In [Table 1](#) the geographic scope of the applied process data is described. Country-specific data is generated by using European process data as a proxy combined with the local electricity mixes. Exceptions are the production of liquid packaging board (LPB) and plant based polymers, which are based on their own country specific process data.

Table 1: Geographic scope of applied process data or electricity prechains

	Beverage cartons	PET bottles	Refillable glass bottles/single use glass jars	Steel cans	Pouch
materials					
LPB	Sweden, Finland				
polymers	Europe ³	Europe ³			Europe ³
plant-based polymers	Brazil				
aluminium	Europe ¹				Europe ¹
tinplate			Europe ⁴	Europe ⁴	
glass			Europe ⁵		
converting					
bodies	Europe ²	Germany	Germany	Germany	Germany
closures	Europe ⁴	Germany	Germany	Germany	Germany
End of Life	Germany	Germany	Germany	Germany	Germany

¹ EU27 + Norway, Switzerland, Iceland [EA 2013], [EA 2018]. The applied dataset is only available as aggregated European dataset. Therefore for the recycling of aluminium cans no local electricity mixes is applied.

² EU28 [ifeu 2016].

³ based on several plants in Europe [PlasticsEurope 2005], [PlasticsEurope 2014a], [PlasticsEurope 2014b], [PlasticsEurope 2017].

⁴ based on several plants in Europe [World steel 2018].

⁵ German process data combined with European (EU28) electricity prechains [ifeu 2016].

Time scope

The packaging specifications listed in [section 2](#) as well as the market situation for the choice of beverage packaging systems refers to 2020. Therefore, the reference time period for the study is 2020.

The applied data is as up-to-date as possible referring to the period between 1996 and 2020 (see [Table 29](#) in [section 3](#)). In the cases of old data used no newer data was available. In this cases, the data has been checked for its representativeness (see for example the choice of dataset for PA6 described in [section 3.1.6](#)). Particularly with regard to data on end-of-life processes of the packages examined, the most current available information is used to correctly represent the recent changes in this area. The datasets for transportation, energy generation and waste treatment processes are taken from ifeu’s internal database in the most recent version. The data for plastic production originates from the Plastics Europe datasets and refer to different years, depending on material and year of publication.

More detailed information on the applied life cycle inventory data sets can be found in [section 3](#).

Technical reference

The process technology underlying the datasets used in the study reflects process configurations as well as technical and environmental levels which are typical for process operations in the reference period.

Completeness

The study is designed as a ‘cradle-to-grave’ LCA and intended to be used in comparative assertions. To ensure that all the relevant data needed for the interpretation are available and complete, all life cycle steps of the packaging systems under study have been subjected to a plausibility and completeness check. The summary of the completeness check according to [ISO 14044] is presented in the following table:

Table 2: The summary of the completeness check according to [ISO 14044]

	Beverage / liquid food cartons	PET bottles	Pouches	Steel cans	Refillable glass bottles/ single use glass jars	Complete?	Representative?
	x: inventory data for all processes available						
Base material production	x	x	x	x	x	yes	yes
Production of packaging (converting)	x	x	x	x	x	yes	yes
Cleaning and filling	x	x	x	x	x	yes	yes
Distribution	x	x	x	x	x	yes	yes
Transportation of materials to the single production steps	x	x	x	x	x	yes	yes
	End of life						
Recycling processes	x	x	x	x	x	yes	yes
MSWI	x	x	x	x	x	yes	yes

Landfill	x	x	x	x	x	yes	yes
Credits	x	x	x	x	x	yes	yes
Life Cycle Impact Assessment							
'Climate Change'	x	x	x	x	x	yes	yes

Consistency

All data intended to be used are considered to be consistent for the described goal and scope regarding: applied data, data accuracy, technology coverage, time-related coverage and geographical coverage (see section 3 for further details).

Sources of data

Process data for base material production and converting were either collected in cooperation with the industry or taken from literature and the ifeu database. Ifeu’s internal database includes data either collected in cooperation with industry or is based on literature. The database is continuously updated. Background processes such as energy generation, transportation, MSWI and landfill were taken from the most recent version of it. All data sources are summarised in Table 29 and described in Section 3.

Precision and uncertainty

For studies to be used in comparative assertions and intended to be disclosed to the public, ISO 14044 asks for an analysis of results for sensitivity and uncertainty. Uncertainties of datasets and chosen parameters are often difficult to determine by mathematically sound statistical methods. Hence, for the calculation of probability distributions of LCA results, statistical methods are usually not applicable or of limited validity. To define the significance of differences of results, an estimated significance threshold of 10 % is chosen as a pragmatic approach. This can be considered a common practice for LCA studies comparing different product systems [Kupfer et al. 2017]. This means differences ≤ 10 % are considered as insignificant.

1.7 Methodological aspects

1.7.1 Process and system allocation

“Allocation refers to partitioning of input or output flows of a process or a product system between the product system under study and one or more other product systems” [ISO 14044, definition 3.17]. This definition comprises the partitioning of flows regarding re-use and recycling, particularly open loop recycling.

In the present study, a distinction is made between process-related and system-related allocation, the former referring to allocation procedures in the context of multi-input and

multi-output processes and the latter referring to allocation procedures in the context of open loop recycling.

Both approaches are further explained in the subsequent sections.

Process-related allocation

For *process-related allocations*, a distinction is made between multi-input and multi-output processes.

Multi-input processes

Multi-input processes occur especially in the area of waste treatment. Relevant processes are modelled in such a way that the partial material and energy flows due to waste treatment of the used packaging materials can be apportioned in a causal way. The modelling of packaging materials that have become waste after use and are disposed in a waste incineration plant is a typical example of multi-input allocation. The allocation for e.g. emissions arising from such multi-input processes has been carried out according to physical and/or chemical cause-relationships (e.g. mass, heating value (for example in MSWI), stoichiometry, etc.).

Multi-output processes

For data sets prepared by the authors of this study, the allocation of the outputs from coupled processes is generally carried out via the mass. If different allocation criteria are used, they are documented in the description of the data in case they are of special importance for the individual data sets. For literature data, different allocation criteria are also documented in the description of the data or reference is made to the data source.

Transport allocation

An allocation between the packaging and contents was carried out for the transportation of the filled packages to the point-of-sale (life cycle step distribution). Only the share in environmental burdens related to transport, which is assigned to the package, has been accounted for in this study. That means the burdens related directly to the beverage and liquid food is excluded. The allocation between package and filling goods is based on mass criterion. The application of the allocation after the method requested by the German Environmental Agency (UBA) [UBA 2000] is checked for the segments which include refillable packaging systems by applying a sensitivity analysis using a more simplified approach. In this approach burdens from a theoretical transportation of only filling goods are subtracted from the burdens from the transportation of packaging material and filling goods. This allocation is applied as the functional unit of the study defines a fixed amount of beverage and liquid food through all scenarios. Impacts related to transporting the beverage and liquid food itself would be the same in all scenarios. Thus, they don't need to be included in this comparative study of beverage and liquid food packaging systems. The assessed impacts in the life cycle step distribution show the only additional impacts due to use of packaging systems.

System-related allocation

System-related allocation is applied in this study regarding open loop recycling and recovery processes. Recycling refers to material recycling, whereas recovery refers to thermal recovery for example in MSWI with energy recovery or cement kilns. System-related allocation is applied to both, recycling and recovery in the end of life of the assessed system and processes regarding the use of recycled materials by the assessed system. System-related allocation is not applied regarding disposal processes like landfills with minor energy recovery possibilities. [Figure 6](#) illustrates the general allocation approach used for uncoupled systems and systems which are coupled through recycling. In [Figure 6](#) (upper diagram) in both, 'system A' and 'system B', a virgin material (e.g. polymer) is produced, converted into a product which is used and finally disposed. A virgin material in this case is to be understood as a material without recycled content. A different situation is shown in the lower diagram of [Figure 6](#). Here product A is recovered after use and supplied as a raw material to 'system B' avoiding thus the environmental burdens related to the production ('MP-B') of the virgin materials, e.g. polymer and the disposal of product A ('Dis-A'). In order to do the allocation consistently, the recovery process 'Rec' has to be taken into account in addition to the virgin material production ('MP-A') and the disposal of product B ('Dis-B'), as already mentioned above.

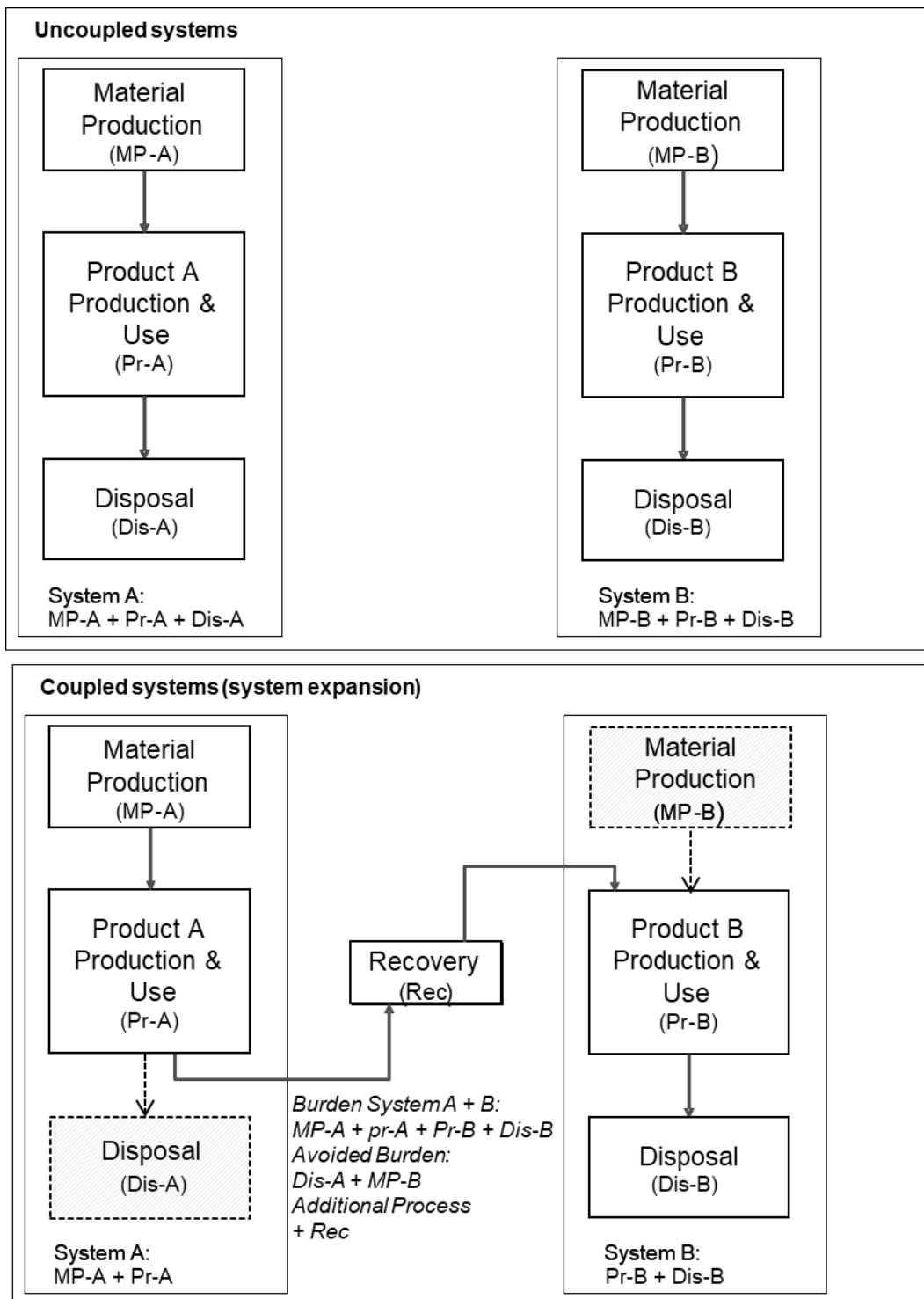


Figure 6: Additional system benefit/burden through recycling (schematic flow chart)¹

If the system boundaries of the LCA are such that only one product system is examined it is necessary to decide how the possible environmental benefits and burdens of the material recovery and recycling and the benefits and burdens of the use of recycled materials shall be allocated (i.e. accounted) to the assessed system. In LCA practice, several allocation methods are found. There is one important premise to be complied with by any allocation

¹ shaded boxes are avoided processes

method chosen: the mass balance of all inputs and outputs of ‘system A’ and ‘system B’ after allocation must be the same as the inputs and outputs calculated for the sum of ‘systems A and B’ before allocation is performed.

System allocation approaches used in this study

The approach chosen for system-related allocation is illustrated in Figure 7 and Figure 8. Both diagrams show two example product systems, referred to as product ‘system A’ and ‘system B’. ‘System A’ shall represent systems under study in this LCA in the case if material is provided for recycling or recovery. ‘System B’ shall represent systems under study in this LCA in the case recycled materials are used.

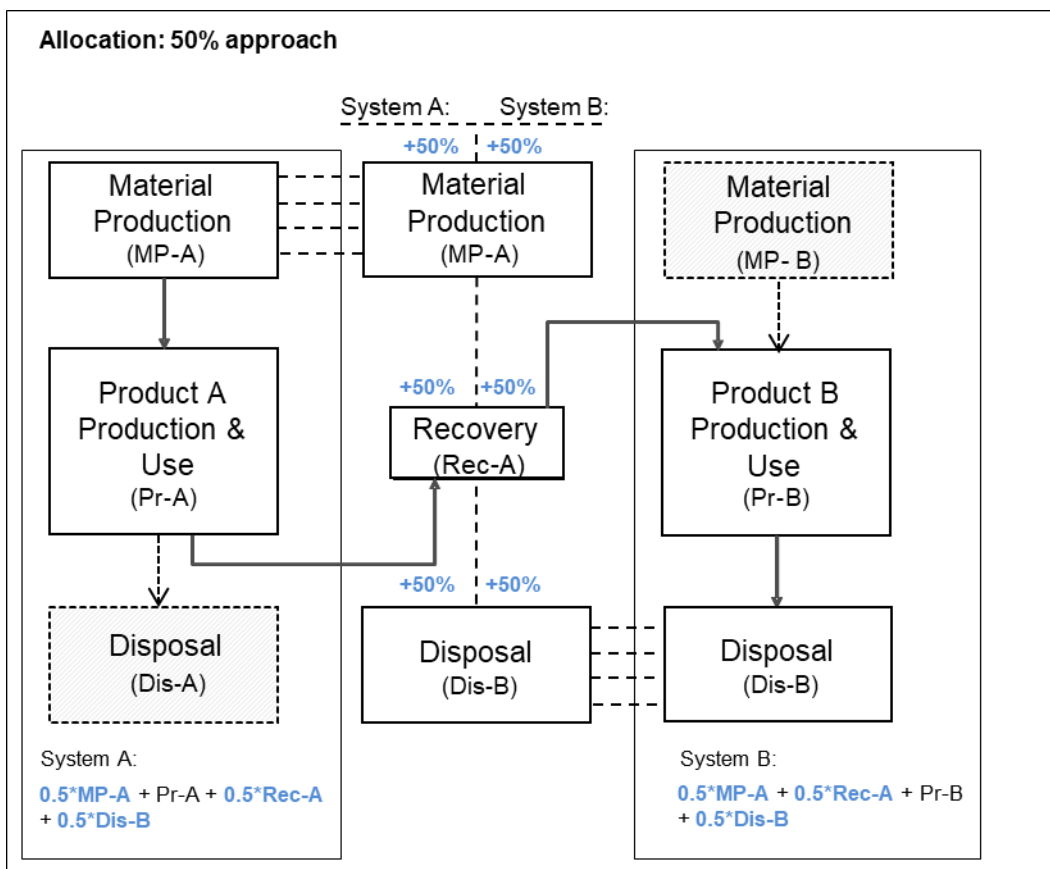


Figure 7: Principles of 50% allocation (schematic flow chart)¹

Allocation with the 50% method (Figure 7)

In this method, benefits and burdens of ‘MP-A’, ‘Rec-A’ and ‘Dis-B’ are equally shared between ‘system A’ and ‘system B’ (50:50 method). Thus, ‘system A’, from its viewpoint, receives a 50% credit for avoided primary material production and is assigned with 50% of the burden or benefit from waste treatment (Dis-B). If recycled material is used in the assessed system, the perspective of ‘system B’ applies. Also in this case benefits and burdens of ‘MP-A’, ‘Rec-A’ and ‘Dis-B’ are equally shared between ‘system A’ and ‘system B’.

¹ shaded boxes are avoided processes

Example 1 ('system A'), virgin beverage carton which is recycled or thermally recovered after its use: All burdens from recycling and recovery processes are shared between the regarded beverage carton system and the following system (use of secondary material or energy production). Also the benefits from replacing virgin materials or grid energy are shared between the regarded system and the following systems.

Example 2 ('system B'), PET bottle containing recycled PET (rPET): All burdens from recycling of the used rPET are shared between the regarded rPET bottle system and the preceding system. Also the benefits from replacing virgin materials are shared between the regarded system and the preceding system.

The 50% method has often been discussed in the context of open loop recycling, see [Fava et al. 1991], [Frischknecht 1998], [Klöppfer 1996] and [Kim et al. 1997]. According to [Klöppfer 2007], this rule is furthermore commonly accepted as a "fair" split between two coupled systems.

The approach of sharing the burdens and benefit from both, providing material for recycling and recovery, as well as using recycled material, follows the goal of encouraging the increase in recyclability as well as the use of recycled material. These goals align with §21 of the German packaging law [VerpackG 2021].

The 50:50 method has been used in numerous LCAs carried out by ifeu and also is the standard approach applied in the packaging LCAs commissioned by the German Environment Agency (UBA). Additional background information on this allocation approach can be found in [UBA 2000] and [UBA 2016].

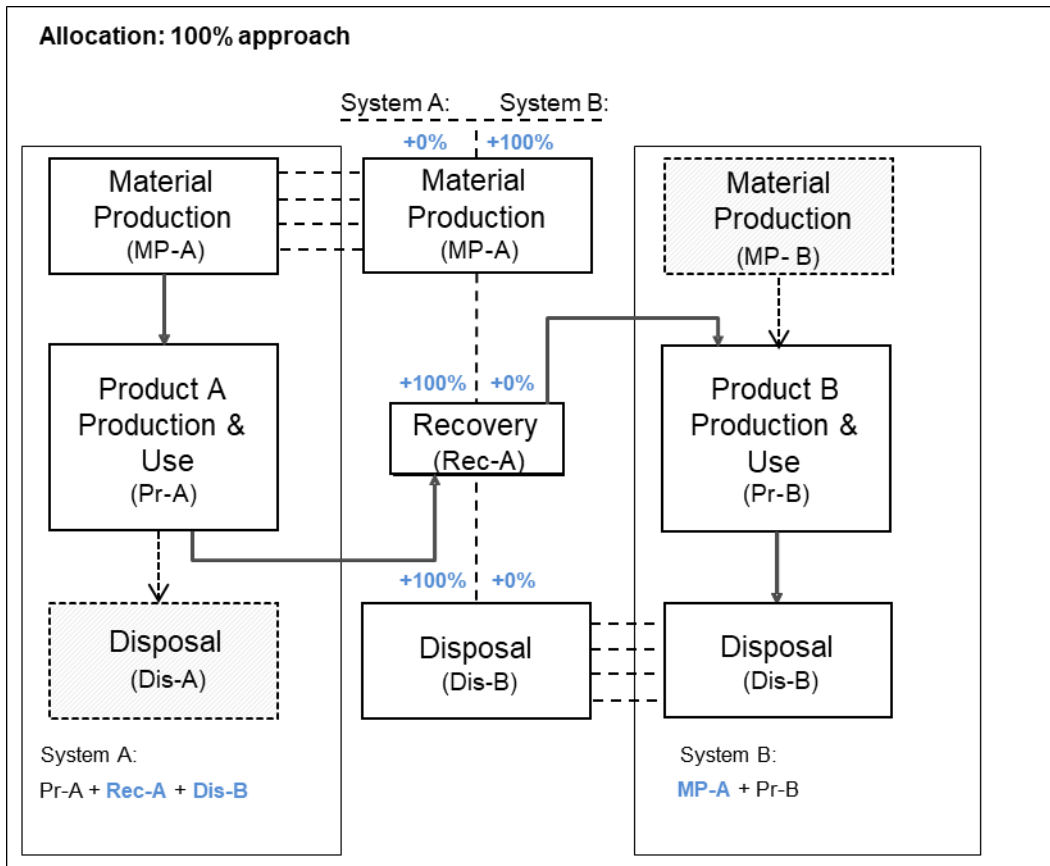


Figure 8: Principles of 100% allocation (schematic flow chart)¹

Allocation with the 100% method (Figure 8)

In this method, the principal rule is applied that ‘system A’ gets all benefits for displacing the virgin material and the involved production process ‘MP-B’. At the same time, all burdens for producing the secondary raw material via ‘Rec-A’ are assigned to ‘system A’. The same is valid for thermal recovery. All benefits and burdens for displacing energy production are allocated to ‘system A’. In addition, also the burdens that are generated by waste treatment of ‘product B’ in ‘Dis-B’ is charged to ‘system A’, whereas the waste treatment of ‘product A’ is avoided and thus charged neither to ‘system A’ nor to ‘system B’.

If recycled material is used in the assessed system, the perspective of ‘system B’ applies. The burdens associated with the production process ‘MP-A’ are then allocated to ‘System B’ (otherwise the mass balance rule would be violated). However, ‘system B’ is not charged with burdens related to ‘Rec’ as the burdens are already accounted for in ‘system A’. At the same time, ‘Dis-B’ is not charged to ‘system B’ (again a requirement of the mass balance rule), as it is already assigned to ‘system A’.

Example 1 (‘system A’), virgin beverage carton which is recycled or thermally recovered after its use: All burdens from recycling and recovery processes are allocated to the

¹ shaded boxes are avoided processes

regarded beverage carton system. Also the benefits from replacing virgin materials or grid energy are fully allocated to the regarded system.

Example 2 ('system B'), PET bottle containing recycled PET (rPET): All burdens from recycling of the used rPET are allocated to the preceding system. Also the benefits from replacing virgin materials are allocated to the preceding system.

The application of the allocation 100% is considered as a conservative approach from the view of the beverage and liquid food carton. It means that a comparatively unfavourable case for the beverage and liquid food cartons is chosen. The plastic and refillable glass bottles benefit more from accounting of 100 % material credits due to the much higher burdens of their avoided primary material production, compared to the production of LPB. The allocation factor of 100 % is expected to lead to higher benefits for plastic and refillable glass bottles.

Following the ISO standard's recommendation on subjective choices, the 50% and 100% allocation methods are applied equally in this study. Conclusions in terms of comparing results between packaging systems are only drawn if they apply to both allocation methods.

General notes regarding Figure 6 to Figure 8

The diagrams are intended to support a general understanding of the allocation process and for that reason, they are strongly simplified. The diagrams serve

- to illustrate the difference between the 50% allocation method and the 100% allocation method
- to show which processes are allocated:
 - primary material production
 - recycling and recovery processes
 - waste treatment of final residues

However, within the study the actual situation is modelled based on certain key parameters, for example the actual recycling flow and the actual recycling efficiency (Table 28) as well as the actual substituted material including different substitution factors.

The allocation of final waste treatment is consistent with UBA LCA methodology [UBA 2000] and [UBA 2016] and additionally this approach – beyond the UBA methodology – is also in accordance with [ISO 14044].

For simplification some aspects are not explicitly documented in the mentioned diagrams, among them the following:

- Material losses occur in both 'systems A and B', but are not shown in the diagrams. These losses are of course taken into account in the calculations; their disposal is included within the respective systems.
- Hence, not all material flows from 'system A' are passed on to 'system B', as the simplified material flow diagrams may imply. Consequently, only the effectively recycled and recovered material's life cycle steps are allocated between 'systems A and B'.

- The diagrams do not show the individual process steps relevant for the waste material flow out of 'packaging system A', which is sorted as residual waste, including the respective final waste treatment.
- For simplification, a substitution factor of 1 underlies the diagrams. However, in the real calculations smaller values are used where appropriate. For example if a material's properties after recycling are different from those of the primary material it replaces, this translates to a loss in material quality. A substitution factor < 1 accounts for such effects. For further details regarding substitution factors please see subsection 'Application of allocation rules'.

Application of allocation rules

The allocation factors have been applied on a mass basis (i.e. the environmental burdens of the recycling process are charged with the total burdens multiplied by the allocation factor) and where appropriate have been combined with substitution factors. The substitution factor indicates what amount of the secondary material substitutes for a certain amount of primary material. For example, a substitution factor of 0.8 means that 1 kg of recycled (secondary) material replaces 0.8 kg of primary material and receives a corresponding credit. With this, a substitution factor < 1 also accounts for so-called 'down-cycling' effects, which describe a recycling process in which waste materials are converted into new materials of lesser quality.

The substitution factors used in the current LCA study to calculate the credits for recycled materials provided for consecutive (down-stream) uses are based on expert judgments from German waste sorting operator "Der Grüne Punkt – Duales System Deutschland GmbH" from the year 2003 [DSD 2003]. The substitution factor for PET from bottles has been raised to 1.0 since that date, as technical advancements made a bottle-to-bottle recycling process possible. Recycled granulate from PET bottles containing PA as barrier material has a lower quality than granulate from PET bottles without PA. Therefore, the substitution factor for recycled PET from PET bottles containing PA is reduced from 1 to 0.9. For the other substitution factors no newer data is available. The substitution factors apply to the secondary materials after the recycling processes with their production losses (see [section 3.13](#)).

- Paper fibres
 - from LPB (carton-based primary packaging): 0.9
 - in cardboard trays (secondary packaging): 0.9
- LDPE from foils: 0.94
- PET in bottles (bottle-to-bottle recycling): 1.0
- HDPE: 0.8
- Glass from bottles: 1
- Steel: 1 (substitution of raw iron)

1.7.2 Biogenic carbon

Renewable materials like paper fibres or plant-based plastics originate from renewable biomass that absorbs carbon from the air. The growth of biomass reduces the amount of CO₂ in the atmosphere. In this study, the fixation of CO₂ by the plants is referred as CO₂ uptake and the (re-)emission of CO₂ at the material's end of life is referred as CO₂ regenerative (CO₂ reg.).

Application and allocation

At the impact assessment level, it must be decided how to model and calculate the uptake and emissions of regenerative CO₂. In the present study, the non-fossil CO₂ has been included at two points in the model, its uptake during the plant growth phase attributed with negative global warming potential (GWP) values and the corresponding re-emissions at end of life with positive ones. In this study regenerative CO₂ is treated in the same way as other resources and emissions and is therefore subject to the same allocation rules as other resources and emissions. According to §21 of the German packaging law [VerpackG 2021] the following practices in packaging production shall be promoted:

- Use of recycled content in packaging systems
- Recyclability of packaging systems
- Use of renewable resources in packaging systems

In the view of the authors it is important that the environmental benefits of all of these practices are made visible in the results of LCA.

The first two practices are considered by the choice of the allocation factor 50% for system-related allocation as one of the two allocation approaches equally applied in this study. As described in [section 1.7.1](#) the application of the allocation 50% shows benefits for the use of recycled content in packaging systems as well as their recycling. In order to not restrain the recyclability of packaging systems and in order to also promote the use of renewable resources a convention in this study is made, that implies that the CO₂ uptake is not considered in credited materials or energy.

The application of the CO₂ uptake in credits would reduce the CO₂ uptake of assessed packaging systems containing regenerative materials by the amount of CO₂ which has been absorbed from the atmosphere by the substituted processes. The selection of substituted processes is based on the current market situation within the addressed geographic scope. Regarding energy credits from the incineration of regenerative materials, the substituted processes are the production of electrical and thermal energy. These to a high extent fossil based processes do absorb negligibly small amounts of regenerative CO₂. Therefore, almost no CO₂ uptake would be attributed to the substituted processes. The benefit of the CO₂ uptake of the assessed packaging systems containing regenerative materials would not be reduced.

On the other hand, if packaging systems containing regenerative materials are materially recycled, and if the substituted processes for the material credits are the production of other primary regenerative materials, the absorption of CO₂ from the atmosphere would

be substituted. Therefore, the benefits of the CO₂ uptake of assessed packaging systems would be reduced by the CO₂ uptake of the substituted processes.

Using the example of mainly regenerative materials like liquid packaging board, the application of the CO₂ uptake in credits would deter from recycling efforts of packaging containing regenerative materials as incineration instead of recycling would lead to lower LCA results for ‘Climate Change’.

The authors of this study acknowledge that with the application of this convention only the producers of products containing primary regenerative materials benefit. This is considered appropriate as these producers are responsible for sourcing renewable materials in the first place. Producers of products which merely contain regenerative materials sourced from recycling processes would not be benefited. As no primary packaging which contain recycled regenerative materials are analysed in this study, this approach of not considering CO₂ uptake in credits is seen suitable within this study. Incineration plants that burn used packaging for energy recovery also do not get a benefit for incinerating plant based materials. This is considered appropriate, because in contrast to the producer of the packaging, the operator running an incineration plant does not deliberately choose plant-based materials for incineration. This convention does also comply with ISO 14040/14044 as the mass balance of all inputs and outputs regarding regenerative CO₂ of ‘system A’ and ‘system B’ together stays the same.

The carbon balance is shown exemplarily for the TB Edge plant-based OSO 30 plant-based 1000 mL in the following table.

Table 3: Carbon balance for TB Edge plant-based OSO 30 plant-based 1000 mL (per functional unit)

Biogenic carbon balance	CO ₂ uptake	Carbon in CO ₂ uptake	Carbon in biog. CO ₂ and CH ₄ emissions		Carbon sequestration in landfills	Carbon emissions and sequestration
Product systems	TB Edge plant-based OSO 30 plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	Subsequent system (incineration with energy recovery)	TB Edge plant-based OSO 30 plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL + Subsequent system (incineration with energy recovery)
Allocation factor 50	59.75 kg CO ₂	16.30 kg C	8.15 kg C	8.15 kg C	0.00 kg C	16.30 kg C
Allocation factor 100	59.75 kg CO ₂	16.30 kg C	16.30 kg C	0.00 kg C	0.00 kg C	16.30 kg C

As in Germany no packaging waste is disposed on landfills there are no CH₄ emissions from biogenic carbon, as well as no sequestration of biogenic carbon.

As described in [section 1.7.1](#) system-related allocation is applied in this study for thermal recovery processes like MSWI with energy recovery and incineration in cement kilns. Therefore, system-related allocation applies for the emissions of CO₂ reg. from thermal recovery of regenerative materials. In case of allocation 50%, half of the CO₂ reg. emissions are attributed to the examined system and half of the CO₂ reg. emissions are attributed to the following system, for example the MSWI plants with thermal recovery.

Together with the full CO₂ uptake for the assessed system and the non-consideration of the CO₂ uptake in credits the mass balance of all regenerative carbon is the same after and before allocation following ISO 14040 and 14044. Regarding the LCA results for 'Climate Change', packaging systems containing regenerative materials benefit if the system-related allocation 50% is applied for recovery processes. When applying the allocation 50% approach the benefit regarding the LCA results for 'Climate Change' of packaging systems containing regenerative materials can promote the increase of use of regenerative materials in packaging system.

In case of applying allocation 100% for recovery processes all the CO₂ reg. emissions are attributed to the assessed system. Therefore, in this case the extra benefit for 'Climate Change' results, packaging systems with primary regenerative materials receive by only getting allocated 50% of the CO₂ reg. emissions is gone.

As these decisions and conventions applied in this study are partly based on political reasons, it is especially important to consider the results of the 100% allocation approach equally alongside those of the 50% allocation approach. All conclusions in this study will always be based on the outcomes of both assessments, the 50% allocation and 100% allocation approach.

