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 UK and Irish 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

commissioned by Tetra Pak

Heidelberg, March 25th 2022

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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)
FSC	Forest Stewardship Council™
FU	Functional unit
GWP	Global Warming Potential
HBEFA	Handbuch für Emissionsfaktoren (Handbook for Emission Factors)
IE	Ireland
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
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
TiO_2	Titanium dioxide
TPA	Tetra Prisma Aseptic
TR	Tetra Rex
TRC	Tetra Recart
TSA	Tetra Stelo Aseptic
TT	Tetra Top
UBA	Umweltbundesamt (German Federal Environmental Agency)
UK	United Kingdom

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 2021). 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 (Schlecht / Wellenreuther 2020). 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 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 UK and Irish market regarding the segments Dairy (chilled), Dairy Alternative (ambient and chilled), 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 UK and Irish 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 (Schlecht / Wellenreuther 2020). Of course, the packaging systems examined in the present study are not exactly identical to the ones in the European baseline study. Also some of the 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. This study includes a further segment - "Dairy Alternatives", which was not included in the European baseline study. It does not introduce a new type of packaging in regard to its material. PET bottles are included in the EU study in other segments. The packaging systems and their attributes are very similar to those of JNSD packaging, which is included in the European baseline study.

Competing packaging systems on the UK and Irish market include:

- vPET bottles (virgin PET in body)
- rPET bottles (share of recycled PET in body)
- vHDPE bottles (virging HDPE in body)
- rHDPE bottles (share of recycled HDPE in body)
- Single use glass jars
- Steel cans made of tinplate
- Aluminium cans
- Stand Up Pouches

All analysed packaging systems are divided into the segments

- 'Family Packs' with volumes of 750 mL – 3000 mL
- 'Portion Packs' with volumes of 250 mL – 500 mL.

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

- Dairy products like milk or milk drinks
  - Family Packs (chilled) with the volume of 1750 mL – 3000 mL
- Dairy alternative products like almond or oat drinks
  - Family Packs (ambient) with the volume of 750 mL – 1000 mL
  - Family Packs (chilled) with the volume of 750 mL – 1000 mL
- Liquid food
  - Portion Packs (ambient) with the volume of 300 mL – 500 mL
- Water
  - Family Packs (ambient) with the volume of 1000 mL – 1500 mL
  - Portion Packs (ambient) with the volume of 250 mL– 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.

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

The results of this study shall 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. The study and/or its results are therefore 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 2021. It is being conducted by the Institute for Energy and Environmental Research Heidelberg GmbH (ifeu).

The members of the project panel are:

- **Tetra Pak**: Martin Gehlen, Nazanin Moradi, Awantika Chadha
- **ifeu**: Samuel Mahami, 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: 2006; ISO 14044: 2006) except of the choice of impact categories. Therefore a critical review process is undertaken by an independent panel of three LCA experts.

The members of the independent panel are

- Guido Sonnemann (chair), France
- Leigh Holloway, eco3 Design Ltd., UK
- Dr. Harald Käb, 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, straws 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
- 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

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 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 as these are impossible to evaluate certainly. 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) as the same amount of beverage or liquid food is transported for all regarded packaging systems (see transport allocation in section 1.7.1).
- Environmental effects from accidents like breakages during transportation as no reliable data is available.
- 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 breakability 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 can be found 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.

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), HDPE bottle (Figure 3), single use glass bottle/jar (Figure 4), aluminium cans (Figure 5), steel cans (food) (Figure 6), and stand up pouches (food) (Figure 7). 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 section 2.3. As there are no refillable bottles established on the UK and Irish market in a significant scale, only single use packaging systems are included in this study.

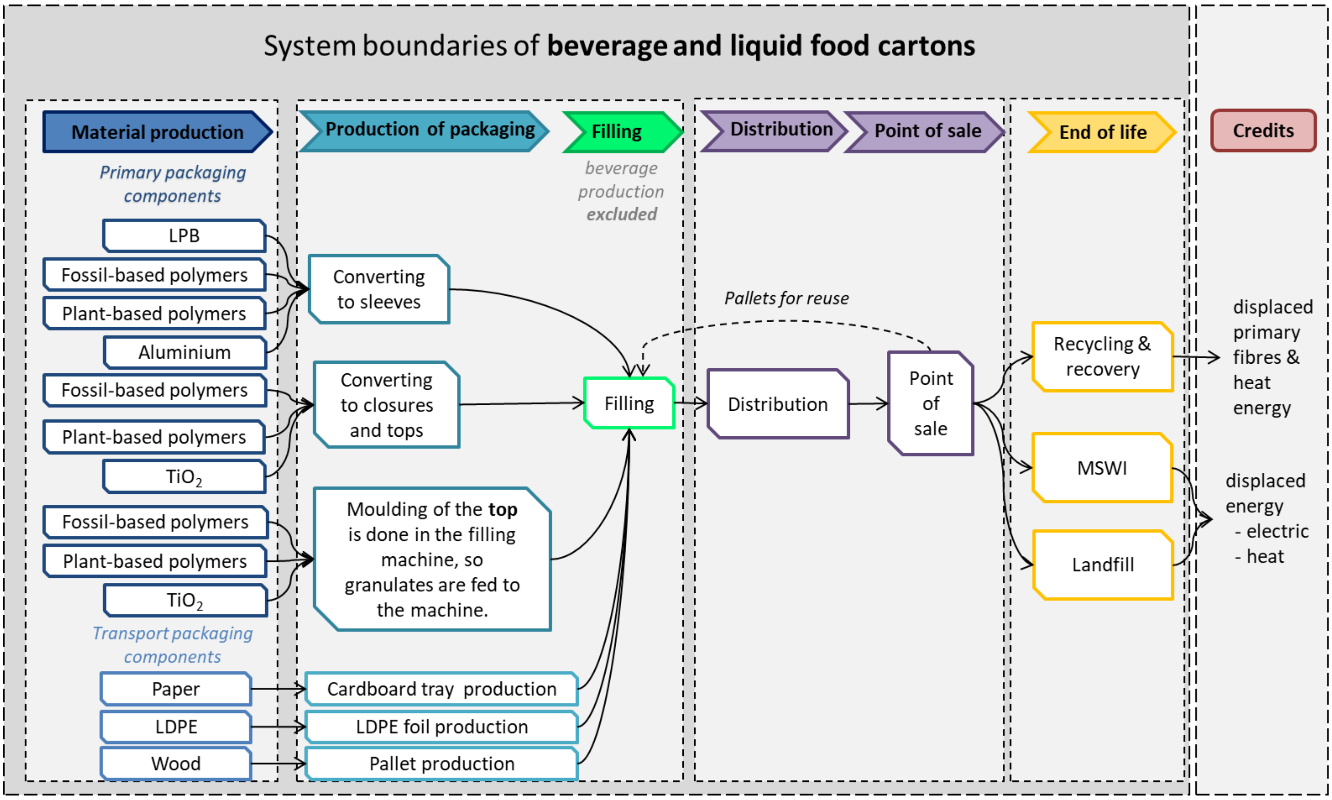

Figure 1: System boundaries of beverage and liquid food cartons

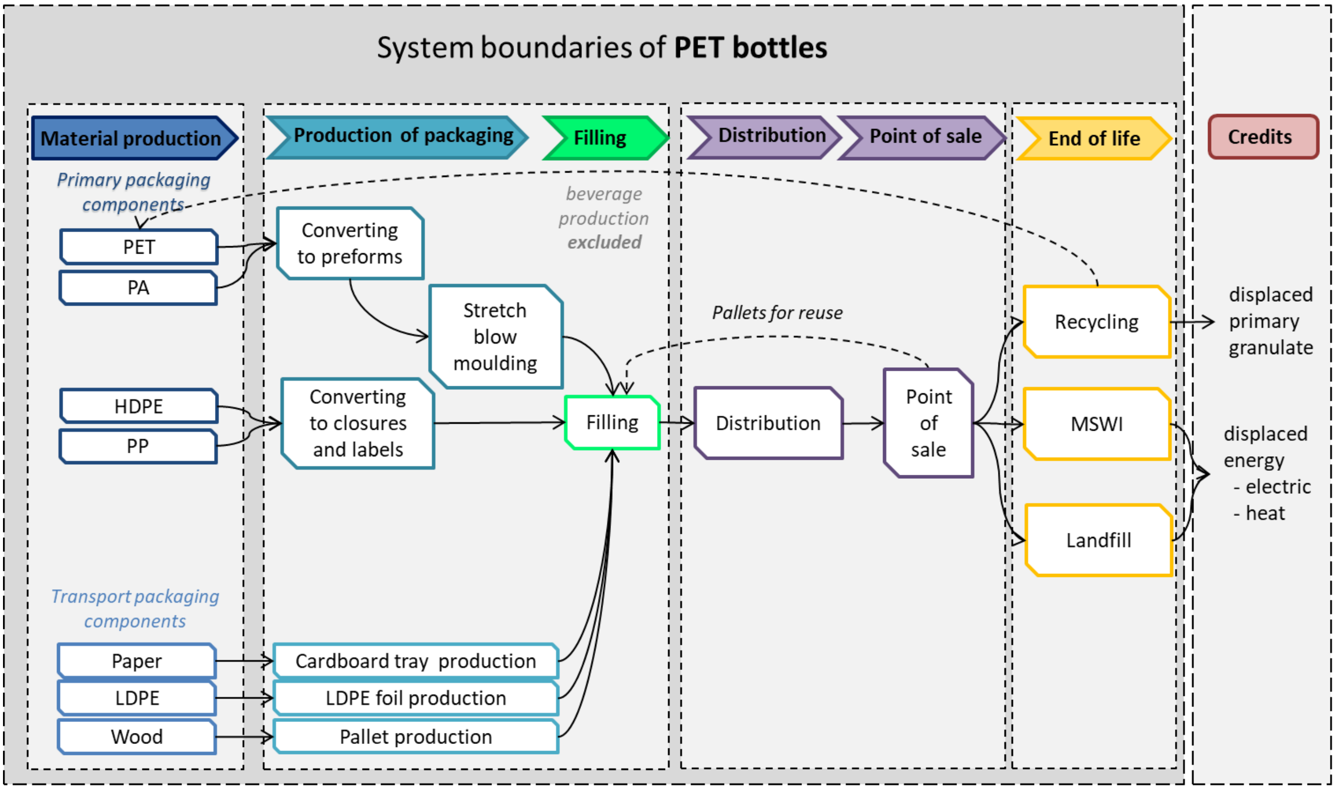

Figure 2: System boundaries of PET bottles

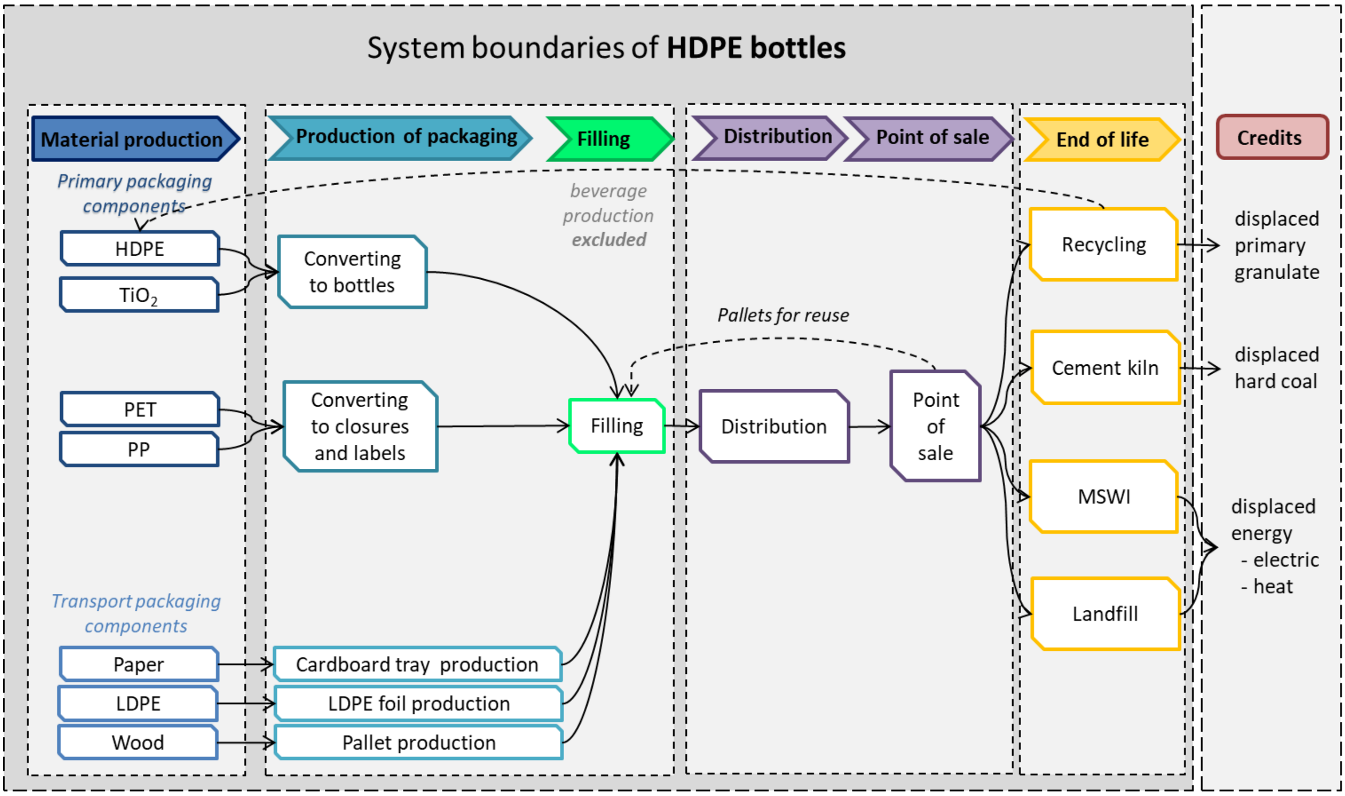

Figure 3: System boundaries of HDPE bottles

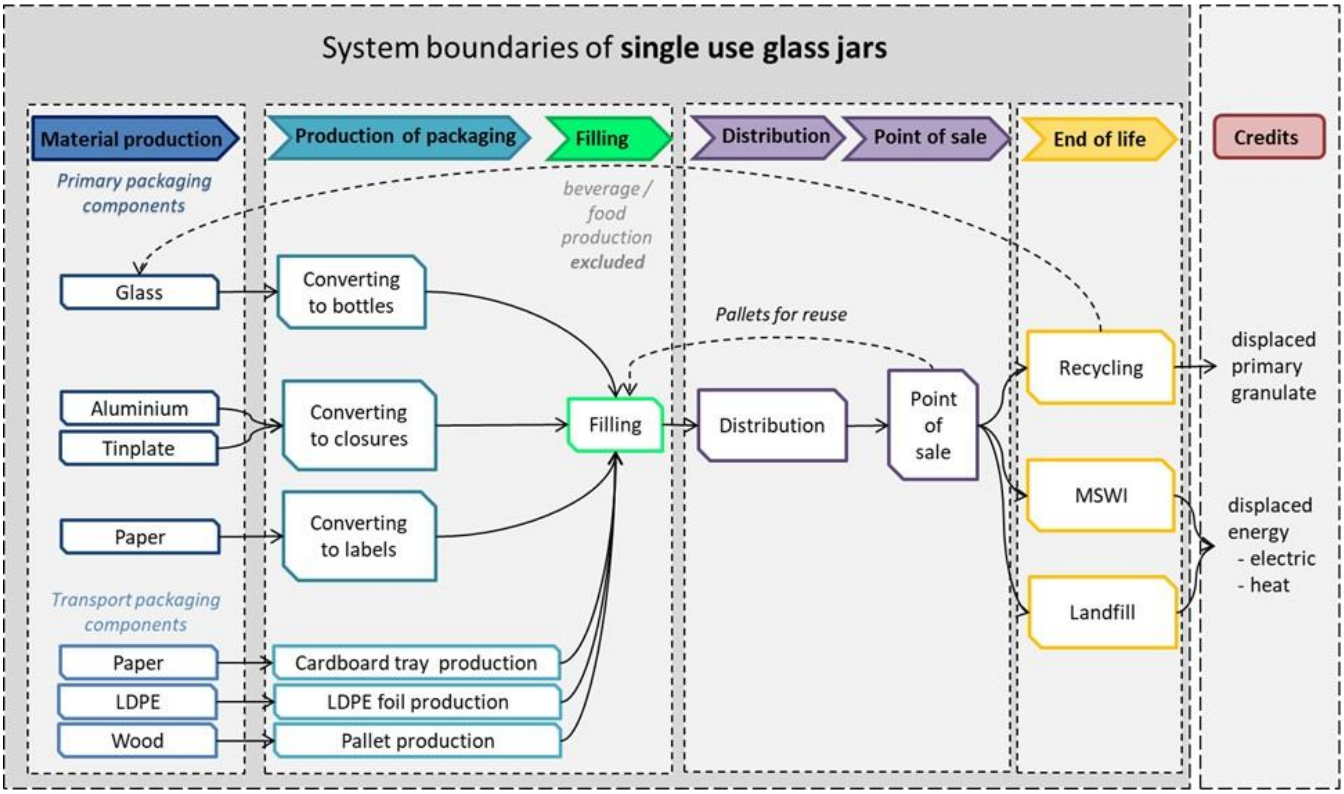

Figure 4: System boundaries of single use glass jars

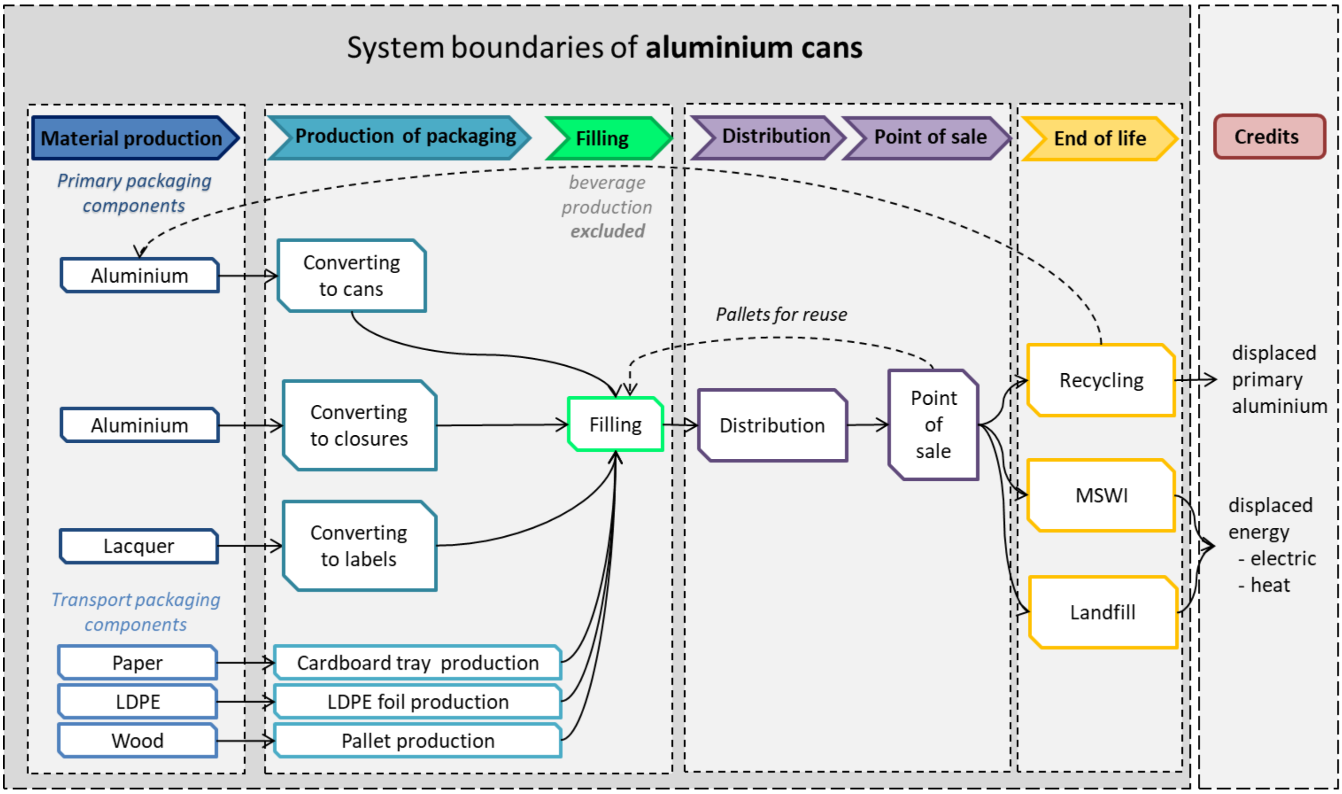

Figure 5: System boundaries of aluminium cans

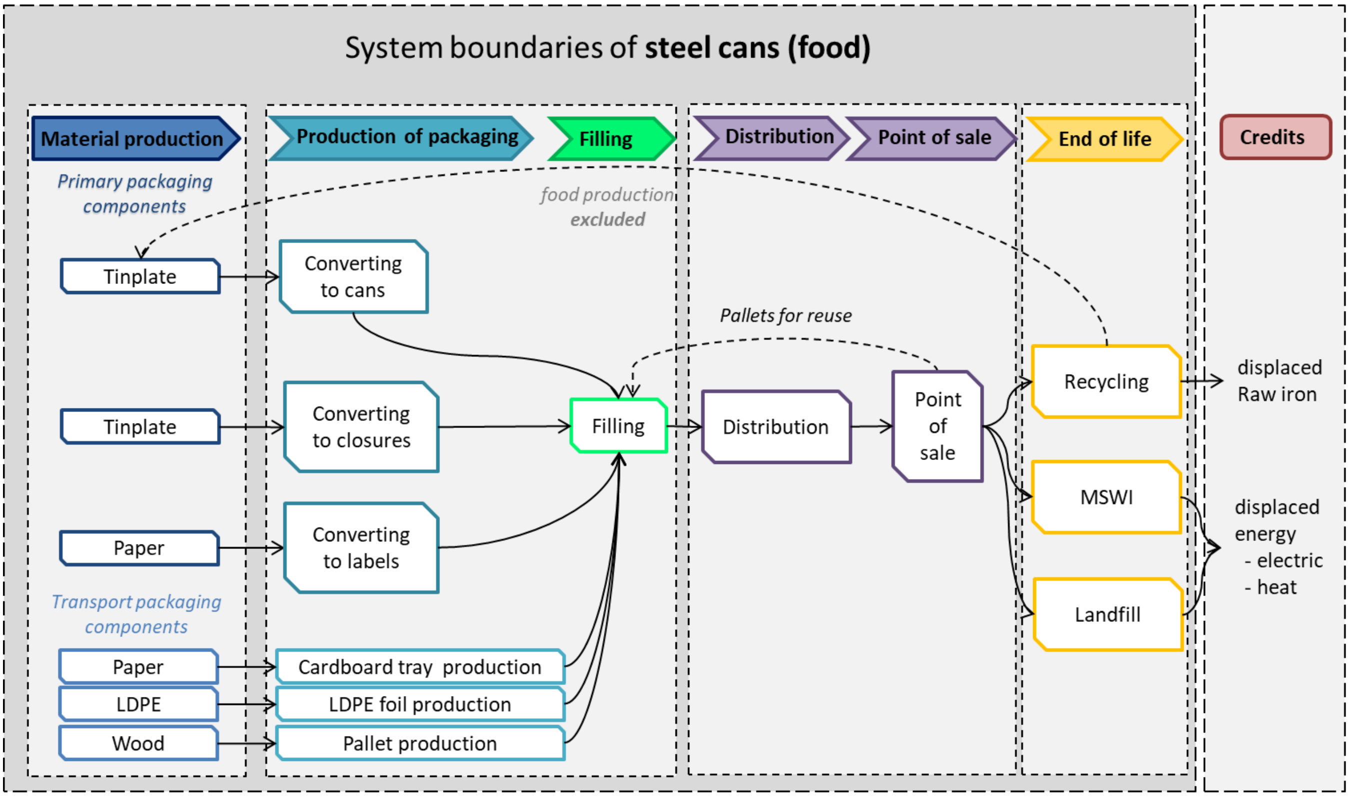

Figure 6: System boundaries of steel cans (food)

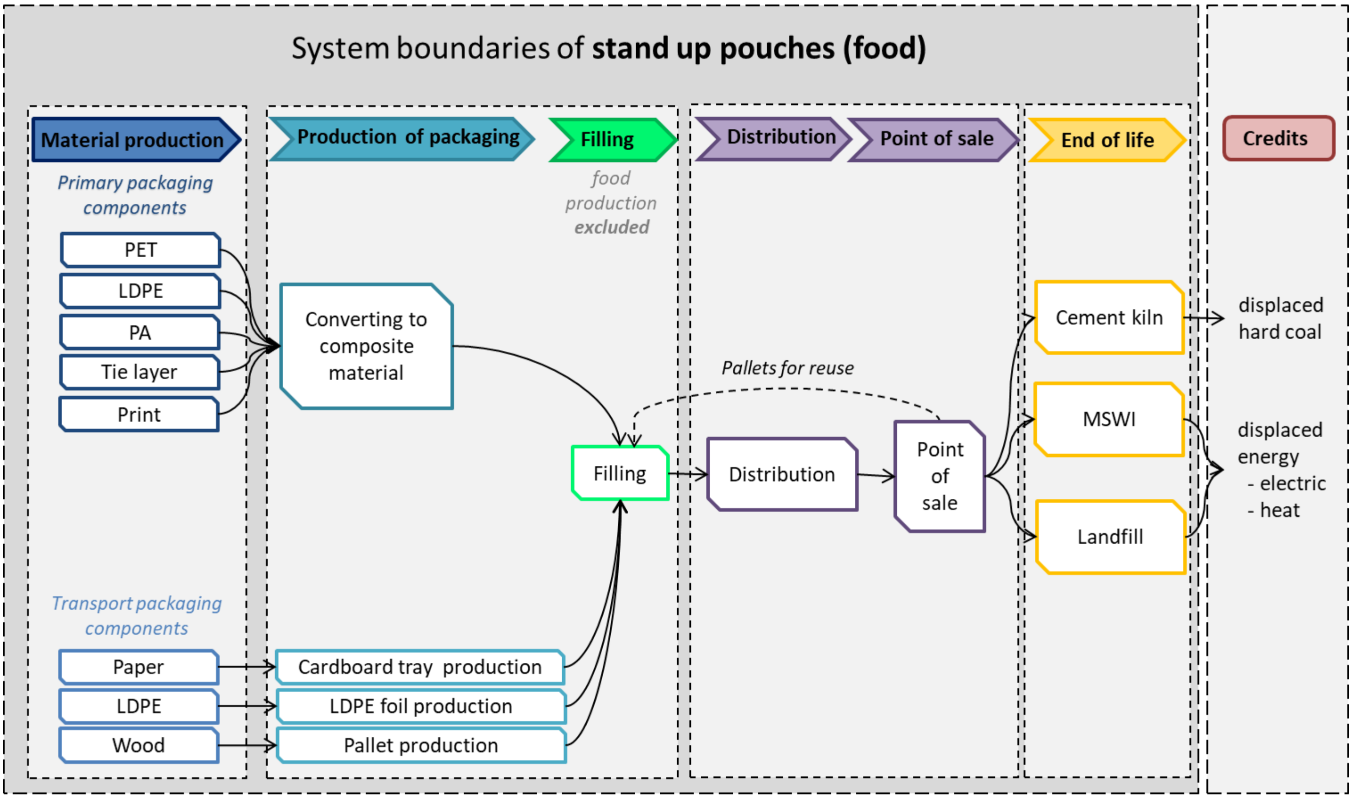

Figure 7: System boundaries of stand up pouches (food)

Cut-off criteria

In order to ensure the symmetry of the packaging systems to be examined and in order 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: 2006), 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 FU. 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. 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. In this study, ink is only considered for the pouch packaging systems (pouch 1 and pouch 2). The ink of these pouches is more than 1% of the total mass of the packaging system.

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 UK and Ireland. Country-specific data for the UK respectively Ireland is generated by using European process data as a proxy combined with the local electricity mixes. A certain share of the raw material production for packaging systems takes place in specific countries. For these, country-specific data is used (liquid packaging board (LPB) and plant based polymers). In cases in which only aggregated datasets are available European average[1] data are used. In Table 1 the geographic scope of the applied data is described.

[1] European data includes UK data before leaving the EU

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

		Beverage cartons	PET bottles	HDPE bottles	Glass bottles, glass jars	Aluminium cans
Materials	LPB	Sweden, Finland				
	polymers	Europe[3]	Europe[3]	Europe[3]		
	plant-based polymers	Brazil	-			
	aluminium	Europe[1]	-			Europe[1]
	tinplate				Europe[4]	
	glass				UK respectively Ireland [5]	
Converting	bodies	Europe[2]	UK respectively Ireland	UK respectively Ireland	UK respectively Ireland	UK respectively Ireland
	closures	Europe[2]	UK respectively Ireland	UK respectively Ireland	UK respectively Ireland	UK respectively Ireland
End of Life		UK respectively Ireland	UK respectively Ireland	UK respectively Ireland	UK respectively Ireland	UK respectively Ireland[1]

[1] EU27 + Norway, Switzerland, Iceland (EAA 2013), (EAA 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 (Fehrenbach et al. 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 UK respectively Irish (EU28) electricity prechains (Fehrenbach et al. 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 2021. Therefore, the reference time period for the study is 2021.

The applied data is as up-to-date as possible referring to the period between 2005 and 2020 (see Table 28 in section 3). Exceptions are the data for steel can converting (1996) and PA6 (1999). In these and other cases in which old data is used no newer data was available. In these cases, the data has been checked for its representativeness (see for example the choice of dataset for PA6 described in section 3.1.6). If possible always the most up to date pre-chains are used (for example electricity production for steel can converting). 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: 2006) is presented in the following table:

Table 2: The summary of the completeness check according to (ISO 14044: 2006)

		Beverage cartons, liquid food cartons	HDPE bottles, PET bottles	Steel cans, aluminium cans	Glass bottles, glass jars	Pouches	Complete ?	Representative ?
Raw materials to consumer	Base material production	☑	☑	☑	☑	☑	✔	✔
	Production of packaging (converting)	☑	☑	☑	☑	☑	✔	✔
	Filling	☑	☑	☑	☑	☑	✔	✔
	Distribution	☑	☑	☑	☑	☑	✔	✔
	Transportation of materials to the single production steps	☑	☑	☑	☑	☑	✔	✔
End of Life	Recycling processes	☑	☑	☑	☑	☑	✔	✔
	MSWI	☑	☑	☑	☑	☑	✔	✔
	Landfill	☑	☑	☑	☑	☑	✔	✔
	Credits	☑	☑	☑	☑	☑	✔	✔
Life Cycle Impact Assessment	'Climate change'	☑	☑	☑	☑	☑	✔	✔

☑ inventory data for all processes available

✔ Complete and representative data available

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 28 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 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 Allocation

Allocation refers to "partitioning the 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: 2006 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 as this is usual practice. 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 processes

An allocation between the packaging and contents was carried out for the transportation of the filled packages to the point-of-sale. 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. This allocation is applied as the FU 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.

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 8 illustrates the general allocation approach used for uncoupled systems and systems which are coupled through recycling. In Figure 8 (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 8. 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, besides the virgin material production ('MP-A') already mentioned above and the disposal of product B ('Dis-B'), also the recovery process 'Rec' has to be taken into consideration.

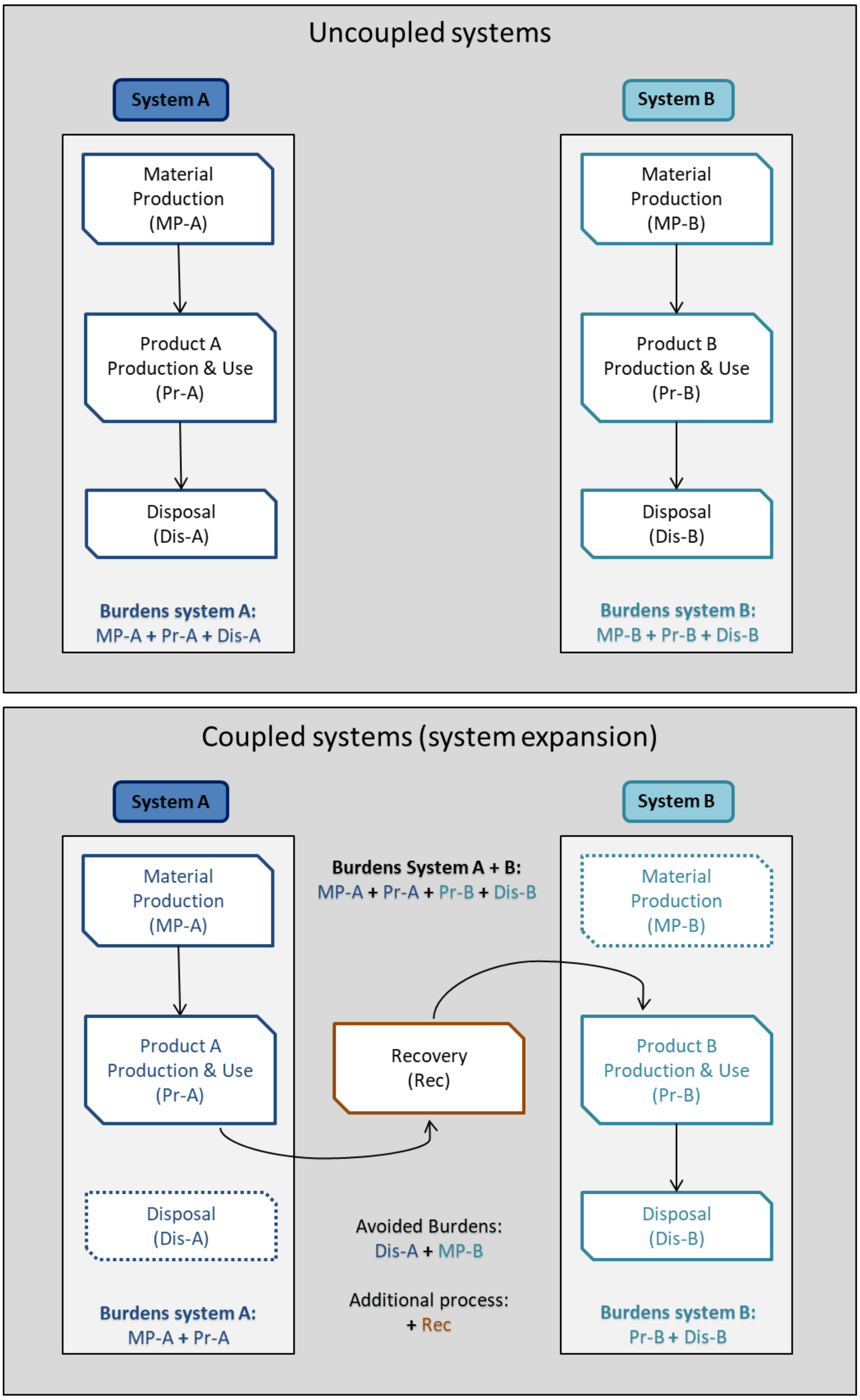

Figure 8: Additional system benefit/burden through recycling (schematic flow chart)[1]

[1] shaded boxes are avoided processes

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 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 9 and Figure 10. Both diagrams show two example product systems, referred to as product 'system A' and 'product 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.

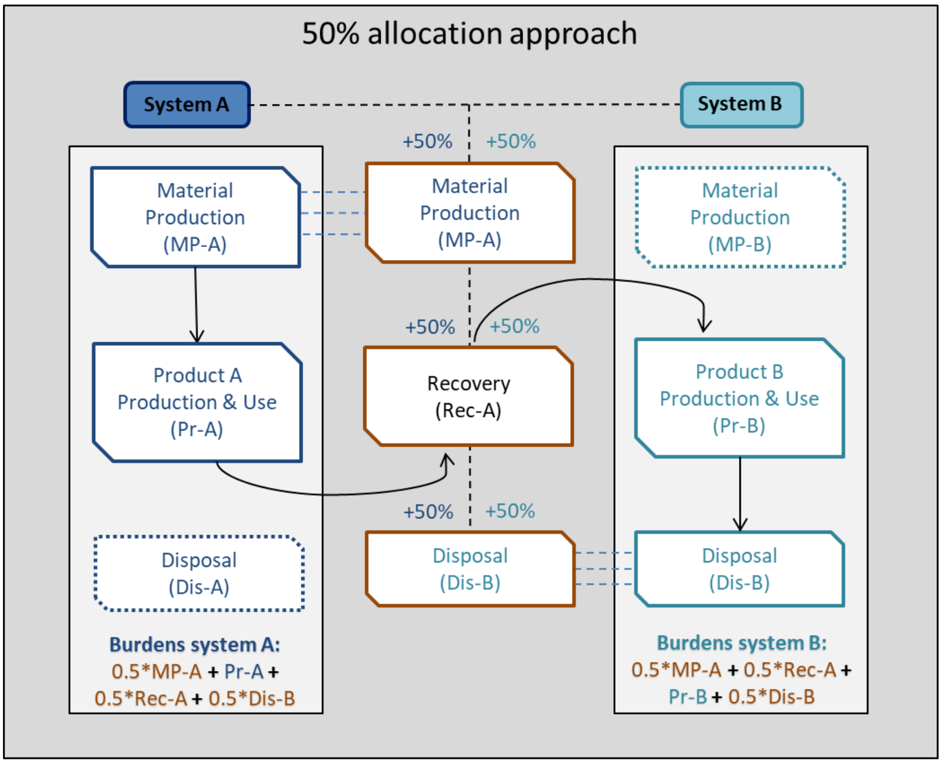

Figure 9: Principles of 50% allocation (schematic flow chart)[1]

Allocation with the 50% method (Figure 9)

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,

[1] shaded boxes are avoided processes

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'.

