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 Italian 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 for the segments: Dairy (ambient), JNSD, wine, oil and liquid food

commissioned by Tetra Pak

Heidelberg, November 04th 2020

ifeu im Weiher 10 D - 69121 Heidelberg Telefon +49 (0)6 221. 47 67 - 0 Telefax +49 (0)6 221. 47 67 - 19 E-Mail ifeu@ifeu.de www.ifeu.de

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Samuel Schlecht

Frank Wellenreuther

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ifeu im Weiher 10 D - 69121 Heidelberg Telefon +49 (0)6 221. 47 67 - 0 Telefax +49 (0)6 221. 47 67 - 19 E-Mail ifeu@ifeu.de www.ifeu.de

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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
HBEFA	Handbuch für Emissionsfaktoren (Handbook for Emission Factors)
HDPE	High-density polyethylene
ifeu	Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JNSD	Juice, nectars and still drinks
LCA	Life cycle assessment
LCI	Life cycle inventory
LDPE	Low density polyethylene
LPB	Liquid packaging board
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
PA	Polyamide
pc	packs
PE	Polyethylene
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
TSA	Tetra Stelo Aseptic
TT	Tetra Top
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 finalized 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 finalized [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 Italian market regarding the segments dairy (ambient), JNSD, wine, oil and liquid food.

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 Italian 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 oil and wine, which were 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 Italian market include:

- PET bottles
- HDPE bottles
- Single use glass bottles
- Steel cans
- Single use glass jars
- Pouches

All analysed packaging systems are divided into the segments

- 'Family Packs' (FP) with volumes from 750 mL to 1000 mL
- 'Portion Packs' (PoP) with volumes from 192.5 mL to 500 mL.

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

- DAIRY products like milk or milk drinks
  - Ambient family packs with the volume of 1000 mL
- Juice, Nectars and still drinks (JNSD)
  - Ambient family packs with the volume of 1000 mL
- WINE
  - Ambient family packs with the volume of 750 mL – 1000 mL
- cooking OIL
  - Ambient family packs with the volume of 1000 mL
- liquid food
  - Ambient portion packs with the volume of 192.5 mL – 390 mL

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

(1) to provide knowledge of the environmental 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 environmental performance regarding Climate Change of these cartons with those of the competing packaging systems with high market relevance on the Italian 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, Ingrid Falcão, Erika Kloow, Erik Lindroth
- **ifeu**: Samuel Schlecht, Frank Wellenreuther

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. These are the same as in the critical review panel of the fully ISO compliant European baseline study.

The members of the independent panel are

- Birgit Grahl (chair), INTEGRAHL, Germany
- Leigh Holloway, eco3 Design, UK
- Alessandra Zamagni, ecoinnovazione, Italy

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 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 studied 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 straws.
- 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

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.
- transport of filled packages from the point of sale to the consumer as no relevant differences between the systems under examination are to be expected and the implementation would be highly speculative as no reliable data is available.
- use phase of packages at the consumers as no relevant differences between the systems under examination are to be expected (for example in regard to cleaning before disposal or chilling at home) and the implementation would be highly speculative as no reliable data is available.

The following simplified flow charts shall illustrate the system boundaries considered for the packaging systems beverage and liquid food carton (Figure 1), PET bottle (Figure 2), HDPE bottle (Figure 3), single use glass bottle/jar (Figure 4), steel can (Figure 5) and pouch (Figure 6). In case recycled material is used as recycled content in a closed loop, the flow charts show a connection between the recycling process and the material supply phase.