1.8 Environmental Impact Assessment

The environmental impact assessment is intended to increase the understanding of the potential environmental impacts for a product system throughout the whole life cycle [ISO 14040 and 14044].

To assess the environmental performance of the examined packaging systems, this local study report only includes the environmental impact category 'Climate Change'. Related information as well as references of applied models is provided below. In this study, 'Climate Change' is applied as a midpoint category. Midpoint indicators represent potential primary environmental impacts and are located between emission and potential harmful effect. This means that the potential damage caused by the substances is not taken into account.

To get an indication on how the packaging systems examined in this study perform in other environmental impact categories like for example Acidification or Eutrophication one can also refer to the result of the European baseline study. Of course, the packaging systems examined in the present study are not exactly identical to the ones in the European baseline study. Also, some background parameters are different due to the different geographical scopes. For this reason, the results of the European baseline study can only be of indicative nature regarding the full set of environmental impact categories.

The results of the impact category 'Climate Change' are expressed by the category indicator Global Warming Potential (GWP), which represents one environmental impact per functional unit. The category indicator results also do not quantify actual environmental damage. [Table 4](#) shows how the terms are applied in this study.

Table 4: Applied terms of ISO 14044 for the environmental impact assessment using the impact category Climate Change as example

Term	Example
Impact category	Climate Change
Life cycle inventory (LCI) results	Amount of climate active gases per functional unit
Characterisation model	Global Warming Potential for a 100-year time period based on IPCC 2013
Category indicator	Global Warming Potential (GWP)
Characterisation factor	Global Warming Potential GWP_i [kg CO ₂ eq. / kg emission i]
Category indicator result	Kilograms of CO ₂ -equivalents per functional unit

Table 5 includes examples, which give an overview of elementary flows for ‘Climate Change’.

Table 5: Examples of elementary flows and their classification into the impact category

Impact category	Elementary Flows								Unit
Climate Change	CO ₂ *	CH ₄ **	N ₂ O	C ₂ F ₂ H ₄	CF ₄	CCl ₄	C ₂ F ₆	R22	kg CO ₂ -e
* CO ₂ fossil and biogenic / ** CH ₄ fossil and CH ₄ biogenic included									

Climate Change addresses the impact of anthropogenic emissions on the radiative forcing of the atmosphere. Greenhouse gas emissions enhance the radiative forcing, resulting in an increase of the earth’s temperature. The characterisation factors applied here are based on the category indicator GWP for a 100-year time horizon [IPCC 2013]. In reference to the functional unit (FU), the category indicator results, GWP results, are expressed as kg CO₂-e per functional unit.

Note on biogenic carbon: At the impact assessment level, it must be decided how to model and calculate CO₂-based GWP. In the present study the non-fossil CO₂ has been included at two points in the model, its uptake during the plant growth phase attributed with negative GWP values and the corresponding re-emissions at end of life with positive ones. For more details see [section 1.7.2](#).

2 Packaging systems and scenarios

In general terms, packaging systems can be defined based on the primary, secondary and tertiary packaging elements they are made up of. The composition of each of these individual packaging elements and their components' masses depend strongly on the function they are designed to fulfil, i.e. on requirements of the filler and retailer as well as the distribution of the packaged product to the point-of-sale. The main function of the examined primary packaging is the packaging and protection of beverages and liquid food. The packaging protects the filled products' freshness, flavours and nutritional qualities during transportation, whilst on sale and at home. All examined packaging systems are considered to achieve this.

All packaging systems examined in this study are presented in the following [section \(2.1\)](#), including the applied end-of-life options ([Section 2.3](#)). [Section 0](#) provides information on all assessed scenarios, including those chosen for sensitivity analyses.

2.1 Selection of packaging systems

The focuses of this study are the beverage and liquid food cartons produced by Tetra Pak for which this study aims to provide knowledge of their strengths and weaknesses regarding Climate Change. The beverage and liquid food cartons are compared with corresponding competing packaging systems.

The choice of beverage and liquid food cartons has been made by Tetra Pak based on market relevance. Cartons of different volumes for the packaging of dairy (chilled and ambient), JNSD (ambient) and liquid food (ambient) have been chosen for examination. For each of these segments typical competing packaging systems have been identified by Tetra Pak which represent the main competing packaging types in Germany for each segment. The representativeness as a main competing packaging type was determined by its market relevance as well as by the importance of the packaging systems in the perspective of Tetra Pak. This includes the importance of competing packaging systems for customers of Tetra Pak. The positioning properties of the products into the market have been taken into account for ensuring the comparability of the analysed packaging systems. Details are shown in [Table 6](#).

Table 6: Selection of competing packaging systems

segment	competing packaging system	reason for selection
DAIRY, Family Pack, Chilled	PET bottle 2 1000 mL	PET bottles for dairy chilled are almost exclusively used for retail private labels. The selected bottle is from one of the leading retailers in Germany
	refillable glass bottle 1 1000 mL	The main brand for refillable glass with fresh milk in Germany.
Dairy, Family Pack, Ambient	PET bottle 1 1000 mL	The main brand in Germany in this segment.
JNSD, Family Pack, Ambient	PET bottle 3 1000 mL	The main brand in Germany in this segment.
	refillable glass bottle 2 1000 mL	The main brand of juice for refillable glass in Germany filled in the standard VdF ¹ bottle.
JNSD, Portion Pack, Ambient	PET bottle 4 50% rPET 330 mL	PET bottles for JNSD portion packs are almost exclusively used for retail private labels. The selected bottle is from one of the leading retailers representing an advanced use of recycled content in Germany.
	Pouch 1 200 mL	The market leader of still drinks in pouches.
Flavoured water, Family Pack, Ambient	PET bottle 5 1000 mL	The main brand in Germany in this segment.
Unflavoured water, Portion Pack, Ambient	PET bottle 6 100% rPET 500 mL	The main non-private label brand in Germany in this segment. The packaging was switched from PET to rPET in 2021.
	PET bottle 7 500 mL	Retail private labels have the strongest market position in water portion packs and exclusively use PET bottles. The selected bottle is from one of the leading retailers.
Liquid Food, Portion Pack, Ambient	Metal Can 1 375 ml	A high market share in private label food.
	single use glass Jar 1 350 ml	A high market share in branded glass liquid food.
	Pouch 2 250 mL	A high market share in private label prepared meals in pouch.

The following tables show which beverage and liquid food cartons are compared with the selected competing systems. The comparison will be conducted as follows:

- Only packaging systems in the same segment are compared to each other
- Chilled and ambient beverage packaging systems are not compared to each other.

¹ Verband der deutschen Fruchtsaft-Industrie e.V. (Association of the German Fruit Juice Industry)

Table 7: List of Tetra Pak beverage cartons in segment **DAIRY, Family Pack, Chilled** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Rex (TR) Arch TwistCap OSO 34 1000 mL	C	Germany	PET bottle 2 1000 mL	C	Germany
			Refillable glass bottle 1 1000 mL	C	Germany
Tetra Rex (TR) Arch plant-based TwistCap OSO 34 plant-based 1000 mL	C	Germany	PET bottle 2 1000 mL	C	Germany
			Refillable glass bottle 1 1000 mL	C	Germany
Tetra Top (TT) Carton bottle plant-based C38 plant-based 1000 mL	C	Germany	PET bottle 2 1000 mL	C	Germany
			Refillable glass bottle 1 1000 mL	C	Germany
Tetra Brik (TB) Edge plant-based OSO 30 plant-based 1000 mL	C	Germany	PET bottle 2 1000 mL	C	Germany
			Refillable glass bottle 1 1000 mL	C	Germany

Table 8: List of Tetra Pak beverage cartons in segment **DAIRY, Family Pack, Ambient** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Brik Aseptic (TBA) Edge WingCap 1000 mL	A	Germany	PET bottle 1 1000 mL	A	Germany
Tetra Brik Aseptic (TBA) Edge plant-based WingCap plant-based 1000 mL	A	Germany	PET bottle 1 1000 mL	A	Germany
Tetra Brik Aseptic (TBA) Ultra Edge plant-based WingCap plant-based 1000 mL	A	Germany	PET bottle 1 1000 mL	A	Germany

Table 9: List of Tetra Pak beverage cartons in segment **JNSD, Family Pack, Ambient** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aseptic (TPA) Square (Light-Spec) HeliCap 27 1000 mL	A	Germany	PET bottle 3 1000 mL	A	Germany
			Refillable glass bottle 2 1000 mL	A	Germany
Tetra Prisma Aseptic (TPA) Square (Light-Spec) plant-based HeliCap 27 plant-based 1000 mL	A	Germany	PET bottle 3 1000 mL	A	Germany
			Refillable glass bottle 2 1000 mL	A	Germany
Tetra Stelo Aseptic (TSA) WingCap 1000 mL	A	Germany	PET bottle 3 1000 mL	A	Germany
			Refillable glass bottle 2 1000 mL	A	Germany
Tetra Stelo Aseptic (TSA) plant-based WingCap plant-based 1000 mL	A	Germany	PET bottle 3 1000 mL	A	Germany
			Refillable glass bottle 2 1000 mL	A	Germany

Table 10: List of Tetra Pak beverage cartons in segment **JNSD, Portion Pack, Ambient** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aseptic (TPA) Square DreamCap 26 500 mL	A	Germany	PET bottle 4 50% rPET 330 mL	A	Germany
			Pouch 1 200 mL	A	Germany
Tetra Prisma Aseptic (TPA) Square plant-based DreamCap 26 plant-based 500 mL	A	Germany	PET bottle 4 50% rPET 330 mL	A	Germany
			Pouch 1 200 mL	A	Germany
Tetra Wedge Aseptic (TWA) paper straw 200 mL	A	Germany	PET bottle 4 50% rPET 330 mL	A	Germany
			Pouch 1 200 mL	A	Germany

Table 11: List of Tetra Pak beverage cartons in segment **Flavoured WATER, Family Pack, Ambient** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aseptic (TPA) Square plant-based HeliCap 27 plant-based 1000 mL	A	Germany	PET bottle 5 1000 mL	A	Germany

Table 12: List of Tetra Pak liquid food cartons in segment **unflavoured WATER, Portion Pack, Ambient** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aseptic (TPA) Edge plant-based DreamCap 26 plant-based 500 mL	A	Germany	PET bottle 6 100% rPET 500 mL	A	Germany
			PET bottle 7 500 mL	A	Germany
Tetra Top Ambient Distribution (TTAD) plant-based C38 plant-based 500 mL	A	Germany	PET bottle 6 100% rPET 500 mL	A	Germany
			PET bottle 7 500 mL	A	Germany

Table 13: List of Tetra Pak liquid food cartons in segment Liquid Food, Portion Pack, Ambient and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Recart 390 ml	A	Germany	Metal Can 1 375 ml	A	Germany
			Single use glass Jar 1 350 ml	A	Germany
			Pouch 2 250 mL	A	Germany

2.2 Packaging specifications

Specifications of beverage and liquid food carton packaging systems are listed in Table 14 to Table 20 and were provided by Tetra Pak. In Tetra Pak's internal database typical specifications of all primary packages sold are registered. The specifications of individual packages of one single carton system may vary to a small degree over different production batches or production sites. To get the final specifications per beverage and liquid food carton type the exact specifications of different batches were averaged taking into consideration the production volumes of each production batch. For confidentiality in case of the polymers used in the beverage and liquid food carton systems no differentiations to specific polymers are shown in the tables. The calculations are calculated with the specific shares of each polymer used. These are disclosed to the critical review panel. Closures can have different colours. To take these into account a standard share of 2% Titanium dioxide (TiO₂) is applied as a colour medium.

Data on secondary and tertiary packaging for beverage and liquid food cartons was also provided by Tetra Pak from its internal packaging system model. The data is periodically updated and the most recent data of 2020 is used in this LCA.

Specifications of the competing packaging types that have been identified as relevant in the examined segments are listed in Table 21 to Table 27. They were determined by ifeu in 2020 based on specific samples collected by Tetra Pak on the German market. For each packaging system three primary packaging samples were assessed by ifeu regarding the type of materials and their quantified weights. Specifications were determined by weighting the separate parts of the packaging systems. Materials were classified by the declaration on the packaging parts or by assessing the density with floating tests. Barrier material included in the bottle bodies was identified as described in the following: All opaque bottles are assumed to contain a share of 5% Titanium dioxide (TiO₂) as a colour medium. Additionally, all opaque bottles were cut open and checked for a black layer. If there was a black layer, a 2.5% content of carbon black as barrier material was assumed. These assumptions were affirmed by experts for plastic packaging systems at Tetra Pak and ifeu. Clear ambient JNSD bottles are assumed to contain 8% of PA as barrier material (average of communicated PA content of three bottle plastic producers¹). Specifications of the pouch 1 are based on Capri Sun AG (2021). Specifications of pouch 2 are based on laboratory analyses of similar food pouches. Specifications of secondary packaging systems were determined by ifeu through weighting of one sample per packaging systems. Material types of secondary packaging system were distinguished between cardboard and LDPE foil. Pallet configuration of competing packaging systems was calculated with the online tool www.onpallet.com. Euro pallets and DHP pallets with a loading height of 1400 mm are the base for the calculation. The weight of shrink foil per pallets is assumed to be the same as for pallets with beverage cartons. Pallet configuration depends on the size of the bottles as well as the amount and arrangement of bottles in each secondary packaging.

¹ <http://www.mgc.co.jp/eng/products/nop/nmxd6/bottle.html>
http://www.fosterpolymers.com/downloads/docs/mx/MX-Nylon_properties.pdf
<http://www51.honeywell.com/sm/aegis/products-n2/aegis-ox.html>

Regarding the included refillable glass bottles use cycles of 10 for Dairy Family Pack Chilled and 27 for JNSD Family Pack Ambient are applied based on ifeu (2020b). These were determined in the separate study Kauertz und Heinisch (2017). The methodologies applied are the combination of the sales volume of filled bottles and the volume of newly bought bottles by the fillers as well as interviews with bottle producers.

These specifications are used to calculate the base scenarios for all packaging systems.

2.2.1 Specifications of beverage and liquid food carton systems

Table 14: Packaging specifications for assessed carton systems for the packaging of Dairy Family Packs (chilled)

	Unit	DAIRY FAMILY PACK CHILLED			
		TR Arch TwistCap OSO 34	TR Arch TwistCap OSO 34 plant-based	TT plant-based C38 plant-based	TB Edge plant-based OSO 30 plant-based
volume	mL	1000	1000	1000	1000
geographic Scope	-	Germany	Germany	Germany	Germany
chilled / ambient	-	chilled	chilled	chilled	chilled
primary packaging (sum) ¹	g	28.8	28.8	30.9	31.8
primary packaging (per FU)	g/FU	28800	28800	30900	31800
composite material (sleeve)	g	26.2	26.2	23.0	29.0
- liquid packaging board	g	22.7	22.7	19.5	24.0
- polymer	g	3.5		1.4	2.4
- plant-based polymer	g		3.5	2.1	2.6
top	g			5.0	
- polymer				0.6	
- plant-based polymer				4.4	
closure	g	2.6	2.6	2.9	2.8
- polymer	g	2.6			
- plant-based polymer	g		2.6	2.9	2.8
secondary packaging (sum) ²	g	120	120	82	103
tray/box (corr.cardboard)	g	120	120	82	103
tertiary packaging (sum) ³	g	25177	25177	25177	25177
pallet	g	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO
number of use cycles	-	25	25	25	25
stretch foil (per pallet) (LDPE)	g	176	176	176	176
pallet configuration					
cartons per tray	pc	10	10	10	12
trays / packs per layer	pc	15	15	15	13
layers per pallet	pc	5	5	4	5
cartons per pallet	pc	750	750	600	780

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 15: Packaging specifications for assessed carton systems for the packaging of Dairy Family Pack (ambient)

		DAIRY FAMILY PACK AMBIENT		
	Unit	TBA Edge WingCap	TBA Edge plant-based WingCap plant-based	TBA Ultra Edge plant-based WingCap plant-based
volume	mL	1000	1000	1000
geographic Scope	-	Germany	Germany	Germany
chilled / ambient	-	ambient	ambient	ambient
primary packaging (sum) ¹	g	31.6	31.6	31.8
primary packaging (per FU)	g/FU	31600	31600	31800
composite material (sleeve)	g	28.6	28.6	28.8
- liquid packaging board	g	22.3	22.3	22.4
- polymer	g	4.9	2.2	2.3
- plant-based polymer	g		2.7	2.7
- aluminium	g	1.4	1.4	1.4
closure	g	3.0	3.0	3.0
- polymer	g	3.0		
- plant-based polymer	g		3.0	3.0
secondary packaging (sum) ²	g	102	102	115
tray/box (corr.cardboard)	g	102	102	115
tertiary packaging (sum) ³	g	25177	25177	25177
pallet	g	25000	25000	25000
type of pallet	-	EURO	EURO	EURO
number of use cycles	-	25	25	25
stretch foil (per pallet) (LDPE)	g	176	176	176
pallet configuration				
cartons per tray	pc	12	12	12
trays / packs per layer	pc	13	13	15
layers per pallet	pc	5	5	5
cartons per pallet	pc	780	780	900

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 16: Packaging specifications for assessed carton systems for the packaging of JNSD Family Packs (ambient)

	Unit	JNSD FAMILY PACK AMBIENT			
		TPA Square Light-Spec HeliCap27	TPA Square Light-Spec plant-based HeliCap27 plant-based	TSA WingCap	TSA plant-based WingCap plant-based
volume	mL	1000	1000	1000	1000
geographic Scope	-	Germany	Germany	Germany	Germany
chilled / ambient	-	ambient	ambient	ambient	ambient
primary packaging (sum)¹	g	37.1	37.0	33.5	33.5
primary packaging (per FU)	g/FU	37100	37000	33500	33500
composite material (sleeve)	g	33.2	33.2	30.5	30.5
- liquid packaging board	g	23.8	23.8	23.4	23.4
- polymer	g	7.5	2.1	5.8	2.9
- plant-based polymer	g		5.4		2.9
- aluminium	g	1.9	1.9	1.3	1.3
closure	g	3.9	3.9	3.0	3.0
- polymer	g	3.9	2.1	3.0	
- plant-based polymer	g		1.8		3.0
secondary packaging (sum)²	g	160	160	154	154
tray/box (corr. cardboard)	g	160	160	154	154
tertiary packaging (sum)³	g	25177	25177	25177	25177
pallet	g	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO
number of use cycles	-	25	25	25	25
stretch foil (per pallet) (LDPE)	g	176	176	176	176
pallet configuration					
cartons per tray	pc	12	12	12	12
trays / packs per layer	pc	12	12	12	12
layers per pallet	pc	5	5	5	5
cartons per pallet	pc	720	720	720	720

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 17: Packaging specifications for assessed carton systems for the packaging of JNSD Portion Packs (ambient)

JNSD PORTION PACK AMBIENT				
	Unit	TPA Square DreamCap 26	TPA Square plant-based DreamCap26 plant-based	TWA Paper Straw
volume	mL	330	330	200
geographic Scope	-	Germany	Germany	Germany
chilled / ambient	-	ambient	ambient	ambient
primary packaging (sum) ¹	g	16.7	16.6	7.5
primary packaging (per FU)	g/FU	50606	50303	37500
composite material (sleeve)	g	13.0	13.0	6.9
- liquid packaging board	g	9.0	9.0	4.6
- polymer	g	3.1	1.5	1.8
- plant-based polymer	g		1.6	
- aluminium	g	0.9	0.9	0.5
straw	g			0.6
- paper				0.5
- polymer (foil)				0.1
closure	g	3.7	3.7	
- polymer	g	3.7	2.1	
- plant-based polymer	g		1.6	
secondary packaging (sum) ²	g	66	66	52
tray/box (corr. cardboard)	g	66	66	52
tertiary packaging (sum) ³	g	25177	25177	25177
pallet	g	25000	25000	25000
type of pallet	-	EURO	EURO	EURO
number of use cycles	-	25	25	25
stretch foil (per pallet) (LDPE)	g	176	176	176
pallet configuration				
cartons per tray	pc	12	12	24
trays / packs per layer	pc	19	19	12
layers per pallet	pc	7	7	6
cartons per pallet	pc	1596	1596	1728

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 18: Packaging specifications for assessed carton systems for the *packaging of Flavoured WATER Family Packs (ambient)*

FLAVOURED WATER FAMILY PACK AMBIENT		
	Unit	TPA Square HC27 plant-based 1000 Germany ambient
volume	mL	
geographic Scope	-	
chilled / ambient	-	
primary packaging (sum) ¹	g	38.2
primary packaging (per FU)	g/FU	38200
composite material (sleeve)	g	34.3
- liquid packaging board	g	25.5
- polymer	g	3.1
- plant-based polymer	g	3.8
- aluminium	g	1.9
closure	g	3.9
- polymer	g	2.1
- plant-based polymer	g	1.8
secondary packaging (sum) ²	g	160
tray/box (corr. cardboard)	g	160
tertiary packaging (sum) ³	g	25177
pallet	g	25000
type of pallet	-	EURO
number of use cycles	-	25
stretch foil (per pallet) (LDPE)	g	176
pallet configuration		
cartons per tray	pc	12
trays / packs per layer	pc	12
layers per pallet	pc	5
cartons per pallet	pc	720

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 19: Packaging specifications for assessed carton systems for the packaging of Unflavoured Water Portion Packs (ambient)

	Unit	UNFLAVOURED WATER PORTION PACK AMBIENT	
		TPA Edge DreamCap26 plant-based	TTAD plant-based C38 plant-based
volume	mL	500	500
geographic Scope	-	Germany	Germany
chilled / ambient	-	ambient	ambient
primary packaging (sum)¹	g	22.0	21.3
primary packaging (per FU)	g/FU	44000	42600
composite material (sleeve)	g	18.3	14.5
- liquid packaging board	g	13.1	11.5
- polymer	g	2.0	0.9
- plant-based polymer	g	2.0	1.4
- aluminium	g	1.2	0.7
top	g		3.9
- polymer	g		0.8
- plant-based polymer	g		3.1
closure	g	3.7	2.9
- polymer	g	2.1	
- plant-based polymer	g	1.6	2.9
secondary packaging (sum)²	g	96	52
tray/box (corr. cardboard)	g	96	52
tertiary packaging (sum)³	g	25177	25177
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles	-	25	25
stretch foil (per pallet) (LDPE)	g	176	176
pallet configuration			
cartons per tray	pc	8	8
trays / packs per layer	pc	20	20
layers per pallet	pc	8	8
cartons per pallet	pc	1280	1280

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 20: Packaging specifications for assessed carton systems for the packaging of Liquid Food Portion Packs (ambient)

LIQUID FOOD PORTION PACK AMBIENT		
	Unit	Tetra Recart
volume	mL	390
geographic Scope	-	Germany
chilled / ambient	-	ambient
primary packaging (sum) ¹	g	17.7
primary packaging (per FU)	g/FU	45385
composite material (sleeve)	g	17.7
- liquid packaging board	g	12.6
- polymer	g	4.3
- aluminium	g	0.8
secondary packaging (sum) ²	g	58
tray/box (corr.cardboard)	g	58
tertiary packaging (sum) ³	g	25177
pallet	g	25000
type of pallet	-	EURO
number of use cycles	-	25
stretch foil (per pallet) (LDPE)	g	176
pallet configuration		
cartons per tray	pc	12
trays / packs per layer	pc	17
layers per pallet	pc	9
cartons per pallet	pc	1836

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

2.2.2 Specifications of alternative packaging systems

Table 21: Packaging specifications for assessed alternative systems in the segment Dairy Family Pack (chilled)

		DAIRY FAMILY PACK CHILLED	
	Unit	PET bottle 2	Refillable glass bottle 1
volume	ml	1000	1000
geographic scope	-	Germany	Germany
chilled / ambient	-	chilled	chilled
clear / opaque	-	clear	clear
primary packaging (sum)¹	g	32.74	394.04
primary packaging (per FU)	g/FU	32740	394040
bottle	g	27.24	388.21
- PET	g	27.24	
- glass	g		388.21
- number of use cycles bottle		1	10
label	g	2.58	1.5
- paper	g	2.58	1.5
closure	g	2.92	4.33
- HDPE	g	2.92	
- tin plate	g		4.33
secondary packaging (sum)²	g	13.20	1100.00
- shrink pack (LDPE)	g	13.20	
- crate	g		1100.00
- number of use cycles crate			100
tertiary packaging (sum)³	g	9680	24018
pallet	g	9500	24000
type of pallet	-	DHP	EURO
number of use cycles		25	25
stretch foil (per pallet) (LDPE)	g	180	18
pallet configuration			
bottles per sec. packaging	pc	6	6
sec. packaging units per layer	pc	10	16
layers per pallet	pc	5	5
bottles per pallet	pc	300	480

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 22: Packaging specifications for assessed alternative systems in the segment Dairy Family Pack (ambient)

		DAIRY FAMILY PACK AMBIENT
	Unit	PET bottle 1
volume	ml	1000
geographic scope	-	Germany
chilled / ambient	-	chilled
clear / opaque	-	opaque
primary packaging (sum) ¹	g	35.0
primary packaging (per FU)	g/FU	35000
bottle	g	28.21
- PET	g	26.09
- TiO ₂	g	1.41
- carbon black	g	0.71
label	g	3.42
- PP	g	3.42
closure	g	3.37
- HDPE	g	3.37
secondary packaging (sum) ²	g	13.20
- shrink pack (LDPE)	g	13.20
tertiary packaging (sum) ³	g	9680
pallet	g	9500
type of pallet	-	DHP
number of use cycles		25
stretch foil (per pallet) (LDPE)	g	180
pallet configuration		
bottles per sec. packaging	pc	6
sec. packaging units per layer	pc	12
layers per pallet	pc	5
bottles per pallet	pc	360

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 23: Packaging specifications for assessed alternative systems in the segment JNSD Family Pack (ambient)

		JNSD FAMILY PACK AMBIENT	
	Unit	PET bottle 3	Refillable glass bottle 2
volume	ml	1000	1000
geographic scope	-	Germany	Germany
chilled / ambient	-	ambient	ambient
clear / opaque	-	clear	clear
primary packaging (sum)¹	g	37.06	604.41
primary packaging (per FU)	g/F U	37060	604410
bottle	g	31.84	601.43
- PET	g	29.29	
- glass	g		601.43
- PA	g	2.55	
number of use cycles bottle		1	27
label	g	2.37	1.51
- paper	g	2.37	1.51
closure	g	2.85	1.47
- HDPE	g	2.85	
- aluminium	g		1.47
secondary packaging (sum)²	g	12.49	1040
- shrink pack (LDPE)	g	12.49	
- crate	g		1040
- number of use cycles crate			100
tertiary packaging (sum)³	g	9680	24018
pallet	g	9500	24000
type of pallet	-	DHP	EURO
number of use cycles		25	25
stretch foil (per pallet) (LDPE)	g	180	18
pallet configuration			
bottles per sec. packaging	pc	6	6
sec. packaging units per layer	pc	11	16
layers per pallet	pc	5	4
bottles per pallet	pc	330	384

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 24: Packaging specifications for assessed alternative systems in the segment JNSD Portion Pack (ambient)

JNSD PORTION PACK AMBIENT			
	Unit	PET bottle 4 50% rPET	Pouch 1
volume	ml	330	200
geographic scope	-	Germany	Germany
chilled / ambient	-	ambient	ambient
clear / opaque	-	clear	opaque
primary packaging (sum)¹	g	23.53	4.1
primary packaging (per FU)	g/FU	71303	20500
bottle/can body	g	20.15	3.8
- PET	g	18.54	0.6
- LDPE	g		2.45
- PA	g	1.61	
- aluminium	g		0.75
- recycled PET content	%	50.0	
label	g	0.33	
- PP	g	0.33	
closure	g	3.05	
- HDPE	g	3.05	
straw	g		0.3
- PP	g		0.3
secondary packaging (sum)²	g	47.35	88.13
- tray/box (corr.cardboard)	g	47.35	88.13
tertiary packaging (sum)³	g	9680	25170
pallet	g	9500	25000
type of pallet	-	DHP	EURO
number of use cycles		25	25
stretch foil (per pallet) (LDPE)	g	180	170
pallet configuration			
bottles per sec. packaging	pc	12	10
sec. packaging units per layer	pc	11	27
layers per pallet	pc	7	9
bottles per pallet	pc	924	2430

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 25: Packaging specifications for assessed alternative systems in the segment *Flavoured Water Family Pack (ambient)*

FLAVOURED WATER FAMILY PACK AMBIENT		
	Unit	PET bottle5
volume	ml	1000
geographic scope	-	Germany
chilled / ambient	-	ambient
clear / opaque	-	clear
primary packaging (sum) ¹	g	35.20
primary packaging (per FU)	g/FU	35200
bottle/can body	g	31.06
- PET	g	31.06
label	g	0.82
- PP	g	0.82
closure	g	3.32
- HDPE	g	3.32
secondary packaging (sum) ²	g	9.59
- shrink pack (LDPE)	g	9.59
tertiary packaging (sum) ³	g	9680
pallet	g	9500
type of pallet	-	DHP
number of use cycles		25
stretch foil (per pallet) (LDPE)	g	180
pallet configuration		
bottles per sec. packaging	pc	6
sec. packaging units per layer	pc	13
layers per pallet	pc	5
bottles per pallet	pc	390

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 26: Packaging specifications for assessed alternative systems in the segment *Unflavoured Water Portion Pack (ambient)*

		UNFLAVOURED WATER PORTION PACK AMBIENT	
	Unit	PET bottle 6 100% rPET	PET bottle 7
volume	ml	500	500
geographic scope	-	Germany	Germany
chilled / ambient	-	ambient	ambient
clear / opaque	-	clear	clear
primary packaging (sum) ¹	g	16.62	15.75
primary packaging (per FU)	g/FU	33240	31500
bottle/can body	g	14.28	13.45
- PET	g	14.28	13.45
- recycled PET content	%	100	
label	g	0.31	0.30
- HDPE	g	0.31	
- PP	g		0.30
closure	g	2.03	2.00
- HDPE	g	2.03	2.00
secondary packaging (sum) ²	g	6.56	4.68
- shrink pack (LDPE)	g	6.56	4.68
tertiary packaging (sum) ³	g	9680	9680
pallet	g	9500	9500
type of pallet	-	DHP	DHP
number of use cycles		25	25
stretch foil (per pallet) (LDPE)	g	180	180
pallet configuration			
bottles per sec. packaging	pc	6	6
sec. packaging units per layer	pc	18	18
layers per pallet	pc	6	6
bottles per pallet	pc	648	648

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

Table 27: Packaging specifications for assessed alternative systems in the segment liquid food (ambient)

LIQUID FOOD AMBIENT				
	Unit	Steel Can 1	Single use glass Jar 1	Pouch 2
volume	ml	375	350	270
geographic scope	-	Germany	Germany	Germany
chilled / ambient	-	ambient	ambient	ambient
clear /opaque	-	opaque	clear	opaque
primary packaging (sum)¹	g	51.61	218.40	8.76
primary packaging (per FU)	g/FU	137627	624000	32444
jar/can/pouch	g	42.19	203.55	8.76
- tin plate	g	42.19		
- glass	g		203.55	
- PP	g			5.35
- PET	g			1.27
- PA	g			1.34
- tie layer	g			0.47
- print	g			0.33
label	g	2.04	1.11	
- paper	g	2.04	1.11	
closure	g	7.38	13.74	
- tin plate	g	7.38	13.74	
secondary packaging (sum)²	g	52.48	39.46	44.39
- shrink pack (LDPE)	g			
- tray/box (corr.cardboard)	g	52.48	39.46	44.39
tertiary packaging (sum)³	g	25170	24018	9680
pallet	g	25000	24000	9500
type of pallet	-	EURO	EURO	DHP
number of use cycles		25	25	25
stretch foil (per pallet) (LDPE)	g	170	18	180
pallet configuration				
pouches/jars/cans per sec. packaging	pc	12	5	6
sec. packaging units per layer	pc	12	20	22
layers per pallet	pc	12	14	7
bottles per pallet	pc	1728	1400	924

¹ per primary packaging unit; ² per secondary packaging unit; ³ per tertiary packaging unit (pallet)

2.3 End-of-life

For each packaging system assessed in the study, the scenarios are modelled and calculated with average recycling rates for post-consumer packaging on the German market. The applied recycling quotas are based on published quotas. The material recycling quotas represent the actual amount of material undergoing a material recycling process after sorting took place. As there is no landfilling of packaging waste (0%) in Germany [EUROSTAT 2020, Nelles et al. 2016] (Table 28), the remaining part of the post-consumer packaging waste passes through the incineration (MSWI). The applied end-of-life quotas and the related references are given in Table 28. As data references preferable local data sources are applied where possible.