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; Kim et al. 1997; Klöpffer 1996). According to (Klöpffer 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 are also in line with those of several packaging waste directives and laws as for example the European Packaging and Packaging Waste Directive (EU 2018) or the German packaging law (Verpackungsgesetz - VerpackG 2017).

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, 2016).

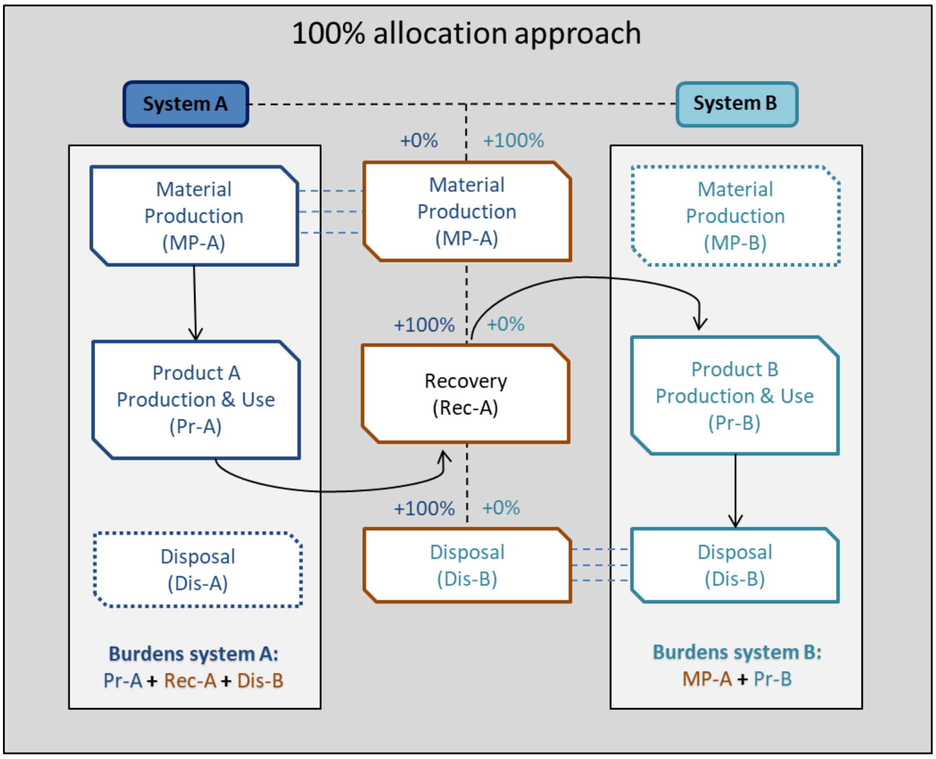

Figure 10: Principles of 100% allocation (schematic flow chart) [1]

Allocation with the 100% method (Figure 10)

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 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 glass jars / bottles.

This approach is also in line with earlier LCA studies done for Tetra Pak.

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 8 to Figure 10

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 25) 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, 2016) and additionally this approach – beyond the UBA methodology – is also in accordance with (ISO 14044: 2006).
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 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
- PET in bottles containing PA (bottle-to-bottle recycling): 0.9
- 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 CO_2 in the atmosphere. In this study, the fixation of CO_2 by the plants is referred as CO_2 uptake and the (re-)emission of CO_2 at the material's end of life is referred as CO_2 regenerative (CO_2 reg.).

Application and allocation

At the impact assessment level, it must be decided how to model and calculate the uptake and emissions of regenerative CO_2. In the present study, the non-fossil CO_2 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. In this study regenerative CO_2 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 packaging waste directives and laws as for example the European Packaging and Packaging Waste Directive (EU 2018) or the German packaging law (Verpackungsgesetz - VerpackG 2017) 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 CO_2 uptake is not considered in credited materials or energy.

The application of the CO_2 uptake in credits would reduce the CO_2 uptake of assessed packaging systems containing regenerative materials by the amount of CO_2 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 CO_2. Therefore almost no CO_2 uptake would be attributed to the substituted processes. The benefit of the CO_2 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 CO_2 from the atmosphere would be substituted. Therefore the benefits of the CO_2 uptake of assessed packaging systems would be reduced by the CO_2 uptake of the substituted processes.

Using the example of mainly regenerative materials like liquid packaging board, the application of the CO_2 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 CO_2 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 CO_2 of 'system A' and 'system B' together stays the same.

The carbon balance is shown exemplarily for the TR plant-based OSO 34 plant-based 1750 mL on the UK market in the following table.

Table 3: Carbon balance for TR plant-based OSO 34 plant-based 1750 mL, UK (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	TR plant-based OSO34 plant-based 1750 mL	TR plant-based OSO34 plant-based 1750 mL	TR plant-based OSO34 plant-based 1750 mL	Subsequent system (incineration with energy recovery)	TR plant-based OSO34 plant-based 1750 mL	TR plant-based OSO34 plant-based 1750 mL + Subsequent system (incineration with energy recovery)
Allocation factor 50	**57.84 kg CO_2**	**15.77 kg C**	6.00 kg C	5.33 kg C	4.44 kg C	**15.77 kg C**
Allocation factor 100	**57.84 kg CO_2**	**15.77 kg C**	11.33 kg C	0.00 kg C	4.44 kg C	**15.77 kg C**

The difference between the emissions of TR plant-based OSO 34 plant-based 1750 mL and those of the following system when applying an allocation factor of 50% can be explained by the emissions from landfills as these are not affected by system allocation.

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 CO_2 reg. from thermal recovery of regenerative materials. In case of allocation 50%, half of the CO_2 reg. emissions are attributed to the examined system and half of the CO_2 reg. emissions are attributed to the following system, for example the MSWI plants with thermal recovery.

Together with the full CO_2 uptake for the assessed system and the non-consideration of the CO_2 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 of the CO_2 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 CO_2 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: 2006; ISO 14044: 2006).

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 of the 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 FU. The category indicator results also do not quantify an 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
LCI results	Amount of climate active gases per FU
Characterisation model	Global Warming Potential for a 100-year time period based on (IPCC 2021)
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 FU

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_2O	$C_2F_2H_4$	CF_4	CCl_4	C_2F_6	R22	kg CO_2-e

* included: CO_2 fossil and biogenic
** included: CH_4 fossil and biogenic

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 2021). In reference to the FU, the category indicator results, GWP results, are expressed as kg CO_2-e per FU.

Note on biogenic carbon: At the impact assessment level, it must be decided how to model and calculate CO_2-based GWP. In the present study the non-fossil CO_2 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 sections (2.1 & 2.2), including the applied end-of-life options (section 2.3). Section 2.4 provides information on all assessed scenarios.

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 environmental aspects. 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), Dairy Alternative (ambient and chilled), Water (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 UK and Ireland 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 also includes the importance of the alternative packaging systems for Tetra Paks customers. 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 and reason of competing packaging systems

Segment	Geographic scope	Competing packaging system	Reason for selection
Dairy Family Pack (chilled)	UK	HDPE bottle 1 2272 mL	Packaging format with the largest market share in this segment in the UK.
		HDPE bottle 2 2000 mL	2 litre HDPE bottles constitutes a growing portion of the UK market share in this segment. The brand chosen is competitive in the category.
	IE	HDPE bottle 3 2750 mL	2.75 - 3 litre HDPE holds the third largest market share in Ireland. The brand and bottle chosen are competitive in the segment.
		HDPE bottle 4 2000 mL	2 litre HDPE holds the largest market share in this segment in Ireland. The brand and bottle chosen are based on market share and competitiveness
		HDPE bottle 5 3000 mL	3 litre HDPE holds the third largest market share. The brand and bottle chosen are competitive in the segment. The bottle is significantly lighter than HDPE bottle 3 with a similar volume.
		HDPE bottle 6 2000 mL	2 litre HDPE holds the largest market share in this segment in Ireland. The brand and bottle chosen are based on market share and competitiveness. The bottle is significantly lighter than HDPE bottle 4 with the same volume.
Dairy Alternative Family Pack (ambient)	UK & IE	PET bottle 1 750 mL	The main competitive packaging in the segment (ambient) filled in PET bottles in UK and Ireland.
Dairy Alternative Family Pack (chilled)	UK & IE	PET bottle 2 750 mL	The main competitive packaging in the segment (chilled) filled in PET bottles in UK and Ireland.
Water Family Pack (ambient)	UK & IE	100% rPET bottle 3 1500 mL	Plastic bottles hold the highest market share in this segment. PET bottles were chosen based on the brand being competitive and the market share.
		50% rPET bottle 4 1500 mL	Plastic bottles hold the highest market share in this segment. PET bottles were chosen based on the brand being competitive and the market share.
		PET bottle 5 1000 mL	Plastic bottles hold the highest market share in this segment. PET bottles were chosen based on the brand being competitive and the market share.
Water Portion Pack (ambient)	UK & IE	PET bottle 6 330 mL	High market share in the segment across both the UK and Ireland.
		30% rPET bottle 7 330 mL	High market share in the segment across both the UK and Ireland.
		PET bottle 8 500 mL	High market share in the segment across both the UK and Ireland.
		51% rPET bottle 9 500 mL	High market share in the segment across both the UK and Ireland.
		Aluminium can 1 250 mL	Main brand in the segment for aluminium cans in the UK and Ireland.
Liquid food Portion Pack (ambient)	UK	Glass jar 1 310 mL	High market share in this segment in the UK.
		Glass Jar 2 410 mL	High market share in this segment in the UK.
		Pouch 1 410 mL	Growing market share in this segment in the UK.
		Pouch 2 500 mL	Growing market share in this segment in the UK.
		Steel can 1 390 mL	Steel can is a common packaging format within the segment. The brand is chosen from a representative mid-tier brand, with a competitive packaging format.

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.

Table 7: List of Tetra Pak beverage cartons in segment **Dairy, Family Pack (chilled)** and corresponding competing packaging systems

Carton based packaging systems	chilled / ambient	Geographic scope	Competing packaging systems	chilled / ambient	Geographic scope
Tetra Rex (TR) plant-based OSO 34 plant-based 1750 mL	❄	UK & IE	HDPE bottle 1 2272 mL	❄	UK
			HDPE bottle 2 2000 mL	❄	UK
			HDPE bottle 3 2750 mL	❄	IE
			HDPE bottle 4 2000 mL	❄	IE
			HDPE bottle 5 3000 mL	❄	IE
			HDPE bottle 6 2000 mL	❄	IE
Tetra Rex (TR) plant-based OSO 34 plant-based 2000 mL	❄	UK & IE	HDPE bottle 1 2272 mL	❄	UK
			HDPE bottle 2 2000 mL	❄	UK
			HDPE bottle 3 2750 mL	❄	IE
			HDPE bottle 4 2000 mL	❄	IE
			HDPE bottle 5 3000 mL	❄	IE
			HDPE bottle 6 2000 mL	❄	IE

Table 8: List of Tetra Pak beverage cartons in segment **Dairy Alternative, Family Pack (ambient)** and corresponding competing packaging systems

Carton based packaging systems	chilled / ambient	Geographic scope	Competing packaging systems	chilled / ambient	Geographic scope
Tetra Brik Aseptic (TBA) Edge plant-based LightCap 30 plant-based 1000 mL	ambient	UK & IE	PET bottle 2 750 mL	ambient	UK & IE
Tetra Stelo Aseptic (TSA) Edge plant-based WingCap 30 plant-based 1000 mL	ambient	UK & IE	PET bottle 2 750 mL	ambient	UK & IE

Table 9: List of Tetra Pak beverage cartons in segment **Dairy Alternative, Family Pack (chilled)** and corresponding competing packaging systems

Carton based packaging systems	chilled / ambient	Geographic scope	Competing packaging systems	chilled / ambient	Geographic scope
Tetra Rex (TR) Plastic Barrier plant-based OSO 34 plant-based 1000 mL	chilled	UK & IE	PET bottle 1 750 mL	chilled	UK & IE

Table 10: List of Tetra Pak beverage cartons in segment **Water, Family Pack (ambient)** and corresponding competing packaging systems

Carton based packaging systems	chilled / ambient	Geographic scope	Competing packaging systems	chilled / ambient	Geographic scope
Tetra Prisma Aseptic (TPA) Square plant-based HeliCap 27 plant-based 1000 mL	ambient	UK & IE	100% rPET bottle 3 1500 mL	ambient	UK & IE
			50% rPET bottle 4 1500 mL	ambient	UK & IE
			PET bottle 5 1000 mL	ambient	UK & IE
Tetra Brik Aseptic (TBA) Slim plant-based HeliCap23 plant-based 1500 mL	ambient	UK & IE	100% rPET bottle 3 1500 mL	ambient	UK & IE
			50% rPET bottle 4 1500 mL	ambient	UK & IE
			PET bottle 5 1000 mL	ambient	UK & IE

Table 11: List of Tetra Pak beverage cartons in segment **Water, Portion Pack (ambient)** and corresponding competing packaging systems

Carton based packaging systems	chilled / ambient	Geographic scope	Competing packaging systems	chilled / ambient	Geographic scope
Tetra Top (TT) Midi Eifel C38 plant-based 330 mL	ambient	UK & IE	PET bottle 6 330 mL	ambient	UK & IE
			30% rPET bottle 7 330 mL	ambient	UK & IE
			Aluminium can 1 250 mL	ambient	UK & IE
			PET bottle 8 500 mL	ambient	UK & IE
			51% rPET bottle 9 500 mL	ambient	UK & IE
Tetra Top (TT) Midi plant-based Eifel C38 plant-based 330 mL	ambient	UK & IE	PET bottle 6 330 mL	ambient	UK & IE
			30% rPET bottle 7 330 mL	ambient	UK & IE
			Aluminium can 1 250 mL	ambient	UK & IE
			PET bottle 8 500 mL	ambient	UK & IE
			51% rPET bottle 9 500 mL	ambient	UK & IE
Tetra Prisma Aseptic (TPA) Edge plant-based DreamCap 26 plant-based 330 mL	ambient	UK & IE	PET bottle 6 330 mL	ambient	UK & IE
			30% rPET bottle 7 330 mL	ambient	UK & IE
			Aluminium can 1 250 mL	ambient	UK & IE
			PET bottle 8 500 mL	ambient	UK & IE
			51% rPET bottle 9 500 mL	ambient	UK & IE
Tetra Top (TT) Midi plant-based Eifel C38 plant-based 500 mL	ambient	UK & IE	PET bottle 6 330 mL	ambient	UK & IE
			30% rPET bottle 7 330 mL	ambient	UK & IE
			Aluminium can 1 250 mL	ambient	UK & IE
			PET bottle 8 500 mL	ambient	UK & IE
			51% rPET bottle 9 500 mL	ambient	UK & IE
Tetra Prisma Aseptic (TPA) Edge Plant-based DreamCap 26 plant-based 500 mL	ambient	UK & IE	PET bottle 6 330 mL	ambient	UK & IE
			30% rPET bottle 7 330 mL	ambient	UK & IE
			Aluminium can 1 250 mL	ambient	UK & IE
			PET bottle 8 500 mL	ambient	UK & IE
			51% rPET bottle 9 500 mL	ambient	UK & IE

Table 12: List of Tetra Pak liquid food cartons in segment **Liquid food, Portion Pack (ambient)** and corresponding competing packaging systems

Carton based packaging systems	chilled / ambient	Geographic scope	Competing packaging systems	chilled / ambient	Geographic scope
Tetra Recart (TRC) 340 mL	ambient	UK	Glass jar 1 310 mL	ambient	UK
			Glass Jar 2 410 mL	ambient	UK
			Pouch 1 410 mL	ambient	UK
			Pouch 2 500 mL	ambient	UK
			Steel can 1 390 mL	ambient	UK
Tetra Recart (TRC) 390 mL	ambient	UK	Glass jar 1 310 mL	ambient	UK
			Glass Jar 2 410 mL	ambient	UK
			Pouch 1 410 mL	ambient	UK
			Pouch 2 500 mL	ambient	UK
			Steel can 1 390 mL	ambient	UK
Tetra Recart (TRC) 500 mL	ambient	UK	Glass jar 1 310 mL	ambient	UK
			Glass Jar 2 410 mL	ambient	UK
			Pouch 1 410 mL	ambient	UK
			Pouch 2 500 mL	ambient	UK
			Steel can 1 390 mL	ambient	UK

2.2 Packaging specifications

Specifications of beverage and liquid food carton packaging systems are listed in Table 13 to Table 18 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 confidentially 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.

In case of primary packaging of beverage and liquid food cartons no materials with recycled content are used.

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 19 to Table 24. They were determined by ifeu in 2021 based on samples collected by Tetra Pak on the UK and Irish market. For each packaging system 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% TiO_2 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 Dairy Alternative bottles are assumed to contain 8% of PA as barrier material (average of communicated PA content of three bottle plastic producers[1]). Specifications of pouches are based on laboratory analyses of similar food pouches Specifications of secondary packaging systems were determined with the calculated surface of the secondary packaging and the average weight per area for LDPE foil and cardboard.

In case of primary packaging of PET and HDPE bottles, recycled content of bottle material is only applied in base scenarios in case it is stated on the respective bottle. As scenario variants an increased recycled content of PET and HDPE in bottles of up to 100% is applied. For closures and labels no recycled content is applied. In case of primary packaging of aluminium cans a recycled content of 50% (EAFA 2022) in body and closure is applied in base scenarios. As scenario variants an increased recycled content of aluminium in can body and closure of up to 100% is applied. In case of glass packaging (white glass) a recycled content (cullet rate) of 69.5% BVGlas (2012). In case of steel cans a recycled content (scrap input) of 2% (World Steel 2018) is applied. In case of multilayer foils for pouches no recycled content in applied.

Pallet configuration of competing packaging systems was calculated with the online tool *www.onpallet.com*. Euro pallets with a loading height of 1400mm are the base for the calculation. The weight of shrink foil per pallets is assumed to be the same as for pallets

[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

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.

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 13: Packaging specifications for assessed carton systems for the packaging of **Dairy, Family Pack (chilled)**

Dairy Family Pack (chilled)

Specification	Unit	Packaging system	
		TR plant-based OSO 34 plant-based	**TR plant-based OSO 34 plant-based**
volume	mL	1750	2000
geographic Scope	-	UK & IE	UK & IE
chilled	-		
ambient			
primary packaging (sum)¹	**g**	**49.3**	**53.3**
primary packaging (per FU)	**g/FU**	**28171**	**26650**
composite material (sleeve)	g	46.7	50.7
- liquid packaging board	g	41.8	45.4
- fossil-based polymer	g		
- plant-based polymer	g	4.9	5.3
closure	g	2.6	2.6
- fossil-based polymer	g		
- plant-based polymer	g	2.6	2.6
secondary packaging (sum)²	**g**	184.2	196.0
- tray/box (corr.cardboard)	g	184.2	196.0
tertiary packaging (sum)³	g	**25170**	**25170**
- pallet	g	25000	25000
number of use cycles	-	25	25
- stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
cartons per tray	pc	8	8
trays / packs per layer	pc	9	9
layers per pallet	pc	4	4
cartons per pallet	pc	288	288

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

Table 14: Packaging specifications for assessed carton systems for the packaging of **Dairy Alternative, Family Pack (ambient)**

Dairy Alternative Family Pack (ambient)

Specification	Unit	Packaging system	
		TBA Edge plant-based LightCap 30 plant-based	TSA Edge plant-based WingCap 30 plant-based
volume	mL	1000	1000
geographic Scope	-	UK & IE	UK & IE
chilled / ambient	-	ambient	ambient
primary packaging (sum)[1]	**g**	**31.5**	**33.5**
primary packaging (per FU)	**g/FU**	**31500**	**33500**
composite material (sleeve)	g	28.5	30.3
- liquid packaging board	g	22.3	23.4
- fossil-based polymer	g	2.2	2.7
- plant-based polymer	g	2.6	2.9
- aluminium	g	1.4	1.3
closure	g	3.0	3.1
- fossil-based polymer	g		
- plant-based polymer	g	3.0	3.1
secondary packaging (sum)[2]	**g**	**145.0**	**176.4**
- tray/box (corr.cardboard)	g	145.0	176.4
tertiary packaging (sum)[3]	**g**	**25170**	**25170**
- pallet	g	25000	25000
number of use cycles	-	25	25
- stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
cartons per tray	pc	10	12
trays / packs per layer	pc	15	12
layers per pallet	pc	5	5
cartons per pallet	pc	750	720

[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 Alternative, Family Pack (chilled)**

Dairy Alternative Family Pack (chilled)

Specification	Unit	Packaging system
		TR Plastic Barrier plant-based OSO 34 plant-based
volume	mL	1000
geographic Scope	-	UK & IE
chilled / ambient	-	chilled
primary packaging (sum)¹	**g**	**30.5**
primary packaging (per FU)	**g/FU**	**30500**
composite material (sleeve)	g	27.9
- liquid packaging board	g	22.8
- fossil-based polymer	g	1.2
- plant-based polymer	g	3.9
closure	g	2.6
- fossil-based polymer	g	
- plant-based polymer	g	2.6
secondary packaging (sum)²	**g**	**156.8**
- tray/box (corr.cardboard)	g	156.8
tertiary packaging (sum)³	**g**	**25170**
- pallet	g	25000
number of use cycles	-	25
- stretch foil (per pallet) (LDPE)	g	170
pallet configuration		
cartons per tray	pc	10
trays / packs per layer	pc	15
layers per pallet	pc	4
cartons per pallet	pc	600

[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 **Water, Family Pack (ambient)**

Water Family Pack (ambient)

Specification	Unit	Packaging system	
		TPA Square plant-based HeliCap 27 plant-based	**TBA Slim plant-based HeliCap 23 plant-based**
volume	mL	1000	1500
geographic Scope	-	UK & IE	UK & IE
chilled / ambient	-	ambient	ambient
primary packaging (sum)[1]	**g**	**38.2**	**44.3**
primary packaging (per FU)	**g/FU**	**38200**	**29533**
composite material (sleeve)	g	34.3	41.6
- liquid packaging board	g	25.5	31.7
- fossil-based polymer	g	3.1	4.1
- plant-based polymer	g	3.8	4.0
- aluminium	g	1.9	1.8
closure	g	3.9	2.7
- fossil-based polymer	g	2.1	1.4
- plant-based polymer	g	1.8	1.3
secondary packaging (sum)[2]	**g**	**133.3**	**172.5**
- tray/box (corr.cardboard)	g	133.3	172.5
tertiary packaging (sum)[3]	**g**	**25170**	**25170**
- pallet	g	25000	25000
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	18	16
layers per pallet	pc	5	4
cartons per pallet	pc	720	512

[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 **Water, Portion Pack (ambient)**

Water Portion Pack (ambient)

Specification	Unit	Packaging system				
		TT Midi Eifel C38 plant-based	TT Midi plant-based Eifel C38 plant-based	TPA Edge plant-based DreamCap 26 plant-based	TT Midi plant-based Eifel C38 plant-based	TPA Edge plant-based DreamCap 26 plant-based
volume	mL	330	330	330	500	500
geographic Scope	-	UK & IE	UK & IE	UK & IE	UK & IE	UK & IE
chilled	-					
ambient						
primary packaging (sum)[1]	**g**	**17.9**	**17.9**	**16.2**	**21.7**	**21.9**
primary packaging (per FU)	**g/FU**	**54242**	**54242**	**49091**	**43400**	**43800**
composite material (sleeve)	g	11.1	11.1	12.5	14.9	18.2
- liquid packaging board	g	8.6	8.6	8.7	11.5	13.1
- fossil-based polymer	g	1.9	0.9	1.5	1.3	1.9
- plant-based polymer	g		1.0	1.4	1.4	2.0
- aluminium	g	0.6	0.6	0.9	0.7	1.2
top	g	3.9	3.9		3.9	
- fossil-based polymer	g	0.5	0.5		0.5	
- plant-based polymer	g	3.4	3.4		3.4	
closure	g	2.9	2.9	3.7	2.9	3.7
- fossil-based polymer	g			2.2		2.2
- plant-based polymer	g	2.9	2.9	1.5	2.9	1.5
secondary packaging (sum)[2]	**g**	**78.4**	**78.4**	**105.8**	**109.8**	**129.4**
- tray/box (corr.cardboard)	g	78.4	78.4	105.8	109.8	129.4
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**	**25170**	**25170**
- pallet	g	25000	25000	25000	25000	25000
number of use cycles	-	25	25	25	25	25
- stretch foil (per pallet) (LDPE)	g	170	170	170	170	170
pallet configuration						
cartons per tray	pc	8	8	12	12	12
trays / packs per layer	pc	27	27	19	19	16
layers per pallet	pc	7	7	8	5	6
cartons per pallet	pc	1512	1512	1824	1140	1152

[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 **Liquid food, Portion Pack (ambient)**

Liquid food Portion Pack (ambient)

Specification	Unit	Packaging system		
		TRC	TRC	TRC
volume	mL	340	390	500
geographic Scope	-	UK	UK	UK
chilled / ambient	-	ambient	ambient	ambient
primary packaging (sum)[1]	g	**16.4**	**17.7**	**20.5**
primary packaging (per FU)	g/FU	**48235**	**45385**	**41000**
composite material (sleeve)	g	16.4	17.7	20.5
- liquid packaging board	g	11.7	12.6	14.6
- aluminium	g	0.7	0.8	0.9
- fossil-based polymer	g	4.0	4.3	5.0
secondary packaging (sum)[2]	g	**54.9**	**109.8**	**70.6**
- tray/box (corr.cardboard)	g	54.9	109.8	70.6
tertiary packaging (sum)[3]	g	**25170**	**25170**	**25170**
- pallet	g	25000	25000	25000
number of use cycles	-	25	25	25
- stretch foil (per pallet) (LDPE)	g	170	170	170
pallet configuration				
cartons per tray	pc	8	16	8
trays / packs per layer	pc	24	12	24
layers per pallet	pc	12	11	8
cartons per pallet	pc	2304	2112	1536

[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 19: Packaging specifications for assessed alternative systems in the segment **Dairy, Family Pack (chilled)**

Dairy Family Pack (chilled)

Specification	Unit	Packaging system					
		HDPE bottle 1	HDPE bottle 2	HDPE bottle 3	HDPE bottle 4	HDPE bottle 5	HDPE bottle 6
volume	mL	2272	2000	2750	2000	3000	2000
geographic Scope	-	UK	UK	IE	IE	IE	IE
clear / opaque	-	clear	opaque	clear	clear	clear	clear
chilled / ambient	-	chilled	chilled	chilled	chilled	chilled	chilled
primary packaging (sum)[1]	**g**	**35.23**	**37.78**	**70.22**	**48.63**	**62.61**	**39.14**
primary packaging (per FU)	**g/FU**	**15506**	**18890**	**25535**	**24315**	**20870**	**19570**
bottle	g	32.97	34.62	66.01	45.02	58.29	35.10
- HDPE	g	32.97	32.89	66.01	45.02	58.29	35.10
- recycled HDPE	%	base 0% variant 30/50/100%	base 0% variant 30/50/100%	base 0% variant 30/50/100%	base 0% variant 30/50/100%	base 0% variant 30/50/100%	base 0% variant 30/50/100%
- TiO2	g		1.73				
label	g	0.73	1.13	1.59	1.05	1.65	1.43
- PP	g	0.73	1.13	1.59	1.05	1.65	1.43
closure	g	1.33	1.75	2.62	2.56	2.67	2.61
- HDPE	g	1.33	1.75	2.62	2.56	2.67	2.61
pull tab	g	0.20	0.28				
- aluminium	g	0.20	0.28				
tertiary packaging (sum)[3]	**g**	**32000**	**32000**	**32000**	**32000**	**32000**	**32000**
- rollcontainer	g	32000	32000	32000	32000	32000	32000
type of packaging	-	Rollcontainer	Rollcontainer	Rollcontainer	Rollcontainer	Rollcontainer	Rollcontainer
number of use cycles	-	200	200	200	200	200	200
rollcontainer configuration							
- bottles per layer	pc	12	12	10	12	10	12
- layers per rollcontainer	pc	4	4	4	4	4	4
- bottles per rollcontainer	pc	48	48	40	48	40	48

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

Table 20: Packaging specifications for assessed alternative systems in the segment **Dairy Alternative, Family Pack (ambient)**

Dairy Alternative Family Pack (ambient)		
Specification	**Unit**	**Packaging system**
		PET bottle 1
volume	mL	750
geographic Scope	-	UK & IE
clear / opaque	-	clear
chilled / ambient	-	ambient
primary packaging (sum)[1]	**g**	**57.32**
primary packaging (per FU)	**g/FU**	**76427**
bottle	g	42.26
- PET	g	38.88
- recycled PET	%	base 0%
- PA	g	3.38
label	g	3.69
- PET	g	3.69
closure	g	11.12
- HDPE	g	11.12
pull tab	g	0.25
- aluminium	g	0.25
secondary packaging (sum)[2]	**g**	**156.62**
- tray/box (corr.cardboard)	g	156.62
tertiary packaging (sum)[3]	**g**	**25170**
- pallet	g	25000
number of use cycles	-	25
- stretch foil (per pallet) (LDPE)	g	170
pallet configuration		
bottles per tray	pc	8
trays / packs per layer	pc	12
layers per pallet	pc	5
bottles per pallet	pc	480

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

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

Dairy Alternative Family Pack (chilled)		
Specification	**Unit**	**Packaging system**
		PET bottle 2
volume	mL	750
geographic Scope	-	UK & IE
clear / opaque	-	clear
chilled / ambient	-	chilled
primary packaging (sum)[1]	**g**	**39.02**
primary packaging (per FU)	**g/FU**	**52027**
bottle	g	34.14
- PET	g	34.14
- recycled PET	%	base 0%
label	g	1.81
- HDPE		1.68
- paper	g	0.13
closure	g	3.07
- HDPE	g	3.07
secondary packaging (sum)[2]	**g**	**129.86**
- tray/box (corr.cardboard)	g	129.86
tertiary packaging (sum)[3]	**g**	**25170**
- pallet	g	25000
number of use cycles	-	25
- stretch foil (per pallet) (LDPE)	g	170
pallet configuration		
bottles per tray	pc	8
trays / packs per layer	pc	17
layers per pallet	pc	5
bottles per pallet	pc	680

[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 **Water, Family Pack (ambient)**

Water Family Pack (ambient)				
Specification	**Unit**	**Packaging system**		
		100% rPET bottle 3	**50% rPET bottle 4**	**PET bottle 5**
volume	mL	1500	1500	1000
geographic Scope	-	UK & IE	UK & IE	UK & IE
clear / opaque	-	clear	clear	clear
chilled / ambient	-	ambient	ambient	ambient
primary packaging (sum)[1]	**g**	**30.97**	**41.05**	**29.37**
primary packaging (per FU)	**g/FU**	**20647**	**27367**	**29370**
bottle	g	28.27	38.76	27.03
- PET	g	28.27	38.76	27.03
- recycled PET	%	base 100%	base 50%	base 0% variant 50/100%
label	g	0.66	0.34	0.41
- PP	g	0.66	0.34	0.41
closure	g	2.04	1.95	1.93
- HDPE	g	2.04	1.95	1.93
secondary packaging (sum)[2]	**g**	**20.74**	**21.67**	**16.92**
- shrink pack (LDPE)	g	20.74	21.67	16.92
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**
- pallet	g	25000	25000	25000
number of use cycles	-	25	25	25
- stretch foil (per pallet) (LDPE)	g	170	170	170
pallet configuration				
bottles per tray	pc	6	6	6
trays / packs per layer	pc	17	17	21
layers per pallet	pc	4	3	4
bottles per pallet	pc	408	306	504

[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 **Water, Portion Pack (ambient)**

Water Portion Pack (ambient)

Specification	Unit	Packaging system				
		PET bottle 6	**30% rPET bottle 7**	**PET bottle 8**	**51% rPET bottle 9**	**Aluminium can 1**
volume	mL	330	330	500	500	250
geographic Scope	-	UK & IE	UK & IE	UK & IE	UK & IE	UK & IE
clear / opaque	-	clear	clear	clear	clear	
chilled	-					
ambient						
primary packaging (sum)[1]	**g**	**15.08**	**16.16**	**16.00**	**12.41**	**10.57**
primary packaging (per FU)	**g/FU**	**45697**	**48970**	**32000**	**24820**	**42280**
bottle / can	g	10.75	13.80	14.13	10.82	10.57
- PET	g	10.75	13.80	14.13	10.82	
- recycled PET	%	base 0%	base 30% variant 50/100%	base 0%	base 51% variant 100%	
- aluminium	g					7.46
- recycled aluminium	%					base 50% variant 100%
label	g	0.24	0.31	0.17	0.27	
- PP	g	0.24	0.31	0.17	0.27	
closure	g	4.09	2.05	1.70	1.32	
- HDPE	g	1.65	2.05	1.70	1.32	
- PP	g	2.44				
- aluminium	g					3.11
- recycled aluminium	%					base 50% variant 100%
secondary packaging (sum)[2]	**g**	**13.70**	**86.72**	**11.13**	**12.59**	**73.45**
- shrink pack (LDPE)	g	13.70		11.13	12.59	
- tray/box (corr.cardboard)	g		86.72			73.45
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**	**25170**	**25170**
- pallet	g	25000	25000	25000	25000	25000
number of use cycles	-	25	25	25	25	25
- stretch foil (per pallet) (LDPE)	g	170	170	170	170	170
pallet configuration						
bottles / cans per tray	pc	12	24	6	12	10
trays / packs per layer	pc	18	9	31	18	26
layers per pallet	pc	8	8	6	6	10
bottles / cans per pallet	pc	1728	1728	1116	1296	2600

[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 **Liquid food, Portion Pack (ambient)**

Liquid food Portion Pack (ambient)

Specification	Unit	Packaging system				
		Glass jar 1	Glass jar 2	Pouch 1	Pouch 2	Steel can 1
volume	mL	310	410	410	500	390
geographic Scope	-	UK	UK	UK	UK	UK
chilled / ambient	-					
primary packaging (sum)[1]	**g**	**208.47**	**243.07**	**8.77**	**9.92**	**59.00**
primary packaging (per FU)	**g/FU**	**672484**	**592854**	**21390**	**19840**	**151282**
jar/pouch/can	g	200.91	233.63	8.3	9.39	59.00
- PET	g			1.27	1.44	
- LDPE	g			5.36	6.06	
- PA	g			1.34	1.51	
- print	g			0.33	0.38	
- tie layer				0.47	0.53	
- glass	g	200.91	233.63			
- tin plate	g					50.00
label	g	0.97	1.37			2.0
- paper	g	0.97	1.37			2.0
closure	g	6.59	8.07			7.0
- tinplate		6.59	8.07			7.0
secondary packaging (sum)[2]	**g**	**18.86**	**27.19**	**74.55**	**76.19**	**56.00**
- tray/box (corr.cardboard)	g	18.86	27.19	74.55	76.19	56.00
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**	**25170**	**25170**
- pallet	g	25000	25000	25000	25000	25000
number of use cycles	-	25	25	25	25	25
- stretch foil (per pallet) (LDPE)	g	170	170	170	170	170
pallet configuration						
packs per tray	pc	6	6	6	4	12
trays / packs per layer	pc	26	26	38	29	6
layers per pallet	pc	9	9	7	6	12
packs per pallet	pc	1404	1404	1596	696	864

[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 UK and Irish market. The applied recycling quotas are based on published quotas. In case of beverage cartons the recycling quota is confidentially provided by (EXTR:ACT 2020). The material recycling quotas represent the actual amount of material undergoing a material recycling process after sorting took place. The remaining part of the post-consumer packaging waste is modelled and calculated according to the average split between landfilling and incineration (MSWI) in UK and Ireland. The applied end-of-life quotas and the related references are given in Table 25 and Table 26. Preferable local data sources are applied if possible.

Table 25: Applied end of life quotas for beverage and liquid food cartons and competing packaging systems in UK:

Geographical scope	Packaging system	EOL quota, source and reference year	Material recycling	MSWI	Landfill
UK		MSWI / landfill split		73.2%	26.8%
		source		(Eurostat 2021)	
		reference year		2018	
	Beverage and liquid food carton	quota	confidential	confidential	confidential
		source	(EXTR:ACT 2020)	(EXTR:ACT 2020), (Eurostat 2021)	
		reference year	2019	2018, 2019	
	PET bottles	quota	53.1%	34.3%	12.6%
		source	(RECOUP 2020)	(RECOUP 2020), (Eurostat 2021)	
		reference year	2019	2018, 2019	
	HDPE bottles[1]	quota	53.1%	34.3%	12.6%
		source	(RECOUP 2020)	(RECOUP 2020), (Eurostat 2021)	
		reference year	2019	2018, 2019	
	Glass bottles/jars[2]	quota	75.8%	17.7%	6.5%
		source	(Defra 2021)	(Defra 2021), (Eurostat 2021)	
		reference year	2020	2018, 2020	
	Pouches[3]	quota	7%	68.1%	24.9%
		source	(Niaounakis 2019; RECOUP 2020)	(Niaounakis 2019; RECOUP 2020), (Eurostat 2021)	
		reference year	2019	2018	
	Aluminium cans[4]	quota	69.0%	22.7%	8.3%
		source	(Defra 2021)	(Defra 2021), (Eurostat 2021)	
		reference year	2020	2018, 2020	
	Steel cans[5]	quota	78.7%	15.6%	5.7%
		source	(Defra 2021)	(Defra 2021), (Eurostat 2021)	
		reference year	2020	2018, 2020	

[1]white opaque HDPE bottles are not materially recycled (see section 3.13)
[2]recycling quota for all glass packaging (see section 3.13)
[3]multilayer pouches are not materially recycled (see section 3.13). Recycling quota refers to pouches collected for fuel substitution.
[4]recycling quota for all aluminium packaging (see section 3.13)
[5]recycling quota for all steel packaging (see section 3.13).