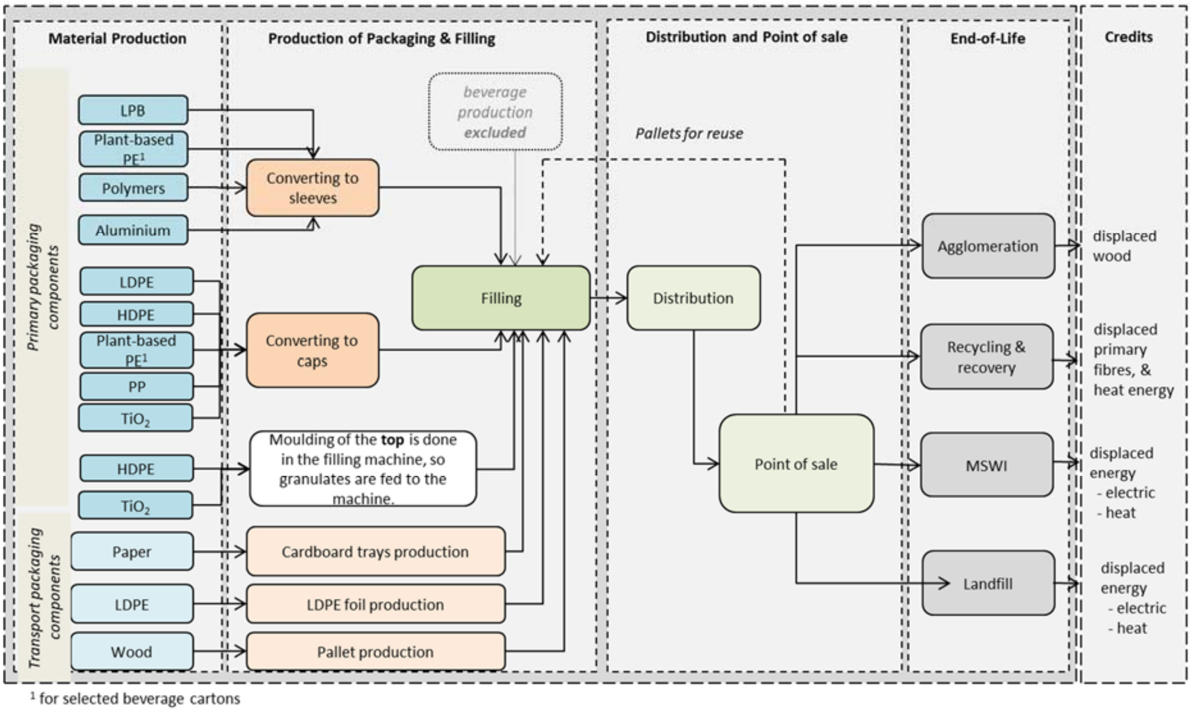

Figure 1: System boundaries of beverage and liquid food cartons

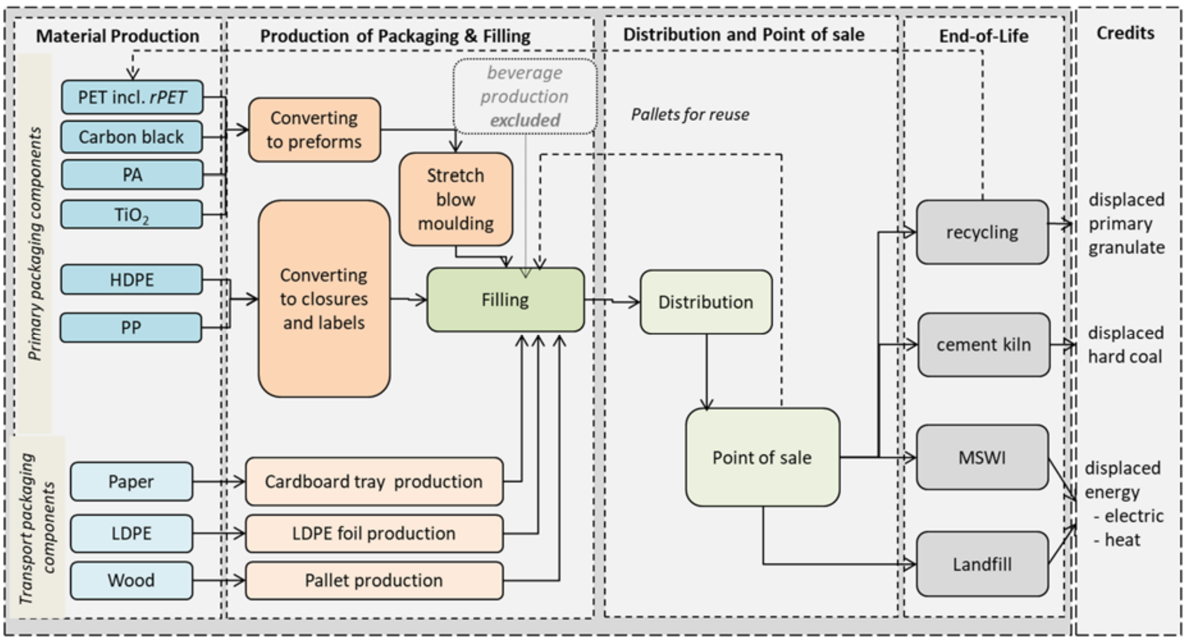

Figure 2: System boundaries of PET bottles

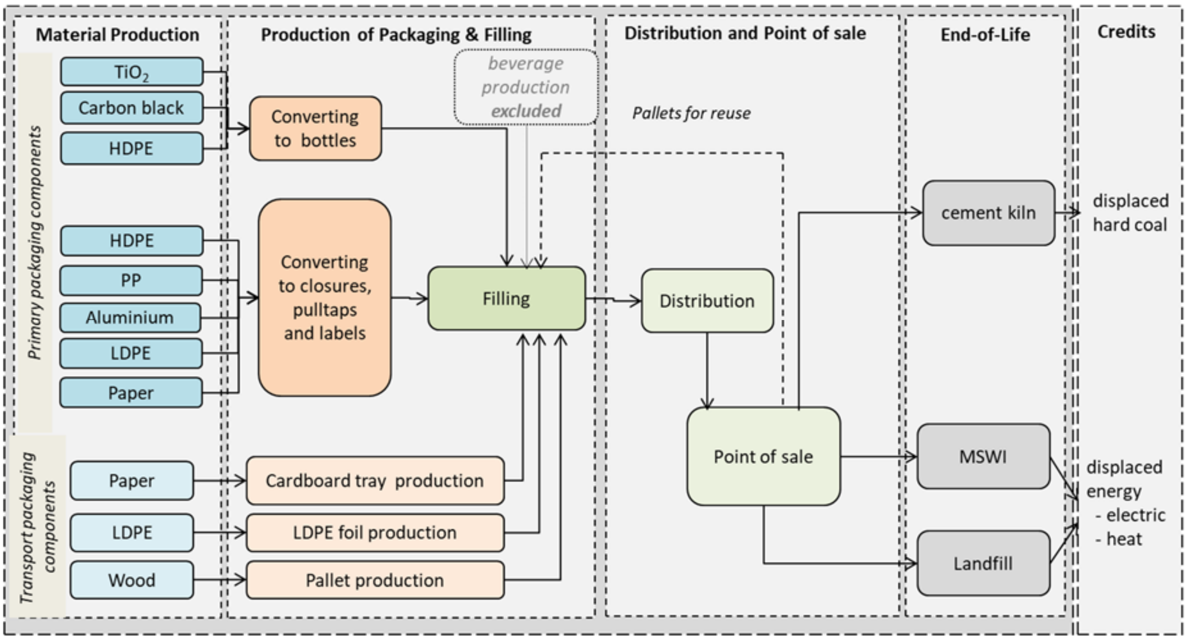

Figure 3: System boundaries of HDPE bottles

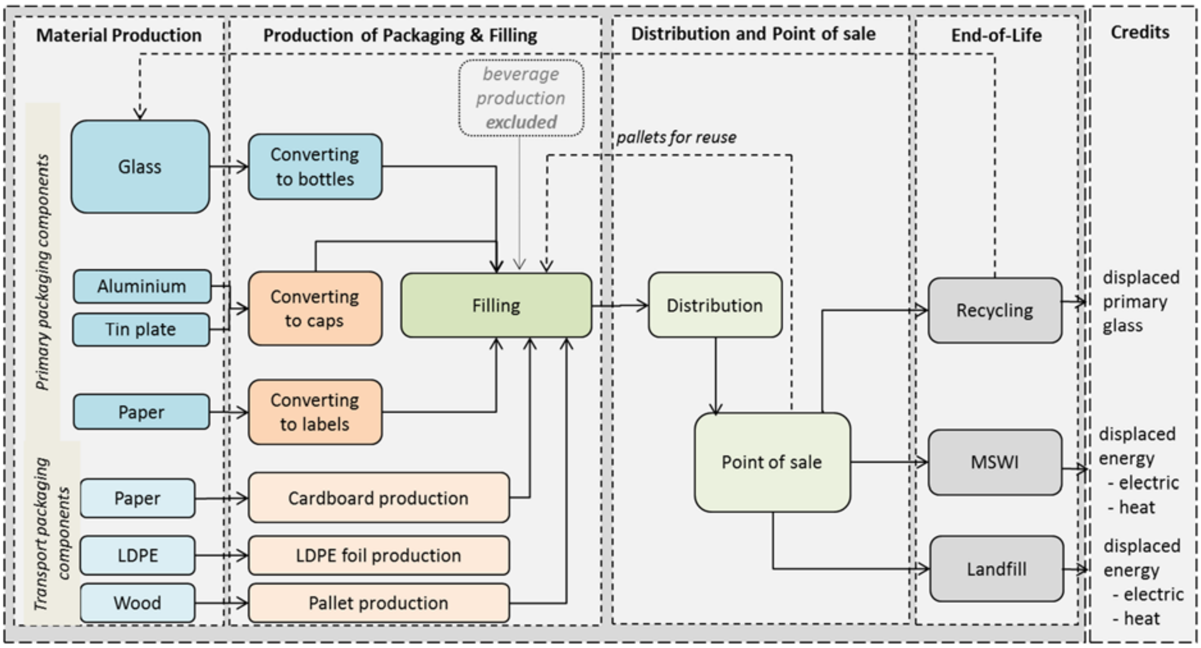

Figure 4: System boundaries of single use glass bottles/jars

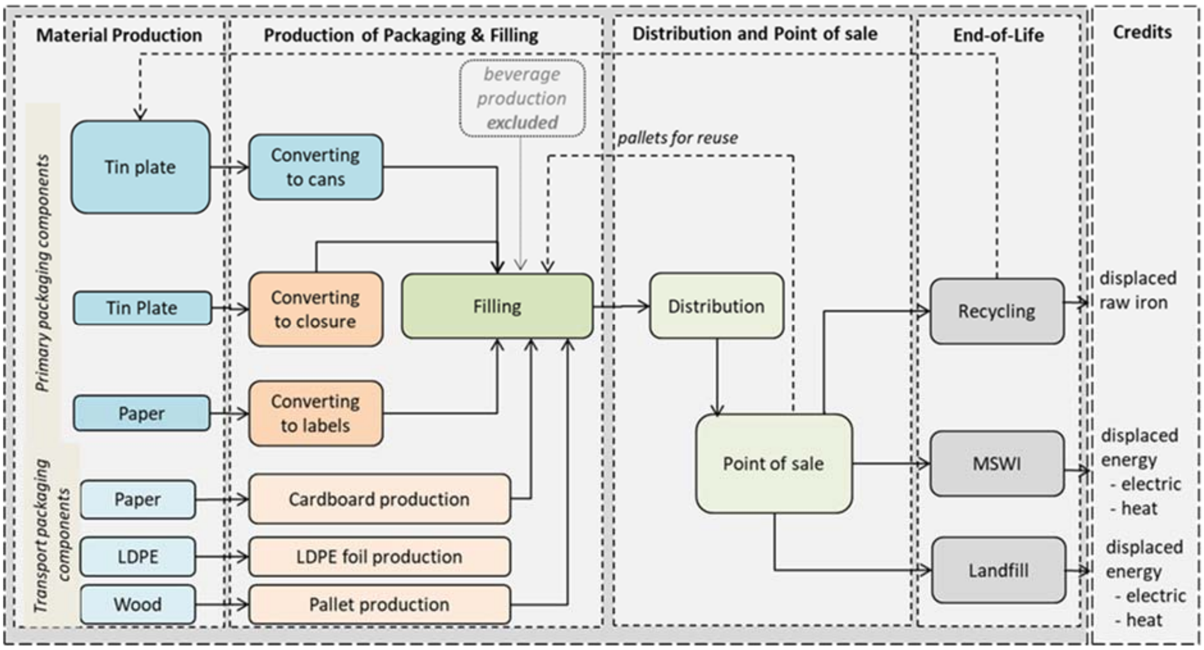

Figure 5: System boundaries steel can

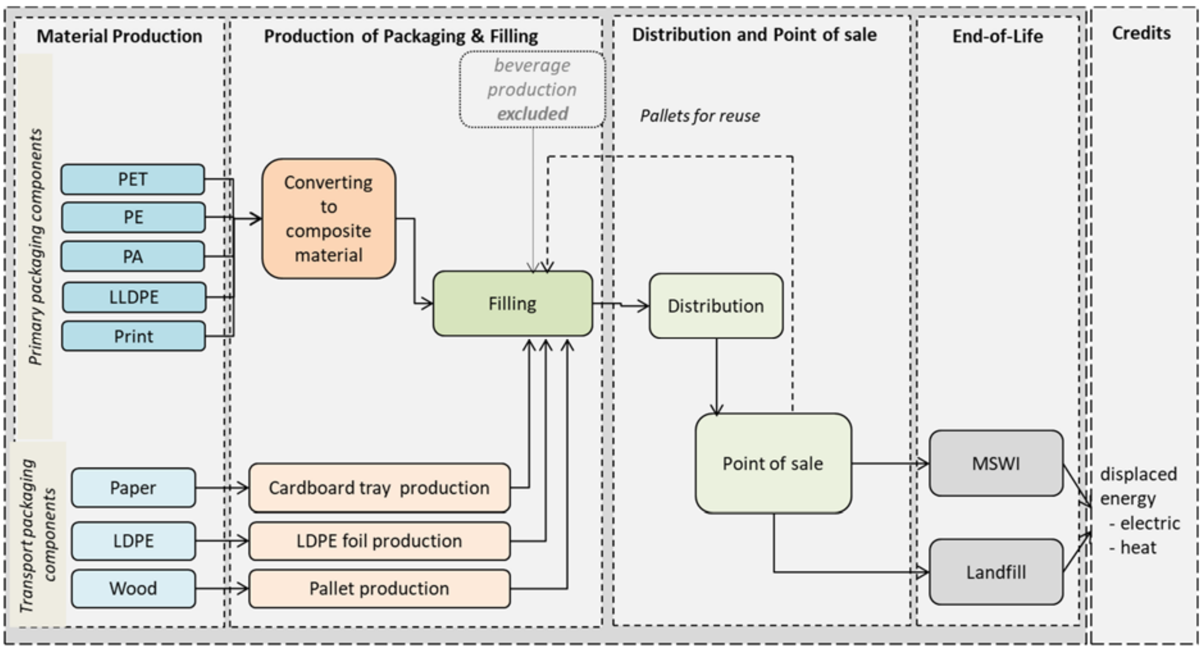

Figure 6: System boundaries pouch

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 FU. 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 Italy. 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 mostly European average data are used, as Tetra Pak sources its materials mainly from Europe. Examples are the liquid packaging board production process (country-specific) and the production of aluminium foil (available only as European average).

