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 Greek market

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

commissioned by Tetra Pak

Heidelberg, June 23rd 2021

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Heidelberg, May 17th 2021

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Abbreviations

ACE	Alliance for Beverage Cartons and the Environment
BC	Beverage carton
CED	Cumulative energy demand
CML	Centrum voor Milieukunde (Center of Environmental Science), Leiden University, Netherlands
COD	Chemical oxygen demand
CRD	Cumulative raw material demand
EA	European Aluminium
EEA	European Environment Agency
EU27+2	European Union & Switzerland and Norway
FEFCO	Fédération Européenne des Fabricants de Carton Ondulé (Brussels)
FU	Functional unit
GWP	Global Warming Potential
GR	Greece
HBEFA	Handbuch für Emissionsfaktoren (Handbook for Emission Factors)
ifeu	Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research)
IN	India
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JNSD	Juice, nectars and still drinks
LCA	Life cycle assessment
LCI	Life cycle inventory
LDPE	Low density polyethylene
LPB	Liquid packaging board
MIR	Maximum Incremental Reactivity
MSWI	Municipal solid waste incineration
NMIR	Nitrogen-Maximum Incremental Reactivity
NMVOC	Non-methane volatile organic compounds
NO_X	Nitrogen oxides

ODP	Ozone Depletion Potential
OW	One way
pc	packs
PET	Polyethylene terephthalate
PM2.5	Particulate matter with an aerodynamic diameter of 2.5 µm or smaller
PP	Polypropylene
rPET	recycled PET
SBM	Stretch blow moulding
TB	Tetra Brik
TBA	Tetra Brik Aseptic
TGA	Tetra Gemina Aseptic
TiO_2	Titanium dioxide
TPA	Tetra Prisma Aseptic
TR	Tetra Rex
TR	Turkey
TSA	Tetra Stelo Aseptic
UBA	Umweltbundesamt (German Federal Environmental Agency)
UHT	Ultra-heat treatment
VOC	Volatile organic compounds
WMO	World Meteorological Organization

1 Goal and scope

1.1 Background and objectives

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

An integral part of Tetra Pak's business strategy and activities is the systematic work on the efficient use of resources and energy. The 2020 environmental targets of Tetra Pak focus on the use of sustainable materials to continuously improve the entire value chain and the increase of recycling to further reduce the impact on the environment. Since 2006, Tetra Pak has had a partnership with the WWF, based on a shared commitment to promote responsible forest management. Tetra Pak are active members in the WWF's Global Forest & Trade Network (GFTN). Also, all paperboard sourced by Tetra Pak comes from wood from Forest Stewardship Council™ (FSC™)-certified forests and other controlled sources.

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

In February 2020 a European baseline study has been finalised [IFEU 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. These will focus on Climate Change and will refer to the European baseline study for other environmental impact categories.

This report is the local supplement study for the Greek market regarding the segments dairy (chilled), Juice, Nectars and still drinks (JNSD) (ambient and chilled), olive oil (ambient) and liquid food (ambient).

The goal of this study is to deliver the environmental 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 Greek market. This assessment is done following the rules of life cycle assessment (i.e. ISO 14040/14044), but without assessing further impact categories apart from Climate Change.

To get an indication of how the packaging systems examined in this study perform in other environmental impact categories like for example Acidification or Eutrophication one can also refer to the result of the European baseline study [IFEU 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 also includes packaging for olive oil, which was not included in the European baseline study. The packaging systems and their attributes are very similar to those of JNSD packaging, though, which is included in the European baseline study.

Competing packaging systems on the Greek market include:

- PET bottles
- Aluminium cans
- Steel cans (made from tin plate)
- Single use glass jars

All analysed packaging systems are divided into the segments

- 'Family Packs' (FP) with volumes from 750 mL to 1500 mL
- 'Portion Packs' (PoP) with volumes from 250 mL to 500 mL.

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

- DAIRY products like milk or milk drinks
  - Chilled family packs with the volume of 1000 mL – 1500 mL
  - Chilled portion packs with the volume of 330 mL – 500 mL
- Juice, Nectars and still drinks (JNSD)
  - Chilled family packs with the volume of 1000 mL
  - Ambient family packs with the volume of 1000 mL
  - Chilled portion packs with the volume of 250 mL – 330 mL
- Olive oil
  - Ambient family packs with the volume of 1000 mL
- liquid food
  - Ambient portion packs with the volume of 390 mL – 400 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 Greek 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 2020. It is being conducted by the Institute for Energy and Environmental Research Heidelberg GmbH (ifeu).

The members of the project panel are:

- **Tetra Pak**: Dina Epifanova, Christina Klouri, Adam Constantinos, Erika Kloow, Erik Lindroth
- **ifeu**: Samuel Schlecht, Frank Wellenreuther, Saskia Grünwasser

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

1.3 Use of the study and target audience

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

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

The members of the independent panel are

- Birgit Grahl (chair), INTEGRAHL, Germany
- Leigh Holloway, Eco3 Design Ltd, United Kingdom
- Guido Sonnemann, France

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

1.4 Functional unit

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

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

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

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

1.5 System boundaries

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

In general, the study covers the following steps:

- production, converting, recycling and final disposal of the primary base materials used in the primary packaging elements from the studied systems including closures and labels.
- production, converting, recycling and final disposal of primary packaging elements and related transports
- production, recycling and final disposal of transport packaging (stretch foil, pallets, cardboard trays)
- production and disposal of process chemicals, as far as not excluded by the cut-off criteria (see below)
- transports of packaging material from producers to converters and fillers
- 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
- environmental effects of cooling during transport where relevant (chilled dairy products and chilled JNSD PET bottles).

Not included are:

- the production and disposal of the infrastructure (machines, transport media, roads, etc.) and their maintenance (spare parts, heating of production halls) as no significant impact is expected. To determine if infrastructure can be excluded the authors apply two criteria by Reinout Heijungs [Heijungs et al. 1992] and Rolf Frischknecht [Frischknecht et al. 2007]: Capital goods should be included if the costs of maintenance and depreciation are a substantial part of the product and if environmental hot spots within the supply chain can be identified. Considering relevant information about the supply chain from producers and retailers both criteria are considered to remain unfulfilled. An inclusion of capital goods might also lead to data asymmetries as data on infrastructure is not available for many production data sets.

- production of beverage and liquid food and transport to fillers as no relevant differences between the systems under examination are to be expected
- distribution of beverage and liquid food from the filler to the point-of-sale (distribution of packages is included).
- environmental effects from accidents like breakages during transportation.
- losses of beverage and liquid food at different points in the supply and consumption chain which might occur for instance in the filling process, during handling and storage, etc. as they are considered to be roughly the same for all examined packaging systems. Significant differences in the amount of lost beverage and liquid food between the assessed packaging systems might be conceivable only if non-intended uses or product treatments are considered as for example in regard to different 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 are being cooled at the points of sales
- transport of filled packages from the point of sale to the consumer as no relevant differences between the systems under examination are to be expected and the implementation would be highly speculative as no reliable data is available.
- use phase of packages at the consumers as no relevant differences between the systems under examination are to be expected (for example in regard to cleaning before disposal or chilling at home) and the implementation would be highly speculative as no reliable data is available.

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), single use glass bottle/jar (Figure 3) and steel can (Figure 4).

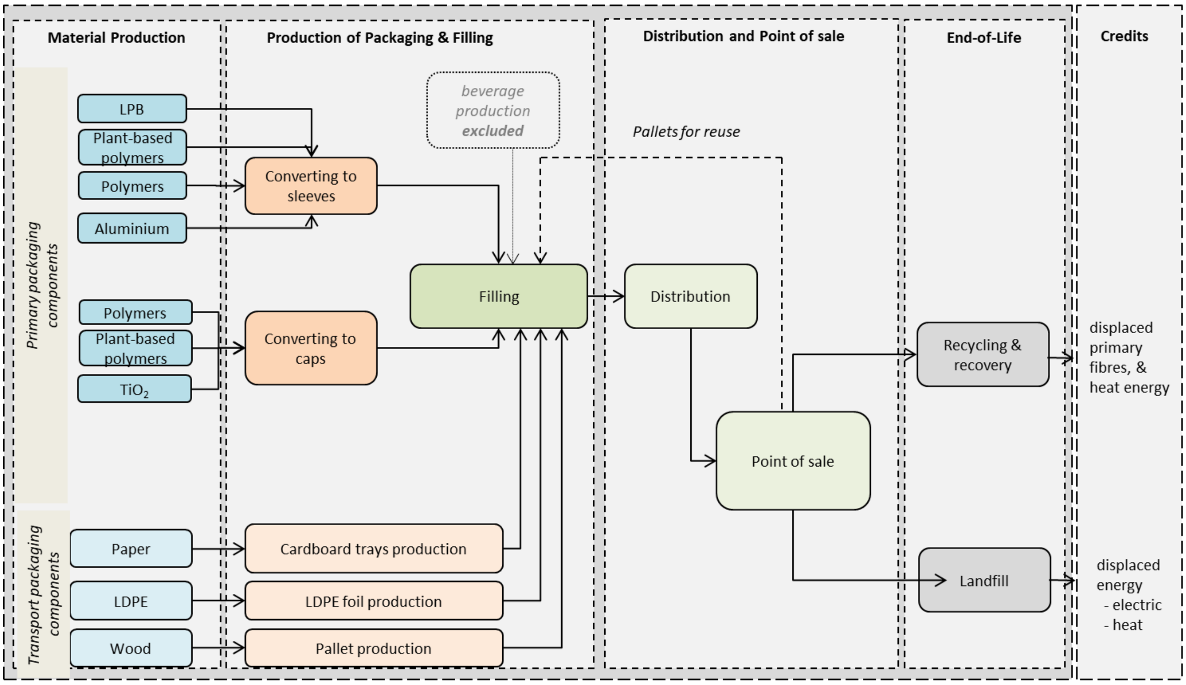

Figure 1: System boundaries of beverage and liquid food cartons

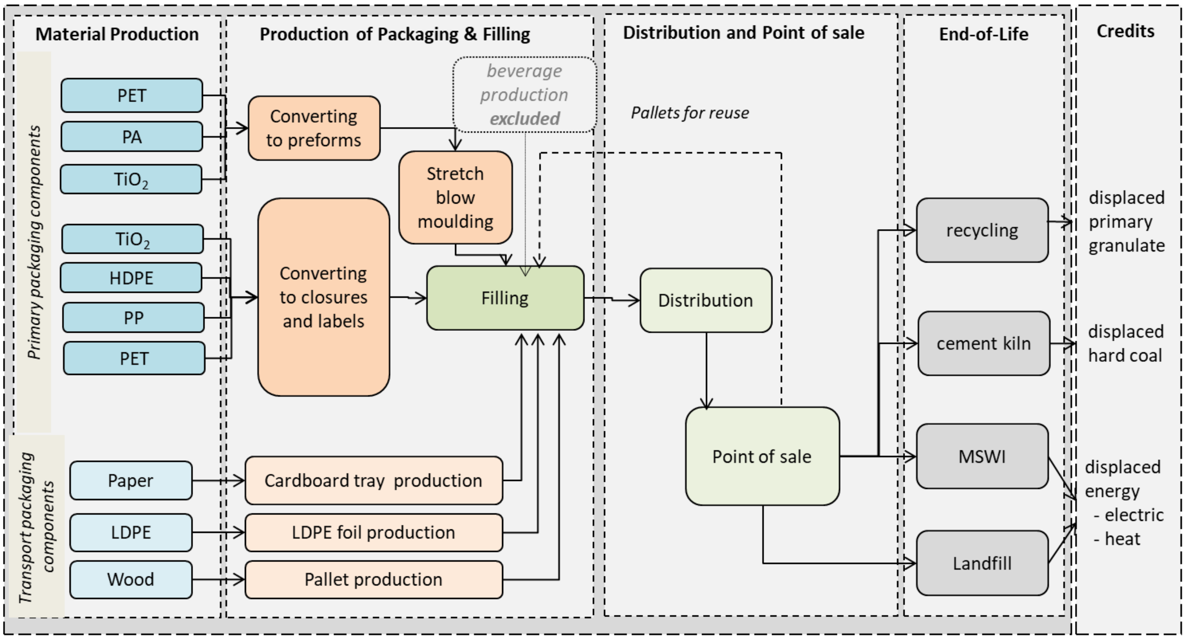

Figure 2: System boundaries of PET bottles

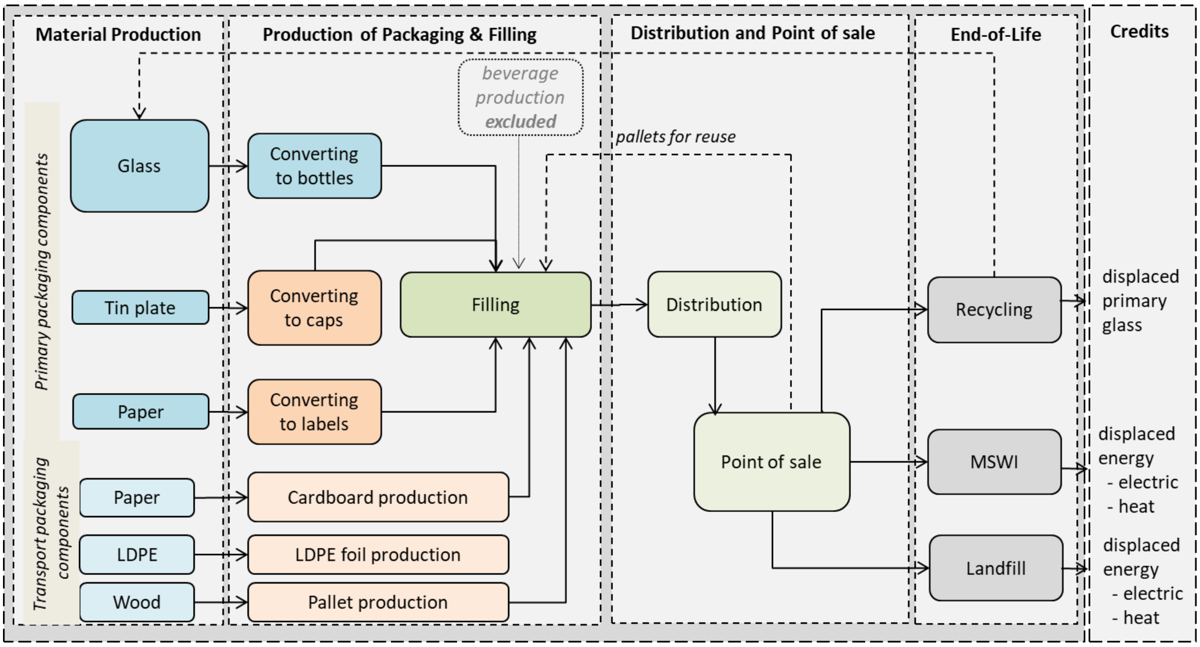

Figure 3: System boundaries of single use glass jars

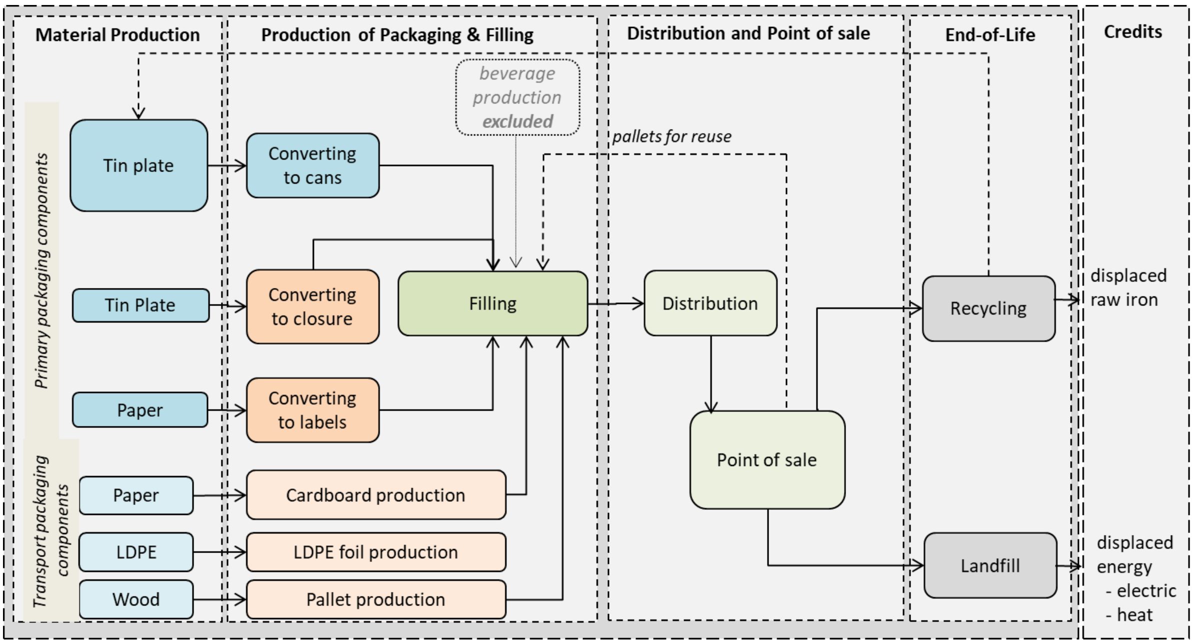

Figure 4: System boundaries steel can

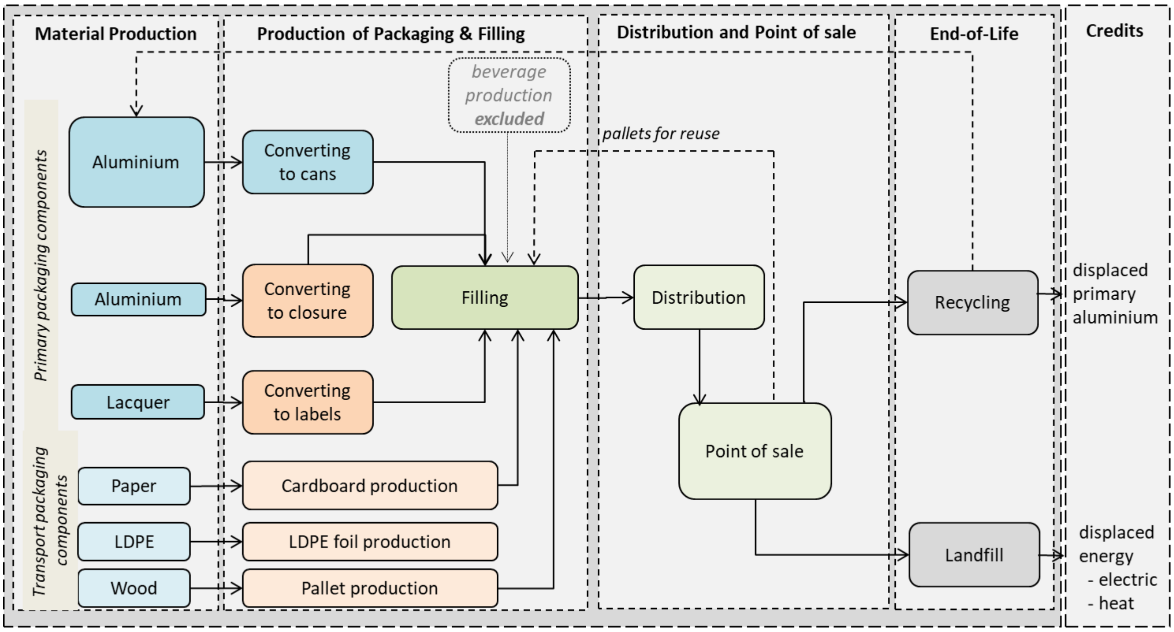

Figure 5: System boundaries aluminium can

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], cut-off criteria shall consider mass, energy or environmental significance. Regarding mass-related cut-off, prechains from preceding systems with an input material share of less than 1% of the total mass input of a considered process were excluded from the present study. However, total cut-off is not to surpass 5% of input materials as referred to the functional unit. In rare cases low input material shares may show environmental relevance, for example flows that include known toxic substances. In these cases no cut off of these low input materials is applied. 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 in all analysed impact categories 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.

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

In case of End of Life, shares of primary packaging material are exported for recycling. These shares are stated in Table 1 as well as in the flow charts describing the end of life of each packaging type in section 2.3. For recycling processes country-specific data is generated by using European process data as a proxy combined with the local electricity mixes (see section 3.13).

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

	Beverage cartons	PET bottles	Glass jars	Steel cans	Aluminium cans
materials					
LPB	Sweden, Finland				
polymers	Europe	Europe			
plant-based polymers	Brazil				
aluminium	Europe				Europe
tinplate			Europe	Europe	
glass			Europe		
converting					
bodies	Europe	Greece*	Europe**	Greece	Greece
closures	Greece	Greece			Greece
End of Life	Greece (40%), Turkey (30%), India (30%)	Greece (78%), Europe (22%)	Europe (100%)	Greece	Greece, Europe***

* Additional sensitivity analysis with PET preform production in Europe

** As all Greek post-consumer glass is exported to Europe and glass production includes high shares of glass cullet, also the glass body production is modelled in Europe

*** The applied dataset is only available as aggregated European dataset. Therefore for the recycling of aluminium cans no local electricity mixes is applied.

Time scope

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

The applied data is as up-to-date as possible referring to the period between 1999 and 2020 (see Table 28 in section 3). Where only old datasets are available, the data has been checked for its representativeness (see for example the choice of dataset for PA6 described in section 3.1.6). Particularly with regard to data on end-of-life processes of the packages examined, the most current available information is used to correctly represent the recent changes in this area. The datasets for transportation, energy generation and waste treatment processes are taken from ifeu's internal database in the most recent version. The data for plastic production originates from the Plastics Europe datasets and refer to different years, depending on material and year of publication.

More detailed information on the applied life cycle inventory data sets can be found in section 3.

Technical reference

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

Completeness

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

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

Life cycle steps	Beverage / liquid food cartons	PET bottles	Aluminium cans	Steel cans	Glass bottles/ jars	Complete?	Repre-sentative?
	x: inventory data for all processes available						
Base material production	x	x	x	x	x	yes	yes
Production of packaging (converting)	x	x	x	x	x	yes	yes
Filling	x	x	x	x	x	yes	yes
Distribution	x	x	x	x	x	yes	yes
Transportation of materials to the single production steps	x	x	x	x	x	yes	yes
	End of life						
Recycling processes	x	x	x	x	x	yes	yes
MSWI	x	x	x	x	x	yes	yes
Landfill	x	x	x	x	x	yes	yes
Credits	x	x	x	x	x	yes	yes
	Life Cycle Impact Assessment						
'Climate Change'	x	x	x	x	x	yes	yes

Consistency

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

Sources of data

Process data for base material production and converting were either collected in cooperation with the industry or taken from literature and the ifeu database. Ifeu's internal database includes data either collected in cooperation with industry or is based on literature. The database is continuously updated. Background processes such as energy generation, transportation, MSWI and landfill were taken from the most recent version of it. All data sources are summarised in Table 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 of input or output flows of a process or a product system between the product system under study and one or more other product systems" [ISO 14044, definition 3.17]. This definition comprises the partitioning of flows regarding re-use and recycling, particularly open loop recycling.

In the present study, a distinction is made between process-related and system-related allocation, the former referring to allocation procedures in the context of multi-input and multi-output processes and the latter referring to allocation procedures in the context of open loop recycling.

Both approaches are further explained in the subsequent sections.

Process-related allocation

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

Multi-input processes

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

Multi-output processes

For data sets prepared by the authors of this study, the allocation of the outputs from coupled processes is generally carried out via the mass 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 functional unit of the study defines a fixed amount of beverage and liquid food through all scenarios. Impacts related to transporting the beverage and liquid food itself would be the same in all scenarios. Thus, they don't need to be included in this comparative study of beverage and liquid food packaging systems.