Table 26: Applied end of life quotas for beverage cartons and competing packaging systems in IE:

Geographical scope	Packaging system	EOL quota, source and reference year	Material recycling	MSWI	Landfill
IE		MSWI / landfill split		74.8%	25.2%
		source		(Eurostat 2021)	
		reference year		2018	
	Beverage and liquid food carton	quota	confidential	confidential	confidential
		source	(EXTR:ACT 2020)	(EXTR:ACT 2020), (Eurostat 2021)	
		reference year	2019	2018, 2019	
	PET bottles[1]	quota	27.5%	54.3%	18.2%
		source	(epa 2021)	(epa 2021), (Eurostat 2021)	
		reference year	2019	2018, 2019	
	HDPE bottles[1]	quota	27.5%	54.3%	18.2%
		source	(epa 2021)	(epa 2021), (Eurostat 2021)	
		reference year	2019	2018, 2019	
	Aluminium cans[2]	quota	69.0%	23.2%	7.8%
		source	(epa 2021)	(epa 2021), (Eurostat 2021)	
		reference year	2019	2018, 2019	

[1]recycling quota for all plastic packaging material (see section 3.13)
[2]recycling quota for all aluminium packaging (see section 3.13)

The following flow charts illustrate the applied specified end-of-life models for UK and Ireland of beverage and liquid food cartons, clear PET bottles, clear and white opaque HDPE bottles, glass bottles / jars, pouches, aluminium and steel cans. The percentages going into the recycling path as well going into MSWI and landfill from disposal in each flowchart corresponds to the material recycling quotas in **Table 25** and **Table 26**. For the sorting process typical efficiencies from the internal ifeu database are applied (beverage and liquid food cartons 90%, plastic bottles 90%, glass bottles / jars 99%, aluminium and steel cans 96%).

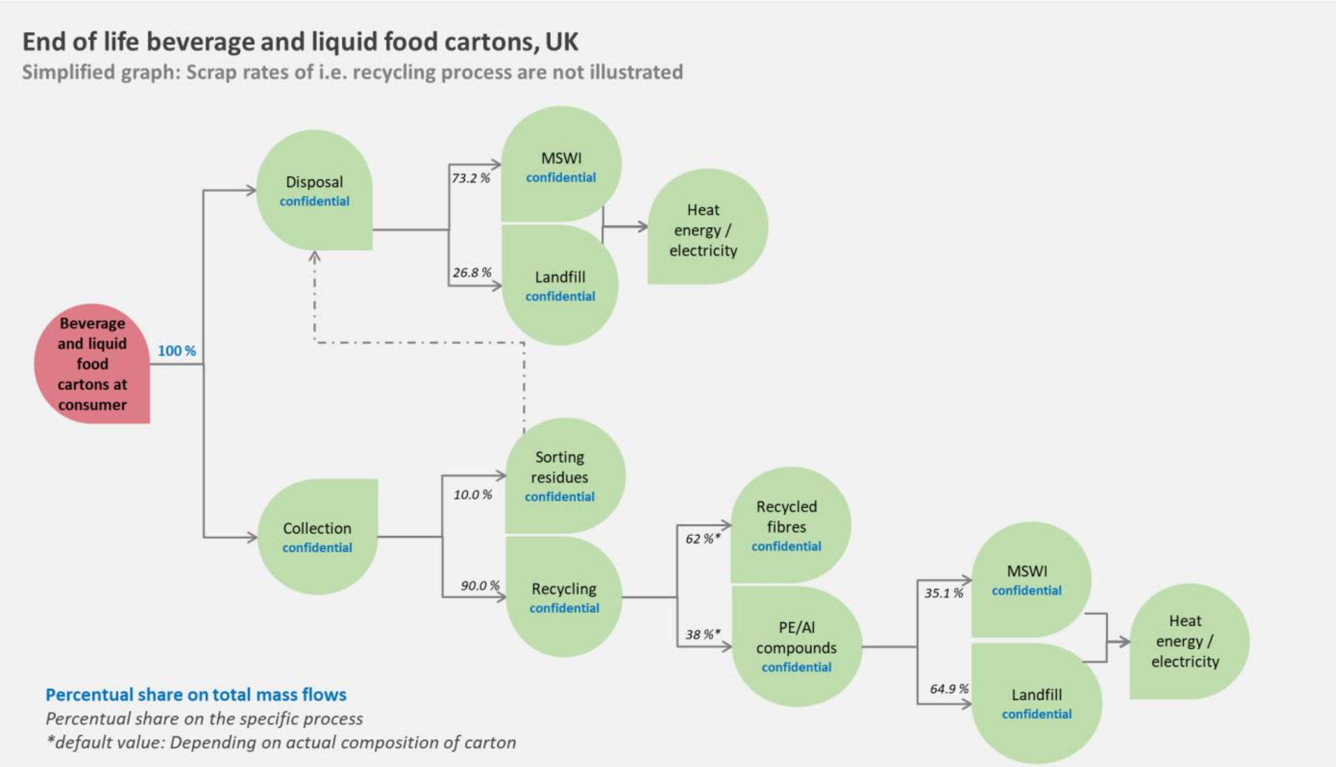

Figure 11: Applied end-of-life quotas for beverage and liquid food cartons in UK

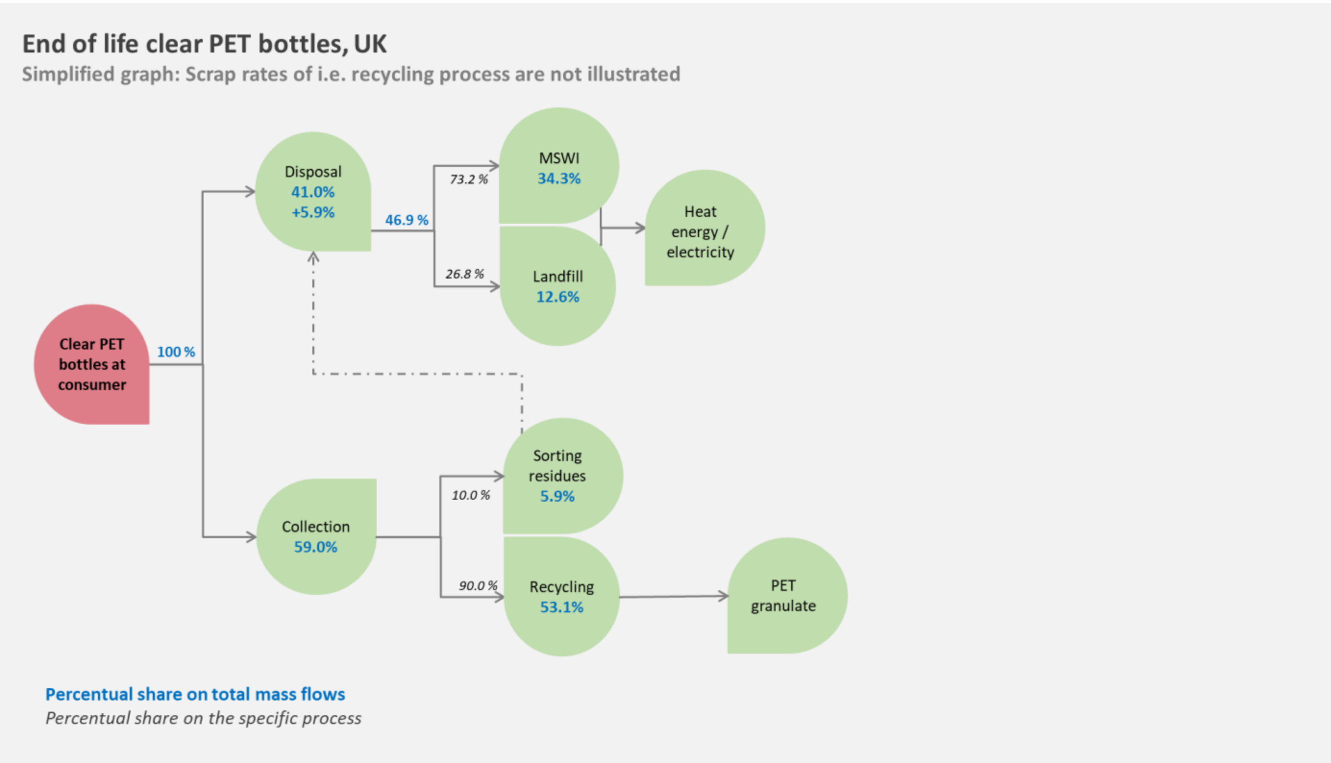

Figure 12: Applied end-of-life quotas for clear PET bottles in UK

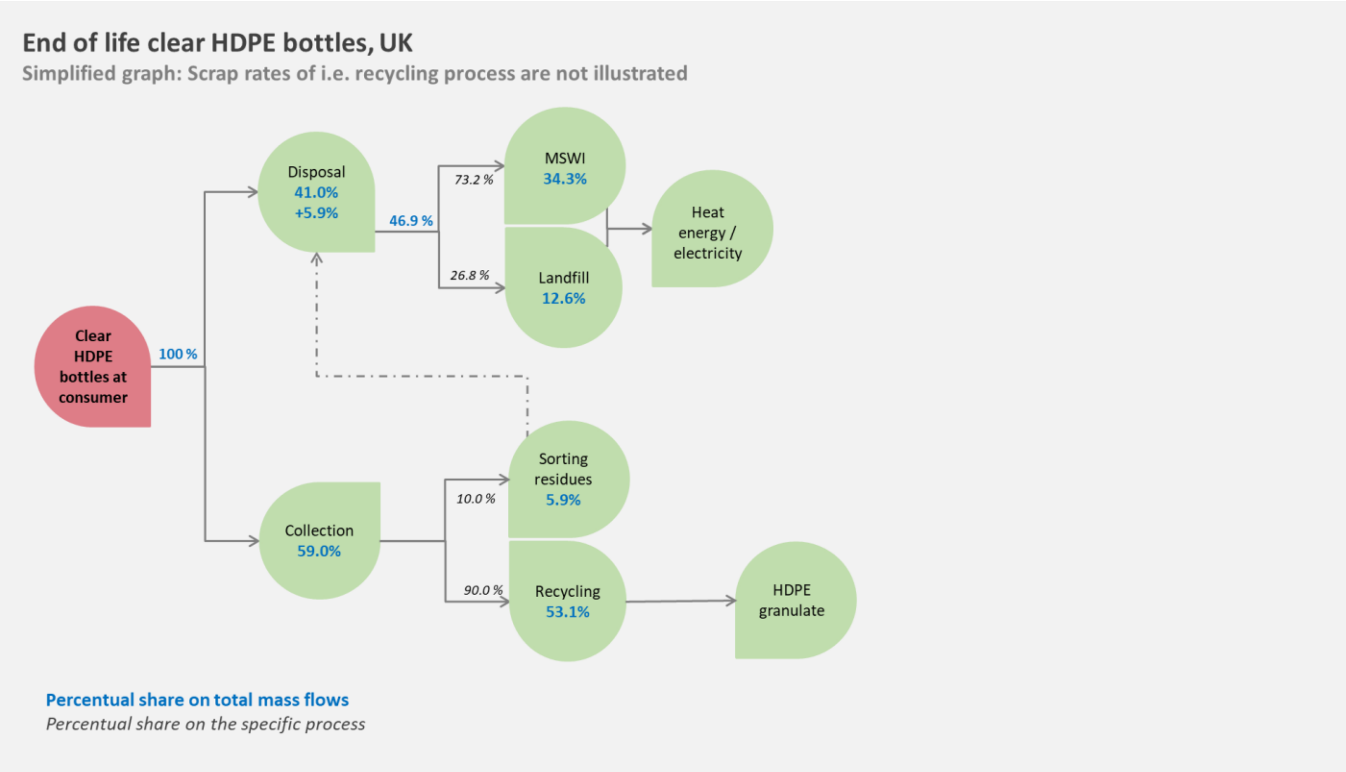

Figure 13: Applied end-of-life quotas for clear HDPE bottles in UK

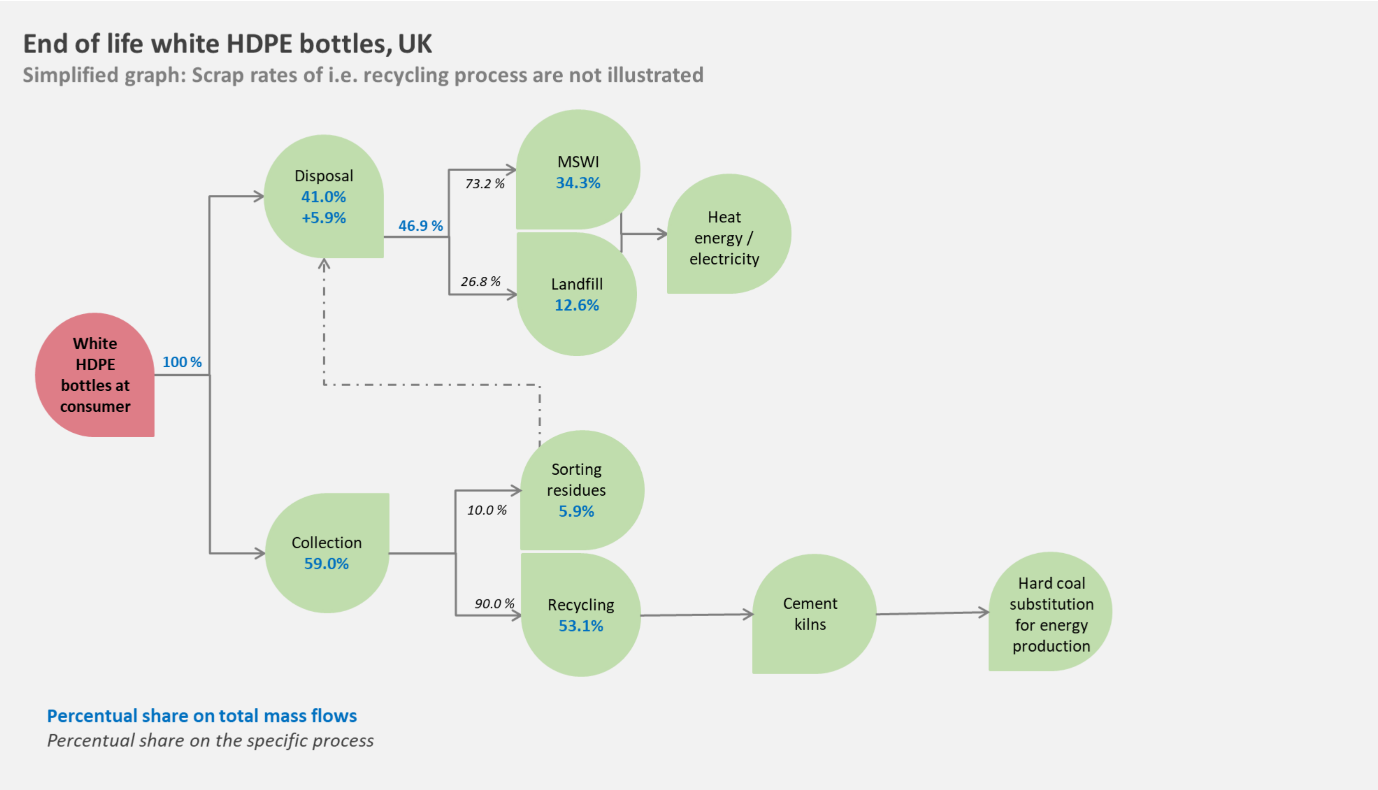

Figure 14: Applied end-of-life quotas for white HDPE bottles in UK

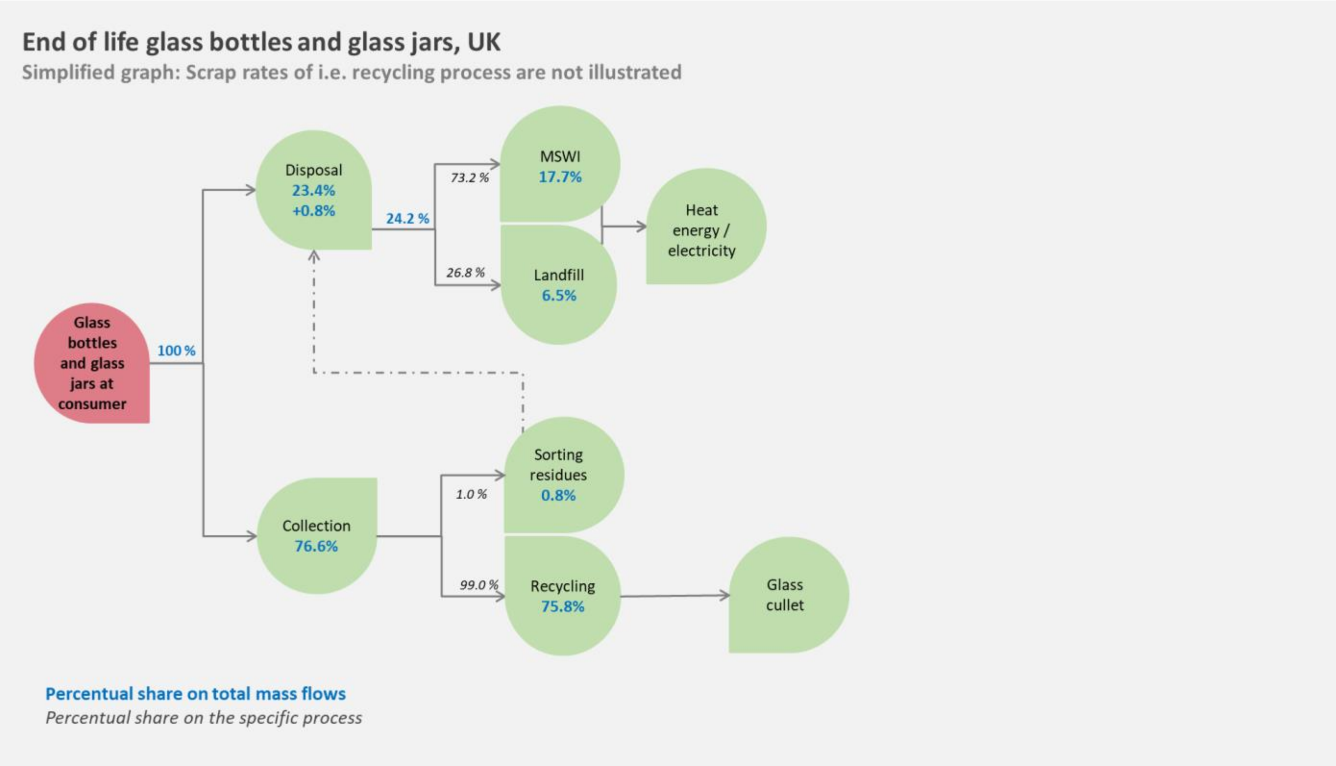

Figure 15: Applied end-of-life quotas for glass bottles/jars in UK

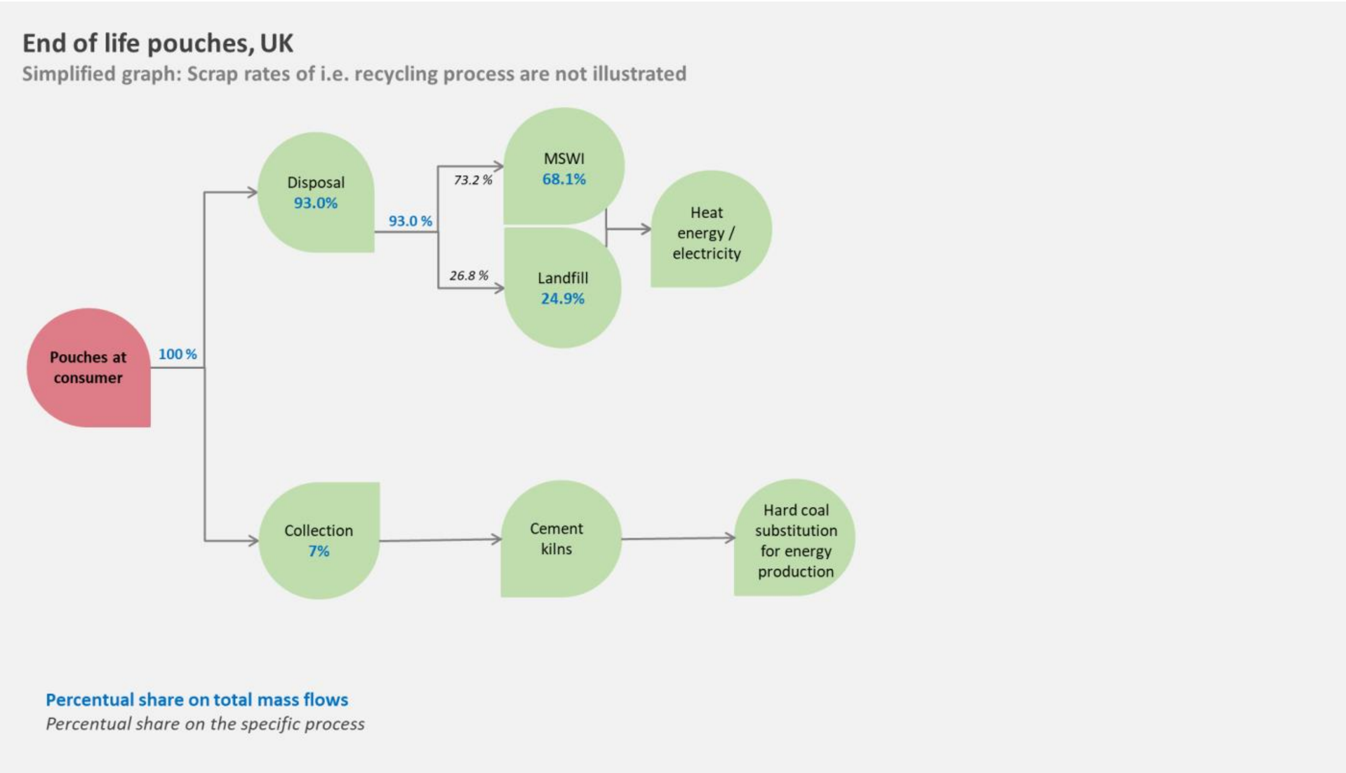

Figure 16: Applied end-of-life quotas for pouches in UK

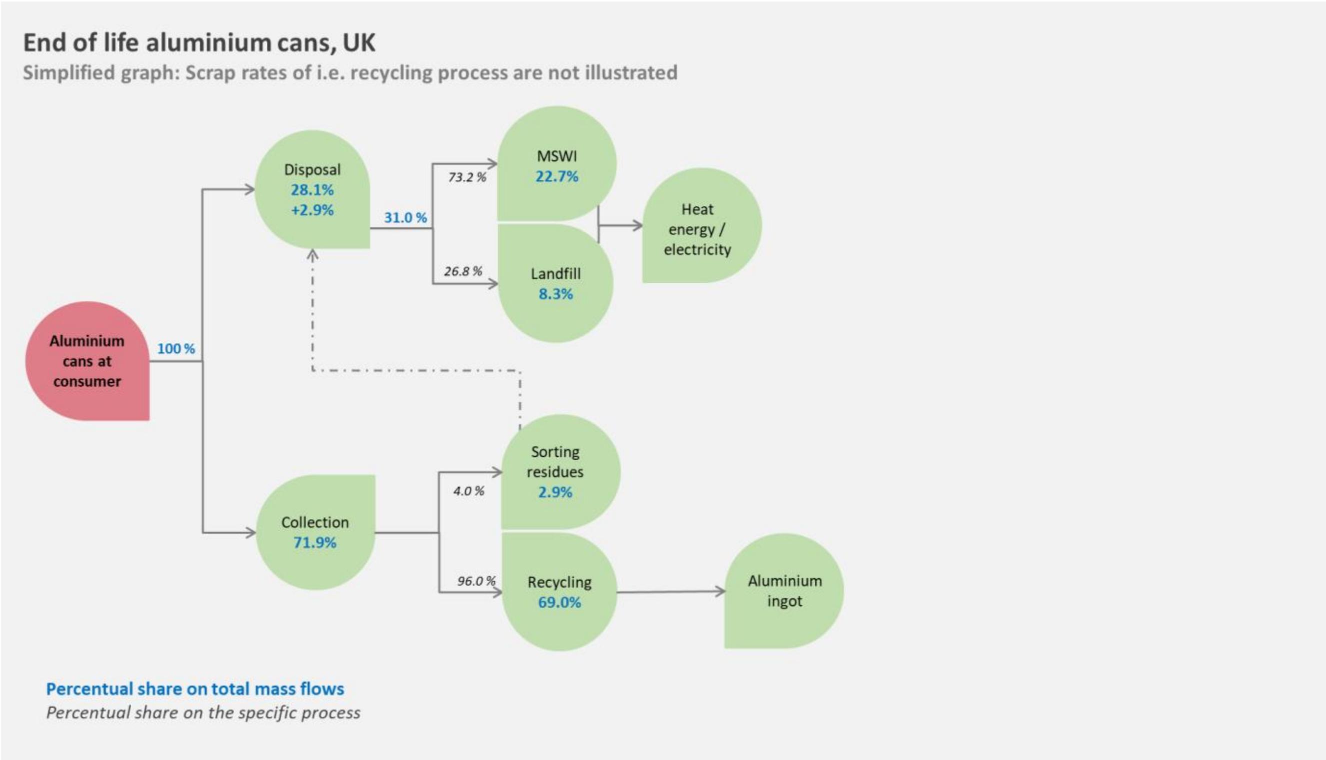

Figure 17: Applied end-of-life quotas for aluminium cans in UK

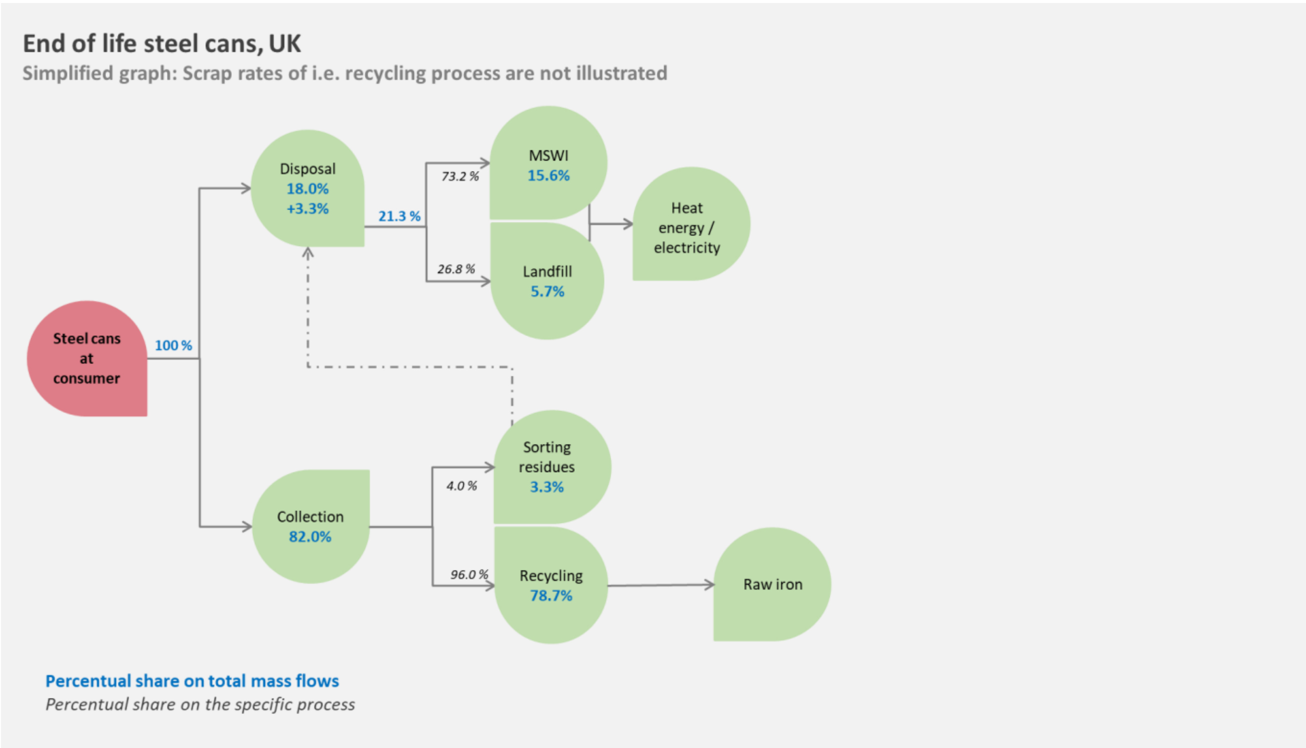

Figure 18: Applied end-of-life quotas for steel cans in UK

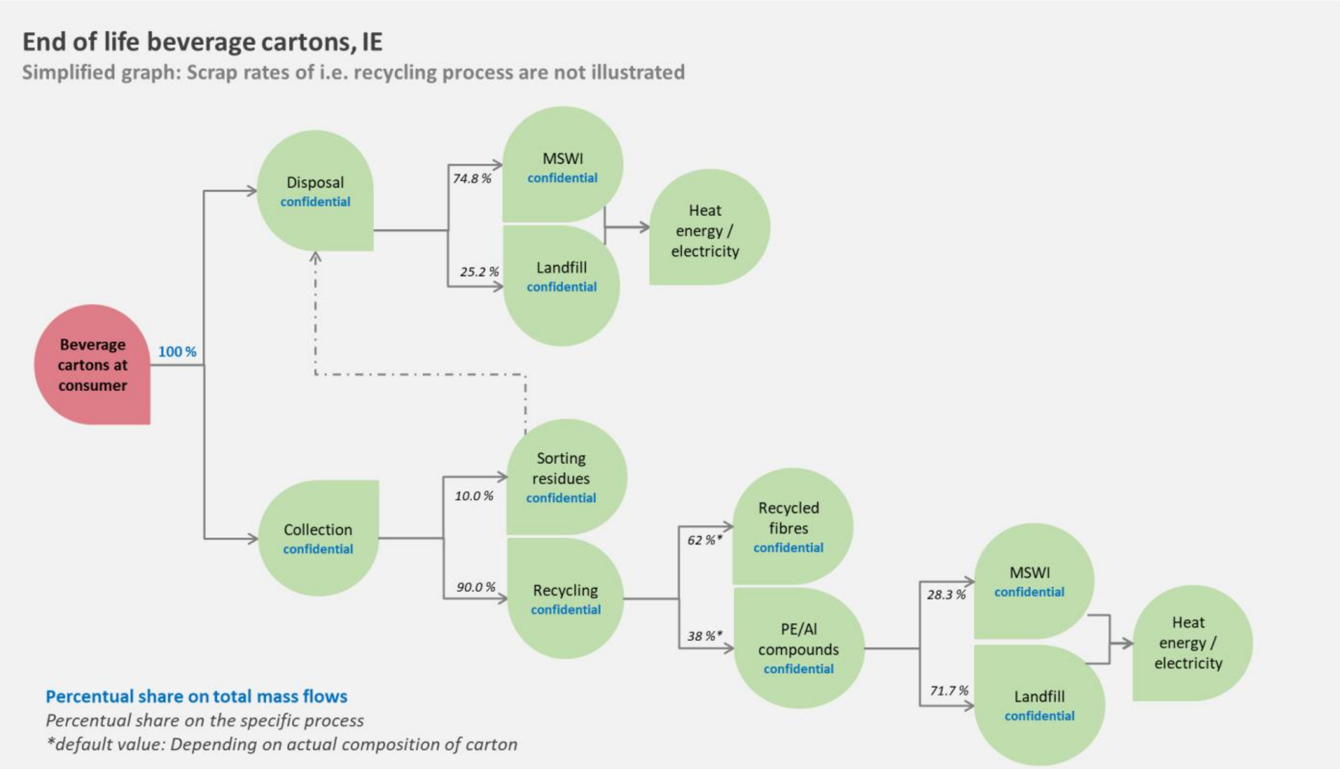

Figure 19: Applied end-of-life quotas for beverage cartons in IE

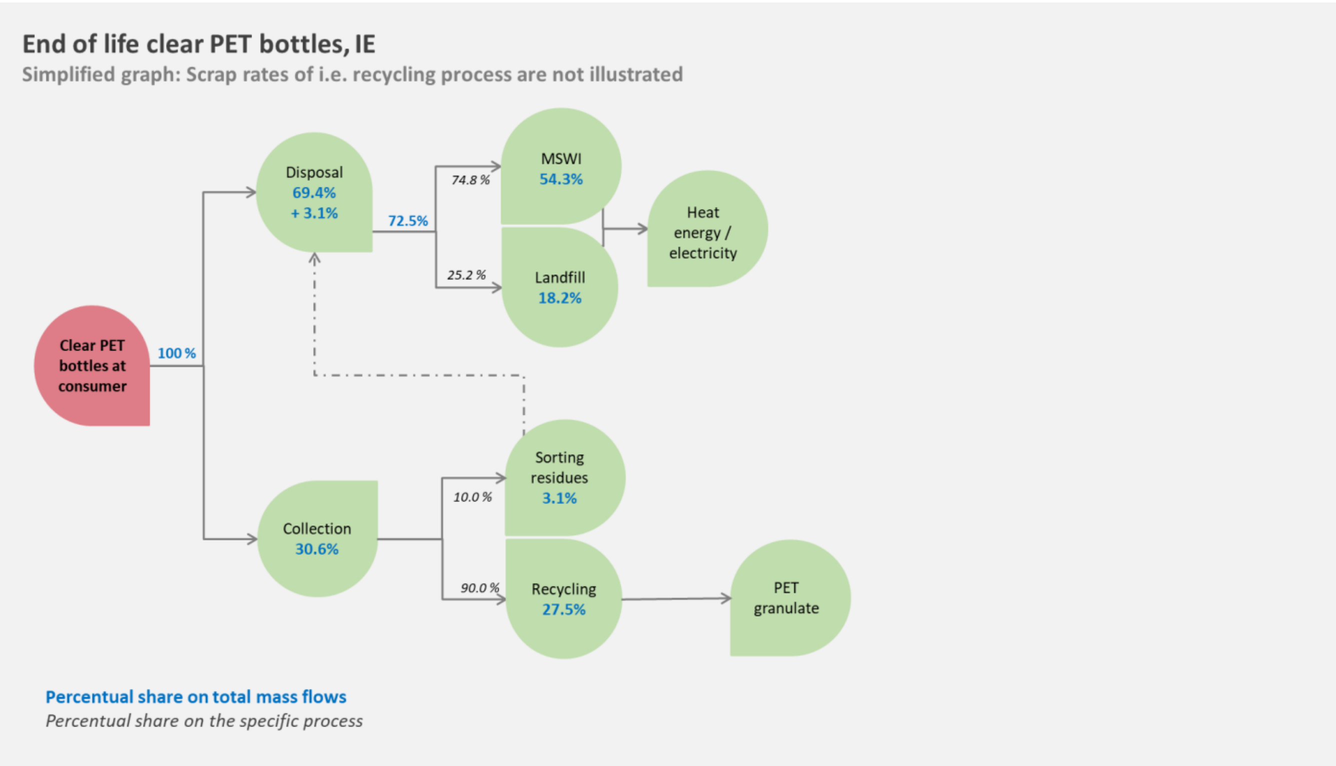

Figure 20: Applied end-of-life quotas for clear PET bottles in IE

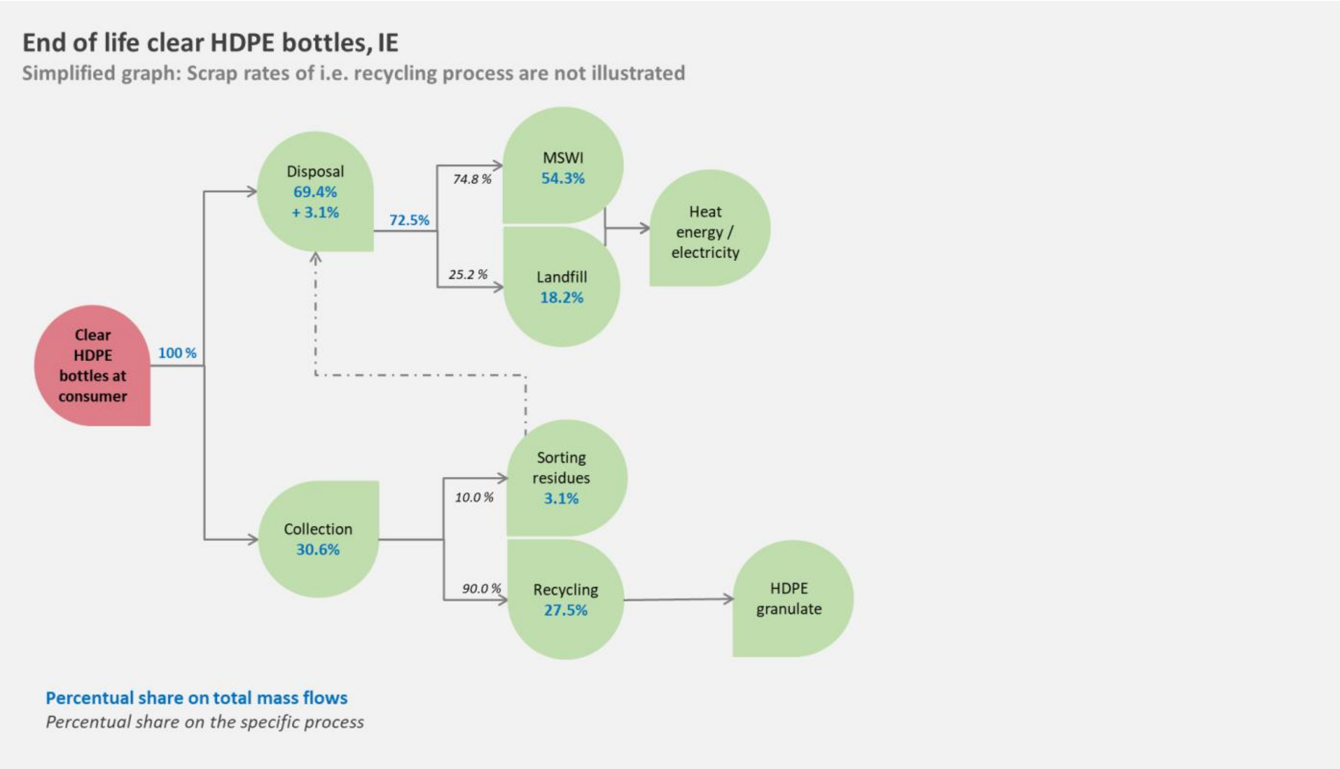

Figure 21: Applied end-of-life quotas for HDPE bottles in IE

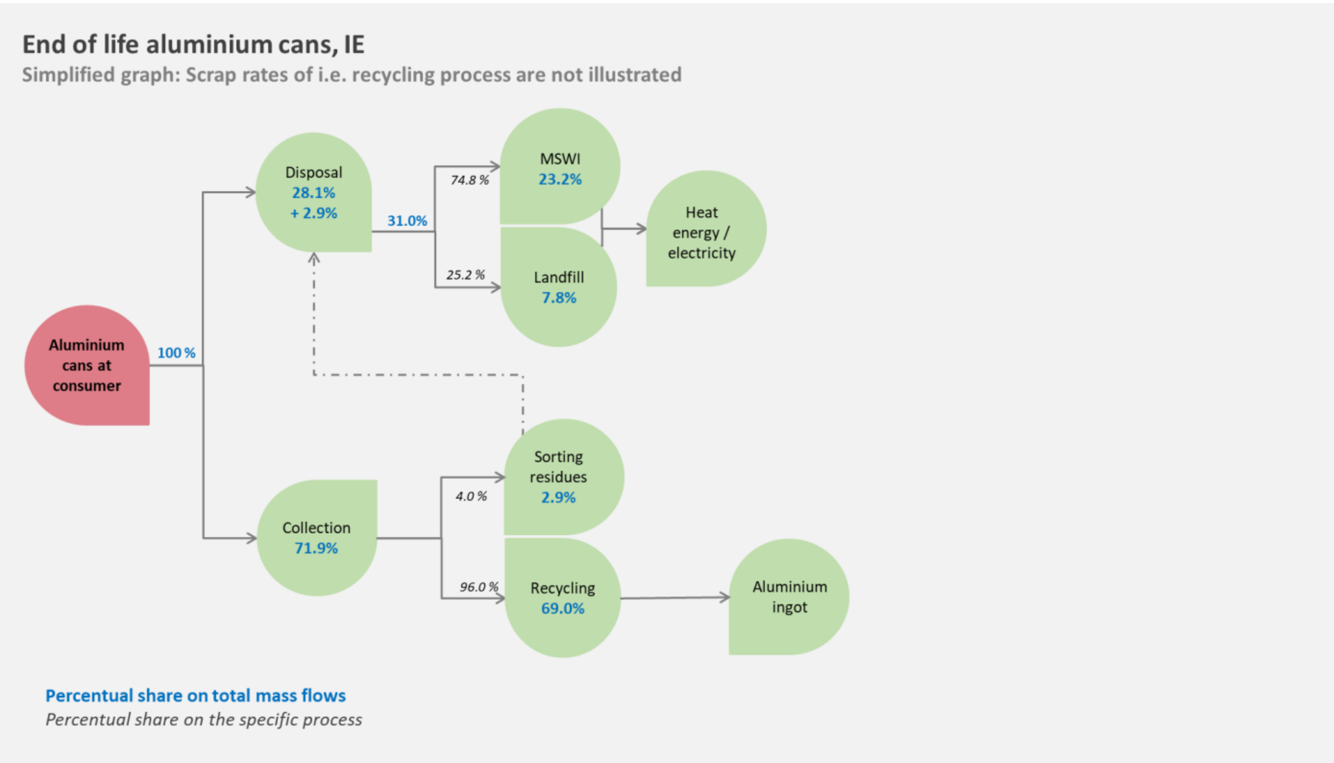

Figure 22: Applied end-of-life quotas for aluminium cans in IE

2.4 Scenarios

2.4.1 Base scenarios

For each of the studied packaging systems a scenario for the UK and Irish 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 Scenario variants regarding recycled content in PET bottles, HDPE bottles and aluminium cans

PET bottles, HDPE bottles and aluminium cans in the base scenarios are modelled without recycled content or with their specific share of recycled content. As PET bottles, HDPE bottles and aluminium cans could be produced with up to 100% recycled content, scenario variants are calculated for the packaging systems listed in Table 27. Additionally to the base scenarios the packaging systems are calculated with increased recycled content shares of 30%, 50% and 100%. The results are shown in break-even graphs with a recycled content ranging from the value of the base scenario up to 100%. In these analyses, the allocation factor applied for open-loop-recycling is 50%.