Time scope

The packaging specifications listed in section 2 as well as the market situation for the choice of beverage and liquid food packaging systems refers to 2020. Therefore, the reference time period for the comparison of packaging systems is 2020. Where no figures are available for these years, the used data shall be as up-to-date as possible. Particularly with regard to data on end-of-life processes of the examined packages, the most current information available is used to correctly represent the recent changes in this area.

Most of the applied data refers to the period between 1999 and 2020 (see Table 21 in section 3). In cases where only old datasets are available, the data has been checked for its representativeness. The datasets for transportation, energy generation and waste treatment processes (except recycling process for beverage and liquid food cartons) 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 1: The summary of the completeness check according to [ISO 14044]

Life cycle steps	Beverage / liquid food cartons	HDPE/PET bottles	Steel cans	Glass bottles/ jars	Pouch	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 summarized in Table 21 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, the source is generally referred to.

Transport processes

An allocation between the packaging and contents was carried out for the transportation of the filled packages to the point-of-sale. Only the share in environmental burdens related to transport, which is assigned to the package, has been accounted for in this study. That means the burdens related directly to the beverage and liquid food is excluded. The allocation between package and filling goods is based on mass criterion. This allocation is applied as the FU of the study defines a fixed amount of beverage and liquid food through all scenarios. Impacts related to transporting the beverage and liquid food itself would be the same in all scenarios. Thus, they don't need to be included in this comparative study of beverage and liquid food packaging systems.

System-related allocation

System-related allocation is applied in this study regarding open loop recycling and recovery processes. Recycling refers to material recycling, whereas recovery refers to thermal recovery for example in MSWI with energy recovery or cement kilns. System-related allocation is applied to both, recycling and recovery in the end of life of the assessed system and processes regarding the use of recycled materials by the assessed system. System-related allocation is not applied regarding disposal processes like landfills with minor energy recovery possibilities. Figure 7 illustrates the general allocation approach used for uncoupled systems and systems which are coupled through recycling. In Figure 7 (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 7. 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.

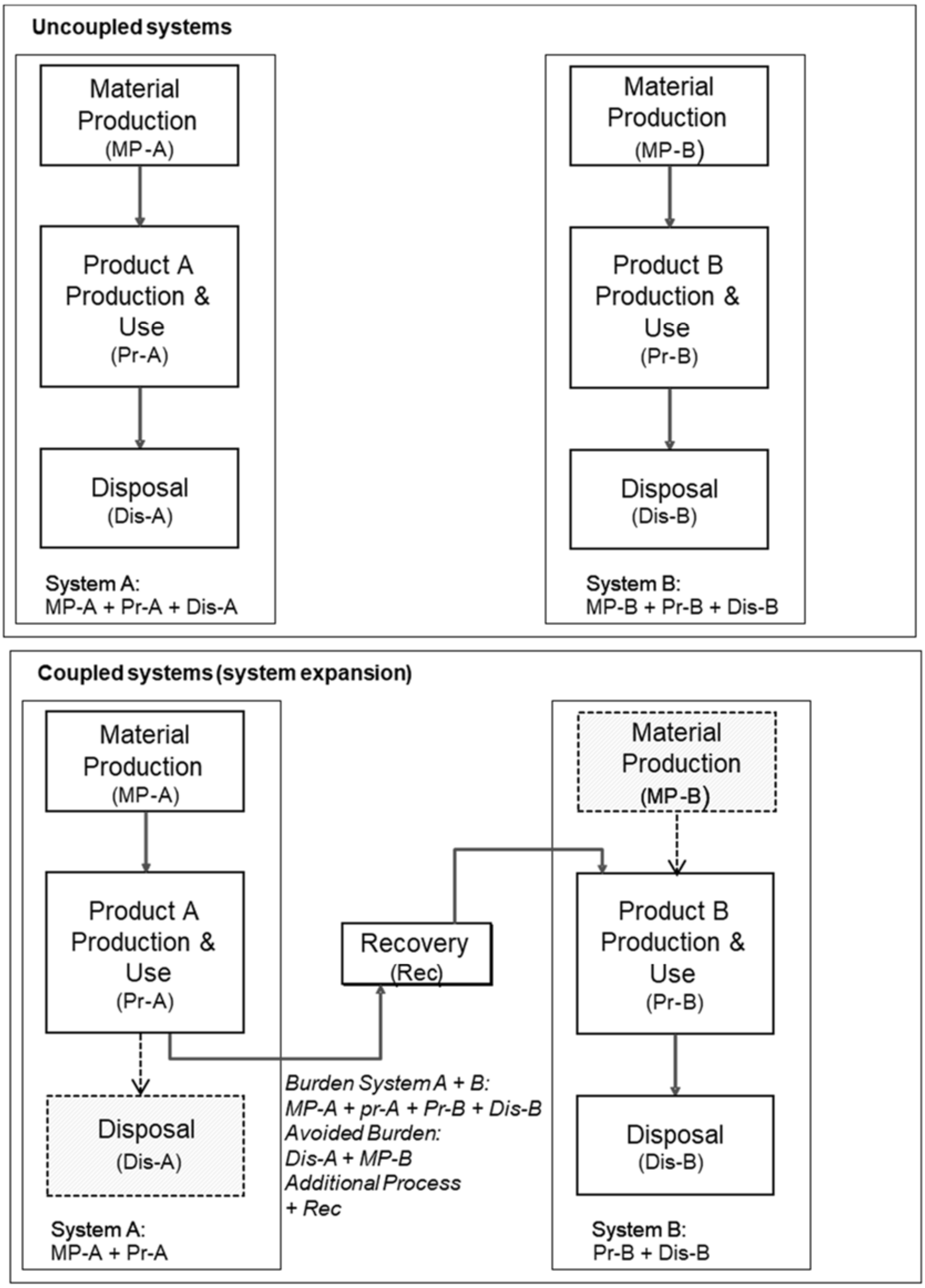

Figure 7: Additional system benefit/burden through recycling (schematic flow chart)[1]

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 8 and Figure 9. 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.

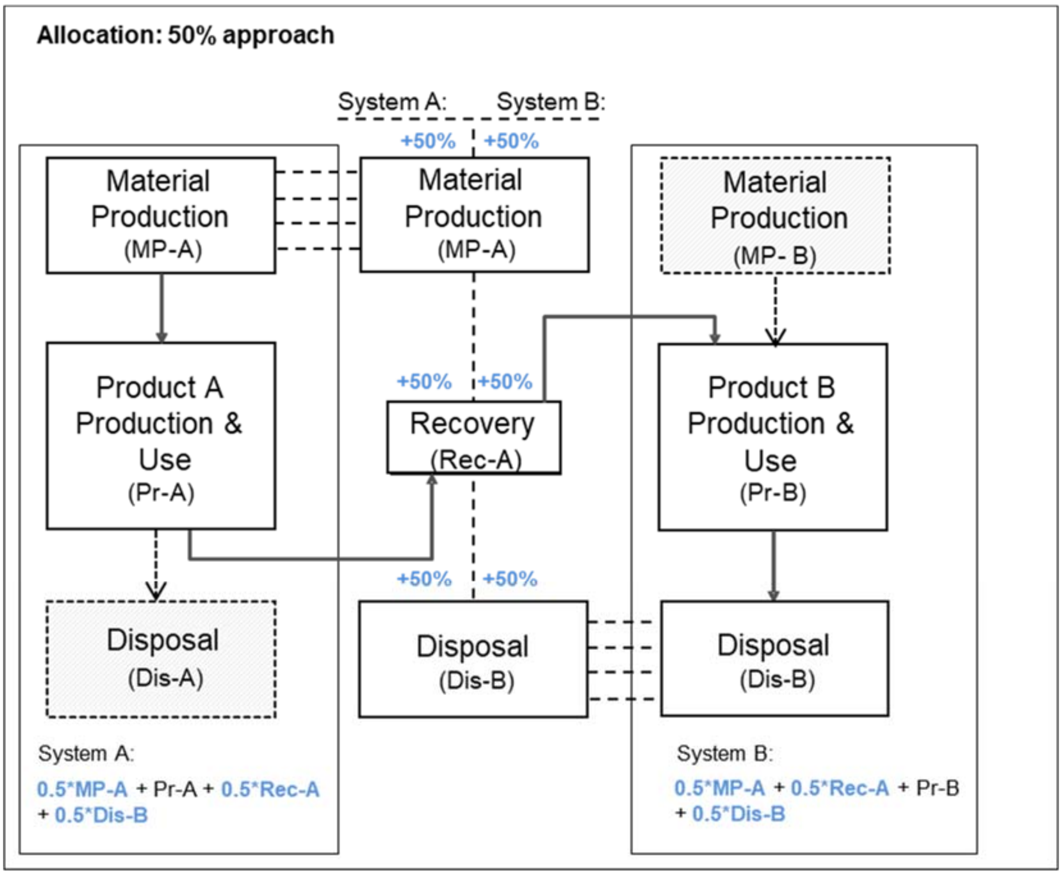

Figure 8: Principles of 50% allocation (schematic flow chart)[1]

Allocation with the 50% method (Figure 8)

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).