System-related allocation

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

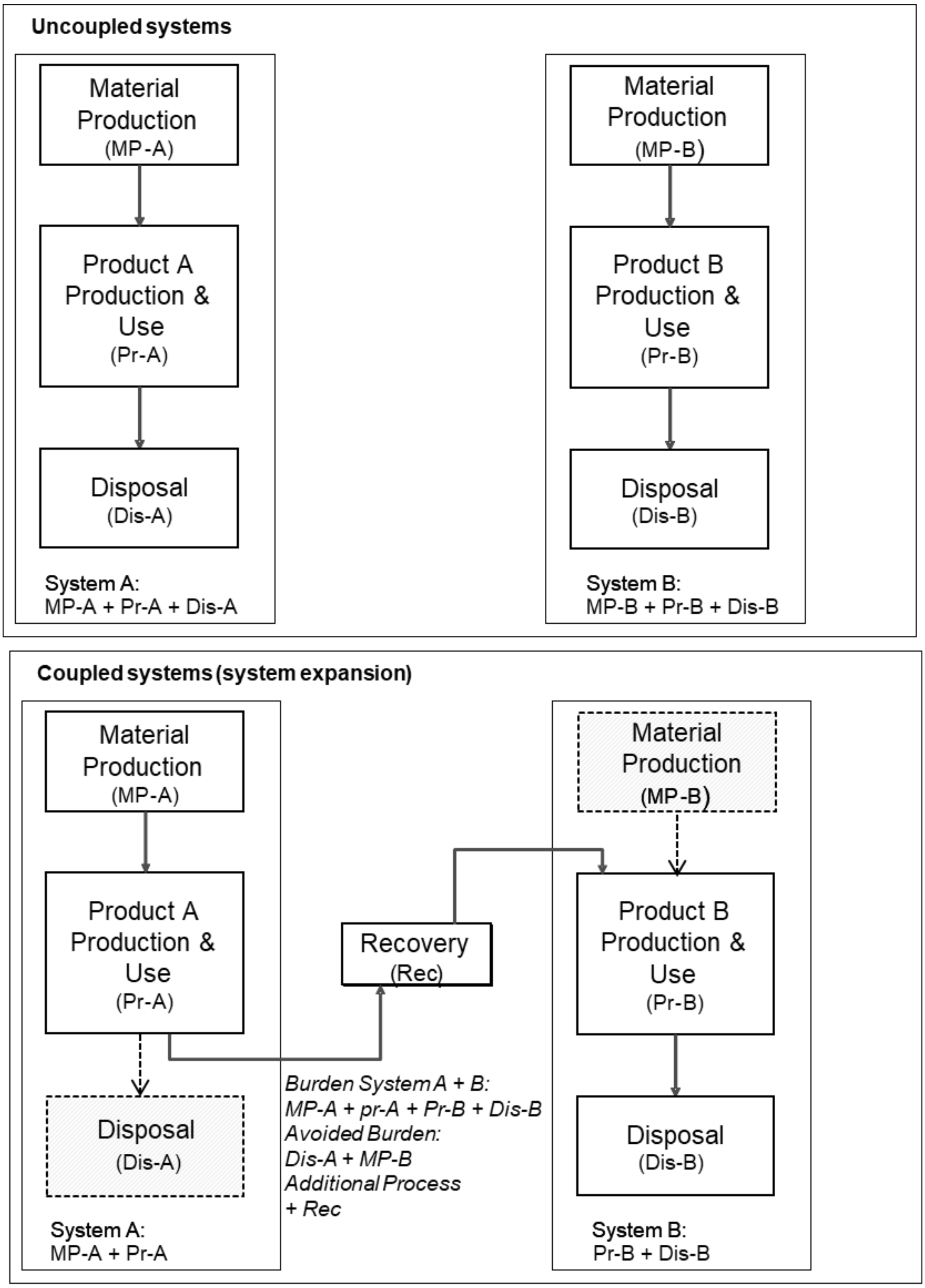

Figure 6: Additional system benefit/burden through recycling (schematic flow chart)[1]

If the system boundaries of the LCA are such that only one product system is examined it is necessary to decide how the possible environmental benefits and burdens of the polymer 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

[1] shaded boxes are avoided processes

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 7 and Figure 8. 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.

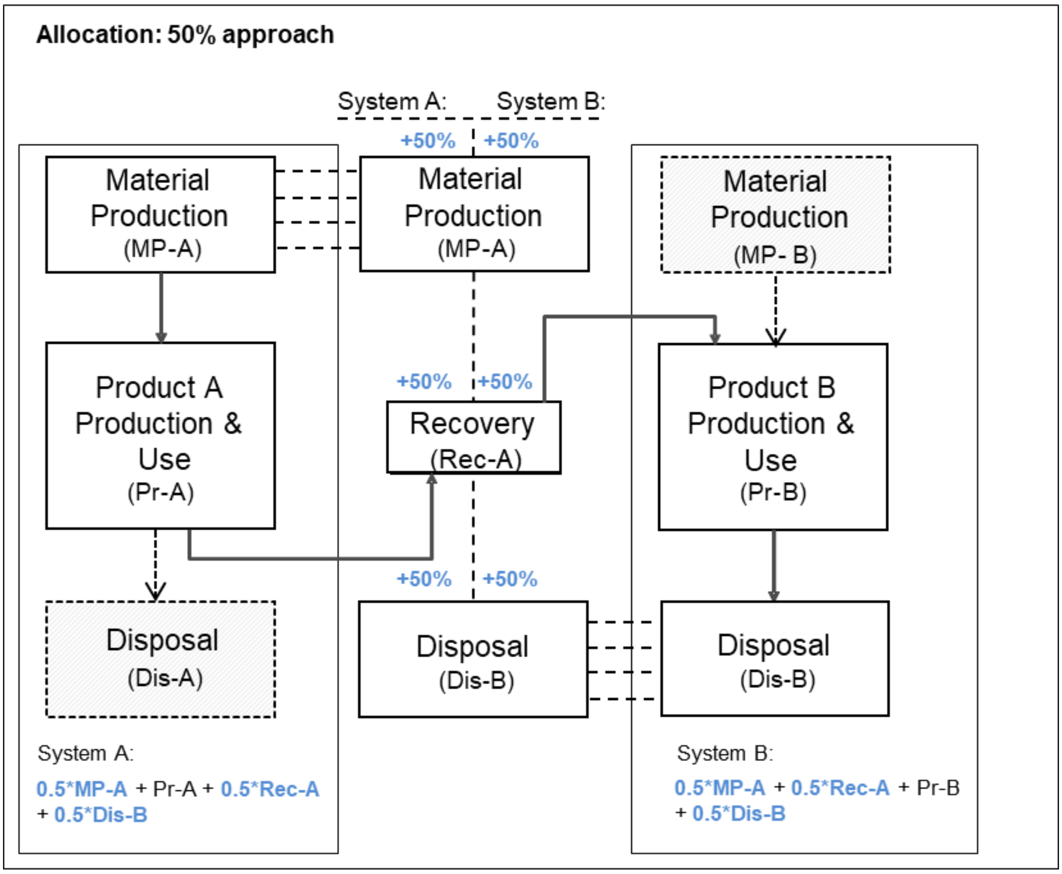

Figure 7: Principles of 50% allocation (schematic flow chart)[1]

Allocation with the 50% method (Figure 7)

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

[1] shaded boxes are avoided processes

The 50% method has often been discussed in the context of open loop recycling, see [Fava et al. 1991], [Frischknecht 1998], [Klöpffer 1996] and [Kim et al. 1997]. 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 align with §21 of the German packaging law [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] and [UBA 2016].

This allocation approach is similar to the approach described in the European guidelines for product environmental footprints (PEF).

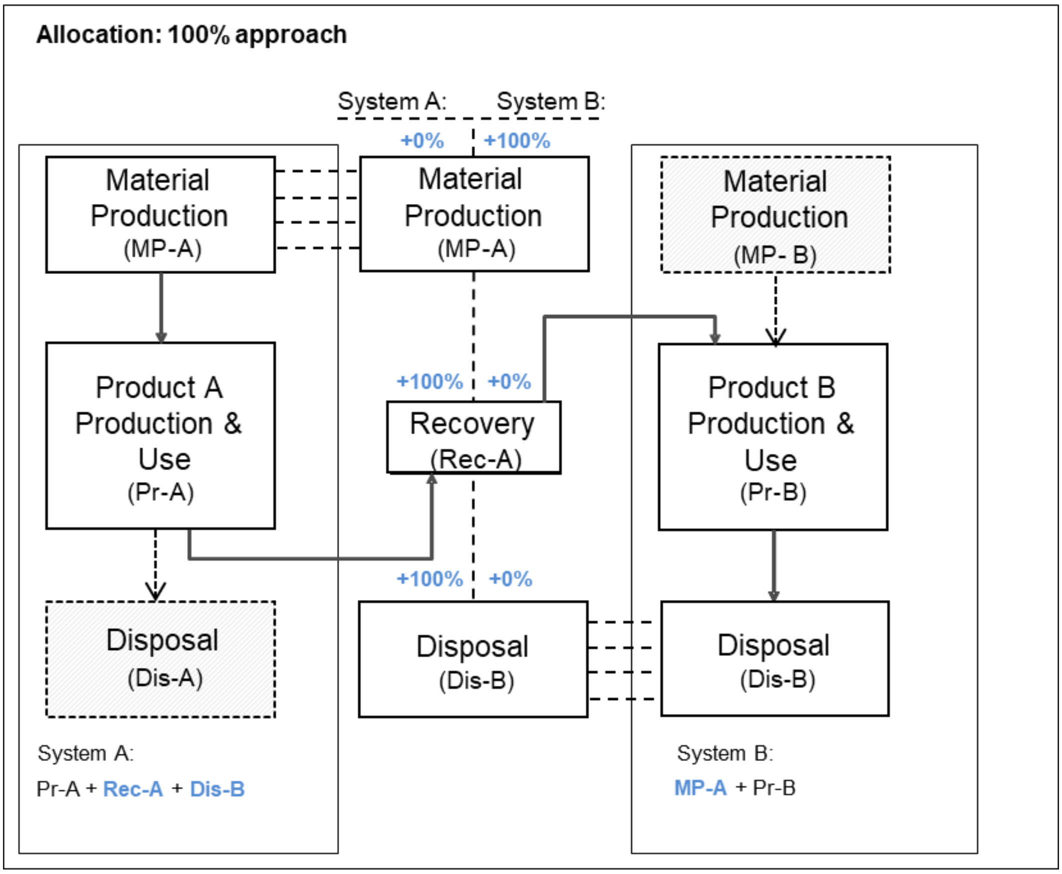

Figure 8: Principles of 100% allocation (schematic flow chart) [1]

[1] shaded boxes are avoided processes

Allocation with the 100% method (Figure 8)

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

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

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 bottles.

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

General notes regarding Figure 6 to Figure 8

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

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

However, within the study the actual situation is modelled based on certain key parameters, for example the actual recycling flow and the actual recycling efficiency (Table 27) as well as the actual substituted material including different substitution factors.

The allocation of final waste treatment is consistent with UBA LCA methodology [UBA 2000] and [UBA 2016] and additionally this approach – beyond the UBA methodology – is also in accordance with [ISO 14044].
For simplification some aspects are not explicitly documented in the mentioned diagrams, among them the following:

- Material losses occur in both 'systems A and B', but are not shown in the diagrams. These losses are of course taken into account in the calculations; their disposal is included within the respective systems.
- Hence, not all material flows from 'system A' are passed on to 'system B', as the simplified material flow diagrams may imply. Consequently only the effectively recycled and recovered material's life cycle steps are allocated between 'systems A and B'.
- The diagrams do not show the individual process steps relevant for the waste material flow out of 'packaging system A', which is sorted as residual waste, including the respective final waste treatment.
- For simplification, a substitution factor of 1 underlies the diagrams. However, in the real calculations smaller values are used where appropriate. For example if a material's properties after recycling are different from those of the primary material it replaces, this translates to a loss in material quality. A substitution factor < 1 accounts for such effects. For further details regarding substitution factors please see subsection 'Application of allocation rules'.

Application of allocation rules

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

The substitution factors used in the current LCA study to calculate the credits for recycled materials provided for consecutive (down-stream) uses are based on expert judgments from German waste sorting operator "Der Grüne Punkt – Duales System Deutschland GmbH" from the year 2003 [DSD 2003]. The substitution factor for PET from bottles has been raised to 1.0 since that date, as technical advancements made a bottle-to-bottle recycling process possible. Recycled granulate from PET bottles containing PA as barrier material has a lower quality than granulate from PET bottles without PA. Therefore the substitution factor recycled PET from PET bottles containing PA is reduced from 1 to 0.9.

- 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)
- Aluminium: 1

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 §21 of the German packaging law [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.

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 and 14044].

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

To get an indication on how the packaging systems examined in this study perform in other environmental impact categories like for example Acidification or Eutrophication one can also refer to the result of the European baseline study. Of course the packaging systems examined in the present study are not exactly identical to the ones in the European baseline study. Also some 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 GWP, which represents one environmental impact per functional unit. The category indicator results also do not quantify an actual environmental damage. Table 3 shows how the terms are applied in this study.

Table 3: 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 functional unit
Characterisation model	Global Warming Potential for a 100-year time period based on IPCC 2013
Category indicator	Global Warming Potential (GWP)
Characterisation factor	Global Warming Potential GWP_i [kg CO_2eq. / kg emission i]
Category indicator result	Kilograms of CO_2-equivalents per functional unit

Table 4 includes examples, which give an overview of elementary flows for 'Climate Change'.

Table 4: 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
* CO_2 fossil and biogenic / ** CH_4 fossil and CH_4 biogenic included									

Climate Change addresses the impact of anthropogenic emissions on the radiative forcing of the atmosphere. Greenhouse gas emissions enhance the radiative forcing, resulting in an increase of the earth's temperature. The characterisation factors applied here are based on the category indicator Global Warming Potential (GWP) for a 100-year time horizon [IPCC 2013]. In reference to the functional unit (fu), the category indicator results, GWP results, are expressed as kg CO_2-e per functional unit.

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, including those chosen for sensitivity analyses.

2.1 Selection of packaging systems

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

The choice of beverage and liquid food cartons has been made by Tetra Pak based on market relevance. Cartons of different volumes for the packaging of dairy (chilled), JNSD (ambient), olive oil (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 Greece for each segment. The representativeness as a main competing packaging type was determined by their market relevance as well as by the importance of the packaging systems in the perspective of Tetra Pak. This includes the importance of competing packaging systems for customers of Tetra Pak. The positioning properties of the products into the market have been taken into account for ensuring the comparability of the analysed packaging systems. Details are shown in Table 5.

Table 5: Selection of competing packaging systems

Segment	Competing packaging system	reason for selection
DAIRY, Family Pack, Chilled	PET bottle 2 1500 mL	Plastic bottles have a strong market share within the segment. The PET bottles with highest market share were selected.
	PET bottle 1 1000 mL	
DAIRY, Portion Pack, Chilled	PET bottle 3 500 mL	Plastic bottles have a strong market share within the segment. PET bottles with highest market share and from known brands were selected.
	PET bottle 4 500 mL	
	PET bottle 5 500 mL	
JNSD, Family Pack, Chilled	PET bottle 8 1000 mL	PET is the dominant packaging solution in chilled JNSD segment. The chosen PET bottle has the highest market share in the segment.
	PET bottle 9 1000 mL	PET is the dominant packaging solution in chilled JNSD segment. The chosen PET bottle is among the highest market shares in the segment.
JNSD, Family Pack, Ambient	PET bottle 10 1000 ml	Ambient PET bottles are not present in the Greek market of JNSD. In order to include a comparable packaging system for the ambient JNSD beverage cartons, the most common ambient PET bottle in the JNSD segment from the Italian market was selected.
JNSD, Portion Pack, Chilled	Aluminium Can 1 330 mL	The can selected is the most common packaging system for all players in the chilled JNSD category.
	PET bottle 7 250 mL	The PET bottle selected is the one of the brand with the highest market share in the segment.
Olive oil, Family Pack, Ambient	PET bottle 6 1000 ml	The PET bottle of the most known brand in this segment is selected.
Liquid Food, Portion Pack, Ambient	Glass Jar 1 400 ml	Standard glass jar is selected. Glass jars are the most common package in the segment.
	Steel can 1 400 ml	Standard food can is selected. Steel cans are the most common package in the segment.

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 with the exception of the chilled JNSD segments. In these segments all assessed packaging systems are chilled at the point of sale. While the assessed PET bottles have to be chilled from filling until consumption, the assessed beverage cartons and cans in the JNSD segment are ambient packaging systems which are only placed

chilled at the points of sale. As ambient packaging systems need additional barrier material this approach is conservative from the perspective of the beverage cartons.

Table 6: List of Tetra Pak beverage cartons in segment **DAIRY, Family Pack, Chilled** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Brik Aseptic (TBA) Edge plant-based WingCap 30 plant-based 1500 mL	C	Greece	PET bottle 2 1500 mL	C	Greece
			PET bottle 1 1000 mL	C	Greece
Tetra Brik Aseptic (TBA) Slim plant-based HeliCap 30 plant-based 1500 mL	C	Greece	PET bottle 2 1500 mL	C	Greece
			PET bottle 1 1000 mL	C	Greece
Tetra Brik Aseptic (TBA) Edge plant-based WingCap 30 plant-based 1000 mL	C	Greece	PET bottle 2 1500 mL	C	Greece
			PET bottle 1 1000 mL	C	Greece
Tetra Brik Aseptic (TBA) Edge plant-based LightCap 30 plant-based 1000 mL	C	Greece	PET bottle 2 1500 mL	C	Greece
			PET bottle 1 1000 mL	C	Greece
Tetra Brik Aseptic (TBA) Ultra Edge plant-based WingCap 30 plant-based 1000 mL	C	Greece	PET bottle 2 1500 mL	C	Greece
			PET bottle 1 1000 mL	C	Greece
Tetra Rex (TR) plant-based sleeve TwistCap OSO 34 plant-based 1000 mL	C	Greece	PET bottle 2 1500 mL	C	Greece
			PET bottle 1 1000 mL	C	Greece
Tetra Gemina Aseptic (TGA) plant-based HeliCap 27 plant-based 1000 mL	C	Greece	PET bottle 2 1500 mL	C	Greece
			PET bottle 1 1000 mL	C	Greece

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

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Gemina Aseptic (TGA) plant-based HeliCap 27 plant-based 500 mL	C	Greece	PET bottle 3 500 mL	C	Greece
			PET bottle 4 500 mL	C	Greece
			PET bottle 5 500 mL	C	Greece

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

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Gemina Aseptic (TGA) plant-based HeliCap 27 plant-based 1000 mL	C	Greece	PET bottle 8 1000 mL	C	Greece
			PET bottle 9 1000 mL	C	Greece
Tetra Prisma Aspetic (TPA) Square lightspec plant-based HeliCap 27 plant-based 1000 mL	C	Greece	PET bottle 8 1000 mL	C	Greece
			PET bottle 9 1000 mL	C	Greece

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

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aspetic (TPA) Square lightspec HeliCap 27 1000 mL	A	Greece	PET bottle 10 1000 mL	A	Greece
Tetra Prisma Aspetic (TPA) Square lightspec plant-based HeliCap 27 plant-based 1000 mL	A	Greece	PET bottle 10 1000 mL	A	Greece
Tetra Stelo Aseptic (TSA) Edge plant-based WingCap 30 plant-based 1000 mL	A	Greece	PET bottle 10 1000 mL	A	Greece

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

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aspetic (TPA) plant-based DreamCap 26 plant-based optimized 330 mL	C	Greece	Aluminium Can 1 330 mL	C	Greece
			PET bottle 7 250 mL	C	Greece
Tetra Prisma Aspetic (TPA) Edge plant-based DreamCap 26 plant-based 250 mL	C	Greece	Aluminium Can 1 330 mL	C	Greece
			PET bottle 7 250 mL	C	Greece

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

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aseptic (TPA) Square metalized StreamCap 1000 mL	A	Greece	PET bottle 6 1000 mL	A	Greece

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 (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Recart 390 ml	A	Greece	Glass Jar 1 400 ml	A	Greece
			Steel can 1 400 ml	A	Greece

2.2 Packaging specifications

Specifications of beverage and liquid food carton packaging systems are listed in Table 13 to Table 19 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.

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 2019 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 20 to Table 26. They were determined by ifeu in 2020 based on specific samples collected by Tetra Pak on the Greek market. For each packaging system three primary packaging samples were analysed 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 analysing 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 JNSD and olive oil bottles are assumed to contain 8% of PA as barrier material (average of communicated PA content of three bottle plastic producers[1]). Specifications of secondary packaging systems were determined by Tetra Pak through weighting of one sample per packaging systems. Material types of secondary packaging system were distinguished between cardboard and LDPE foil. Pallet configuration of competing packaging systems was calculated with the online tool *www.onpallet.com*. Euro pallets 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 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.

[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

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 Packs (chilled)*

		DAIRY FAMILY PACK CHILLED						
	Unit	TBA Edge plant-based WingCap30 plant-based	TBA Slim plant-based HeliCap23 plant-based	TBA Edge plant-based WingCap30 plant-based	TBA Edge plant-based LightCap30 plant-based	TBA Ultra Edge plant-based WingCap30 plant-based	TR Base plant-based TwistCap34 plant-based	TGA plant-based HeliCap27 plant-based
volume	mL	1500	1500	1000	1000	1000	1000	1000
geographic Scope	-	Greece	Greece	Greece	Greece	Greece	Greece	Greece
chilled / ambient	-	chilled	chilled	chilled	chilled	chilled	chilled	chilled
primary packaging (sum)[1]	**g**	**44.5**	**45.9**	**31.7**	**31.5**	**31.5**	**28.9**	**35.4**
primary packaging (per FU)	**g/FU**	**29667**	**30600**	**31700**	**31500**	**31500**	**28900**	**35400**
composite material (sleeve)	**g**	**41.5**	**43.2**	**28.7**	**28.6**	**28.4**	**26.3**	**31.5**
- liquid packaging board	g	31.9	31.9	22.3	22.3	22.0	22.8	22.4
- polymer	g	3.9	3.5	2.3	2.2	2.3		2.2
- plant-based polymer	g	3.9	6.0	2.7	2.7	2.7	3.5	4.9
- aluminium	g	1.8	1.8	1.4	1.4	1.4		2.0
closure	**g**	**3.0**	**2.7**	**3.0**	**2.9**	**3.1**	**2.6**	**3.9**
- polymer	g		1.3					2.1
- plant-based polymer	g	3.0	1.4	3.0	2.9	3.1	2.6	1.8
pull tab	**g**					**0.04**		
- aluminium	g					0.04		
secondary packaging (sum)[2]	**g**	**220**	**220**	**220**	**220**	**220**	**220**	**220**
tray/box (corr.cardboard)	g	220	220	220	220	220	220	220
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**	**25170**	**25170**	**25170**	**25170**
pallet	g	25000	25000	25000	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO	EURO	EURO	EURO
number of use cycles	-	25	25	25	25	25	25	25
stretch foil (per pallet) (LDPE)	g	170	170	170	170	170	170	170
pallet configuration								
cartons per tray	pc	8	8	12	12	12	12	12
trays / packs per layer	pc	16	16	13	13	15	11	15
layers per pallet	pc	4	4	5	5	5	4	4
cartons per pallet	pc	512	512	780	780	900	528	720

[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 Portion Packs (chilled)*

		DAIRY PORTION PACK CHILLED
	Unit	TGA plant-based HeliCap27 plant-based
volume	mL	500
geographic Scope	-	Greece
chilled / ambient	-	chilled
primary packaging (sum)[1]	**g**	**24.3**
primary packaging (per FU)	**g/FU**	**48600**
composite material (sleeve)	**g**	**20.4**
- liquid packaging board	g	14.5
- polymer	g	1.4
- plant-based polymer	g	3.2
- aluminium	g	1.3
closure	**g**	**3.9**
- polymer	g	2.1
- plant-based polymer	g	1.8
secondary packaging (sum)[2]	**g**	**180**
tray/box (corr.cardboard)	g	180
tertiary packaging (sum)[3]	**g**	**25170**
pallet	g	25000
type of pallet	-	EURO
number of use cycles	-	25
stretch foil (per pallet) (LDPE)	g	170
pallet configuration		
cartons per tray	pc	12
trays / packs per layer	pc	14
layers per pallet	pc	7
cartons per pallet	pc	1176

[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 JNSD Family Packs -chilled)*

		JNSD FAMILY PACK CHILLED	
	Unit	TGA Square lightspec plant-based HeliCap27 plant-based	TPA Square plant-based HeliCap27 plant-based
volume	mL	1000	1000
geographic Scope	-	Greece	Greece
chilled / ambient	-	ambient	ambient
primary packaging (sum)[1]	g	35.4	37.1
primary packaging (per FU)	g/FU	35400	37100
composite material (sleeve)	g	31.5	33.2
- liquid packaging board	g	22.4	23.8
- polymer	g	2.2	2.2
- plant-based polymer	g	4.9	5.3
- aluminium	g	2.0	1.9
closure	g	3.9	3.9
- polymer	g	2.1	2.1
- plant-based polymer	g	1.8	1.8
secondary packaging (sum)[2]	g	240	230
tray/box (corr.cardboard)	g	240	230
tertiary packaging (sum)[3]	g	25170	25170
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles	-	25	25
stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
cartons per tray	pc	12	12
trays / packs per layer	pc	15	13
layers per pallet	pc	5	5
cartons per pallet	pc	900	780