The flow charts in Figure 9 - Figure 15 illustrate the applied specified end-of-life model of beverage and liquid food cartons, clear PET bottles deposit (water) and non-deposit (non-water), single use glass jars as well as steel cans. The graphs illustrate only the end of life of single use packaging systems, as the end of life flow of refillable bottles is way smaller because of their multiple trip rates. The percentages going into the recycling path as well going into MSWI from disposal in each flowchart corresponds to the material recycling quotas in Table 28.

Table 28: Applied end of life quotas for beverage and liquid food cartons and competing packaging systems in Germany:

Geographical scope	Packaging system	Material recycling	MSWI	Landfill	
Germany	Beverage and liquid food carton	quota	76%	24%	0%
		source	[UBA 2020]	[EUROSTAT 2020]	
		reference year	2018	2018	
	PET bottles deposit (water)	quota	97%	3%	0%
		source	[GVM 2020]	[EUROSTAT 2020]	
		reference year	2019	2018	
	PET bottles non-deposit ¹ (non-water)	quota	63%	37%	0%
		source	[GVM 2020]	[EUROSTAT 2020]	
		reference year	2019	2018	
	Glass bottles refillable	quota	83%	17%	0%
		source	[UBA 2020]	[EUROSTAT 2020]	
		reference year	2018	2018	
	Glass jars single use	quota	83%	17%	0%
		source	[UBA 2020]	[EUROSTAT 2020]	
		reference year	2018	2018	
	Pouch ²	quota	67%	33%	0%
		source	[UBA 2020] [Niaounakis 2019]	[EUROSTAT 2020]	
		reference year	2018	2018	
	Steel and aluminium cans	quota	90%	10%	0%
		source	[UBA 2020]	[EUROSTAT 2020]	
		reference year	2018	2018	

¹white opaque bottles and bottles with PA as barrier material are not materially recycled (see section 3.13)

²multilayer pouches are not materially recycled (see section 3.13)

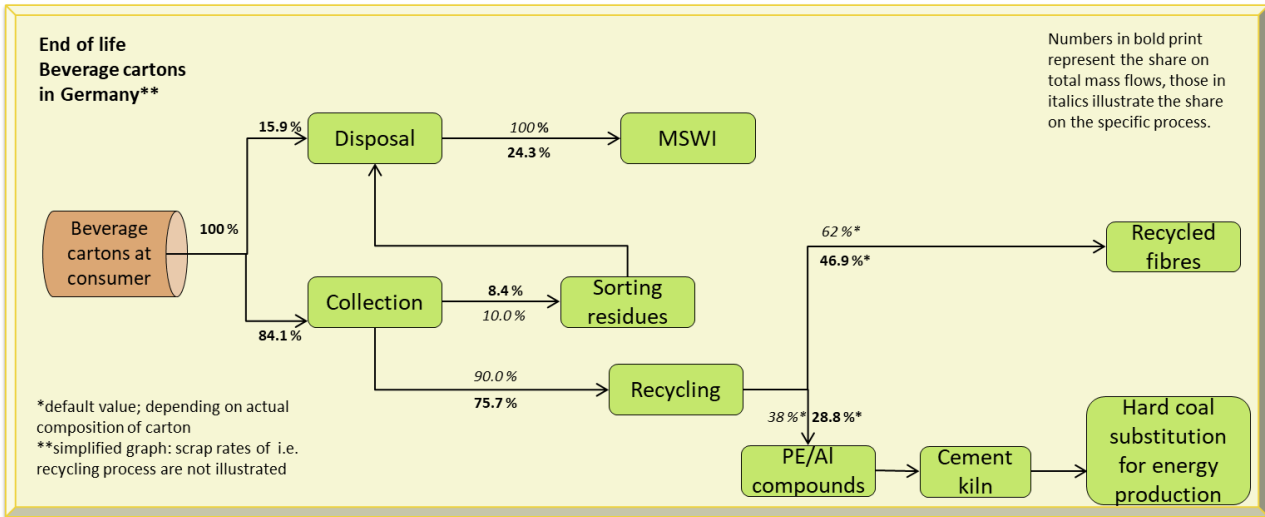


Figure 9: Applied end-of-life quotas for beverage and liquid food cartons in Germany

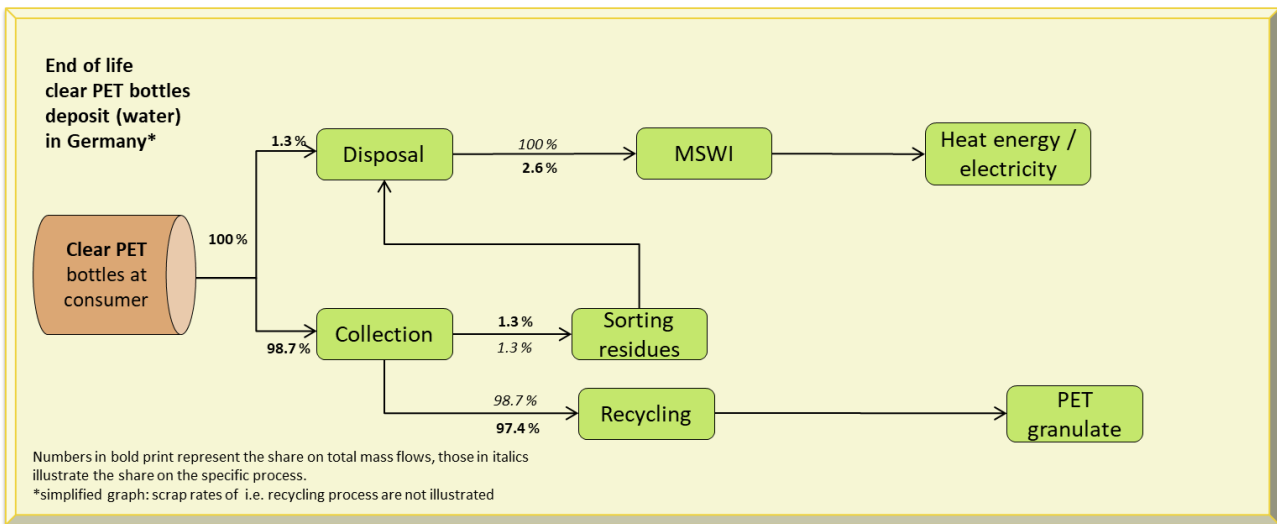


Figure 10: Applied end-of-life quotas for clear PET bottles deposit (water) in Germany

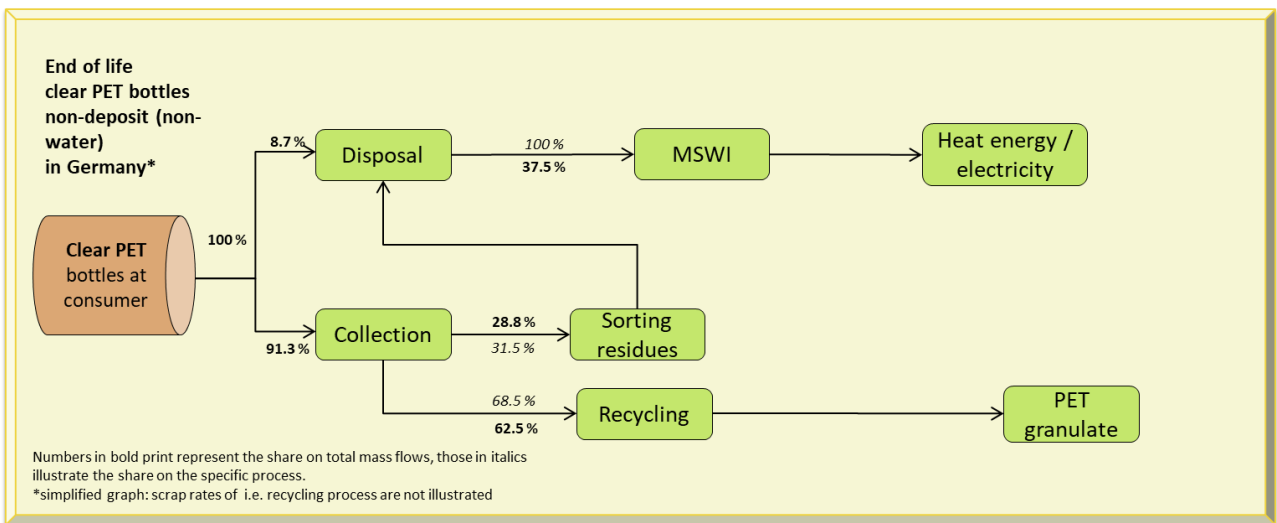


Figure 11: Applied end-of-life quotas for clear PET bottles, non-deposit (non-water) in Germany

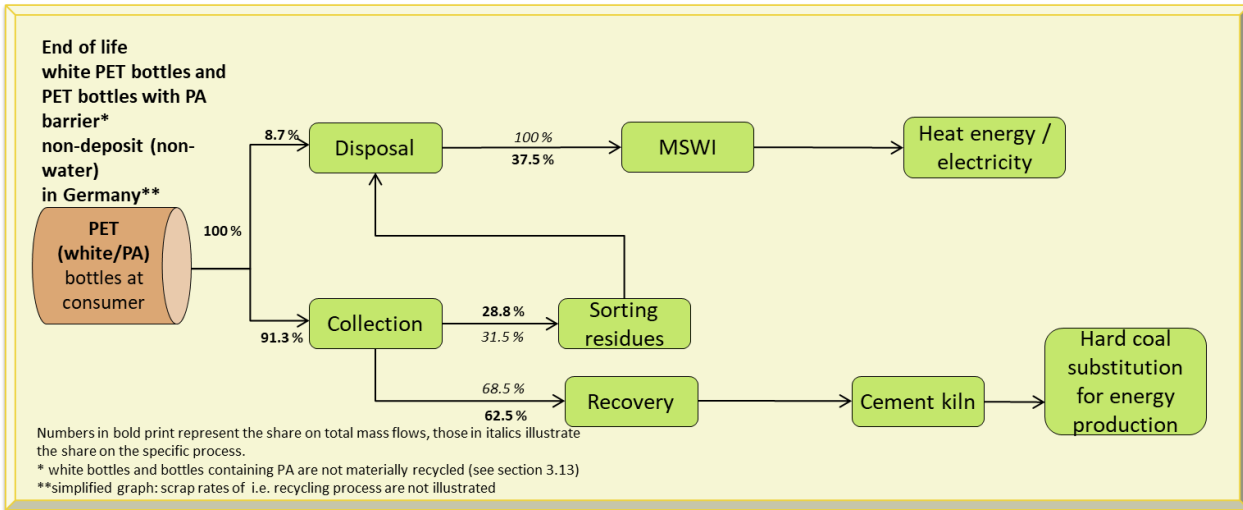


Figure 12: Applied end-of-life quotas for white PET bottles and PET bottles, non-deposit (non-water) in Germany

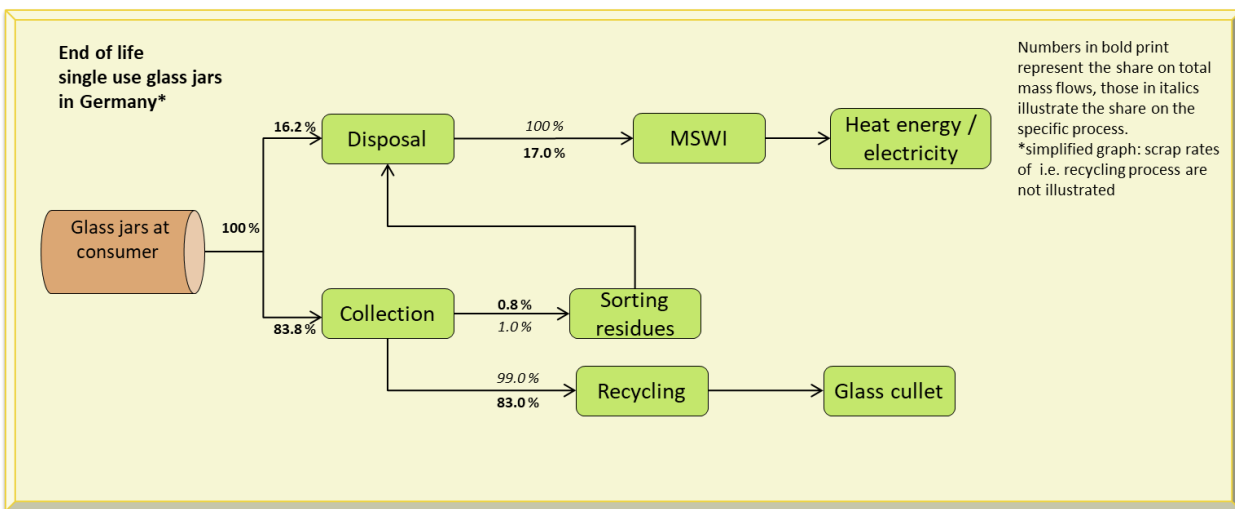


Figure 13: Applied end-of-life quotas for single use glass jars in Germany

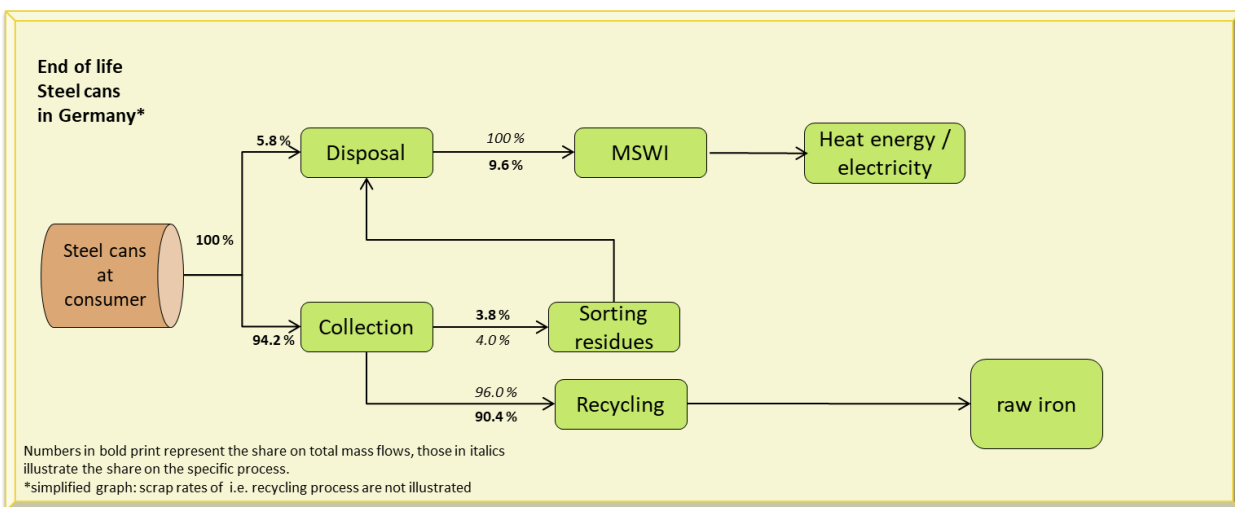


Figure 14: Applied end-of-life quotas for steel cans in Germany

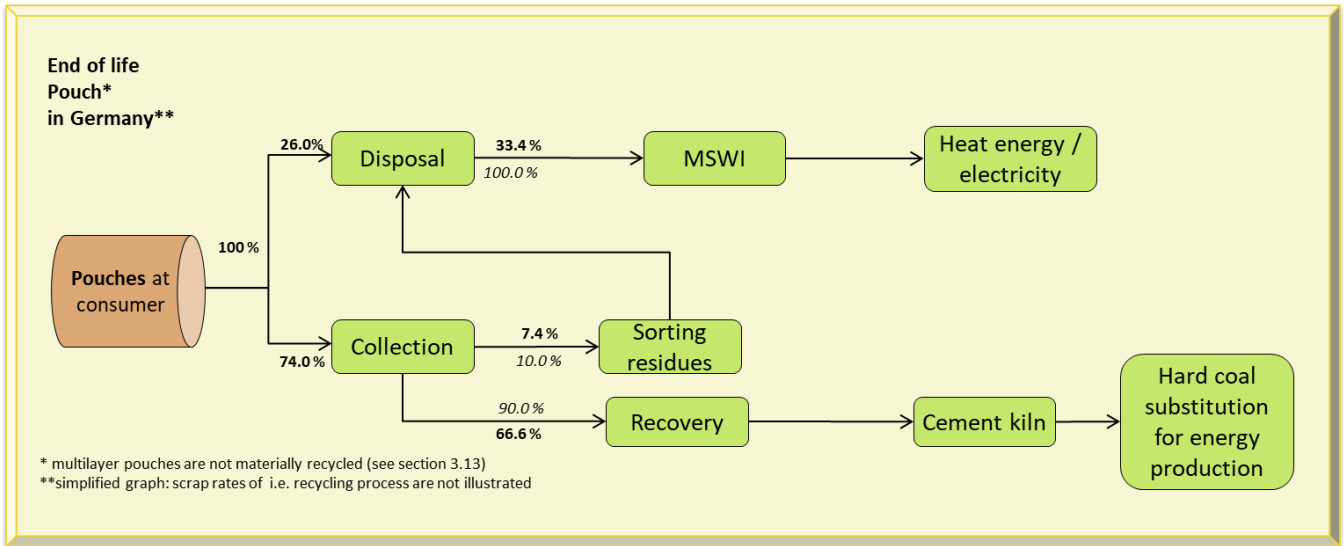


Figure 15: Applied end-of-life quotas for pouches in Germany

2.4 Scenarios

2.4.1 Base scenarios

For each of the studied packaging systems a scenario for the German market is defined, which is intended to reflect the most realistic situation under the described scope. These scenarios are clustered into groups within the same segment and volume group. Following the ISO standard's recommendation, a variation of the allocation procedure shall be conducted. Therefore, two equal scenarios regarding the open-loop allocation are calculated for each packaging system:

- with a system allocation factor of 50 %
- with a system allocation factor of 100 %

2.4.2 Sensitivity analyses

In order to check the influence of the applied transport allocation a sensitivity analysis is applied with a second allocation approach (see [section 1.7.1](#)). In order to cover the different types of distribution, this sensitivity analysis is applied in the segments in which single use and refillable packages are compared. The sensitivity analysis is calculated with the system allocation factor of 100% as the comparative results show with this system allocation factor the least differences. There are several beverage cartons included in these segments. For these sensitivity analyses only the beverage carton with the highest net results is selected.

2.4.3 Scenario variants

No further scenario variants are included in this country specific supplement study. Indicative findings regarding scenario variants of the recycled content of PET bottles or reduced weight of plastic bottles can be derived from the results of similar packaging systems in the European baseline study [ifeu 2020a].

3 Life cycle inventory (LCI)

Data on processes for packaging material production and converting were either collected in cooperation with the industry or taken from literature and the ifeu database. Concerning background processes (energy generation, transportation as well as waste treatment and recycling), the most recent version of ifeu’s internal, continuously updated database was used. Table 29 gives an overview of important datasets applied in the current study. Primary data collected in 2020 for example for filling processes are not extrapolated to the end of the year as the data are based on machine consumption. All data used meet the general requirements and characteristics regarding data gathering and data quality as summarised in section 1.6.

Table 29: Overview on inventory/process datasets used in the current study

Material / Process step	Source	Reference period	primary / secondary data
Intermediate goods			
PP	Plastics Europe, published online April 2014	2011	secondary
HDPE	Plastics Europe, published April 2014	2011	secondary
LDPE	Plastics Europe, published April 2014	2011	secondary
Plant-based PE	[Braskem 2018]	2015	secondary
PET	Plastics Europe, published online June 2017	2015	secondary
PA6	Plastics Europe, last online retrieval in 2005	1999	secondary
Titanium dioxide	Ecoinvent V.3.4	2017	secondary
Tinplate	[World Steel 2018]	2014	secondary
Aluminium (primary)	EA Environmental Profile report 2018 [EA 2018]	2015	secondary
Aluminium foil	EA Environmental Profile report 2013 [EA 2013]	2010	secondary
Corrugated cardboard	[FEFCO 2018]	2017	secondary
Liquid packaging board	ifeu data, obtained from ACE [ACE & ifeu 2011]	2009	secondary
Production			
BC converting	Tetra Pak	2017	primary
Glass bottle/jar converting including glass production	[UBA 2016]	2012/2015	secondary
PET bottle production	ifeu database	2010-2015	primary
Steel (tinplate) can converting	[BUWAL 1998], ifeu database	1996-2015	secondary

Material / Process step	Source	Reference period	primary / secondary data
Pouch production	ifeu database	2007/2018	primary
Filling			
Filling of beverage and liquid food cartons	Data provided by Tetra Pak	2020	primary
Filling plastic bottles	ifeu database	2010-2015	primary
Filling single use glass jars	provided by Tetra Recart based on machine consumption data specifications	2005	primary
Cleaning and filling refillable glass bottles	ifeu database	2005-2020	primary
Recovery			
Beverage and liquid food carton recycling	ifeu database, based on data from various European recycling plants	2004	primary
PET bottle	ifeu database, data collected from different recyclers in Germany and Europe	2009	primary
Glass bottle	ifeu database	2012	primary/ secondary
Steel can	ifeu database	2008	primary
Background data			
electricity production	ifeu database, based on statistics and power plant models	2015	secondary
Municipal waste incineration	ifeu database, based on statistics and incineration plant models	2008	secondary
Thermal recovery in cement kilns	ifeu database, German cement industry association (VDZ)	2006	primary
lorry transport	ifeu database, based on statistics and transport models, emission factors based on HBEFA 3.3 [INFRAS 2017].	2009	secondary
rail transport	[EcoTransIT 2016]	2016	secondary
sea ship transport	[EcoTransIT 2016]	2016	secondary

3.1 Plastics

The following plastics are used within the packaging systems under study:

- Polypropylene (PP)
- High density polyethylene (HDPE)
- Low density polyethylene (LDPE)
- Plant-Based polyethylene
- Polyethylene terephthalate (PET)

3.1.1 Polypropylene (PP)

Polypropylene (PP) is produced by catalytic polymerisation of propylene into long-chained polypropylene. The two important processing methods are low pressure precipitation polymerisation and gas phase polymerisation. In a subsequent processing stage the polymer powder is converted to granulate using an extruder.

The present LCA study utilises data published by Plastics Europe [PlasticsEurope 2014a]. The dataset covers the production of PP from cradle to the polymer factory gate. The polymerisation data refer to the 2011 time period and were acquired from a total of 35 polymerisation plants producing. The total PP production in Europe (EU27+2) in 2011/2012 was 8,500,000 tonnes. The Plastics Europe data set hence represented 77% of PP production in Europe.

3.1.2 High Density Polyethylene (HDPE)

High density polyethylene (HDPE) is produced by a variety of low pressure methods and has fewer side-chains than LDPE. The present LCA study uses the eco-profile published on the website of Plastics Europe [PlasticsEurope 2014b].

The dataset covers the production of HDPE-granulate from the extraction of the raw materials from the natural environment, including processes associated with this. The data refer to the 2011 time period and were acquired from a total of 21 participating polymerisation units. The data set represented 68% of HDPE production in Europe (EU27+2).

3.1.3 Low Density Polyethylene (LDPE)

Low density polyethylene (LDPE) is manufactured in a high pressure process and contains a high number of long side chains. The present LCA study uses the eco-profile published on the website of Plastics Europe [PlasticsEurope 2014b].

The data set covers the production of LDPE granulates from the extraction of the raw materials from the natural environment, including processes associated with this. The data refer to the 2011 time period. Data were acquired from a total of 22 participating polymerisation units. The data set represent 72% of LDPE production in Europe (EU27+2).

3.1.4 Plant-based polyethylene

All packaging systems analysed in this study, which contain plant-based Polyethylene (PE) are beverage carton systems. The plant-based PE used by Tetra Pak in the assessed beverage carton systems is supplied by Braskem in Brazil. The PE is produced from ethanol based on sugar cane. The plant-based PE has the same characteristics as fossil-based PE. Therefore, the same end of life applies to plant-based PE and fossil-based PE. The plant-based PE in this study shall not be mistaken with biodegradable plastics. This study uses two LCA datasets provided by Braskem, one for plant-based HDPE and one for plant-based LDPE [Braskem 2018]. In order to address co-products for produced bioelectricity in the plant-based PE production, the Braskem LCA datasets used in this study use the approach of economical allocation instead of substitution of energy production. The allocation approach complies with previous studies regarding plant-based and fossil HDPE [Murphy 2013]. Credits for land use change have been excluded from the datasets as underlying assumptions and models are not known.

3.1.5 PET (polyethylene terephthalate)

Polyethylene terephthalate (PET) is produced by direct esterification and melt polycondensation of purified terephthalic acid (PTA) and ethylene glycol. The model underlying this LCA study uses the Eco-profile published on the website of Plastics Europe with a reference year of 2015 [PlasticsEurope 2017], that represents the production in European PET plants. Data for foreground processes of PTA production are taken from the PTA eco-profile [CPME 2016] which is based on primary data from five European PTA producers covering 79% of the PTA production in Europe. The foreground process of ethylene glycol production is taken from the Eco-profile of steam cracker products [PlasticsEurope 2012]. For PET production data from 12 production lines at 10 production sites in Belgium, Germany, Lithuania (2 lines), the Netherlands, Poland, Spain (4 lines) and United Kingdom (2 lines) supplied data with an overall PTA volume of 2.9 million tonnes – this represents 85% of the European production volume (3.4 million tonnes).

3.1.6 Polyamid 6 (PA6)

PA6 is manufactured from the precursors benzene and hydroxylamine. The present LCA study uses the ecoprofile published on the website of Plastics Europe (data last calculated March 2005) and referring to the year 1999 [PlasticsEurope 2005]. A more recent dataset is available provided by PlasticsEurope. However, in this dataset ammonium sulphate is seen as a by-product of the PA6 production process of the PA6 pre-product caprolactam. The datasets uses a substitution approach to account for ammonium sulphate. As basically all ammonium sulphate on the market is derived from the PA6 production, in the view of the authors it is not valid to substitute a separate ammonium sulphate production process. Even within the PlasticsEurope methodology this approach is only allowed, “...if there is a dominant, identifiable production path for the displaced product” [PlasticsEurope 2019]. Unfortunately, no dataset applying another approach apart from the substitution approach is available.

3.2 Production of primary material for aluminium bars and foils

The data set for primary aluminium covers the manufacture of aluminium ingots starting from bauxite extraction, via aluminium oxide manufacture and on to the manufacture of the final aluminium bars. This includes the manufacture of the anodes and the electrolysis. The data set is based on information acquired by the European Aluminium (EA) covering the year 2015. The data are covering primary aluminium used in Europe consisting of 51% European aluminium data and 49% IAI data developed by the International Aluminium Institute (IAI) for imported aluminium [EA 2018].

The data set for aluminium foil (5-200 µm) is based on data acquired by the EA together with EAFA covering the year 2010 for the manufacture of semi-finished products made of aluminium. For aluminium foils, this represents 51% of the total production in Europe (EU27 + EFTA countries). Aluminium foil for the packages examined in this study is assumed to be sourced in Europe. According to EA [EA 2013], the foil production is modelled with 57% of the production done through strip casting technology and 43% through classical production route. The dataset includes the electricity prechains, which are based on actual practice and are not a European average electricity mix.

3.3 Manufacture of tinplate

Data for the production of tinplate refer to the year 2014 and was provided by WORLD STEEL [WORLD STEEL 2018]. The data set is based on a weighted average site-specific data (gate-to-gate) of European steel producers whereas the electricity grid mix included in the data is country-specific. According to World Steel, the dataset represents about 95% of the annual European supply or production volume. A recycled content of approximately 2% is reported for tinplate. The low recycled content is based on the dataset provided by World Steel.

3.4 Glass and glass bottles

The data used for the manufacture are data acquired by UBA [2016] and represents the German production in 2012. The energy consumption and the emissions for the glass manufacturing process are determined by the composition of the raw mineral material and in particular by the scrubbing and the fossil energy resource used for the direct heating. The applied electricity prechains are modelled with the German electricity mix based on 2015. A newer 2016 data set from [FEVE 2016] is not applied, because of its methodological approach of substituting gas, coal and oil based thermal energy on the market with sold heat surplus of the glass production process. As the dataset used in this study has lower impacts as the FEVE dataset from 2016, a conservative approach in the perspective of the beverage and liquid food carton systems is applied. As the dataset represents the German glass production the representativeness on the European market is not known.

3.5 Production of liquid packaging board (LPB)

The production of LPB was modelled using data gathered from all board producers in Sweden and Finland. It covers data from four different production sites where more than 95% of European LPB is produced. The reference year of these data is 2009. It was published in the ELCD database and is the most recent available.

The four datasets based on similar productions volumes were combined to one average. They cover all process steps including pulping, bleaching and board manufacture. They were combined with data sets for the process chemicals used from ifeu's database and Ecoinvent 2.2 (Ecoinvent 3.7 data are still based on the same datasets), including a forestry model to calculate inventories for this sub-system. Energy required is supplied by electricity as well as renewable by on-site energy production by incineration of wood and bark. The specific energy sources were taken into account.

3.6 Corrugated board and manufacture of cardboard trays

For the manufacture of corrugated cardboard and corrugated cardboard packaging the data sets published by FEFCO in 2018 [FEFCO 2018] were used. More specifically, the data sets for the manufacture of 'Kraftliners' (predominantly based on primary fibres), 'Testliners' and 'Wellenstoff' (both based on waste paper) as well as for corrugated cardboard packaging were used. The data sets represent weighted average values from European locations recorded in the FEFCO data set. They refer to the year 2017. All corrugated board and cardboard trays are assumed to be sourced from European production. The data represents about 54% of the European cardboard production.

In order to ensure stability, a fraction of fresh fibres is often used for the corrugated cardboard trays. According to [FEFCO 2018] this fraction on average is 11.5% in Europe. Due to a lack of more specific information this split was also used for the present study.

3.7 Titanium dioxide (TiO₂)

TiO₂ can be produced via different processes. The two most prevalent are the chloride process and the sulphate process. For the chloride process, the crude ore is reduced with carbon and oxidised with chlorine. After distillation of the resulting tetrachloride, it is re-oxidised to get pure titanium dioxide. In the alternative sulphate process, the TiO₂ is won by hydrolysis from Ilmenite, a titanium-iron oxide, which leads to a co-production of sulfuric acid.

The data used in this study are a mix of both production processes and are taken from Ecoinvent database 3.4. The data refers to the years 1997 to 2017 and is representative for Europe.

3.8 Converting

3.8.1 Converting of beverage and liquid food cartons

The manufacture of composite board was modelled using European average converting data from Tetra Pak that refer to the year 2017. The converting process covers the lamination of LPB with LDPE and aluminium including, cutting and packing of the

composite material. The packaging materials used for shipping of carton sleeves to fillers are included in the model as well as the transportation of the package material.

Process data provided by Tetra Pak were then coupled with required prechains, such as process heat, grid European electricity and inventory data for transport packaging used for shipping the coated composite board to the filler.