Table 27: Scenario variants: recycled content in PET bottles, HDPE bottles and aluminium cans

Segment	Geographic scope	Beverage carton system	Competing packaging system	Scenario variant (recycled content (%))
Dairy Family Pack (chilled)	UK	TR plant-based OSO 34 plant-based 1750 mL	HDPE bottle 1 2272 mL	Base scenario 0%, 30/50/100%
		TR plant-based OSO 34 plant-based 2000 mL	HDPE bottle 2 2000 mL	Base scenario 0%, 30/50/100%
	Ireland	TR plant-based OSO 34 plant-based 1750 mL	HDPE bottle 3 2750 mL	Base scenario 0%, 30/50/100%
			HDPE bottle 4 2000 mL	Base scenario 0%, 30/50/100%
		TR plant-based OSO 34 plant-based 2000 mL	HDPE bottle 5 3000 mL	Base scenario 0%, 30/50/100%
			HDPE bottle 6 2000 mL	Base scenario 0%, 30/50/100%
Water Family Pack (ambient)	UK & Ireland	TPA Square plant-based HeliCap 27 plant-based 1000 mL	PET bottle 5 1000 mL	Base scenario 0%, 50/100%
		TBA Slim plant-based HeliCap 23 plant-based 1500 mL		
Water Portion Pack (ambient)	UK & Ireland	TT Midi Eifel C38 plant-based 330 mL	30% rPET bottle 7 330 mL	Base scenario 30%, 50/100%
		TT Midi plant-based Eifel C38 plant-based 330 mL	51% rPET bottle 9 500 mL	Base scenario 51%, 100%
		TPA Edge plant-based DreamCap 26 plant-based 330 mL	Aluminium can 1 250 mL	Base scenario 50%, 100%
		TT Midi plant-based Eifel C38 plant-based 500 mL		
		TPA Edge plant-based DreamCap 26 plant-based 500 mL		

3 Life cycle inventory

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 28 gives an overview of important datasets applied in the current study. Primary data collected in 2019 for example for filling processes are not extrapolated for 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 28: Overview on inventory/process datasets used in the current study

Material / process	Source	Reference year/ period	Collected data
Intermediate goods			
PP	(PlasticsEurope 2014a)	2011	secondary
HDPE	(PlasticsEurope 2014a)	2011	secondary
LDPE	(PlasticsEurope 2014a)	2011	secondary
Plant-based PE	(Braskem 2018)	2015	secondary
PET	(PlasticsEurope 2017)	2015	secondary
PA6	(PlasticsEurope 2005)	1999	secondary
Titanium dioxide	(Ecoinvent 3.4 2017)	2017	secondary
Tinplate	(World Steel 2018)	2014	secondary
Aluminium (primary)	(EAA 2018)	2015	secondary
Aluminium foil	(EAA 2013)	2010	secondary
Corrugated cardboard	(FEFCO / Cepi Container Board 2018)	2017	secondary
Liquid packaging board	ifeu data, obtained from ACE (ACE / ifeu 2020)	2018	secondary
Production			
BC converting	(Tetra Pak 2017)	2017	primary
Glass bottle / glass jar converting including glass production	(BVGlas 2012) / (Fehrenbach et al. 2016)	2011/2016	secondary
Preform production	Data provided by Tetra Pak	2019	primary
HDPE bottle production	Data provided by Tetra Pak	2019	primary
Steel (tinplate) can Converting	(BUWAL 1998), ifeu database	1996-2015	secondary
Aluminium can converting	ifeu database	2009	primary

Material / process	Source	Reference year/ period	Collected data
Filling			
Filling of beverage and liquid food cartons	Data provided by Tetra Pak	2019	primary
Filling plastic bottles	Data provided by Tetra Pak. SBM is included in data for PET bottles	2019	primary
Filling glass bottles	ifeu data obtained from various fillers	2012	primary
Filling aluminium cans	ifeu database	2011	primary
Filling steel cans	provided by Tetra Recart based on machine consumption data specifications ifeu data obtained from various fillers	2005	primary
Filling glass jars	provided by Tetra Recart based on machine consumption data specifications ifeu data obtained from various fillers	2005	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
HDPE bottle	ifeu database, data collected from different recyclers in Germany and Europe	2008	primary
Glass jar	ifeu database, (FEVE 2006)	2012	primary/ secondary
Aluminium can (post-consumer)	(EAA 2013)	2010	secondary
Aluminium can (post-industrial)	(EAA 2018)	2015	secondary
Steel can	ifeu database	2008	primary
Background data			
Electricity production	ifeu database, based on statistics and power plant models	2018	secondary
Municipal waste incineration	ifeu database, based on statistics and incineration plant models	2016-2020	secondary
Landfill	ifeu database, based on statistics and landfill models	2019	secondary
Lorry transport	ifeu database, based on statistics and transport models, emission factors based on HBEFA 4.1 (INFRAS 2019).	2017	secondary
Rail transport	(EcoTransIT World 2016)	2016	secondary
Sea ship transport	(EcoTransIT World 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)
- Polyamide 6 (PA6)

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, Portugal, 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 PA6 (polyamide)

Polyamide 6 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 dataset 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, foils and sheets

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 (EAA 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 (EAA 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.

The data set for aluminium sheet covers the production of cold rolled steel starting from aluminium bars. It includes homogenization, hot rolling, cold rolling and annealing. The data set is based on 88% of the cold rolled steel production in 2015 (EAA 2018).

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 Word Steal 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 jars

The data used for the manufacture are data acquired by Bundesverband Glasindustrie e.V. (BVGlas) 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 UK and Irish electricity mix based on 2018. A newer 2016 data set from FEVE (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 liquid packaging board (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 2018. It is the most recent available and also published in the ELCD database.

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 3.6 including a forestry model to calculate inventories for this sub-system. Energy required is supplied by electricity as well as by renewable 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 (FEFCO / Cepi Container Board 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 card-board trays. According to (FEFCO / Cepi Container Board 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

Titanium dioxide (TiO_2) 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 TiO_2 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 – 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, European grid electricity and inventory data for transport packaging used for shipping the coated composite board to the filler.

3.8.2 PET preform and 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 for the SBM and preform production were provided by Tetra Pak and crosschecked with the internal ifeu database. The process data is coupled with the required prechain of the UK and Irish electricity mix in order to adjust the process data to the production in UK and Ireland.

3.8.3 HDPE bottle production

Unlike PET bottle production HDPE bottle production is not split into two different processes. Data for these converting processes were provided by Tetra Pak and crosschecked with the internal ifeu database. The process data is coupled with the required prechain of the UK and Irish electricity mix in order to adjust the process data to the production in UK and Ireland.

3.8.4 Converting of aluminium can

Data for the converting step from aluminium sheets to aluminium cans and aluminium closures are taken from the internal ifeu data base and are based on confidentially collected datasets from two European beverage can producers in 2009. The process data is coupled with the required prechain of the UK and Irish electricity mix in order to adjust the process data to the production in UK and Ireland.

3.8.5 Converting of steel can

Data gathering for the manufacturing of 3-piece tinplate 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 UK and Irish electricity mix in order to adjust the process data to the production in UK and Ireland.

3.9 Closure production

The closures made of fossil and plant-based polymers and fossil based polypropylene 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 is coupled with the required prechain of the UK and Irish electricity mix in order to adjust the process data to the production in UK and Ireland.

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 bottles was provided by Tetra Pak and crosschecked with the internal ifeu database. The data for PET bottles includes the electricity demand for stretch blow moulding. Filling data for the analysed aluminium can is based on the ifeu internal database. For the filling of glass bottles, data collected from various fillers (confidential) with a reference year of 2011 has been used. The data were still evaluated to be valid for 2019, as filling machines and technologies have not changed since then. Filling data for the analysed steel can and 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 UK and Irish electricity mix in order to adjust the process data to the production in UK and Ireland.

3.11 Transport settings

Table 29 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. through exchanges with representatives of the logistic sector and suppliers.

Table 29: Transport distances and means: Transport defined by distance and mode (km/mode)

Packaging element Geographic scope [Reference]	**Distance of material producer to converter (km)**	**Distance of converter to filler (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[3]	
Plant-based PE Brazil	10800 / sea[1] 700 / road[1]	
Aluminium EU27 + Norway, Switzerland, Iceland (EAA 2013), (EAA 2018)	460 / road[1]	
Paperboard for composite board Sweden, Finland	300 / road[2] 950 / sea[2] 800 / rail[2]	
Cardboard for trays EU 27 + Norway, Switzerland (FEFCO / Cepi Container Board 2018)	primary fibres: 500 / sea, 400 / rail, 250 / road[2] secondary fibres: 300/road[2]	
Wood for pallets Northern Europe	100 / road[3]	
LDPE stretch foil based on several plants in Europe (PlasticsEurope 2005), (PlasticsEurope 2014a), (PlasticsEurope 2014b), (PlasticsEurope 2017)	500/road (material production site = converter)[3]	
Trays EU28		500 / road[3]
Pallets EU28		100 / road[3]
Converted carton rolls EU28		700 / road[3]

[1]calculation
[2]taken from published LCI reports
[3]assumption

3.12 Distribution of filled packs from filler to point of sale

Table 30 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). Distances have been calculated as average distances from representative filling plants to one representative distribution center in each country. The applied distances from distribution centers to point of sales are educated estimates. For each country the same distribution model is applied for all packages.

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. No primary data is available on average empty return distances. For this reason an estimation of 33% of the delivery distance is calculated as an empty return trip. This estimation is based on confidential previous studies. This is only valid for the distribution steps to the distribution centres. Usually no utilisation of lorries on their return trips from the point of sale to the warehouse is possible as the full return trip to the warehouse is attributed as an empty return trip to the examined system.

Table 30: Distribution distances in km for the according countries

	Distribution distance			
	Distribution Step 1		Distribution step 2	
Country	**Filler → distribution centre** (delivery)	**Distribution centre → filler** (return trip)	**Distribution centre → POS** (delivery)	**POS → distribution centre** (return trip)
UK	300 km	99 km	70 km	70 km
Ireland	225 km	74 km	70 km	70 km

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. Paper is separated from plastic and aluminium layers with an efficiency of 98%. The secondary fibre material is used e.g. as a raw material for cardboard. A substitution factor 0.9 is applied. Rejects, in term of plastics and aluminium compounds are thermally recovered in MSWI or disposed on landfills. Related process data 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. Beverage cartons on the Irish market are exported for recycling. 85% of beverage cartons on the UK market are exported for recycling. The process data is coupled with the required prechain of the UK electricity mix as well as a global electricity mix for the share of exported cartons in order to adjust the process data to the recycling location.

Plastic bottles

Plastic bottles (PET and HDPE) 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. Plastic bottles on the Irish market are exported globally for recycling. 56% of Plastic bottles on the UK market are exported globally for recycling. The process data is coupled with the required prechain of the UK electricity mix as well as a global electricity mix for the share of exported plastic bottles in order to adjust the process data to the recycling location.

On the Irish market no specific data for recycling rates of PET and HDPE bottles is available. Therefore the published recycling rate (epa 2021) of all plastic packaging is applied for plastic bottles in this study.

On the UK market besides clear plastic bottles also white opaque HDPE bottles are assessed. The applied recycling rate of 53.1% for clear PET and HDPE bottles is based on the collection rate of 59% of plastic bottles in the UK (RECOUP 2020) and an assumed standard sorting rate of 90%. Another source states a lower recycling rate (28%) for HDPE bottles (plastic expert 2022). The large difference to the 59% collection rate can be explained by sorting out white opaque HDPE bottles as it is also common for white PET bottles (EPBP 2021). Therefore in the model of this study collected white HDPE bottles are sorted out ending up in a mixed plastic fraction and undergo thermal treatment (cement kiln) instead of regranulation.

Glass jars

On the UK market no specific data for recycling rates of and jars is available. Therefore the published reycling rate (Defra 2021) of all glass packaging is applied for glass jars in this study.

The glass of collected 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 BVGlas (2012). The reference period is 2012. Process data are coupled with required prechains and the market related electricity grid mix.

Steel cans

On the UK market no specific data for recycling rates of steel cans is available. Therefore the published reycling rate (Defra 2021) of all steel packaging is applied for steel cans in this study.

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).

Aluminium cans

On the UK and Irish market no specific data for recycling rates of aluminium cans is available. Therefore the published recycling rate (Defra 2021), (epa 2021) of all aluminium packaging is applied for aluminium cans in this study.

The dataset for recycling of post-consumer aluminium cans is based on the recycling process for end-of-life aluminium products which includes the preparation of post-consumer scrap (EAA 2013). The dataset for recycling of post-industrial aluminium scrap is based on the remelting process for scrap coming directly from the fabricators. This dataset does not include scrap preparation (EAA 2018).

3.14 Background data

3.14.1 Transport processes

<u>Lorry transport</u>

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' (Notter et al. 2019). The 'Handbook' is a database application 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. The emission factors used in this study refer to the year 2017.

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/TEU[1]) and an utilisation capacity 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 environmental 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 (Fehrenbach et al. 2016). It is based on national electricity mix data by the International Energy Agency (IEA)[2]. The UK and Irish electricity mix is applied as a prechain for most processes (see Table 1 and section 3). Regarding beverage cartons, electricity generation is considered using Swedish and Finnish mix of energy suppliers in the year 2018 for the production of LPB and the European mix of energy suppliers in the year 2018 for the converting of sleeves. The applied shares of energy sources to the related market are given in Table 31.

[1] Twenty-foot Equivalent Unit
[2] http://www.iea.org/statistics/

Table 31: Share of energy source to specific energy mix, reference year 2018.

Energy source		Geographic scope				
		UK	Ireland	EU 28	Sweden	Finland
	Hard coal	5.01%	6.83%	9.59%	0.20%	8.11%
	Brown coal	0.00%	6.65%	9.45%	0.18%	4.86%
	Fuel oil	0.22%	0.44%	1.47%	0.18%	0.32%
	Natural gas	39.48%	50.84%	20.05%	0.56%	6.98%
	Nuclear energy	19.58%	0.00%	25.36%	41.00%	32.26%
	Hydropower, wind, solar & geothermal	23.65%	31.60%	27.48%	49.90%	28.66%
	Hydropower	7.37%	7.42%	41.18%	78.53%	69.18%
	Wind power	76.27%	92.41%	44.36%	20.98%	30.37%
	Solar energy	16.36%	0.17%	13.72%	0.49%	0.45%
	Geothermal energy	0.00%	0.00%	0.74%	0.00%	0.00%
	Biomass energy	9.50%	1.63%	5.10%	6.07%	17.15%
	Waste	2.54%	2.01%	1.50%	1.91%	1.66%

3.14.3 Municipal waste incineration

The electrical and thermal efficiencies of the municipal solid waste incineration plants (MSWI) are shown in Table 32.

Table 32: Electrical and thermal efficiencies of the incineration plants for UK and Ireland.

Geographic Scope	Electrical efficiency	Thermal efficiency	Reference period	Source
UK	20%	4%	2016	(Tolvik 2021)
Ireland	20%	0%	2016	(CEWEP 2018)

Compared with the electrical and thermal efficiencies for Europe, UK and Ireland show higher electrical efficiencies but very low thermal efficiencies.

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.

3.14.4 Landfill

The landfill model accounts for the emissions and the consumption of resources for the deposition of domestic wastes on a sanitary landfill site. As information regarding an average landfill standard in specific countries is hardly available, assumptions regarding the equipment with and the efficiency of the landfill gas capture system (the two parameters which determine the net methane recovery rate) had to be made. Besides the parameters determining the landfill standard, another relevant system parameter is the degree of degradation of the beverage and liquid food carton material on a landfill. Empirical data regarding degradation rates of laminated cartons are not known to be available by the authors of the present study.

The following assumptions, especially relevant for the degradable board material, underlay the landfill model applied in this LCA study:

In this study the 100 years perspective is applied. The share of methane recovered via landfill gas capture systems (55% in the UK and 59.25% in Ireland) is based on data from National Inventory Reports (NIR) under consideration of different catchment efficiencies at different stages of landfill operation. The majority of captured methane is used for energy conversion. The remaining share is flared.

Regarding the degradation of the carton board under landfill conditions, it is assumed that it behaves like coated paper-based material in general. According to (Micales / Skog 1997) 30% of paper is decomposed anaerobically on landfills.

It is assumed that the degraded carbon is converted into landfill gas with 50% methane content by volume (IPCC 2006) Emissions of methane from biogenic materials (e.g. during landfill) are always accounted at the inventory level AND in form of GWP.

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 primarily 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 UK

In this section, the results of the examined packaging systems for UK 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, HDPE including additives, e.g. carbon black for the body of plastic bottles and pouches, as well as steel and aluminium 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, pouches 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')**
- 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')**
- CO_2 emissions from incineration of plant-based and renewable materials **('CO_2 reg. (recycling & disposal)')**; in the following also the term regenerative CO_2 emissions is used
- Uptake of atmospheric CO_2 during the plant growth phase ('**CO_2-uptake**')

The top down order in the legends refer to the top down order in the following diagrams.

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 CO_2 uptake (second stacked bar with negative values)
- net results as a 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 ≤ 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)

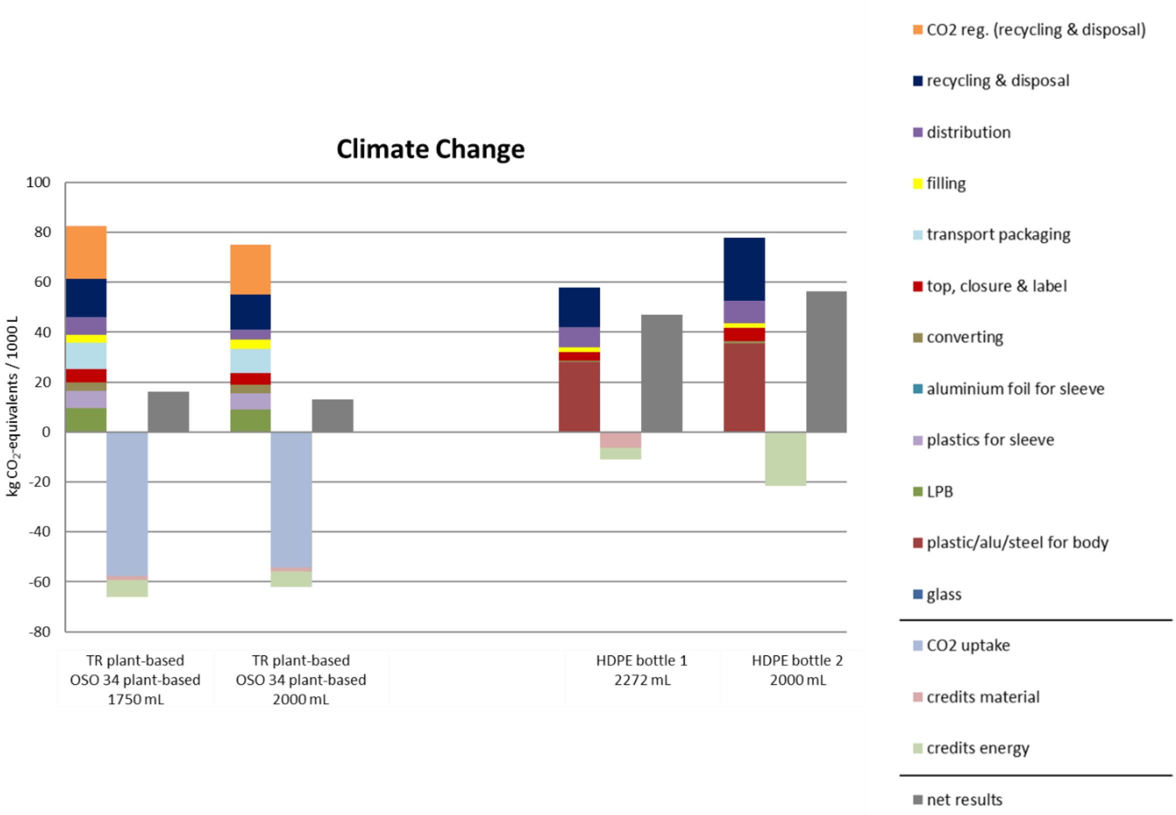

Figure 23: Climate Change results of **segment Dairy Family Pack (chilled)**, allocation factor 50%

Table 33: Climate Change results of **segment Dairy Family Pack (chilled)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Dairy Family Pack (chilled) Allocation 50 UK		TR plant-based OSO 34 plant-based 1750 mL	TR plant-based OSO 34 plant-based 2000 mL		HDPE bottle 1 2272 mL	HDPE bottle 2 2000 mL
Climate Change [kg CO_2-e/1000 L]	burdens	61.26	55.24		57.85	77.90
	CO_2 (reg)	21.10	19.78		0.00	0.00
	credits	-8.37	-7.83		-10.99	-21.52
	CO_2 uptake	-57.84	-54.27		0.00	0.00
	net results	16.15	12.92		46.86	56.38

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 minor 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 (12%) and the production of plastics for sleeves (8%-9%).

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

Small shares (6%) of total burdens for 'Climate Change' are caused from the production of closures.

The production and provision of 'transport packaging' for the beverage carton system shows 13% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'filling' shows small shares of burdens (4%-5%) for the beverage cartons.

The life cycle step 'distribution' shows 5%-9% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'recycling & disposal' of the assessed beverage cartons is one of the most relevant life cycle step for 'Climate Change' (18%-19%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons, these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 26% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 8%-9%. Material credits for 'Climate Change' are low (2% of total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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, the major share (45%-48%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows small shares of burdens for 'Climate Change (1%) for HDPE bottles in this segment.

The life cycle step 'top, closure & label' shows small impact shares (6%-7%) mainly attributed to the different plastics used for the closure.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (less than 1%) for climate change due to the high trip rate of the rollcontainers used for the HDPE bottles in this segment.

The life cycle steps 'filling' (3%) shows small shares and 'distribution' (12%-14%) shows minor shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable to major shares (28%-33%). Shares of the assessed HDPE bottle 1 result from recycling and incineration of the bottle in MSWI plants. Shares of the assessed white HDPE bottle 2 result from thermal treatment in cement kilns.

Material credits of the 53.1% recycled transparent HDPE bottle 1 reduce the total burdens by 11% by substituting virgin HDPE. The influence of material credits for the white opaque HDPE bottle 2 on the net result is not relevant for 'Climate Change' as the white plastic bottles are not materially recycled.

Energy credits of HDPE bottle 1 are small (8%) due to the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix. Energy credits of the white HDPE bottle 2 are higher (28%) due to the substitution of fossil fuels in cement kilns.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

4.1.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.1.1.

Table 34: Comparison of net results: **TR plant-based OSO 34 plant-based 1750 mL** versus competing carton and alternative packaging systems in **segment Dairy Family Pack (chilled)**, allocation factor 50%

Dairy Family Pack (chilled) Allocation 50 UK	The net results of **TR plant-based OSO 34 plant-based 1750 mL** are lower (green)/ higher (red)/ similar (white) than those of		
	TR plant-based OSO 34 plant-based 2000 mL	HDPE bottle 1 2272 mL	HDPE bottle 2 2000 mL
Climate Change	+25%	-66%	-71%

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

Table 35: Comparison of net results: **TR plant-based OSO 34 plant-based 2000 mL** versus competing carton and alternative packaging systems in **segment Dairy Family Pack (chilled)**, allocation factor 50%

Dairy Family Pack (chilled) Allocation 50 UK	The net results of **TR plant-based OSO 34 plant-based 2000 mL** are lower (green)/ higher (red)/ similar (white) than those of		
	TR plant-based OSO 34 plant-based 1750 mL	HDPE bottle 1 2272 mL	HDPE bottle 2 2000 mL
Climate Change	-20%	-72%	-77%

4.2 Results allocation factor 100%; Dairy Family Pack (chilled)

4.2.1 Presentation of results Dairy Family Pack (chilled)

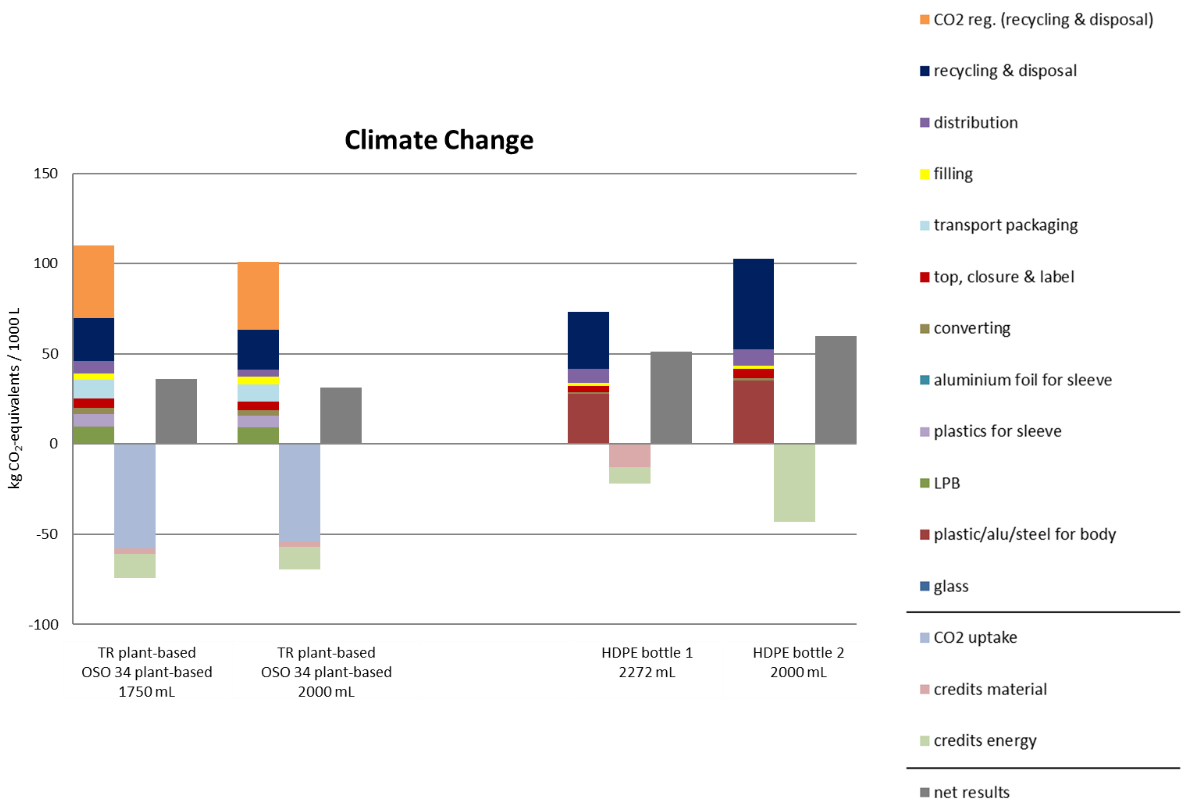

Figure 24: Climate Change results of **segment Dairy Family Pack (chilled)**, allocation factor 100%

Table 36: Climate Change results of **segment Dairy Family Pack (chilled)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Dairy Family Pack (chilled) Allocation 100 UK		TR plant-based OSO 34 plant-based 1750 mL	TR plant-based OSO 34 plant-based 2000 mL		HDPE bottle 1 2272 mL	HDPE bottle 2 2000 mL
Climate Change [kg CO_2-e/1000 L]	burdens	69.79	63.26		73.33	102.70
	CO_2 (reg)	40.40	37.86		0.00	0.00
	credits	-16.44	-15.38		-21.98	-43.04
	CO_2 uptake	-57.84	-54.27		0.00	0.00
	net results	35.91	31.47		51.35	59.66

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 substituted coal in cement kilns 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 carton 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In case of HDPE bottles higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low thermal efficiency of MSWI in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

4.2.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.2.1.

Table 37: Comparison of net results: **TR plant-based OSO 34 plant-based 1750 mL** versus competing carton and alternative packaging systems in **segment Dairy Family Pack (chilled)**, allocation factor 100%

Dairy Family Pack (chilled) Allocation 100 UK	The net results of **TR plant-based OSO 34 plant-based 1750 mL** are lower (green)/ higher (red)/ similar (white) than those of		
	TR plant-based OSO 34 plant-based 2000 mL	HDPE bottle 1 2272 mL	HDPE bottle 2 2000 mL
Climate Change	+14%	-30%	-40%

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

Table 38: Comparison of net results: **TR plant-based OSO 34 plant-based 2000 mL** versus competing carton and alternative packaging systems in **segment Dairy Family Pack (chilled)**, allocation factor 100%

Dairy Family Pack (chilled) Allocation 100 UK	The net results of **TR plant-based OSO 34 plant-based 2000 mL** are lower (green)/ higher (red)/ similar (white) than those of		
	TR plant-based OSO 34 plant-based 1750 mL	HDPE bottle 1 2272 mL	HDPE bottle 2 2000 mL
Climate Change	-12%	-39%	-47%

4.3 Results allocation factor 50%; Dairy Alternative Family Pack (ambient)

4.3.1 Presentation of results Dairy Alternative Family Pack (ambient)

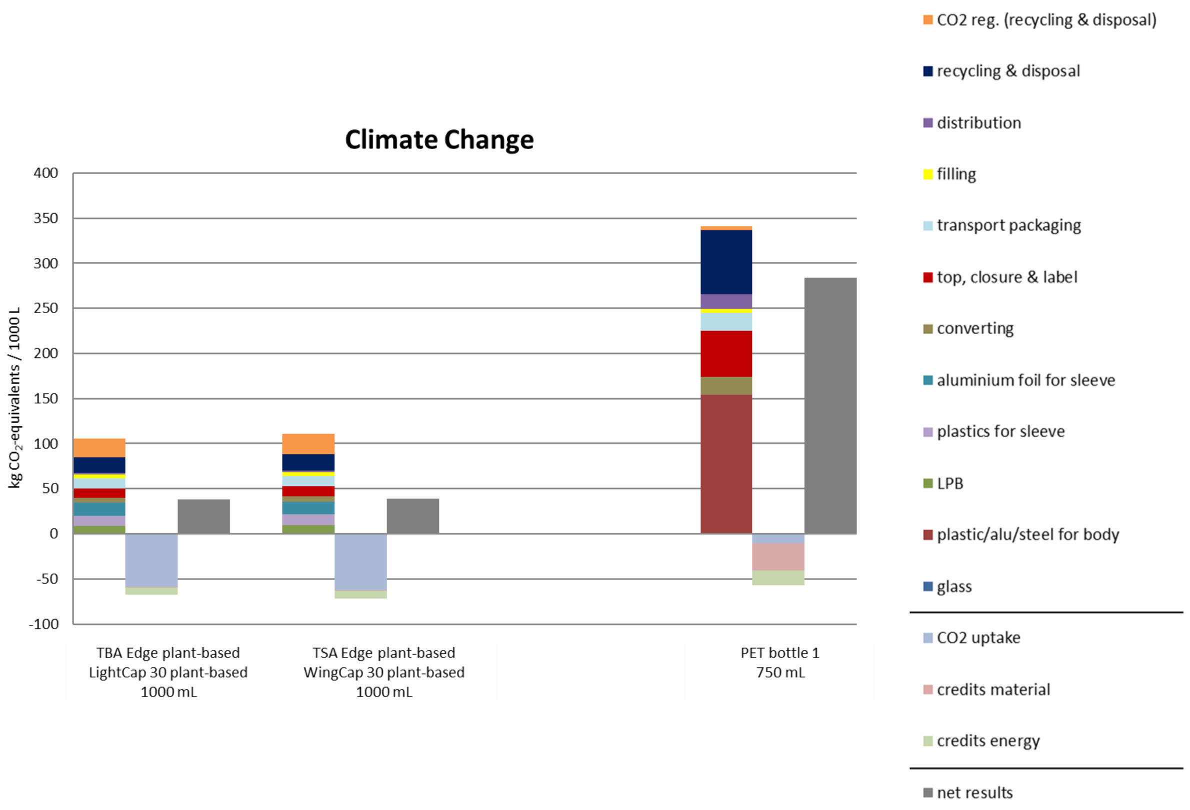

Figure 25: Climate Change results of **segment Dairy Alternative Family Pack (ambient)**, allocation factor 50%

Table 39: Climate Change results of **segment Dairy Alternative Family Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Dairy Alternative Family Pack (ambient) Allocation 50 UK		TBA Edge plant-based LightCap 30 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL		PET bottle 1 750 mL
Climate Change [kg CO_2-e/1000 L]	burdens	84.89	88.57		336.49
	CO_2 (reg)	21.13	22.27		4.16
	credits	-9.09	-9.70		-47.06
	CO_2 uptake	-58.70	-62.04		-10.07
	net results	38.23	39.09		283.52

4.3.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the Dairy Alternative Family Pack (ambient) segment, a minor 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 (8%), the production of plastics for sleeves (10%-11%) and the production of aluminium foil for sleeve (12%-14%).