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

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

		JNSD FAMILY PACK AMBIENT		
	Unit	TPA Square lightspec HeliCap27	TPA Square lightspec plant-based HeliCap27 plant-based	TSA Edge plant-based WingCap30 plant-based
volume	mL	1000	1000	1000
geographic Scope	-	Greece	Greece	Greece
chilled / ambient	-	ambient	ambient	ambient
primary packaging (sum)[1]	g	37.1	37.1	33.5
primary packaging (per FU)	g/FU	37100	37100	33500
composite material (sleeve)	g	33.2	33.2	30.3
- liquid packaging board	g	23.8	23.8	23.4
- polymer	g	7.5	2.2	2.7
- plant-based polymer	g		5.3	2.9
- aluminium	g	1.9	1.9	1.3
closure	g	3.9	3.9	3.1
- HDPE		1.8		
- polymer	g	2.1	2.1	
- plant-based polymer	g		1.8	3.1
pull tab	g			0.04
- aluminium				0.04
secondary packaging (sum)[2]	g	230	230	230
tray/box (corr.cardboard)	g	230	230	230
tertiary packaging (sum)[3]	g	25170	25170	25170
pallet	g	25000	25000	25000
type of pallet	-	EURO	EURO	EURO
number of use cycles	-	25	25	25
stretch foil (per pallet) (LDPE)	g	170	170	170
pallet configuration				
cartons per tray	pc	12	12	12
trays / packs per layer	pc	13	13	13
layers per pallet	pc	5	5	5
cartons per pallet	pc	780	780	780

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

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

		JNSD PORTION PACK CHILLED	
	Unit	TPA plant-based DreamCap26 plant-based (optimized)	TPA Edge plant-based DreamCap26 plant-based
volume	mL	330	250
geographic Scope	-	Greece	Greece
chilled / ambient	-	ambient	ambient
primary packaging (sum)[1]	g	**16.6**	**14.4**
primary packaging (per FU)	g/FU	**50303**	**57600**
composite material (sleeve)	g	**12.9**	**10.7**
- liquid packaging board	g	8.7	7.2
- polymer	g	1.9	0.8
- plant-based polymer	g	1.4	1.9
- aluminium	g	0.9	0.8
closure	g	**3.7**	**3.7**
- polymer	g	2.2	2.1
- plant-based polymer	g	1.5	1.6
secondary packaging (sum)[2]	g	**175**	**180**
tray/box (corr.cardboard)	g	175	180
tertiary packaging (sum)[3]	g	**25170**	**25170**
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles	-	25	25
stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
cartons per tray	pc	24	16
trays / packs per layer	pc	10	15
layers per pallet	pc	7	8
cartons per pallet	pc	1680	1920

[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 Olive Oil Family Packs (ambient)*

		OLIVE OIL FAMILY PACK AMBIENT
	Unit	TPA Square metalized StreamCap
volume	mL	1000
geographic Scope	-	Greece
chilled / ambient	-	ambient
primary packaging (sum)[1]	**g**	**39.8**
primary packaging (per FU)	**g/FU**	**39800**
composite material (sleeve)	**g**	**35.7**
- liquid packaging board	g	23.8
- polymer	g	10.0
- aluminium	g	1.9
closure	**g**	**4.1**
- polymer	g	4.1
secondary packaging (sum)[2]	**g**	**220**
tray/box (corr.cardboard)	g	220
tertiary packaging (sum)[3]	**g**	**25170**
pallet	g	25000
type of pallet	-	EURO
number of use cycles	-	25
stretch foil (per pallet) (LDPE)	g	170
pallet configuration		
cartons per tray	pc	12
trays / packs per layer	pc	12
layers per pallet	pc	5
cartons per pallet	pc	720

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

Table 19: Packaging specifications for assessed carton systems for the *packaging of Liquid Food Portion Packs (ambient)*

		LIQUID FOOD PORTION PACK AMBIENT
	Unit	Tetra Recart
volume	mL	390
geographic Scope	-	Greece
chilled / ambient	-	ambient
primary packaging (sum)[1]	g	**17.7**
primary packaging (per FU)	g/FU	**45385**
composite material (sleeve)	g	**17.7**
- liquid packaging board	g	12.6
- polymer	g	4.3
- aluminium	g	0.8
secondary packaging (sum)[2]	g	**52.0**
tray/box (corr.cardboard)	g	52.0
tertiary packaging (sum)[3]	g	**25170**
pallet	g	25000
type of pallet	-	EURO
number of use cycles	-	25
stretch foil (per pallet) (LDPE)	g	170
pallet configuration		
cartons per tray	pc	16
trays / packs per layer	pc	12
layers per pallet	pc	10
cartons per pallet	pc	1920

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

		DAIRY FAMILY PACK CHILLED	
	Unit	PET bottle 2	PET bottle 1
volume	ml	1500	1000
geographic scope	-	Greece	Greece
chilled / ambient	-	chilled	chilled
clear / opaque	-	clear	clear
primary packaging (sum)[1]	g	**57.79**	**51.91**
primary packaging (per FU)	g/FU	**38527**	**51910**
bottle	g	**53.61**	**48.04**
- PET	g	53.61	48.04
label	g	**1.24**	**0.95**
- PP	g	1.24	
- PET	g		0.95
closure	g	**2.94**	**2.93**
- HDPE	g	2.94	2.93
secondary packaging (sum)[2]	g	**23.00**	**28.00**
- shrink pack (LDPE)	g	23.00	28.00
tertiary packaging (sum)[3]	g	**25170**	**25170**
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles		25	25
stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
bottles per sec. packaging	pc	6	12
sec. packaging units per layer	pc	17	13
layers per pallet	pc	4	5
bottles per pallet	pc	408	780

[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 Portion Pack (chilled)*

		DAIRY PORTION PACK CHILLED		
	Unit	PET bottle 3	PET bottle 4	PET bottle 5
volume	ml	500	500	500
geographic scope	-	Greece	Greece	Greece
chilled / ambient	-	chilled	chilled	chilled
clear / opaque	-	opaque	clear	clear
primary packaging (sum)[1]	**g**	**29.01**	**33.12**	**26.06**
primary packaging (per FU)	**g/FU**	**58020**	**66240**	**52120**
bottle	**g**	**23.29**	**29.61**	**21.98**
- PET	g	22.13	29.61	21.98
- TiO2	g	1.16		
label	**g**	**2.79**	**0.63**	**1.18**
- PP	g			1.18
- HDPE	g	2.79	0.63	
closure	**g**	**2.93**	**2.88**	**2.90**
- HDPE	g	2.93	2.88	2.90
secondary packaging (sum)[2]	**g**	**17.00**	**17.00**	**17.00**
- tray/box (corr.cardboard)	g	17.00	17.00	17.00
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**
pallet	g	25000	25000	25000
type of pallet	-	EURO	EURO	EURO
number of use cycles		25	25	25
stretch foil (per pallet) (LDPE)	g	170	170	170
pallet configuration				
bottles per sec. packaging	pc	12	12	12
sec. packaging units per layer	pc	13	21	21
layers per pallet	pc	7	6	6
bottles per pallet	pc	1092	1512	1512

[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 *JNSD Family Pack (chilled)*

		JNSD FAMILY PACK CHILLED	
	Unit	PET bottle 8	PET bottle 9
volume	ml	1000	1000
geographic scope	-	Greece	Greece
chilled / ambient	-	chilled	chilled
clear / opaque	-	clear	clear
primary packaging (sum)[1]	**g**	**53.62**	**63.03**
primary packaging (per FU)	**g/FU**	**53620**	**63030**
bottle	**g**	**38.54**	**49.44**
- PET	g	38.54	49.44
label	**g**	**0.83**	**2.59**
- PP	g	0.83	
- PET	g		2.59
closure	**g**	**14.26**	**11.00**
- HDPE	g		11.00
- PP	g	14.26	
secondary packaging (sum)[2]	**g**	**28.00**	**28.00**
- shrink pack (LDPE)	g	28.00	28.00
tertiary packaging (sum)[3]	**g**	**25170**	**25170**
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles		25	25
stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
bottles per sec. packaging	pc	12	12
sec. packaging units per layer	pc	11	9
layers per pallet	pc	5	5
bottles per pallet	pc	660	540

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

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

		JNSD FAMILY PACK AMBIENT
	Unit	PET bottle 10
volume	ml	1000
geographic scope	-	Greece
chilled / ambient	-	ambient
clear / opaque	-	clear
primary packaging (sum)[1]	**g**	**35.15**
primary packaging (per FU)	**g/FU**	**35150**
bottle	**g**	**28.50**
- PET	g	26.22
- PA	g	2.28
label	**g**	**3.16**
- HDPE	g	3.16
closure	**g**	**3.27**
- HDPE	g	3.27
secondary packaging (sum)[2]	**g**	**15.35**
- shrink pack (LDPE)	g	15.35
tertiary packaging (sum)[3]	**g**	**25170**
pallet	g	25000
type of pallet	-	EURO
number of use cycles		25
stretch foil (per pallet) (LDPE)	g	170
pallet configuration		
bottles per sec. packaging	pc	6
sec. packaging units per layer	pc	17
layers per pallet	pc	5
bottles per pallet	pc	510

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

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

		JNSD PORTION PACK AMBIENT-CHILLED	
	Unit	Alu can 1	PET bottle 7
volume	ml	330	250
geographic scope	-	Greece	Greece
chilled / ambient	-	ambient	chilled
clear / opaque	-		clear
primary packaging (sum)[1]	**g**	**12.23**	**28.17**
primary packaging (per FU)	**g/FU**	**37061**	**112680**
bottle/can body	**g**	**9.10**	**18.70**
- PET	g		18.70
- aluminium	g	9.10	
- recycled content	%	50%	
label	**g**		**0.36**
- PP	g		0.36
- laquer	g	0.40	
closure	**g**	**2.73**	**9.11**
- PP	g		9.11
- aluminium	g	2.73	
secondary packaging (sum)[2]	**g**	**17.00**	**17.00**
- shrink pack (LDPE)	g	17.00	17.00
tertiary packaging (sum)[3]	**g**	**25170**	**25170**
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles		25	25
stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
bottles per sec. packaging	pc	12	18
sec. packaging units per layer	pc	20	14
layers per pallet	pc	9	8
bottles per pallet	pc	2160	2016

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

Table 25: Packaging specifications for assessed alternative systems in the segment *OIL Family Pack (ambient-chilled)*

		OIL FAMILY PACK AMBIENT-CHILLED
	Unit	PET bottle 6
volume	ml	1000
geographic scope	-	Greece
chilled / ambient	-	ambient
clear / opaque	-	clear
primary packaging (sum)[1]	**g**	**70.17**
primary packaging (per FU)	**g/FU**	**70170**
bottle	**g**	**61.86**
- PET	g	56.91
- PA	g	4.95
label	**g**	**3.34**
- HDPE	g	3.34
closure	**g**	**4.97**
- HDPE	g	4.97
secondary packaging (sum)[2]	**g**	**220.00**
- tray/box (corr.cardboard)	g	220.00
tertiary packaging (sum)[3]	**g**	**25170**
pallet	g	25000
type of pallet	-	EURO
number of use cycles		25
stretch foil (per pallet) (LDPE)	g	170
pallet configuration		
bottles per sec. packaging	pc	12
sec. packaging units per layer	pc	9
layers per pallet	pc	4
bottles per pallet	pc	432

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

Table 26: Packaging specifications for assessed alternative systems in the segment *liquid food (ambient)*

		LIQUID FOOD AMBIENT	
	Unit	Steel can 1	Glass jar 1
volume	ml	400	400
geographic scope	-	Greece	Greece
chilled / ambient	-	ambient	ambient
clear /opaque	-		white glass
primary packaging (sum)[1]	**g**	**51.24**	**204.27**
primary packaging (per FU)	**g/FU**	**128100**	**510675**
jar/can	**g**	**42.52**	**195.40**
- tin plate	g	42.52	
- glass	g		195.40
- external cullet rate			69.5%.
label	**g**	**2.07**	**0.72**
- paper	g	2.07	0.72
closure	**g**	**6.64**	**8.16**
- tinplate	g	6.64	8.16
secondary packaging (sum)[2]	**g**	**69.00**	**220.00**
- shrink pack (LDPE)	g	17.00	
- tray/box (corr.cardboard)	g	52.00	220.00
tertiary packaging (sum)[3]	**g**	**25170**	**25170**
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles		25	25
stretch foil (per pallet) (LDPE)	g	25000	25000
pallet configuration			
pouches/jars/cans per sec. packaging	pc	12	12
sec. packaging units per layer	pc	13	15
layers per pallet	pc	12	9
bottles per pallet	pc	1872	1620

[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 Greek market. The applied recycling quotas are based on published quotas. The material recycling quotas represent the actual amount of material undergoing a material recycling process after sorting took place. The remaining part of the post-consumer packaging waste is modelled and calculated according to the average split between landfilling and incineration (MSWI) in Greece. As there is no energy recovery from MSWI plants in Greece [Sakalis & Kalogirou 2017], the share of MSWI is 0%. The applied end-of-life quotas and the related references are given in Table 27. As data references preferable local data sources are applied where possible.

Table 27: Applied end of life quotas for beverage and liquid food cartons and competing packaging systems in Greece:

Geographical scope	Packaging system		Material recycling	MSWI	Landfill
Greece	Beverage and liquid food carton	quota	22%	0%	78%
		source	[HERRCO 2020]	[Sakalis & Kalogirou 2017]	
		reference year	2019	2017	
	PET bottles[1]	quota	60%	0%	40%
		source	[HERRCO 2020]	[Sakalis & Kalogirou 2017]	
		reference year	2019	2017	
	Glass bottles/jars	quota	43%	0%	57%
		source	[HERRCO 2020]	[Sakalis & Kalogirou 2017]	
		reference year	2019	2017	
	Steel and aluminium cans	quota	44%	0%	56%
		source	[HERRCO 2020]	[Sakalis & Kalogirou 2017]	
		reference year	2019	2017	

[1]white opaque bottles are not materially recycled (see section 3.13)

The flow charts in Figure 9 - Figure 14 illustrate the applied specified end-of-life model of beverage and liquid food cartons, clear and white PET bottles, glass bottles and jars as well as steel and aluminium 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 27.

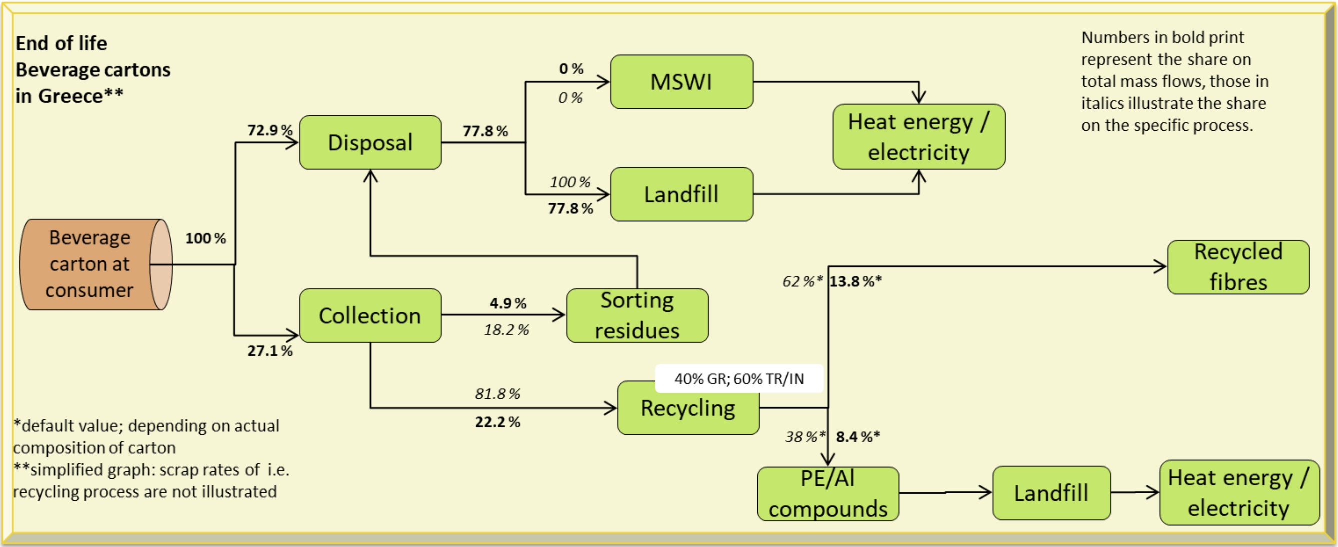

Figure 9: Applied end-of-life quotas for beverage and liquid food cartons in Greece