3.8.2 PET bottle production

The production of PET bottles is usually split into two different processes: the production of preforms from PET granulate, including drying of granulate, and the stretch blow moulding (SBM) of the actual bottles. While energy consumption of the preform production strongly correlates with preform weight, one of the major factors influencing energy consumption of SBM is the volume of the produced bottles. Data provided from the ifeu database for the SBM and preform production has been collected from various preform producers and fillers (for the stretch blow moulding processes) as applied in ifeu (2020b). The process data is coupled with the required prechain of the local German electricity mix in order to adjust the process data to the production in Germany.

3.8.3 Converting of steel can

Data gathering for the manufacturing of 3-piece tinsplate food cans has been attempted within this study, but unfortunately without success. Thus, older food can manufacturing data had to be used. The converting dataset was taken from the literature [BUWAL 1998] and related prechains were taken in their most current version from the ifeu internal database. The process data refer to the year 1996. According to APEAL [APEAL 2008], the BUWAL converting process dataset is the only available food can converting dataset for the time being. The process data is coupled with the required prechain of the local German electricity mix in order to adjust the process data to the production in Germany.

3.9 Closure production

The closures made of fossil and plant-based polymers are produced by injection moulding. The data for the production were taken from ifeu's internal database and are based on values measured in Germany and other European countries and data taken from literature. The process data were coupled with the required prechains such as the production of PE and German grid electricity in order to adjust the process data to the production in Germany. In case of closures of beverage cartons there is no production in Germany. To model a European production process data is coupled with the European electricity mix.

3.10 Filling

Filling processes are similar for beverage and liquid food cartons and alternative packaging systems regarding material and energy flows. The respective data for beverage and liquid food cartons were provided by Tetra Pak in 2021 distinguishing between the consumption of electric and thermal energy as well as of water and air demand. Those were cross-checked by ifeu with data collected for earlier studies. The data for the filling of plastic and the cleaning and filling of refillable glass bottles was provided by the internal ifeu database

as applied in ifeu (2020b). Filling data for the analysed steel can and single use glass jar were provided by Tetra Recart based on machine consumption data specifications referring to the year 2005. Within this study the same data were used. The process data is coupled with the required prechain of the local German electricity mix in order to adjust the process data to the filling in Germany.

3.11 Transport settings

Table 30 provides an overview of the transport settings (distances and modes) applied for packaging materials. Data were obtained from Tetra Pak, ACE and several producers of raw materials. Where no such data were available, expert judgements were made, e.g. exchanges with representatives from the logistic sector and suppliers.

Table 30: Transport distances and means: Transport defined by distance and mode [km/mode]

Packaging element Geographic scope [Reference]	Material producer to converter Distance [km]	Converter to filler Distance [km]
HDPE, LDPE, PP, PET granulate for all packages based on several plants in Europe [PlasticsEurope 2005], [PlasticsEurope 2014a], [PlasticsEurope 2014b], [PlasticsEurope 2017]	500 / road ¹	
Plant-based PE Brazil	10800 / sea ¹ 700 / road ¹	
Aluminium EU27 + Norway, Switzerland, Iceland [EA 2013], [EA 2018]	460 / road ¹	
Paper board for composite board Sweden, Finland	300 / road ² 950 / sea ² 800 / rail ²	
Cardboard for trays EU 27 + Norway, Switzerland [FEFCO 2018]	primary fibres: 500 / sea, 400 / rail, 250 / road ² secondary fibres: 300/road ²	
Wood for pallets Northern Europe	100 / road ¹	
LDPE stretch foil based on several plants in Europe [PlasticsEurope 2005], [PlasticsEurope 2014a], [PlasticsEurope 2014b], [PlasticsEurope 2017]	500/road (material production site = converter) ¹	
Trays EU28 [ifeu 2016]		500 / road ¹
Pallets EU28 [ifeu 2016]		100 / road ¹
Converted carton rolls EU28 [ifeu 2016]		700 / road ¹
¹ Assumption/calculation ² taken from published LCI reports		

3.12 Distribution of filled packs from filler to point of sale

Table 31 shows the applied distribution distances in this study. Distribution centres are the places where the products are temporarily stored and then distributed to the different point of sales (i.e. supermarkets).

The applied distances for dairy and JNSD segments are based on the ifeu (2020b) in which data was applied according to Roß (2017a) and Roß (2017b). The methodology to determine the distances is based on the identification of filling locations based on the labelling on packages. Combined with expert knowledge regarding the logistics of the different point of sale types in Germany standardized transport processes were derived. For the water segment, the distances for single use PET bottles from Deloitte (2013) are applied. As there is no primary data available for the food segment, an average of ambient segments (dairy, JNSD, water) is applied.

Regarding single use packaging systems it is assumed, that not the full return distance is driven with an empty load, as lorries and trains load other goods (outside the system boundaries of this study) for at least part of their journey. As these other goods usually cannot be loaded at the final point of the beverage packaging delivery it is assumed that a certain part of the return trip is made without any load and so has to be allocated to the distribution system. Therefore, for single used systems a partial share of the distance is applied for return trips.

In case of refillable systems, the full distance is applied in which the empty packaging systems are transported back to the filler to be refilled.

Table 31: Distribution distances in km for the examined packaging systems

Segment	Distribution distance [km] as applied in this study			
	Distribution Step 1		Distribution step 2	
	filler > distribution centre (delivery)	distribution centre > filler (return trip)	distribution centre > POS (delivery)	POS > distribution centre (return trip)
Dairy chilled - single use	265	61	62	41
Dairy chilled - refillable	265	265	62	62
Dairy ambient	242	50	62	43
JNSD - single use	282	102	52	36
JNSD - refillable	282	282	52	52
Water	168	27	35	35
Food	231	60	50	38

3.13 Recovery and recycling

Beverage and liquid food cartons

Beverage and liquid food cartons which are collected and sorted are subsequently sent to a paper recycling facility for fibre recovery. The efficiency of the fibre recycling is 98%. The secondary fibre material is used e.g. as a raw material for cardboard. A substitution factor 0.9 is applied. Rejects, in terms of plastics and aluminium compounds, are thermally recovered in cement kilns. In 2021 a plant for material recycling of polymer and aluminium rejects was opened in Germany. This is not included in the study as process data was not yet available during the preparation of the study. Related process data including efficiencies used are taken from ifeu's internal database, referring to the year 2004 and are based on data from various European recycling plants collected by ifeu. The process data is coupled with the prechain of German electricity mix in order to the recycling in Germany.

Plastic bottles

Plastic bottles which are collected and sorted are usually followed by a regranulation process. Ultimately the different plastics are separated by density (PET, PE, PP). They are shredded to flakes, other plastic components are separated and the flakes are washed before further use. The data used in the current study is based on ifeu's internal database based on data from various recycling plants including the efficiency of the PET recycling of 86%. The process data is coupled with the prechain of German electricity mix in order to the recycling in Germany.

White opaque PET plastic bottles used for the packaging of dairy products are not sorted into specific recycling fractions. A mix of opaque bottles into the recycling stream of clear bottles reduces the quality of the produced recycled plastic. Therefore, opaque PET bottles are removed from the recycling stream of a large amount of recycling plants [EPBP 2018]. Therefore, in the model of this study white plastic bottles end up in a mixed plastic fraction and undergo thermal treatment (cement kiln) instead of regranulation.

Due to barrier materials (PA), the recyclability of PET juice bottles is limited. Therefore, these bottles also end up in a mixed plastic fraction and undergo thermal treatment (cement kiln) instead of regranulation.

Future technologies for potential recycling of white opaque PET or PET bottles containing PA (e.g. chemical recycling, solvent based recycling) are not implemented on a relevant scale on the market yet, therefore such technologies are not considered in this study.

Refillable glass bottles and single use glass jars

The glass of collected glass bottles and jars is shredded and the ground glass serves as an input in the glass production, the share of external cullet is modelled as 69.5%. The data used in the current study is drawn from ifeu's internal database, and furthermore information received from 'The European Container Glass Federation'. The reference period is 2012. Process data are coupled with required prechains and the German electricity grid mix.

Steel cans

Steel cans, as a traditional food package, are sorted into a steel fraction in sorting plants. The sorted post-consumer steel packaging waste fraction is then assumed to substitute pig iron in the steelmaking process (without further pre-treatment). It is implemented in the life cycle model partly as closed-loop and partly as open-loop recycling with the criterion being the scrap input per ton steel product (as it is specified in the steel inventory dataset). Data are taken from the ifeu database based on collected data from the European Steel industry. If the recovery rate of steel packaging is higher than what is required to cover the defined scrap input, the remaining post-consumer steel waste is assumed to leave the steel can system. In the model, it substitutes pig iron for a steelmaking process in a subsequent product system (Substitution factor 1.0).

Pouches

As multilayer films are currently not recycled [Niaounakis 2019] no recycling process for pouches is included in this study. These end up in a mixed plastic fraction and undergo thermal treatment (cement kiln) instead of regranulation.

Future technologies for potential recycling of multilayer pouches (e.g. chemical recycling, solvent based recycling) are not implemented on a relevant scale on the market yet, therefore such technologies are not considered in this study.

3.14 Background data

3.14.1 Transport processes

Lorry transport

The dataset used is based on standard emission data that were collated, validated, extrapolated and evaluated for the Austrian, German, French, Norwegian, Swedish and Swiss Environment Agencies in the 'Handbook of emission factors' [INFRAS 2017]. The 'Handbook' is a database application referring to the year 2017 and giving as a result the transport distance related fuel consumption and the emissions differentiated into lorry size classes and road categories. Data are based on average fleet compositions within several lorry size classes. Data in this study refer to lorries with a loading capacity of 23 tonnes for the distribution from fillers to distribution centres and a mix of lorries with loading capacities of 23t, 15t and 8t for the distribution from distribution centres to the point of sale. As the distribution of juice in refillable glass bottles in Germany very rarely takes place in lorries with a loading capacity of 23 tonnes, a loading capacity of 15t is modelled for the distribution from filler to distribution centre for the refillable glass bottle 2 in the JNSD Family Pack (ambient) segment (ifeu (2020b)). The emission factors used in this study refer to the year 2016.

Based on the above-mentioned parameters – lorry size class and road category – the fuel consumption and emissions as a function of the transport load and distance were determined (tonne km). Wherever cooling during transport is required, additional fuel consumption is modelled accordingly based on data from ifeu's internal database.

Ship transport

The data used for the present study represent freight transport with an overseas container ship (10.5 t/TEU¹) and a capacity utilisation of 70% [EcoTransIT World 2016]. Energy use is based on an average fleet composition of this ship category with data taken from [EcoTransIT World 2016]. The Ecological Transport Information Tool (EcoTransIT) calculates environmental impacts of any freight transport. Emission factors and fuel consumption have been applied for direct emissions (tank-to-wheel) based on [EcoTransIT World 2016]. For the consideration of well-to-tank emissions, data were taken from ifeu's internal database.

Rail transport

The data used for rail transport for the present study also is based on data from [EcoTransIT World 2016]. Emission factors and fuel consumption have been applied for direct emissions based on [EcoTransIT World 2016]. The needed electricity is modelled with the electricity mix of the country the train is operating (see also [section 3.14.2](#)).

3.14.2 Electricity generation

Modelling of electricity generation is particularly relevant for the production of base materials as well as for converting, filling processes and recycling processes. Electric power supply is modelled using country specific grid electricity mixes, since the climate change burdens of power production varies strongly depending on the electricity generation technology. The country-specific electricity mixes are obtained from a master network for grid power modelling maintained and annually updated at ifeu as described in [ifeu 2016]. It is based on national electricity mix data by the International Energy Agency (IEA)². As a prechain for most processes the German electricity mix is applied (see [Table 1](#) and [section 3](#)). Regarding beverage cartons, electricity generation is considered using Swedish and Finnish mix of energy suppliers in the year 2015 for the production of LPB and the European mix of energy suppliers in the year 2015 for the converting of sleeves. The applied shares of energy sources to the related market are given in [Table 32](#).

¹ Twenty-foot Equivalent Unit

² <http://www.iea.org/statistics/>

Table 32: Share of energy source to specific energy mix, reference year 2015.

geographic scope	Germany	EU 28	Sweden	Finland
Energy source				
Hard coal	0.00%	14.11%	0.23%	7.34%
Brown coal	42.06%	10.32%	0.00%	0.00%
Fuel oil	9.29%	1.65%	0.15%	0.30%
Natural gas	18.78%	16.51%	0.67%	12.65%
Nuclear energy	0.00%	26.70%	33.85%	33.66%
Hydropower/Wind/Solar/Geothermal	29.21%	24.50%	57.99%	29.14%
<i>Hydropower</i>	42.28%	45.74%	82.15%	87.77%
<i>Wind power</i>	32.04%	40.42%	17.75%	12.18%
<i>Solar energy</i>	25.68%	13.01%	0.10%	0.04%
<i>Geothermal energy</i>	0.00%	0.83%	0.00%	0.00%
Biomass energy	0.44%	4.84%	5.36%	15.69%
Waste	0.21%	1.35%	1.75%	1.23%

3.14.3 Municipal solid waste incineration

The electrical and thermal efficiencies of the municipal solid waste incineration plants (MSWI) are shown in [Table 33](#).

Table 33: Electrical and thermal efficiencies of the incineration plants.

Geographic Scope	Electrical efficiency	Thermal efficiency	Reference period	Source
Germany	10%	26%	2017	[CEWEP 2018]

The efficiencies are used as parameters for the incineration model, which assumes a technical standard (especially regarding flue gas cleaning) that complies with the

requirements given by the EU incineration directive, ([EC 2000] Council Directive 2000/76/EC).

The electric energy generated in MSWI plants is assumed to substitute market specific grid electricity. Thermal energy recovered in MSWI plants is assumed to serve as process heat. The mix of heat energy sources represents a European average assumed to be produced by 50% gas and 50% oil. According to the knowledge of the authors of this study, official data regarding this aspect are not available.

3.14.4 Landfill

As there is no landfilling of packaging waste in Germany [Nelles et al. 2016], the remaining part of the post-consumer packaging waste passes through the incineration (MSWI).

3.14.5 Thermal recovery in cement kilns

The process data for thermal recovery in cement kilns refer to the year 2006 and are taken from ifeu's database based on information provided by the German cement industry association (VDZ). The applied process data cover emissions from the treatment in the clinker burning process. Parameters are restricted to those which change compared to the use of primary fuels. The output cement clinker is a function of the energy potential of the fuel and considers the demand of base material. The primary substitution of hard coal in cement kilns was confirmed by the economic, technical and scientific association for the German cement industry (VDZ e.V.) [VDZ 2019]

4 Results

In this section, the results of the examined packaging systems for Germany are presented separately for the different categories in graphic form.

The following individual life cycle elements are shown in sectoral (stacked) bar charts

- Production and transport of glass including converting to bottle (**'Glass'**)
- Production and transport of PET, including additives, e.g. TiO₂ for the body of plastic bottles, aluminium for pouch bodies and steel for can bodies (**'Plastic/Alu/Steel for body'**)
- Production and transport of liquid packaging board (**'LPB'**)
- Production and transport of plastics and additives for beverage and liquid food carton (**'plastics for sleeve'**)
- Production and transport of aluminium & converting to foil for beverage and liquid food cartons (**'aluminium foil for sleeve'**)
- Converting processes of cartons, plastic bottles, SUP and cans (**'converting'**)
- Production, converting and transport of closures, tops, straws and labels and their base materials (**'top, closure & label'**)
- Production of secondary and tertiary packaging: wooden pallets, LDPE shrink wrap and corrugated cardboard trays (**'transport packaging'**)
- Cleaning (only refillable bottles) and filling process including packaging handling (**'filling'**)
- Retail of the packages from filler to the point-of-sale including cooling during transport if relevant (**'distribution'**)
- Sorting, recycling and disposal processes (**'recycling & disposal'**)
- CO₂ emissions from incineration of plant-based and renewable materials (**'CO₂ reg. (EOL)'**); in the following also the term regenerative CO₂ emissions is used
- Uptake of atmospheric CO₂ during the plant growth phase (**'CO₂-uptake'**)

Secondary products (recycled materials and recovered energy) are obtained through recovery processes of used packaging materials, e.g. recycled fibres from cartons may replace primary fibres. It is assumed, that those secondary materials are used by a subsequent system. In order to consider this effect in the LCA, the environmental impacts of the packaging system under investigation are reduced by means of credits based on the environmental burdens of the substituted material. Following the ISO standard's recommendation on subjective choices, both, the so-called 50% and 100% allocation methods are used for the recycling and recovery as well as crediting procedure to verify the influence of the allocation method on the final results. (see [section 1.7](#)). For each segment the results are shown for the allocation factor 50% and allocation factor 100%.

The credits are shown in form of separate bars in the LCA results diagrams. They are broken down into:

- credits for material recycling (**'credits material'**)
- credits for energy recovery (replacing e.g. grid electricity) (**'credits energy'**)

The LCA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

Each impact category diagram includes three bars per packaging system under investigation, which illustrate (from left to right):

- sectoral results of the packaging system itself (first stacked bar with positive values)
- credits given for secondary products leaving the system and CO₂ uptake (second stacked bar with negative values)
- net results as results of the subtraction of credits from overall environmental burdens (grey bar)

All results refer to the primary and transport packaging material flows required for the delivery of 1000 L beverage and liquid food to the point of sale, including the end-of-life of the packaging materials.

A note on significance: For studies intended to be used in comparative assertions intended to be disclosed to the public, ISO 14044 asks for an analysis of results for sensitivity and uncertainty. It's often not possible to determine uncertainties of datasets and chosen parameters by mathematically sound statistical methods. Hence, for the calculation of probability distributions of LCA results, statistical methods are usually not applicable or of limited validity. To define the significance of differences of results, an estimated significance threshold of 10% is chosen. This can be considered a common practice for LCA studies comparing different product systems. This means differences $\leq 10\%$ are considered as insignificant.

4.1 Results allocation factor 50%; DAIRY FAMILY PACK CHILLED

4.1.1 Presentation of results DAIRY FAMILY PACK CHILLED

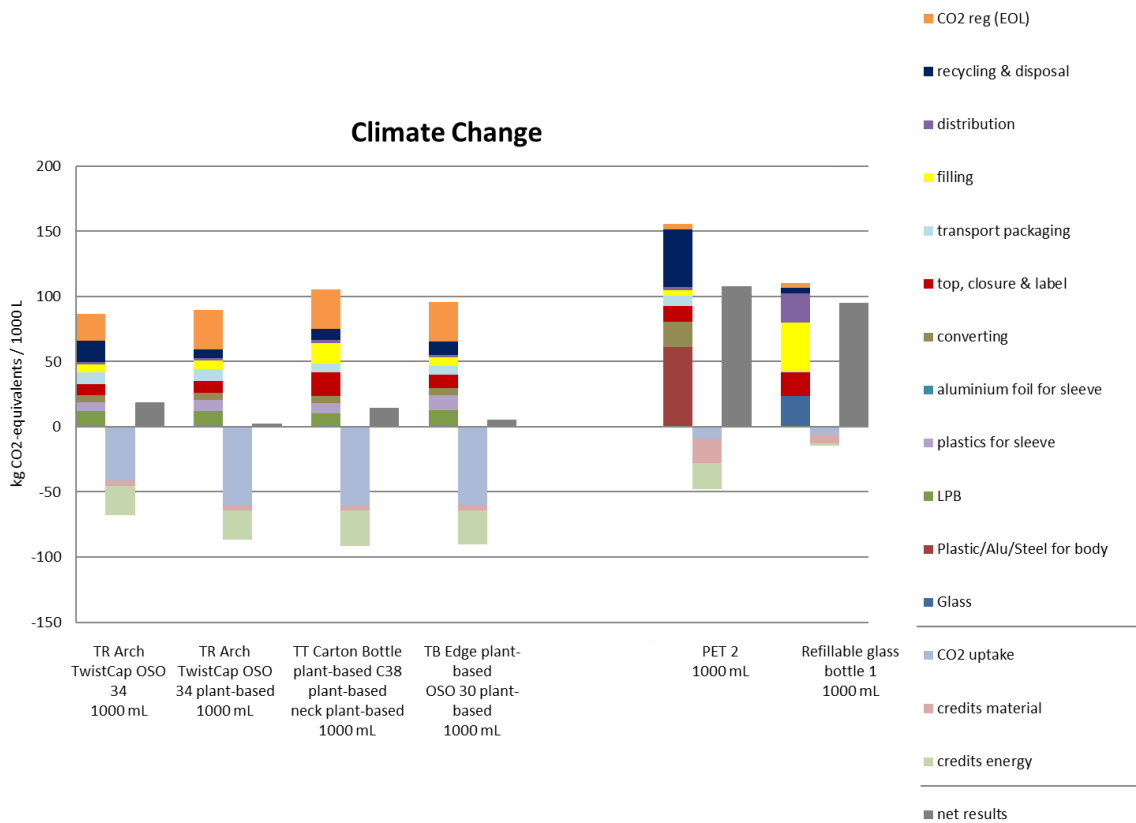


Figure 16: Climate Change results of segment DAIRY FAMILY PACK CHILLED, allocation factor 50%

Table 34: Climate Change results of segment DAIRY FAMILY PACK CHILLED - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TR Arch TwistCap OSO 34 1000 mL	TR Arch TwistCap OSO 34 plant-based 1000 mL	TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	66.08	59.41	75.20	65.66	151.43	106.89
	CO2 (reg)	20.69	30.09	30.41	29.87	4.46	3.06
	Credits	-26.57	-26.64	-30.49	-30.48	-39.00	-8.52
	CO2 uptake	-41.37	-60.18	-60.81	-59.75	-8.92	-6.12
	net results	18.82	2.68	14.30	5.31	107.97	95.31

4.1.2 Description and interpretation

Beverage carton systems (specifications see [section 2.2.1](#))

For the beverage carton systems considered in the DAIRY FAMILY PACK CHILLED segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (10%-14%) and the production of plastics for sleeves (8%-12%).

The converting to sleeves accounts only small shares (5%-6%) of the total burdens for 'Climate Change'.

Minor shares (10%-17%) of total burdens for 'Climate Change' are caused from the production of closures.

The production and provision of 'transport packaging' for the beverage carton systems shows 6%-11% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'filling' shows small to minor shares of burdens (7%-15%) for the beverage cartons.

The life cycle step 'distribution' shows 2% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows small to minor shares of total burdens for 'Climate Change' (8%-19%) resulting from recycling processes and the incineration of fossil materials.

'CO₂ reg. (recycling & disposal)' describes separately all regenerative CO₂ emissions from the incineration of biogenic material in MSWI or cement kilns. They contribute to 24%-33% of the total burdens for 'Climate Change'.

Energy credits sum up to 25%-27% resulting from incineration in MSWI or cement kilns. Material credits for 'Climate Change' are low (3%-5% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions.

The uptake of CO₂ by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the convention in this study which implies that no CO₂ uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO₂ uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for the assessed system. (see [section 1.7.2](#))

Plastic bottles (specifications see [section 2.2.2](#))

In the assessed plastic bottle system in the DAIRY FAMILY PACK CHILLED segment, a major share (39%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottle in this segment minor shares of burdens for 'Climate Change (12%).'.

The life cycle step 'top, closure & label' shows small impact shares (8%) mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (5%) for climate change.

The life cycle steps 'filling' (3%) and 'distribution' (2%) show only small shares of burdens in the bottle system.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (28%) for the assessed plastic bottles resulting from the recycling processes and incineration of the bottles.

Material credits reduce the total burdens by 12% resulting from the substitution of virgin PET.

Energy credits reduce the total burdens by 13% from the incineration of PET bottles.

Refillable glass bottle (specifications see [section 2.2.2](#))

The production of the 'glass' material shows considerable shares of burdens for 'Climate Change' (22%). Without the use cycle of 10 of the refillable glass bottles, this share of total burdens would be remarkably higher.

The life cycle step 'filling' (34%) shows major shares of burdens due to the extra handling of refillable bottles which includes for example cleaning processes.

The life cycle step 'distribution' (20%) shows considerable shares of burdens due to the extra redistribution of the empty bottles, the small amount of packaging systems per pallet, leading to low lorry utilisation, as well as due to the heavy bottle weight the high share of packaging weight in the lorries.

The life cycle step 'top, closure & label' shows minor impact shares (16%) attributed to the steel production and converting of the closure as well as the production of the paper label.

The other life cycle steps show only small shares of impact (up to 4%).

The influence of material credits on the net result is also small for 'Climate Change'. They reduce the overall burdens by 6%.

Due to the high MSWI with energy recovery and no landfilling in Germany, Energy credits show 2%.

4.1.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category ‘Climate Change’ compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see section 1.6 on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 35: Comparison of net results: **TR Arch TwistCap OSO 34 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Germany Allocation 50	The net results of TR Arch TwistCap OSO 34 1000 mL are lower (green)/ higher (orange) than those of				
	TR Arch TwistCap OSO 34 plant-based 1000 mL	TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	+603%	+32%	+254%	-83%	-80%

Table 36: Comparison of net results: **TR Arch TwistCap OSO 34 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Germany Allocation 50	The net results of TR Arch TwistCap OSO 34 plant-based are lower (green)/ higher (orange) than those of				
	TR Arch TwistCap OSO 34 1000 mL	TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	-86%	-81%	-50%	-98%	-97%

Table 37: Comparison of net results: **TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Germany Allocation 50	The net results of TT Carton Bottle plant-based C38 plant-based neck plant-based are lower (green)/ higher (orange) than those of				
	TR Arch TwistCap OSO 34 1000 mL	TR Arch TwistCap OSO 34 plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	-24%	+434%	+169%	-87%	-85%

¹ ((| net result heading – net result column|) / net result column)*100

Table 38: Comparison of net results: **TB Edge plant-based OSO 30 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

<i>DAIRY FAMILY PACK (chilled), Germany Allocation 50</i>	The net results of TB Edge plant-based OSO 30 plant-based are lower (green)/ higher (orange) than those of				
	TR Arch TwistCap OSO 34 1000 mL	TR Arch TwistCap OSO 34 plant-based 1000 mL	TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	-72%	+98%	-63%	-95%	-94%

4.2 Results allocation factor 100%; DAIRY FAMILY PACK CHILLED

4.2.1 Presentation of results DAIRY FAMILY PACK CHILLED

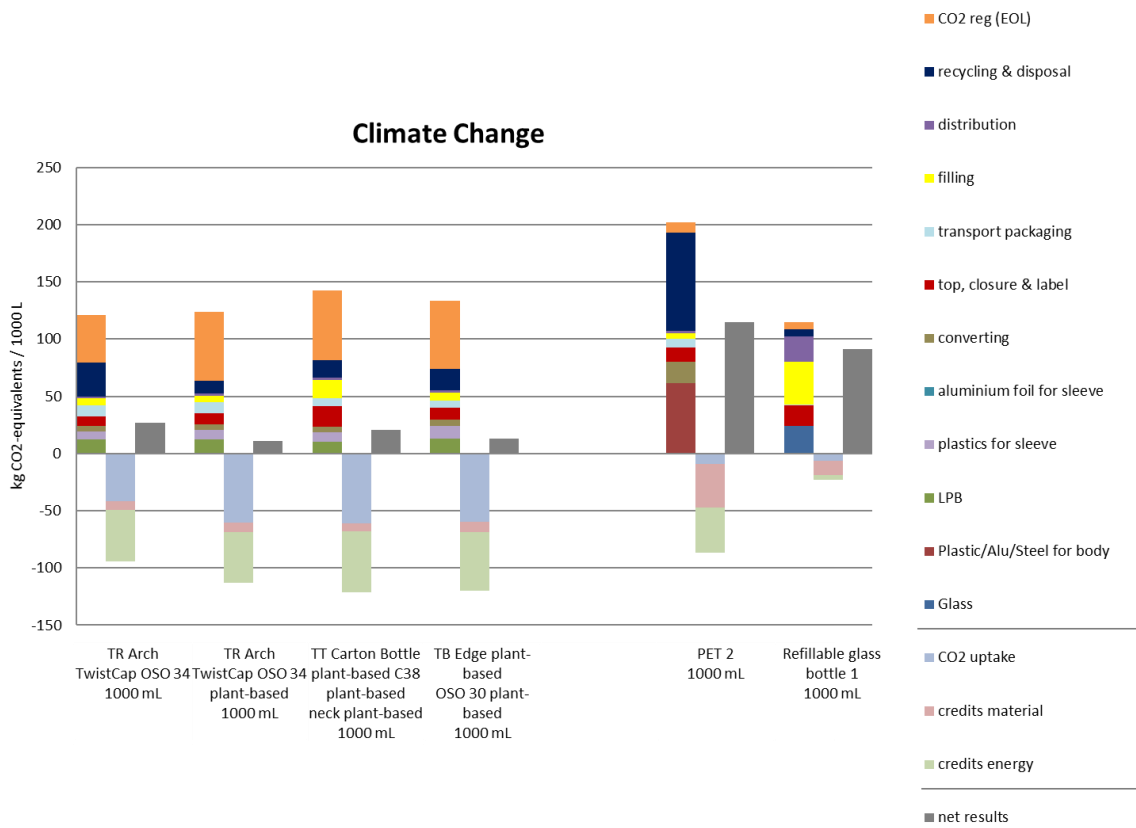


Figure 17: Climate Change results of segment DAIRY FAMILY PACK CHILLED, allocation factor 100%

Table 39: Climate Change results of segment DAIRY FAMILY PACK CHILLED - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TR Arch TwistCap OSO 34 1000 mL	TR Arch TwistCap OSO 34 plant-based 1000 mL	TT Carton Bottle plant-based C38 neck plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	79.77	63.78	81.46	73.63	193.09	108.46
	CO ₂ (reg)	41.37	60.18	60.81	59.75	8.92	6.12
	Credits	-52.67	-52.81	-60.58	-60.45	-78.02	-17.03
	CO ₂ uptake	-41.37	-60.18	-60.81	-59.75	-8.92	-6.12
	net results	27.10	10.97	20.89	13.18	115.07	91.44

4.2.2 Description and interpretation

In this section the differences of the allocation factor 100% and the allocation factor 50% are described. Detailed descriptions and interpretation including the contribution of the life cycle steps are included for the allocation 50% results (see [section 4.1.2](#)).

A higher allocation factor implies the allocation of more burdens from the end-of-life processes (for example emissions from incineration, emissions from the production of electricity for recycling processes). It also implies the allocation of more credits for the substitution of other processes (for example energy credits for avoided electricity generation due to energy recovery at MSWIs or material credits for avoided production of new materials).

When applying an allocation factor of 100%, all burdens and all credits are allocated to the assessed system.

In the cases of beverage cartons in the segment DAIRY FAMILY PACK CHILLED applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also, the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO₂ reg. (recycling & disposal)' are allocated to the assessed system (see [section 1.7.2](#)).

In the case of the plastic bottle, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits (material and energy credits) is similar than that of the burdens regardless of the allocation factor.

In case of the refillable glass bottle, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as due to the reuse of the bottle burdens from recycling and incineration as well as credits are low.