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

Minor shares (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 10%-11% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'filling' shows small shares of burdens (4%) for the beverage carton systems.

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

The life cycle step 'recycling & disposal' of the assessed beverage carton is one of the most relevant life cycle steps for 'Climate Change' (16%-17%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 20% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 7%. Material credits for 'Climate Change' are low (1% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 then is 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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 Alternative Family Pack (ambient) segment, a major share (45%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows a small share of 6% of the total burdens for the PET bottle in this segment.

The life cycle step 'top, closure & label' shows minor impacts shares (15%) mainly attributed to the different plastics used for the closure.

The production and provision of 'transport packaging' for PET bottle 1 shows small impact shares (6%) for climate change.

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

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (21%) for the clear PET bottle 1 resulting from the recycling and incineration in MSWI plants of the bottle.

Material credits from 53.1% recycled PET bottles reduce the total burdens by 9% by substituting virgin PET.

For the clear PET bottle energy credits are low (5%) due to the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

4.3.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.3.1.

Table 40: Comparison of net results: **TBA Edge plant-based LightCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (ambient)**, allocation factor 50%

Dairy Alternative Family Pack (ambient) Allocation 50 UK	The net results of **TBA Edge plant-based LightCap 30 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of	
	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 1 750 mL
Climate Change	-2%	-87%

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

Table 41: Comparison of net results: **TSA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (ambient)**, allocation factor 50%

Dairy Alternative Family Pack (ambient) Allocation 50 UK	The net results of **TSA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of	
	TBA Edge plant-based LightCap 30 plant-based 1000 mL	PET bottle 1 750 mL
Climate Change	+2%	-86%

4.4 Results allocation factor 100%; Dairy Alternative Family Pack (ambient)

4.4.1 Presentation of results Dairy Alternative Family Pack (ambient)

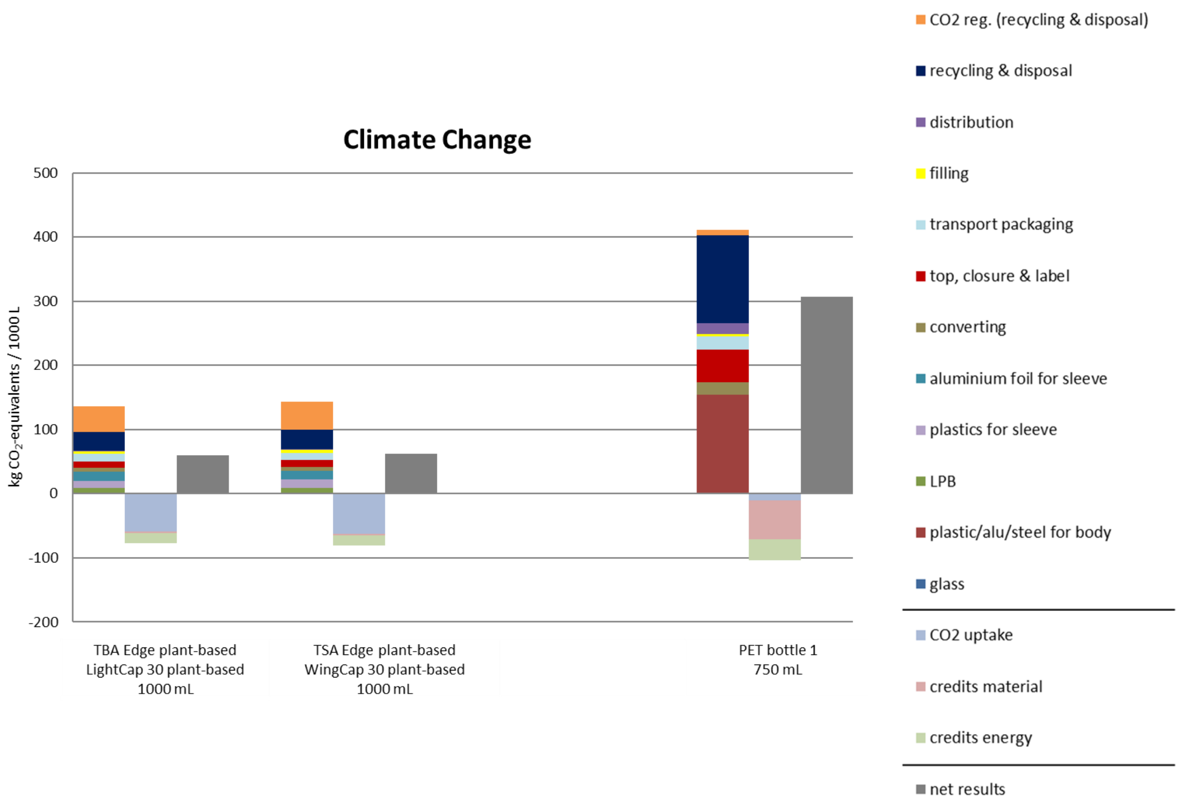

Figure 26: Climate Change results of **segment Dairy Alternative Family Pack (ambient)**, allocation factor 100%

Table 42: Climate Change results of **segment Dairy Alternative Family Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Dairy Alternative Family Pack (ambient) Allocation 100 UK		TBA Edge plant-based LightCap 30 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL		PET bottle 1 750 mL
Climate Change [kg CO_2-e/1000 L]	burdens	95.65	100.29		402.27
	CO_2 (reg)	40.52	42.72		8.31
	credits	-17.90	-19.11		-94.04
	CO_2 uptake	-58.70	-62.04		-10.07
	net results	59.57	61.86		306.48

4.4.2 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 4.3.2).

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 substituted coal in cement kilns 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 Alternative 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In case of the PET bottle higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low thermal efficiency of MSWI in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

4.4.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.4.1.

Table 43: Comparison of net results: **TBA Edge plant-based LightCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (ambient)**, allocation factor 100%

Dairy Alternative Family Pack (ambient) Allocation 100 UK	The net results of **TBA Edge plant-based LightCap 30 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of	
	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 1 750 mL
Climate Change	-4%	-81%

Table 44: Comparison of net results: **TSA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (ambient)**, allocation factor 100%

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

Dairy Alternative Family Pack (ambient) Allocation 100 UK	The net results of **TSA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of	
	TBA Edge plant-based LightCap 30 plant-based 1000 mL	PET bottle 1 750 mL
Climate Change	+4%	-80%

4.5 Results allocation factor 50%; Dairy Alternative Family Pack (chilled)

4.5.1 Presentation of results Dairy Alternative Family Pack (chilled)

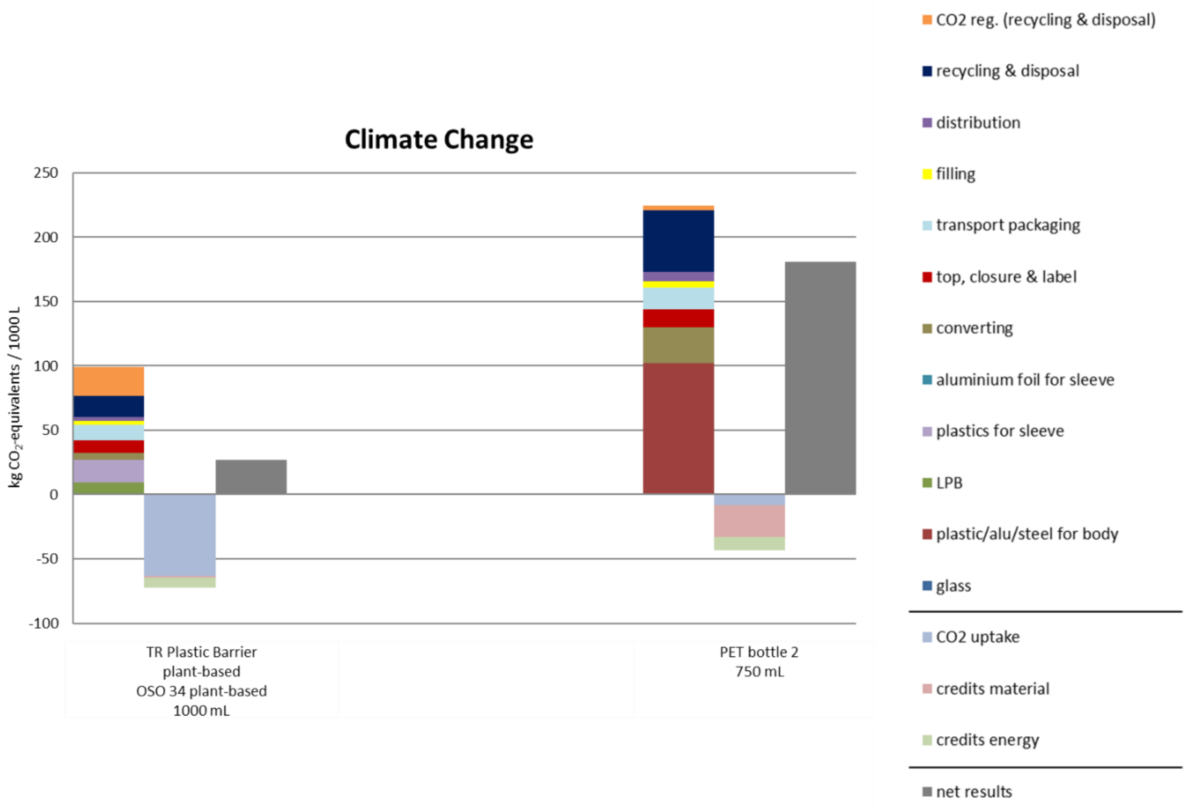

Figure 27: Climate Change results of **segment Dairy Alternative Family Pack (chilled)**, allocation factor 50%

Table 45: Climate Change results of **segment Dairy Alternative Family Pack (chilled)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Dairy Alternative Family Pack (chilled) Allocation 50 UK		TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL		PET bottle 2 750 mL
Climate Change [kg CO_2-e/1000 L]	burdens	76.58		221.02
	CO_2 (reg)	22.60		3.28
	credits	-9.16		-35.13
	CO_2 uptake	-63.03		-8.05
	net results	26.99		181.12

4.5.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton system considered in the Dairy Alternative Family Pack (chilled) segment, a minor 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%) and the production of plastics for sleeves (18%).

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

Small shares (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 system shows 12% of the total burdens for ‘Climate Change’ for the beverage carton.

The life cycle step ‘filling’ shows small shares of burdens (3%) for the beverage carton system.

The life cycle step ‘distribution’ shows 3% of the total burdens for ‘Climate Change’ for the beverage carton.

The life cycle step ‘recycling & disposal’ of the assessed beverage carton is one of the most relevant life cycle steps for ‘Climate Change’ (17%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 23% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 8%. Material credits for 'Climate Change' are low (1% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 then is 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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 Dairy Alternative Family Pack (chilled) segment, a major share (45%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows a share of 13% of the total burdens for the PET bottle 2 in this segment due to the high energy demand.

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

The production and provision of 'transport packaging' for the bottle systems shows small impact shares (7%) for climate change.

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

The PET bottles' 'recycling & disposal' life cycle step shows considerable shares (22%) for the clear PET bottle resulting from the recycling and incineration in MSWI plants of the bottle.

In case of the 53.1% recycled clear PET bottle 2, material credits reduce the total burdens by 11% by substituting virgin PET.

For the clear PET bottle energy credits are low (5%) due to the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

4.5.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.5.1.

Table 46: Comparison of net results: **TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (chilled)**, allocation factor 50%

Dairy Alternative Family Pack (chilled) Allocation 50 UK	The net results of **TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of
	PET bottle 2 750 mL
Climate Change	-85%

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

4.6 Results allocation factor 100%; Dairy Alternative Family Pack (chilled)

4.6.1 Presentation of results Dairy Alternative Family Pack (chilled)

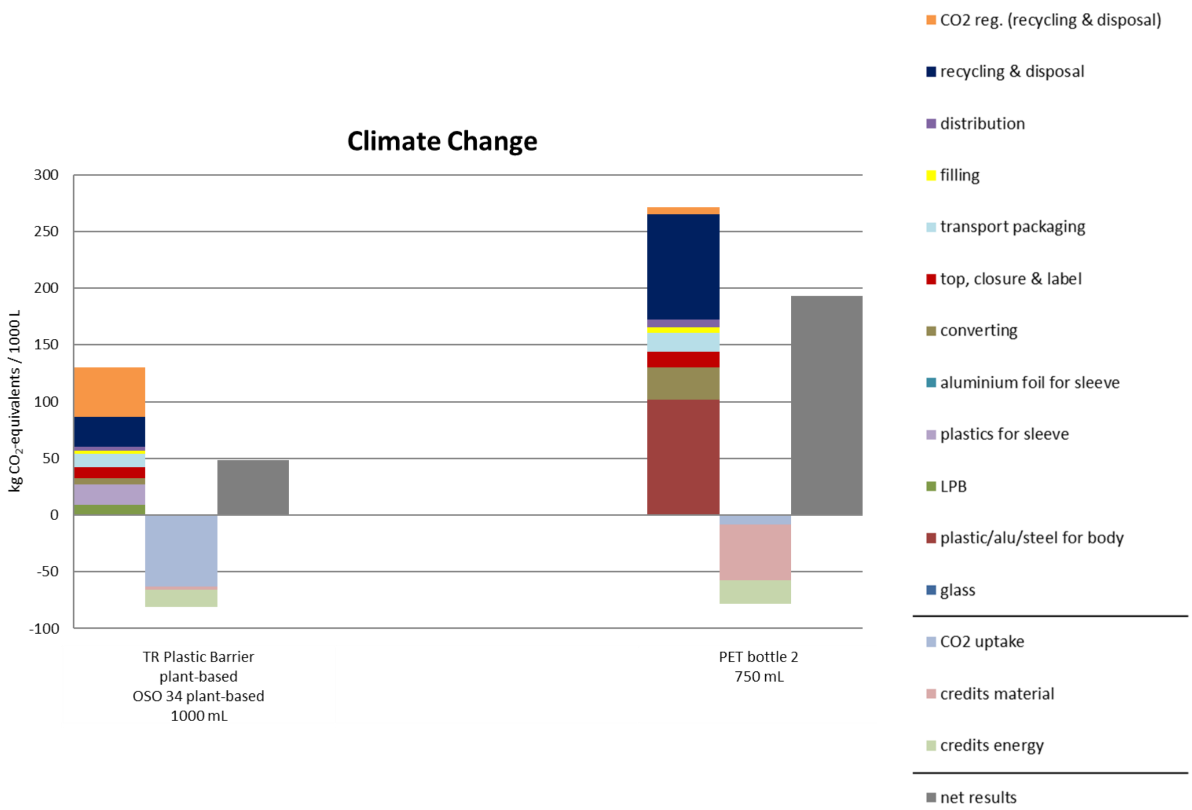

Figure 28: Climate Change results of **segment Dairy Alternative Family Pack (chilled)**, allocation factor 100%

Table 47: Climate Change results of **segment Dairy Alternative Family Pack (chilled)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Dairy Alternative Family Pack (chilled) Allocation 100 UK		TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL		PET bottle 2 750 mL
Climate Change [kg CO_2-e/1000 L]	burdens	86.42		265.05
	CO_2 (reg)	43.41		6.56
	credits	-18.03		-70.18
	CO_2 uptake	-63.03		-8.05
	net results	48.77		193.38

4.6.2 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 4.5.2).

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 substituted coal in cement kilns 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 Alternative 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 matter is gone when applying the allocation factor 100% as all burdens from ‘CO_2 reg. (recycling & disposal)’ are allocated to the assessed system (see section 1.7.2).

In case of the PET bottle higher net results for ‘Climate Change’ are shown when applying the allocation factor 100% instead of 50% due to the low thermal efficiency of MSWI in the UK and a relatively low ‘Climate Change’ intensive substituted electricity mix.

4.6.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.6.1.

Table 48: Comparison of net results: **TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (chilled)**, allocation factor 100%

Dairy Alternative Family Pack (chilled) Allocation 100 UK	The net results of **TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of
	PET bottle 2 750 mL
Climate Change	-75%

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

4.7 Results allocation factor 50%; Water Family Pack (ambient)

4.7.1 Presentation of results Water Family Pack (ambient)

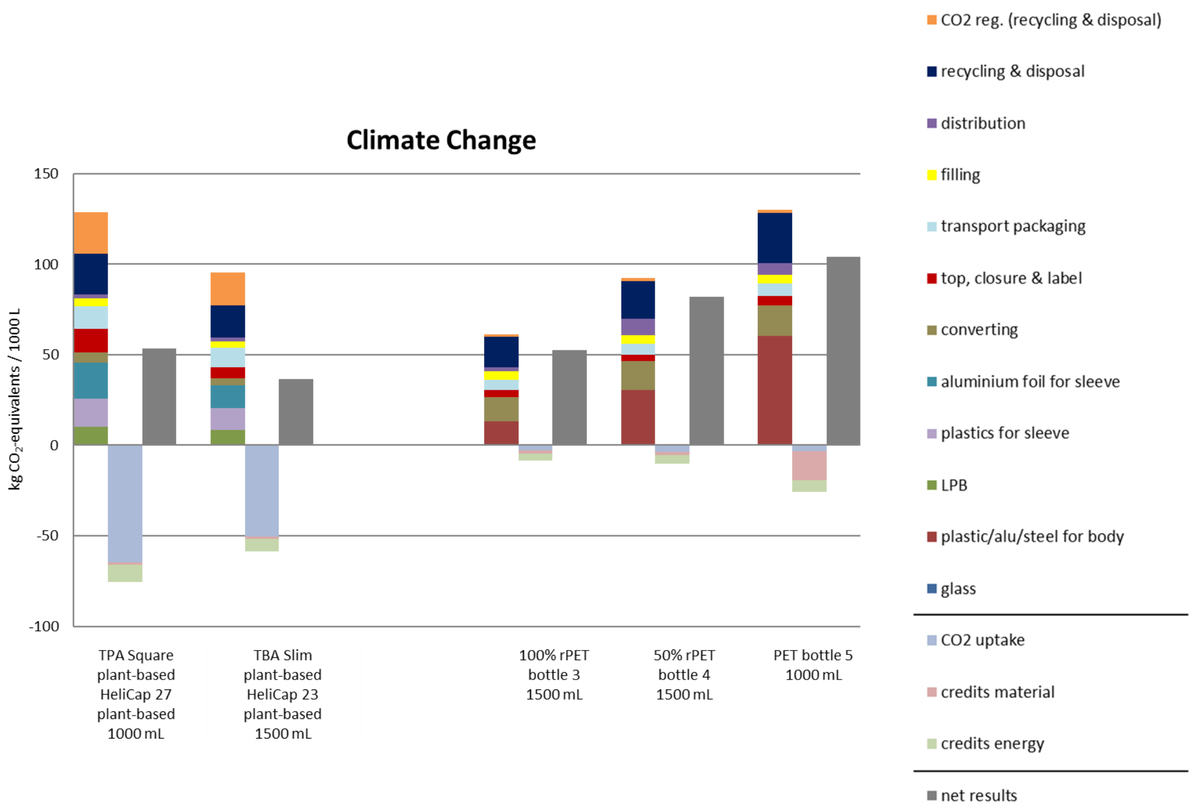

Figure 29: Climate Change results of **segment Water Family Pack (ambient)**, allocation factor 50%

Table 49: Climate Change results of **segment Water Family Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Water Family Pack (ambient) Allocation 50 UK		TPA Square plant-based HeliCap 27 plant-based 1000 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL		100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change [kg CO_2-e/1000 L]	burdens	105.62	77.16		59.93	90.56	128.30
	CO_2 (reg)	23.27	18.34		1.31	1.75	1.59
	credits	-10.94	-8.51		-5.72	-6.60	-22.40
	CO_2 uptake	-64.59	-50.28		-2.82	-3.77	-3.43
	net results	53.36	36.71		52.71	81.94	104.06

4.7.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the 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 (8%-9%), production of plastics for sleeves (12%-13%) and the production of aluminium foil for sleeve (13%-15%).

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

Small shares (6%-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 10%-12% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'filling' shows smalls shares of burdens (3%-4%) for the beverage carton systems.

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 is one of the most relevant life cycle step for 'Climate Change' (17%-19%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 18%-19% of the total burdens for 'Climate Change'. For thermal recovery, system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 7%-8%. Material credits for 'Climate Change' are low (1% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 then is 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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 Water Family Pack (ambient) segment, the biggest part (21%-47%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows a minor to considerable share of burdens for 'Climate Change (13%-22%) for the PET bottles in this segment.

The life cycle step 'top, closure & label' shows small impacts shares (4%-6%) mainly attributed to the different plastics used for the closure.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (5%-9%) for climate change.

The life cycle steps 'filling' (4%-8%) and 'distribution' (4%-9%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (21%-27%) for the assessed plastic bottles resulting from the recycling and incineration in MSWI plants of the bottle.

Material credits from the 53.1% recycled PET bottle without recycled content reduce the total burdens by 12% by substituting open loop virgin PET. Material credits for PET bottles with 50% and 100% recycled content are very low (2%-3%) as the 53.1% recycled PET is used as recycled content in a closed loop, resulting in lower plastic production impacts.

For the PET bottles energy credits are low (5%-7%) due to the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

4.7.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.7.1.

Table 50: Comparison of net results: **TPA Square plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment Water Family Pack (ambient)**, allocation factor 50%

Water Family Pack (ambient) Allocation 50 UK	The net results of **TPA Square plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of			
	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change	+45%	+1%	-35%	-49%

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

Table 51: Comparison of net results: **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** versus competing cartons and alternative packaging systems in **segment Water Family Pack (ambient)**, allocation factor 50%

Water Family Pack (ambient) Allocation 50 UK	The net results of **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** are lower (green)/ higher (red)/ similar (white) than those of			
	TPA Square plant-based HeliCap 27 plant-based 1000 mL	100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change	-31%	-30%	-55%	-65%

4.8 Results allocation factor 100%; Water Family Pack (ambient)

4.8.1 Presentation of results Water Family Pack (ambient)

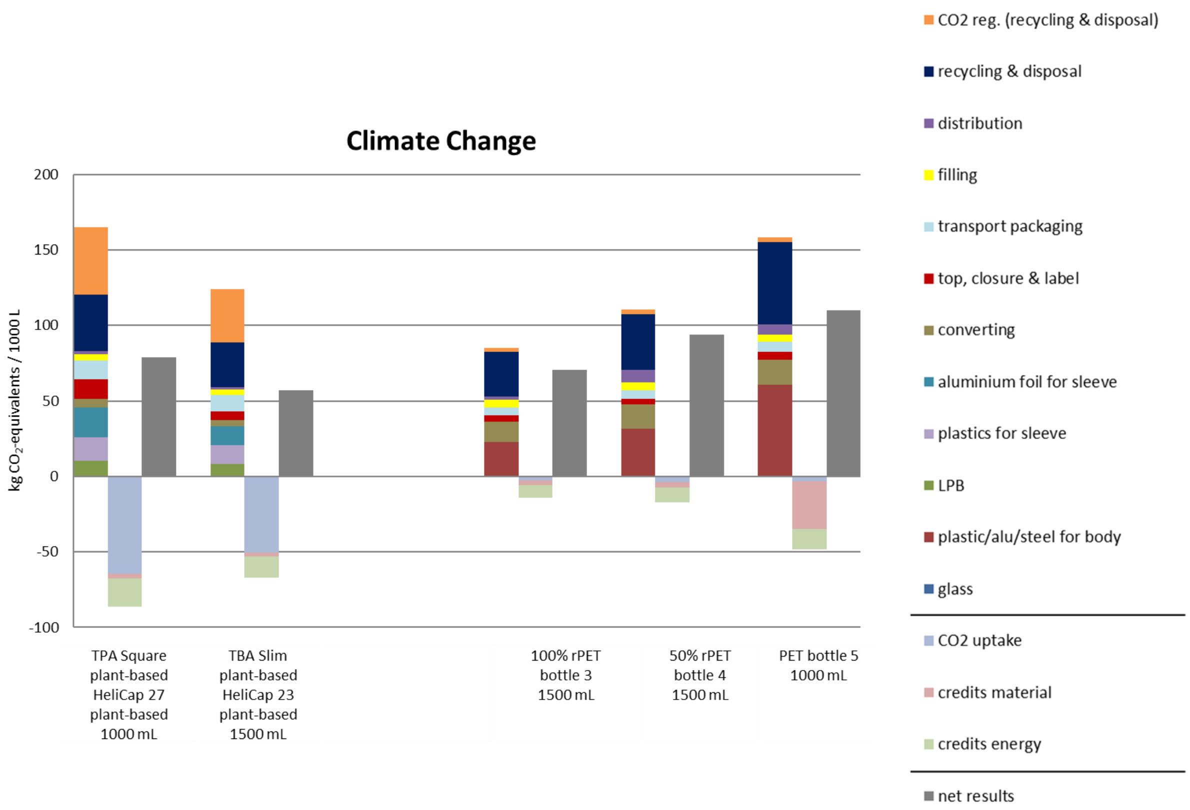

Figure 30: Climate Change results of **segment Water Family Pack (ambient)**, allocation factor 100%

Table 52: Climate Change results of **segment Water Family Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Water Family Pack (ambient) Allocation 100 UK		TPA Square plant-based HeliCap 27 plant-based 1000 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL		100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change [kg CO_2-e/1000 L]	burdens	120.60	88.81		82.29	107.23	154.99
	CO_2 (reg)	44.55	35.03		2.62	3.50	3.18
	credits	-21.56	-16.75		-11.44	-13.21	-44.82
	CO_2 uptake	-64.59	-50.28		-2.82	-3.77	-3.43
	net results	79.01	56.80		70.64	93.75	109.93

4.8.2 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 4.7.2).

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 substituted coal in cement kilns 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 carton in the segment 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In case of PET bottles higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low thermal efficiency of MSWI in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

In the case of the PET bottles with 50% and 100% recycled PET content higher net results for 'Climate Change' are additionally 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.

4.8.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.8.1.

Table 53: Comparison of net results: **TPA Square plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment Water Family Pack (ambient)**, allocation factor 100%

Water Family Pack (ambient) Allocation 100 UK	The net results of **TPA Square plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of			
	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change	+39%	+12%	-16%	-28%

Table 54: Comparison of net results: **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** versus competing cartons and alternative packaging systems in **segment Water Family Pack (ambient)**, allocation factor 100%

Water Family Pack (ambient) Allocation 100 UK	The net results of **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** are lower (green)/ higher (red)/ similar (white) than those of			
	TPA Square plant-based HeliCap 27 plant-based 1000 mL	100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change	-28%	-20%	-39%	-48%

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

4.9 Results allocation factor 50%; Water Portion Pack (ambient)

4.9.1 Presentation of results Water Portion Pack (ambient)

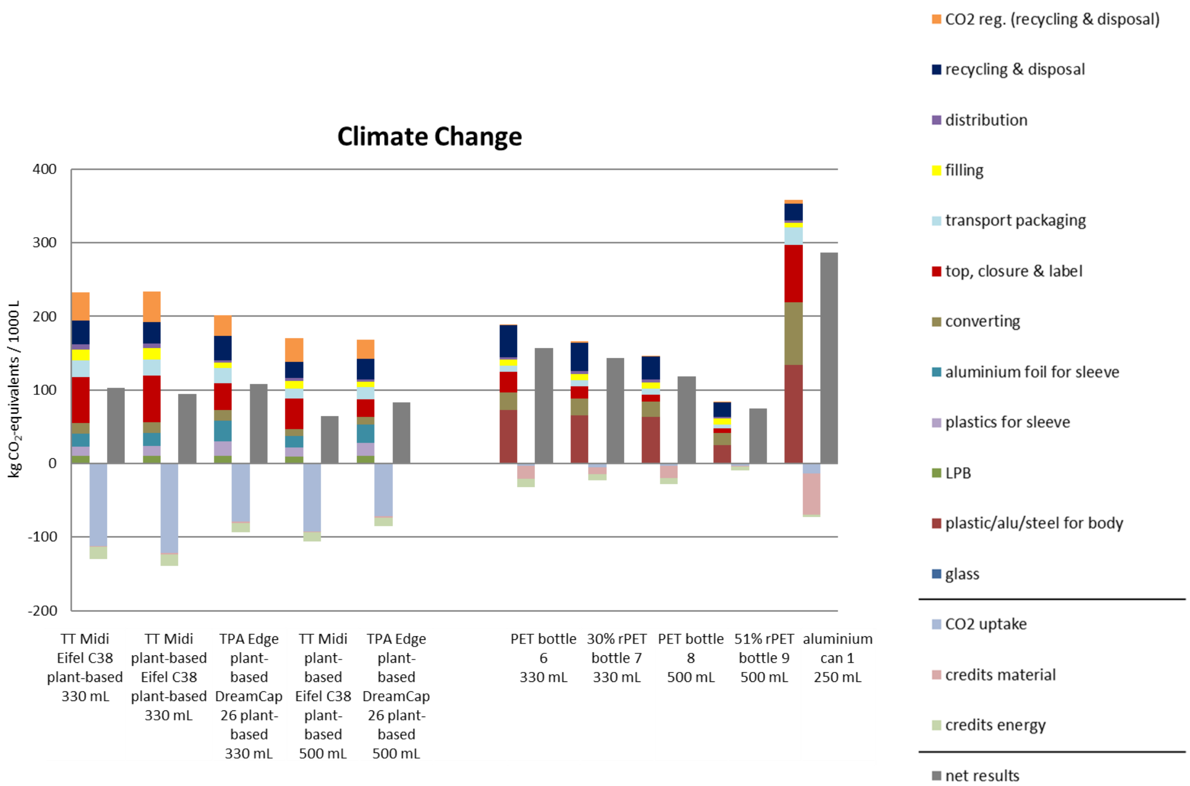

Figure 31: Climate Change results of **segment Water Portion Pack (ambient)**, allocation factor 50%

Table 55: Climate Change results of **segment Water Portion Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Water Portion Pack (ambient) Allocation 50 UK		TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL		PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change [kg CO_2-e/1000 L]	burdens	193.88	192.36	173.26	138.18	142.23		187.93	164.28	144.90	82.86	353.37
	CO_2 (reg)	38.53	41.49	28.40	31.68	25.99		1.41	2.22	1.44	1.24	5.32
	credits	-17.56	-17.56	-15.01	-13.55	-13.08		-29.18	-18.09	-24.78	-6.73	-58.47
	CO_2 uptake	-111.86	-121.85	-78.97	-92.40	-72.03		-3.03	-5.24	-3.10	-2.67	-13.78
	net results	102.99	94.44	107.68	63.91	83.11		157.13	143.16	118.46	74.71	286.43

4.9.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the 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 (5%-6%), production of plastics for sleeves (5%-10%) and the production of aluminium foil for sleeve (8%-15%).

The converting to sleeves accounts only for small shares (6%-7%) of the total burdens for 'Climate Change'.

Regarding the TT cartons considerable shares (24%-27%) of total burdens for 'Climate Change' are caused from the production of closures and tops, especially due to the higher amount of plant-based plastic materials of the tops. Regarding the TPA cartons this life cycle step contributes to minor shares (14%-18%) of total burdens.

The production and provision of 'transport packaging' for the beverage carton systems shows 8%-10% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'filling' shows smalls shares of burdens (4%-6%) for the beverage carton systems.

The life cycle step 'distribution' shows 1%-3% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows minor shares for 'Climate Change' (12%-17%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 14%-19% of the total burdens for 'Climate Change'. For thermal recovery, system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 7%. Material credits for 'Climate Change' are low (1% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 then is 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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 Water Portion Pack (ambient) segment, the biggest part (30%-43%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows a minor share of burdens for 'Climate Change (12%-20%) for the PET bottles in this segment.

The life cycle step 'top, closure & label' shows small to minor impacts shares (6%-15%) mainly attributed to the different plastics used for the closure.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (4%-6%) for climate change.

The life cycle steps 'filling' (4%-10%) and 'distribution' (2%-3%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (21%-23%) for the assessed plastic bottles resulting from the recycling and final disposal of the bottle.

Material credits from the 53.1% recycled PET bottles without recycled content reduce the total burdens by 10%-12% by substituting open loop virgin PET. Material credits for the PET bottle with 30%, and 51% recycled content material credits are lower (2%-6%) as the 53.1% recycled PET is used as recycled content in a closed loop leading to lower impacts from plastic production.

For the PET bottles energy credits are low (5%-6%) due to the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

Aluminium can (specifications see section 2.2.2)

In the assessed aluminium can system in the Water Portion Pack (ambient) segment, the biggest part (37%) of the environmental burdens for 'Climate Change' is caused by the production of the aluminium of the can body.

The 'converting' process shows also a considerable share of burdens for 'Climate Change' (24%) for the can body.

The life cycle step 'top, closure & label' shows considerable impacts shares (22%) attributed to the aluminium production and converting of the cap of the can.

The life cycle steps 'transport packaging' (6%), 'filling' (2%) and 'distribution' (1%) show only small shares of burdens for the can.

The aluminium cans' 'recycling & disposal' life cycle step shows small shares of burdens regarding 'Climate Change' (6%). These result mainly from the recycling process of aluminium.

Material credits from 69% recycled aluminium cans reduce the overall 'Climate Change' burdens by around 16%. Most of the aluminium is being recycled in a closed loop feeding the 50% recycled content of the aluminium cans leading to lower impacts from aluminium production. The influence of energy credits on the net result is low (1% of total burdens) due to the low heating value of aluminium.

4.9.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.9.1.

Table 56: Comparison of net results: **TT Midi Eifel C38 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 UK	The net results of **TT Midi Eifel C38 plant-based 330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	+9%	-4%	+61%	+24%	-34%	-28%	-13%	+38%	-64%

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

Table 57: Comparison of net results: **TT Midi plant-based Eifel C38 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 UK	The net results of **TT Midi plant-based Eifel C38 plant-based 330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-8%	-12%	+48%	+14%	-40%	-34%	-20%	+26%	-67%

Table 58: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 UK	The net results of **TPA Edge plant-based DreamCap 26 plant-based 330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	+5%	+14%	+68%	+30%	-31%	-25%	-9%	+44%	-62%

Table 59: Comparison of net results: **TT Midi plant-based Eifel C38 plant-based 500 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 UK	The net results of **TT Midi plant-based Eifel C38 plant-based 500 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-38%	-32%	-41%	-23%	-59%	-55%	-46%	-14%	-78%

Table 60: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 500 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 UK	The net results of **TPA Edge plant-based DreamCap 26 plant-based 500 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-19%	-12%	-23%	+30%	-47%	-42%	-30%	+11%	-71%

4.10 Results allocation factor 100%; Water Portion Pack (ambient)

4.10.1 Presentation of results Water Portion Pack (ambient)

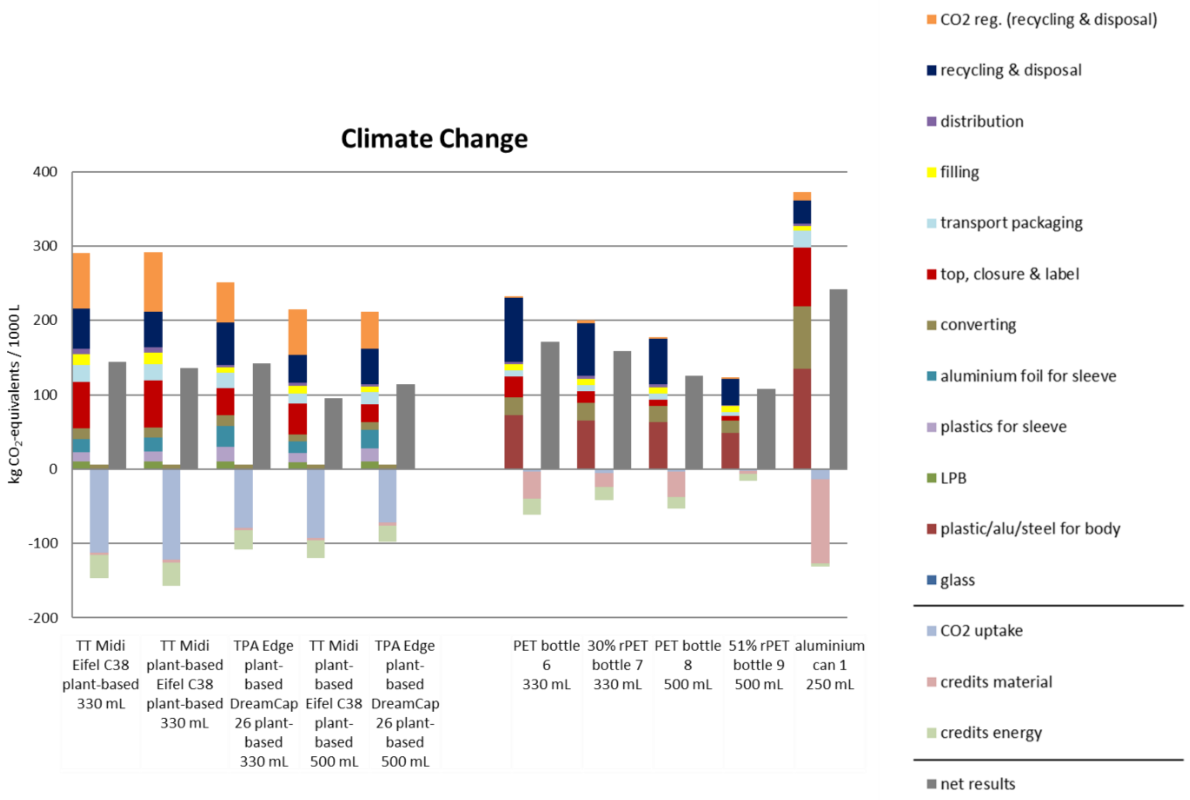

Figure 32: Climate Change results of **segment Water Portion Pack (ambient)**, allocation factor 100%

Table 61: Climate Change results of **segment Water Portion Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Water Portion Pack (ambient) Allocation 100 UK		TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL		PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change [kg CO_2-e/1000 L]	burdens	215.93	211.45	196.75	153.04	161.59		230.00	195.68	174.84	121.25	361.75
	CO_2 (reg)	74.69	80.61	54.47	61.47	49.80		2.81	4.43	2.88	2.48	10.63
	credits	-34.74	-34.74	-29.63	-26.80	-25.81		-58.38	-36.15	-49.57	-13.47	-116.81
	CO_2 uptake	-111.86	-121.85	-78.97	-92.40	-72.03		-3.03	-5.24	-3.10	-2.67	-13.78
	net results	144.02	135.46	142.62	95.31	113.55		171.40	158.72	125.05	107.59	241.79

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 substituted coal in cement kilns 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 carton in the segment 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In case of PET bottles higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low thermal efficiency of MSWI in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

In the case of the PET bottles with 30% and 51% recycled PET content higher net results for 'Climate Change' are additionally 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 aluminium can, lower net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as with the high recycling rate of aluminium cans material credits show higher benefits than the burdens of the recycling process.