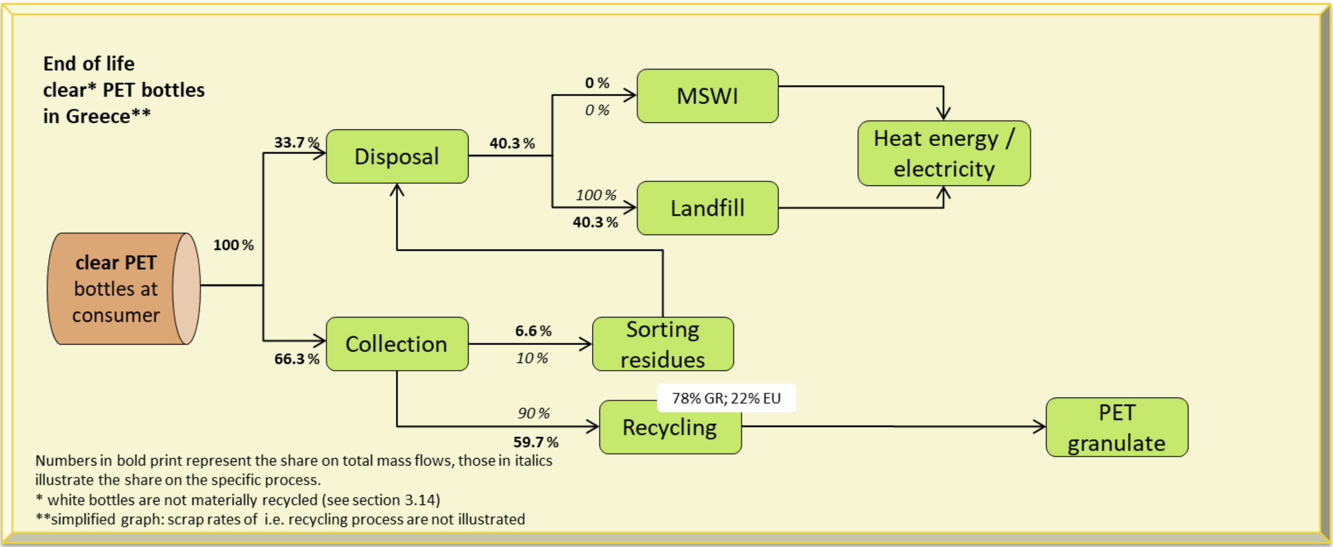

Figure 10: Applied end-of-life quotas for clear PET bottles in Greece

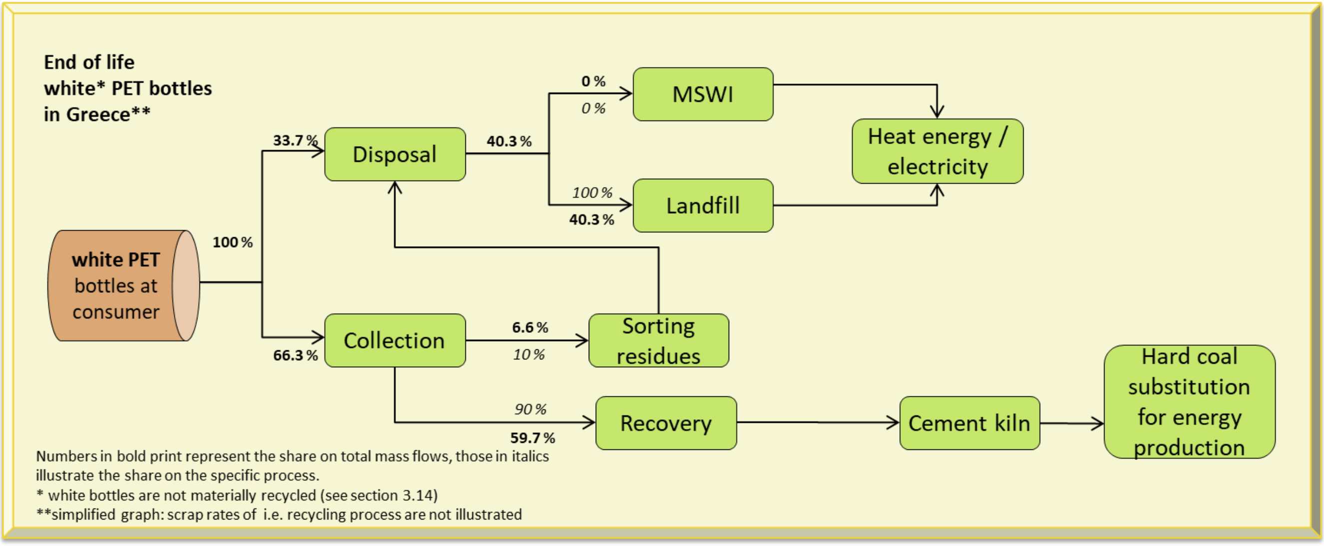

Figure 11: Applied end-of-life quotas for white PET bottles in Greece

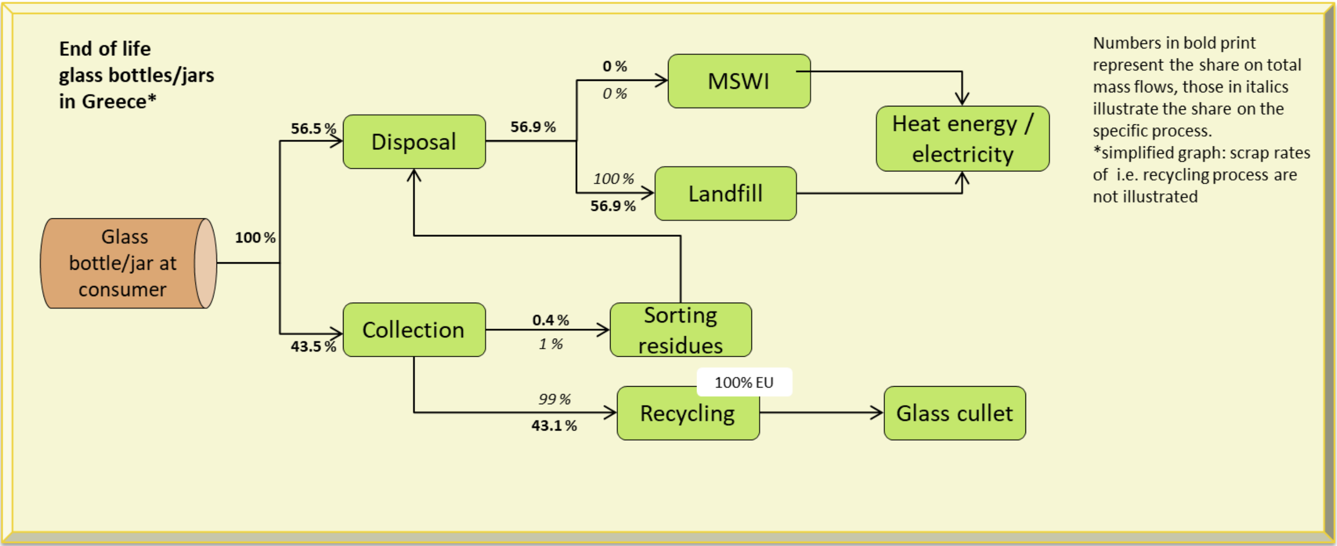

Figure 12: Applied end-of-life quotas for glass bottles/jars in Greece

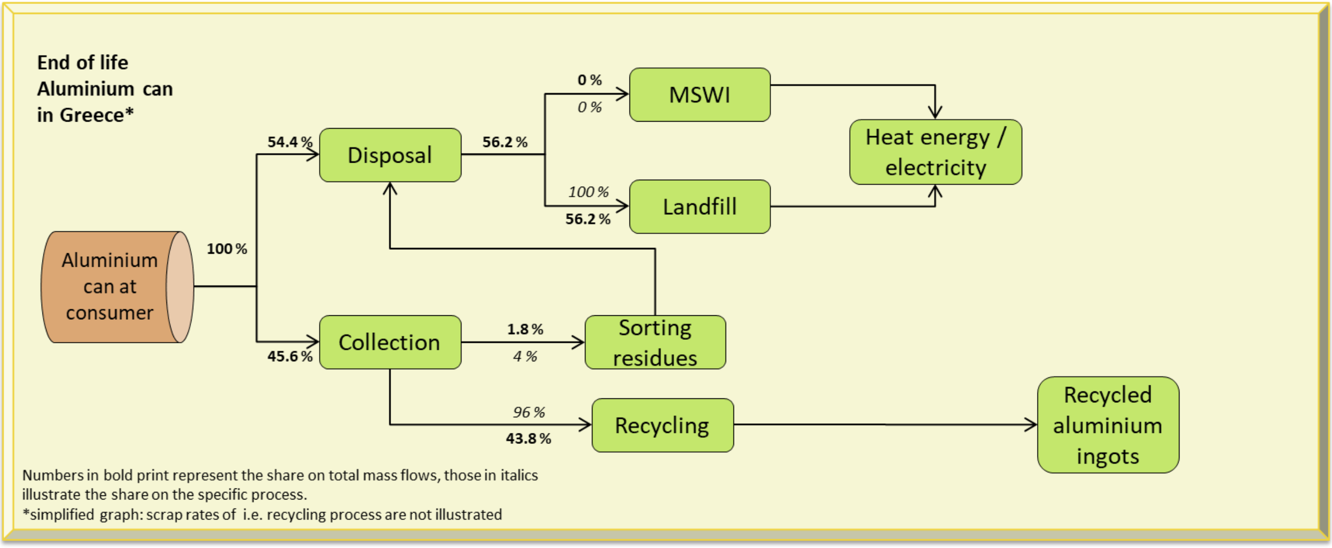

Figure 13: Applied end-of-life quotas for aluminium cans in Greece

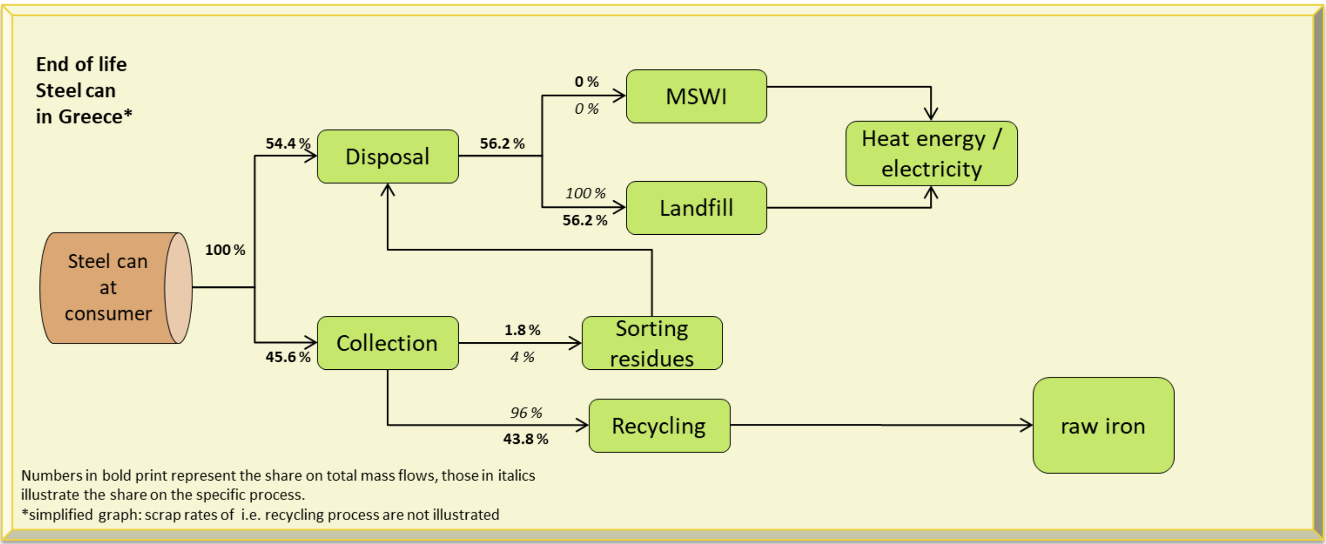

Figure 14: Applied end-of-life quotas for steel cans in Greece

2.4 Scenarios

2.4.1 Base scenarios

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

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

2.4.2 Sensitivity scenarios

In the base scenarios, the converting process of PET bottles is modelled at the same location as the filling process. Therefore, the electric energy demand of all PET bottle converting processes is modelled with the Greek electricity mix. The reason for modelling the PET bottle converting process at the filling location is based on the provided filling and converting data from modern interconnected facilities. The high share of brown coal in the Greek electricity production (see section 3.14.2) leads to a high 'Climate Change' intensity of the Greek electricity mix. Therefore, the life cycle step converting of plastic bottles shows for PET bottles relatively high burdens for 'Climate Change'. Beverage cartons are converted in plants throughout Europe. Therefore the electricity demand of converting processes for beverage cartons is modelled with the less 'Climate Change' intensive European Electricity mix (see section 3.14.2). It is possible that also PET preforms are not produced at the filling site but being imported from other European countries. In order to consider the effects of less 'Climate Change' intensive PET preform production in Europe, sensitivity scenarios are calculated with European electricity mix in PET preform processes including the additional transport to the filling sites. As the comparative results with allocation factor 100% are conservative in perspective of the beverage cartons, these sensitivity analyses are calculated with the allocation factor 100%. This sensitivity analysis is conducted for the following segments in which comparative results of PET bottles and beverage cartons show the smallest differences:

- Dairy chilled family pack
- Dairy chilled portion pack
- JNSD ambient family pack

2.4.3 Scenario variants

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

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 step	Source	Reference period	primary / secondary data
Intermediate goods			
PP	Plastics Europe, published online April 2014	2011	secondary
HDPE	Plastics Europe, published April 2014	2011	secondary
LDPE	Plastics Europe, published April 2014	2011	secondary
Plant-based PE	[Braskem 2018]	2015	secondary
PET	Plastics Europe, published online June 2017	2015	secondary
PA6	Plastics Europe, last online retrieval in 2005	1999	secondary
Titanium dioxide	Ecoinvent V.3.4	2017	secondary
Tinplate	[World Steel 2018]	2014	secondary
Aluminium (primary)	EA Environmental Profile report 2018 [EA 2018]	2015	secondary
Aluminium foil	EA Environmental Profile report 2013 [EA 2013]	2010	secondary
Corrugated cardboard	[FEFCO 2018]	2017	secondary
Liquid packaging board	ifeu data, obtained from ACE [ACE 2012]	2009	secondary
Production			
BC converting	Tetra Pak	2017	primary
Glass jar converting including glass production	UBA 2000 (bottle glass); energy prechains 2015	2000/2015	secondary
Preform production	Data provided by Tetra Pak, gathered in 2019	2019	primary
Steel (tinplate) can converting	[BUWAL 1998], ifeu database	1996-2015	secondary

Material / Process step	Source	Reference period	primary / secondary data
Aluminium can converting	ifeu database	2009	primary
Filling			
Filling of beverage and liquid food cartons	Data provided by Tetra Pak	2019	primary
Filling plastic bottles	Data provided by Tetra Pak, gathered in 2019, ifeu data obtained from various fillers SBM is included in data for PET bottles	2019	primary
Filling aluminium cans	ifeu database	2011	primary
Filling glass jars	provided by Tetra Recart based on machine consumption data specifications	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
Glass bottle	ifeu database, [FEVE 2006]	2004/2005	primary/ secondary
Aluminium can (post-consumer)	EA Environmental Profile report 2013 [EA 2013]	2010	secondary
Aluminium can (post-industrial)	EA Environmental Profile report 2018 [EA 2018]	2015	secondary
Steel can	ifeu database	2008	primary
Background data			
electricity production	ifeu database, based on statistics and power plant models	2015	secondary
Municipal waste incineration	ifeu database, based on statistics and incineration plant models	2008	secondary
Landfill	ifeu database, based on statistics and landfill models	2008	secondary
Thermal recovery in cement kilns	ifeu database, German cement industry association (VDZ)	2006	primary
lorry transport	ifeu database, based on statistics and transport models, emission factors based on HBEFA 3.3 [INFRAS 2017].	2009	secondary
rail transport	[EcoTransIT 2016]	2016	secondary
sea ship transport	[EcoTransIT 2016]	2016	secondary

3.1 Plastics

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

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

3.1.1 Polypropylene (PP)

Polypropylene (PP) is produced by catalytic polymerisation of propylene into long-chained polypropylene. The two important processing methods are low pressure precipitation polymerisation and gas phase polymerisation. In a subsequent processing stage the polymer powder is converted to granulate using an extruder.
The present LCA study utilises data published by Plastics Europe [PlasticsEurope 2014a]. The dataset covers the production of PP from cradle to the polymer factory gate. The polymerisation data refer to the 2011 time period and were acquired from a total of 35 polymerisation plants producing. The total PP production in Europe (EU27+2) in 2011/2012 was 8,500,000 tonnes. The Plastics Europe data set hence represented 77% of PP production in Europe.

3.1.2 High Density Polyethylene (HDPE)

High density polyethylene (HDPE) is produced by a variety of low pressure methods and has fewer side-chains than LDPE. The present LCA study uses the eco-profile published on the website of Plastics Europe [Plastics Europe 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 [Plastics Europe 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 in the plant-based PE production, the LCA datasets used in the Braskem study use the approach of economical allocation. 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 [Plastics Europe 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 [PlasticEurope 2012b]. For PET production data from 12 production lines at 10 productions sites in Belgium, Germany, Lithuania (2 lines), the Netherlands, Poland, Spain (4 lines) and United Kingdom (2 lines) supplied data with an overall PTA volume of 2.9 million tonnes – this represents 85% of the European production volume (3.4 million tonnes).

3.1.6 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 [Plastics Europe 2005]. A more recent dataset is available provided by PlasticsEurope. However in this dataset ammonium sulphate is seen as a by-product of the PA6 production process of the PA6 pre-product caprolactam. The datasets uses a substitution approach to account for ammonium sulphate. As basically all ammonium sulphate on the market is derived from the PA6 production, in the view of the authors it is not valid to substitute a separate ammonium sulphate production process. Even within the PlasticsEurope methodology this approach is only allowed, "…if there is a dominant, identifiable production path for the displaced product" [Plastics Europe 2019]. Unfortunately, no dataset applying another approach apart from the substitution approach is available.

3.2 Production of primary material for aluminium bars and foils

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

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

3.3 Manufacture of tinplate

Data for the production of tinplate refer to the year 2014 and was provided by WORLD STEAL [WORLD STEAL 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.

3.4 Glass and glass bottles

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 European electricity mix based on 2015. A newer 2016 data set from FEVE [Bettens & Bagard 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 2009. 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 2.2 (Ecoinvent 3.7 data are still based on the same datasets), including a forestry model to calculate inventories for this sub-system. Energy required is supplied by electricity as well as renewable by on-site energy production by incineration of wood and bark. The specific energy sources were taken into account.

3.6 Corrugated board and manufacture of cardboard trays

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

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

3.7 Titanium dioxide

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, grid European 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 prechain of the local Greek electricity mix in order to adjust the process data to the production in Greece.

3.8.3 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 prechain of the local Greek electricity mix in order to adjust the process data to the production in Greece.

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 prechain of the local Greek electricity mix in order to adjust the process data to the production in Greece.

3.9 Closure production

The closures made of fossil and plant-based polymers are produced by injection moulding. The data for the production were taken from ifeu's internal database and are based on values measured in Germany and other European countries and data taken from literature. The process data were coupled with required prechains such as the production of PE and Greek grid electricity in order to adjust the process data to the production in Greece.

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 2019 distinguishing between the consumption of electric and thermal energy as well as of water and air demand. Those were crosschecked 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. 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 prechain of the local Greek electricity mix in order to adjust the process data to the filling in Greece.

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. exchanges with representatives from the logistic sector and suppliers.

Table 29: Transport distances and means: Transport defined by distance and mode [km/mode]

Packaging element	Material producer to converter Distance [km]	Converter to filler Distance [km]
HDPE, LDPE, PP, PET granulate for all packages	500 / road*	
Plant-based PE	10800 / sea* 700 / road*	
Aluminium	460 / road*	
Paper board for composite board	300 / road** 950 / sea** 800 / rail**	
Cardboard for trays	primary fibres: 500 / sea, 400 / rail, 250 / road** secondary fibres: 300/road**	
Wood for pallets	100 / road*	
LDPE stretch foil	500/road (material production site = converter)*	
Trays		500 / road*
Pallets		100 / road*
Converted carton rolls		700 / road*

***Assumption/Calculation; **taken from published LCI reports**

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). Due to the small area of Greece the applied distances are smaller than in the European baseline study [ifeu 2020].

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 30% 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.

In order to take into account the distribution to the Greek Islands an estimated distance for ship transport of 42 km is added. The distance is based on the distance from Piraeus to the island with the highest population and the Greek island population share.

Table 30: Distribution distances in km for the examined packaging systems

	Distribution distance [km] as applied in this study				
	Distribution Step 1		Distribution step 2		Ship transport
segment	filler > distribution centre (delivery)	distribution centre > filler (return trip)	distribution centre > POS (delivery)	POS > distribution centre (return trip)	
dairy chilled	150	45	75	75	42
all other segments	250	75	75	75	42

3.13 Recovery and recycling

Beverage and liquid food cartons

Beverage and liquid food cartons which are collected and sorted are subsequently sent to a paper recycling facility for fibre recovery. The 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 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. The process data is coupled with the mixed prechain of Greek, Turkish and Indian electricity mix in order to adjust the process data to the shares of beverage carton recycling in Greece (40%), Turkey (30%) and India (30%). Additional transport for exported shares is included.

Plastic bottles

Plastic bottles which are collected and sorted are usually followed by a regranulation process. Ultimately the different plastics are separated by density (PET, PE, PP). They are shredded to flakes, other plastic components are separated and the flakes are washed before further use. The data used in the current study is based on ifeu's internal database based on data from various recycling plants. . The process data is coupled with the mixed prechain of Greek and European electricity mix in order to adjust the process data to the shares of plastic bottle recycling in Greece (78%) and Europe (22%). Additional transport for exported shares is included.

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

Glass bottles and jars

The glass of collected glass bottles and jars is shredded and the ground glass serves as an input in the glass production, the share of external cullet is modelled as 69.5%. The data used in the current study is drawn from ifeu's internal database, and furthermore information received from 'The European Container Glass Federation' [FEVE 2006]. The reference period is 2012. Process data are coupled with required prechains and the European electricity grid mix as 100% of used glass in Greece is exported to Europe for recycling. Additional transport for exported shares is included.

Steel cans

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

Aluminium cans

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 [EA 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 [EA 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' [INFRAS 2017]. The 'Handbook' is a database application referring to the year 2017 and giving as a result the transport distance related fuel consumption and the emissions differentiated into lorry size classes and road categories. Data are based on average fleet compositions within several lorry size classes. Data in this study refer to lorries with a loading capacity of 23 tonnes. The emission factors used in this study refer to the year 2016.

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

Ship transport

The data used for the present study represent freight transport with an overseas container ship (10.5 t/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 [ifeu 2016]. It is based on national electricity mix data by the International Energy Agency (IEA)[2]. As a prechain for most processes the Greek electricity mix is applied (see Table 1 and section 3). Regarding beverage cartons, electricity generation is considered using Swedish and Finnish mix of energy suppliers in the year 2015 for the production of LPB and the European mix of energy suppliers in the year 2015 for the converting of sleeves. As beverage cartons are partially exported for recycling to India and Turkey a mix of Greek, Turkish and Indian grid electricity is applied as a prechain for the process data of beverage carton recycling. 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 2015.

geographic scope	Greece	Turkey	India	EU 28	Sweden	Finland
Energy source						
Hard coal	0.00%	15.67%	63.33%	14.11%	0.23%	7.34%
Brown coal	42.06%	12.16%	11.20%	10.32%	0.00%	0.00%
Fuel oil	9.29%	0.83%	1.65%	1.65%	0.15%	0.30%
Natural gas	18.78%	37.98%	5.01%	16.51%	0.67%	12.65%
Nuclear energy	0.00%	0.00%	2.71%	26.70%	33.85%	33.66%
Hydropower/Wind /Solar/Geothermal	29.21%	32.85%	14.21%	24.50%	57.99%	29.14%
Hydropower	42.28%	81.65%	74.14%	45.74%	82.15%	87.77%
Wind power	32.04%	14.17%	22.98%	40.42%	17.75%	12.18%
Solar energy	25.68%	0.22%	2.87%	13.01%	0.10%	0.04%
Geothermal energy	0.00%	3.95%	0.00%	0.83%	0.00%	0.00%
Biomass energy	0.44%	0.47%	1.78%	4.84%	5.36%	15.69%
Waste	0.21%	0.04%	0.12%	1.35%	1.75%	1.23%

3.14.3 Municipal solid waste incineration

The electrical and thermal efficiencies of the municipal solid waste incineration plants (MSWI) are shown in Table 32. In Greece there is no energy recovery from MSWI plants [Sakalis & Kalogirou 2017]. For the incineration of exported PET bottles the European efficiencies are applied.

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

Geographic Scope	Electrical efficiency	Thermal efficiency	Reference period	Source
Europe	12%	29%	2010	[CEWEP 2012]

The efficiencies are used as parameters for the incineration model, which assumes a technical standard (especially regarding flue gas cleaning) that complies with the requirements given by the EU incineration directive, ([EC 2000] Council Directive 2000/76/EC).

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

3.14.4 Landfill

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 (29%) is based on data from National Inventory Reports (NIR) under consideration of different catchment efficiencies at different stages of landfill operation. The captured methane is used for energy conversion.

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 and 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

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

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

- production and transport of glass including converting to bottle (**'Glass'**)
- production and transport of PET, including additives, e.g. TiO_2 for the body of plastic bottles, aluminium and steel for can bodies (**'Plastic/Alu/Steel for body'**)
- production and transport of liquid packaging board **('LPB')**
- production and transport of plastics and additives for beverage and liquid food carton **('plastics for sleeve')**
- production and transport of aluminium & converting to foil for beverage and liquid food cartons **('aluminium foil for sleeve')**
- converting processes of cartons, plastic bottles, SUP and cans **('converting')**
- production, converting and transport of closures, tops, straws and labels and their base materials **('top, closure & label')**
- production of secondary and tertiary packaging: wooden pallets, LDPE shrink wrap and corrugated cardboard trays **('transport packaging')**
- 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. (EOL)')**; 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**')

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

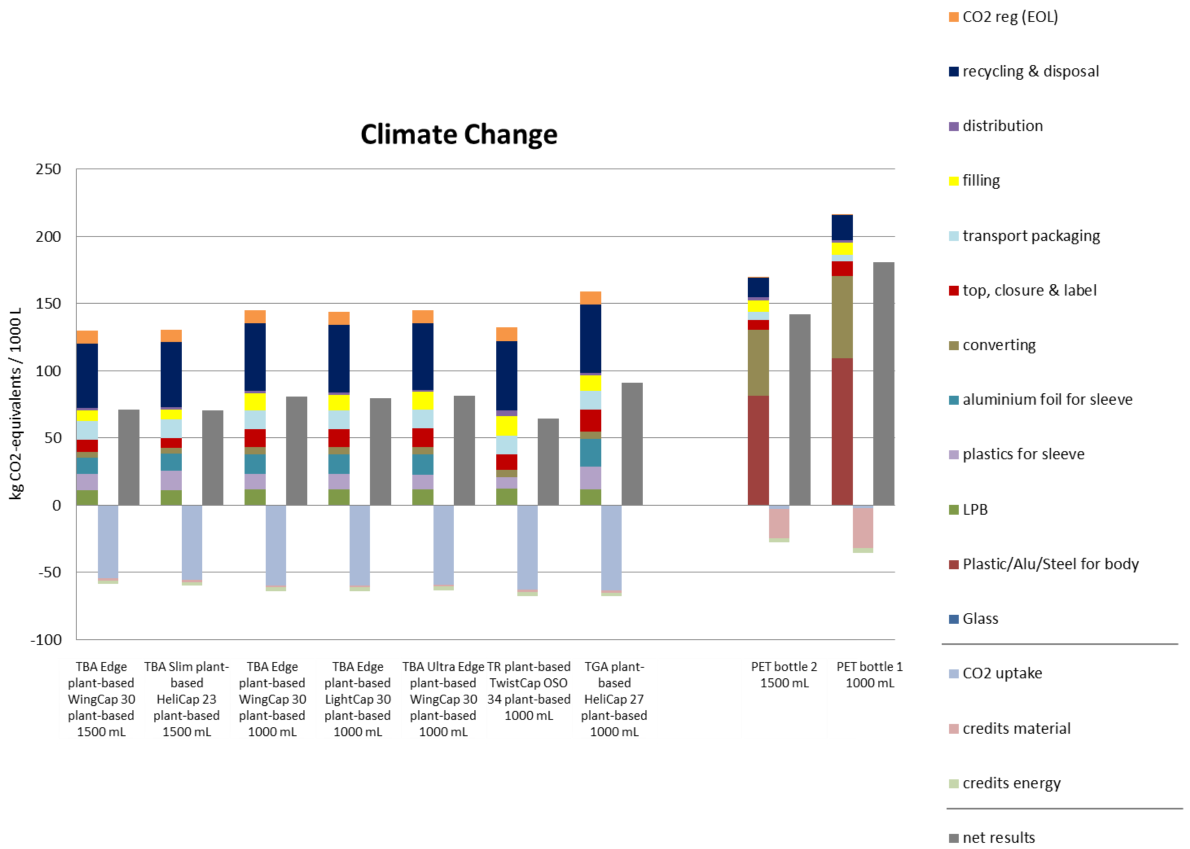

Figure 15: Climate Change results of **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

Table 33: Climate Change results of **segment DAIRY FAMILY PACK CHILLED** - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL		PET bottle 2 1500 mL	PET bottle 1 1000 mL
	Burdens	120.31	121.06	135.05	134.19	135.37	121.80	149.19		169.03	215.65
	CO2 (reg)	9.27	9.23	9.66	9.69	9.44	10.25	9.75		1.03	0.81
	Credits	-4.10	-4.10	-4.30	-4.33	-4.22	-4.48	-4.35		-25.13	-33.65
Climate Change	CO2 uptake	-54.70	-55.87	-59.79	-59.75	-59.26	-62.95	-63.49		-2.82	-2.22
[kg CO2-e/1000 L]	net results	70.78	70.32	80.62	79.79	81.32	64.63	91.10		142.11	180.60

4.1.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the DAIRY FAMILY PACK CHILLED segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (7%-9%), the production of plastics for sleeves (6%-11%) and except of the TR carton the production of aluminium foil (10%-13%).

The converting to sleeves accounts only small shares (3%-4%) of the total burdens for 'Climate Change'.

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

The production and provision of 'transport packaging' for the beverage carton systems shows 9%-11% of the total burdens for 'Climate Change' for the beverage cartons.

The life cycle step 'filling' shows small to minor shares of burdens (6%-11%) for the beverage cartons.

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 is the most relevant life cycle step for 'Climate Change' (32%-39%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paper board.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons in Greece these derive from landfills. They contribute to 6%-8% of the total burdens for 'Climate Change'.

Due to the lack of MSWI with energy recovery in Greece, Turkey and India, energy credits sum up to only 2% resulting from small amounts of energy recovery in landfills. 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 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 of 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 FAMILY PACK CHILLED segment, a major share (48%-50%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottles in this segment considerable shares of burdens for 'Climate Change (28%-29%) due to the 'Climate Change' intensive Greek electricity mix.

The life cycle step 'top, closure & label' shows small impacts shares (4%-5%) mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (2%-4%) for climate change.

The life cycle steps 'filling' (4%-5%) and 'distribution' (1%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows small shares (8%-9%) for the assessed plastic bottles resulting from the recycling processes and in case of exported bottles from incineration of the bottles.

Material credits reduce the total burdens by 13%-14% resulting from the substitution of virgin PET.

The influence of energy credits on the net result is low due to the lack of MSWI with energy recovery in Greece. The small reduction of net results by energy credits (2%) results from the incineration of exported PET bottles.