4.2.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category 'Climate Change' compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging

systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 40: Comparison of net results: **TR Arch TwistCap OSO 34 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Germany Allocation 100	The net results of TR Arch TwistCap OSO 34 1000 mL are lower (green)/ higher (orange) than those of				
	TR Arch TwistCap OSO 34 plant-based 1000 mL	TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	+147%	+30%	+106%	-76%	-70%

Table 41: Comparison of net results: **TR Arch TwistCap OSO 34 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Germany Allocation 100	The net results of TR Arch TwistCap OSO 34 plant-based 1000 mL are lower (green)/ higher (orange) than those of				
	TR Arch TwistCap OSO 34 1000 mL	TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	-60%	-47%	-17%	-90%	-88%

Table 42: Comparison of net results: **TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Germany Allocation 100	The net results of TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL are lower (green)/ higher (orange) than those of				
	TR Arch TwistCap OSO 34 1000 mL	TR Arch TwistCap OSO 34 plant-based 1000 mL	TB Edge plant-based OSO 30 plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	-23%	+90%	+58%	-82%	-77%

Table 43: Comparison of net results: **TB Edge plant-based OSO 30 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

¹ ((|net result heading – net result column|) / net result column)*100

DAIRY FAMILY PACK (chilled), Germany Allocation 100	The net results of TB Edge plant-based OSO 30 plant-based 1000 mL are lower (green)/ higher (orange) than those of				
	TR Arch TwistCap OSO 34 1000 mL	TR Arch TwistCap OSO 34 plant-based 1000 mL	TT Carton Bottle plant-based C38 plant-based neck plant-based 1000 mL	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	-51%	+20%	-37%	-89%	-86%

4.3 Results sensitivity analyses regarding transport allocation; DAIRY FAMILY PACK CHILLED

4.3.1 Presentation of results DAIRY FAMILY PACK CHILLED

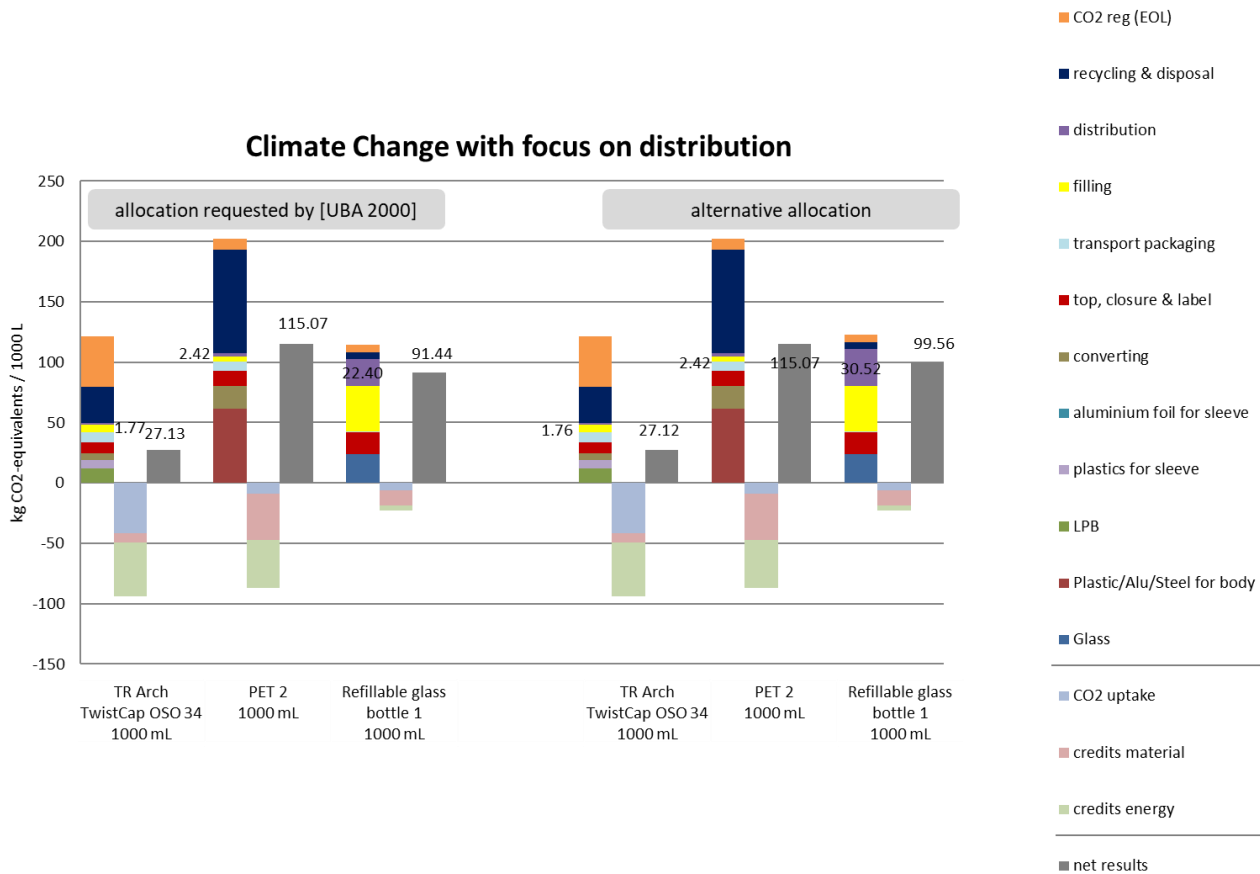


Figure 18: Climate Change results of segment **DAIRY FAMILY PACK CHILLED**, sensitivity analyses with focus on distribution; system allocation factor 100%

4.3.2 Description and interpretation

In this section the differences in the results of the transport allocation in the life cycle step distribution requested by [UBA 2000] and the alternative approach (see section 0) are described. Values of the distribution life cycle step and net results are separately displayed in the figure to show the impact of the sensitivity analysis. The results of the two allocation approaches show similar results. Whereas distribution impacts of the single use packaging systems can be seen as the same, the alternative allocation approach shows higher impacts than the approach requested by [UBA 2000] in case of the refillable glass bottle. The difference derives from a different approach regarding the allocation of the empty return trip of refillable packaging system. Whereas the approach requested by [UBA 2000] allocates the impacts of the empty return trip with the full distance to the non-regarded filling good, the alternative approach allocates the impacts of the empty return trip with a partial distance (as for single use packaging systems) to the non-regarded filling good.

As seen in the tables in the following sections the choice of transport allocation has no impact on the comparative results between the regarded beverage carton and the competing packaging systems.

4.3.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category ‘Climate Change’ compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see section 1.6 on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 44 shows the comparisons with the transport allocation requested by [UBA 2000].

Table 45 shows the comparisons with the alternative transport allocation.

Table 44: Comparison of net results: TR Arch TwistCap OSO 34 1000 mL versus competing alternative packaging systems in segment DAIRY FAMILY PACK CHILLED, transport allocation requested by [UBA 2000], system allocation factor 100%

DAIRY FAMILY PACK (chilled), Germany Allocation 100 Transport allocation requested by [UBA 2000]	The net results of TR Arch TwistCap OSO 34 1000 mL are lower (green)/ higher (orange) than those of	
	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	-76%	-69%

Table 45: Comparison of net results: TR Arch TwistCap OSO 34 1000 mL versus competing alternative packaging systems in segment DAIRY FAMILY PACK CHILLED, alternative transport allocation, system allocation factor 100%

DAIRY FAMILY PACK (chilled), Germany Allocation 100 Alternative transport allocation	The net results of TR Arch TwistCap OSO 34 1000 mL are lower (green)/ higher (orange) than those of	
	PET 2 1000 mL	Refillable glass bottle 1 1000 mL
Climate Change	-76%	-72%

¹ ((| net result heading – net result column|) / net result column)*100

4.4 Results allocation factor 50%; DAIRY FAMILY PACK AMBIENT

4.4.1 Presentation of results DAIRY FAMILY PACK AMBIENT

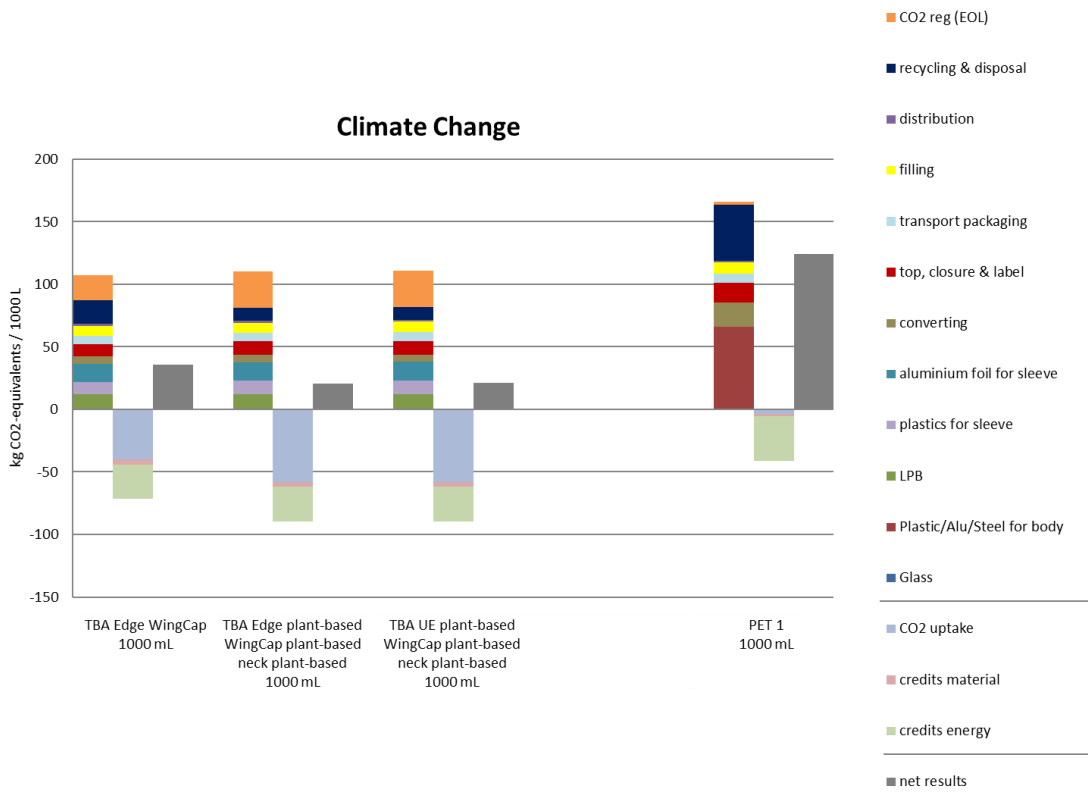


Figure 19: Climate Change results of segment DAIRY FAMILY PACK AMBIENT, allocation factor 50%

Table 46: Climate Change results of segment DAIRY FAMILY PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge WingCap 1000 mL	TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL	TBA UE plant-based WingCap plant-based neck plant-based 1000 mL	PET 1 1000 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	87.36	81.13	81.92	163.86
	CO ₂ (reg)	20.13	28.98	28.97	1.82
	Credits	-31.43	-31.52	-31.58	-37.56
	CO ₂ uptake	-40.26	-57.96	-57.94	-3.65
	net results	35.80	20.63	21.37	124.48

4.4.2 Description and interpretation

Beverage carton systems (specifications see [section 2.2.1](#))

For the beverage carton system considered in the DAIRY FAMILY PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (11%), production of plastics for sleeves (9%-10%) and the production of aluminium foil (13%-14%).

The converting to sleeves accounts only small shares (5%) of the total burdens for 'Climate Change'.

Minor shares (9%-10%) of total burdens for 'Climate Change' are caused from the production of closures.

The production and provision of 'transport packaging' for the beverage carton systems shows 6%-7% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'filling' shows minor shares of burdens (7%-8%) for the beverage carton.

The life cycle step 'distribution' shows 1% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows small to minor shares of total burdens for 'Climate Change' (10%-18%) resulting from recycling processes and the incineration of fossil materials.

'CO₂ reg. (recycling & disposal)' describes separately all regenerative CO₂ emissions from the incineration of biogenic material in MSWI or cement kilns. They contribute to 19%-26% of the total burdens for 'Climate Change'.

Energy credits sum up to 25% resulting from incineration in MSWI or cement kilns. Material credits for 'Climate Change' are low (4% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions.

The uptake of CO₂ by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the convention in this study which implies that no CO₂ uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO₂ uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for of the assessed system. (see [section 1.7.2](#))

Plastic bottle (specifications see [section 2.2.2](#))

In the assessed plastic bottle system in the DAIRY FAMILY PACK AMBIENT segment, the biggest part (40%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottle in this segment a minor share of burdens for 'Climate Change (12%).'.

The life cycle step 'top, closure & label' shows small impacts shares (9%) mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle systems shows small impact shares (4%) for climate change.

The life cycle steps 'filling' (6%) and 'distribution' (1%) show only small shares of burdens for the bottle system.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (27%) for the assessed plastic bottles resulting from thermal recovery in cement kilns.

For the white opaque plastic bottle material credits reduce the total burdens by only 1% resulting from the recycling of secondary and tertiary packaging as white opaque bottles are not materially recycled

Energy credits reduce the total burdens by 21% from thermal recovery in cement kilns.

4.4.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category 'Climate Change' compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

¹ $((| \text{net result heading} - \text{net result column} |) / \text{net result column}) * 100$

Table 47: Comparison of net results: **TBA Edge WingCap 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

<i>DAIRY FAMILY PACK (ambient), Germany Allocation 50</i>	The net results of TBA Edge WingCap 1000 mL are lower (green)/ higher (orange) than those of		
	TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL	TBA UE plant-based WingCap plant-based neck plant-based 1000 mL	PET 1 1000 mL
Climate Change	+74%	+68%	-71%

Table 48: Comparison of net results: **TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

<i>DAIRY FAMILY PACK (ambient), Germany Allocation 50</i>	The net results of TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL are lower (green)/ higher (orange) than those of		
	TBA Edge WingCap 1000 mL	TBA UE plant-based WingCap plant-based neck plant-based 1000 mL	PET 1 1000 mL
Climate Change	-42%	-3%	-83%

Table 49: Comparison of net results: **TBA UE plant-based WingCap plant-based neck plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

<i>DAIRY FAMILY PACK (ambient), Germany Allocation 50</i>	The net results of TBA UE plant-based WingCap plant-based neck plant-based 1000 mL are lower (green)/ higher (orange) than those of		
	TBA Edge WingCap 1000 mL	TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL	PET 1 1000 mL
Climate Change	-40%	+4%	-83%

4.5 Results allocation factor 100%; DAIRY FAMILY PACK AMBIENT

4.5.1 Presentation of results DAIRY FAMILY PACK AMBIENT

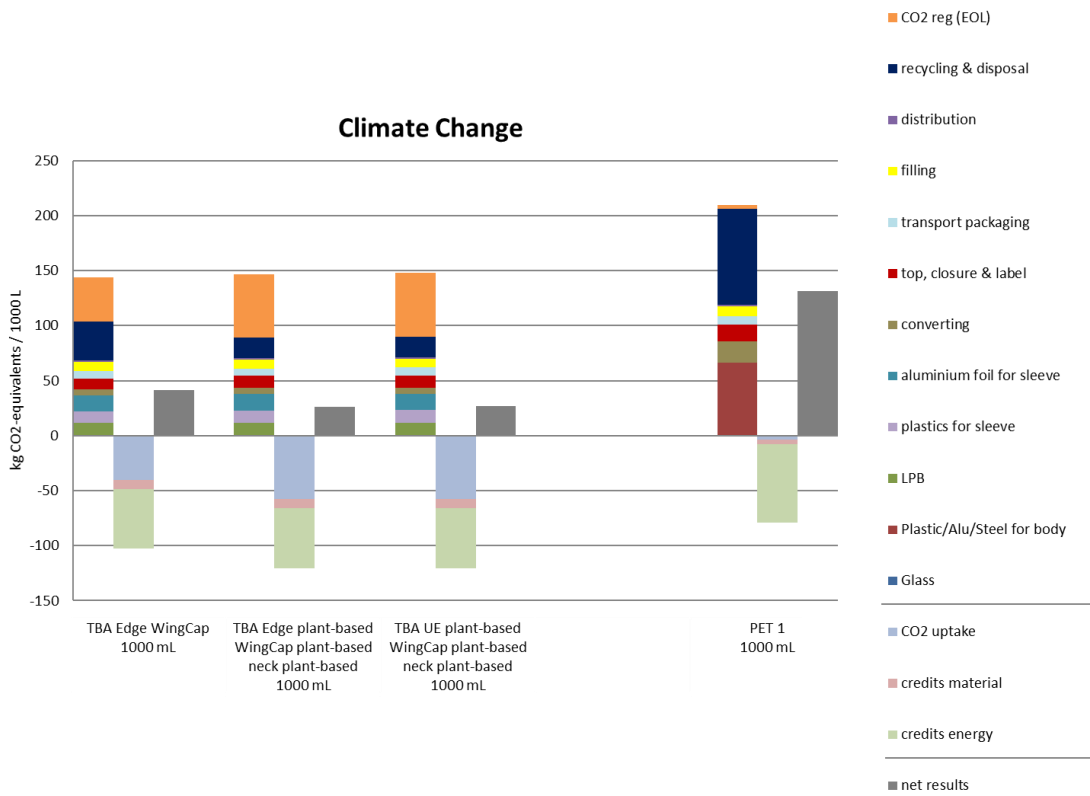


Figure 20: Climate Change results of segment DAIRY FAMILY PACK AMBIENT, allocation factor 100%

Table 50: Climate Change results of **segment DAIRY FAMILY PACK AMBIENT** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Edge WingCap 1000 mL	TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL	TBA UE plant-based WingCap plant-based neck plant-based 1000 mL		PET 1 1000 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	103.86	88.90	89.83		206.32
	CO ₂ (reg)	40.26	57.96	57.94		3.65
	Credits	-62.38	-62.56	-62.68		-75.15
	CO ₂ uptake	-40.26	-57.96	-57.94		-3.65
	net results	41.48	26.34	27.15		131.17

4.5.2 Description and interpretation

In this section the differences of the allocation factor 100% and the allocation factor 50% are described. Detailed descriptions and interpretation including the contribution of the life cycle steps are included for the allocation 50% results (see [section 4.1.2](#)).

A higher allocation factor implies the allocation of more burdens from the end-of-life processes (for example emissions from incineration, emissions from the production of electricity for recycling processes). It also implies the allocation of more credits for the substitution of other processes (for example energy credits for avoided electricity generation due to energy recovery at MSWIs or material credits for avoided production of new materials).

When applying an allocation factor of 100%, all burdens and all credits are allocated to the assessed system.

In the cases of beverage cartons in the segment DAIRY FAMILY PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also, the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO₂ reg. (recycling & disposal)' are allocated to the assessed system (see [section 1.7.2](#)).

In case of the PET bottle, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits from incineration in cement kilns is similar than that of the burdens from incinerating regardless of the allocation factor.

4.5.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category ‘Climate Change’ compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see section 1.6 on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 51: Comparison of net results: **TBA Edge WingCap 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

<i>DAIRY FAMILY PACK (ambient), Germany Allocation 100</i>	The net results of TBA Edge WingCap 1000 mL are lower (green)/ higher (orange) than those of		
	TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL	TBA UE plant-based WingCap plant-based neck plant-based 1000 mL	PET 1 1000 mL
Climate Change	+57%	+53%	-68%

Table 52: Comparison of net results: **TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

<i>DAIRY FAMILY PACK (ambient), Germany Allocation 100</i>	The net results of TBA Edge plant-based WingCap plant-based neck plant-based 1000 mL are lower (green)/ higher (orange) than those of		
	TBA Edge WingCap 1000 mL	TBA UE plant-based WingCap plant-based neck plant-based 1000 mL	PET 1 1000 mL
Climate Change	-37%	-3%	-80%

¹ ((|net result heading – net result column|) / net result column)*100

Table 53: Comparison of net results: **TBA UE plant-based WingCap plant-based neck plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

<i>DAIRY FAMILY PACK (ambient), Germany Allocation 100</i>	The net results of TBA UE plant-based WingCap plant-based neck plant-based 1000 mL are lower (green)/ higher (orange) than those of		
	TBA Edge WingCap 1000 mL	TBA Edge plant- based WingCap plant- based neck plant-based 1000 mL	PET 1 1000 mL
Climate Change	-35%	+3%	-79%

4.6 Results allocation factor 50%; JNSD FAMILY PACK AMBIENT

4.6.1 Presentation of results JNSD FAMILY PACK AMBIENT

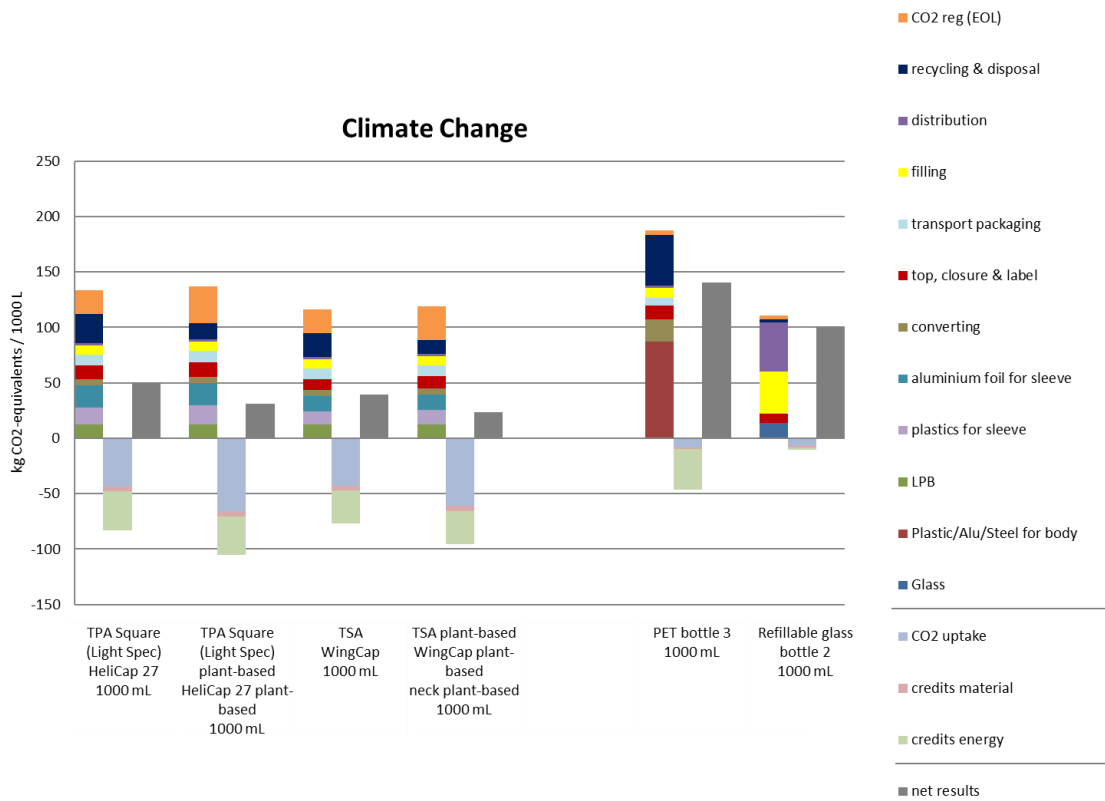


Figure 21: Climate Change results of segment JNSD FAMILY PACK AMBIENT, allocation factor 50%

Table 54: Climate Change results of segment JNSD FAMILY PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Square (Light Spec) HeliCap 27 1000 mL	TPA Square (Light Spec) plant-based HeliCap 27 plant-based 1000 mL	TSA WingCap 1000 mL	TSA plant-based WingCap plant-based neck plant-based 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	111.96	103.94	94.76	88.30	183.47	107.15
	CO ₂ (reg)	21.81	33.02	21.48	30.65	4.07	3.50
	Credits	-39.48	-39.52	-33.99	-34.08	-38.60	-3.61
	CO ₂ uptake	-43.62	-66.04	-42.95	-61.29	-8.15	-6.99
	net results	50.67	31.40	39.30	23.57	140.80	100.04

4.6.2 Description and interpretation

Beverage carton systems (specifications see [section 2.2.1](#))

For the beverage carton systems considered in the JNSD FAMILY PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (9%-11%), the production of plastics for sleeves (10%-13%) and the production of aluminium foil (12%-15%).

The converting to sleeves accounts only small shares (4%-5%) of the total burdens for 'Climate Change'.

Small shares (8%-9%) of total burdens for 'Climate Change' are caused from the production of closures.

The production and provision of 'transport packaging' for the beverage carton systems shows 8%-9% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'filling' shows small shares of burdens (6%-7%) for the beverage carton systems.

The life cycle step 'distribution' shows 1%-2% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows minor shares of total burdens for 'Climate Change' (11%-20%) resulting from recycling processes and the incineration of fossil materials.

'CO₂ reg. (recycling & disposal)' describes separately all regenerative CO₂ emissions from the incineration of biogenic material in MSWI or cement kilns. They contribute to 16%-26% of the total burdens for 'Climate Change'.

Energy credits sum up to 25%-26% resulting from incineration in MSWI or cement kilns. Material credits for 'Climate Change' are low (3%-4% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions.

The uptake of CO₂ by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the convention in this study which implies that no CO₂ uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO₂ uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for the assessed system. (see [section 1.7.2](#))

Plastic bottles (specifications see [section 2.2.2](#))

In the assessed plastic bottle systems in the JNSD FAMILY PACK AMBIENT segment, a major share (46%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottle in this segment minor shares of burdens for 'Climate Change' (11%).

The life cycle step 'top, closure & label' shows small impacts shares (6%) mainly attributed to the different plastics used for the relatively heavy closures.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (4%) for climate change.

The life cycle steps 'filling' (5%) and 'distribution' (1%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (24%) for the assessed plastic bottles resulting from thermal recovery in cement kilns.

For the PA containing plastic bottle material credits reduce the total burdens by only 1% resulting from the recycling of secondary and tertiary packaging as PET bottles containing PA are not materially recycled

Energy credits reduce the total burdens by 20% from thermal recovery in cement kilns.

Refillable glass bottle (specifications see [section 2.2.2](#))

The production of the 'glass' material shows minor shares of burdens for 'Climate Change' (12%). Without the use cycle of 27 of the refillable glass bottles, this share of total burdens would be remarkably higher.

The life cycle step 'filling' (34%) shows major shares of burdens due to the extra handling of refillable bottles which includes for example cleaning processes.

The life cycle step 'distribution' (40%) shows major shares of burdens due to the extra redistribution of the empty bottles, the small amount of packaging systems per pallet, leading to low lorry utilisation, as well as due to the heavy bottle weight the high share of packaging weight in the lorries. Additional shares of burdens for the refillable glass bottle in this segment are based on the local distribution with lorries with a loading capacity of 15t.

The life cycle step 'top, closure & label' shows small impact shares (7%) attributed to the aluminium production and converting of the closure as well as the production of the paper label.

The other life cycle steps show only small shares of impact (up to 3%).

The influence of material credits on the net result is also small for ‘Climate Change’. They reduce the overall burdens by 2%.

Due to the high MSWI with energy recovery and no landfilling in Germany, Energy credits show 2%.

4.6.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category ‘Climate Change’ compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see section 1.6 on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 55: Comparison of net results: **TSA Square (Light Spec) HeliCap 27 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Germany Allocation 50	The net results of TPA Square (Light Spec) HeliCap 27 1000 mL are lower (green)/ higher (orange) than those of				
	TPA Square (Light Spec) plant- based HeliCap 27 plant- based 1000 mL	TSA WingCap 1000 mL	TSA plant-based WingCap plant- based neck plant-based 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	+61%	+29%	+115%	-64%	-49%

¹ ((| net result heading – net result column|) / net result column)*100

Table 56: Comparison of net results: **TPA Square (Light Spec) plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Germany Allocation 50	The net results of TPA Square (Light Spec) plant-based HeliCap 27 plant-based 1000 mL are lower (green)/ higher (orange) than those of				
	TPA Square (Light Spec) HeliCap 27 1000 mL	TSA WingCap 1000 mL	TSA plant-based WingCap plant- based neck plant-based 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	-38%	-20%	+33%	-78%	-69%

Table 57: Comparison of net results: **TSA WingCap 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Germany Allocation 50	The net results of TSA WingCap 1000 mL are lower (green)/ higher (orange) than those of				
	TPA Square (Light Spec) HeliCap 27 1000 mL	TPA Square (Light Spec) plant-based HeliCap 27 plant- based 1000 mL	TSA plant-based WingCap plant- based neck plant-based 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	-22%	+25%	+67%	-72%	-61%

Table 58: Comparison of net results: **TSA plant-based WingCap plant-based neck plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Germany Allocation 50	The net results of TSA plant-based WingCap plant-based neck plant-based 1000 mL are lower (green)/ higher (orange) than those of				
	TPA Square (Light Spec) HeliCap 27 1000 mL	TPA Square (Light Spec) plant- based HeliCap 27 plant- based 1000 mL	TSA WingCap 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	-53%	-25%	-40%	-83%	-76%

4.7 Results allocation factor 100%; JNSD FAMILY PACK AMBIENT

4.7.1 Presentation of results JNSD FAMILY PACK AMBIENT

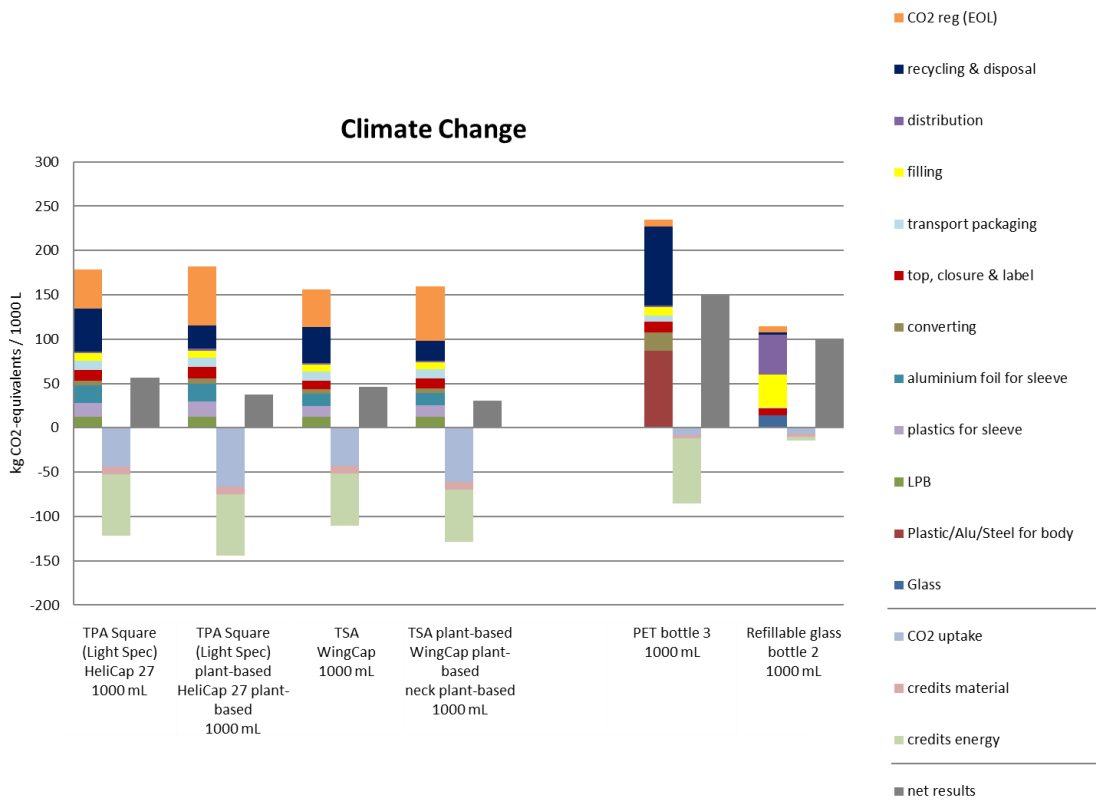


Figure 22: Climate Change results of segment JNSD FAMILY PACK AMBIENT, allocation factor 100%

Table 59: Climate Change results of segment JNSD FAMILY PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Square (Light Spec) HeliCap 27 1000 mL	TPA Square (Light Spec) plant-based HeliCap 27 plant-based 1000 mL	TSA WingCap 1000 mL	TSA plant-based WingCap plant-based neck plant-based 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	134.84	115.62	113.37	97.84	226.64	107.87
	CO2 (reg)	43.62	66.04	42.95	61.29	8.15	6.99
	Credits	-78.46	-78.53	-67.49	-67.66	-77.22	-7.20
	CO2 uptake	-43.62	-66.04	-42.95	-61.29	-8.15	-6.99
	net results	56.39	37.09	45.88	30.18	149.42	100.67

4.7.2 Description and interpretation

In this section the differences of the allocation factor 100% and the allocation factor 50% are described. Detailed descriptions and interpretation including the contribution of the life cycle steps are included for the allocation 50% results (see [section 4.1.2](#)).