4.10.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.10.1.

Table 62: Comparison of net results: **TT Midi Eifel C38 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 UK	The net results of **TT Midi Eifel C38 plant-based** **330 mL** are lower (green)/ higher (red)/ similar (white) than those of							
	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	+6%	+1%	+51%	+27%	-16%	-9%	+15%	+34%	-40%

Table 63: Comparison of net results: **TT Midi plant-based Eifel C38 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 UK	The net results of **TT Midi plant-based Eifel C38 plant-based** **330 mL** are lower (green)/ higher (red)/ similar (white) than those of							
	TT Midi Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-6%	-5%	+42%	+19%	-21%	-15%	+8%	+26%	-44%

Table 64: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 UK	The net results of **TPA Edge plant-based DreamCap 26 plant-based** **330 mL** are lower (green)/ higher (red)/ similar (white) than those of							
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-1%	+5%	+50%	+26%	-17%	-10%	+14%	+33%	-41%

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

Table 65: Comparison of net results: **TT Midi plant-based Eifel C38 plant-based 500 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 UK	The net results of **TT Midi plant-based Eifel C38 plant-based** **500 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-34%	-30%	-33%	-16%	-44%	-40%	-24%	-11%	-61%

Table 66: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 500 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 UK	The net results of **TPA Edge plant-based DreamCap 26 plant-based** **500 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-21%	-16%	-20%	+19%	-34%	-28%	-9%	+6%	-53%

4.11 Results allocation factor 50%; Liquid Food Portion Pack (ambient)

4.11.1 Presentation of results Liquid Food Portion Pack (ambient)

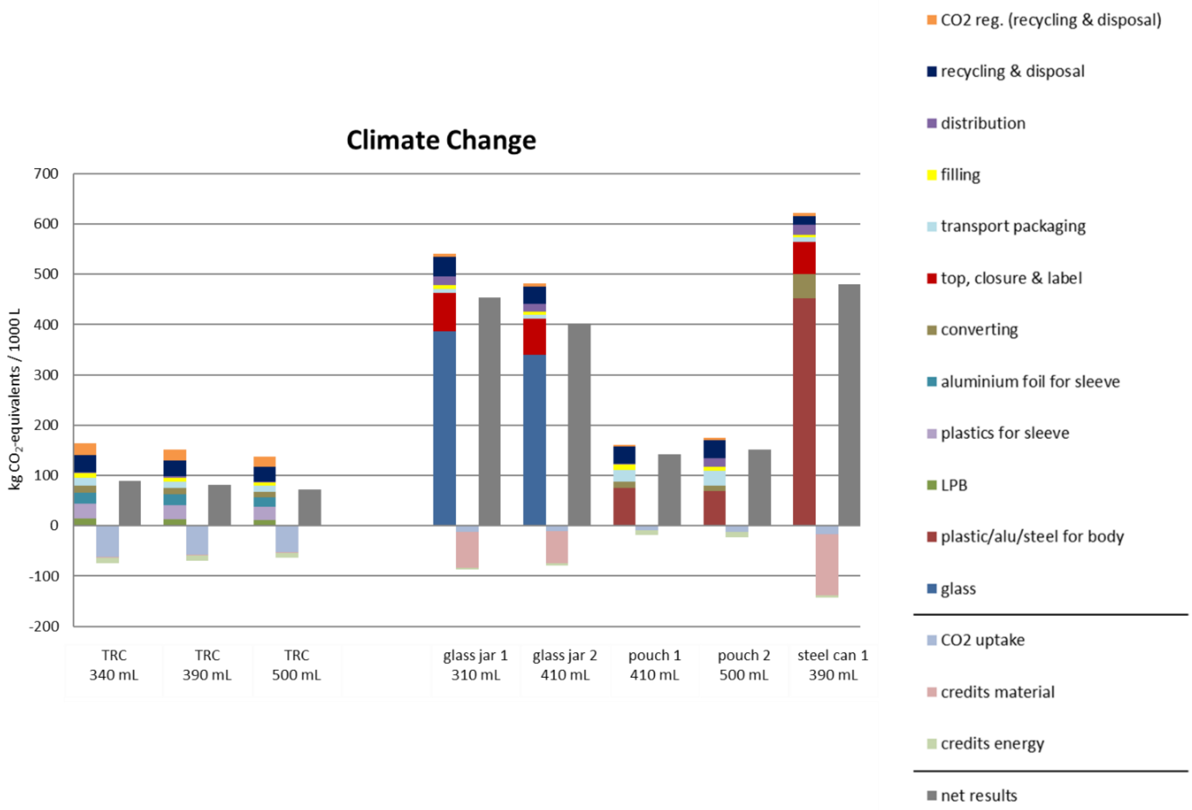

Figure 33: Climate Change results of **segment Liquid Food Portion Pack (ambient)**, allocation factor 50%

Table 67: Climate Change results of **segment Liquid Food Portion Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Liquid Food Portion Pack (ambient) Allocation 50 UK		TRC 340 mL	TRC 390 mL	TRC 500 mL		glass jar 1 310 mL	glass jar 2 410 mL	pouch 1 410 mL	pouch 2 500 mL	steel can 1 390 mL
Climate Change [kg CO_2-e/1000 L]	burdens	139.96	128.80	116.55		534.80	475.47	157.80	169.52	615.64
	CO_2 (reg)	23.41	21.84	20.06		5.93	5.69	3.47	5.12	6.46
	credits	-13.29	-12.42	-11.36		-75.42	-67.22	-10.38	-10.58	-125.82
	CO_2 uptake	-61.64	-57.59	-52.71		-11.86	-11.37	-8.76	-12.66	-16.76
	net results	88.44	80.63	72.54		453.45	402.56	142.13	151.40	479.51

4.11.2 Description and interpretation

Liquid food 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 beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (8%-9%), production of plastics for sleeves (19%) and the production of aluminium foil for sleeve (13%-14%).

The converting to sleeves accounts only for small shares (7%-9%) 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 beverage carton systems shows small shares (9%-10%) of the total burdens for 'Climate Change' for the liquid food carton.

The life cycle step 'filling' shows small shares of burdens (4%-5%) for the liquid food carton system.

The life cycle step 'distribution' shows only 1%-2% of the total burdens for 'Climate Change' for the liquid food carton.

The life cycle step 'recycling & disposal' of the assessed liquid food carton is the most relevant life cycle step for 'Climate Change' (20%-21%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 14%-15% of the total burdens for 'Climate Change'. For thermal recovery, system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in the UK and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 7%. Material credits for 'Climate Change' are low (1% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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. This amount of carbon can be re-emitted in the end-of-life either by landfilling or by incineration. Due to the convention in this study which implies that no CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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).

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 (73%) of the environmental burdens for 'Climate Change' is caused by the production of the steel of the can body.

The 'converting' process shows a small share of burdens for 'Climate Change (8%) for the can body.

The life cycle step 'top, closure & label' shows also small impacts shares (10%) 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' (1%) and 'distribution' (3%) 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%). These result mainly from the degradation of the paper labels on landfills, which emit methane.

The influence of material credits on the net result is relevant for 'Climate Change'. The 78.7% recycled steel cans reduce the overall burdens by around 20% due to the substitution of raw steel with recycled steel from the cans. Energy credits are almost zero resulting only to a very small amount from incinerating and landfilling of tertiary packaging (pallets).

Glass jar (specifications see section 2.2.2)

Similar to the steel can, the production of the 'glass' material is the main contributor to the overall burdens for the glass jar. The production of glass clearly dominates the results for 'Climate Change' (71%-72%).

Most other life cycle steps play only a minor role compared to the glass production. The exception is, 'top, closure & label', which shows 14%-15% of the total burdens resulting from the production of the tin plate closure.

Energy credits only show small shares (less than 1%) resulting from incinerating and landfilling of secondary and tertiary packaging.

Material credits from 75.8% recycled glass jars reduce the overall 'Climate Change' burdens by around 13%. Most of the glass is being recycled in a closed loop feeding the 69.5% external cullet of the glass jars leading to lower impacts from glass production.

The influence of material credits on the net result is minor for 'Climate Change'. They reduce the overall burdens by 13% as most of the glass is being recycled in a closed loop.

Pouch (specifications see section 2.2.2)

In the assessed pouches in the Liquid Food Portion Pack (ambient) segment, a major share (40%-47%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the pouches.

The 'converting' process shows a small share of burdens for 'Climate Change (6%-8%) for the pouches in this segment.

As the pouches have 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 pouches shows minor impact shares (14%-17%) for climate change.

The life cycle steps 'filling' (5%-7%) and 'distribution' (1%-10%) show small shares of burdens for the pouches.

The pouches' 'recycling & disposal' life cycle step shows considerable shares (20%-21%) for the assessed pouches 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 reduction of net results by energy credits (6%) results from the incineration of pouches.

4.11.3 Comparison between packaging systems

The following table shows the net results per FU of the assessed beverage carton 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 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.11.1.

Table 68: Comparison of net results: **TRC 340 mL** versus alternative packaging systems in **segment Liquid Food Portion Pack (ambient)**, allocation factor 50%

Liquid Food Portion Pack (ambient) Allocation 50 UK	The net results of TRC 340 mL are lower (green)/ higher (red)/ similar (white) than those of						
	TRC 390 mL	TRC 500 mL	glass jar 1 310 mL	glass jar 2 410 mL	pouch 1 410 mL	pouch 2 500 mL	steel can 1 390 mL
Climate Change	+10%	+22%	-80%	-78%	-38%	-42%	-82%

Table 69: Comparison of net results: **TRC 390 mL** versus alternative packaging systems in **segment Liquid Food Portion Pack (ambient)**, allocation factor 50%

Liquid Food Portion Pack (ambient) Allocation 50 UK	The net results of TRC 390 mL are lower (green)/ higher (red)/ similar (white) than those of						
	TRC 340 mL	TRC 500 mL	glass jar 1 310 mL	glass jar 2 410 mL	pouch 1 410 mL	pouch 2 500 mL	steel can 1 390 mL
Climate Change	-9%	+11%	-82%	-80%	-43%	-47%	-83%

Table 70: Comparison of net results: **TRC 500 mL** versus alternative packaging systems in **segment Liquid Food Portion Pack (ambient)**, allocation factor 50%

Liquid Food Portion Pack (ambient) Allocation 50 UK	The net results of TRC 500 mL are lower (green)/ higher (red)/ similar (white) than those of						
	TRC 340 mL	TRC 390 mL	glass jar 1 310 mL	glass jar 2 410 mL	pouch 1 410 mL	pouch 2 500 mL	steel can 1 390 mL
Climate Change	-18%	-10%	-84%	-82%	-49%	-52%	-85%

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

4.12 Results allocation factor 100%; Liquid Food Portion Pack (ambient)

4.12.1 Presentation of results Liquid Food Portion Pack (ambient)

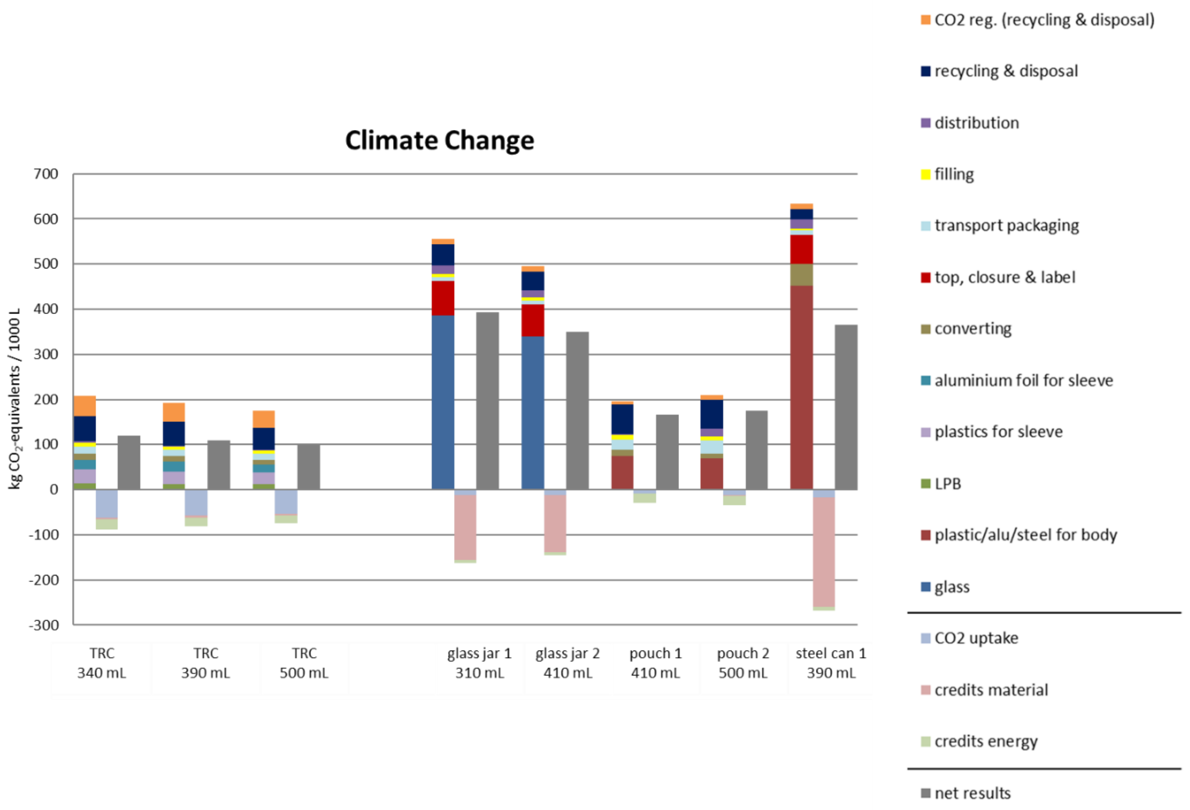

Figure 34: Climate Change results of **segment Liquid Food Portion Pack (ambient)**, allocation factor 100%

Table 71: Climate Change results of **segment Liquid Food Portion Pack (ambient)** burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Liquid Food Portion Pack (ambient) Allocation 100 UK		TRC 340 mL	TRC 390 mL	TRC 500 mL		glass jar 1 310 mL	glass jar 2 410 mL	pouch 1 410 mL	pouch 2 500 mL	steel can 1 390 mL
Climate Change [kg CO_2-e/1000 L]	burdens	163.50	150.73	136.59		543.81	483.84	188.27	199.21	620.97
	CO_2 (reg)	44.20	41.26	37.89		11.86	11.37	6.93	10.24	13.26
	credits	-26.15	-24.45	-22.35		-150.84	-134.44	-20.65	-21.03	-251.98
	CO_2 uptake	-61.64	-57.59	-52.71		-11.86	-11.37	-8.76	-12.66	-16.76
	net results	119.91	109.96	99.42		392.98	349.40	165.79	175.77	365.49

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 substituted coal in cement kilns 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In the case of the glass jars, 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 the case of the steel can, 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 the case of the pouches, higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low thermal efficiency of MSWI in the UK and a relatively low 'Climate Change' intensive substituted electricity mix.

4.12.3 Comparison between packaging systems

The following table shows the net results per FU of the assessed beverage carton 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 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 comparison[1]. The absolute values of net results are shown in the result table in section 4.12.1.

Table 72: Comparison of net results: **TRC 340 mL** versus competing cartons and alternative packaging systems in **segment Liquid Food Portion Pack (ambient)**, allocation factor 100%

Liquid Food Portion Pack (ambient) Allocation 100 UK	The net results of **TRC 340 mL** are lower (green)/ higher (red)/ similar (white) than those of						
	TRC 390 mL	TRC 500 mL	glass jar 1 310 mL	glass jar 2 410 mL	pouch 1 410 mL	pouch 2 500 mL	steel can 1 390 mL
Climate Change	+9%	+21%	-69%	-66%	-28%	-32%	-67%

Table 73: Comparison of net results: **TRC 390 mL** versus competing cartons and alternative packaging systems in **segment Liquid Food Portion Pack (ambient)**, allocation factor 100%

Liquid Food Portion Pack (ambient) Allocation 100 UK	The net results of **TRC 390 mL** are lower (green)/ higher (red)/ similar (white) than those of						
	TRC 340 mL	TRC 500 mL	glass jar 1 310 mL	glass jar 2 410 mL	pouch 1 410 mL	pouch 2 500 mL	steel can 1 390 mL
Climate Change	-8%	+11%	-72%	-69%	-34%	-37%	-70%

Table 74: Comparison of net results: **TRC 500 mL** versus competing cartons and alternative packaging systems in **segment Liquid Food Portion Pack (ambient)**, allocation factor 100%

Liquid Food Portion Pack (ambient) Allocation 100 UK	The net results of **TRC 500 mL** are lower (green)/ higher (red)/ similar (white) than those of						
	TRC 340 mL	TRC 390 mL	glass jar 1 310 mL	glass jar 2 410 mL	pouch 1 410 mL	pouch 2 500 mL	steel can 1 390 mL
Climate Change	-17%	-10%	-75%	-72%	-40%	-43%	-73%

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

5 Results IE

In this section, the results of the examined packaging systems for Ireland 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, HDPE including additives, e.g. carbon black for the body of plastic bottles and pouches, as well as steel and aluminium 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, pouches 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')**
- 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')**
- CO_2 emissions from incineration of plant-based and renewable materials **('CO_2 reg. (recycling & disposal')')**; in the following also the term regenerative CO_2 emissions is used
- Uptake of atmospheric CO_2 during the plant growth phase ('**CO_2-uptake**')

The top down order in the legends refer to the top down order in the following diagrams.

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 CO_2 uptake (second stacked bar with negative values)
- net results as a 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 ≤ 10% are considered as insignificant.

5.1 Results allocation factor 50%; Dairy Family Pack (chilled)

5.1.1 Presentation of results Dairy Family Pack (chilled)

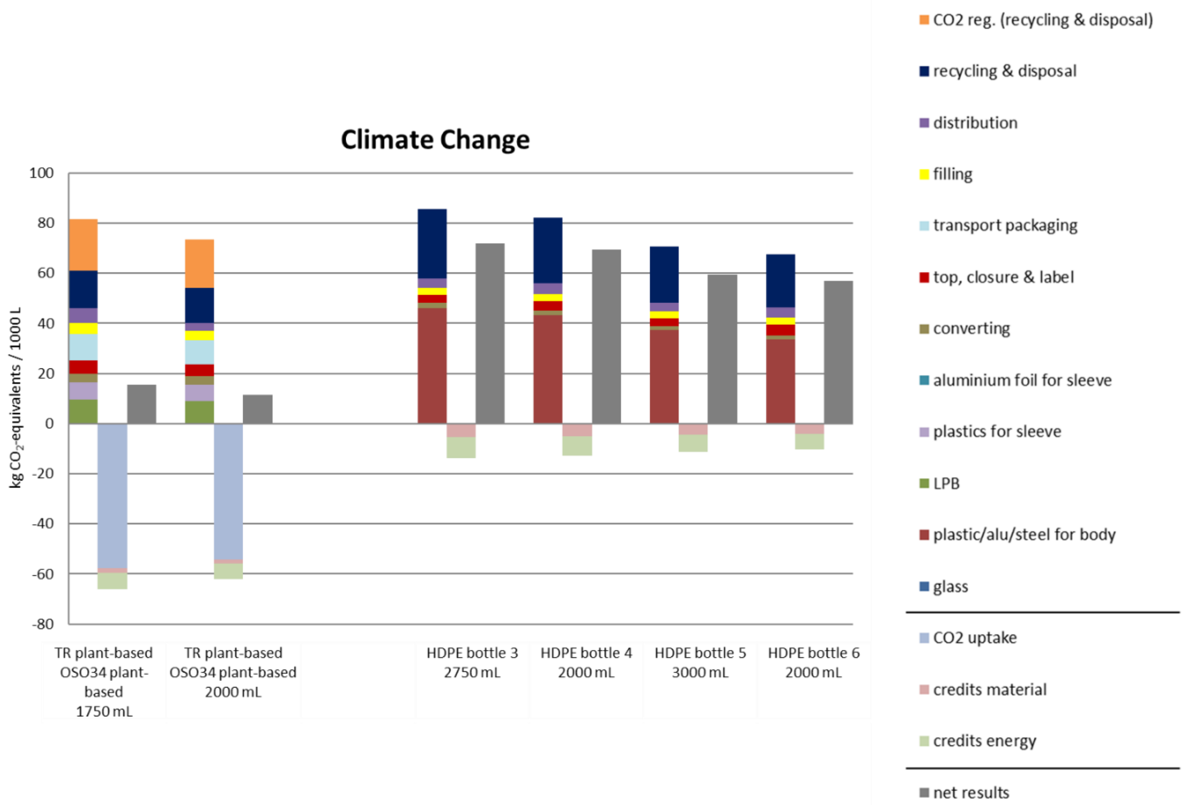

Figure 35: Climate Change results of **segment Dairy Family Pack (chilled)**, allocation factor 50%

Table 75: Climate Change results of **segment Dairy Family Pack (chilled)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Dairy Family Pack (chilled) Allocation 50 IE		TR plant-based OSO34 plant-based 1750 mL	TR plant-based OSO34 plant-based 2000 mL		HDPE bottle 3 2750 mL	HDPE bottle 4 2000 mL	HDPE bottle 5 3000 mL	HDPE bottle 6 2000 mL
Climate Change [kg CO_2-e/1000 L]	burdens	60.99	54.17		85.47	82.26	70.72	67.52
	CO_2 (reg)	20.57	19.28		0.00	0.00	0.00	0.00
	credits	-8.24	-7.71		-13.65	-12.98	-11.15	-10.42
	CO_2 uptake	-57.84	-54.27		0.00	0.00	0.00	0.00
	net results	15.47	11.47		71.82	69.28	59.57	57.10

5.1.2 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 minor 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 (12%) and the production of plastics for sleeves (8%-9%).

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

Small shares (6%-7%) of total burdens for 'Climate Change' are caused from the production of closures.

The production and provision of 'transport packaging' for the beverage carton system shows 13% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'filling' shows small shares of burdens (5%-6%) for the beverage cartons.

The life cycle step 'distribution' shows 4%-7% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'recycling & disposal' of the assessed beverage cartons is one of the most relevant life cycle step for 'Climate Change' (18%-19%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons, these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 25%-26% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 8%. Material credits for 'Climate Change' are low (2% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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, the major share (50%-54%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows a small share of burdens for 'Climate Change (2%) for the HDPE bottles in this segment.

The life cycle step 'top, closure & label' shows small impacts shares (4%-6%) mainly attributed to the different plastics used for the closure.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (less than 1%) for climate change due to the high trip rate of the rollcontainers used for the HDPE bottles in this segment.

The life cycle steps 'filling' (3%-4%) and 'distribution' (4%-6%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows major shares (31%-32%) for the assessed plastic bottles resulting from the recycling and incineration in MSWI plants of the bottles.

Material credits from the 27.5% recycled HDPE bottles reduce the total burdens by 6% by substituting virgin HDPE.

For the HDPE bottles energy credits are low (9%-10%) due to the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

5.1.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.1.1.

Table 76: Comparison of net results: **TR plant-based OSO 34 plant-based 1750 mL** versus competing carton and alternative packaging systems in **segment Dairy Family Pack (chilled)**, allocation factor 50%

Dairy Family Pack (chilled) Allocation 50 IE	The net results of **TR plant-based OSO34 plant-based** **1750 mL** are lower (green)/ higher (red)/ similar (white) than those of				
	TR plant-based OSO34 plant-based 2000 mL	HDPE bottle 3 2750 mL	HDPE bottle 4 2000 mL	HDPE bottle 5 3000 mL	HDPE bottle 6 2000 mL
Climate Change	+35%	-78%	-78%	-74%	-73%

Table 77: Comparison of net results: **TR plant-based OSO 34 plant-based 2000 mL** versus competing carton and alternative packaging systems in **segment Dairy Family Pack (chilled)**, allocation factor 50%

Dairy Family Pack (chilled) Allocation 50 IE	The net results of **TR plant-based OSO34 plant-based** **2000 mL** are lower (green)/ higher (red)/ similar (white) than those of				
	TR plant-based OSO34 plant-based 1750 mL	HDPE bottle 3 2750 mL	HDPE bottle 4 2000 mL	HDPE bottle 5 3000 mL	HDPE bottle 6 2000 mL
Climate Change	-26%	-84%	-83%	-81%	-80%

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

5.2 Results allocation factor 100%; Dairy Family Pack (chilled)

5.2.1 Presentation of results Dairy Family Pack (chilled)

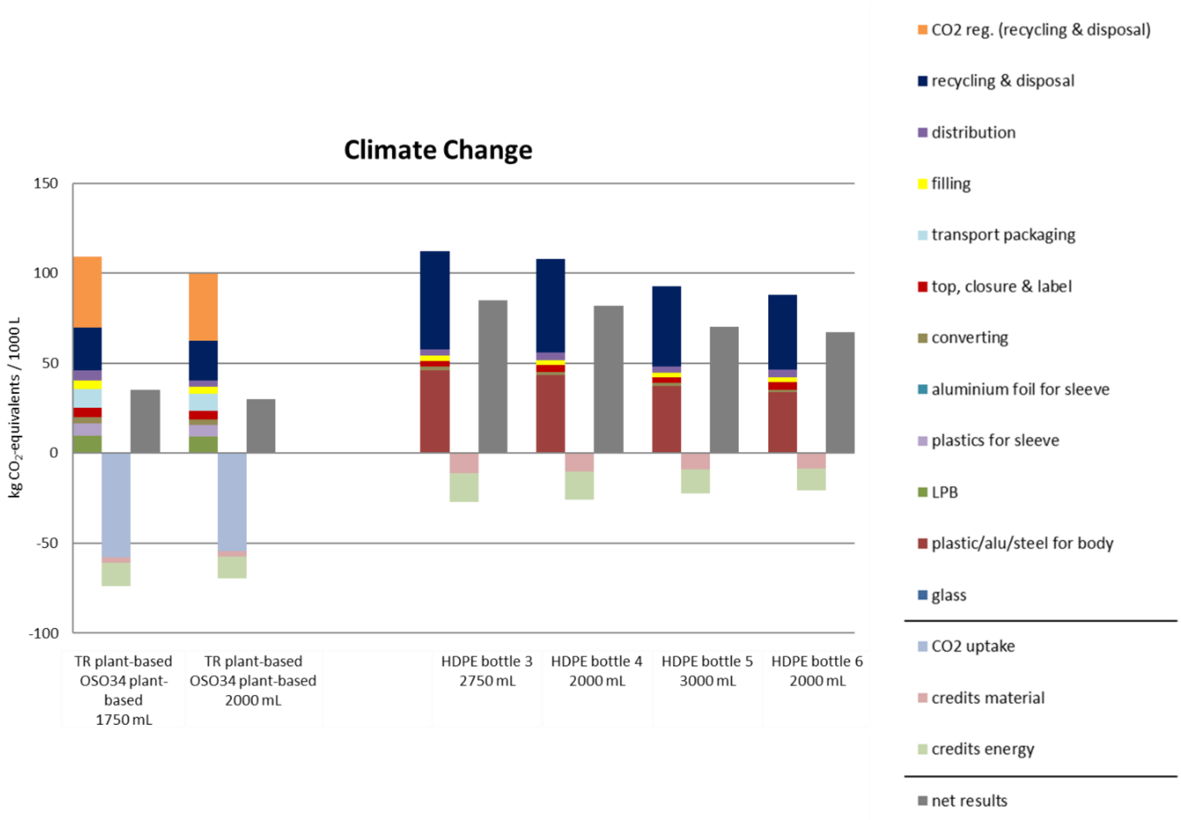

Figure 36: Climate Change results of **segment Dairy Family Pack (chilled)**, allocation factor 100%

Table 78: Climate Change results of **segment Dairy Family Pack (chilled)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Dairy Family Pack (chilled) Allocation 100 IE		TR plant-based OSO34 plant-based 1750 mL	TR plant-based OSO34 plant-based 2000 mL		HDPE bottle 3 2750 mL	HDPE bottle 4 2000 mL	HDPE bottle 5 3000 mL	HDPE bottle 6 2000 mL
Climate Change [kg CO_2-e/1000 L]	burdens	69.94	62.58		112.41	107.90	92.73	88.12
	CO_2 (reg)	39.45	36.97		0.00	0.00	0.00	0.00
	credits	-16.22	-15.16		-27.30	-25.95	-22.30	-20.84
	CO_2 uptake	-57.84	-54.27		0.00	0.00	0.00	0.00
	net results	35.34	30.12		85.11	81.95	70.44	67.28

5.2.2 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 5.1.2).

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 substituted coal in cement kilns 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 carton 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In case of HDPE bottles higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low recycling rate and low thermal efficiency of MSWI in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

5.2.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.2.1.

Table 79: Comparison of net results: **TR plant-based OSO 34 plant-based 1750 mL** versus competing carton and alternative packaging systems in **segment Dairy Family Pack (chilled)**, allocation factor 100%

Dairy Family Pack (chilled) Allocation 100 IE	The net results of **TR plant-based OSO34 plant-based** **1750 mL** are lower (green)/ higher (red)/ similar (white) than those of				
	TR plant-based OSO34 plant-based 2000 mL	HDPE bottle 3 2750 mL	HDPE bottle 4 2000 mL	HDPE bottle 5 3000 mL	HDPE bottle 6 2000 mL
Climate Change	+17%	-58%	-57%	-50%	-47%

Table 80: Comparison of net results: **TR plant-based OSO 34 plant-based 2000 mL** versus competing carton and alternative packaging systems in **segment Dairy Family Pack (chilled)**, allocation factor 100%

Dairy Family Pack (chilled) Allocation 100 IE	The net results of **TR plant-based OSO34 plant-based** **2000 mL** are lower (green)/ higher (red)/ similar (white) than those of				
	TR plant-based OSO34 plant-based 1750 mL	HDPE bottle 3 2750 mL	HDPE bottle 4 2000 mL	HDPE bottle 5 3000 mL	HDPE bottle 6 2000 mL
Climate Change	-15%	-65%	-63%	-57%	-55%

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

5.3 Results allocation factor 50%; Dairy Alternative Family Pack (ambient)

5.3.1 Presentation of results Dairy Alternative Family Pack (ambient)

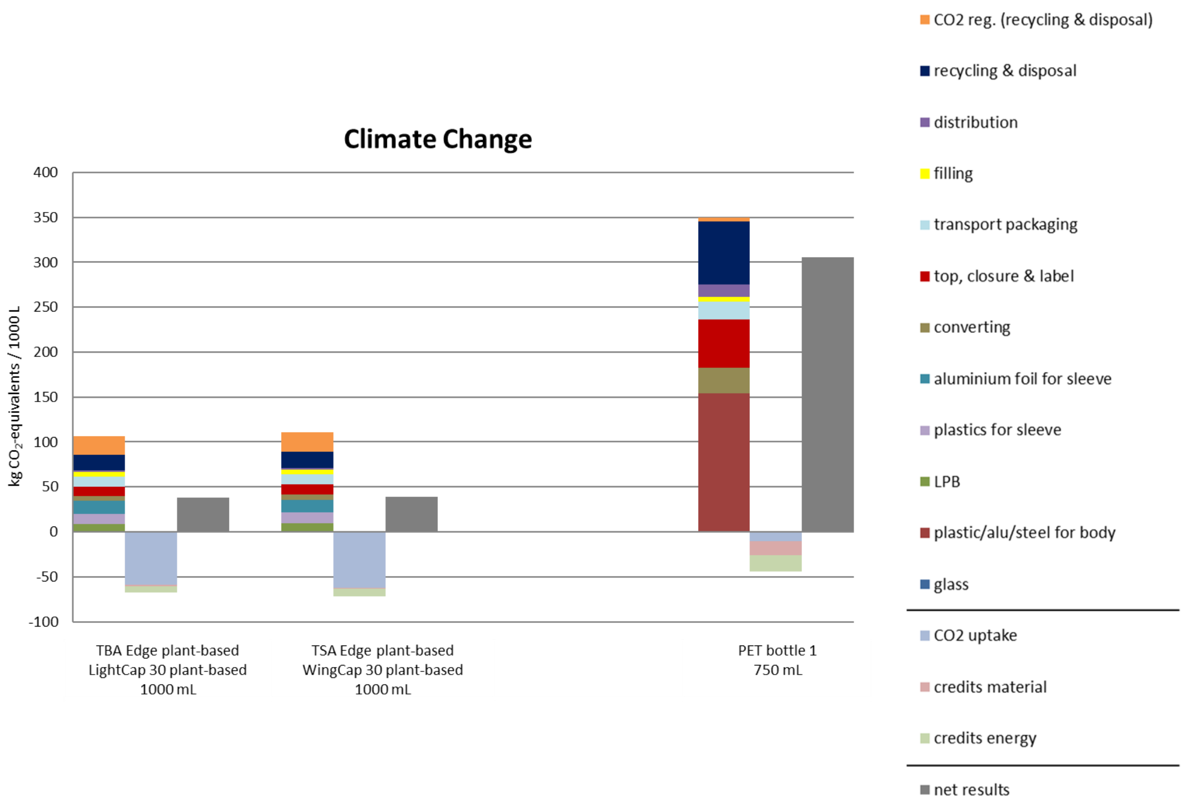

Figure 37: Climate Change results of **segment Dairy Alternative Family Pack (ambient)**, allocation factor 50%

Table 81: Climate Change results of **segment Dairy Alternative Family Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Dairy Alternative Family Pack (ambient) Allocation 50 IE		TBA Edge plant-based LightCap 30 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL		PET bottle 1 750 mL
Climate Change [kg CO_2-e/1000 L]	burdens	85.61	89.33		345.33
	CO_2 (reg)	20.57	21.66		4.21
	credits	-9.03	-9.64		-34.36
	CO_2 uptake	-58.70	-62.04		-10.07
	net results	38.45	39.32		305.10

5.3.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the Dairy Alternative Family Pack (ambient) segment, a minor 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 (8%), the production of plastics for sleeves (10%-11%) and the production of aluminium foil for sleeve (12%-14%).

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

Small shares (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 10%-11% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'filling' shows small shares of burdens (5%) for the beverage carton system.

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 carton is one of the most relevant life cycle step for 'Climate Change' (16%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 19%-20% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 7%. Material credits for 'Climate Change' are low (1% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 then is 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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 Alternative Family Pack (ambient) segment, a major share (44%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottle.

The 'converting' process shows a small share of 8% of the total burdens for the PET bottle in this segment.

The life cycle step 'top, closure & label' shows minor impacts shares (15%) mainly attributed to the different plastics used for the closure.

The production and provision of 'transport packaging' for the bottle systems shows small impact shares (6%) for climate change.

The life cycle steps 'filling' (2%) and 'distribution' (4%) show only small shares of burdens for the plastic bottle.

The plastic bottles' 'recycling & disposal' life cycle step shows minor shares (20%) for the assessed clear PET bottle resulting from the recycling and incineration in MSWI plants of the bottles.

Material credits from the 27.5% recycled PET bottles reduce the total burdens by 5% by substituting virgin PET.

Energy credits are low (5%) due to the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

5.3.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.3.1.