4.1.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

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

Table 34: Comparison of net results: **TBA Edge plant-based WingCap 30 plant-based 1500 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Greece Allocation 50	The net results of **TBA Edge plant-based WingCap 30 plant-based 1500 mL** are lower (green)/ higher (orange) than those of							
	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+1%	-12%	-11%	-13%	+10%	-22%	-50%	-61%

Table 35: Comparison of net results: **TBA Square plant-based HeliCap 23 plant-based 1500 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Greece Allocation 50	The net results of **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	-1%	-13%	-12%	-14%	+9%	-23%	-51%	-61%

Table 36: Comparison of net results: **TBA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Greece Allocation 50	The net results of **TBA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+14%	+15%	+1%	-1%	+25%	-12%	-43%	-55%

Table 37: 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 FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Greece Allocation 50	The net results of **TBA Edge plant-based LightCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+13%	+13%	-1%	-2%	+23%	-12%	-44%	-56%

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

DAIRY FAMILY PACK (chilled), Greece Allocation 50	The net results of **TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+15%	+16%	+1%	+2%	+26%	-11%	-43%	-55%

Table 39: Comparison of net results: **TR plant-based TwistCap OSO 34 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Greece Allocation 50	The net results of **TR plant-based TwistCap OSO 34 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	-9%	-8%	-20%	-19%	-21%	-29%	-55%	-64%

Table 40: Comparison of net results: **TGA plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Greece Allocation 50	The net results of **TGA plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+29%	+30%	+13%	+14%	+12%	+41%	-36%	-50%

4.2 Results allocation factor 100%; DAIRY FAMILY PACK CHILLED

4.2.1 Presentation of results DAIRY FAMILY PACK CHILLED

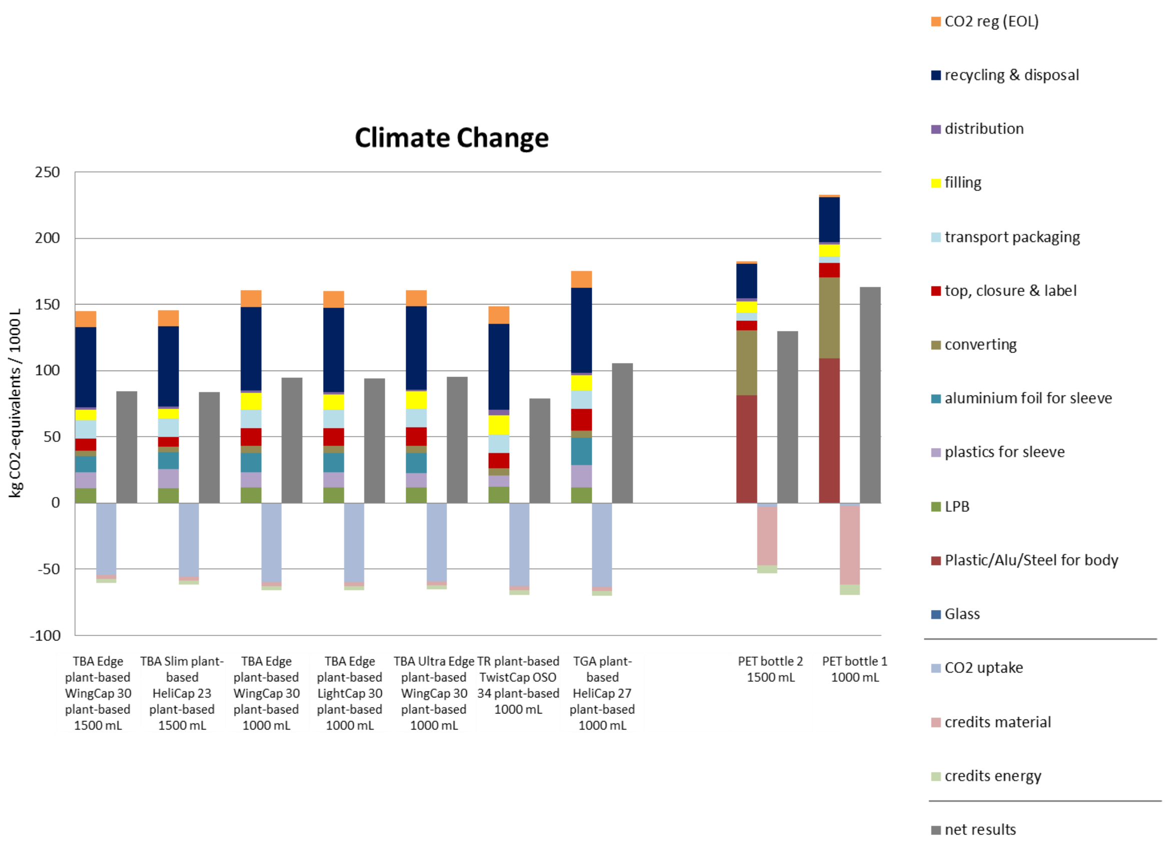

Figure 16: Climate Change results of **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

Table 41: Climate Change results of **segment DAIRY FAMILY PACK CHILLED** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL		PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	132.88	133.69	148.16	147.45	148.30	135.18	162.59		180.70	230.94
	CO2 (reg)	11.97	11.90	12.47	12.52	12.11	13.50	12.61		2.07	1.62
	Credits	-6.02	-6.01	-6.32	-6.38	-6.19	-6.63	-6.41		-50.27	-67.30
	CO2 uptake	-54.70	-55.87	-59.79	-59.75	-59.26	-62.95	-63.49		-2.82	-2.22
	net results	84.13	83.71	94.52	93.84	94.96	79.10	105.31		129.67	163.05

4.2.2 Description and interpretation

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

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

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

In the cases of beverage cartons in the segment DAIRY FAMILY PACK CHILLED applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In the cases of the plastic bottles, 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 mainly recycling regardless of the allocation factor.

4.2.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

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

Table 42: Comparison of net results: **TBA Edge plant-based WingCap 30 plant-based 1500 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Greece Allocation 100	The net results of **TBA Edge plant-based WingCap 30 plant-based 1500 mL** are lower (green)/ higher (orange) than those of							
	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+1%	-11%	-10%	-11%	+6%	-20%	-35%	-48%

Table 43: Comparison of net results: **TBA Square plant-based HeliCap 23 plant-based 1500 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Greece Allocation 100	The net results of **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	-1%	-11%	-11%	-12%	+6%	-21%	-35%	-49%

Table 44: Comparison of net results: **TBA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Greece Allocation 100	The net results of **TBA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+12%	+13%	+1%	-0%	+19%	-10%	-27%	-42%

Table 45: 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 FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Greece Allocation 100	The net results of **TBA Edge plant-based LightCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+12%	+12%	-1%	-1%	+19%	-11%	-28%	-42%

Table 46: Comparison of net results: **TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Greece Allocation 100	The net results of **TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+13%	+13%	+0%	+1%	+20%	-10%	-27%	-42%

Table 47: Comparison of net results: **TR plant-based TwistCap OSO 34 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Greece Allocation 100	The net results of **TR plant-based TwistCap OSO 34 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	-6%	-5%	-16%	-16%	-17%	-25%	-39%	-51%

Table 48: Comparison of net results: **TGA plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Greece Allocation 100	The net results of **TGA plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+25%	+26%	+11%	+12%	+11%	+33%	-19%	-35%

4.3 Results sensitivity EU PET preform production (allocation factor 100%); DAIRY FAMILY PACK CHILLED

4.3.1 Presentation of results DAIRY FAMILY PACK CHILLED

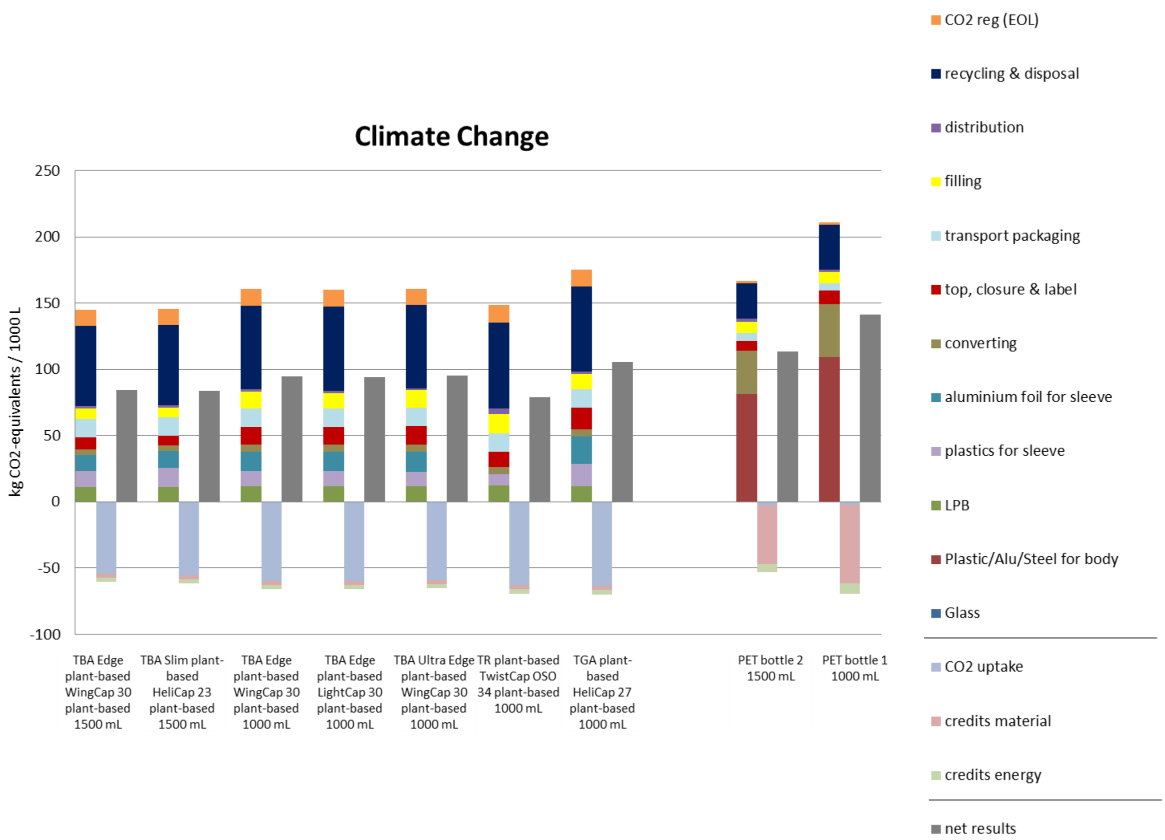

Figure 17: Climate Change results of **segment DAIRY FAMILY PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

Table 49: Climate Change results of **segment DAIRY FAMILY PACK CHILLED** - burdens, credits and net results per functional unit of 1000 L, sensitivity EU PET preform production (allocation factor 100%) (All figures are rounded to two decimal places.)

sensitivity EU PET preform production (allocation factor 100%)		TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL		PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	132.88	133.69	148.16	147.45	148.30	135.18	162.59		164.64	209.36
	CO2 (reg)	11.97	11.90	12.47	12.52	12.11	13.50	12.61		2.07	1.62
	Credits	-6.02	-6.01	-6.32	-6.38	-6.19	-6.63	-6.41		-50.27	-67.30
	CO2 uptake	-54.70	-55.87	-59.79	-59.75	-59.26	-62.95	-63.49		-2.82	-2.22
	net results	84.13	83.71	94.52	93.84	94.96	79.10	105.31		113.62	141.47

4.3.2 Description and interpretation

In this section the effects of the sensitivity analyses for PET preform production in Europe are described. Detailed descriptions and interpretation including the contribution of all life cycle steps are included for the allocation 50% results (see section 4.1.2).

With PET preform production modelled for Europe the "Climate Change" impact of the life cycle step "converting" is reduced by 33%-35% compared to PET preform production modelled for Greece as in the base scenarios. This leads to 12%-13% lower net results compared to the allocation 100% base scenarios.

4.3.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

Table 50: Comparison of net results: **TBA Edge plant-based WingCap 30 plant-based 1500 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

DAIRY FAMILY PACK (chilled), Greece sensitivity EU PET preform production (allocation factor 100%)	The net results of **TBA Edge plant-based WingCap 30 plant-based 1500 mL** are lower (green)/ higher (orange) than those of							
	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+1%	-11%	-10%	-11%	+6%	-20%	-26%	-41%

Table 51: Comparison of net results: **TBA Square plant-based HeliCap 23 plant-based 1500 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

DAIRY FAMILY PACK (chilled), Greece sensitivity EU PET preform production (allocation factor 100%)	The net results of **TBA Slim plant-based HeliCap 23 plant-based 1500 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	-1%	-11%	-11%	-12%	+6%	-21%	-26%	-41%

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

Table 52: Comparison of net results: **TBA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

DAIRY FAMILY PACK (chilled), Greece sensitivity EU PET preform production (allocation factor 100%)	The net results of **TBA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+12%	+13%	+1%	-0%	+19%	-10%	-17%	-33%

Table 53: 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 FAMILY PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

DAIRY FAMILY PACK (chilled), Greece sensitivity EU PET preform production (allocation factor 100%)	The net results of **TBA Edge plant-based LightCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+12%	+12%	-1%	-1%	+19%	-11%	-17%	-34%

Table 54: Comparison of net results: **TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

DAIRY FAMILY PACK (chilled), Greece sensitivity EU PET preform production (allocation factor 100%)	The net results of **TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+13%	+13%	+0%	+1%	+20%	-10%	-16%	-33%

Table 55: Comparison of net results: **TR plant-based TwistCap OSO 34 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

DAIRY FAMILY PACK (chilled), Greece sensitivity EU PET preform production (allocation factor 100%)	The net results of **TR plant-based TwistCap OSO 34 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TGA plant-based HeliCap 27 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	-6%	-5%	-16%	-16%	-17%	-25%	-30%	-44%

Table 56: Comparison of net results: **TGA plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment DAIRY FAMILY PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

DAIRY FAMILY PACK (chilled), Greece sensitivity EU PET preform production (allocation factor 100%)	The net results of **TGA plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based WingCap 30 plant-based 1500 mL	TBA Slim plant-based HeliCap 23 plant-based 1500 mL	TBA Edge plant-based WingCap 30 plant-based 1000 mL	TBA Edge plant-based LightCap 30 plant-based 1000 mL	TBA Ultra Edge plant-based WingCap 30 plant-based 1000 mL	TR plant-based TwistCap OSO 34 plant-based 1000 mL	PET bottle 2 1500 mL	PET bottle 1 1000 mL
Climate Change	+25%	+26%	+11%	+12%	+11%	+33%	-7%	-26%

4.4 Results allocation factor 50%; DAIRY PORTION PACK CHILLED

4.4.1 Presentation of results DAIRY PORTION PACK CHILLED

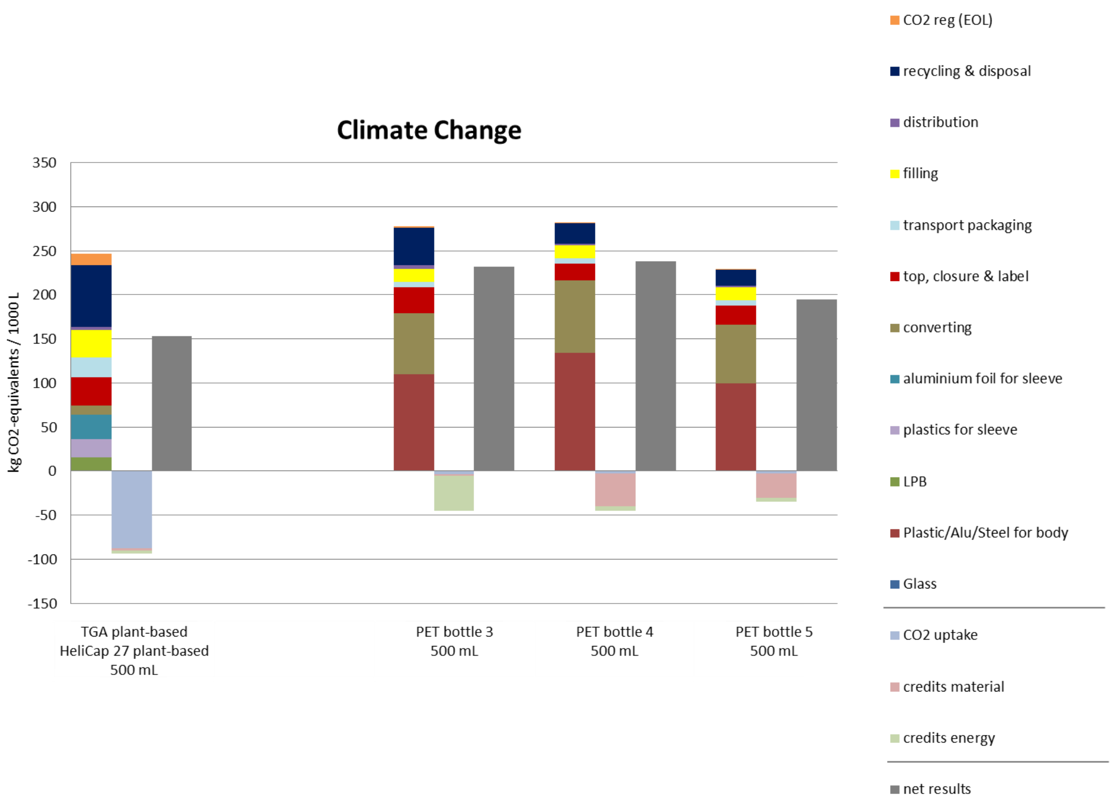

Figure 18: Climate Change results of **segment DAIRY PORTION PACK CHILLED**, allocation factor 50%

Table 57: Climate Change results of **segment DAIRY PORTION PACK CHILLED** - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TGA plant-based HeliCap 27 plant-based 500 mL		PET bottle 3 500 mL	PET bottle 4 500 mL	PET bottle 5 500 mL
Climate Change [kg CO2-e/1000 L]	Burdens	233.63		276.37	281.54	228.28
	CO2 (reg)	13.11		1.16	0.84	0.84
	Credits	-5.80		-42.18	-42.33	-32.19
	CO2 uptake	-87.58		-3.17	-2.29	-2.29
	net results	153.36		232.18	237.76	194.64

4.4.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton system considered in the DAIRY PORTION PACK CHILLED segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (6%), production of plastics for sleeves (9%) and the production of aluminium foil (11%).

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

Minor shares (13%) 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 9% of the total burdens for 'Climate Change' for the beverage carton.

The life cycle step 'filling' shows minor shares of burdens (13%) for the beverage carton.

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

The life cycle step 'recycling & disposal' of the assessed beverage carton is the most relevant life cycle step for 'Climate Change' (28%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paper board.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons in Greece these derive from landfills. They contribute to 5% of the total burdens for 'Climate Change'.

Due to the lack of MSWI with energy recovery in Greece, Turkey and India, energy credits sum up to only 2% resulting from small amounts of energy recovery in landfills. 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 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 of the assessed system. (see section 1.7.2)

Plastic bottle (specifications see section 2.2.2)

In the assessed plastic bottle systems in the DAIRY FAMILY PACK CHILLED segment, the biggest part (40%-48%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottle in this segment a considerable share of burdens for 'Climate Change (25%-29%) due to the 'Climate Change' intensive Greek electricity mix.

The life cycle step 'top, closure & label' shows small to minor impacts shares (7%-11%) mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle systems shows small impact shares (2%-3%) for climate change.

The life cycle steps 'filling' (5%-6%) and 'distribution' (1%-2%) show only small shares of burdens for all bottle systems.

The plastic bottle's 'recycling & disposal' life cycle step shows small shares (8%) for the assessed clear plastic bottles resulting from the recycling processes and in case of exported bottles from incineration of the bottles. In case of the white opaque PET bottle 3 minor shares of total burdens (15%) are shown resulting from the incineration in cement kilns.

For the clear plastic bottles material credits reduce the total burdens by (12%-13%) resulting from the substitution of virgin PET. The influence of material credits on the net result for the white opaque PET bottle 3 is not relevant for 'Climate Change' as the white plastic bottles are not materially recycled.

The influence of energy credits for the clear PET bottles on the net result is low due to the lack of MSWI with energy recovery in Greece. The small reduction of net results by energy credits (2%) results from the incineration of exported PET bottles. The influence of energy credits on the net result regarding the white opaque PET bottle 3 is higher (15%) due to the substitution of fossil fuels in cement kilns.

4.4.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

Table 58: Comparison of net results: **TGA plant-based HeliCap 27 plant-based 500 mL** versus alternative packaging systems in **segment DAIRY PORTION PACK CHILLED**, allocation factor 50%

DAIRY PORTION PACK (chilled), Greece Allocation 50	The net results of **TGA plant-based HeliCap 27 plant-based 500 mL** are lower (green)/ higher (orange) than those of		
	PET bottle 3 500 mL	PET bottle 4 500 mL	PET bottle 5 500 mL
Climate Change	-34%	-35%	-21%

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

4.5 Results allocation factor 100%; DAIRY PORTION PACK CHILLED

4.5.1 Presentation of results DAIRY PORTION PACK CHILLED

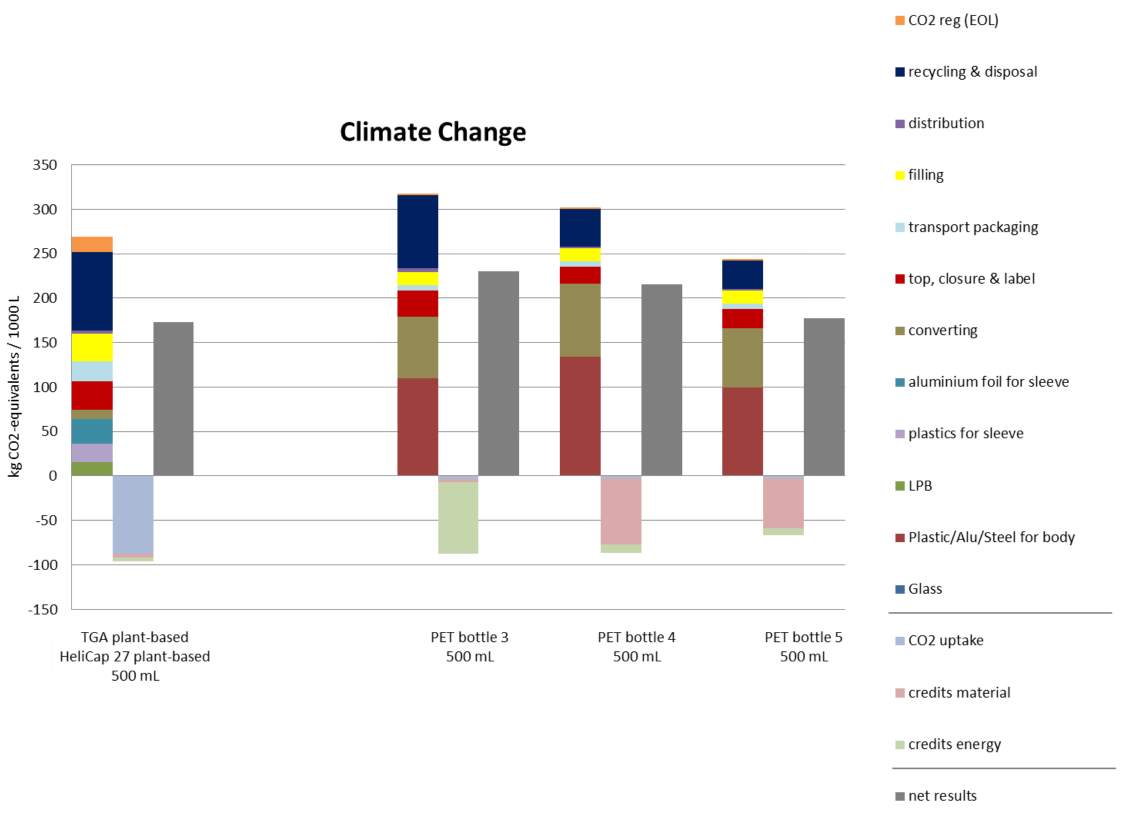

Figure 19: Climate Change results of **segment DAIRY PORTION PACK CHILLED**, allocation factor 100%

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

Allocation 100		TGA plant-based HeliCap 27 plant-based 500 mL		PET bottle 3 500 mL	PET bottle 4 500 mL	PET bottle 5 500 mL
Climate Change [kg CO2-e/1000 L]	Burdens	252.08		315.47	300.49	242.70
	CO2 (reg)	16.79		2.32	1.67	1.67
	Credits	-8.50		-84.35	-84.65	-64.37
	CO2 uptake	-87.58		-3.17	-2.29	-2.29
	net results	172.79		230.27	215.23	177.72

4.5.2 Description and interpretation

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

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

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

In the cases of beverage cartons in the segment DAIRY PORTION PACK CHILLED applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

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

4.5.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

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

Table 60: Comparison of net results: **TGA plant-based HeliCap 27 plant-based 500 mL** versus alternative packaging systems in **segment DAIRY PORTION PACK CHILLED**, allocation factor 100%