A higher allocation factor implies the allocation of more burdens from the end-of-life processes (for example emissions from incineration, emissions from the production of electricity for recycling processes). It also implies the allocation of more credits for the substitution of other processes (for example energy credits for avoided electricity generation due to energy recovery at MSWIs or material credits for avoided production of new materials).

When applying an allocation factor of 100%, all burdens and all credits are allocated to the assessed system.

In the cases of beverage cartons in the segment JNSD FAMILY PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also, the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO₂ reg. (recycling & disposal)' are allocated to the assessed system (see [section 1.7.2](#)).

In case of the PET bottle, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits from incineration in cement kilns is similar than that of the burdens from incinerating regardless of the allocation factor.

In case of the refillable glass bottle, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as due to the reuse of the bottle burdens from recycling and incineration as well as credits are low.

4.7.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category 'Climate Change' compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

¹ $((| \text{net result heading} - \text{net result column} |) / \text{net result column}) * 100$

Table 60: Comparison of net results: **TPA Square (Light Spec) HeliCap 27 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Germany Allocation 100	The net results of TPA Square (Light Spec) HeliCap 27 1000 mL are lower (green)/ higher (orange) than those of				
	TPA Square (Light Spec) plant- based HeliCap 27 plant- based 1000 mL	TSA WingCap 1000 mL	TSA plant-based WingCap plant- based neck plant-based 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	+52%	+23%	+87%	-62%	-44%

Table 61: Comparison of net results: **TPA Square (Light Spec) plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Germany Allocation 100	The net results of TPA Square (Light Spec) plant-based HeliCap 27 plant-based 1000 mL are lower (green)/ higher (orange) than those of				
	TPA Square (Light Spec) HeliCap 27 1000 mL	TSA WingCap 1000 mL	TSA plant-based WingCap plant- based neck plant-based 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	-34%	-19%	+23%	-75%	-63%

Table 62: Comparison of net results: **TSA WingCap 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Germany Allocation 100	The net results of TSA WingCap 1000 mL are lower (green)/ higher (orange) than those of				
	TPA Square (Light Spec) HeliCap 27 1000 mL	TPA Square (Light Spec) plant- based HeliCap 27 plant- based 1000 mL	TSA plant-based WingCap plant- based neck plant-based 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	-19%	+24%	+52%	-69%	-54%

Table 63: Comparison of net results: **TSA plant-based WingCap plant-based neck plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Germany Allocation 100	The net results of TSA plant-based WingCap plant-based neck plant-based 1000 mL are lower (green)/ higher (orange) than those of				
	TPA Square (Light Spec) HeliCap 27 1000 mL	TPA Square (Light Spec) plant- based HeliCap 27 plant- based 1000 mL	TSA WingCap 1000 mL	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	-46%	-19%	-34%	-80%	-70%

4.8 Results sensitivity analyses regarding transport allocation; JNSD FAMILY PACK AMBIENT

4.8.1 Presentation of results JNSD FAMILY PACK AMBIENT

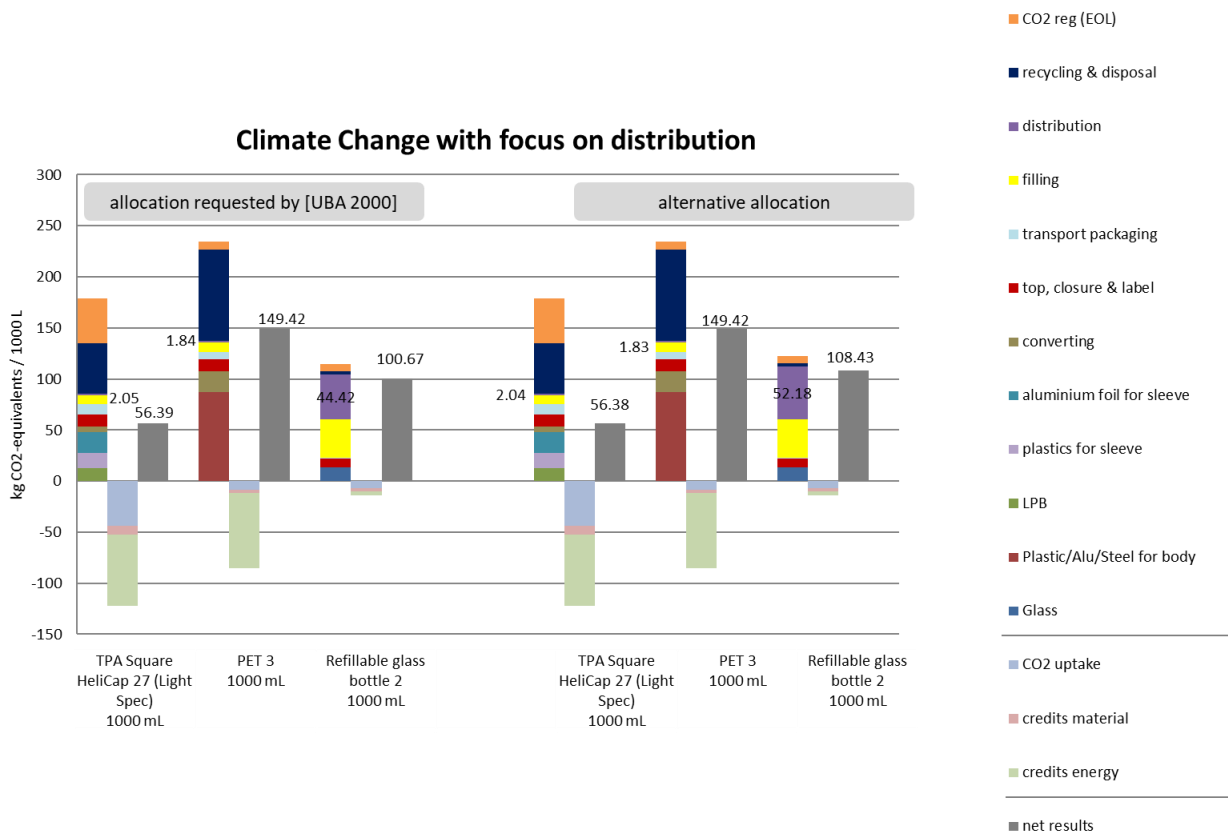


Figure 23: Climate Change results of **segment JNSD FAMILY PACK AMBIENT**, sensitivity analyses with **focus on distribution**; system allocation factor 100%

4.8.2 Description and interpretation

In this section the differences in the results of the transport allocation in the life cycle step distribution requested by [UBA 2000] and the alternative approach (see [section 0](#)) are described. Values of the distribution life cycle step and net results are separately displayed in the figure to show the impact of the sensitivity analysis. The results of the two allocation approaches show similar results. Whereas distribution impacts of the single use packaging systems can be seen as the same, the alternative allocation approach shows higher impacts than the approach requested by [UBA 2000] in case of the refillable glass bottle. The difference derives from a different approach regarding the allocation of the empty return trip of refillable packaging system. Whereas the approach requested by [UBA 2000] allocates the impacts of the empty return trip with the full distance to the non-regarded filling good, the alternative approach allocates the impacts of the empty return trip with a partial distance (as for single use packaging systems) to the non-regarded filling good.

As seen in the tables in the following sections the choice of transport allocation has no impact on the comparative results between the regarded beverage carton and the competing packaging systems.

4.8.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category ‘Climate Change’ compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see section 1.6 on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 64 shows the comparisons with the transport allocation requested by [UBA 2000].

Table 65 shows the comparisons with the alternative transport allocation.

Table 64: Comparison of net results: **TPA Square (Light Spec) HeliCap 27 1000 mL** versus competing alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, transport allocation requested by [UBA 2000], system allocation factor 100%

<i>JNSD FAMILY PACK (ambient), Germany Allocation 100 Transport allocation requested by [UBA 2000]</i>	The net results of TPA Square (Light Spec) HeliCap 27 1000 mL are lower (green)/ higher (orange) than those of	
	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	-61%	-42%

Table 65: Comparison of net results: **TPA Square (Light Spec) HeliCap 27 1000 mL** versus competing alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, alternative transport allocation, system allocation factor 100%

<i>JNSD FAMILY PACK (ambient), Germany Allocation 100 Alternative transport allocation</i>	The net results of TPA Square (Light Spec) HeliCap 27 1000 mL are lower (green)/ higher (orange) than those of	
	PET bottle 3 1000 mL	Refillable glass bottle 2 1000 mL
Climate Change	-61%	-47%

¹ ((| net result heading – net result column|) / net result column)*100

4.9 Results allocation factor 50%; JNSD PORTION PACK AMBIENT

4.9.1 Presentation of results JNSD PORTION PACK AMBIENT

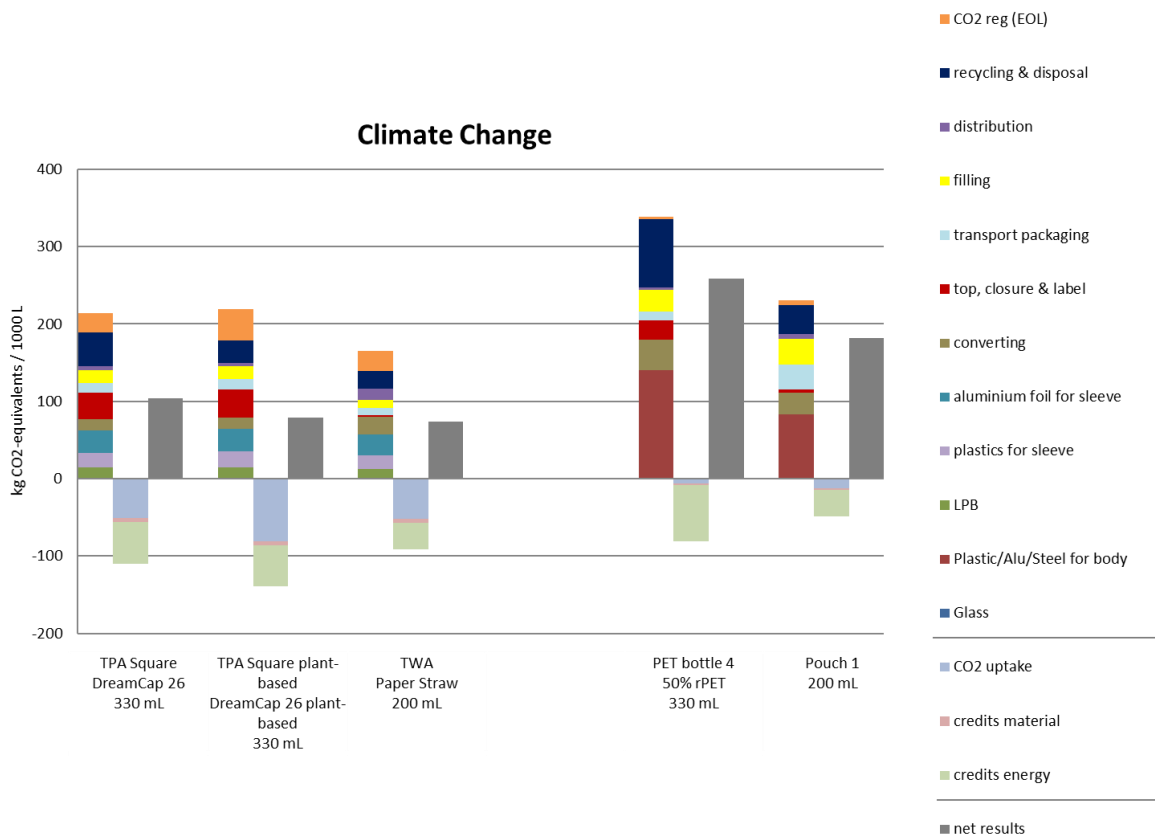


Figure 24: Climate Change results of segment JNSD PORTION PACK AMBIENT, allocation factor 50%

Table 66: Climate Change results of segment JNSD PORTION PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Square DreamCap 26 330 mL	TPA Square plant-based DreamCap 26 plant-based 330 mL	TWA Paper Straw 200 mL	PET bottle 4 50% rPET 330 mL	Pouch 1 200 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	188.57	178.33	139.30	335.53	224.23
	CO ₂ (reg)	25.56	40.31	26.18	3.36	6.22
	Credits	-58.69	-58.92	-39.52	-73.90	-36.18
	CO ₂ uptake	-51.11	-80.61	-52.36	-6.72	-12.45
	net results	104.32	79.11	73.60	258.27	181.83

4.9.2 Description and interpretation

Beverage carton systems (specifications see [section 2.2.1](#))

For the beverage carton systems considered in the JNSD PORTION PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (7%), the production of plastics for sleeves (9%-11%) and the production of aluminium foil (13%-16%).

The converting to sleeves accounts only small shares (7%-14%) of the total burdens for 'Climate Change'.

Minor shares (16%-17%) of total burdens for 'Climate Change' are caused from the production of closures. In case of the TWA carton with paper straw this life cycle step shows only 2% of the total burdens resulting from the production of the paper straw.

The production and provision of 'transport packaging' for the beverage carton systems shows 6% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'filling' shows small shares of burdens (6%-8%) for the beverage carton systems.

The life cycle step 'distribution' shows 2%-9% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows minor to considerable shares of total burdens for 'Climate Change' (13%-20%) resulting from recycling processes and the incineration of fossil materials.

'CO₂ reg. (recycling & disposal)' describes separately all regenerative CO₂ emissions from the incineration of biogenic material in MSWI or cement kilns. They contribute to 12%-18% of the total burdens for 'Climate Change'.

Energy credits sum up to 21%-25% resulting from incineration in MSWI or cement kilns. Material credits for 'Climate Change' are low (2%-3% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions.

The uptake of CO₂ by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the convention in this study which implies that no CO₂ uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO₂ uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for of the assessed system. (see [section 1.7.2](#))

Plastic bottles (specifications see [section 2.2.2](#))

In the assessed plastic bottle system in the JNSD PORTION PACK AMBIENT segment, a major share (41%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottle in this segment a minor share of burdens for 'Climate Change' (11%).

The life cycle step 'top, closure & label' shows small impacts shares (7%) mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (3%) for climate change.

The life cycle steps 'filling' (8%) and 'distribution' (1%) show only small shares of burdens for the bottle system.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (26%) for the assessed plastic bottles resulting from thermal recovery in cement kilns.

For the PA containing plastic bottle material credits reduce the total burdens by only 1% resulting from the recycling of secondary and tertiary packaging as PET bottles containing PA are not materially recycled.

Energy credits reduce the total burdens by 21% from thermal recovery in cement kilns.

Pouch (specifications see [section 2.2.2](#))

In the assessed pouch in the JNSD PORTION PACK AMBIENT segment, a major share (36%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the pouch.

The 'converting' process shows for the pouch in this segment a minor share of burdens for 'Climate Change' (12%).

As the pouch has no closure no shares of total burdens for 'Climate Change' are caused from life cycle step 'top, closure & label'.

The production and provision of 'transport packaging' for the pouch shows minor impact shares (14%) for climate change.

The life cycle steps 'filling' (14%) and 'distribution' (3%) show small to minor shares of burdens for the pouch.

The pouches' 'recycling & disposal' life cycle step shows minor shares (16%) for the assessed pouch resulting from incineration of the pouches.

Material credits reduce the total burdens by 1% resulting from the recycling of secondary and tertiary packaging.

The influence of energy credits on the net result is high due to 100% MSWI with energy recovery in Germany. The high reduction of net results by energy credits (15%) results from the incineration of pouches.

4.9.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category ‘Climate Change’ compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see section 1.6 on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 67: Comparison of net results: **TPA Square DreamCap 26 330 mL** versus competing cartons and alternative packaging systems in **segment JNSD PORTION PACK AMBIENT**, allocation factor 50%

JNSD PORTION PACK (ambient), Germany Allocation 50	The net results of TPA Square DreamCap 26 330 mL are lower (green)/ higher (orange) than those of			
	TPA Square plant-based DreamCap 26 plant-based 330 mL	TWA Paper Straw 200 mL	PET bottle 4 50% rPET 330 mL	Pouch 1 200 mL
Climate Change	+32%	+42%	-60%	-43%

Table 68: Comparison of net results: **TPA Square plant-based DreamCap 26 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment JNSD PORTION PACK AMBIENT**, allocation factor 50%

JNSD PORTION PACK (ambient), Germany Allocation 50	The net results of TPA Square plant-based DreamCap 26 plant-based 330 mL are lower (green)/ higher (orange) than those of			
	TPA Square DreamCap 26 330 mL	TWA Paper Straw 200 mL	PET bottle 4 50% rPET 330 mL	Pouch 1 200 mL
Climate Change	-24%	+7%	-69%	-56%

¹ ((| net result heading – net result column|) / net result column)*100

Table 69: Comparison of net results: **TWA Paper Straw 200 mL** versus competing cartons and alternative packaging systems in **segment JNSD PORTION PACK AMBIENT**, allocation factor 50%

<i>JNSD PORTION PACK (ambient), Germany Allocation 50</i>	The net results of TWA Paper Straw 200 mL are lower (green)/ higher (orange) than those of			
	TPA Square DreamCap 26 330 mL	TPA Square plant- based DreamCap 26 plant-based 330 mL	PET bottle 4 50% rPET 330 mL	Pouch 1 200 mL
Climate Change	-29%	-7%	-72%	-60%

4.10 Results allocation factor 100%; JNSD PORTION PACK AMBIENT

4.10.1 Presentation of results JNSD PORTION PACK AMBIENT

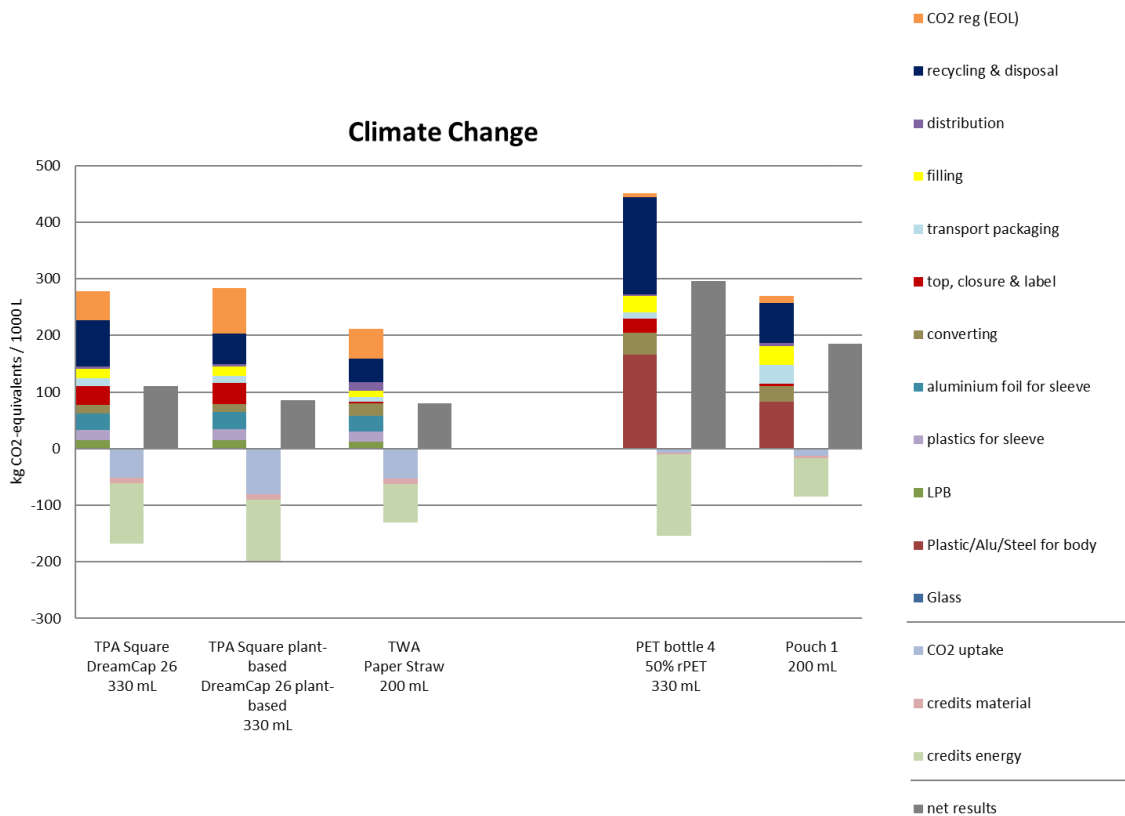


Figure 25: Climate Change results of segment JNSD PORTION PACK AMBIENT, allocation factor 100%

Table 70: Climate Change results of segment JNSD PORTION PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Square DreamCap 26 330 mL	TPA Square plant-based DreamCap 26 plant-based 330 mL	TWA Paper Straw 200 mL	PET bottle 4 50% rPET 330 mL	Pouch 1 200 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	227.41	202.69	158.51	443.93	257.69
	CO ₂ (reg)	51.11	80.61	52.36	6.72	12.45
	Credits	-116.81	-117.27	-78.49	-147.80	-72.36
	CO ₂ uptake	-51.11	-80.61	-52.36	-6.72	-12.45
	net results	110.60	85.41	80.02	296.13	185.33

4.10.2 Description and interpretation

In this section the differences of the allocation factor 100% and the allocation factor 50% are described. Detailed descriptions and interpretation including the contribution of the life cycle steps are included for the allocation 50% results (see [section 4.9.2](#)).

A higher allocation factor implies the allocation of more burdens from the end-of-life processes (for example emissions from incineration, emissions from the production of electricity for recycling processes). It also implies the allocation of more credits for the substitution of other processes (for example energy credits for avoided electricity generation due to energy recovery at MSWIs or material credits for avoided production of new materials).

When applying an allocation factor of 100%, all burdens and all credits are allocated to the assessed system.

In the cases of beverage cartons in the segment JNSD PORTION PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also, the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO₂ reg. (recycling & disposal)' are allocated to the assessed system (see [section 1.7.2](#)).

In the case of the plastic bottle with 50% recycled PET content, higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as with allocation factor 100% all burdens from the original material production are allocated to the regarded system.

In case of the pouch, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits from incineration in cement kilns is similar than that of the burdens from incinerating regardless of the allocation factor.

4.10.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category 'Climate Change' compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging

systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 71: Comparison of net results: **TPA Square DreamCap 26 330 mL** versus competing cartons and alternative packaging systems in **segment JNSD PORTION PACK AMBIENT**, allocation factor 100%

JNSD PORTION PACK (ambient), Germany Allocation 100	The net results of TPA Square DreamCap 26 330 mL are lower (green)/ higher (orange) than those of			
	TPA Square plant-based DreamCap 26 plant-based 330 mL	TWA Paper Straw 200 mL	PET bottle 4 50% rPET 330 mL	Pouch 1 200 mL
Climate Change	+29%	+38%	-63%	-40%

Table 72: Comparison of net results: **TPA Square plant-based DreamCap 26 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment JNSD PORTION PACK AMBIENT**, allocation factor 100%

JNSD PORTION PACK (ambient), Germany Allocation 100	The net results of TPA Square plant-based DreamCap 26 plant-based 330 mL are lower (green)/ higher (orange) than those of			
	TPA Square DreamCap 26 330 mL	TWA Paper Straw 200 mL	PET bottle 4 50% rPET 330 mL	Pouch 1 200 mL
Climate Change	-23%	+7%	-71%	-54%

Table 73: Comparison of net results: **TWA Paper Straw 200 mL** versus competing cartons and alternative packaging systems in **segment JNSD PORTION PACK AMBIENT**, allocation factor 100%

JNSD PORTION PACK (ambient), Germany Allocation 100	The net results of TWA Paper Straw 200 mL are lower (green)/ higher (orange) than those of			
	TPA Square DreamCap 26 330 mL	TPA Square plant-based DreamCap 26 plant-based 330 mL	PET bottle 4 50% rPET 330 mL	Pouch 1 200 mL
Climate Change	-28%	-6%	-73%	-57%

¹ ((| net result heading – net result column|) / net result column)*100

4.11 Results allocation factor 50%; FLAVOURED WATER FAMILY PACK AMBIENT

4.11.1 Presentation of results FLAVOURED WATER FAMILY PACK AMBIENT

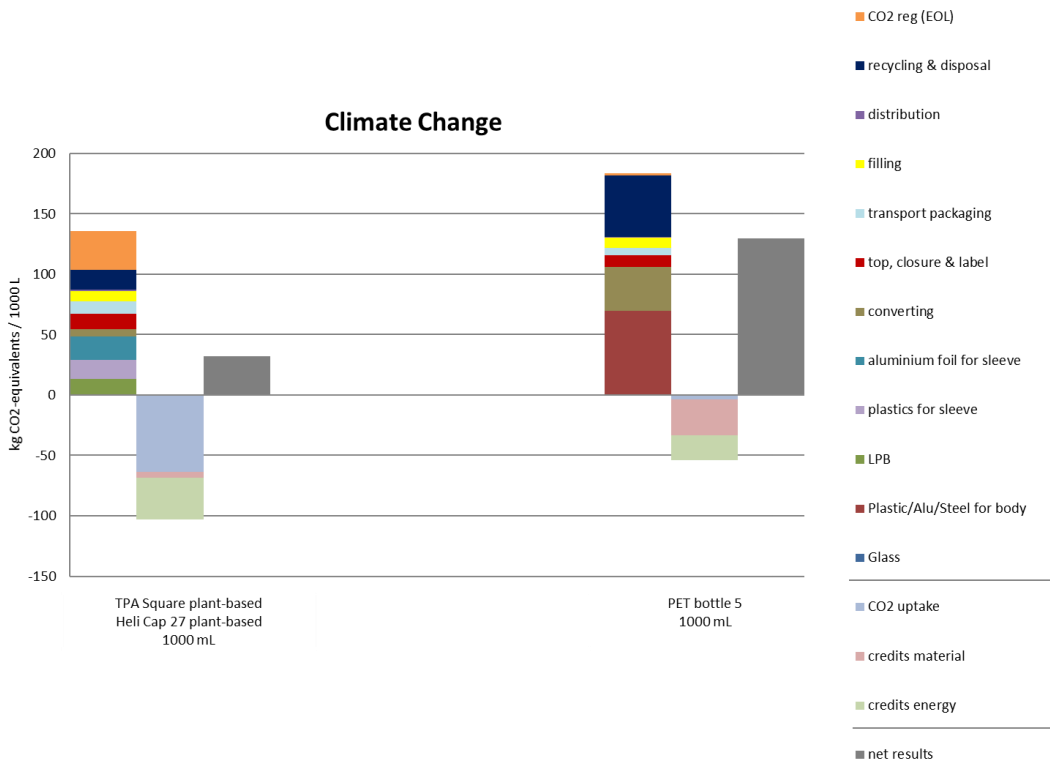


Figure 26: Climate Change results of segment FLAVOURED WATER FAMILY PACK AMBIENT, allocation factor 50%

Table 74: Climate Change results of segment FLAVOURED WATER FAMILY PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Square plant-based Heli Cap 27 plant-based 1000 mL	PET bottle 5 1000 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	103.60	181.60
	CO ₂ (reg)	31.91	1.68
	Credits	-39.42	-50.56
	CO ₂ uptake	-63.82	-3.37
	net results	32.27	129.36

4.11.2 Description and interpretation

Beverage carton systems (specifications see [section 2.2.1](#))

For the beverage carton system considered in the FLAVOURED WATER FAMILY PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (10%), the production of plastics for sleeves (11%) and the production of aluminium foil (15%).

The converting to sleeves accounts only small shares (4%) of the total burdens for 'Climate Change'.

Minor shares (10%) of total burdens for 'Climate Change' are caused from the production of closures due to the relatively high weight of closures compared to the sleeve.

The production and provision of 'transport packaging' for the beverage carton systems shows 8% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'filling' shows minor shares of burdens (6%) for the beverage carton systems.

The life cycle step 'distribution' shows 1% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows minor shares of total burdens for 'Climate Change' (12%) resulting from recycling processes and the incineration of fossil materials.

'CO₂ reg. (recycling & disposal)' describes separately all regenerative CO₂ emissions from the incineration of biogenic material in MSWI or cement kilns. They contribute to 23% of the total burdens for 'Climate Change'.

Energy credits sum up to 26% resulting from incineration in MSWI or cement kilns. Material credits for 'Climate Change' are low (3% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions.

The uptake of CO₂ by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the convention in this study which implies that no CO₂ uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO₂ uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for of the assessed system. (see [section 1.7.2](#))

Plastic bottle (specifications see [section 2.2.2](#))

In the assessed plastic bottle system in the FLAVOURED WATER FAMILY PACK AMBIENT segment, a major share (38%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottle.

The 'converting' process shows for the PET bottle in this segment a minor shares of burdens for 'Climate Change' (20%).

The life cycle step 'top, closure & label' shows considerable impacts shares (5%) mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (3%) for climate change.

The life cycle steps 'filling' (5%) and 'distribution' (less than 1%) show only small shares of burdens for the bottle system.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (28%) for the assessed plastic bottles resulting from the recycling processes and incineration of the bottles.

Material credits reduce the total burdens by 16% resulting from the substitution of virgin PET.

Energy credits reduce the total burdens by 11% from the incineration of PET bottles.

4.11.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category 'Climate Change' compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

¹ $((| \text{net result heading} - \text{net result column} |) / \text{net result column}) * 100$

Table 75: Comparison of net results: **TPA Square plant-based Heli Cap 27 plant-based 1000 mL** versus alternative packaging systems in **segment FLAVOURED WATER FAMILY PACK AMBIENT**, allocation factor 50%

<p><i>FLAVOURED WATER, FAMILY PACK (ambient), Germany Allocation 50</i></p>	<p>The net results of TPA Square plant-based Heli Cap 27 plant-based 1000 mL are lower (green)/ higher (orange) than those of</p>
	<p>PET bottle 5 1000 mL</p>
<p>Climate Change</p>	<p>-75%</p>

4.12 Results allocation factor 100%; FLAVOURED WATER FAMILY PACK AMBIENT

4.12.1 Presentation of results FLAVOURED WATER FAMILY PACK AMBIENT

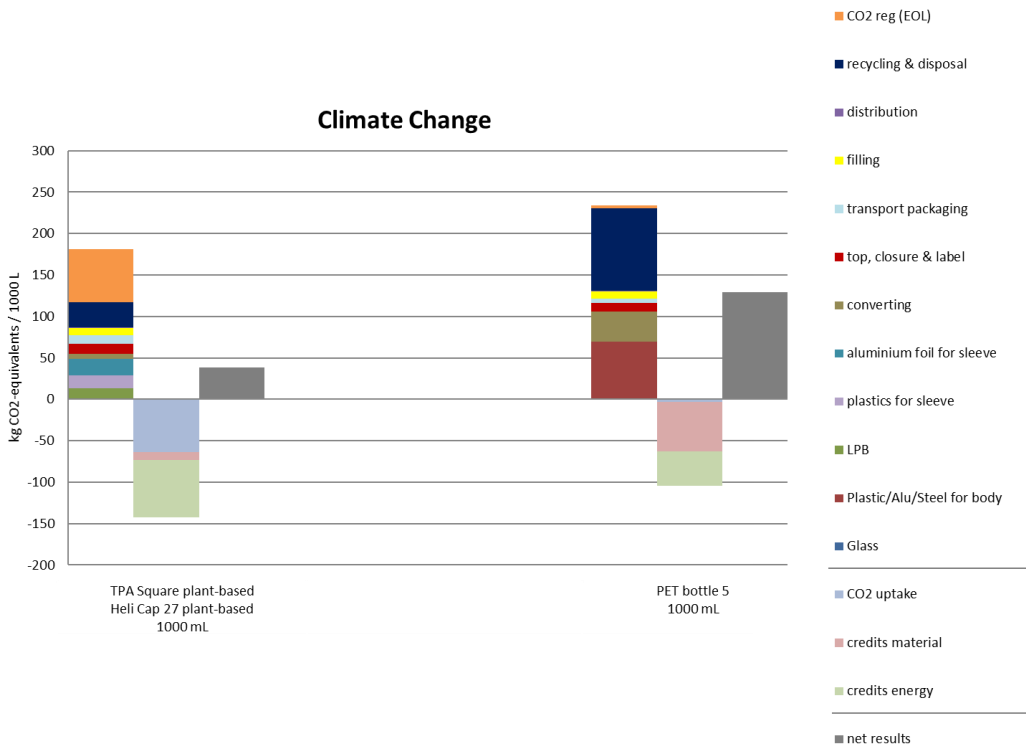


Figure 27: Climate Change results of segment **FLAVOURED WATER FAMILY PACK AMBIENT**, allocation factor 100%

Table 76: Climate Change results of **segment FLAVOURED WATER FAMILY PACK AMBIENT** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Square plant-based Heli Cap 27 plant-based 1000 mL	PET bottle 5 1000 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	116.93	230.59
	CO ₂ (reg)	63.82	3.37
	Credits	-78.30	-101.14
	CO ₂ uptake	-63.82	-3.37
	net results	38.62	129.44

4.12.2 Description and interpretation

In this section the differences of the allocation factor 100% and the allocation factor 50% are described. Detailed descriptions and interpretation including the contribution of the life cycle steps are included for the allocation 50% results (see [section 4.11.2](#)).