Table 82: Comparison of net results: **TBA Edge plant-based LightCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (ambient)** allocation factor 50%

Dairy Alternative Family Pack (ambient) Allocation 50 IE	The net results of **TBA Edge plant-based LightCap 30 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of	
	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 1 750 mL
Climate Change	-2%	-87%

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

Table 83: Comparison of net results: **TSA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (ambient)**, allocation factor 50%

Dairy Alternative Family Pack (ambient) Allocation 50 IE	The net results of **TSA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of	
	TBA Edge plant-based LightCap 30 plant-based 1000 mL	PET bottle 1 750 mL
Climate Change	+2%	-87%

5.4 Results allocation factor 100%; Dairy Alternative Family Pack (ambient)

5.4.1 Presentation of results Dairy Alternative Family Pack (ambient)

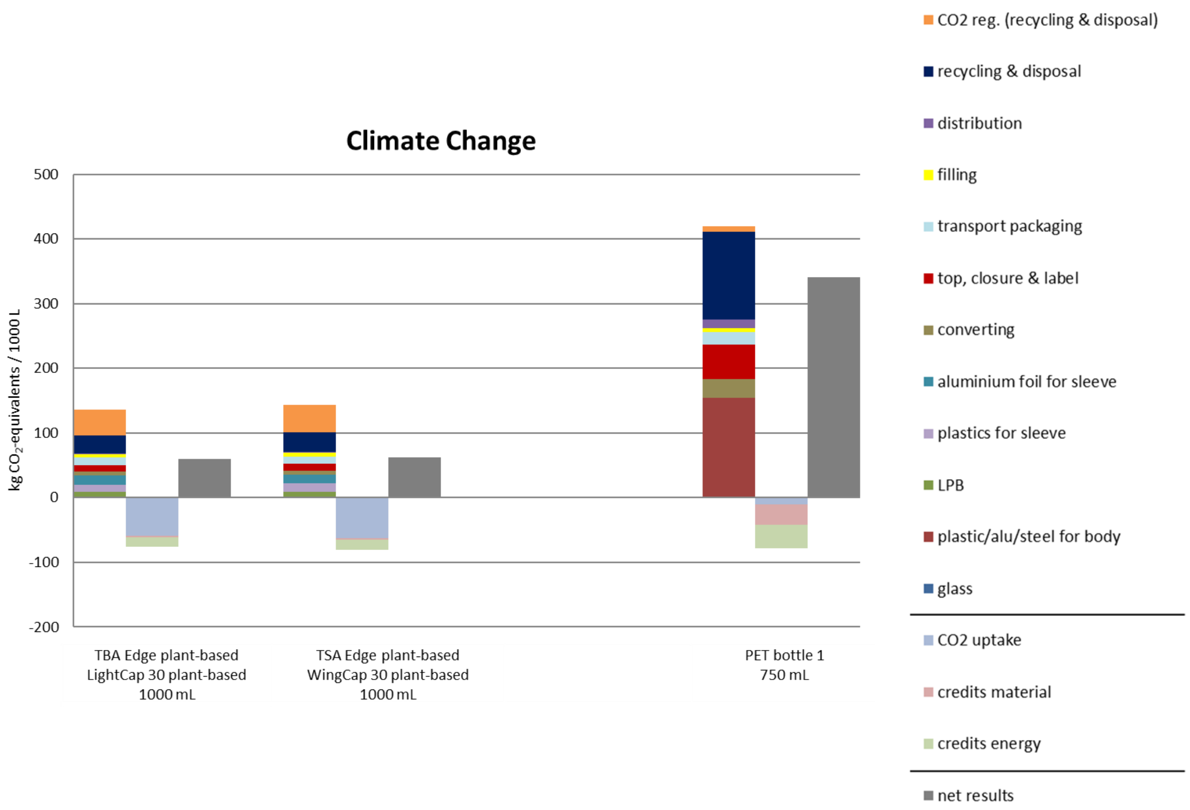

Figure 38: Climate Change results of **segment Dairy Alternative Family Pack (ambient)**, allocation factor 100%

Table 84: Climate Change results of **segment Dairy Alternative Family Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Dairy Alternative Family Pack (ambient) Allocation 100 IE		TBA Edge plant-based LightCap 30 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL		PET bottle 1 750 mL
Climate Change [kg CO_2-e/1000 L]	burdens	96.65	101.33		411.14
	CO_2 (reg)	39.50	41.63		8.42
	credits	-17.79	-19.00		-68.65
	CO_2 uptake	-58.70	-62.04		-10.07
	net results	59.67	61.92		340.84

5.4.2 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 5.3.2).

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 substituted coal in cement kilns 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 Alternative 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In case of the PET bottle higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low recycling rate and low thermal efficiency of MSWI in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

5.4.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.4.1.

Table 85: Comparison of net results: **TBA Edge plant-based LightCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (ambient)**, allocation factor 100%

Dairy Alternative Family Pack (ambient) Allocation 100 IE	The net results of **TBA Edge plant-based LightCap 30 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of	
	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 1 750 mL
Climate Change	-4%	-82%

Table 86: Comparison of net results: **TSA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (ambient)**, allocation factor 100%

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

Dairy Alternative Family Pack (ambient) Allocation 100 IE	The net results of **TSA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of	
	TBA Edge plant-based LightCap 30 plant-based 1000 mL	PET bottle 1 750 mL
Climate Change	+4%	-82%

5.5 Results allocation factor 50%; Dairy Alternative Family Pack (chilled)

5.5.1 Presentation of results Dairy Alternative Family Pack (chilled)

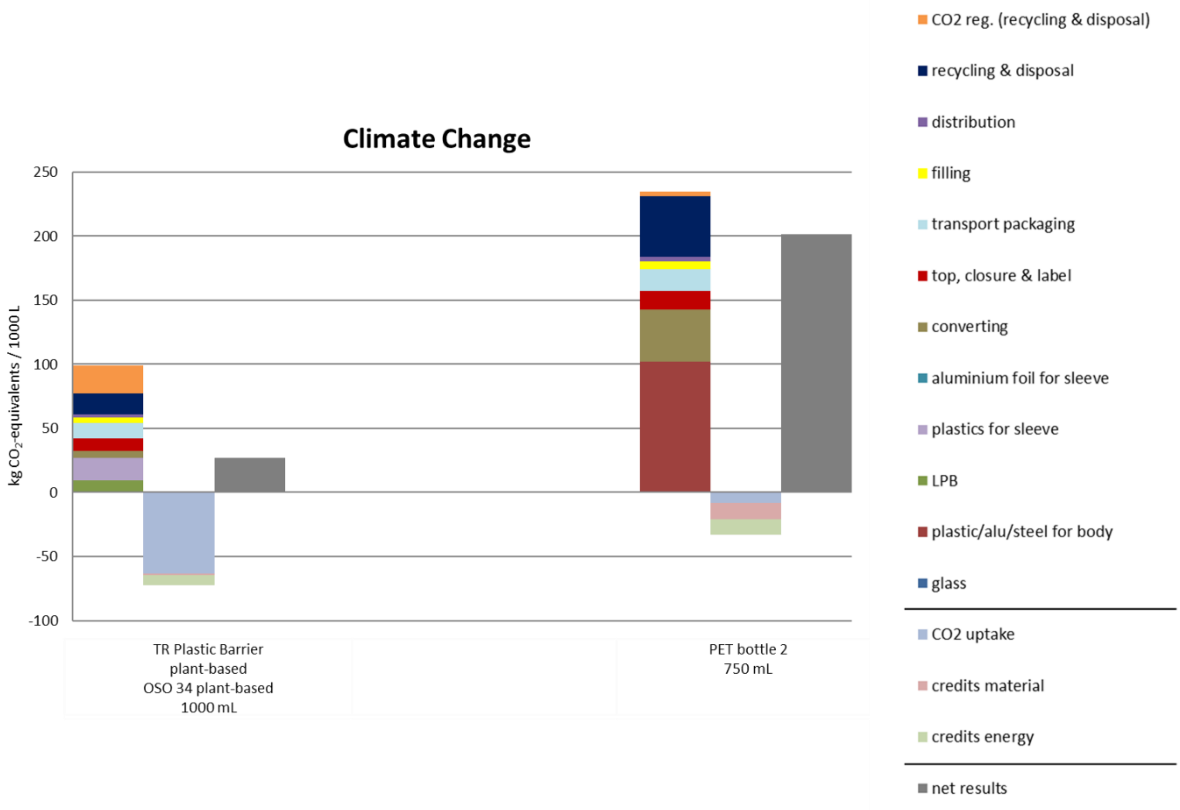

Figure 39: Climate Change results of **segment Dairy Alternative Family Pack (chilled)**, allocation factor 50%

Table 87: Climate Change results of **segment Dairy Alternative Family Pack (chilled)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Dairy Alternative Family Pack (chilled) Allocation 50 IE		TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL		PET bottle 2 750 mL
Climate Change [kg CO_2-e/1000 L]	burdens	76.96		231.16
	CO_2 (reg)	21.97		3.33
	credits	-9.09		-24.78
	CO_2 uptake	-63.03		-8.05
	net results	26.81		201.66

5.5.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the Dairy Alternative Family Pack (chilled) segment, a minor 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%) and the production of plastics for sleeves (18%).

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

Small shares (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 12% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'filling' shows small shares of burdens (4%) for the beverage carton system.

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

The life cycle step 'recycling & disposal' of the assessed beverage carton is one of the most relevant life cycle step for 'Climate Change' (16%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 22% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 8%. Material credits for 'Climate Change' are low (2% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 then is 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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 Dairy Alternative Family Pack (chilled) segment, a major share (43%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows a minor share of 17% of the total burdens for the PET bottle in this segment due to the high energy demand.

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

The production and provision of 'transport packaging' for the bottle systems shows small impact shares (7%) for climate change.

The life cycle steps 'filling' (3%) and 'distribution' (1%) show only small shares of burdens for the plastic bottles.

The plastic bottles' 'recycling & disposal' life cycle step shows minor shares (20%) for the assessed clear PET bottle resulting from the recycling and incineration in MSWI plants of the bottles.

Material credits from the 27.5% recycled PET bottles reduce the total burdens by 6% by substituting virgin PET.

Energy credits are low (5%) due to the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

5.5.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.5.1.

Table 88: Comparison of net results: **TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (chilled)**, allocation factor 50%

Dairy Alternative Family Pack (chilled) Allocation 50 IE	The net results of **TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of
	PET bottle 2 750 mL
Climate Change	-87%

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

5.6 Results allocation factor 100%; Dairy Alternative Family Pack (chilled)

5.6.1 Presentation of results Dairy Alternative Family Pack (chilled)

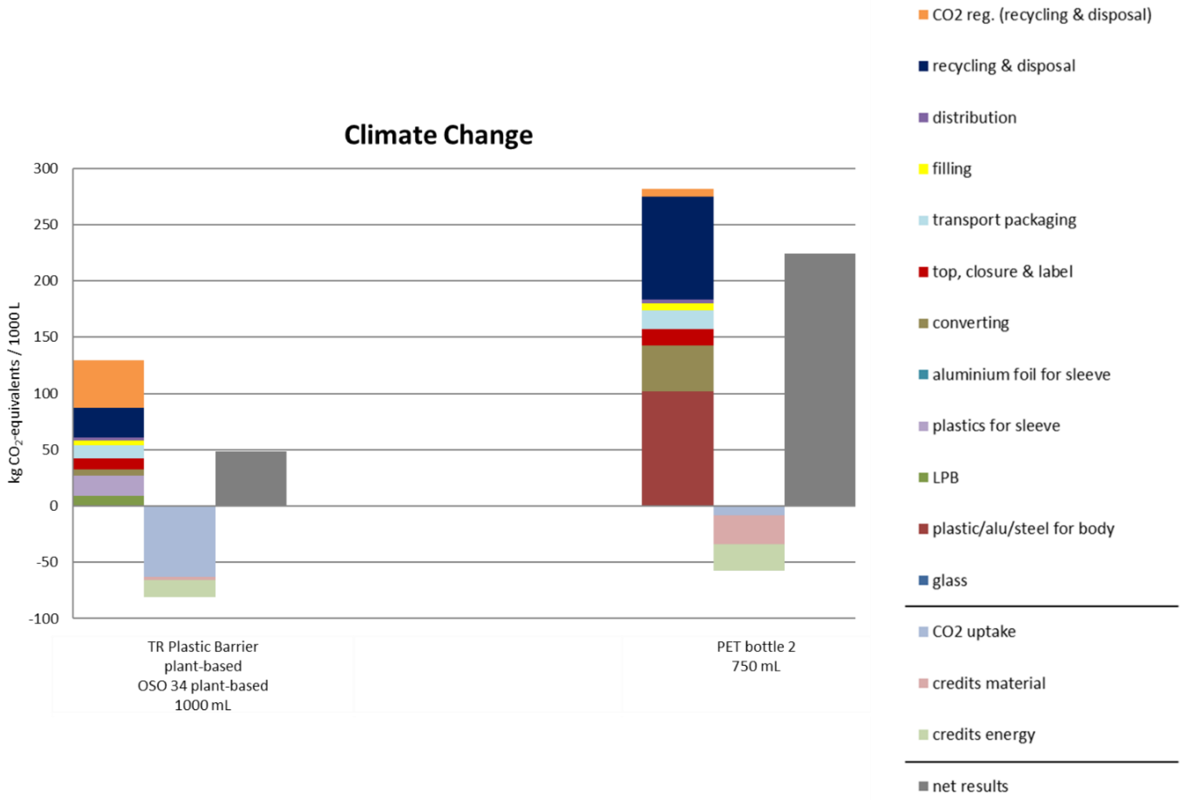

Figure 40: Climate Change results of **segment Dairy Alternative Family Pack (chilled)**, allocation factor 100%

Table 89: Climate Change results of **segment Dairy Alternative Family Pack (chilled)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Dairy Alternative Family Pack (chilled) Allocation 100 IE		TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL		PET bottle 2 750 mL
Climate Change [kg CO_2-e/1000 L]	burdens	87.16		274.92
	CO_2 (reg)	42.26		6.65
	credits	-17.90		-49.48
	CO_2 uptake	-63.03		-8.05
	net results	48.48		224.04

5.6.2 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 5.2.2).

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 substituted coal in cement kilns 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 Alternative 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In case of the PET bottle higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low recycling rate and low thermal efficiency of MSWI in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

5.6.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.6.1.

Table 90: Comparison of net results: **TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment Dairy Alternative Family Pack (chilled)**, allocation factor 100%

Dairy Alternative Family Pack (chilled) Allocation 100 IE	The net results of **TR Plastic Barrier plant-based OSO 34 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of
	PET bottle 2 750 mL
Climate Change	-78%

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

5.7 Results allocation factor 50%; Water Family Pack (ambient)

5.7.1 Presentation of results Water Family Pack (ambient)

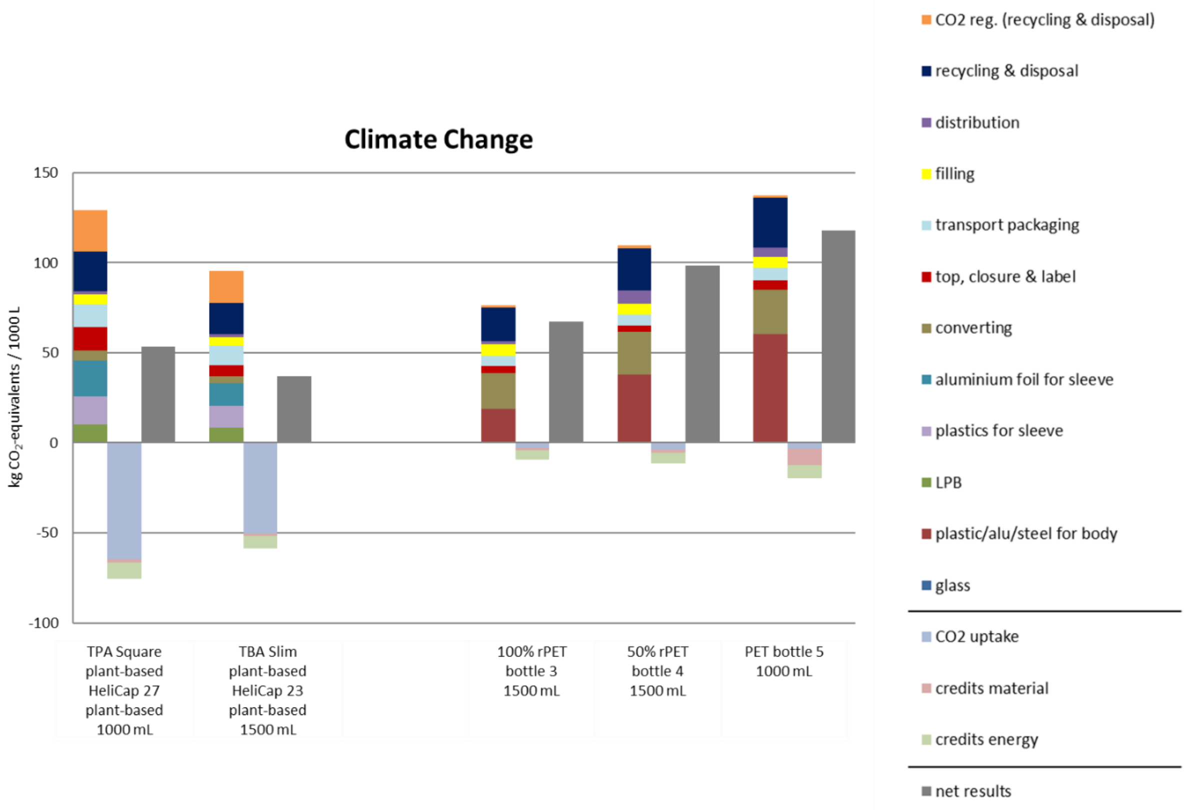

Figure 41: Climate Change results of **segment Water Family Pack (ambient)**, allocation factor 50%

Table 91: Climate Change results of **segment Water Family Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Water Family Pack (ambient) Allocation 50 IE		TPA Square plant-based HeliCap 27 plant-based 1000 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL		100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change [kg CO_2-e/1000 L]	burdens	106.31	77.67		75.13	108.13	135.95
	CO_2 (reg)	22.64	17.87		1.32	1.76	1.60
	credits	-10.89	-8.44		-6.50	-7.80	-16.16
	CO_2 uptake	-64.59	-50.28		-2.82	-3.77	-3.43
	net results	53.48	36.82		67.13	98.32	117.97

5.7.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the 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 (8%-9%), production of plastics for sleeves (12%-13%) and the production of aluminium foil for sleeve (13%-15%).

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

Small shares (6%-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 10%-12% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'filling' shows smalls shares of burdens (4%-5%) for the beverage carton systems.

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

The life cycle step 'recycling & disposal' of the assessed beverage cartons is one of the most relevant life cycle step for 'Climate Change' (17%-18%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 18%-19% of the total burdens for 'Climate Change'. For thermal recovery, system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 7%. Material credits for 'Climate Change' are low (1% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 then is 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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 Water Family Pack (ambient) segment, the biggest part (25%-44%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows a minor to considerable share of burdens for 'Climate Change (18%-26%) for the PET bottles in this segment.

The life cycle step 'top, closure & label' shows small impacts shares (3%-5%) mainly attributed to the different plastics used for the closure.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (5%-7%) for climate change.

The life cycle steps 'filling' (5%-8%) and 'distribution' (2%-6%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows minor to considerable shares (20%-25%) for the assessed plastic bottles resulting from the recycling and incineration in MSWI plants of the bottles.

Material credits from the 27.5% recycled PET bottle without recycled content reduce the total burdens by 6% by substituting open loop virgin PET. Material credits for the PET bottle with 50% and 100% recycled content material credits are very low (1%-2%) as the 27.5% recycled PET is used as recycled content in a closed loop, resulting in lower plastic production impacts.

For the PET bottles energy credits are low (5%-7%) due to the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

5.7.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.7.1.

Table 92: Comparison of net results: **TPA Square plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment Water Family Pack (ambient)**, allocation factor 50%

Water Family Pack (ambient) Allocation 50 IE	The net results of **TPA Square plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of			
	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change	+45%	-20%	-46%	-55%

Table 93: Comparison of net results: **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** versus competing cartons and alternative packaging systems in **segment Water Family Pack (ambient)**, allocation factor 50%

Water Family Pack (ambient) Allocation 50 IE	The net results of **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** are lower (green)/ higher (red)/ similar (white) than those of			
	TPA Square plant-based HeliCap 27 plant-based 1000 mL	100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change	-31%	-45%	-63%	-69%

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

5.8 Results allocation factor 100%; Water Family Pack (ambient)

5.8.1 Presentation of results Water Family Pack (ambient)

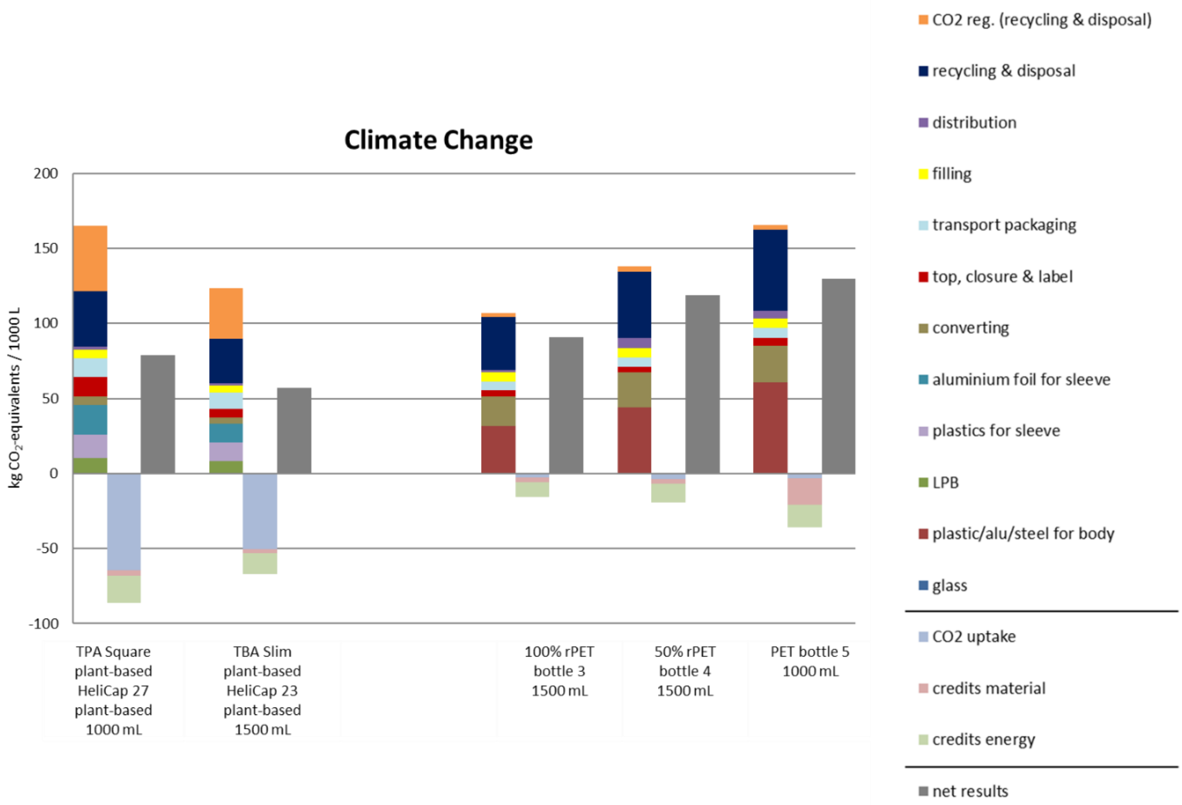

Figure 42: Climate Change results of **segment Water Family Pack (ambient)**, allocation factor 100%

Table 94: Climate Change results of **segment Water Family Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Water Family Pack (ambient) Allocation 100 IE		TPA Square plant-based HeliCap 27 plant-based 1000 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL		100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change [kg CO_2-e/1000 L]	burdens	121.51	89.51		104.20	134.47	162.52
	CO_2 (reg)	43.42	34.20		2.63	3.51	3.20
	credits	-21.47	-16.64		-13.01	-15.62	-32.33
	CO_2 uptake	-64.59	-50.28		-2.82	-3.77	-3.43
	net results	78.87	56.79		91.00	118.59	129.96

5.8.2 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 5.7.2).

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 substituted coal in cement kilns 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 carton in the segment 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 matter is gone when applying the allocation factor 100% as all burdens from ‘CO_2 reg. (recycling & disposal)’ are allocated to the assessed system (see section 1.7.2).

In case of PET bottles higher net results for ‘Climate Change’ are shown when applying the allocation factor 100% instead of 50% due to the low recycling rate and low thermal efficiency of MSWI in Ireland and a relatively low ‘Climate Change’ intensive substituted electricity mix.

In the case of the PET bottles with 50% and 100% recycled PET content higher net results for ‘Climate Change’ are additionally 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.

5.8.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.8.1.

Table 95: Comparison of net results: **TPA Square plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment Water Family Pack (ambient)**, allocation factor 100%

Water Family Pack (ambient) Allocation 100 IE	The net results of **TPA Square plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (red)/ similar (white) than those of			
	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change	+39%	-13%	-33%	-39%

Table 96: Comparison of net results: **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** versus competing cartons and alternative packaging systems in **segment Water Family Pack (ambient)**, allocation factor 100%

Water Family Pack (ambient) Allocation 100 IE	The net results of **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** are lower (green)/ higher (red)/ similar (white) than those of			
	TPA Square plant-based HeliCap 27 plant-based 1000 mL	100% rPET bottle 3 1500 mL	50% rPET bottle 4 1500 mL	PET bottle 5 1000 mL
Climate Change	-28%	-38%	-52%	-56%

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

5.9 Results allocation factor 50%; Water Portion Pack (ambient)

5.9.1 Presentation of results Water Portion Pack (ambient)

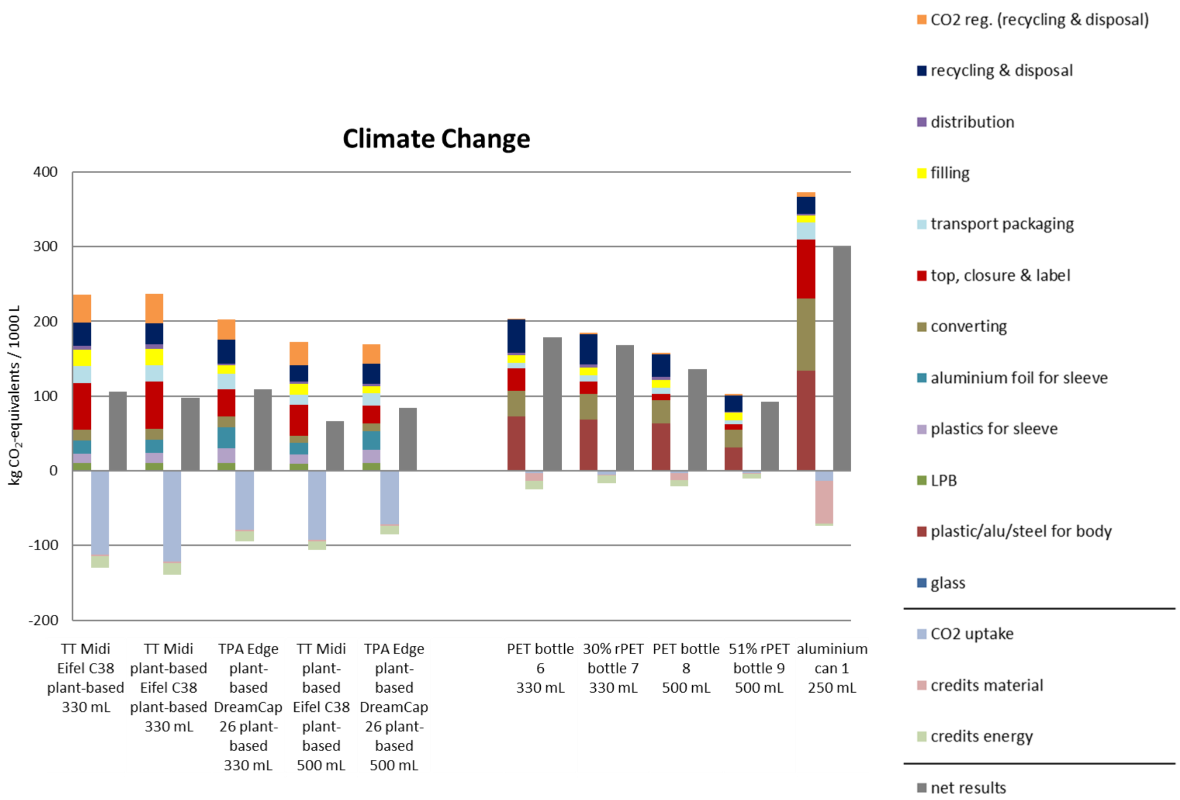

Figure 43: Climate Change results of **segment Water Portion Pack (ambient)**, allocation factor 50%

Table 97: Climate Change results of **segment Water Portion Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Water Portion Pack (ambient) Allocation 50 IE		TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL		PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change [kg CO_2-e/1000 L]	burdens	198.48	197.17	175.25	141.42	143.71		202.00	182.80	156.22	101.23	367.03
	CO_2 (reg)	37.24	39.98	27.63	30.57	25.29		1.41	2.24	1.44	1.24	5.41
	credits	-17.71	-17.71	-15.09	-13.61	-13.09		-22.28	-11.78	-18.06	-7.46	-59.83
	CO_2 uptake	-111.86	-121.85	-78.97	-92.40	-72.03		-3.03	-5.24	-3.10	-2.67	-13.78
	net results	106.14	97.59	108.82	65.98	83.88		178.11	168.02	136.50	92.34	298.83

5.9.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the 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 (4%-6%), production of plastics for sleeves (5%-10%) and the production of aluminium foil for sleeve (8%-15%).

The converting to sleeves accounts only for small shares (6%-7%) of the total burdens for 'Climate Change'.

Regarding the TT cartons considerable shares (24%-27%) of total burdens for 'Climate Change' are caused from the production of closures and tops, especially due to the higher amount of plant-based plastic materials of the tops. Regarding the TPA cartons this life cycle step contributes to minor shares (14%-18%) of total burdens.

The production and provision of 'transport packaging' for the beverage carton systems shows 8%-10% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'filling' shows smalls shares of burdens (6%-9%) for the beverage carton systems.

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

The life cycle step 'recycling & disposal' of the assessed beverage cartons shows minor shares for 'Climate Change' (12%-16%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paperboard.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 14%-18% of the total burdens for 'Climate Change'. For thermal recovery, system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result mainly from the recovery of energy in MSWI plants. Because of the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix, energy credits sum up to only 7%. Material credits for 'Climate Change' are low (1% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 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 then is 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 CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 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 Water Portion Pack (ambient) segment, the biggest part (31%-40) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows a minor to considerable share of burdens for 'Climate Change (17%-23%) for the PET bottles in this segment.

The life cycle step 'top, closure & label' shows small to minor impacts shares (6%-15%) mainly attributed to the different plastics used for the closure.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (4%-5%) for climate change.

The life cycle steps 'filling' (5%-10%) and 'distribution' (1%-2%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares (20%-22%) for the assessed plastic bottles resulting from the recycling and incineration in MSWI plants of the bottle.

Material credits from the 27.5% recycled PET bottles reduce the total burdens by 1%-6% by substituting virgin PET.

For the PET bottles energy credits are low (5%-6%) due to the low thermal efficiency of MSWI with energy recovery in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

Small amounts of CO_2 uptake and corresponding CO_2 reg. emissions are caused by the biogenic material in secondary and tertiary packaging.

Aluminium can (specifications see section 2.2.2)

In the assessed aluminium can system in the Water Portion Pack (ambient) segment, the biggest part (36%) of the environmental burdens for 'Climate Change' is caused by the production of the aluminium of the can body.

The 'converting' process shows also a considerable share of burdens for 'Climate Change' (26%) for the can body.

The life cycle step 'top, closure & label' shows considerable impacts shares (21%) attributed to the aluminium production and converting of the cap of the can.

The life cycle steps 'transport packaging' (6%), 'filling' (3%) and 'distribution' (1%) show only small shares of burdens for the can.

The aluminium cans' 'recycling & disposal' life cycle step shows small shares of burdens regarding 'Climate Change' (6%). These result mainly from the recycling process of aluminium.

Material credits from 69% recycled aluminium cans reduce the overall 'Climate Change' burdens by around 15%. Most of the aluminium is being recycled in a closed loop feeding the 50% recycled content of the aluminium cans leading to lower impacts from aluminium production. The influence of energy credits on the net result is low (1% of total burdens) due to the low heating value of aluminium.

5.9.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.9.1.

Table 98: Comparison of net results: **TT Midi Eifel C38 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 IE	The net results of **TT Midi Eifel C38 plant-based** **330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	+9%	-2%	+61%	+27%	-40%	-37%	-22%	+15%	-64%

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

Table 99: Comparison of net results: **TT Midi plant-based Eifel C38 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 IE	The net results of **TT Midi plant-based Eifel C38 plant-based** **330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-8%	-10%	+48%	+16%	-45%	-42%	-29%	+6%	-67%

Table 100: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 IE	The net results of **TPA Edge plant-based DreamCap 26 plant-based** **330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	+3%	+12%	+65%	+30%	-39%	-35%	-20%	+18%	-64%

Table 101: Comparison of net results: **TT Midi plant-based Eifel C38 plant-based 500 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 IE	The net results of **TT Midi plant-based Eifel C38 plant-based** **500 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-38%	-32%	-39%	-21%	-63%	-61%	-52%	-29%	-78%

Table 102: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 500 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 50%

Water Portion Pack (ambient) Allocation 50 IE	The net results of **TPA Edge plant-based DreamCap 26 plant-based** **500 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-21%	-14%	-23%	+27%	-53%	-50%	-39%	-9%	-72%

5.10 Results allocation factor 100%; Water Portion Pack (ambient)

5.10.1 Presentation of results Water Portion Pack (ambient)

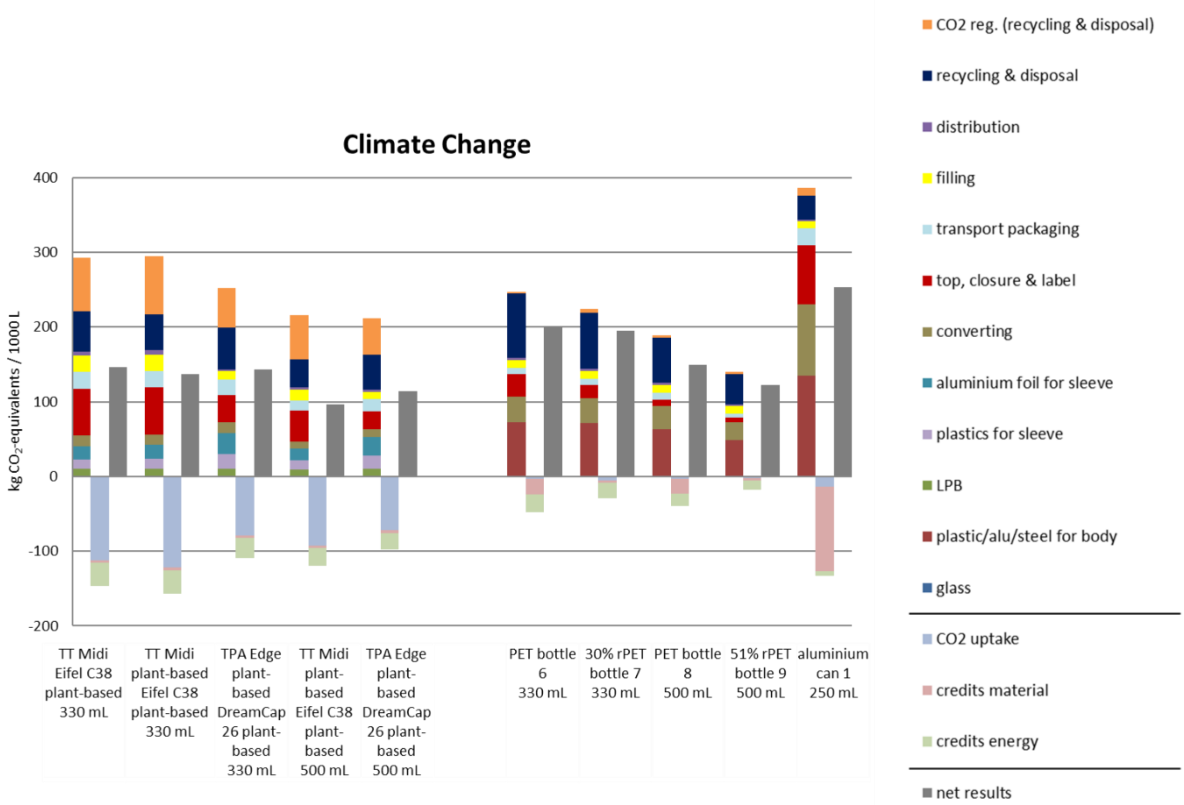

Figure 44: Climate Change results of **segment Water Portion Pack (ambient)**, allocation factor 100%

Table 103: Climate Change results of **segment Water Portion Pack (ambient)** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Water Portion Pack (ambient) Allocation 100 IE		TT Midi C38 plant-based 330 mL	TT Midi plant-based C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL		PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change [kg CO_2-e/1000 L]	burdens	220.60	216.53	198.78	156.52	163.19		244.60	219.40	186.15	137.28	375.43
	CO_2 (reg)	72.24	77.73	53.07	59.35	48.54		2.83	4.48	2.89	2.49	10.82
	credits	-35.06	-35.06	-29.84	-26.93	-25.86		-44.57	-23.53	-36.15	-14.94	-119.58
	CO_2 uptake	-111.86	-121.85	-78.97	-92.40	-72.03		-3.03	-5.24	-3.10	-2.67	-13.78
	net results	145.91	137.36	143.04	96.55	113.85		199.82	195.11	149.79	122.16	252.89

5.10.2 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 5.9.2).

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 substituted coal in cement kilns 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 carton in the segment 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 matter is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In case of PET bottles higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% due to the low recycling rate and low thermal efficiency of MSWI in Ireland and a relatively low 'Climate Change' intensive substituted electricity mix.

In the case of the PET bottles with 30% and 51% recycled PET content higher net results for 'Climate Change' are additionally 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 aluminium can, lower net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as with the high recycling rate of aluminium cans material credits show higher benefits than the burdens of the recycling process.

5.10.3 Comparison between packaging systems

The following tables show the net results per FU of the assessed beverage carton 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 comparison[1]. The absolute values of net results are shown in the result table in section 5.10.1.