DAIRY PORTION PACK (chilled), Greece Allocation 100	The net results of **TGA plant-based HeliCap 27 plant-based 500 mL** are lower (green)/ higher (orange) than those of		
	PET bottle 3 500 mL	PET bottle 4 500 mL	PET bottle 5 500 mL
Climate Change	-25%	-20%	-3%

4.6 Results sensitivity EU PET preform production (allocation factor 100%); DAIRY PORTION PACK CHILLED

4.6.1 Presentation of results DAIRY PORTION PACK CHILLED

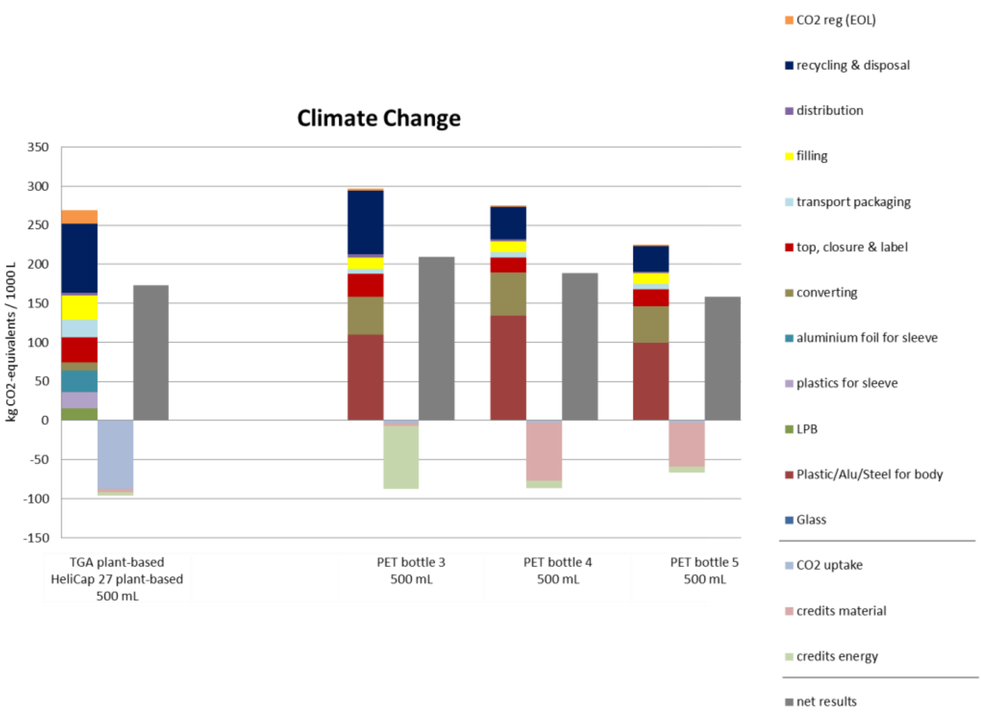

Figure 20: Climate Change results of **segment DAIRY PORTION PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

Table 61: Climate Change results of **segment DAIRY PORTION PACK CHILLED** - burdens, credits and net results per functional unit of 1000 L, sensitivity EU PET preform production (allocation factor 100%) (All figures are rounded to two decimal places.)

sensitivity EU PET preform production (allocation factor 100%)		TGA plant-based HeliCap 27 plant-based 500 mL		PET bottle 3 500 mL	PET bottle 4 500 mL	PET bottle 5 500 mL
Climate Change [kg CO2-e/1000 L]	Burdens	252.08		294.54	273.89	222.95
	CO2 (reg)	16.79		2.32	1.67	1.67
	Credits	-8.50		-84.35	-84.65	-64.37
	CO2 uptake	-87.58		-3.17	-2.29	-2.29
	net results	172.79		209.34	188.63	157.97

4.6.2 Description and interpretation

In this section the effects of the sensitivity analyses for PET preform production in Europe are described. Detailed descriptions and interpretation including the contribution of all life cycle steps are included for the allocation 50% results (see section 4.1.2).

With PET preform production modelled for Europe the "Climate Change" impacts of the life cycle step "converting" is reduced by 30%-33% compared to PET preform production modelled for Greece as in the base scenarios. This leads to 10%-12% lower net results compared to the allocation 100% base scenarios.

4.6.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

Table 62: Comparison of net results: **TGA plant-based HeliCap 27 plant-based 500 mL** versus a competing carton and alternative packaging systems in **segment DAIRY PORTION PACK CHILLED**, sensitivity EU PET preform production (allocation factor 100%)

DAIRY PORTION PACK (chilled), Greece sensitivity EU PET preform production (allocation factor 100%)	The net results of **TGA plant-based HeliCap 27 plant-based 500 mL** are lower (green)/ higher (orange) than those of		
	PET bottle 3 500 mL	PET bottle 4 500 mL	PET bottle 5 500 mL
Climate Change	-17%	-8%	+9%

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

4.7 Results allocation factor 50%; JNSD FAMILY PACK CHILLED

4.7.1 Presentation of results JNSD FAMILY PACK CHILLED

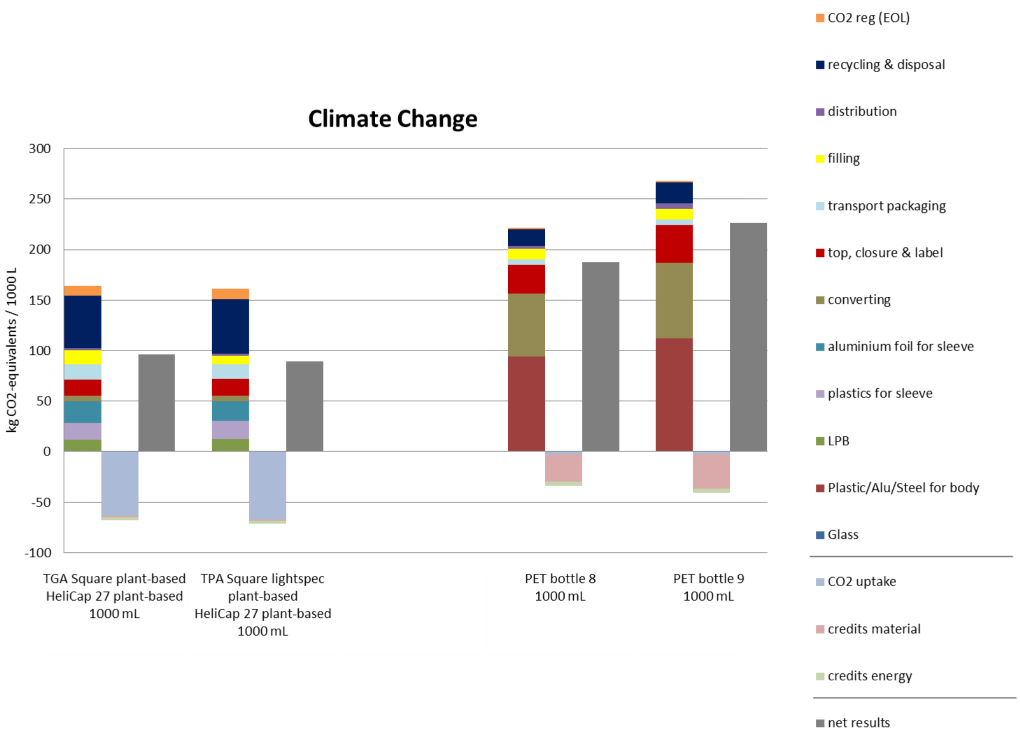

Figure 21: Climate Change results of **segment JNSD FAMILY PACK CHILLED**, allocation factor 50%

Table 63: Climate Change results of **segment JNSD FAMILY PACK CHILLED** - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TGA Square plant-based HeliCap 27 plant-based 1000 mL	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL		PET bottle 8 1000 mL	PET bottle 9 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	154.25	150.77		220.42	266.35
	CO2 (reg)	9.68	10.20		0.96	1.17
	Credits	-4.35	-4.59		-31.43	-37.86
	CO2 uptake	-63.64	-67.11		-2.62	-3.20
	net results	95.94	89.27		187.33	226.46

4.7.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the JNSD FAMILY PACK CHILLED segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (7%-8%), the production of plastics for sleeves (10%-11%) and the production of aluminium foil (12%-13%).

The converting to sleeves accounts only small shares (3%-4%) 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 9% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'filling' shows small shares of burdens (5%-9%) for the beverage carton systems.

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

The life cycle step 'recycling & disposal' of the assessed beverage cartons is the most relevant life cycle step for 'Climate Change' (32%-34%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paper board.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons in Greece these derive from landfills. They contribute to 6% of the total burdens for 'Climate Change'.

Due to the lack of MSWI with energy recovery in Greece, Turkey and India, energy credits sum up to only 2% resulting from small amounts of energy recovery in landfills. 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 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 of the assessed system. (see section 1.7.2)

Plastic bottles (specifications see section 2.2.2)

In the assessed plastic bottle systems in the JNSD FAMILY PACK CHILLED segment, a major share (42%-43%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottles in this segment considerable shares of burdens for 'Climate Change (28%) due to the 'Climate Change' intensive Greek electricity mix.

The life cycle step 'top, closure & label' shows considerable impacts shares (13%-14%) mainly attributed to the different plastics used for the relatively heavy closures.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (2%) for climate change.

The life cycle steps 'filling' (4%-5%) and 'distribution' (1%-2%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows small shares (8%) for the assessed plastic bottles resulting from the recycling processes and in case of exported bottles from incineration of the bottles.

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

The influence of energy credits on the net result is low due to the lack of MSWI with energy recovery in Greece. The small reduction of net results by energy credits (2%) results from the incineration of exported PET bottles.

4.7.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

Table 64: Comparison of net results: **TGA Square plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK CHILLED**, allocation factor 50%

JNSD FAMILY PACK (chilled), Greece Allocation 50	The net results of **TGA Square plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	PET bottle 8 1000 mL	PET bottle 9 1000 mL
Climate Change	+7%	-49%	-58%

Table 65: Comparison of net results: **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK CHILLED**, allocation factor 50%

JNSD FAMILY PACK (chilled), Greece Allocation 50	The net results of **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TGA Square plant-based HeliCap 27 plant-based 1000 mL	PET bottle 8 1000 mL	PET bottle 9 1000 mL
Climate Change	-7%	-52%	-61%

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

4.8 Results allocation factor 100%; JNSD FAMILY PACK CHILLED

4.8.1 Presentation of results JNSD FAMILY PACK CHILLED

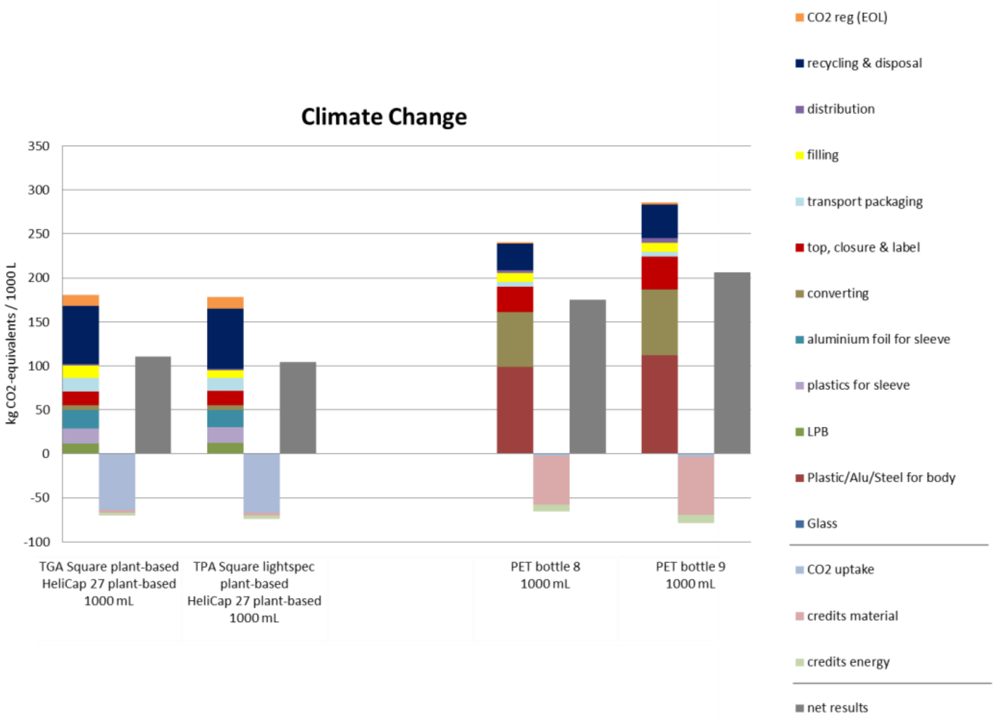

Figure 22: Climate Change results of **segment JNSD FAMILY PACK CHILLED**, allocation factor 100%

Table 66: Climate Change results of **segment JNSD FAMILY PACK CHILLED** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TGA Square plant-based HeliCap 27 plant-based 1000 mL	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL		PET bottle 8 1000 mL	PET bottle 9 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	167.89	164.94		238.82	283.11
	CO2 (reg)	12.37	13.11		1.92	2.34
	Credits	-6.38	-6.75		-62.86	-75.72
	CO2 uptake	-63.64	-67.11		-2.62	-3.20
	net results	110.24	104.19		175.26	206.53

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 4.1.2).

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

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

In the cases of beverage cartons in the segment JNSD FAMILY PACK CHILLED applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In the cases of the plastic bottles, 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 mainly recycling regardless of the allocation factor.

4.8.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

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

Table 67: Comparison of net results: **TGA Square plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK CHILLED**, allocation factor 100%

JNSD FAMILY PACK (chilled), Greece Allocation 100	The net results of **TGA Square plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	PET bottle 8 1000 mL	PET bottle 9 1000 mL
Climate Change	+6%	-37%	-47%

Table 68: Comparison of net results: **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK CHILLED**, allocation factor 100%

JNSD FAMILY PACK (chilled), Greece Allocation 100	The net results of **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TGA Square plant-based HeliCap 27 plant-based 1000 mL	PET bottle 8 1000 mL	PET bottle 9 1000 mL
Climate Change	-5%	-41%	-50%

4.9 Results allocation factor 50%; JNSD FAMILY PACK AMBIENT

4.9.1 Presentation of results JNSD FAMILY PACK AMBIENT

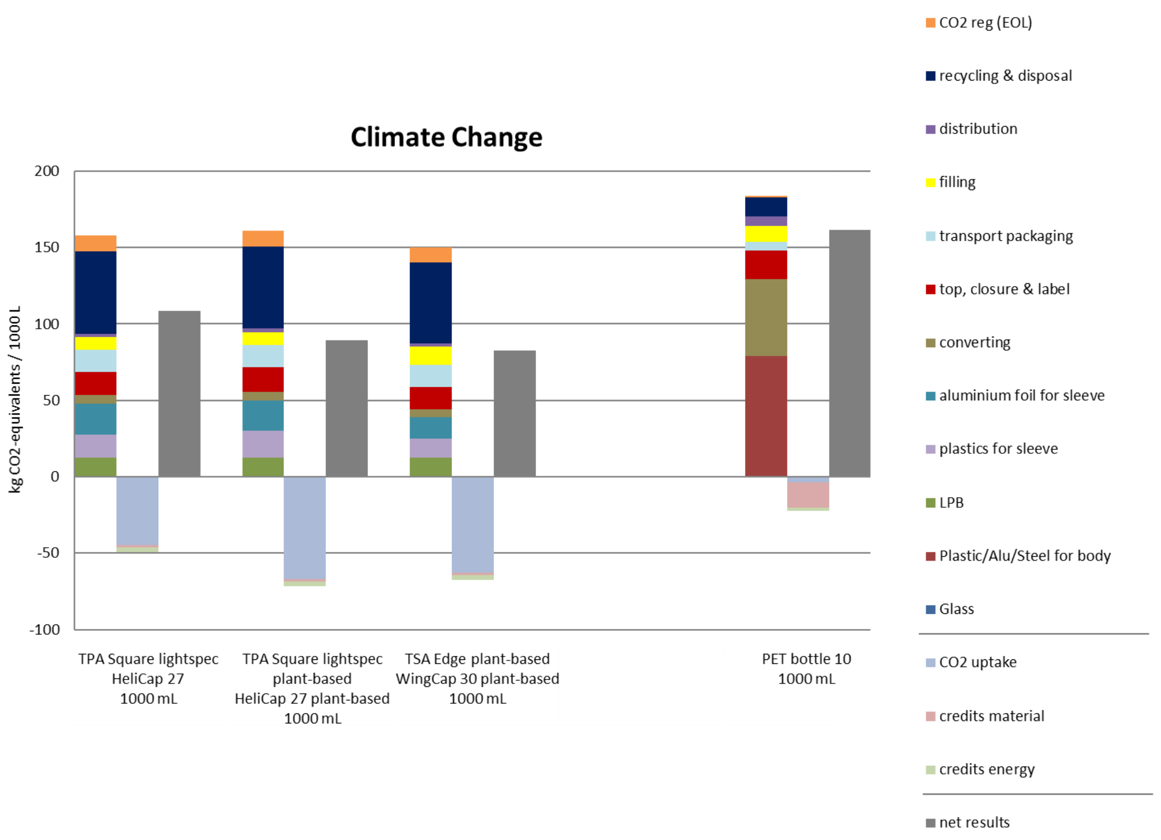

Figure 23: Climate Change results of **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

Table 69: Climate Change results of segment JNSD FAMILY PACK AMBIENT - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Square lightspec HeliCap 27 1000 mL	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL		PET bottle 10 1000 mL
	Burdens	147.69	150.77	140.17		182.66
	CO2 (reg)	10.11	10.20	10.11		1.24
	Credits	-4.59	-4.59	-4.53		-19.13
Climate Change	CO2 uptake	-44.76	-67.11	-62.96		-3.39
[kg CO2-e/1000 L]	net results	108.46	89.27	82.80		161.39

4.9.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the JNSD FAMILY PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (8%), the production of plastics for sleeves (8%) and the production of aluminium foil (9%-13%).

The converting to sleeves accounts only small shares (4%) 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 9%-10% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'filling' shows small shares of burdens (5%-8%) for the beverage carton systems.

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

The life cycle step 'recycling & disposal' of the assessed beverage cartons is the most relevant life cycle step for 'Climate Change' (34%-35%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paper board.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons in Greece these derive from landfills. They contribute to 6%-7% of the total burdens for 'Climate Change'.

Due to the lack of MSWI with energy recovery in Greece, Turkey and India, energy credits sum up to only 2% resulting from small amounts of energy recovery in landfills. 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 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 of the assessed system. (see section 1.7.2)

Plastic bottles (specifications see section 2.2.2)

In the assessed plastic bottle system in the JNSD FAMILY PACK AMBIENT 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 for the PET bottle in this segment a considerable share of burdens for 'Climate Change (28%) due to the 'Climate Change' intensive Greek electricity mix.

The life cycle step 'top, closure & label' shows small impacts shares (10%) mainly attributed to the different plastics used for the closures.

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

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

The plastic bottles' 'recycling & disposal' life cycle step shows small shares (7%) for the assessed plastic bottle resulting from the recycling processes and in case of exported bottles from incineration of the bottles.

Material credits reduce the total burdens by 9% resulting from the substitution of virgin PET.

The influence of energy credits on the net result is low due to the lack of MSWI with energy recovery in Greece. The small reduction of net results by energy credits (1%) results from the incineration of exported PET bottles.

4.9.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

Table 70: Comparison of net results: **TPA Square lightspec HeliCap 27 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Greece Allocation 50	The net results of **TPA Square lightspec HeliCap 27 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	+21%	+31%	-33%

Table 71: Comparison of net results: **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Greece Allocation 50	The net results of **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec HeliCap 27 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	-18%	+8%	-45%

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

Table 72: Comparison of net results: **TSA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Greece Allocation 50	The net results of **TSA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec HeliCap 27 1000 mL	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	-24%	-7%	-49%

4.10 Results allocation factor 100%; JNSD FAMILY PACK AMBIENT

4.10.1 Presentation of results JNSD FAMILY PACK AMBIENT

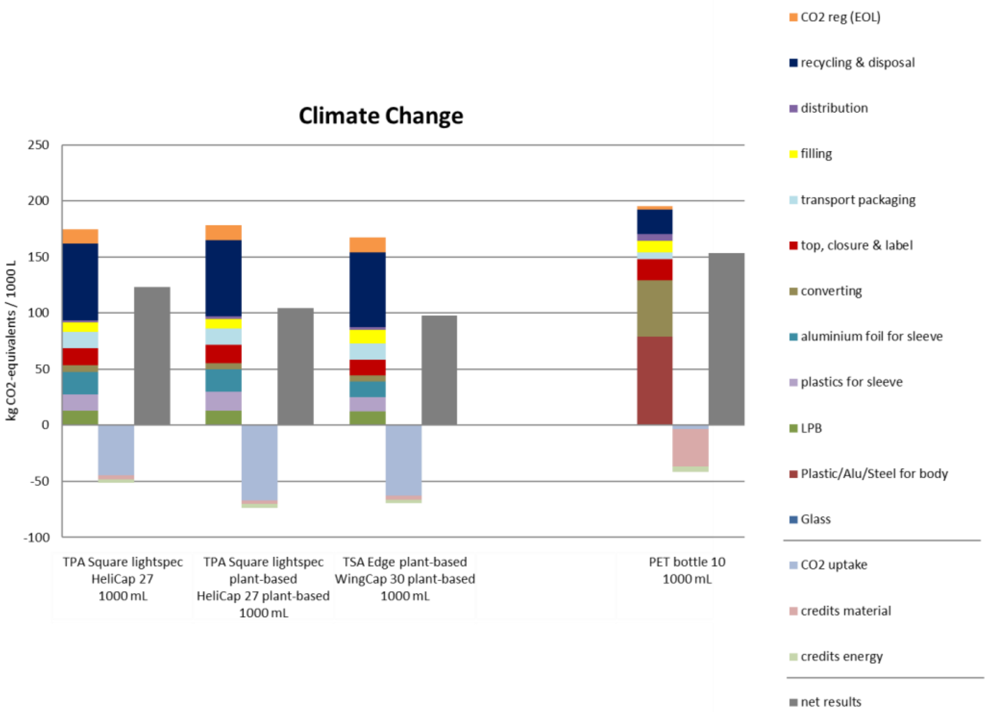

Figure 24: Climate Change results of **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

Table 73: Climate Change results of **segment JNSD FAMILY PACK AMBIENT** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Square lightspec HeliCap 27 1000 mL	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL		PET bottle 10 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	161.95	164.94	154.07		192.51
	CO2 (reg)	12.94	13.11	13.05		2.48
	Credits	-6.75	-6.75	-6.67		-38.25
	CO2 uptake	-44.76	-67.11	-62.96		-3.39
	net results	123.38	104.19	97.49		153.35

4.10.2 Description and interpretation

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

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

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

In the cases of beverage cartons in the segment JNSD FAMILY PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In the cases of the plastic bottles, 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 mainly recycling regardless of the allocation factor.