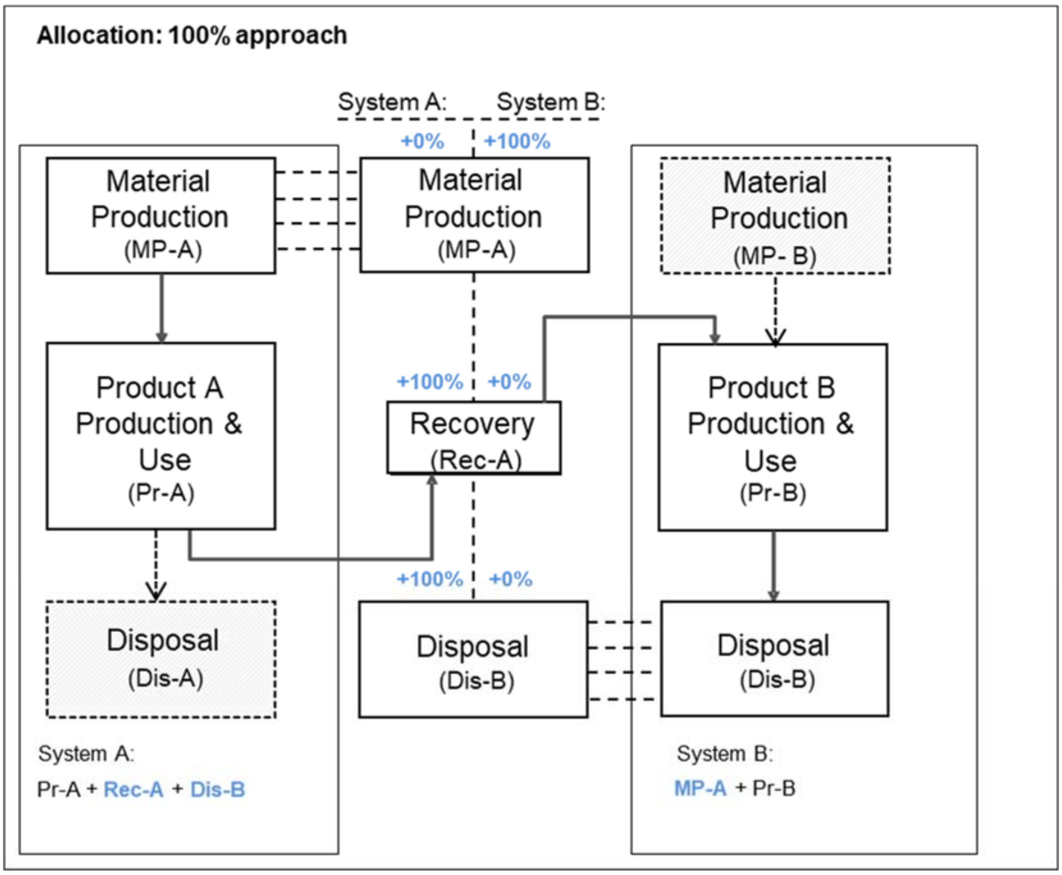

Figure 9: Principles of 100% allocation (schematic flow chart) [1]

[1] shaded boxes are avoided processes

Allocation with the 100% method (Figure 9)

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 7 to Figure 9

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 20) 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)

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 (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 credits.

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 packaging systems 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. 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 potential environmental impacts per FU. The category indicator results also do not quantify an actual environmental damage. Table 2 shows how the terms are applied in this study.

Table 2: Applied terms of ISO 14044 for the environmental impact assessment using the impact category Climate Change as example

Term	Example
Impact category	Climate Change
LCI results	Amount of climate active gases per FU
Characterisation model	Global Warming Potential for a 100-year time period based on IPCC 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 FU

Table 3 includes examples, which give an overview of elementary flows for 'Climate Change'.

Table 3: 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 FU, the category indicator results, GWP results, are expressed as kg CO_2-e per FU.

Note on biogenic carbon: At the impact assessment level, it must be decided how to model and calculate CO_2-based GWP. In the present study the non-fossil CO_2 has been included at two points in the model, its uptake during the plant growth phase attributed with negative GWP values and the corresponding re-emissions at end of life with positive ones. For more details see section 1.7.2.

2 Packaging systems and scenarios

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

All packaging systems examined in this study are presented in the following sections (2.1 & 2.2), including the applied end-of-life options (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 environmental aspects. The beverage and liquid food cartons are compared with corresponding competing packaging systems.

The choice of beverage and liquid food cartons has been made by Tetra Pak based on market relevance. Cartons of different volumes for the packaging of dairy, JNSD (Juice, nectars, still drinks), wine, cooking oil and liquid food 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 Italy for each segment. The representativeness as a main competing packaging type was determined by market relevance as well as by the importance of the packaging systems in the perspective of Tetra Pak. The positioning properties of the products into the market have ben taken into account for ensuring the comparability of the analysed packaging systems. Details are shown in Table 4.

Table 4: Selection of competing packaging systems

Segment	Competing packaging system	reason for selection
DAIRY, Family Pack, Ambient	PET bottle 3 1000 mL	Plastic bottles have the highest market share of competing packaging systems. The plastic bottles with highest market share of the main two brands are selected.
	HDPE bottle 1 1000 mL	
JNSD, Family Pack, Ambient	PET bottle 4 1000 mL	The hot fill PET bottle with highest market share selected, representing an alternative of ambient PET bottles on the market.
	PET bottle 4a 50% rPET 1000 mL	A version with 50% recycled content is included as this was the highest share of recycled content allowed in Italy at the time of selection
	PET bottle 6 1000 mL	The PET bottle of the leading brand in the Juice segment is selected.
	PET bottle 6a 50% rPET 1000 mL	A version with 50% recycled content is included as this was the highest share of recycled content allowed at the time of selection
WINE, Family Pack, Ambient	Glass bottle 1 750 ml	Competition with low-medium price wines. A glass bottle of low-medium price wines is selected, being 2nd in market share.
cooking OIL, Family Pack, Ambient	PET bottle 13 50% rPET 1000 ml	The PET bottle of one of the most known brand in this segment is selected.
	Glass bottle 2 1000 ml	The glass bottle of the brand with the second highest market share selected
Liquid Food, Portion Pack, Ambient	Pouch 1 193 mL	Pouch included as an alternative for food packaging
	Steel can 1 350 ml	Standard food can selected
	Glass Jar 1 350 ml	Standard glass jar selected

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

Table 5: List of Tetra Pak beverage cartons in segment **DAIRY, Family Pack, Ambient** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Brik Aseptic (TBA) Edge LC 30 1000 mL	A	Italy	PET bottle 3 1000 mL	A	Italy
			HDPE bottle 1 1000 mL	A	Italy
Tetra Brik Aseptic (TBA) Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	A	Italy	PET bottle 3 1000 mL	A	Italy
			HDPE bottle 1 1000 mL	A	Italy
Tetra Stelo Aseptic (TSA) Edge plant-based WingCap plant-based + plant based compound 1000 mL	A	Italy	PET bottle 3 1000 mL	A	Italy
			HDPE bottle 1 1000 mL	A	Italy
Tetra Brik Aseptic (TBA) UE plant-based WingCap plant-based + plant-based compound 1000 mL	A	Italy	PET bottle 3 1000 mL	A	Italy
			HDPE bottle 1 1000 mL	A	Italy
Tetra Brik Aseptic (TBA) Edge LC 30 Dairy Alternatives 1000 mL	A	Italy	PET bottle 3 1000 mL	A	Italy
			HDPE bottle 1 1000 mL	A	Italy
Tetra Brik Aseptic (TBA) Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	A	Italy	PET bottle 3 1000 mL	A	Italy
			HDPE bottle 1 1000 mL	A	Italy

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

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aseptic (TPA) Square HeliCap27 1000 mL	A	Italy	PET bottle 4 1000 mL	A	Italy
			PET bottle 4a 50% rPET 1000 mL	A	Italy
			PET bottle 6 1000 mL	A	Italy
			PET bottle 6a 50% rPET 1000 mL	A	Italy
Tetra Brik Aseptic (TBA) Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	A	Italy	PET bottle 4 1000 mL	A	Italy
			PET bottle 4a 50% rPET 1000 mL	A	Italy
			PET bottle 6 1000 mL	A	Italy
			PET bottle 6a 50% rPET 1000 mL	A	Italy
Tetra Brik Aseptic (TBA) Edge LC 30 Air 1000 mL	A	Italy	PET bottle 4 1000 mL	A	Italy
			PET bottle 4a 50% rPET 1000 mL	A	Italy
			PET bottle 6 1000 mL	A	Italy
			PET bottle 6a 50% rPET 1000 mL	A	Italy
Tetra Prisma Aseptic (TPA) Square plant-based HeliCap 27 plant-based 1000 mL	A	Italy	PET bottle 4 1000 mL	A	Italy
			PET bottle 4a 50% rPET 1000 mL	A	Italy
			PET bottle 6 1000 mL	A	Italy
			PET bottle 6a 50% rPET 1000 mL	A	Italy
Tetra Gemina Aseptic (TGA) Square plant-based HeliCap 27 plant-based 1000 mL	A	Italy	PET bottle 4 1000 mL	A	Italy
			PET bottle 4a 50% rPET 1000 mL	A	Italy
			PET bottle 6 1000 mL	A	Italy
			PET bottle 6a 50% rPET 1000 mL	A	Italy