A higher allocation factor implies the allocation of more burdens from the end-of-life processes (for example emissions from incineration, emissions from the production of electricity for recycling processes). It also implies the allocation of more credits for the substitution of other processes (for example energy credits for avoided electricity generation due to energy recovery at MSWIs or material credits for avoided production of new materials).

When applying an allocation factor of 100%, all burdens and all credits are allocated to the assessed system.

In the cases of beverage cartons in the segment FLAVOURED WATER FAMILY PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also, the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO₂ reg. (recycling & disposal)' are allocated to the assessed system (see [section 1.7.2](#)).

In the case of the plastic bottle, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits (material and energy credits) is similar than that of the burdens regardless of the allocation factor.

4.12.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category ‘Climate Change’ compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 77: Comparison of net results: **TPA Square plant-based Heli Cap 27 plant-based 1000 mL** versus alternative packaging systems in **segment FLAVOURED WATER FAMILY PACK AMBIENT**, allocation factor 100%

<i>FLAVOURED WATER, FAMILY PACK (ambient), Germany Allocation 100</i>	The net results of TPA Square plant-based Heli Cap 27 plant-based 1000 mL are lower (green)/ higher (orange) than those of
	PET bottle 5 1000 mL
Climate Change	-70%

¹ ((|net result heading – net result column|) / net result column)*100

4.13 Results allocation factor 50%; UNFLAVOURED WATER PORTION PACK AMBIENT

4.13.1 Presentation of results UNFLAVOURED WATER PORTION PACK AMBIENT

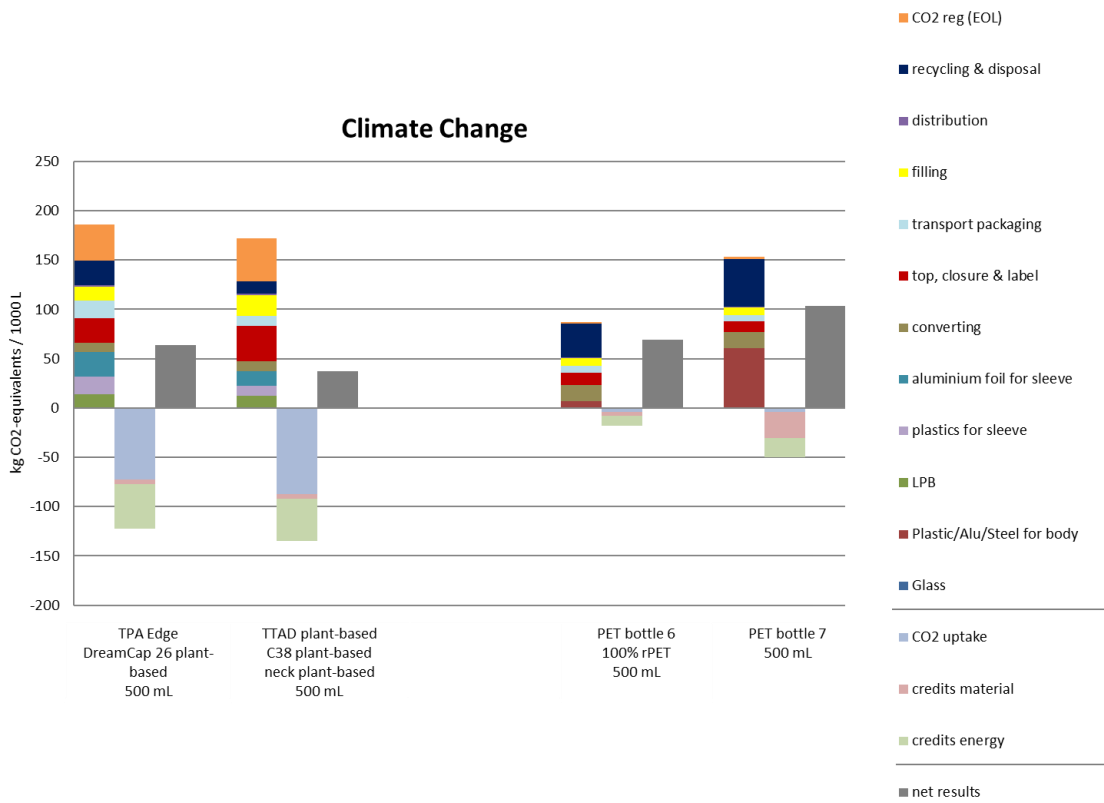


Figure 28: Climate Change results of segment UNFLAVOURED WATER PORTION PACK AMBIENT, allocation factor 50%

Table 78: Climate Change results of segment UNFLAVOURED WATER PORTION PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Edge DreamCap 26 plant-based 500 mL	TTAD plant-based C38 plant-based neck plant-based 500 mL	PET bottle 6 100% rPET 500 mL	PET bottle 7 500 mL
Climate Change [kg CO2-e/1000 L]	Burdens	149.44	128.11	85.34	151.23
	CO2 (reg)	36.31	43.87	2.03	2.03
	Credits	-49.56	-47.24	-13.92	-45.96
	CO2 uptake	-72.62	-87.74	-4.05	-4.05
	net results	63.57	37.00	69.40	103.24

4.13.2 Description and interpretation

Beverage carton system (specifications see [section 2.2.1](#))

For the beverage carton systems considered in the UNFLAVOURED WATER PORTION PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (7%), the production of plastics for sleeves (6%-10%) and the production of aluminium foil (9%-13%).

The converting to sleeves accounts only small shares (5%-6%) of the total burdens for 'Climate Change'.

Regarding the TPA carton, minor shares (13%) of total burdens for 'Climate Change' are caused from the production of closures. Regarding the TT carton, this life cycle steps contributes to considerable (21%) shares of total burden due to the higher weight of the top.

The production and provision of 'transport packaging' for the beverage carton systems show 6%-10% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'filling' shows small to minor shares of burdens (8%-12%) for the beverage carton.

The life cycle step 'distribution' shows 1% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows small to minor shares of total burdens for 'Climate Change' (7%-13%) resulting from recycling processes and the incineration of fossil materials.

'CO₂ reg. (recycling & disposal)' describes separately all regenerative CO₂ emissions from the incineration of biogenic material in MSWI or cement kilns. They contribute to 19%-25% of the total burdens for 'Climate Change'.

Energy credits sum up to 24%-25% resulting from incineration in MSWI or cement kilns. Material credits for 'Climate Change' are low (3% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions.

The uptake of CO₂ by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the convention in this study which implies that no CO₂ uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO₂ uptake is applied and seen

in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for of the assessed system. (see [section 1.7.2](#))

Plastic bottle (specifications see [section 2.2.2](#))

In the assessed plastic bottle system in the UNFLAVOURED WATER PORTION PACK AMBIENT segment, the major share (40%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles. For the rPET bottle containing 100% recycled PET it only contributes to small shares (8%) as most of the recycled material is sourced in a closed loop.

The 'converting' process shows for the PET bottles in this segment a minor share of burdens for 'Climate Change' (11%-19%).

The life cycle step 'top, closure & label' shows small (PET 7%) to minor (rPET 14%) impacts shares mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (4%-8%) for climate change.

The life cycle steps 'filling' (5%-8%) and 'distribution' (1%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (32%-39%) for the assessed plastic bottles resulting from the recycling processes and incineration of the bottles.

Material credits regarding the rPET bottle reduce the total burdens by 5% resulting only from the recycling of secondary and tertiary packaging. All recycled PET is used as closed loop material, reducing the burdens for plastic production. Regarding the PET bottle material, credits reduce the total burdens by 17% resulting from the substitution of virgin PET.

Energy credits reduce the total burdens by 11%-13% from the incineration of PET bottles.

4.13.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category 'Climate Change' compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging

systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 79: Comparison of net results: **TPA Edge DreamCap 26 plant-based 500 mL** versus a competing carton and alternative packaging systems in **segment UNFLAVOURED WATER PORTION PACK AMBIENT**, allocation factor 50%

<i>UNFLAVOURED WATER, PORTION PACK (ambient), Germany Allocation 50</i>	The net results of TPA Edge DreamCap 26 plant-based 500 mL are lower (green)/ higher (orange) than those of		
	TTAD plant-based C38 plant-based neck plant-based 500 mL	PET bottle 6 100% rPET 500 mL	PET bottle 7 500 mL
Climate Change	+72%	-8%	-38%

Table 80: Comparison of net results: **TTAD plant-based C38 plant-based neck plant-based 500 mL** versus a competing carton and alternative packaging systems in **segment UNFLAVOURED WATER PORTION PACK AMBIENT**, allocation factor 50%

<i>UNFLAVOURED WATER, PORTION PACK (ambient), Germany Allocation 50</i>	The net results of TTAD plant-based C38 plant-based neck plant- based 500 mL are lower (green)/ higher (orange) than those of		
	TPA Edge DreamCap 26 plant-based 500 mL	PET bottle 6 100% rPET 500 mL	PET bottle 7 500 mL
Climate Change	-42%	-47%	-64%

¹ ((| net result heading – net result column|) / net result column)*100

4.14 Results allocation factor 100%; UNFLAVOURED WATER PORTION PACK AMBIENT

4.14.1 Presentation of results UNFLAVOURED WATER PORTION PACK AMBIENT

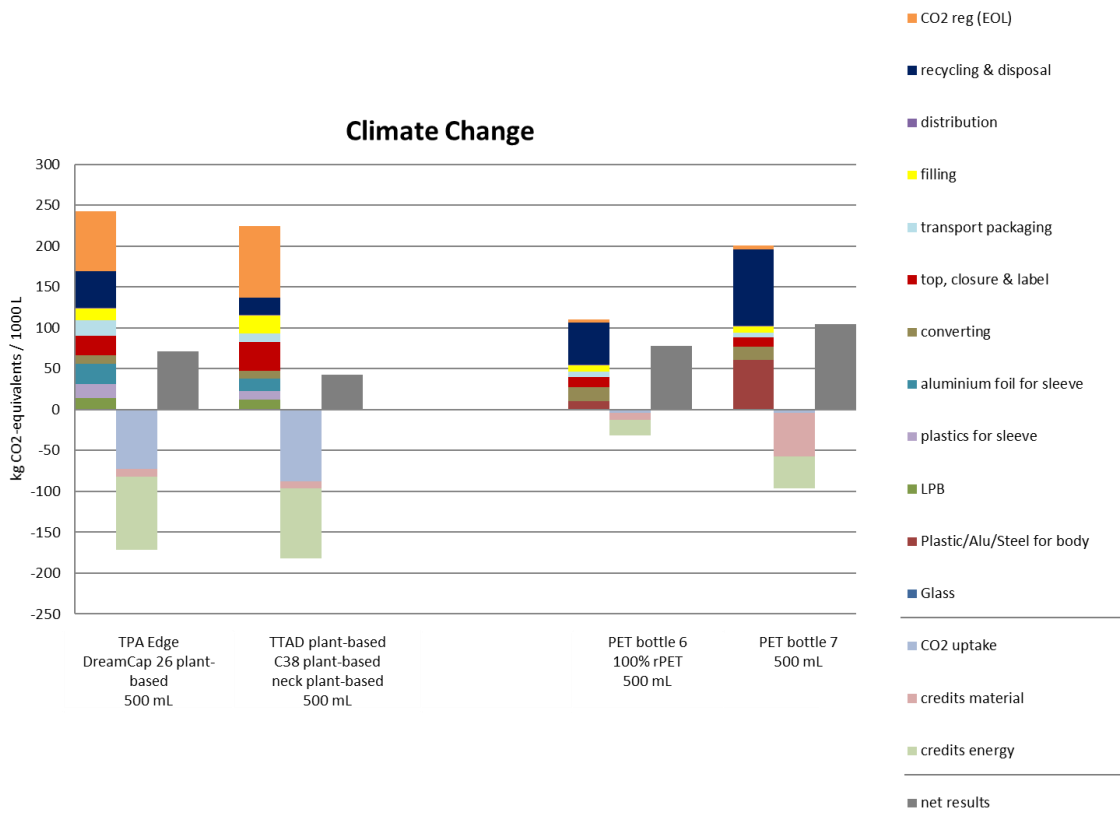


Figure 29: Climate Change results of segment UNFLAVOURED WATER PORTION PACK AMBIENT, allocation factor 100%

Table 81: Climate Change results of **segment UNFLAVOURED WATER PORTION PACK AMBIENT** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Edge DreamCap 26 plant-based 500 mL	TTAD plant-based C38 plant-based neck plant-based 500 mL		PET bottle 6 100% rPET 500 mL	PET bottle 7 500 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	169.71	136.83		106.00	196.23
	CO ₂ (reg)	72.62	87.74		4.05	4.05
	Credits	-98.57	-93.99		-27.86	-91.94
	CO ₂ uptake	-72.62	-87.74		-4.05	-4.05
	net results	71.13	42.85		78.14	104.29

4.14.2 Description and interpretation

In this section the differences of the allocation factor 100% and the allocation factor 50% are described. Detailed descriptions and interpretation including the contribution of the life cycle steps are included for the allocation 50% results (see [section 4.9.2](#)).

A higher allocation factor implies the allocation of more burdens from the end-of-life processes (for example emissions from incineration, emissions from the production of electricity for recycling processes). It also implies the allocation of more credits for the substitution of other processes (for example energy credits for avoided electricity generation due to energy recovery at MSWIs or material credits for avoided production of new materials).

When applying an allocation factor of 100%, all burdens and all credits are allocated to the assessed system.

In the cases of beverage cartons in the segment UNFLAVOURED WATER PORTION PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO₂ reg. (recycling & disposal)' are allocated to the assessed system (see [section 1.7.2](#)).

In the case of the rPET plastic bottle with 100% recycled PET content, higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as with allocation factor 100% all burdens from the original material production are allocated to the regarded system.

In the case of the plastic bottle without recycled content, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the

absolute value of the credits (material and energy credits) is similar than that of the burdens regardless of the allocation factor.

4.14.3 Comparison between packaging systems

The following tables show the net results per functional unit of the assessed beverage cartons systems for the impact category ‘Climate Change’ compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see section 1.6 on precision and uncertainty).

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison¹.

Table 82: Comparison of net results: **TPA Edge DreamCap 26 plant-based 500 mL** versus a competing carton and alternative packaging systems in **segment UNFLAVOURED WATER PORTION PACK AMBIENT**, allocation factor 100%

UNFLAVOURED WATER, PORTION PACK (ambient), Germany Allocation 100	The net results of TPA Edge DreamCap 26 plant-based 500 mL are lower (green)/ higher (orange) than those of		
	TTAD plant-based C38 plant-based neck plant-based 500 mL	PET bottle 6 100% rPET 500 mL	PET bottle 7 500 mL
Climate Change	+66%	-9%	-32%

¹ ((|net result heading – net result column|) / net result column)*100

Table 83: Comparison of net results: **TTAD plant-based C38 plant-based neck plant-based 500 mL** versus a competing carton and alternative packaging systems in **segment UNFLAVOURED WATER PORTION PACK AMBIENT**, allocation factor 100%

<i>UNFLAVOURED WATER, PORTION PACK (ambient), Germany Allocation 100</i>	The net results of TTAD plant-based C38 plant-based neck plant-based 500 mL are lower (green)/ higher (orange) than those of		
	TPA Edge DreamCap 26 plant-based 500 mL	PET bottle 6 100% rPET 500 mL	PET bottle 7 500 mL
Climate Change	-40%	-45%	-59%

4.15 Results allocation factor 50%; LIQUID FOOD PORTION PACK AMBIENT

4.15.1 Presentation of results LIQUID FOOD PORTION PACK AMBIENT

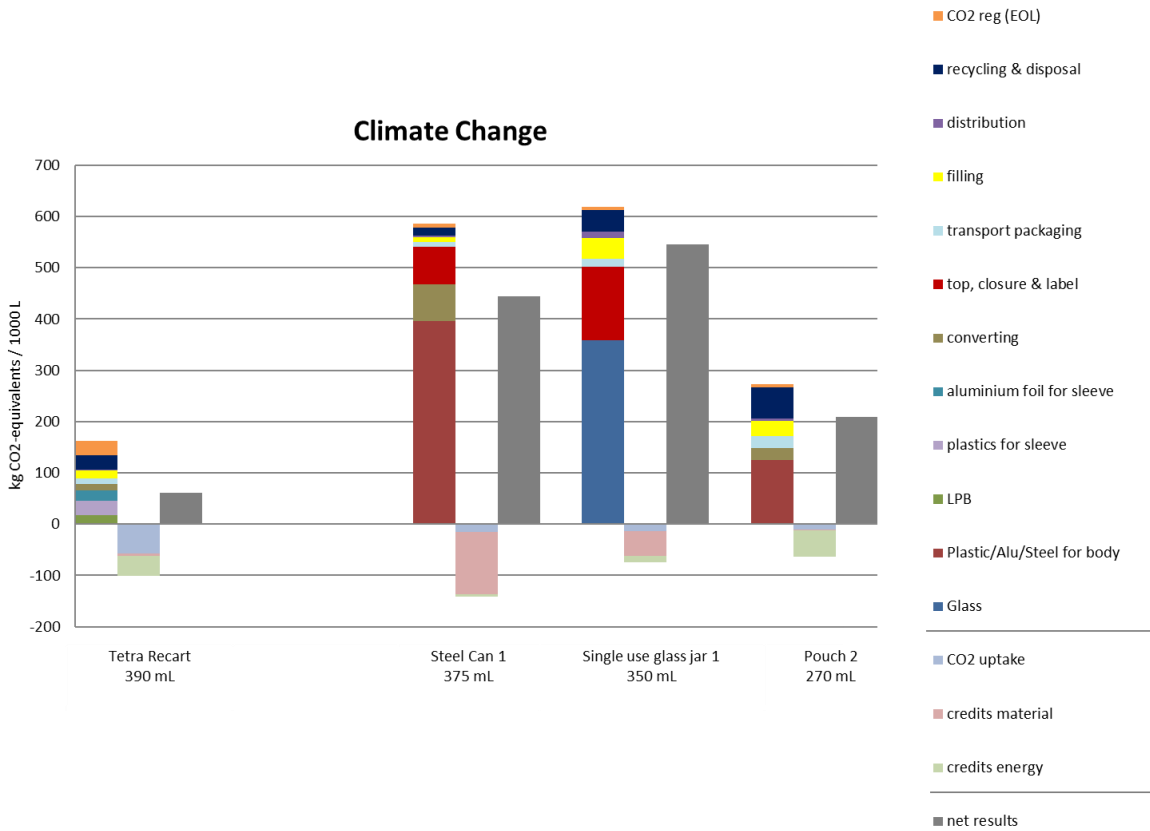


Figure 30: Climate Change results of segment LIQUID FOOD PORTION PACK AMBIENT, allocation factor 50%

Table 84: Climate Change results of segment LIQUID FOOD PORTION PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		Tetra Recart 390 mL	Steel Can 1 375 mL	Single use glass Jar 1 350 mL	Pouch 2 270 mL
Climate Change [kg CO2-e/1000 L]	Burdens	133.55	578.41	612.19	266.97
	CO2 (reg)	28.42	7.40	6.93	5.40
	Credits	-44.60	-127.49	-59.97	-52.74
	CO2 uptake	-56.85	-14.79	-13.85	-10.81
	net results	60.52	443.52	545.30	208.83

4.15.2 Description and interpretation

Beverage carton systems (specifications see [section 2.2.1](#))

For the liquid food carton system considered in the LIQUID FOOD PORTION PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the food carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (10%), the production of plastics for sleeves (17%) and the production of aluminium foil (13%).

The converting to sleeves accounts only small shares (8%) of the total burdens for 'Climate Change'.

As the Tetra Recart has no closure no shares of total burdens for 'Climate Change' are caused from life cycle step 'top, closure & label'.

The production and provision of 'transport packaging' for the liquid food carton systems shows 6% of the total burdens for 'Climate Change' for the liquid food carton.

The life cycle step 'filling' shows small to minor shares of burdens (10%) for the liquid food carton.

The life cycle step 'distribution' shows 1% of the total burdens for 'Climate Change' for the liquid food carton.

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows minor shares of total burdens for 'Climate Change' (16%) resulting from recycling processes and the incineration of fossil materials.

'CO₂ reg. (recycling & disposal)' describes separately all regenerative CO₂ emissions from the incineration of biogenic material in MSWI or cement kilns. They contribute to 18% of the total burdens for 'Climate Change'.

Energy credits sum up to 24% resulting from incineration in MSWI or cement kilns. Material credits for 'Climate Change' are low (4% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions.

The uptake of CO₂ by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the convention in this study which implies that no CO₂ uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO₂ uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for of the assessed system. (see [section 1.7.2](#))

Steel can (specifications see [section 2.2.2](#))

In the assessed steel can system in the LIQUID FOOD PORTION PACK AMBIENT segment, the major share (68%) of the environmental burdens for 'Climate Change' is caused by the production of the steel of the can body.

The 'converting' process for the can body shows minor share of burdens for 'Climate Change' (12%).

The life cycle step 'top, closure & label' shows also minor impact shares (13%) attributed to the steel production and converting of the cap of the can as well as the production of the paper label.

The life cycle steps 'transport packaging' (2%), 'filling' (2%) and 'distribution' (1%) show only small shares of burdens for the can.

The steel cans' 'recycling & disposal' life cycle step shows small shares of burdens regarding 'Climate Change' (3%).

The influence of material credits on the net result is relevant for 'Climate Change'. They reduce the overall burdens by around 21% due to the substitution of raw steel with recycled steel from the cans.

Energy credits only reduce the total burdens by less than 1% resulting only from secondary and tertiary packaging.

Single use glass jar (specifications see [section 2.2.2](#))

The production of the 'glass' material is the main contributor to the overall burdens for the glass bottle. The production of glass clearly dominates the results for 'Climate Change' (58%).

The life cycle step 'top, closure & label' shows considerable impact shares (23%) attributed to the steel production and converting of the closure as well as the production of the paper label.

The other life cycle steps show only small shares of impact (up to 7%).

The influence of material credits on the net result is also small for 'Climate Change'. They reduce the overall burdens by 8% as most of the glass is being recycled in a closed loop.

Energy credits only reduce the total burdens by 2% resulting only from secondary and tertiary packaging.

Pouch (specifications see [section 2.2.2](#))

In the assessed pouch in the LIQUID FOOD PORTION PACK AMBIENT segment, a major share (46%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the pouch.

The 'converting' process shows for the pouch in this segment a small share of burdens for 'Climate Change (8%).

As the pouch has no closure no shares of total burdens for 'Climate Change' are caused from life cycle step 'top, closure & label'.

The production and provision of 'transport packaging' for the pouch shows small impact shares (9%) for climate change.

The life cycle steps 'filling' (11%) and 'distribution' (2%) show small to minor shares of burdens for the pouch.

The pouches' 'recycling & disposal' life cycle step shows considerable shares (22%) for the assessed pouch resulting from incineration of the pouches.

Material credits reduce the total burdens by less than 1% resulting only from secondary and tertiary packaging as pouches are not materially recycled.

The influence of energy credits on the net result is high due to 100% MSWI with energy recovery in Germany. The high reduction of net results by energy credits (19%) results from the incineration of pouches.

4.15.3 Comparison between packaging systems

The following table shows the net results per functional unit of the assessed beverage cartons systems for the impact category 'Climate Change' compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following table show the difference of net results between the packaging system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system¹.

¹ $((| \text{net result heading} - \text{net result column} |) / \text{net result column}) * 100$

Table 85: Comparison of net results: **Tetra Recart 390 mL** versus competing alternative packaging systems in segment **LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 50%

<i>LIQUID FOOD PORTION PACK (ambient), Germany Allocation 50</i>	The net results of Tetra Recart 390 mL are lower (green)/ higher (orange) than those of		
	Steel Can 1 375 mL	Single use glass Jar 1 350 mL	Pouch 2 270 mL
Climate Change	-86%	-89%	-71%

4.16 Results allocation factor 100%; LIQUID FOOD PORTION PACK AMBIENT

4.16.1 Presentation of results LIQUID FOOD PORTION PACK AMBIENT

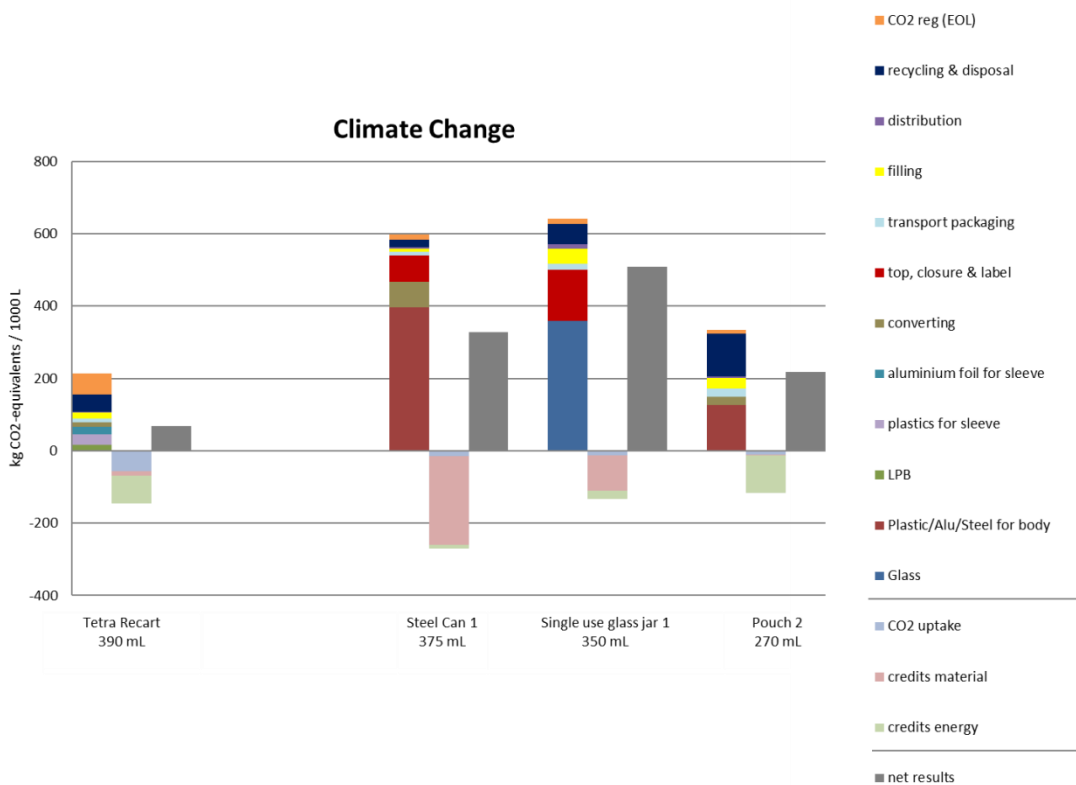


Figure 31: Climate Change results of segment LIQUID FOOD PORTION PACK AMBIENT, allocation factor 100%

Table 86: Climate Change results of segment LIQUID FOOD PORTION PACK AMBIENT burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		Tetra Recart 390 mL	Steel Can 1 375 mL	Single use glass Jar 1 350 mL	Pouch 2 270 mL
Climate Change [kg CO ₂ -e/1000 L]	Burdens	156.41	583.29	627.52	324.01
	CO ₂ (reg)	56.85	14.79	13.85	10.81
	Credits	-88.53	-255.36	-119.84	-105.47
	CO ₂ uptake	-56.85	-14.79	-13.85	-10.81
	net results	67.88	327.92	507.68	218.54

4.16.2 Description and interpretation

In this section the differences of the allocation factor 100% and the allocation factor 50% are described. Detailed descriptions and interpretation including the contribution of the life cycle steps are included for the allocation 50% results (see [section 4.9.2](#)).

A higher allocation factor implies the allocation of more burdens from the end-of-life processes (for example emissions from incineration, emissions from the production of electricity for recycling processes). It also implies the allocation of more credits for the substitution of other processes (for example energy credits for avoided electricity generation due to energy recovery at MSWIs or material credits for avoided production of new materials).

When applying an allocation factor of 100%, all burdens and all credits are allocated to the assessed system.

In the cases of beverage cartons in the segment LIQUID FOOD PORTION PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also, the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO₂ reg. (recycling & disposal)' are allocated to the assessed system (see [section 1.7.2](#)).

In the case of the steel can and glass jar, lower net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits (mainly material credits) is higher than that of the burdens from recycling and disposal regardless of the allocation factor.

In case of the pouch, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits from incineration in cement kilns is similar than that of the burdens from incinerating regardless of the allocation factor.

4.16.3 Comparison between packaging systems

The following table shows the net results per functional unit of the assessed beverage cartons systems for the impact category 'Climate Change' compared to those of the other assessed packaging systems in the same segment. Differences lower than 10% are considered to be insignificant (please see [section 1.6](#) on precision and uncertainty).

The percentages in the following table show the difference of net results between the packaging system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system¹.

¹ $((| \text{net result heading} - \text{net result column} |) / \text{net result column}) * 100$

Table 87: Comparison of net results: **Tetra Recart 390 mL** versus competing alternative packaging systems in **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 100%

<i>LIQUID FOOD PORTION PACK (ambient), Germany Allocation 100</i>	The net results of Tetra Recart 390 mL are lower (green)/ higher (orange) than those of		
	Steel Can 1 375 mL	Single use glass Jar 1 350 mL	Pouch 2 270 mL
Climate Change	-79%	-87%	-69%

5 Conclusions

In the following sections, results are summarised and conclusions are drawn regarding 'Climate Change' of the packaging systems in the different segments on the German market. In this section, results with the 50% allocation factor and the 100% allocation factor are taken into account to the same degree. Also the results of the applied sensitivity analyses regarding transport allocation are taken into account. Differences lower than 10% are considered to be insignificant and stated in the following as "similar impacts" (please see also [section 1.6](#) on precision and uncertainty).

5.1 DAIRY FAMILY PACK CHILLED

For 'Climate Change' all assessed beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared PET bottle and the refillable glass bottle.

The sensitivity analysis regarding transport allocation shows that the choice of transport allocation has no impact on the comparative results between the regarded beverage carton and the competing packaging systems.