4.10.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

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

Table 74: Comparison of net results: **TPA Square lightspec HeliCap 27 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Greece Allocation 100	The net results of **TPA Square lightspec HeliCap 27 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	+18%	+27%	-20%

Table 75: Comparison of net results: **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Greece Allocation 100	The net results of **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec HeliCap 27 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	-16%	+7%	-32%

Table 76: Comparison of net results: **TSA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Greece Allocation 100	The net results of **TSA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec HeliCap 27 1000 mL	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	-21%	-6%	-36%

4.11 Results sensitivity EU PET preform production (allocation factor 100%); JNSD FAMILY PACK AMBIENT

4.11.1 Presentation of results JNSD FAMILY PACK AMBIENT

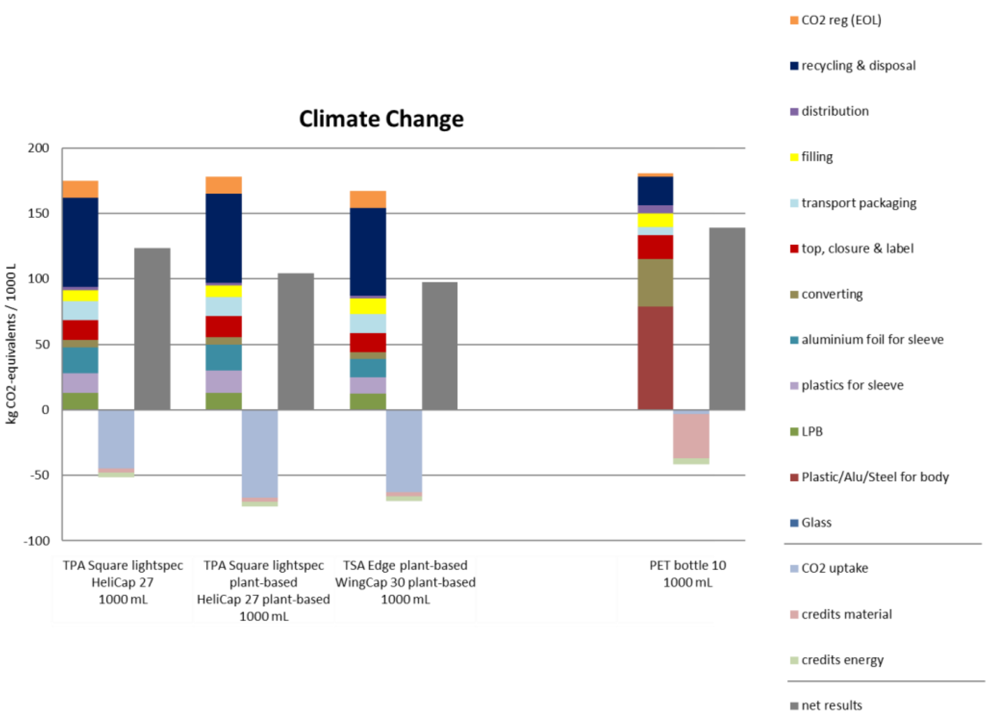

Figure 25: Climate Change results of **segment JNSD FAMILY PACK AMBIENT**, sensitivity EU PET preform production (allocation factor 100%)

Table 77: Climate Change results of **segment JNSD FAMILY PACK AMBIENT** - burdens, credits and net results per functional unit of 1000 L, sensitivity EU PET preform production (allocation factor 100%) (All figures are rounded to two decimal places.)

sensitivity EU PET preform production (allocation factor 100%)		TPA Square lightspec HeliCap 27 1000 mL	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL		PET bottle 10 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	161.95	164.94	154.07		178.10
	CO2 (reg)	12.94	13.11	13.05		2.48
	Credits	-6.75	-6.75	-6.67		-38.25
	CO2 uptake	-44.76	-67.11	-62.96		-3.39
	net results	123.38	104.19	97.49		138.95

4.11.2 Description and interpretation

In this section the effects of the sensitivity analyses for PET preform production in Europe are described. Detailed descriptions and interpretation including the contribution of all life cycle steps are included for the allocation 50% results (see section 4.9.2).

With PET preform production modelled for Europe the "Climate Change" impact of the life cycle step "converting" is reduced by 28% compared to PET preform production modelled for Greece as in the base scenarios. This leads to 9% lower net results compared to the allocation 100% base scenarios.

4.11.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

Table 78: Comparison of net results: **TPA Square lightspec HeliCap 27 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, sensitivity EU PET preform production (allocation factor 100%)

JNSD FAMILY PACK (ambient), Greece sensitivity EU PET preform	The net results of **TPA Square lightspec HeliCap 27 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	+18%	+27%	-11%

Table 79: Comparison of net results: **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, sensitivity EU PET preform production (allocation factor 100%)

JNSD FAMILY PACK (ambient), Greece sensitivity EU PET preform	The net results of **TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec HeliCap 27 1000 mL	TSA Edge plant-based WingCap 30 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	-16%	+7%	-25%

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

Table 80: Comparison of net results: **TSA Edge plant-based WingCap 30 plant-based 1000 mL** versus a competing carton and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, sensitivity EU PET preform production (allocation factor 100%)

JNSD FAMILY PACK (ambient), Greece sensitivity EU PET preform	The net results of **TSA Edge plant-based WingCap 30 plant-based 1000 mL** are lower (green)/ higher (orange) than those of		
	TPA Square lightspec HeliCap 27 1000 mL	TPA Square lightspec plant-based HeliCap 27 plant-based 1000 mL	PET bottle 10 1000 mL
Climate Change	-21%	-6%	-30%

4.12 Results allocation factor 50%; JNSD PORTION PACK CHILLED

4.12.1 Presentation of results JNSD PORTION PACK CHILLED

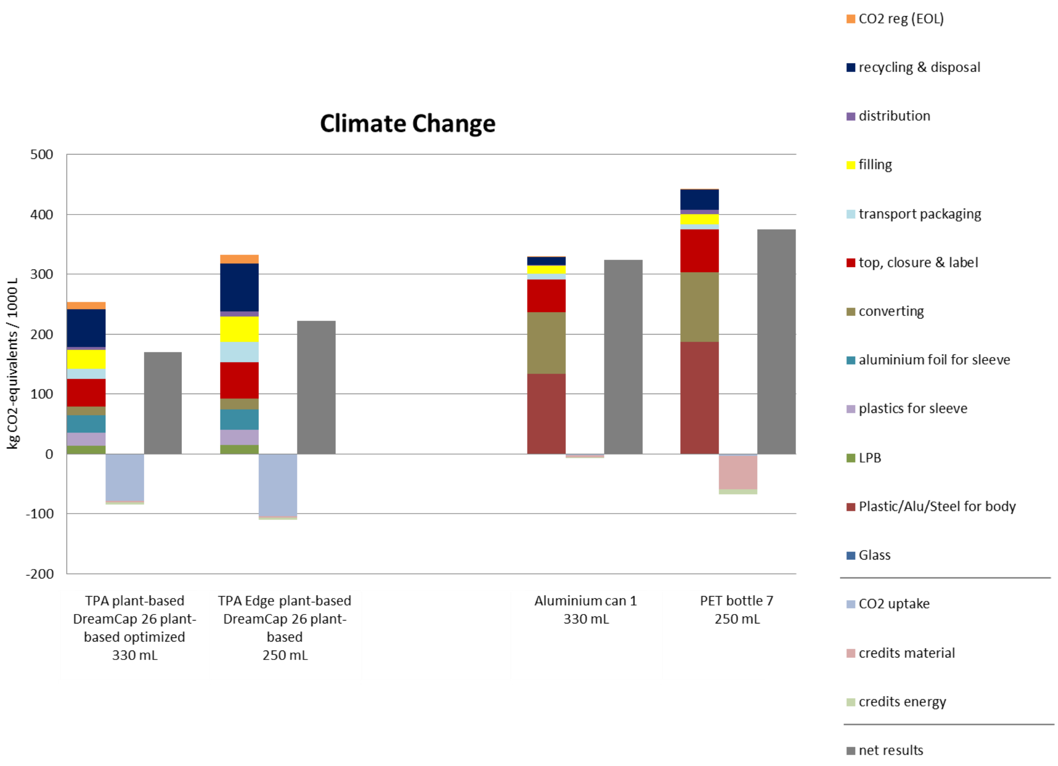

Figure 26: Climate Change results of segment JNSD PORTION PACK CHILLED, allocation factor 50%

Table 81: Climate Change results of segment JNSD PORTION PACK CHILLED - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA plant-based DreamCap 26 plant-based optimized 330 mL	TPA Edge plant-based DreamCap 26 plant-based 250 mL		Aluminium can 1 330 mL	PET bottle 7 250 mL
Climate Change [kg CO2-e/1000 L]	Burdens	241.50	317.95		328.72	440.91
	CO2 (reg)	11.92	14.69		0.92	1.26
	Credits	-5.35	-6.30		-3.62	-64.05
	CO2 uptake	-78.65	-103.95		-2.42	-3.43
	net results	169.43	222.40		323.60	374.68

4.12.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the JNSD PORTION PACK CHILLED segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (5%-6%), the production of plastics for sleeves (8%-9%) and the production of aluminium foil (10%-11%).

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

Considerable shares (18%) of total burdens for 'Climate Change' are caused from the production of closures due to the relatively high weight of closures compared to the sleeve.

The production and provision of 'transport packaging' for the beverage carton systems shows 7%-10% of the total burdens for 'Climate Change' for all beverage cartons.

The life cycle step 'filling' shows minor shares of burdens (13%) for the beverage carton systems.

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

The life cycle step 'recycling & disposal' of the assessed beverage cartons is the most relevant life cycle step for 'Climate Change' (24%-25%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paper board.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons in Greece these derive from landfills. They contribute to 4%-5% of the total burdens for 'Climate Change'.

Due to the lack of MSWI with energy recovery in Greece, Turkey and India, energy credits sum up to only 1% resulting from small amounts of energy recovery in landfills. 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 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 of the assessed system. (see section 1.7.2)

Plastic bottle (specifications see section 2.2.2)

In the assessed plastic bottle system in the JNSD PORTION PACK CHILLED segment, a major share (42%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottle in this segment a considerable shares of burdens for 'Climate Change (26%) due to the 'Climate Change' intensive Greek electricity mix.

The life cycle step 'top, closure & label' shows considerable impacts shares (13%-14%) mainly attributed to the different plastics used for the relatively heavy closures.

The production and provision of 'transport packaging' for the bottle system shows small impact shares (2%) for climate change.

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

The plastic bottle's 'recycling & disposal' life cycle step shows small shares (7%) for the assessed plastic bottles resulting from the recycling processes and in case of exported bottles from incineration of the bottles.

Material credits reduce the total burdens by 13% resulting from the substitution of virgin PET.

The influence of energy credits on the net result is low due to the lack of MSWI with energy recovery in Greece. The small reduction of net results by energy credits (2%) results from the incineration of exported PET bottles.

Aluminium can (specifications see section 2.2.2)

In the assessed aluminium can system in the JNSD PORTION PACK CHILLED segment, a major share (41%) of the environmental burdens for 'Climate Change' is caused by the production of the aluminium of the body.

The 'converting' process shows for the aluminium can in this segment a considerable share of burdens for 'Climate Change (31%) mainly due to the 'Climate Change' intensive Greek electricity mix.

The life cycle step 'top, closure & label' shows considerable impacts shares (17%) mainly attributed to the aluminium production and closure converting processes.

The production and provision of 'transport packaging' for the aluminium can shows small impact shares (2%) for climate change.

The life cycle steps 'filling' (4%) and 'distribution' (1%) show only small shares of burdens for the aluminium can.

The aluminium can 'recycling & disposal' life cycle step shows small shares (4%) for the assessed plastic bottles resulting from the recycling processes and in case of exported bottles from incineration of the bottles.

Material credits reduce the total burdens by only 4%, resulting from secondary and tertiary packaging as the recycled aluminium is used in a closed loop to feed the recycled content of the can. The effects of closed loop recycled material are included in the life cycle step regarding the production of aluminium.

Due to the lack of MSWI with energy recovery in Greece, Energy credits are almost zero resulting only to a very small amount from landfilling of tertiary packaging (pallets).

4.12.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

Table 82: Comparison of net results: **TPA plant-based DreamCap 26 plant-based optimized 330 mL** versus a competing carton and alternative packaging systems in **segment JNSD PORTION PACK CHILLED**, allocation factor 50%

JNSD PORTION PACK (chilled), Greece Allocation 50	The net results of **TPA plant-based DreamCap 26 plant-based** are lower (green)/ higher (orange) than those of		
	TPA Edge plant-based DreamCap 26 plant-based 250 mL	Aluminium can 1 330 mL	PET bottle 7 250 mL
Climate Change	-24%	-48%	-55%

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

Table 83: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 250 mL** versus a competing carton and alternative packaging systems in **segment JNSD PORTION PACK CHILLED**, allocation factor 50%

JNSD PORTION PACK (chilled), Greece Allocation 50	The net results of **TPA Edge plant-based DreamCap 26 plant-based** are lower (green)/ higher (orange) than those of		
	TPA plant-based DreamCap 26 plant-based optimized 330 mL	Aluminium can 1 330 mL	PET bottle 7 250 mL
Climate Change	+31%	-31%	-41%

4.13 Results allocation factor 100%; JNSD PORTION PACK CHILLED

4.13.1 Presentation of results JNSD PORTION PACK CHILLED

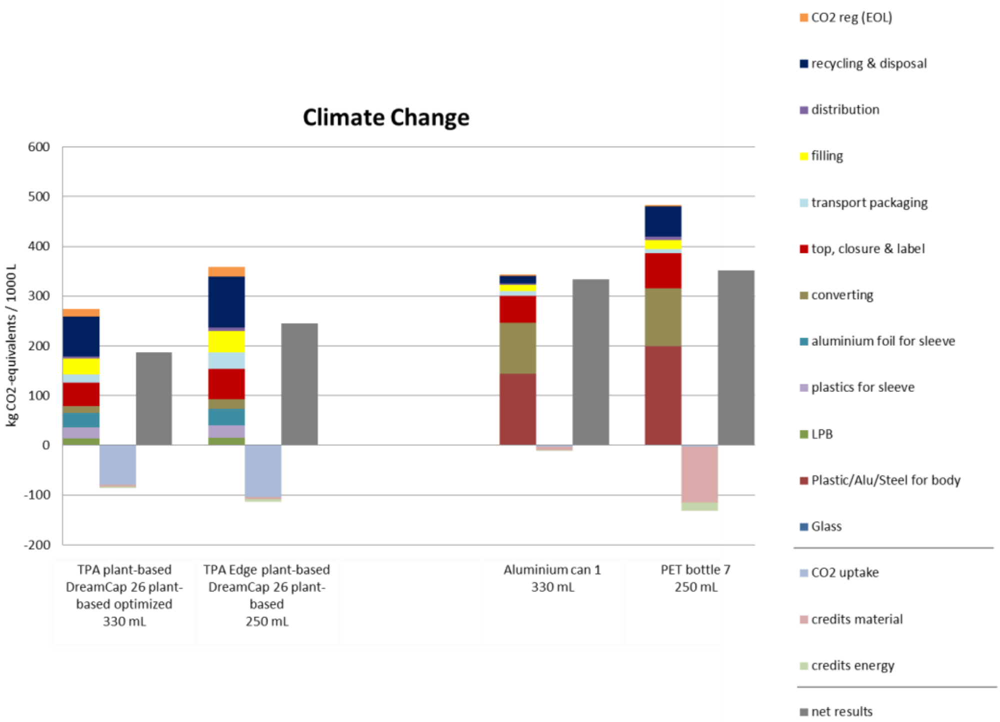

Figure 27: Climate Change results of segment JNSD PORTION PACK CHILLED, allocation factor 100%

Table 84: Climate Change results of segment JNSD PORTION PACK CHILLED - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA plant-based DreamCap 26 plant-based optimized 330 mL	TPA Edge plant-based DreamCap 26 plant-based 250 mL		Aluminium can 1 330 mL	PET bottle 7 250 mL
Climate Change [kg CO2-e/1000 L]	Burdens	258.20	339.27		340.80	479.98
	CO2 (reg)	15.49	18.72		1.84	2.51
	Credits	-7.94	-9.18		-7.21	-128.10
	CO2 uptake	-78.65	-103.95		-2.42	-3.43
	net results	187.10	244.86		333.01	350.96

4.13.2 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 4.12.2).

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

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

In the cases of beverage cartons in the segment JNSD PORTION PACK CHILLED applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In the cases of the plastic bottle, 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 mainly recycling regardless of the allocation factor.

In the cases of the aluminium can, higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the benefits of the recycled content provided by open loop material is not allocated to the regarded system.

4.13.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

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

Table 85: Comparison of net results: **TPA plant-based DreamCap 26 plant-based optimized 330 mL** versus a competing carton and alternative packaging systems in **segment JNSD PORTION PACK CHILLED**, allocation factor 100%

JNSD PORTION PACK (chilled), Greece Allocation 100	The net results of **TPA plant-based DreamCap 26 plant-based optimized 330 mL** are lower (green)/ higher (orange) than those of		
	TPA Edge plant-based DreamCap 26 plant-based 250 mL	Aluminium can 1 330 mL	PET bottle 7 250 mL
Climate Change	-24%	-44%	-47%

Table 86: Comparison of net results: **TPA Edge plant-based DreamCap 26 plant-based 250 mL** versus a competing carton and alternative packaging systems in **segment JNSD PORTION PACK CHILLED**, allocation factor 100%

JNSD PORTION PACK (chilled), Greece Allocation 100	The net results of **TPA Edge plant-based DreamCap 26 plant-based 250 mL** are lower (green)/ higher (orange) than those of		
	TPA plant-based DreamCap 26 plant-based optimized 330 mL	Aluminium can 1 330 mL	PET bottle 7 250 mL
Climate Change	+31%	-26%	-30%

4.14 Results allocation factor 50%; OLIVE OIL FAMILY PACK AMBIENT

4.14.1 Presentation of results OLIVE OIL FAMILY PACK AMBIENT

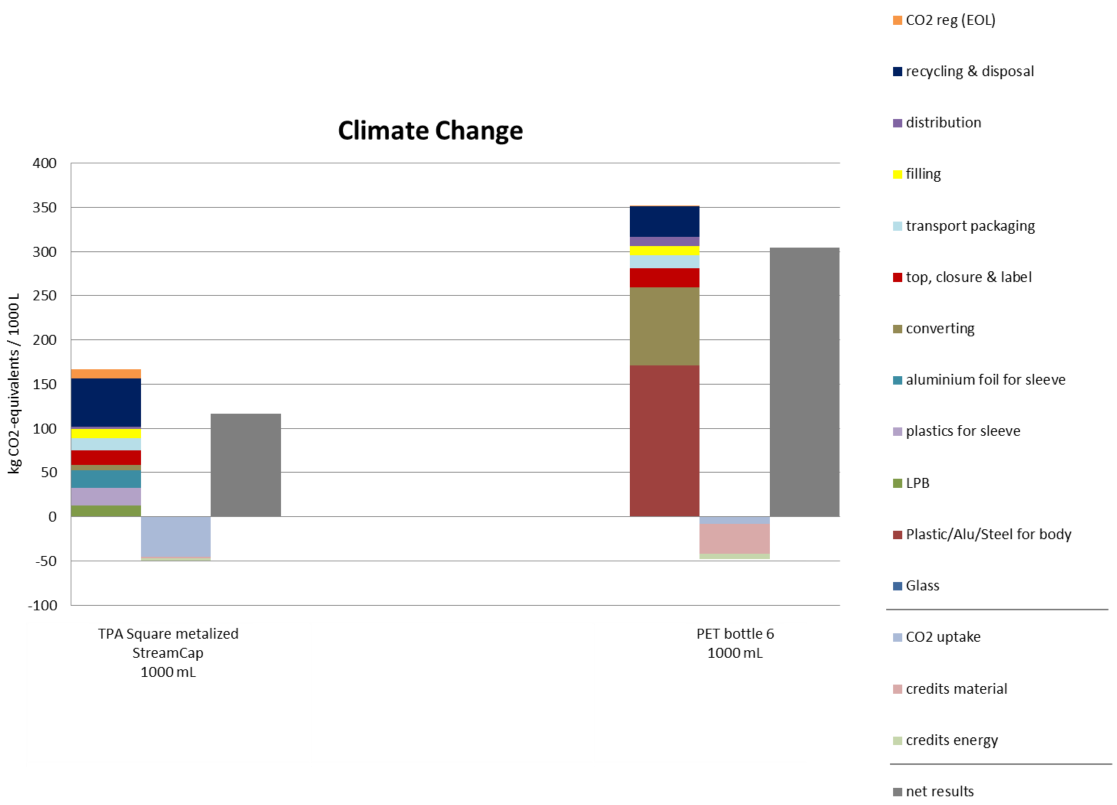

Figure 28: Climate Change results of **segment OLIVE OIL FAMILY PACK AMBIENT**, allocation factor 50%

Table 87: Climate Change results of **segment OLIVE OIL FAMILY PACK AMBIENT** - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Square metalized StreamCap 1000 mL		PET bottle 6 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	156.31	0.00	350.80
	CO2 (reg)	10.20	0.00	1.47
	Credits	-4.65	0.00	-39.86
	CO2 uptake	-45.09	0.00	-7.70
	net results	116.76	0.00	304.70

4.14.2 Description and interpretation

Beverage carton system (specifications see section 2.2.1)

For the beverage carton system considered in the OLIVE OIL 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%), the production of plastics for sleeves (12%) and the production of aluminium foil (12%).

The converting to sleeves accounts only small shares (4%) 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 8% of the total burdens for 'Climate Change' for the beverage carton.

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

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

The life cycle step 'recycling & disposal' of the assessed beverage cartons is the most relevant life cycle step for 'Climate Change' (33%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paper board.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of beverage cartons in Greece these derive from landfills. They contribute to 6% of the total burdens for 'Climate Change'.

Due to the lack of MSWI with energy recovery in Greece, Turkey and India, energy credits sum up to only 2% resulting from small amounts of energy recovery in landfills. 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 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 of the assessed system. (see section 1.7.2)

Plastic bottle (specifications see section 2.2.2)

In the assessed plastic bottle system in the OLIVE OIL FAMILY PACK AMBIENT segment, the major share (49%) of the environmental burdens for 'Climate Change' is caused by the production of the base materials of the bottles.

The 'converting' process shows for the PET bottle in this segment a considerable share of burdens for 'Climate Change (25%) due to the 'Climate Change' intensive Greek electricity mix.

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

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

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

The plastic bottles' 'recycling & disposal' life cycle step shows small shares (10%) for the assessed plastic bottles resulting from the recycling processes and in case of exported bottles from incineration of the bottles.

Material credits reduce the total burdens by 10% resulting from the substitution of virgin PET.

The influence of energy credits on the net result is low due to the lack of MSWI with energy recovery in Greece. The small reduction of net results by energy credits (2%) results from the incineration of exported PET bottles.

4.14.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

Table 88: Comparison of net results: **TPA Square metalized StreamCap 1000 mL** versus competing cartons and alternative packaging systems in **segment OLIVE OIL FAMILY PACK AMBIENT-**, allocation factor 50%

Oil FAMILY PACK (ambient), Greece Allocation 50	The net results of **TPA Square metalized StreamCap 1000 mL** are lower (green)/ higher (orange) than those of
	PET bottle 6 1000 mL
Climate Change	-62%

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

4.15 Results allocation factor 100%; OLIVE OIL FAMILY PACK AMBIENT

4.15.1 Presentation of results OLIVE OIL FAMILY PACK AMBIENT

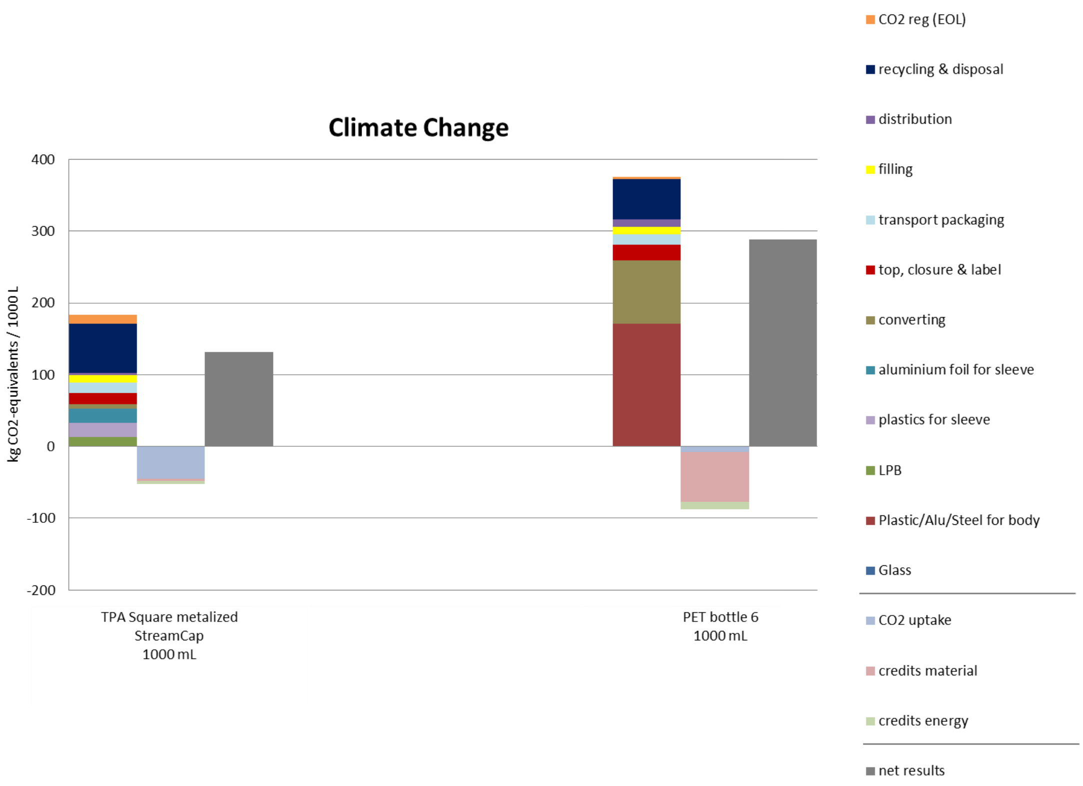

Figure 29: Climate Change results of **segment OLIVE OIL FAMILY PACK AMBIENT**, allocation factor 100%

Table 89: Climate Change results of **segment OLIVE OIL FAMILY PACK AMBIENT** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Square metalized StreamCap 1000 mL		PET bottle 6 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	170.89	0.00	372.82
	CO2 (reg)	13.15	0.00	2.93
	Credits	-6.89	0.00	-79.38
	CO2 uptake	-45.09	0.00	-7.70
	net results	132.06	0.00	288.67

4.15.2 Description and interpretation

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

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

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

In the cases of beverage cartons in the segment OLIVE OIL FAMILY PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

In the cases of the plastic bottles, 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 mainly recycling regardless of the allocation factor.