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

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Brik Aseptic (TBA) Square HeliCap 27 1000 mL	A	Italy	Glass bottle 1 750 ml	A	Italy
Tetra Brik Aseptic (TBA) Square plant-based HeliCap27 plant-based 1000 mL	A	Italy	Glass bottle 1 750 ml	A	Italy
Tetra Prisma Aseptic (TPA) Square HeliCap 27 1000 mL	A	Italy	Glass bottle 1 750 ml	A	Italy
Tetra Prisma Aseptic (TPA) Square plant-based HeliCap 27 plant-based 1000 mL	A	Italy	Glass bottle 1 750 ml	A	Italy

Table 8: List of Tetra Pak beverage cartons in segment **cooking 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	Italy	PET bottle 13 50% rPET 1000 ml	A	Italy
			Glass bottle 2 1000 ml	A	Italy

Table 9: 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	Italy	Pouch 1 193 mL	A	Italy
			Steel can 1 350 ml	A	Italy
			Glass Jar 1 350 ml	A	Italy

2.2 Packaging specifications

Specifications of beverage and liquid food carton packaging systems are listed in Table 10 to Table 14 and were provided by Tetra Pak. In Tetra Pak's internal database typical specifications of all primary packages sold are registered. The specifications of individual packages of one single carton system may vary to a small degree over different production batches or production sites. To get the final specifications per beverage and liquid food carton type the exact specifications of different batches were averaged taking into consideration the production volumes of each production batch. For confidentiality, in case of the polymers used in the beverage and liquid food carton systems no differentiations to specific polymers are shown in the tables. The calculations are calculated with the specific shares of each polymer used. These are disclosed to the critical review panel.

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 15 to Table 19. They were determined by ifeu in 2020 based on samples collected by Tetra Pak on the Italian market. For each packaging system three 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 bottles are assumed to contain 8% of PA as barrier material (average of communicated PA content of three bottle plastic producers[1]). Shares of recycled content of PET were determined by the declaration on the packaging systems. In some cases PET bottles with virgin PET were calculated as variations with an increased share of recycled PET. Specifications of secondary packaging systems were determined by the weighting of one sample per packaging systems. Material types of secondary packaging system were distinguished between cardboard or 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 10: Packaging specifications for assessed carton systems for the *packaging of Dairy Family Packs (ambient)*

		DAIRY FAMILY PACK AMBIENT					
	Unit	TBA Edge LC 30	TBA Edge plant-based LC 30 Air plant-based + plant-based compound	TSA Edge plant-based WingCap plant-based + plant based compound	TBA UE plant-based WingCap plant-based + plant-based compound	TBA Edge LC 30 Dairy Alternatives	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives
volume	mL	1000	1000	1000	1000	1000	1000
geographic Scope	-	Italy	Italy	Italy	Italy	Italy	Italy
chilled / ambient	-	ambient	ambient	ambient	ambient	ambient	ambient
primary packaging (sum)[1]	**g**	**31.2**	**31.2**	**33.4**	**31.9**	**31.2**	**31.2**
primary packaging (per FU)	**g/FU**	**31200**	**31200**	**33400**	**31900**	**31200**	**31200**
composite material (sleeve)	**g**	**28.6**	**28.6**	**30.3**	**28.8**	**28.6**	**28.6**
- liquid packaging board	g	22.3	22.3	23.4	22.4	22.3	22.3
- polymer	g	4.9	2.2	2.7	2.3	4.9	2.2
- plant-based polymer	g		2.7	2.9	2.7		2.7
- aluminium	g	1.4	1.4	1.3	1.4	1.4	1.4
closure	**g**	**2.6**	**2.6**	**3.1**	**3.1**	**2.6**	**2.6**
- polymer	g	2.6				2.6	
- plant-based polymer	g		2.6	3.1	3.1		2.6
pull tab	**g**			**0.04**	**0.04**		
- aluminium	g			0.04	0.04		
secondary packaging (sum)[2]	**g**	**105.8**	**105.8**	**90.2**	**86.2**	**94.1**	**94.1**
tray/box (corr.cardboard)	g	105.8	105.8	90.2	86.2	94.1	94.1
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**	**25170**	**25170**	**25170**
pallet	g	25000	25000	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO	EURO	EURO
number of use cycles	-	25	25	25	25	25	25
stretch foil (per pallet) (LDPE)	g	170	170	170	170	170	170
pallet configuration							
cartons per tray	pc	10	10	6	6	6	6
trays / packs per layer	pc	16	16	26	30	25	25
layers per pallet	pc	5	5	5	5	5	5
cartons per pallet	pc	800	800	780	900	750	750

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

Table 11: Packaging specifications for assessed carton systems for the *packaging of JNSD Family Packs (ambient)*

		JNSD FAMILY PACK AMBIENT				
	Unit	TPA Square HeliCap27	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound	TBA Edge LC 30 Air	TPA Square plant-based HeliCap 27 plant-based	TGA Square plant-based HeliCap 27 plant-based
volume	mL	1000	1000	1000	1000	1000
geographic Scope	-	Italy	Italy	Italy	Italy	Italy
chilled / ambient	-	ambient	ambient	ambient	ambient	ambient
primary packaging (sum)[1]	**g**	**39.0**	**32.2**	**32.1**	**39.1**	**35.4**
primary packaging (per FU)	**g/FU**	**39000**	**32000**	**32100**	**39100**	**35400**
composite material (sleeve)	**g**	**35.1**	**29.5**	**29.5**	**35.2**	**31.5**
- liquid packaging board	g	25.5	22.3	22.3	25.5	22.4
- polymer	g	7.7	2.7	5.8	2.2	2.2
- plant-based polymer	g	0.0	3.1	0.0	5.6	4.9
- aluminium	g	1.9	1.4	1.4	1.9	2.0
closure	**g**	**3.9**	**2.7**	**2.6**	**3.9**	**3.9**
- polymer	g	3.9		2.6	2.1	2.1
- plant-based polymer	g	0.0	2.7	0.0	1.8	1.8
secondary packaging (sum)[2]	**g**	**176.4**	**101.9**	**101.9**	**176.4**	**192.1**
tray/box (corr.cardboard)	g	176.4	101.9	101.9	176.4	192.1
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**	**25170**	**25170**
pallet	g	25000	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO	EURO
number of use cycles	-	25	25	25	25	25
stretch foil (per pallet) (LDPE)	g	170	170	170	170	170
pallet configuration						
cartons per tray	pc	12	12	12	12	12
trays / packs per layer	pc	10	13	13	10	15
layers per pallet	pc	5	5	5	5	4
cartons per pallet	pc	600	780	780	600	720

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

Table 12: Packaging specifications for assessed carton systems for the *packaging of WINE Family Packs (ambient)*

		WINE FAMILY PACK AMBIENT			
	Unit	TBA Square HeliCap 27	TBA Square plant-based HeliCap27 plant-based	TPA Square HeliCap 27	TPA Square plant-based HeliCap 27 plant-based
volume	mL	1000	1000	1000	1000
geographic Scope	-	Italy	Italy	Italy	Italy
chilled / ambient	-	ambient	ambient	ambient	ambient
primary packaging (sum)[1]	**g**	**35.0**	**35.3**	**39.0**	**39.1**
primary packaging (per FU)	**g/FU**	**35000**	**35300**	**39000**	**39100**
composite material (sleeve)	**g**	**31.1**	**31.4**	**35.1**	**35.2**
- liquid packaging board	g	22.3	22.3	25.5	25.5
- polymer	g	6.8	2.2	7.7	2.2
- plant-based polymer	g		4.9		5.6
- aluminium	g	2.0	2.0	1.9	1.9
closure	**g**	**3.9**	**3.9**	**3.9**	**3.9**
- polymer	g	3.9	2.1	3.9	2.1
- plant-based polymer	g		1.8		1.8
secondary packaging (sum)[2]	**g**	**145.0**	**145.0**	**101.9**	**101.9**
tray/box (corr.cardboard)	g	145.0	145.0	101.9	101.9
tertiary packaging (sum)[3]	**g**	**25170**	**25170**	**25170**	**25170**
pallet	g	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO
number of use cycles	-	25	25	25	25
stretch foil (per pallet) (LDPE)	g	170	170	170	170
pallet configuration					
cartons per tray	pc	10	10	12	12
trays / packs per layer	pc	15	15	10	10
layers per pallet	pc	5	5	5	5
cartons per pallet	pc	750	750	600	600

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

Table 13: Packaging specifications for assessed carton systems for the *packaging of OIL Family Packs (ambient)*