Table 104: Comparison of net results: **TT Midi Eifel C38 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 IE	The net results of **TT Midi Eifel C38 plant-based 330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	+6%	+2%	+51%	+28%	-27%	-25%	-3%	+19%	-42%

Table 105: Comparison of net results: **TT Midi plant-based Eifel C38 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 IE	The net results of **TT Midi plant-based Eifel C38 plant-based 330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-6%	-4%	+42%	+21%	-31%	-30%	-8%	+12%	-46%

Table 106: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 330 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 IE	The net results of **TPA Edge plant-based DreamCap 26 plant-based 330 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-2%	+4%	+48%	+26%	-28%	-27%	-5%	+17%	-43%

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

Table 107: Comparison of net results: **TT Midi plant-based Eifel C38 plant-based 500 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 IE	The net results of **TT Midi plant-based Eifel C38 plant-based** **500 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-34%	-30%	-33%	-15%	-52%	-51%	-36%	-21%	-62%

Table 108: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 500 mL** versus competing cartons and alternative packaging systems in **segment Water Portion Pack (ambient)**, allocation factor 100%

Water Portion Pack (ambient) Allocation 100 IE	The net results of **TPA Edge plant-based DreamCap 26 plant-based** **500 mL** are lower (green)/ higher (red)/ similar (white) than those of								
	TT Midi Eifel C38 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 330 mL	TPA Edge plant-based DreamCap 26 plant-based 330 mL	TT Midi plant-based Eifel C38 plant-based 500 mL	PET bottle 6 330 mL	30% rPET bottle 7 330 mL	PET bottle 8 500 mL	51% rPET bottle 9 500 mL	aluminium can 1 250 mL
Climate Change	-22%	-17%	-20%	+18%	-43%	-42%	-24%	-7%	-55%

6 Scenario variants

6.1 UK – recycled content of PET, HDPE and aluminium packaging systems

PET bottles, HDPE bottles and aluminium cans in the base scenarios are modelled with their specific share of recycled content. As PET bottles, HDPE bottles and aluminium cans could be produced with 30%, 50% and 100% recycled content, scenario variants are calculated for the packaging systems listed in Table 27. In these analyses, the allocation factor applied for open-loop-recycling is 50%. Results are shown in the following break-even graphs.

6.1.1 Dairy Family Pack (chilled)

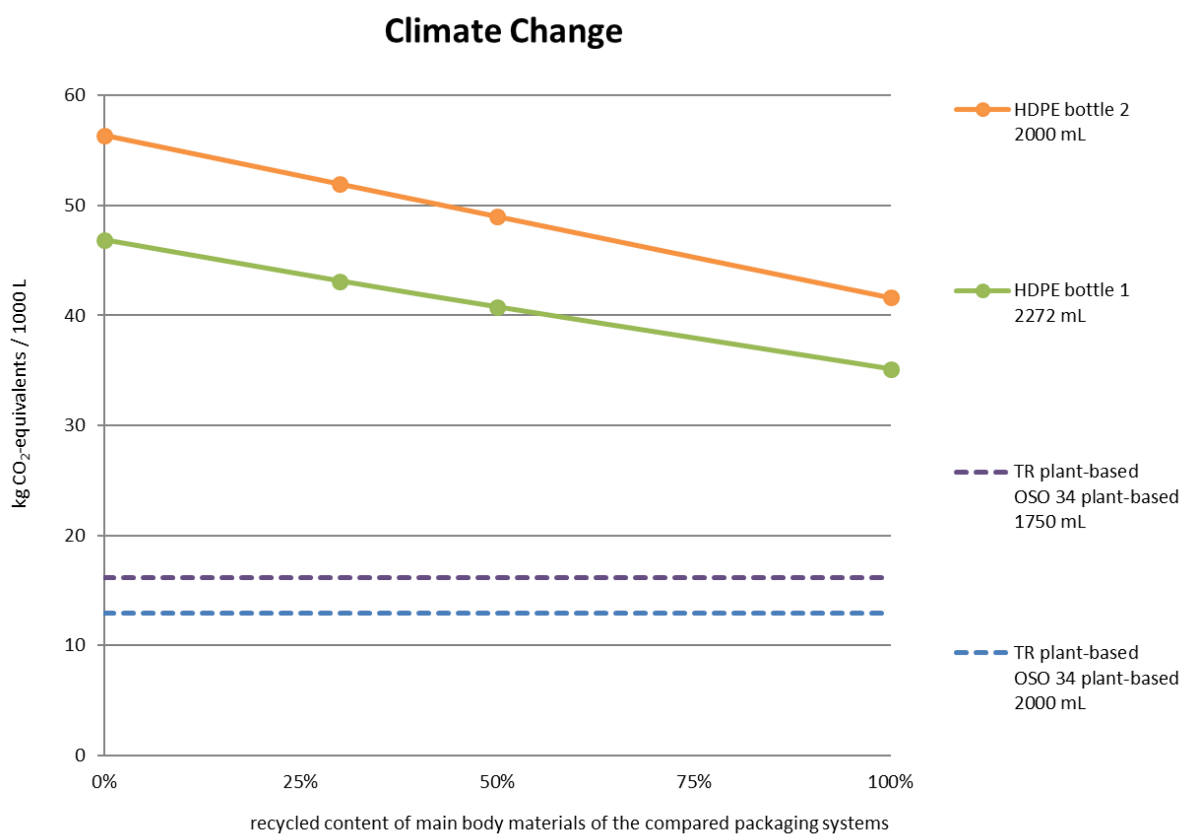

Figure 45: Results for scenario variants recycled HDPE of segment Dairy Family Pack (chilled), UK, allocation factor 50%

Description and Interpretation

The ranking between the HDPE bottles with increased recycled content (0%, 30%, 50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

6.1.2 Water Family Pack (ambient)

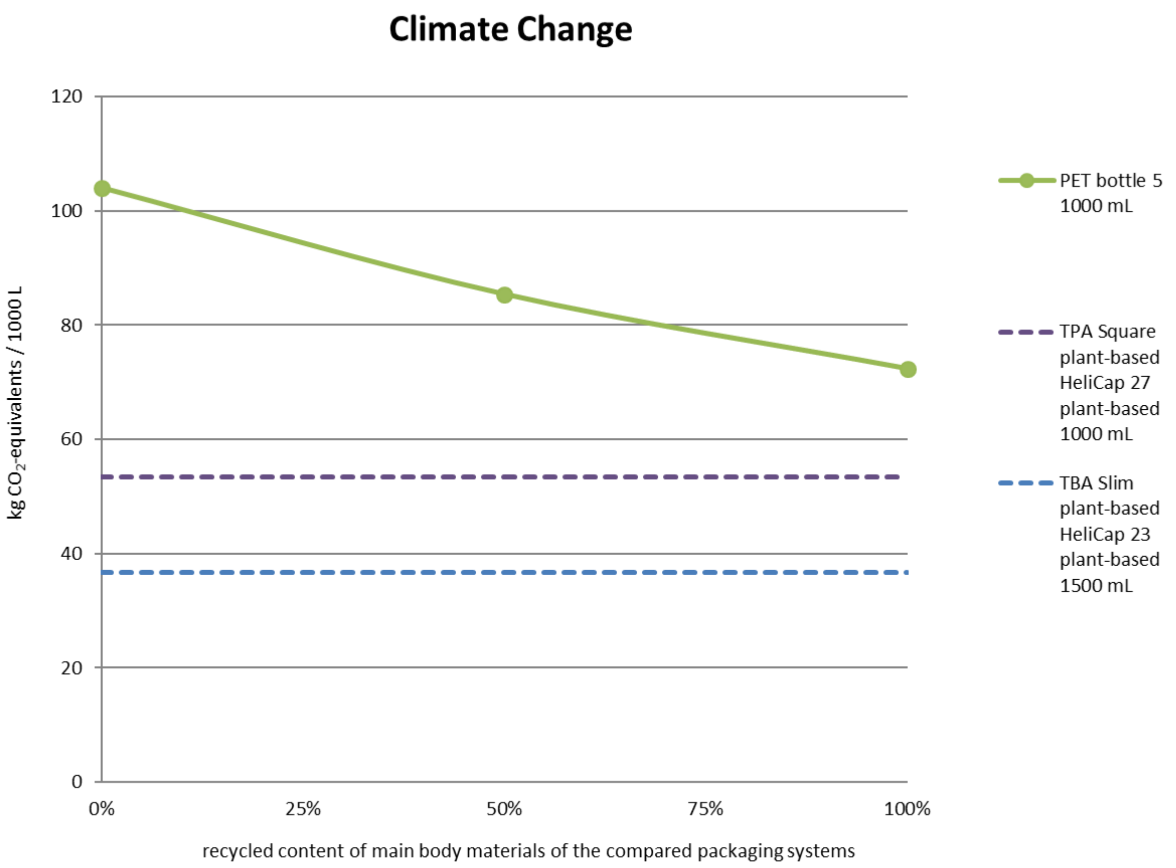

Figure 46: Results for scenario variants recycled PET of segment Water Family Pack (ambient), UK, allocation factor 50%

Description and Interpretation

The ranking between the PET bottle with increased recycled content (0%, 50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

6.1.3 Water Portion Pack (ambient)

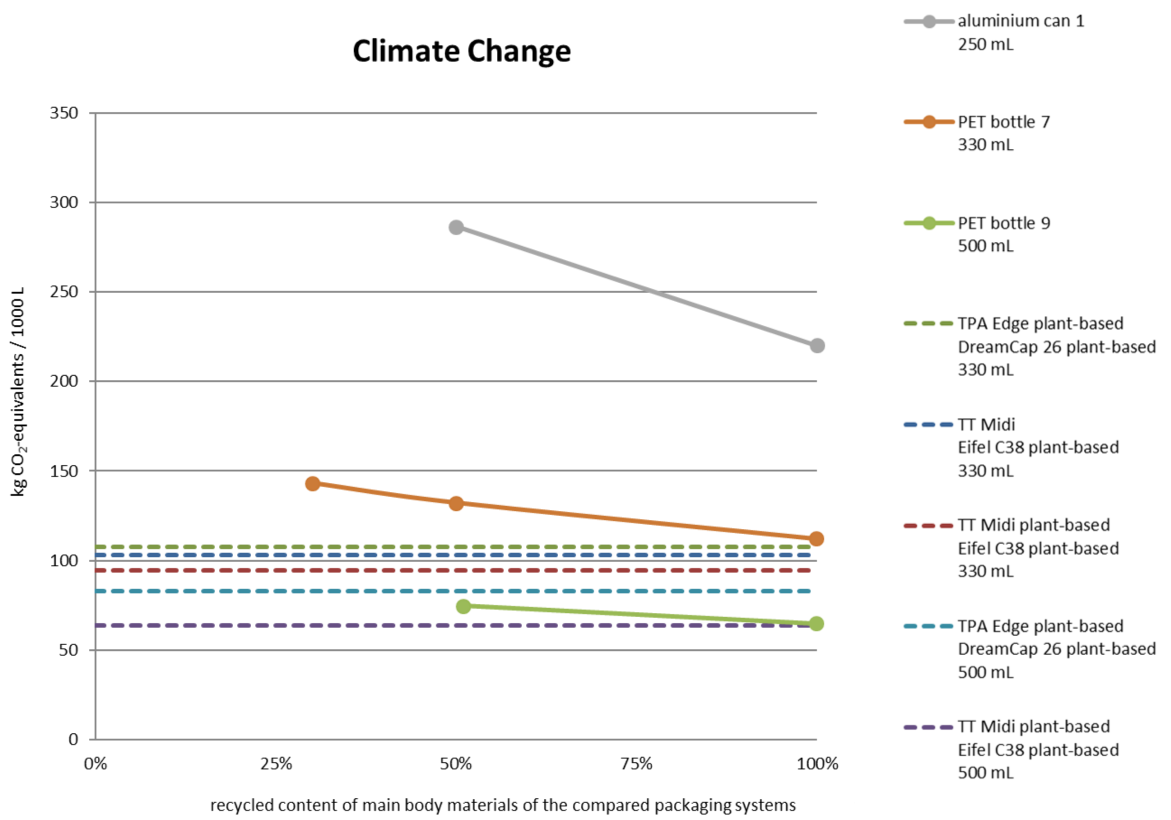

Figure 47: Results for scenario variants recycled PET and aluminium of segment Water Portion Pack (ambient), UK, allocation factor 50%

Description and Interpretation

The ranking between the aluminium can 1 with increased recycled content (50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

The increase of recycled PET content (30%, 50% and 100%) of the 330 mL PET bottle 7 leads with a recycled PET content of 100% to similar impacts as the 330 mL TPA Edge plant-based DreamCap 26 plant-based. Compared to the other regarded beverage cartons the ranking stays the same.

The increase of recycled PET content (50% and 100%) of the 500 mL PET bottle 9 leads with a recycled PET content of 100% to similar impacts as the 500 mL TT Midi plant-based C38 plant-based as well as to lower impacts than the 500 mL TPA Edge plant-based DreamCap 26 plant-based. Compared to the other regarded beverage cartons the ranking stays the same.

6.2 IE – recycled content of PET, HDPE and aluminium packaging systems

PET bottles, HDPE bottles and aluminium cans in the base scenarios are modelled with their specific share of recycled content. As PET bottles, HDPE bottles and aluminium cans could be produced with 30%, 50% and 100% recycled content, scenario variants are calculated for the packaging systems listed in Table 27. In these analyses, the allocation factor applied for open-loop-recycling is 50%. Results are shown in the following break-even graphs.

6.2.1 Dairy Family Pack (chilled)

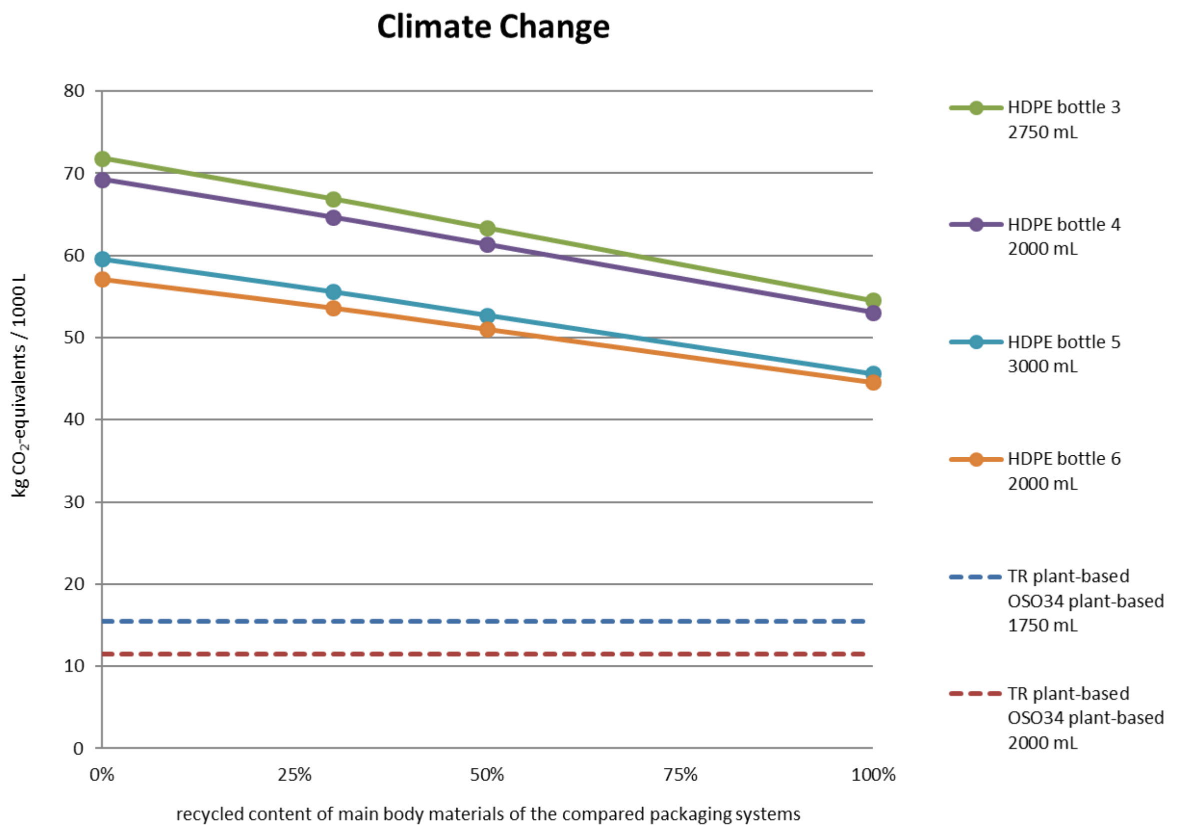

Figure 48: Results for scenario variants recycled HDPE of segment Dairy Family Pack (chilled), IE, allocation factor 50%

Description and Interpretation

The ranking between the HDPE bottles with increased recycled content (0%, 30%, 50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

6.2.2 Water Family Pack (ambient)

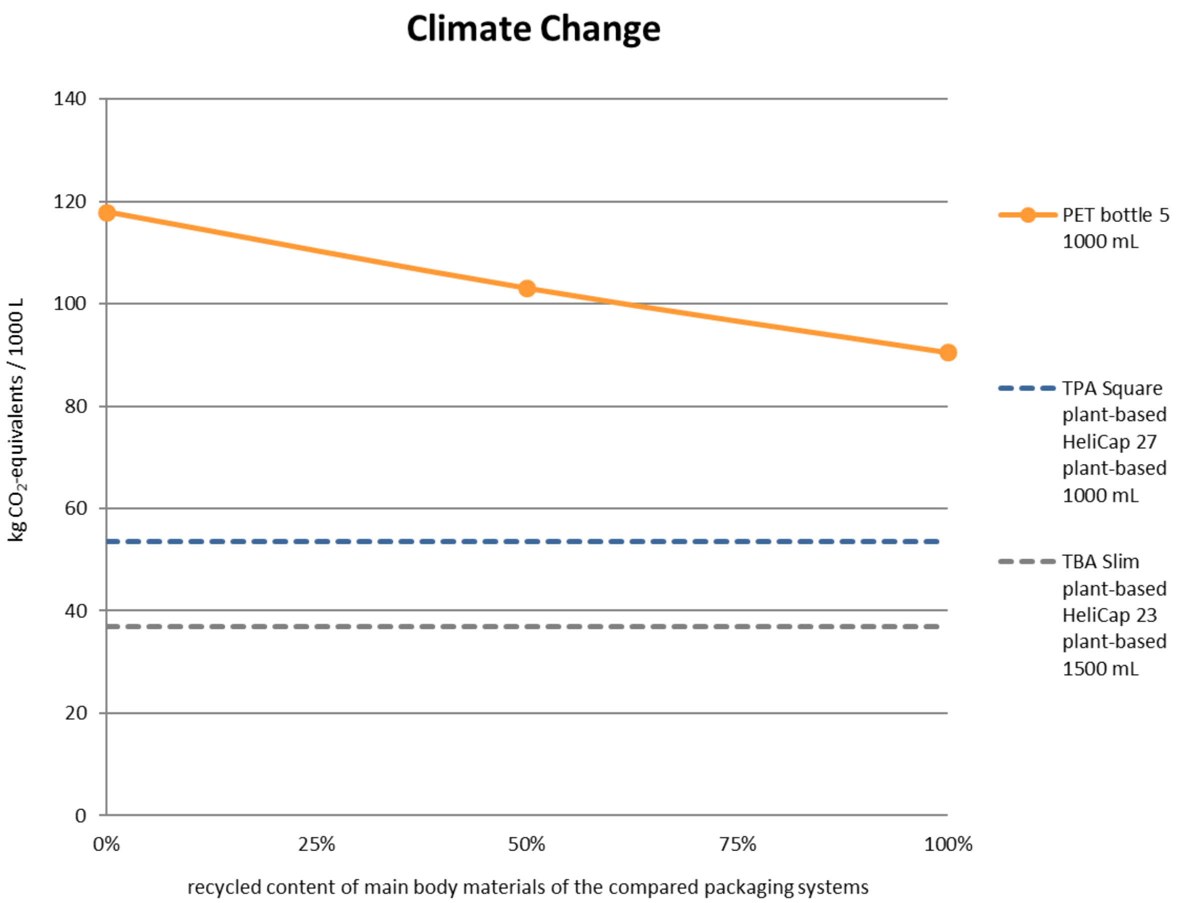

Figure 49: Results for scenario variants recycled PET of segment Water Family Pack (ambient), IE, allocation factor 50%

Description and Interpretation

The ranking between the PET bottle with increased recycled content (0%, 50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

6.2.3 Water Portion Pack (ambient)

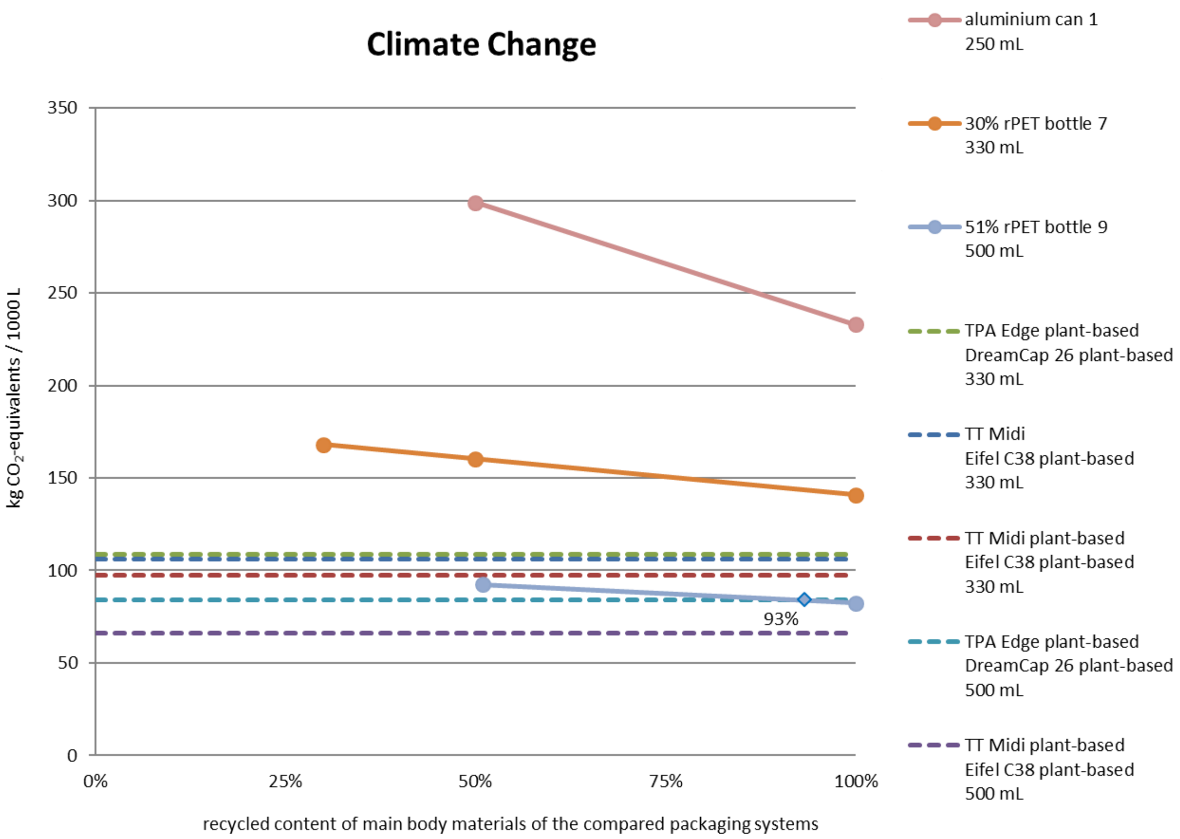

Figure 50: Results for scenario variants recycled PET and aluminium of segment Water Portion Pack (ambient), IE, allocation factor 50%

Description and Interpretation

The ranking between the aluminium can 1 with increased recycled content (50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

The ranking between the PET bottle 7 with increased recycled PET content (30%, 50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

PET bottle 9 (500 mL) with increased recycled PET content (100%) shows one breakeven point with a recycled content of about 93% with the TPA Edge plant-based DreamCap 26 plant-based (500 mL). Increasing the recycled PET content to 100% of the PET bottle 9 (500 mL) therefore leads to lower impacts than the TPA Edge plant-based DreamCap 26 plant-based (500 mL). In the ranking these two packaging systems stay similar.

7 Conclusions UK

The following sections summarise the results of the packaging systems in the different segments on UK market. In addition, conclusions are drawn regarding Climate Change. In this section results with the 50% allocation factor and the 100% allocation factor are taken into account to the same degree. Also the scenario variants regarding the increase of recycled content are considered. 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).

7.1 Dairy Family Pack (chilled)

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

In the **scenario variants**, the assessed beverage cartons in this segment show lower impacts than the HDPE bottles with a recycled content of up to 100%.

7.2 Dairy Alternative Family Pack (ambient)

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

7.3 Dairy Alternative Family Pack (chilled)

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

7.4 Water Family Pack (ambient)

For 'Climate Change' the assessed beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared 50% rPET bottle 4 (1500 mL) and PET bottle 5 (1000 mL).

Compared to the 100% rPET bottle 3 (1500 mL) the assessed beverage cartons do not show throughout lower impacts. With both allocation factors 50% and 100%, the only beverage carton with lower impacts compared to the 100% rPET bottle 3 is TBA Slim plant-based HeliCap 23 plant-based (1500 mL). The TPA Square plant-based HeliCap 27 plant-based (1000 mL) beverage carton shows similar (allocation factor 50%) or higher (allocation factor 100%) impacts than the 100% rPET bottle 3 (1500 mL).

In the **scenario variants**, the assessed beverage cartons in this segment show lower impacts than the PET bottles with a recycled PET content of up to 100%.

7.5 Water Portion Pack (ambient)

The volume of packaging systems in this segment ranges from 250 mL to 500 mL. Regarding comparisons of packaging systems with different volumes, packaging systems with higher volumes have a benefit as their packaging weight per functional unit is usually lower than the packaging weight per functional unit of the packaging systems with lower volumes.

For 'Climate Change' the beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared PET bottle 6 (330 mL), and aluminium can 1 (250 mL).

Compared to the 30% rPET bottle 7 all assessed beverage cartons do show lower impacts with the allocation factor 50%. With allocation factor 100% all regarded beverage cartons except the TT Midi Eifel C38 plant-based (330 mL) show lower impacts than the 30% rPET bottle 7 (330 mL). With allocation factor 100% the TT Midi Eifel C38 plant-based 330 mL shows similar impacts as the 30% rPET bottle 7.

Compared to the PET bottle 8 (500 mL) all assessed beverage cartons except the TPA Edge plant-based DreamCap 26 plant-based (330 mL) do show lower impacts with the allocation factor 50%. With allocation factor 50% the TPA Edge plant-based DreamCap 26 plant-based (330 mL) shows similar impacts as the PET bottle 8 (500 mL).

With allocation factor 100% TT Midi plant-based Eifel C38 plant-based (500 mL) shows lower impacts than the PET bottle 8 (500 mL). With allocation factor 100% the TT Midi Eifel C38 plant-based (330 mL) and the TPA Edge plant-based DreamCap 26 plant-based (330 mL) show higher impacts than the PET bottle 8 (500 mL).

Compared to the 51% rPET bottle 9 (500 mL) the assessed beverage cartons do not show throughout lower impacts. With both allocation factors 50% and 100%, the only beverage carton with lower impacts compared to the 51% rPET bottle 9 (500 mL) is TT Midi plant-based Eifel C38 plant-based 500 mL. All other regarded beverage cartons show higher impacts than the 51% rPET bottle 9 (500 mL) with both allocation factors 50% and 100% except TPA Edge plant-based DreamCap 26 plant-based (500 mL) showing similar impacts in allocation factor 100%.

In the **scenario variants**, the ranking between the aluminium can 1 with increased recycled content (50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

The increase of recycled PET content (30%, 50% and 100%) of the 330 mL PET bottle 7 leads, with a recycled PET content of 100%, to similar impacts as the 330 mL TPA Edge plant-based DreamCap 26 plant-based. Compared to the other regarded beverage cartons the ranking stays the same.

The increase of recycled PET content (50% and 100%) of the 500 mL PET bottle 9 leads, with a recycled PET content of 100%, to similar impacts as the 500 mL TT Midi plant-based C38 plant-based as well as to lower impacts than the 500 mL TPA Edge plant-based DreamCap 26 plant-based. Compared to the other regarded beverage cartons the ranking stays the same.

7.6 Liquid Food Portion Pack (ambient)

For 'Climate Change' the liquid food cartons assessed in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared glass jars, pouches and steel can in UK.

8 Conclusions Ireland

The following sections summarise the results of the packaging systems in the different segments on the Irish market. In addition, conclusions are drawn regarding Climate Change. In this section results with the 50% allocation factor and the 100% allocation factor are taken into account to the same degree. Also the scenario variants regarding the increase of recycled content are considered. 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).

8.1 Dairy Family Pack (chilled)

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

The assessed beverage cartons in this segment show lower impacts than the HDPE bottles with a recycled content of up to 100%.

8.2 Dairy Alternative Family Pack (ambient)

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

8.3 Dairy Alternative Family Pack (chilled)

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

8.4 Water Family Pack (ambient)

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

In the **scenario variants**, the assessed beverage cartons in this segment show lower impacts than the PET bottle with a recycled PET content of up to 100%.

8.5 Water Portion Pack (ambient)

The volume of packaging systems in this segment ranges from 250 mL to 500 mL. Regarding comparisons of packaging systems with different volumes, packaging systems with higher volumes have a benefit as their packaging weight per functional unit is usually lower than the packaging weight per functional unit of the packaging systems with lower volumes.

For 'Climate Change' the beverage cartons in this segment show lower impacts with both, the 50% and the 100% allocation factor than the compared PET bottle 6 (330 mL), 30% rPET bottle 7 (330 mL) and aluminium can 1 (250 mL).

Compared to the PET bottle 8 (500 mL) all assessed beverage cartons do show lower impacts with the allocation factor 50%. With allocation factor 100% the regarded beverage cartons show lower or similar impacts than the PET bottle 8.

Compared to the 51% rPET bottle 9 (500 mL) the assessed beverage cartons do not show throughout lower impacts. With both allocation factors 50% and 100%, the only beverage carton with lower impacts compared to the 51% rPET bottle 9 is TT Midi plant-based Eifel C38 plant-based (500 mL). All other regarded beverage cartons show higher or similar impacts than the 51% rPET bottle 9 with both allocation factors 50% and 100%.

In the **scenario variants**, the ranking between the aluminium can 1 with increased recycled content (50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

Furthermore, the ranking between the PET bottle 7 with increased recycled PET content (30%, 50%, 100%) and the compared beverage cartons stays the same with the regarded increase of recycled content.

PET bottle 9 (500 mL) with increased recycled PET content (50%, 100%) shows with a recycled content of approximately 97% a break even point with the TPA Edge plant-based DreamCap 26 plant-based (500 mL). In the ranking, these two packaging systems stay similar. The increase to a recycled PET content of 100% of the PET bottle 9 leads to lower impacts than the TT Midi plant-based Eifel C38 plant-based (330 mL).

9 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 (chilled), Dairy Alternative (ambient and chilled), 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 UK and Irish 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 UK and Ireland, 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. The applied treatment in cement kilns of white opaque HDPE bottles sorted out after collection is applied based on their typical treatment in cement kilns in Germany.

Limitations concerning the **reference period**:
The results are valid only for the indicated reference year 2021 based on data from 1996 – 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 the environmental category 'Climate Change'.

10 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 performances regarding Climate Change depending on different segments as well as their packaging specifications. Beverage and liquid food cartons benefit from the CO_2 uptake of their biogenic materials in terms of cardboard and in case of plant-based beverage cartons also plant-based polymers. This benefit is shown in a different extent depending on the chosen allocation approach. All conclusions and recommendations are based on the equally consideration of both applied approaches.

Alternative packaging systems examined in this study show high burdens from the production of their base materials, like plastics, glass, aluminium 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 general beverage and liquid food carton systems as well as alternative packaging systems benefit from a larger filling volume leading to lower impacts per functional unit as in most cases the amount of packaging material per functional unit decreases with higher filling volumes. This can be seen for example in the results for the segment Dairy Family Pack (chilled), UK (see section 4.1.1).

In the UK and Ireland Dairy Family Pack (chilled), Dairy Alternative Family Pack (ambient and chilled) and Liquid Food Portion Pack (ambient) segments assessed in this report, the beverage and food cartons show lower climate change impacts than the compared plastic, glass and steel packaging systems.

In addition, in the Water Family Pack (ambient) segment in Ireland, which is examined in this report, beverage cartons show lower climate change impacts than the plastic packaging systems compared.

In the UK and Ireland Water Portion Pack (ambient) and the UK Water Family Pack (ambient) 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 (Schlecht / Wellenreuther 2020) 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. It is important though, to keep in mind that the different geographic parameters also have a major impact on the results.
- In regards to Climate Change it is recommended to prefer beverage cartons over the compared alternative packaging systems in the segments Dairy Family Pack (chilled), Dairy Alternative Family Pack (ambient and chilled), Water Family Pack (ambient) and Liquid Food Portion Pack (ambient)
- As a high share of the Climate Change impacts of beverage and food cartons results from the emissions from landfills, it is recommended to work towards a lower share of beverage and food cartons ending up on landfills.

Compared to the European baseline study finalised (Schlecht / Wellenreuther 2020), beverage and liquid food cartons generally show lower or similar results in the UK and Ireland than similar cartons on the European market. The main reason is the lower landfill rate in UK and Ireland, leading to lower methane emissions from the degradation of paper.

11 References

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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 CO_2 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 CO_2 equivalent.

When calculating CO_2 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 global warming potentials (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 2021).

An excerpt of the most important substances taken into account when calculating the Climate Change are listed below along with the respective CO_2-equivalent factors – expressed as Global Warming Potential (GWP).

Greenhouse gas	CO_2 equivalents (GWP_i)[1]
Carbon dioxide (CO_2). fossil	1
Methane (CH_4)[2] fossil	30
Nitrous oxide (N_2O)	273
Tetrafluoromethane (CF_4)	7380
Hexafluoroethane (C_2F_6)	12400
Halon 1301	7200
R22 ($CHClF_2$)	1960
Tetrachlormethane (CCl_4)	2200
Trichlorethane (CH_3CCl_3)	161
• Source: (IPCC 2021)	

Table A-1: Global warming potential for the most important substances taken into account in this study; CO_2 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.

[1] The values reported by [IPCC 2021] in Appendix A.1 were rounded off to whole numbers.
[2] According to (IPCC 2021), the indirect effect from oxidation of CH_4 to CO_2 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 CO_2 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 1995]: Intergovernmental panel on the climatic change. Climatic Change (IPCC; publisher). Report to the United Nations 1996. New York (USA) 1995.

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[IPCC, 2021] Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press. [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 UK and Irish 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"

Conducted by
IFEU - Institut für Energie- und Umweltforschung Heidelberg gGmbH (the "Practitioner")

Performed for
Tetra Pak® (the "Commissioner")

by

Guido Sonnemann (chairman)
Leigh Holloway
Harald Kaeb

07/04/2022

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1. Procedural Aspects of the Critical Review

This Critical Review was commissioned by Tetra Pak® (commissioner) via Martin Gehlen in late 2021 as a two-stage process. The Life Cycle Assessment (LCA) study was conducted by IFEU - Institut für Energie- und Umweltforschung Heidelberg gGmbH, Germany (practitioner).

A Final Draft Report was submitted on January 28th 2022, comments by the panel were sent on February 24th 2022, and discussed in the telephone conference on March 1st 2022. During the conference call the comments were elaborated by the panel members and discussed with the practitioner IFEU and the commissioner Tetra Pak (TP) in detail.

The review panel received a revised version of the Final Report of the study on March 25th 2022. The Panel had no further queries, so that a preliminary statement was prepared on April 2nd 2022.

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 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.

The present CR statement is delivered to Tetra Pak®. 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 UK and Irish 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 March 25th 2022 - 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, which has been carried out for the UK and Irish 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 study for the UK and Irish market, 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 study explicitly for the UK and Irish market 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 study for the UK and Irish market 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 UK and Irish 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 study for the UK and Irish market 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 study for the UK and Irish market 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 study for the UK and Irish market 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 UK and Irish market (TP products and competing products) are chosen by Tetra Pak according to an analogues 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 recycling quota in the UK and Irish market, 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 supplement study for the UK and Irish market 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 study for the UK and Irish market 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 assumptions of the End of Life (EoL) management in the UK and Irish market are comprehensibly derived and plausible. One feature of the EoL management in the UK and Irish market is that a large proportion is incinerated in comparison to landfilling. Reading research studies examining the level of biodegradation of paper and board in landfill (incl. ultilayer cellulose-based packaging or even liquid beverage cartons), the panel concluded that the results were poor and that more research was recommended to support a better estimate of the degradation rate degradation of carton board. The current hypothesis made in the study is that it behaves like coated paper-based material in general. A reference from 1997 is used to assume that 30% of paper is decomposed anaerobically on landfills. Another feature is that recycled content is very important, for instance the high recycled HDPE content in milk bottles. Therefore, the scenario variants regarding recycled content in PET bottles, HDPE bottles and aluminium cans were developed in this regional supplement for the UK and Irish market.

The influence of the GWP coming from the electricity mix is more or less in the European average in comparison to other regional supplements. The electricity mix of the UK is characterised by 39% natural gas, 5% coal, 20% nuclear, 10% biomass and 32% Hydropower/Wind/Solar /Geothermal, of which 92% wind power The Irish electricity mix is characterised by 51% natural gas, 13% coal, and 24% Hydropower/Wind/Solar /Geothermal, of which 76% wind power.

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 study for the UK and Irish market 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 this 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 study for the UK and Irish market 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 study for the UK and Irish market. 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 Mach 2020". Critical Review included

[ISO 14067] ISO 14067:2018. Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification

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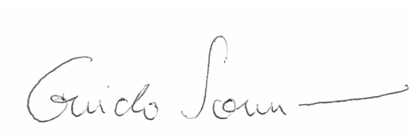		
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