4.15.3 Comparison between packaging systems

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

The percentages in the following tables show the difference of net results between the packaging systems named in the heading compared to the net results of the packaging systems listed in the separate columns. The packaging systems in the columns are the base of the percentual comparison[1].

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

Table 90: Comparison of net results: **TPA Square metalized StreamCap 1000 mL** versus competing cartons and alternative packaging systems in **segment OLIVE OIL FAMILY PACK AMBIENT-**, allocation factor 100%

Oil FAMILY PACK (ambient), Greece Allocation 100	The net results of **TPA Square metalized StreamCap 1000 mL** are lower (green)/ higher (orange) than those of
	PET bottle 6 1000 mL
Climate Change	-54%

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

4.16.1 Presentation of results LIQUID FOOD PORTION PACK AMBIENT

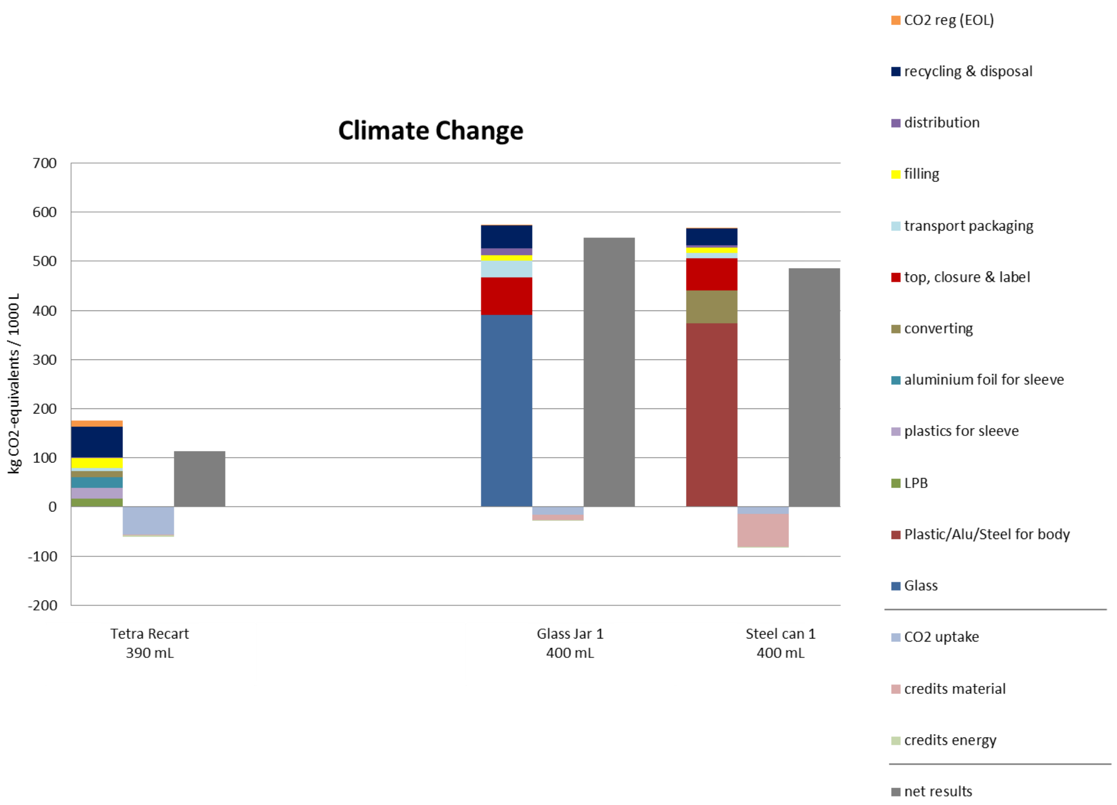

Figure 30: Climate Change results of **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 50%

Table 91: Climate Change results of **segment LIQUID FOOD PORTION PACK AMBIENT** - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		Tetra Recart 390 mL		Glass Jar 1 400 mL	Steel Can 1 400 mL
Climate Change [kg CO2-e/1000 L]	Burdens	163.49		573.59	566.34
	CO2 (reg)	12.09		1.75	0.91
	Credits	-5.74		-11.25	-67.26
	CO2 uptake	-55.95		-15.34	-14.51
	net results	113.89		548.75	485.49

4.16.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

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

The converting to sleeves accounts only small shares (7%) 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 4% of the total burdens for 'Climate Change' for the liquid food carton.

The life cycle step 'filling' shows small to minor shares of burdens (11%) for the liquid food carton.

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

The life cycle step 'recycling & disposal' of the assessed beverage cartons is the most relevant life cycle step for 'Climate Change' (35%). The main contributor in this step is methane emitted by landfills, resulting from the degradation of paper board.

'CO_2 reg. (recycling & disposal)' describes separately all regenerative CO_2 emissions from recycling and disposal processes. In case of liquid food carton in Greece these derive from landfills. They contribute to 7% of the total burdens for 'Climate Change'.

Due to the lack of MSWI with energy recovery in Greece, Turkey and India, energy credits sum up to only 2% resulting from small amounts of energy recovery in landfills. 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 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 of the assessed system. (see section 1.7.2)

Steel can (specifications see section 2.2.2)

In the assessed steel can system in the LIQUID FOOD PORTION PACK AMBIENT segment, the major share (66%) of the environmental burdens for 'Climate Change' is caused by the production of the steel of the can body.

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

The life cycle step 'top, closure & label' shows also minor impacts shares (11%) 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', 'filling' and 'distribution' show only small shares of burdens (1%-2%) for the can.

The steel cans' 'recycling & disposal' life cycle step shows minor shares of burdens regarding 'Climate Change' (6%). 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'. They reduce the overall burdens by around 12% due to the substitution of raw steel with recycled steel from the cans.

Due to the lack of MSWI with energy recovery in Greece, Energy credits are almost zero resulting only to a very small amount from landfilling of tertiary packaging (pallets).

Glass jar (specifications see section 2.2.2)

The production of the 'glass' material is the main contributor to the overall burdens for the glass bottle. The production of glass clearly dominates the results for 'Climate Change' (68%).

Most other life cycle steps play only a minor role compared to the glass production.

The influence of material credits on the net result is also small for 'Climate Change'. They reduce the overall burdens by 2% as most of the glass is being recycled in a closed loop.

Due to the lack of MSWI with energy recovery in Greece, Energy credits are almost zero resulting only to a very small amount from landfilling of tertiary packaging (pallets).

4.16.3 Comparison between packaging systems

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

The percentages in the following table show the difference of net results between the packaging system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 92: Comparison of net results: **Tetra Recart 390 mL** versus alternative packaging systems in **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 50%

LIQUID FOOD PORTION PACK (ambient), Greece Allocation 50	The net results of **Tetra Recart 390 mL** are lower (green)/ higher (orange) than those of	
	Glass Jar 1 400 mL	Steel can 1 400 mL
Climate Change	-79%	-77%

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

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

4.17.1 Presentation of results LIQUID FOOD PORTION PACK AMBIENT

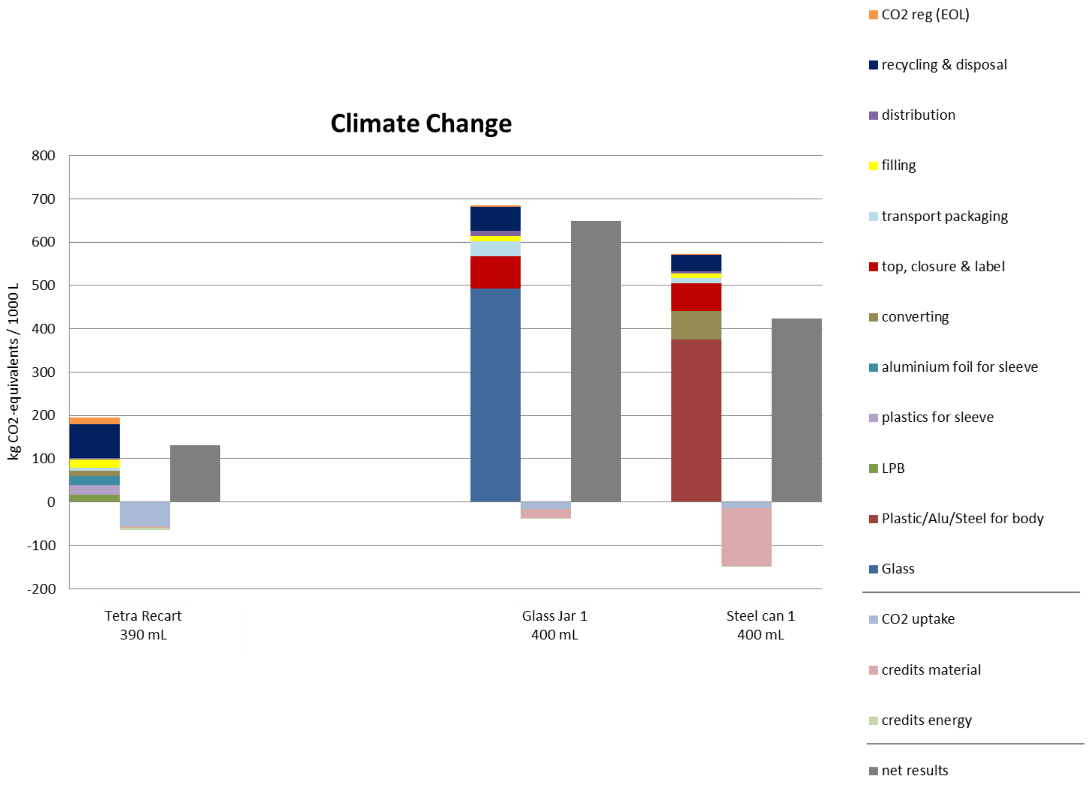

Figure 31: Climate Change results of **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 100%

Table 93: Climate Change results of **segment LIQUID FOOD PORTION PACK AMBIENT** burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		Tetra Recart 390 mL		Glass Jar 1 400 mL	Steel Can 1 400 mL
Climate Change [kg CO2-e/1000 L]	Burdens	179.59		682.28	570.12
	CO2 (reg)	15.58		3.49	1.83
	Credits	-8.53		-22.07	-133.43
	CO2 uptake	-55.95		-15.34	-14.51
	net results	130.69		648.37	424.02

4.17.2 Description and interpretation

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

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

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

In the cases of beverage cartons in the segment LIQUID FOOD PORTION PACK AMBIENT applying the allocation factor 100% instead of 50% leads to higher net results for 'Climate Change'. This is because the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the extra benefit for the assessed systems containing primary biogenic mater is gone when applying the allocation factor 100% as all burdens from 'CO_2 reg. (recycling & disposal)' are allocated to the assessed system (see section 1.7.2).

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 glass Jar, higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the benefits of the recycled content provided by open loop material is not allocated to the regarded system.

4.17.3 Comparison between packaging systems

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

The percentages in the following table show the difference of net results between the packaging system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 94: Comparison of net results: **Tetra Recart 390 mL** versus competing cartons and alternative packaging systems in **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 100%

LIQUID FOOD PORTION PACK (ambient), Greece Allocation 100	The net results of **Tetra Recart 390 mL** are lower (green)/ higher (orange) than those of	
	Glass Jar 1 400 mL	Steel can 1 400 mL
Climate Change	-80%	-69%

5 Conclusions

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

5.1 DAIRY FAMILY PACK CHILLED

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

In case of the sensitivity analysis with PET preform production in Europe instead of Greece the 1500 mL PET bottle 2 shows similar 'Climate Change' impacts than the TGA plant-based HeliCap 27 plant-based 1000 mL. Compared to all other beverage cartons in this segment the 1500 mL PET bottle 2 shows also in case of this sensitivity analysis higher 'Climate Change' impacts. The 1000 mL PET bottle 1 shows also in case of this sensitivity analysis higher 'Climate Change' impacts.

5.2 DAIRY PORTION 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 330 mL PET bottle 3 and the 500 mL PET bottle 4. Compared to the 500 mL PET bottle 5, the assessed beverage carton shows lower impacts with the 50% allocation factor and similar impacts with the 100% allocation.

In case of the sensitivity analysis with PET preform production in Europe instead of Greece the 500 mL PET bottle 4 and the 500 mL PET bottle 5 show similar 'Climate Change' impacts than the compared beverage carton. The 500 mL PET bottle 3 shows also in case of this sensitivity analysis higher 'Climate Change' impacts than the compared beverage carton

5.3 JNSD FAMILY PACK CHILLED

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

In case of the sensitivity analysis with PET preform production in Europe instead of Greece no changes of comparative conclusions are expected in this segment, as the differences between the compared beverage cartons and PET bottles are larger than in the comparisons for which the sensitivity analysis did not show a change in comparative conclusions.

5.4 JNSD FAMILY PACK AMBIENT

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

In case of the sensitivity analysis with PET preform production in Europe instead of Greece the PET bottle 10 shows also in case of this sensitivity analysis higher 'Climate Change' impacts than the compared beverage carton.

5.5 JNSD PORTION PACK CHILLED

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

In case of the sensitivity analysis with PET preform production in Europe instead of Greece no changes of comparative conclusions are expected in this segment, as the differences between the compared beverage cartons and PET bottles are larger than in the comparisons for which the sensitivity analysis did not show a change in comparative conclusions.

5.6 OLIVE OIL FAMILY PACK AMBIENT

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.

In case of the sensitivity analysis with PET preform production in Europe instead of Greece no changes of comparative conclusions are expected in this segment, as the differences between the compared beverage cartons and PET bottles are larger than in the comparisons for which the sensitivity analysis did not show a change in comparative conclusions.

5.7 LIQUID FOOD PORTION PACK AMBIENT

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

6 Limitations

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

Limitations arising from the selection of **market segments**:
The results are valid only for the filling products dairy chilled, JNSD ambient and chilled, olive oil 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 Greek 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 Greece, even for the same packaging systems.

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

Limitations concerning the **reference period**:
The results are valid only for the indicated reference year 2020 based on data from 1999 – 2020. Results cannot be assumed to be valid for (the same) packaging systems at a different point in time.

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

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

7 Overall conclusion and recommendations

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

The beverage and liquid food carton systems analysed in this study show different ’Climate Change’ performances depending on different segments as well as their packaging specifications. They generally show higher results than similar cartons on the European market as presented in the European baseline study. The main reason is the high landfill rate in Greece, leading to high methane emissions from the degradation of paper

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

The climate change intensive Greek electricity mix leads to generally higher impacts in several life cycle steps of the assessed packaging systems. The highest impacts of the climate change intensive Greek electricity mix can be seen for the converting of PET bottles due to its high electric energy demand. The sensitivity analyses regarding PET preform production in Europe instead of Greece decreases the impacts of the PET bottle’s converting considerably.

In the JNSD, Olive oil and food segments assessed in this report, the beverage or food cartons show lower climate change impacts than the compared glass and plastic bottles as well as the aluminium and steel cans.

In the dairy chilled segments assessed, no clear conclusion regarding the Climate Change potential can be drawn.

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

- As this study only includes results for the impact category Climate Change, it is recommended to consult the European baseline study 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 in the segments JNSD Family Pack Chilled, JNSD Family Pack Ambient, JNSD Portion Pack chilled, Olive Oil Family Pack Ambient and Liquid Food Ambient, beverage or liquid food cartons perform more favourably than the compared alternative packaging systems.
- 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.

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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 2013.

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
Methane (CH_4) regenerative	28
Nitrous oxide (N_2O)	265
Tetrafluoromethane	6630
Hexafluoroethane	11100
Halon 1301	6290
R22	1810
Tetrachlormethane	1760
Trichlorethane	160
• Source: [IPCC 2013]	

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

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[IPCC 1995]: Intergovernmental panel on the climatic change. Climatic Change (IPCC; publisher). Report to the United Nations 1996. New York (USA) 1995.

[1] The values reported by [IPCC 2013] in Appendix 8.A were rounded off to whole numbers.

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

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Appendix B:

Critical Review Report

Update of
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 Greek market

As supplement of the study

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

to the Commissioner:
Tetra Pak®

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

Performed for
Tetra Pak® Moscow, Russia (the "Commissioner")

by

Birgit Grahl (chair)
Leigh Holloway
Guido Sonnemann

19.7.2021

Content

1. Procedural Aspects of the Critical Review

This Critical Review was commissioned by Tetra Pak® Moscow, Russia (commissioner) via Dina Epifanova in November 2020 as a two-stage process. The LCA study was conducted by IFEU-Institut, Heidelberg, Germany (practitioner).

A Final Draft Report was submitted on 3rd December 2020, commented by the panel, and discussed in the telephone conference on 19th January 2021. During the conference calls the comments were elaborated by the panel members and discussed with the practitioner in detail.

The review panel received a second version of the Final Report of the study on 29th January 2021. After few queries were clarified, the final report was sent to the panel on 8th February 2021. The statements and comments in the supplement CR-statement dated 9th February 2021 are based on this final version.

On 29th June 2021 the panel received an update on the study. One packaging specification of the Tetra Pak® carton packaging was updated, another one was added and a supplementary sensitivity analysis was included. The changes respectively the addition in the packaging specifications are plausible and the supplemented sensitivity analysis is useful. These changes do not affect the overall conclusions and recommendations. In this respect, the following statements of the Supplement Critical Review Statement dated 9th February 2021 are still valid.

Formally this critical review is a review by “interested parties” (panel method) according to ISO 14040 section 7.3.3 [2] and ISO 14044 section 4.2.3.7 and 6.3 [3] because the study includes comparative assertions of competing packaging systems and is intended to be disclosed to third parties.

Despite this title, however, the inclusion of further representatives of "interested parties" is optional and was not explicitly intended in this study. The review panel is neutral with regard to and independent from any commercial interests of the commissioner. The panel had to be aware of issues relevant to other interested parties, as it was outside the scope of the present project to invite governmental or non-governmental organisations or other interested parties, e.g. competitors or consumers.

The reviewers emphasise the open and constructive atmosphere of the project. All necessary data, including confidential ones upon request, were presented to the reviewers and all issues were discussed openly. All comments of the panel have been treated by the practitioner with sufficient detail in the final report. The resulting critical review (CR) statement represents the consensus between the reviewers.

Note: The present CR statement is delivered to Tetra Pak® Moscow, Russia. 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 Greek 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 8th February 2021 including update in the version of 23rd June 2021 - and no other report, extract or publication which may eventually be undertaken. The CR panel conclusions are given regarding the current state of the art and the information received. The conclusions expressed by the CR panel are specific to the context and content of the present study only and shall not be generalised any further.

2. General Comments

This study for the Greek 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 Greek study, the same LCA model is used as in the European baseline study, but region-specific data like packaging solutions, electricity mix and end-of-life data are used, and the only impact category considered is climate change with the impact category indicator GWP. The study was not conducted according to ISO 14067.

However, the authors of the Greek study explicitly point out that knowledge and understanding of the European study must be used to interpret the results, since the relevance of the GWP in relation to other impact categories is discussed there. The European study as a full LCA considers a sufficient number of relevant impact categories and indicators.

The panel points out that if only one impact category is considered, there is no conformity with ISO 14044, as section 4.4.1 clearly states: "The LCIA phase includes the collection of indicator results for the different impact categories, which together represent the LCIA profile for the product system". In this respect, the Greek study must be communicated as supplement study with explicit reference to the European study and differentiated analysis: In the overall view of all impact category results considered in the European study, it must be analysed to what extent the GWP permits directional reliability of environmental statements. Based on the comments provided by the CR Panel this aspect has been sufficiently discussed in the study and indicated in the subtitle of the study.

The panel expressly emphasizes the importance of, and requires considering the results of, other impact categories discussed in the European study in order to understand the environmental relevance of the packaging examined in the Greek 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 Greek study are considered. The methodological statements made for the European study in [Tetra Pak EU 2020] are not repeated here.

3. Supplement Statements by the reviewer as required by ISO 14044

According to ISO 14044 section 6.1
"The critical review process shall ensure that:

- *the methods used to carry out the LCA are consistent with this International Standard,*
- *the methods used to carry out the LCA are scientifically and technically valid,*
- *the data used are appropriate and reasonable in relation to the goal of the study,*
- *the interpretations reflect the limitations identified and the goal of the study and*
- *the study report is transparent and consistent."*

These criteria were also applied in this supplement Critical Review. In the following supplement sections 3.1 to 3.5, these items are discussed for the specifics of the Greek study according to the reviewer´s best judgement and considering the ISO standards 14040 and 14044.

3.1 Supplement: Consistency of the methods with ISO 14040 and 14044

The Greek study uses the same model as the European study (see CR-statement in [Tetra Pak EU 2020]) for another geographical system boundary and reduced impact assessment.

- Packaging solutions in the Greek 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 Greek recycling quota, end-of-life options, and the specific electricity mix (cf. section 3.3).
- The impact assessment is limited to a single impact category, climate change, with the indicator Global Warming Potential (GWP) (cf. also section 3.2).

The report of the Greek supplement study contains all the necessary methodological information in the same detail as the European study. In this respect, the supplement study is consistent with ISO 14040 and ISO 14044 except for the requirements for impact assessment.

Since only one impact category is considered the reviewers conclude that in this respect the study as stand-alone-study does not fulfil the requirements of the international standards but may be useful as region specific supplement study.

Regarding the consistency of aspects other than impact assessment, see chapter 3.1 of the CR statement in [Tetra Pak EU 2020].

3.2 Supplement: Scientific and technical validity of the methods used

The GWP data in the Greek study are calculated according to the same methodological specifications as in the European study. The study explicitly states that the significance of the other impact categories in the European study in relation to GWP shall be used to interpret the results. This requires special challenges for the communication of the study by Tetra Pak.

Regarding the scientific and technical validity of aspects other than limited impact assessment, see chapter 3.1 of the CR statement in [Tetra Pak EU 2020].

3.3 Supplement: Appropriateness of data in relation to the goal of the study

Detailed qualitative and quantitative information on the polymers used in Tetra Pak packaging, some of which are not specified in the report for reasons of confidentiality, was provided to the panel and considered plausible.

As one data source, the study refers to an "ifeu internal data base", which contains confidential data. During discussions with the practitioner, sufficient background information was provided to the panel so that data and data processing are considered plausible.

The criteria for the selection of competing products and the derivation of their composition are comprehensibly documented.

The assumptions of the EoL management in Greece are comprehensibly derived and plausible. A special feature of the Greek EoL management is that no waste incineration takes place, a large proportion is landfilled and packaging waste is exported for recycling. The export was taken into account in the study and plausible data was provided.

The study mentions the influence of the GWP intensive Greek electricity mix that is mainly relevant for competing products where energy intensive production processes are carried out in Greece. The electricity mix is particularly relevant for preform production for PET bottles in Greece. A sensitivity analysis of this production in Europe instead of Greece decreases the impacts of the PET bottle's converting considerably. Nevertheless the directional reliability of the comparative conclusions remains stable.

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 Greek study was conducted according to the same model as the European study, all statements made in the CR statement section 4 in [Tetra Pak EU 2020] apply accordingly to the Greek 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 Greek study considers with GWP only one impact category the study is, as a stand-alone study, not consistent with the ISO standards 14040 and 14044.

The study can be used as an orientation supplement to the European study, as it can be plausibly expected that the relative importance of the impact potentials documented in [Tetra Pak EU 2020] will not differ fundamentally in relation to each other in the Greek study. However, caution is advised here, and the panel warns against emphasizing GWP in communication alone.

References:

[ISO 14040] ISO 14040:2006. Environmental management - Life cycle assessment - Principles and framework

[ISO 14044] ISO 14044:2006. Environmental management - Life cycle assessment - Requirements and guidelines

[Tetra Pak EU 2020] Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the European market – Final Report – 9th 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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