		OIL FAMILY PACK AMBIENT
	Unit	TPA Sq Metalized StreamCap
volume	mL	1000
geographic Scope	-	Italy
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	**125.4**
tray/box (corr.cardboard)	g	125.4
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	10
layers per pallet	pc	5
cartons per pallet	pc	600

[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 LIQUID FOOD Portion Packs (ambient)*

		LIQUID FOOD PORTION PACK AMBIENT
	Unit	Tetra Recart
volume	mL	390
geographic Scope	-	Italy
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 15: Packaging specifications for assessed alternative systems in the segment *Dairy Family Pack (ambient)*

		DAIRY FAMILY PACK AMBIENT	
	Unit	PET bottle 3	HDPE bottle 1
volume	ml	1000	1000
geographic scope	-	Italy	Italy
chilled / ambient	-	ambient	ambient
clear / opaque	-	opaque	opaque
primary packaging (sum)[1]	g	34.45	32.83
primary packaging (per FU)	g/FU	34450	32830
bottle	g	31.19	28.75
- PET	g	29.63	
- HDPE	g		26.59
- TiO2	g	1.56	1.44
- carbon black	g		0.72
label	g	0.67	0.80
- PP	g	0.67	0.80
closure	g	2.33	2.89
- HDPE	g	2.33	
- PP	g		2.89
pull tap	g	0.26	0.39
- aluminium	g	0.26	0.39
secondary packaging (sum)[2]	g	17.33	13.69
- shrink pack (LDPE)	g	16.66	13.11
- handle (paper)	g	0.67	0.58
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	6
sec. packaging units per layer	pc	21	21
layers per pallet	pc	5	5
bottles per pallet	pc	630	630

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

Table 16: Packaging specifications for assessed alternative systems in the segment *JNSD Family Pack (ambient)*

		JNSD FAMILY PACK AMBIENT			
	Unit	PET bottle 4	PET bottle 4a	PET bottle 6	PET bottle 6a
volume	ml	1000	1000	1000	1000
geographic scope	-	Italy	Italy	Italy	Italy
chilled / ambient	-	ambient	ambient	ambient	ambient
clear / opaque	-	clear	clear	clear	clear
primary packaging (sum)[1]	g	**54.52**	**54.52**	**35.15**	**35.15**
primary packaging (per FU)	g/FU	**54520**	**54520**	**35150**	**35150**
bottle	g	**47.75**	**47.75**	**28.50**	**28.50**
- PET	g	43.93	43.93	26.22	26.22
- recycled content	g		50 %		50%
- PA	g	3.82	3.82	2.28	2.28
label	g	**3.45**	**3.45**	**3.16**	**3.16**
- HDPE	g	3.45	3.45	3.16	3.16
closure	g	**3.32**	**3.32**	**3.27**	**3.27**
- HDPE	g	3.32	3.32	3.27	3.27
pull tab	g			**0.22**	**0.22**
- LDPE	g			0.11	0.11
- aluminium	g			0.11	0.11
secondary packaging (sum)[2]	g	**21.98**	**21.98**	**15.35**	**15.35**
- shrink pack (LDPE)	g	21.62	21.62	15.35	15.35
- handle (paper)	g	0.36	0.36		
tertiary packaging (sum)[3]	g	**25170**	**25170**	**25170**	**25170**
pallet	g	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO
number of use cycles		25	25	25	25
stretch foil (per pallet) (LDPE)	g	170	170	170	170
pallet configuration					
bottles per sec. packaging	pc	6	6	6	6
sec. packaging units per layer	pc	17	17	17	17
layers per pallet	pc	5	5	5	5
bottles per pallet	pc	510	510	510	510

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

Table 17: Packaging specifications for assessed alternative systems in the segment *WINE Family Pack (ambient)*

		WINE FAMILY PACK AMBIENT
	Unit	Glass bottle 1
volume	ml	750
geographic scope	-	Italy
chilled / ambient	-	ambient
clear / opaque	-	green glass
primary packaging (sum)[1]	g	**384.66**
primary packaging (per FU)	g/FU	**512880**
bottle	g	**378.83**
- external cullet rate	g	85.4 %
- glass	g	378.83
label	g	**1.75**
- paper	g	0.89
- PP	g	0.86
closure	g	**4.08**
- cork	g	4.08
secondary packaging (sum)[2]	g	**255.95**
- tray/box (corr.cardboard)	g	**255.95**
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	25
layers per pallet	pc	4
bottles per pallet	pc	600

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

Table 18: Packaging specifications for assessed alternative systems in the segment *OIL Family Pack (ambient)*

		OIL FAMILY PACK AMBIENT	
	Unit	PET bottle 13	Glass bottle 2
volume	ml	1000	1000
geographic scope	-	Italy	Italy
chilled / ambient	-	ambient	ambient
clear / opaque	-	clear	green glass
primary packaging (sum)[1]	**g**	**41.32**	**457.46**
primary packaging (per FU)	**g/FU**	**41320**	**457460**
bottle	**g**	**32.83**	**448.80**
- PET	g	30.21	
- external cullet rate	g	50 %	85.4 %
- PA	g	2.63	
- glass	g		448.80
label	**g**	**4.55**	**2.57**
- paper	g		2.57
- PET	g	4.55	
closure	**g**	**3.94**	**6.09**
- PP	g	3.94	2.02
- aluminium	g		4.07
secondary packaging (sum)[2]	**g**	**262.38**	**128.4**
- shrink pack (LDPE)	g		**31.26**
- tray/box (corr.cardboard)	g	**262.38**	**97.14**
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	12	9
layers per pallet	pc	5	5
bottles per pallet	pc	360	540

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

Table 19: Packaging specifications for assessed alternative systems in the segment *liquid food (ambient)*

		LIQUID FOOD AMBIENT		
	Unit	Pouch 1	Steel can 1	Glass jar 1
volume	ml	192.5	350	350
geographic scope	-	Italy	Italy	Italy
chilled / ambient	-	ambient	ambient	white glass
primary packaging (sum)[1]	g	6.61	52.65	210.14
primary packaging (per FU)	g/FU	34338	150429	600400
jar/can/pouch	g	6.61	43.86	200.89
- PET	g	0.96		
- PE	g	4.04		
- PA	g	1.01		
- tie layer	g	0.35		
- ink	g	0.25		
- tin plate	g		43.86	
- glass	g			200.89
- external cullet rate				69.5 %
label	g		2.13	1.41
- paper	g		2.13	1.41
closure	g		6.66	7.84
- tinplate	g		6.66	7.84
secondary packaging (sum)[2]	g	87.57	29.96	41.89
- tray	g	87.57	29.96	41.89
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				
pouches/jars/cans per sec. packaging	pc	6	3	6
sec. packaging units per layer	pc	29	53	26
layers per pallet	pc	7	12	10
bottles per pallet	pc	1218	1908	1560

[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 Italian 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 Italy. The material treated in MSWI is energetically recovered. The applied end-of-life quotas and the related references are given in Table 20. As data references preferable local data sources are applied where possible.

Table 20: Applied end of life quotas for beverage and liquid food cartons and competing packaging systems in Italy:

Geographical scope	Packaging system		Material recycling	MSWI	Landfill
Italy	Beverage and liquid food carton	quota	29%	34%	38%
		source	[ACE 2020]	[Eurostat 2020]	
		reference year	2018	2018	
	PET bottles[1,2]	quota	45%	26%	29%
		source	[COREPLA 2019]	[Eurostat 2020]	
		reference year	2018	2018	
	HDPE bottles[1,2]	quota	45%	26%	29%
		source	[COREPLA 2019]	[Eurostat 2020]	
		reference year	2018	2018	
	Glass bottles/jars	quota	76%	11%	13%
		source	[CoReVe 2019]	[Eurostat 2020]	
		reference year	2018	2018	
	Steel cans[3]	quota	79%	10%	11%
		source	[RICREA 2019]	[Eurostat 2020]	
		reference year	2018	2018	
	Pouches	quota	0%	47%	53%
		source	[Niaounakis 2019]	[Eurostat 2020]	
		reference year	2019	2018	

[1]white opaque bottles are not materially recycled (see section 3.14)

[2]recycling quota for all plastic packaging material

[3]rate for all steel material

The following flow charts illustrate the applied specified end-of-life model of beverage and liquid food cartons, clear PET bottles and white plastic (PET and HDPE) bottles, glass bottles and jars, steel cans and pouches. 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 20.