5.2 DAIRY FAMILY PACK AMBIENT

For 'Climate Change' all assessed beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared PET bottle.

The sensitivity analyses regarding transport allocation applied in other segments show that the choice of transport allocation has no impact on the net results of the regarded single use packaging systems in this segment.

5.3 JNSD FAMILY PACK AMBIENT

For 'Climate Change' all assessed beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared PET bottle and the refillable glass bottle.

The sensitivity analysis regarding transport allocation shows that the choice of transport allocation has no impact on the comparative results between the regarded beverage carton and the competing packaging systems.

5.4 JNSD PORTION PACK AMBIENT

For 'Climate Change' all assessed beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared PET bottle and the pouch.

The sensitivity analyses regarding transport allocation applied in other segments show that the choice of transport allocation has no impact on the net results of the regarded single use packaging systems in this segment.

5.5 FLAVOURED WATER FAMILY PACK AMBIENT

For 'Climate Change' all assessed beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared PET bottle.

The sensitivity analyses regarding transport allocation applied in other segments show that the choice of transport allocation has no impact on the net results of the regarded single use packaging systems in this segment.

5.6 UNFLAVOURED WATER PORTION PACK AMBIENT

For 'Climate Change' all assessed beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared PET bottle 7.

In case of the PET bottle 6 100% rPET, the TTAD plant-based C38 plant-based neck plant-based 500 mL shows lower impacts with both, the 50% and the 100% allocation, while the TPA Edge DreamCap 26 plant-based 500 mL shows similar impacts with both allocation factors.

The sensitivity analyses regarding transport allocation applied in other segments show that the choice of transport allocation has no impact on the net results of the regarded single use packaging systems in this segment.

5.7 LIQUID FOOD PORTION PACK AMBIENT

For 'Climate Change' the liquid food carton assessed in this segment shows lower impacts with both, the 50% and the 100% allocation factor than the compared steel can, single use glass jar and pouch.

The sensitivity analyses regarding transport allocation applied in other segments show that the choice of transport allocation has no impact on the net results of the regarded single use packaging systems in this segment.

6 Limitations

The results of the base scenarios and analysed packaging systems and the respective comparisons between packaging systems are valid within the framework conditions described in sections 1 and 2. The following limitations must be taken into account, however.

Limitations arising from the selection of **market segments**:

The results are valid only for the filling products dairy (ambient and chilled), JNSD (ambient), flavoured water (ambient)) and liquid food (ambient). Even though carton packaging systems and assessed competing packaging systems are common in other market segments, other filling products create different requirements towards their packaging and thus certain characteristics may differ strongly, e.g. barrier functions.

Limitations concerning **selection of packaging systems**:

The results are valid only for the exact packaging systems, which have been chosen by Tetra Pak. Even though this selection is based on market data, it does not represent the whole German market.

Limitations concerning **packaging system specifications**:

The results are valid only for the examined packaging systems as defined by the specific system parameters, since any alternation of the latter may potentially change the overall 'Climate Change' profile.

The filling volume and weight of a certain type of packaging can vary considerably for all packaging types that were studied. The volume of each selected packaging system chosen for this study represents the predominant packaging size on the market. It is not possible to transfer the results of this study to packages with other filling volumes or weight specifications.

Each packaging system is defined by multiple system parameters, which may potentially alter the overall 'Climate Change' profile. All packaging specifications of the carton packaging systems were provided by Tetra Pak and are to represent the typical packaging systems used in the analysed market segment. These data have been cross-checked by ifeu.

To some extent, there may be a certain variation of design (i.e. specifications) within a specific packaging system. Packaging specifications different from the ones used in this study cannot be compared directly with the results of this study.

Limitations concerning the chosen **environmental impact potentials** and applied **assessment methods**:

The environmental category 'Climate Change' applied in this study covers assessment methods considered by the authors to be the most appropriate to assess the potential environmental impact. It should be noted that the use of different impact assessment

methods for 'Climate Change' could lead to other results concerning the environmental ranking of packaging systems. The results are valid only for the specific characterisation model used for the step from inventory data to impact assessment.

Limitations concerning the analysed impact **categories**:

The results are valid only for the environmental impact category 'Climate Change', which is examined. They are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks. This means that the potential damage caused by 'Climate Change' is not taken into account.

Limitations concerning **conventions**:

Conventions are required to take biogenic carbon into account in calculations. The results of this study are only valid for the conventions explained and justified in detail in [section 1.7.2](#).

Limitations concerning **geographic boundaries**:

The results are valid only for the indicated geographic scope and cannot be assumed to be valid in geographic regions other than Germany, even for the same packaging systems.

This applies particularly for the end-of-life settings as the mix of waste treatment routes (recycling and incineration) and specific technologies used within these routes may differ, e.g. in other countries.

Limitations concerning the **reference period**:

The results are valid only for the indicated reference year 2020 based on data from 2000 to 2021. Results cannot be assumed to be valid for (the same) packaging systems at a different point in time.

Limitations concerning **data**:

The results are valid only for the data used and described in this report: To the knowledge of the authors, the data mentioned in section 3 represents the best available and most appropriate data for the purpose of this study. It is based on figures provided by the commissioner and data from ifeu's internal database. In addition, the different quality level of the data does not affect the results of the study and the conclusions.

For all packaging systems, the same methodological choices were applied concerning allocation rules, system boundaries and the calculation of environmental category 'Climate Change'.

7 Overall conclusion and recommendations

The following overall conclusions summarise the findings of the analysed packaging comparisons. These overall conclusions should not be used for statements of specific packaging systems in specific segments. Regarding conclusions of specific packaging systems in specific segments, the detailed conclusion section of each segment should be consulted.

The beverage and liquid food carton systems analysed in this study show different 'Climate Change' performances depending on different segments as well as their packaging specifications. Beverage and liquid food cartons benefit from the CO₂ uptake of their biogenic materials in terms of cardboard and in case of plant-based beverage cartons also plant-based polymers.

Beverage and liquid food cartons generally show lower results than similar cartons on the European market as presented in the European baseline study. The main reason is the landfilling in Europe, leading to high methane emissions from the degradation of paper, whereas there is no landfilling of packaging waste in Germany.

Alternative packaging systems examined in this study show high burdens from the production of their base materials, like plastics, glass or steel. For beverage and liquid food cartons, on the other hand the production of LPB does not contribute as much to the 'Climate Change' impact, as its production utilises mainly renewable energy leading to lower 'Climate Change' impacts.

In the dairy, JNSD, flavoured water family pack and food segments assessed in this report, the beverage or food cartons show lower climate change impacts than the compared plastic bottles, refillable glass bottles as well as the single use glass jars and steel cans.

In the unflavoured water portion pack segment assessed, no clear conclusion regarding the Climate Change potential can be drawn.

From the findings of this study the authors develop the following recommendations:

- As this study only includes results for the impact category Climate Change, it is recommended to consult the European baseline study [ifeu 2020a] in order to get an indication how results of other impact categories may look for similar packaging systems. The knowledge and understanding of the European study regarding the other impact categories is necessary to understand the broad environmental relevance of the examined packaging.¹ It is important though, to

¹ Please note the European baseline study does not show results for refillable bottles as these were not in the scope for the European market. For an indication how refillable bottles perform in environmental

keep in mind that the different geographic parameters also have a major impact on the results.

- In regard to Climate Change in the segments Dairy Family Pack Chilled, Dairy Family Pack Ambient, JNSD Family Pack Ambient, JNSD Portion Pack Ambient, Flavoured Water Family Pack Ambient and Liquid Food Ambient, beverage or liquid food cartons perform more favourably than the compared alternative packaging systems.

impacts categories besides Climate Change, a recent LCA for the German market exists [ifeu 2020b] that includes refillable bottles that can be requested at the German Association of Cardboard Packaging for Liquid Foods (FKN). Please note this report is currently only available in German language (<https://www.getraenkekarton.de/>).

8 References

[ACE & ifeu 2011]: LCI dataset for Liquid Packaging Board (LPB) production, October 2011.

[APEAL 2008]: personal communication by email between IFEU and JeanPierre Taverne, APEAL, May 2008.

[Braskem 2018]: LCA datasets for plant-based HDPE and LDPE (economical allocation). Provided by Braskem in 2018.

[BUWAL 1998] Bundesamt für Umwelt, Wald und Landschaft: Ökoinventare für Verpackungen; Schriftenreihe Umwelt 250/II; Bern, 1998.

[Capri Sun AG 2021]: Capri Sun Verpackung – Der flexible Beutel. <https://www.capri-sun.com/de/de/ueber-uns/der-trinkpack/>. (Accessed May 2021)

[CEWEP 2018]: CEWEP Country report 2018. Germany. Confederation of European Waste-to-Energy Plants (CEWEP), 2018.

[CPME 2016]: Purified Terephthalic Acid (PTA). Eco-profiles and Environmental Product Declarations of the PET Manufacturers in Europe, February 2016, Committee of PET Manufacturers in Europe.

[Deloitte 2013]: Umlaufzahlen und Transportentfernungen in der Getränkeindustrie. December 2013

[DSD 2003]: Produktspezifikationen Grüner Punkt, Der Grüne Punkt: Duales System Deutschland GmbH, 2003

[EA 2013]: Environmental Profile Report for the European Aluminium Industry - Life-Cycle inventory data for aluminium production and transformation processes in Europe. Report published by the European Aluminium Association. April 2013.

[EA 2018]: ENVIRONMENTAL PROFILE REPORT Life-Cycle inventory data for aluminium production and transformation processes in Europe. Report published by the European Aluminium Association. February 2018.

[EcoTransIT World 2016]: Ecological Transport Information Tool for Worldwide Transport-Methodology and Data Update. EcoTransIT World Initiative (EWI) .Berne, Hannover, Heidelberg. June 2016

[EPBP 2018]: <http://www.epbp.org/design-guidelines/products> (February 2017)

[Eurostat 2020]: Eurostat Municipal Waste Luxembourg, 2016. <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do> (Accessed October 2020)

[Fava et al. 1991]: Fava, James A., SETAC (Society), SETAC Foundation for Environmental Education. A Technical Framework for Life-cycle Assessments. 1991.

[FEVE 2006:] Western European Glass Recycling. Available online at <http://www.feve.org/> (accessed November 2006)

[FEVE 2016]: Life Cycle Assessment of Container Glass in Europe - Methodological report. European Container Glass Federation, Brussels. S. 76.

[FEFCO 2018]: European Database for Corrugated Board Life Cycle Studies 2018. Fédération Européenne des Fabricantes de Papiers pour Ondulé (FEFCO) and Cepi Container Board. Brussels. 2018.

[Frischknecht 1998]: Frischknecht. R., Life Cycle Inventory Analysis for Decision-Making: Scope-dependent Inventory System Models and Context-specific Joint Product Allocation. PhD Thesis. ETH Zürich. Switzerland, 1998.

[Heijungs et al. 1992]: Heijungs R, Guinée J, Lankreijer RM, Udo de Haes HA, Wegener Sleeswijk Environmental life cycle assessment of products – Guide. Novem, rivm, Centre of Environmental Science (CML), Leiden, The Netherlands, October 1992

[ifeu 2016]: Lauwigi, C.; Fehrenbach, H.; Liebich A.; Ludmann, S.: Documentation for the UMBERTO based electricity grid model created by IFEU. 2016. <https://www.ifeu.de/wp-content/uploads/Documentation-IFEU-Electricity-Model-2016-06.pdf>

[ifeu 2020a]: Schlecht, S. Wellenreuther F.: Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the European market. Commissioned by Tetra Pak

[ifeu 2020b]: Kauertz, B. Busch, M. Bader, J.: Ökobilanzielle Betrachtung von Getränkeverbundkartons in Deutschland - In den Getränkesegmenten Säfte und Nektare sowie H-Milch und Frischmilch. Heidelberg. October 2020. Commissioned by the German Association of Cardboard Packaging for Liquid Foods (FKN)

[INFRAS 2017]: HBEFA. Handbuch Emissionsfaktoren des Straßenverkehrs, Version 3.3, INFRAS. UBA Berlin, UBA Wien, BUWAL Bern, 2017.

[IPCC 2013]: Stocker,T.F.; Qin,D.; Plattner,D.-K.; Tignor,M.; Allen,S.K.; Boschung,J.; Nauels,A.; Xia,Y.; Bex,V.; Midgley,P.M. (eds.): Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[ISO 14040]: Environmental management – Life cycle assessment – Principles and framework (ISO 14040:2006); German and English version EN ISO 14040:2006.

[ISO 14044]: Environmental management – Life cycle assessment – Requirements and guidelines (ISO 14044:2006); German and English version EN ISO 14044:2006.

[Kauertz und Heinisch 2017]: Kauertz, B.; Heinisch, J. Fachgutachten zur Ermittlung und Bestimmung der Verpackungen im Getränkesegment Säfte und Nektare und den Getränkegruppen H-Milch und pasteurisierte Konsummilch/ESL-Milch. Institut für Energie- und Umweltforschung Heidelberg GmbH und GVM Gesellschaft für Verpackungsmarktforschung mbH im Auftrag des Fachverbands für Kartonverpackungen für flüssige Lebensmittel e.V. Heidelberg/Mainz. 2017.[Klöpffer 1996]: Allocation rule for open-loop recycling in LCA; Klöpffer. in Int. J. LCA 1 (1) 27-32 (1996)

[Klöpffer 2007]: personal communication, November 27th, 2007

[Kupfer et al. 2017]: Dr. Thilo Kupfer, Dr. Martin Baitz, Dr. Cecilia Makishi Colodel, Morten Kokborg, Steffen Schöll, Matthias Rudolf, Dr. Lionel Thellier, Maria Gonzalez, Dr. Oliver Schuller, Jasmin Hengstler, Alexander Stoffregen, Dr. Annette Köhler, Daniel Thylmann. 2017. GaBi Database & Modelling Principles. thinkstep AG. Leinfelden-Echterdingen. http://www.gabi-software.com/fileadmin/GaBi_Databases/GaBi_Modelling_Principles_2017.pdf (Accessed January 6th, 2018)

[Murphy 2013] Murphy, R. Cradle-to-Gate Life Cycle Assessment (LCA) of Braskem biopolyethylene resin. Relatório confidencial. 2013

[Nelles et al. 2016]: Nelles, M., Grünes, J., Morscheck, G.. Waste Management in Germany – Development to a Sustainable Circular Economy? Procedia Environmental Sciences, 35, 6–14. <https://doi.org/10.1016/j.proenv.2016.07.001>

[Niaounakis 2019]: Niaounakis, Michael. *Recycling of Flexible Plastic Packaging*. William Andrew, 2019.

[PlasticsEurope 2005]: Boustead, I.: Eco-profiles of the European Plastics Industry – Nylon6 (PA6), data last calculated March 2005, report prepared for Plastics Europe, Brussels, 2005. <http://www.lca.plasticseurope.org/index.htm> (August 2005)

[PlasticsEurope 2012]: Ethylene, Propylene, Butadiene, Pyrolysis Gasoline, Ethylene Oxide (EO), Ethylene Glycols (MEG, DEG, TEG). Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers, November 2012, PlasticsEurope.

[PlasticsEurope 2014a]: Eco-profiles and Environmental Product Declarations of the European Plastic Manufactures – Polypropylene (PP), PlasticsEurope, April 2014. (download May 2014 <http://www.lca.plasticseurope.org/index.htm>)

[PlasticsEurope 2014b]: Eco-profiles and Environmental Product Declarations of the European Plastic Manufactures – High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), Linear Low-Density Polyethylene (LLDPE), PlasticsEurope, April 2014. (download May 2014 <http://www.lca.plasticseurope.org/index.htm>)

[PlasticsEurope 2017]: Polyethylene Terephthalate (PET) (Bottle Grade) CPME. Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers, June 2017, PlasticsEurope.

[PlasticsEurope 2019]: Eco-profiles program and methodology PlasticsEurope Version 3.0. Plastics Europe, 2018. https://www.plasticseurope.org/download_file/view/715/183

[Roß 2017a]: Exklusivstudie Distributionsentfernungen von Getränkeverpackungen 2015/2016 Arbeitsergebnisse H-Milch/ESL Milch 1 Liter. MarktSensor im Auftrag des Fachverbands für Kartonverpackungen für flüssige Lebensmittel e.V. Neuhausen. 2017.

Roß (2017b): Exklusivstudie Distributionsentfernungen von Getränkeverpackungen 2015/2016 Arbeitsergebnisse Fruchtsaft/Fruchtnektar 1 Liter. MarktSensor im Auftrag des Fachverbands für Kartonverpackungen für flüssige Lebensmittel e.V. Neuhausen. 2017.

[Tetra Pak 2020]: Carton packages for food and beverages. Tetra Pak. 2020. <https://www.tetrapak.com/packaging> (download Feb 2020).

[UBA 2000]: Umweltbundesamt. Berlin (Hrsg.): Ökobilanz für Getränkeverpackungen II. Hauptteil, UBA-Texte 37/00, Berlin, 2000.

[UBA 2016]: Detzel A., Kauertz B., Grahl B., Heinisch J.. Umweltbundesamt. Berlin (Hrsg.): Prüfung und Aktualisierung der Ökobilanzen für Getränkeverpackungen. UBA-Texte 19/2016. Berlin. 2016.

[VDZ 2019]: Economic, technical and scientific association for the German cement industry. 2019

[VerpackG 2021]: Gesetz zur Fortentwicklung der haushaltsnahen Getrennterfassung von wertstoffhaltigen Abfällen. Last edit 27.01.2021.

[World Steel 2018]: LCI Dataset for tinplate provided by WORLD STEEL

Appendix A: Impact categories

The impact categories used in this study are introduced below and the corresponding characterisation factors are quantified. In each case, references are given for the origin of the methods that were used. The procedure for calculating the indicator result is given at the end of each sub-section.

A.1 Climate change

Climate Change is the impact of anthropogenic emissions on the radiative forcing of the atmosphere causing a temperature rise at the earth's surface. This could lead to adverse environmental effects on ecosystems and human health. This mechanism is described in detail in the relative references [IPCC 1995]. The category most used in life cycle assessments up to now is the radiative forcing [CML 2002, Klöpffer 1995] and is given as CO₂ equivalents. The characterisation method is a generally recognised method.

The Intergovernmental Panel on Climate Change (IPCC) is an international body of experts that computes and extrapolates methods and relevant parameters for all substances that influence climate change. The latest IPCC reports available at the time of LCA calculations commonly represent the scientific basis for quantifying climate change.

All carbon dioxide emissions, whether they are of regenerative or fossil origin, are accounted for with a characterisation factor of 1 CO₂ equivalent.

When calculating CO₂ equivalents, the gases' residence times in the troposphere is taken into account and the question arises as to what period of time should be used for the climate model calculations for the purposes of the product life cycle. Calculation models for 20, 50 and 100 years have been developed over the years, leading to different GWPs. The models for 20 years are based on the most reliable prognosis; for longer time spans (500-year GWPs have been used at times), the uncertainties increase [CML 2002]. The Centre of Environmental Science – Leiden University (CML) as well as the German Environmental Agency both recommend modelling on a 100-year basis because it allows to better reflect the long-term impact of Climate Change. According to this recommendation, the 'characterisation factor' applied in the current study for assessing the impact on climate change is the *Global Warming Potential* for a 100-year time period based on IPCC 2013.

An excerpt of the most important substances taken into account when calculating the Climate Change are listed below along with the respective CO₂-equivalent factors – expressed as GWP.

Greenhouse gas	CO ₂ equivalents (GWP _i) ¹
Carbon dioxide (CO ₂). fossil	1
Methane (CH ₄) ² fossil	30
Methane (CH ₄) regenerative	28
Nitrous oxide (N ₂ O)	265
Tetrafluoromethane	6630
Hexafluoroethane	11100
Halon 1301	6290
R22	1810
Tetrachlormethane	1760
Trichlorethane	160
● Source: [IPCC 2013]	

Table A-1: Global warming potential for the most important substances taken into account in this study; CO₂ equivalent values for the 100-year perspective

Numerous other gases likely have an impact on GWP by IPCC. Those greenhouse gases are not represented in Table A-1 as they are not part of the inventory of this LCA study.

The contribution to the Climate Change is obtained by summing the products of the amount of each emitted harmful material (m_i) of relevance for Climate Change and the respective GWP (GWP_i) using the following equation:

$$GWP = \sum_i (m_i \times GWP_i)$$

A.2 References (for Appendix A)

[CML 2002]: Guinée. J.B. (Ed.) – Centre of Environmental Science – Leiden University (CML). de Bruijn. H.. van Duin. R.. Huijbregts. M.. Lindeijer. E.. Roorda. A.. van der Ven. B.. Weidema. B.: Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards, Eco-Efficiency in Industry and Science Vol. 7, Kluwer Academic Publishers.,Netherlands 2002.

[IPCC 1995]: Intergovernmental panel on the climatic change. Climatic Change (IPCC; publisher). Report to the United Nations 1996. New York (USA) 1995.

¹ The values reported by [IPCC 2013] in Appendix 8.A were rounded off to whole numbers.

² According to [IPCC 2013], the indirect effect from oxidation of CH₄ to CO₂ is considered in the GWP value for fossil methane (based on Boucher et al., 2009). The calculation for the additional effect on GWP is based on the assumption, that 50% of the carbon is lost due to deposition as formaldehyde to the surface (IPCC 2013). The GWP reported for unspecified methane does not include the CO₂ oxidation effect from fossil methane and is thus appropriate methane emissions from biogenic sources and fossil sources for which the carbon has been accounted for in the LCI.

[IPCC 2013] Stocker,T.F.; Qin,D.; Plattner,D.-K.; Tignor,M.; Allen,S.K.; Boschung,J.; Nauels,A.; Xia,Y.; Bex,V.; Midgley,P.M. (eds.): Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[Klöpffer & Renner 1995]: Methodik der Wirkungsbilanz im Rahmen von Produkt-Ökobilanzen unter Berücksichtigung nicht oder nur schwer quantifizierbarer Umwelt-Kategorien. UBA-Texte 23/95. Berlin. 1995.

Appendix B:

Critical Review Report

Supplement Critical Review Statement according to ISO 14040 and 14044

of the study

“Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the German market

As supplement of the study

“Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the European market”

to the Commissioner
Tetra Pak®

Conducted by
IFEU - Institut für Energie- und Umweltforschung Heidelberg GmbH (the “Practitioner”)

Performed for
Tetra Pak® (the “Commissioner”)

by

Guido Sonnemann (chairman)
Leigh Holloway
Harald Kaeb

18/09/2021

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1. Procedural Aspects of the Critical Review

This Critical Review was commissioned by Tetra Pak® Moscow, Russia, (commissioner) via Dina Epifanova in early June 2021 as a two-stage process. The Life Cycle Assessment (LCA) study was conducted by IFEU-Institut, Heidelberg, Germany (practitioner).

A Final Draft Report was submitted on 2 August 2021, comments by the panel were sent on 17 August 2021, additional information was supplied on 19 August 2021, and then the report was discussed in the telephone conference on 1 September 2021. During the conference calls the comments were elaborated by the panel members and discussed in detail with the practitioner IFEU and the commissioner Tetra Pak® (TP) represented by Martin Gehlen from Tetra Pak® Germany.

The review panel received written responses on the comments made and a revised version of the Final Report of the study on 8 September 2021. The Panel had no further queries. Therefore, the statements and comments in this supplement CR-statement dated 18 September 2021 refer to this final version.

Formally this critical review is a review by "interested parties" (panel method) according to ISO 14040 section 7.3.3 [2] and ISO 14044 section 4.2.3.7 and 6.3 [3] because the study includes comparative assertions of competing packaging systems and is intended to be disclosed to third parties.

Despite this title, however, the inclusion of further representatives of "interested parties" is optional and was not explicitly intended in this study. The review panel is neutral with regard to and independent from any commercial interests of the commissioner. The panel had to be aware of issues relevant to other interested parties, as it was outside the scope of the present project to invite governmental or non-governmental organisations or other interested parties, e.g. competitors or consumers.

The reviewers emphasise the open and constructive atmosphere of the project. All necessary data, including confidential ones upon request, were presented to the reviewers and all issues were discussed openly. All comments of the panel have been treated by the practitioner with sufficient detail in the final report. The resulting critical review (CR) statement represents the consensus between the reviewers.

Note: The present CR statement is delivered to Tetra Pak® Germany. The CR panel cannot be held responsible of the use of its work by any third party and not for a potential misuse in communication done by the commissioner itself. The conclusions of the CR panel cover the full report from the study "Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the German market (Supplement to Comparative Life Cycle

Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the European market) – Final Report in the version of 8 September 2021 - and no other report, extract or publication which may eventually be undertaken. The CR panel conclusions are given regarding the current state of the art and the information received. The conclusions expressed by the CR panel are specific to the context and content of the present study only and shall not be generalised any further.

2. General Comments

This study for the German market is one of the regional supplement studies based on the European study [Tetra Pak EU 2020]. The European Study is a full LCA according to ISO 14040 and ISO 14044 (cf. Critical Review Statement in [Tetra Pak EU 2020]). In the German study, the same LCA model is used as in the European baseline study, but region-specific data like packaging solutions, electricity mix and end-of-life data are used, and the only impact category considered is climate change with the impact category indicator Global Warming Potential (GWP). The study was not conducted according to ISO 14067.

However, the authors of the German study explicitly point out that knowledge and understanding of the European study must be used to interpret the results, since the relevance of the GWP in relation to other impact categories is discussed there. The European study as a full LCA considers a sufficient number of relevant impact categories and indicators.

The panel points out that if only one impact category is considered, there is no conformity with ISO 14044, as section 4.4.1 clearly states: "The LCIA phase includes the collection of indicator results for the different impact categories, which together represent the LCIA profile for the product system". In this respect, the German study must be communicated as supplement study with explicit reference to the European study and differentiated analysis: In the overall view of all impact category results considered in the European study, it must be analysed to what extent the GWP permits directional reliability of environmental statements. Based on the comments provided by the CR Panel this aspect has been sufficiently discussed in the study and indicated in the subtitle of the study.

The panel expressly emphasizes the importance of, and requires considering the results of, other impact categories discussed in the European study in order to understand the environmental relevance of the packaging examined in the German market. In this context, the panel warns against emphasizing GWP in communication alone.

The Panel expressly points out that the CR-statement published in the European study mandatorily applies to this supplement CR Statement.

In the following, only the specifics of the German study are considered. The methodological statements made for the European study in [Tetra Pak EU 2020] are not repeated here.

3. Supplement Statements by the reviewer as required by ISO 14044

According to ISO 14044 section 6.1

"The critical review process shall ensure that:

- *the methods used to carry out the LCA are consistent with this International Standard,*
- *the methods used to carry out the LCA are scientifically and technically valid,*
- *the data used are appropriate and reasonable in relation to the goal of the study,*
- *the interpretations reflect the limitations identified and the goal of the study and*
- *the study report is transparent and consistent."*

These criteria were also applied in this supplement Critical Review. In the following supplement sections 3.1 to 3.5, these items are discussed for the specifics of the German study according to the reviewer's best judgement and considering the ISO standards 14040 and 14044.

3.1 Supplement: Consistency of the methods with ISO 14040 and 14044

The German study uses the same model as the European study (see CR-statement in [Tetra Pak EU 2020]) for another geographical system boundary and reduced impact assessment.

- Packaging solutions in the German market (TP products and competing products) are chosen by Tetra Pak according to an analogous procedure similar to the selection of packaging systems in the European study (cf. section 3.1 and 3.3 in CR-statement in [Tetra Pak 2020 EU]. The selection criteria of competing products based on product and market characteristics are comprehensibly documented.
- Specified are the German recycling quota, end-of-life options, and the specific electricity mix (cf. section 3.3).
- The impact assessment is limited to a single impact category, climate change, with the indicator Global Warming Potential (GWP) (cf. also section 3.2).

The report of the German supplement study contains all the necessary methodological information in the same detail as the European study. In this respect, the supplement study is consistent with ISO 14040 and ISO 14044 except for the requirements for impact assessment.

Since only one impact category is considered, the reviewers conclude that in this respect the study as stand-alone-study does not fulfil the requirements of the international standards but may be useful as region specific supplement study.

Regarding the consistency of aspects other than impact assessment, see chapter 3.1 of the CR statement in [Tetra Pak EU 2020].

3.2 Supplement: Scientific and technical validity of the methods used

The GWP data in the German study are calculated according to the same methodological specifications as in the European study. The study explicitly states that the significance of the other impact categories in the European study in relation to GWP shall be used to interpret the results. This requires special challenges for the communication of the study by Tetra Pak.

Regarding the scientific and technical validity of aspects other than limited impact assessment, see chapter 3.1 of the CR statement in [Tetra Pak EU 2020].

3.3 Supplement: Appropriateness of data in relation to the goal of the study

Detailed qualitative and quantitative information on the polymers used in Tetra Pak packaging, some of which are not specified in the report for reasons of confidentiality, was provided to the panel and considered plausible.

As one data source, the study refers to an "ifeu internal data base", which contains confidential data. During discussions with the practitioner, sufficient background information was provided to the panel so that data and data processing are considered plausible.

The criteria for the selection of competing products and the derivation of their composition are comprehensibly documented. Confidential market research data with regard to market shares were provided by Tetra Pak to the panel as well.

The influence of the GWP coming from the German electricity mix is relevant in comparison to other regional supplements. The German electricity mix according to data provided for the reference year 2015 is characterised by 42% brown coal, 9% fuel oil, 19% natural gas, 29% Hydropower/Wind/Solar /Geothermal and 1% energy from biomass and waste.

The assumptions of the End of Life (EoL) management in Germany are comprehensibly derived and plausible. A special feature of the German EoL management is that no packaging waste is landfilled. Information on landfilling is still included in the study in order to show differences to the EU baseline study.

A special feature of this supplement for the German market in comparison to other regional supplements is the consideration of recycled PET, whose assessment therefore got the particular attention of the CR.

Regarding the appropriateness of data other than that discussed above see chapter 3.3 of the CR statement in [Tetra Pak EU 2020].

3.4 Supplement: Assessment of interpretation referring to limitations and goal of the study

The interpretation is limited to GWP. In this context it is important to have in mind that conventions are required to take biogenic carbon into account in the calculations. The results of this study are only valid for the conventions explained and justified in detail in chapter 1.7.2.

Regarding interpretation other than that discussed above see chapter 3.4 of the CR statement in [Tetra Pak EU 2020].

3.5 Supplement: Transparency and consistency of study report

Regarding transparency of the report see chapter 3.5 of the CR statement in [Tetra Pak EU 2020].

4 Conclusion

As the German study was conducted according to the same model as the European study, all statements made in the CR statement section 4 in [Tetra Pak EU 2020] apply accordingly to the German study with the exception of the statements on impact assessment.

In the CR-statement of [Tetra Pak EU 2020] the reviewers conclude that the European study has been conducted according to and in consistency with the ISO standards 14040 and 14044.

Since the German study considers with GWP only one impact category the study is, as a stand-alone study, not consistent with the ISO standards 14040 and 14044.

The study can be used as an orientation supplement to the European study, as it can be plausibly expected that the relative importance of the impact potentials documented in [Tetra Pak EU 2020] will not differ fundamentally in relation to each other in the German study. However, caution is advised here, and the panel warns against emphasizing GWP in communication alone.

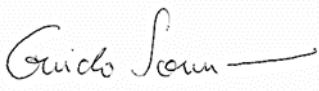
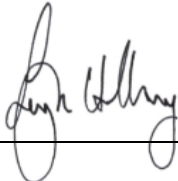

References:

[ISO 14040] ISO 14040:2006. Environmental management - Life cycle assessment - Principles and framework

[ISO 14044] ISO 14044:2006. Environmental management - Life cycle assessment - Requirements and guidelines

[Tetra Pak EU 2020] Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the European market – Final Report – 9th March 2020”. Critical Review included

[ISO 14067] ISO 14067:2018. Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification

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