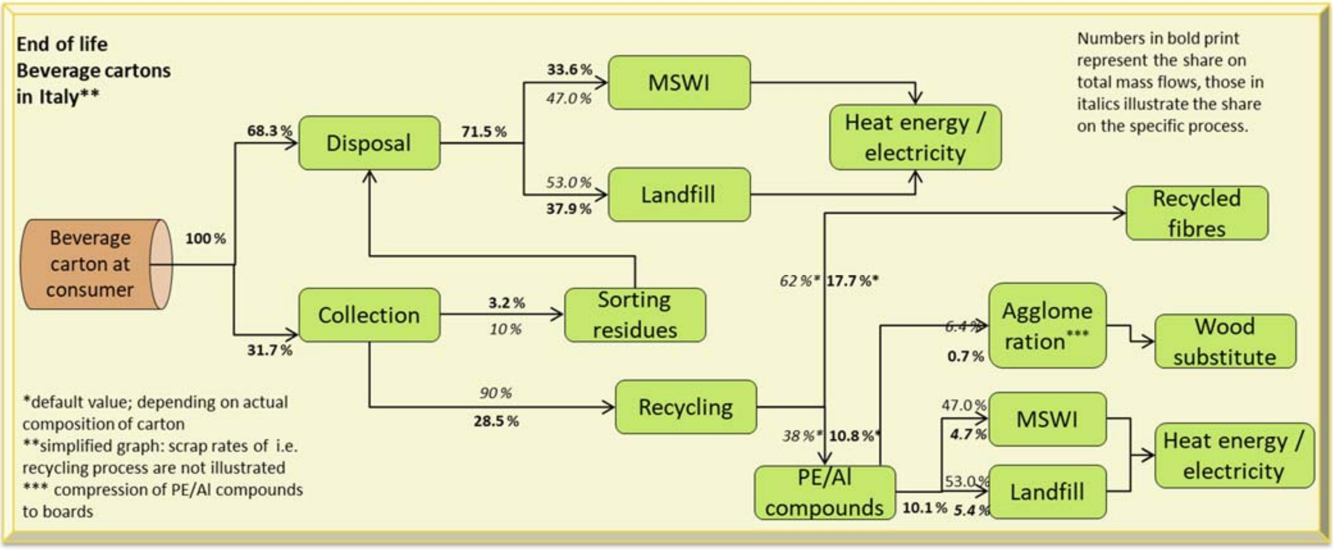

Figure 10: Applied end-of-life quotas for beverage and liquid food cartons in Italy

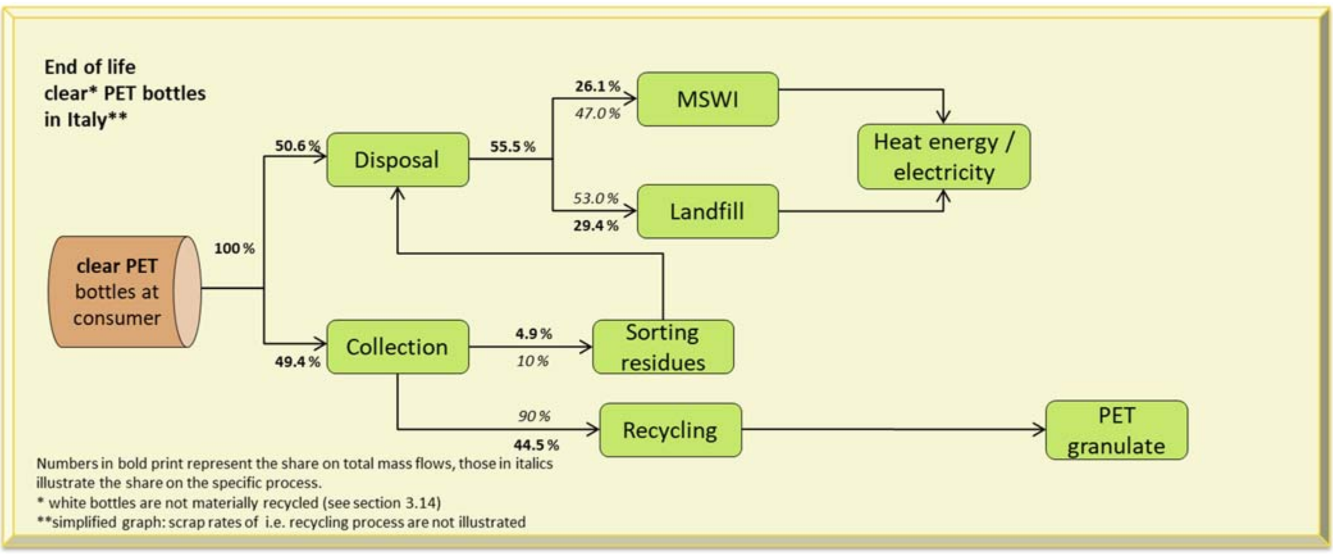

Figure 11: Applied end-of-life quotas for clear PET bottles in Italy

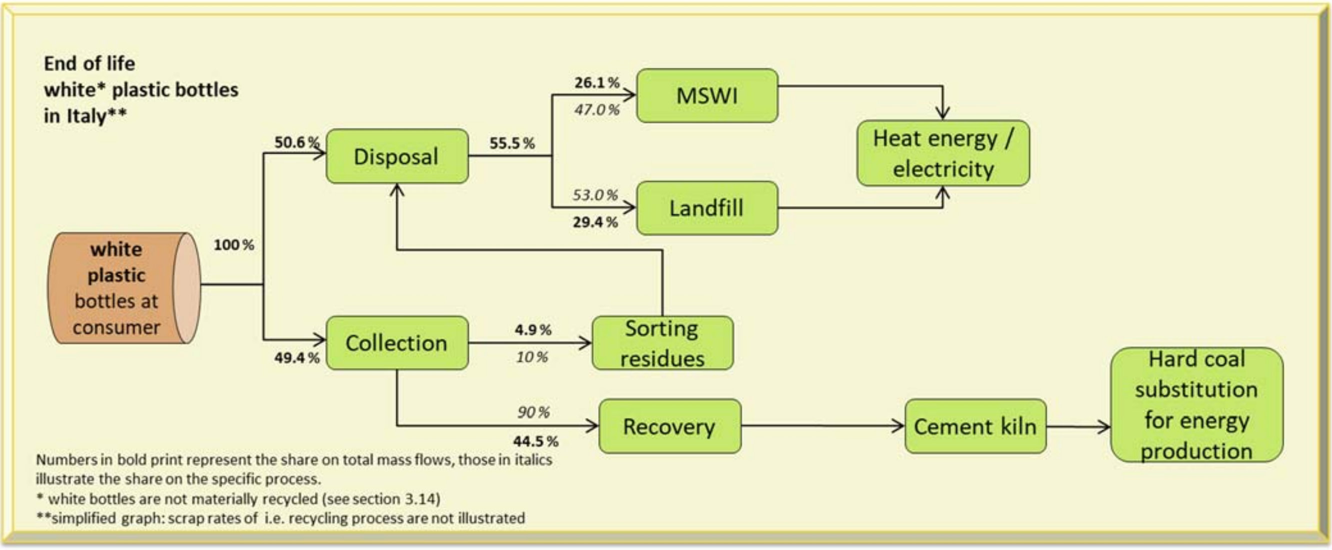

Figure 12: Applied end-of-life quotas for white plastic bottles (PET and HDPE) in Italy

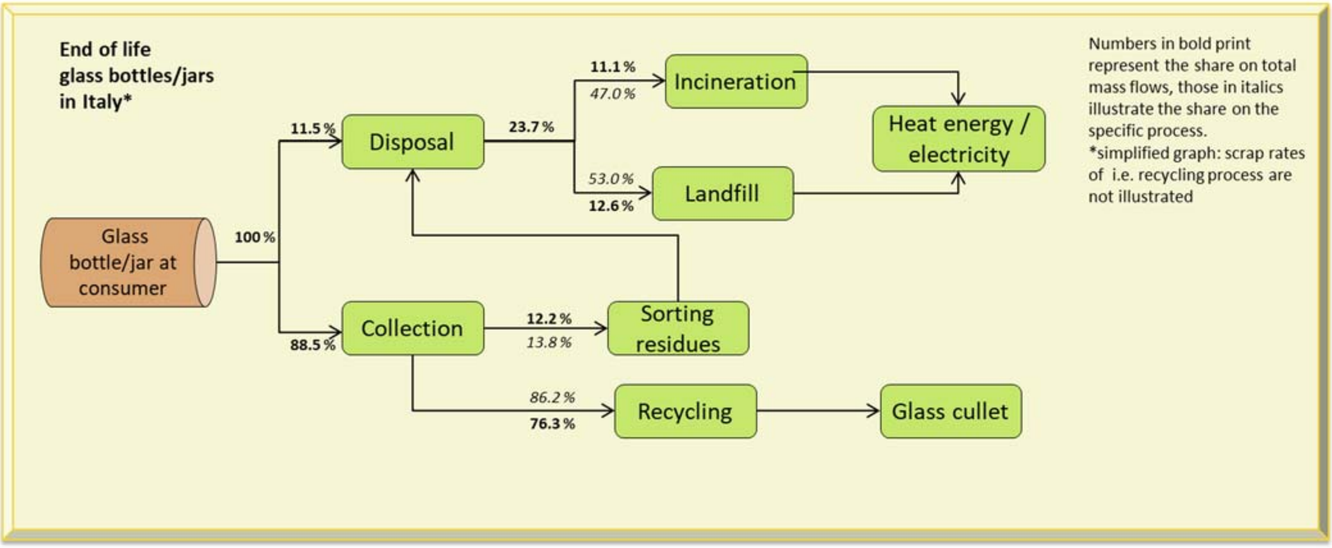

Figure 13: Applied end-of-life quotas for glass bottles/jars in Italy

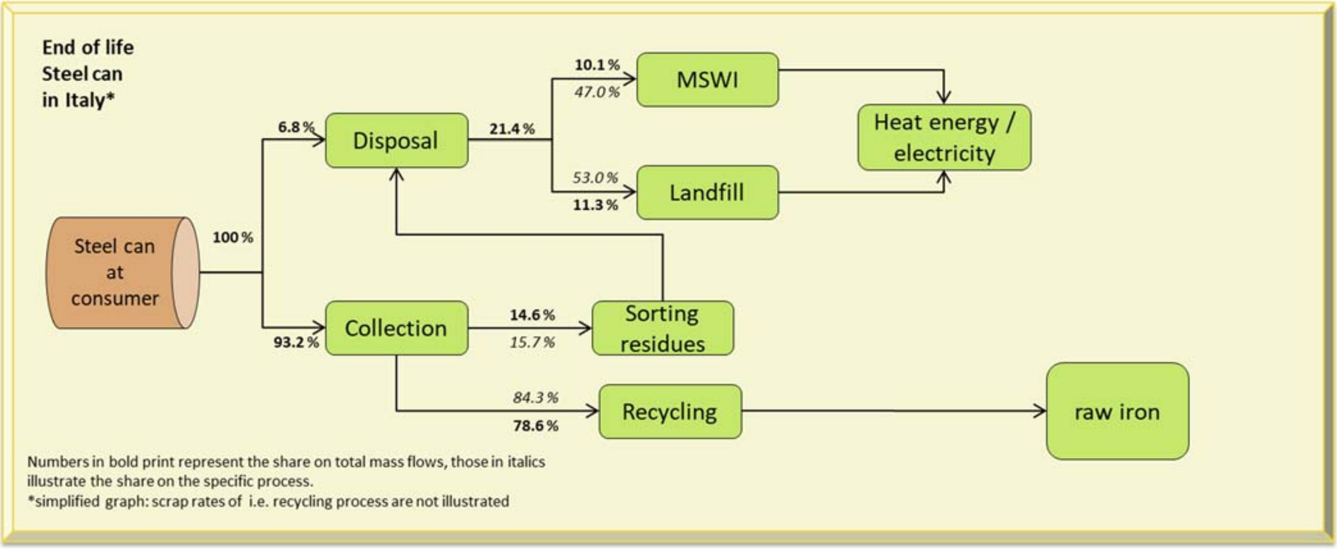

Figure 14: Applied end-of-life quotas for steel cans in Italy

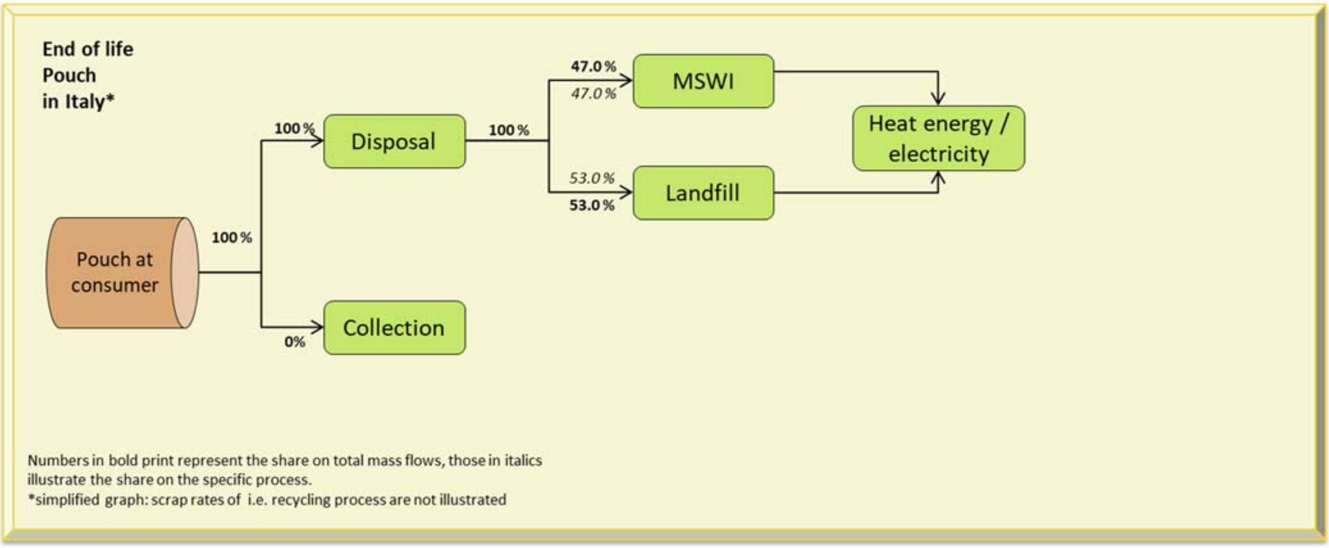

Figure 15: Applied end-of-life quotas for pouches in Italy

2.4 Scenarios

2.4.1 Base scenarios

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

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

2.4.2 Scenario variants

No further scenario variants are included in this country specific supplement study. Indicative findings regarding scenario variants like plant-based plastics in HDPE bottles, increased 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 21 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 21: 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
Carbon Black	Ecoinvent V.3.4	2011-2015	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
Cork stoppers	[Demertzi 2015], [Ecoinvent 3.6]	2009	secondary
Production			
BC converting	Tetra Pak	2017	primary
Glass bottle converting including glass production	UBA 2000 (bottle glass); energy prechains 2012	2000/2012	secondary
Preform production	Data provided by Tetra Pak, gathered in 2019	2019	primary

Material / Process step	Source	Reference period	primary / secondary data
HDPE bottle production	Data provided by Tetra Pak, gathered in 2019	2019	primary
Pouch production	ifeu database	2007/2018	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 glass bottles	ifeu data obtained from various fillers	2012	primary
Recovery			
Beverage and liquid food carton recycling	ifeu database, based on data from various European recycling plants	2004	primary
PET bottle	ifeu database, data collected from different recyclers in Germany and Europe	2009	primary
HDPE bottle	ifeu database, data collected from different recyclers in Germany and Europe	2008	primary
Glass bottle	ifeu database, [FEVE 2006]	2004/2005	primary/ secondary
Steel can	ifeu database	2008	primary
Background data			
electricity production	ifeu database, based on statistics and power plant models	2015	secondary
Municipal waste incineration	ifeu database, based on statistics and incineration plant models	2008	secondary
Landfill	ifeu database, based on statistics and landfill models	2008	secondary
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)
- Polyamide 6 (PA6)

3.1.1 Polypropylene (PP)

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

3.1.2 High Density Polyethylene (HDPE)

High density polyethylene (HDPE) is produced by a variety of low pressure methods and has fewer side-chains than LDPE. The present LCA study uses the eco-profile published on the website of Plastics Europe [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 only exceptions are the two sensitivity analyses with 100% plant-based HDPE bottles. 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 this 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 also represent the situation in 2012. 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 (same datasets as in Ecoinvent 3.1), including a forestry model to calculate inventories for this sub-system. Energy required is supplied by electricity as well as 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 card-board 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 oxidized with chlorine. After distillation of the resulting tetrachloride it is re-oxidized 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 Carbon Black

Carbon black is mostly produced by an oil-furnace process, a partial combustion process of liquid aromatic residual hydrocarbons. [Ecoinvent 3.4, Voll & Kleinschmitt 2010, Dannenberg & Paquin 2000].

The data used in this study is based on the ecoinvent 3.4 database.

3.9 Converting

3.9.1 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 electricity and inventory data for transport packaging used for shipping the coated composite board to the filler.

3.9.2 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.

3.9.3 HDPE bottle production

Unlike PET bottle production HDPE bottle production is not split into two different processes. Blow moulding takes place at the same site as the extrusion of HDPE. Data for these converting processes were provided by Tetra Pak and crosschecked with the internal ifeu database.

3.9.4 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.

3.9.5 Production of pouches

Data for the production of pouches are taken from the internal ifeu data base. These are based on data collected from various European pouch producers in the context of studies for the European industry association for flexible packaging (FPE) and is considered to be representative for an average European pouch production. The dataset is based on data from 2007 and 2018.

3.10 Closure production

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

Data for the production of cork stoppers for wine bottles are taken from [Demertzi 2015]. These data are originally collected from a Portuguese company that is considered to be a representative unit of the industrial cork sector. Prechain data has been taken from Ecoinvent 3.6.

3.11 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 cross-checked by ifeu with data collected for earlier studies. The data for the filling of plastic bottles was provided by Tetra Pak and crosschecked with the internal ifeu database. The data for PET bottles includes the electricity demand for stretch blow moulding. For the filling of glass bottles, data collected from various fillers (confidential) with a reference year of 2011 has been used. The data were still evaluated to be valid for 2019, as filling machines and technologies have not changed since then. Filling data for the analysed steel can were provided by Tetra Recart based on machine consumption data specifications referring to the year 2005. Within this study the same data were used.

3.12 Transport settings

Table 22 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 22: 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**

3.13 Distribution of filled packs from filler to point of sale

Table 23 shows the applied distribution distances in this study. Distribution centres are the places where the products are temporarily stored and then distributed to the different point of sales (i.e. supermarkets). The distances are based on the distances 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. A minimum return trip of 60km is assumed in cases the delivery distance is lower than 180km. If distances are lower than 60 km, the same distance is applied for the empty return trip. This is only valid for the distribution steps to the distribution centres. Usually no utilisation of lorries on their return trips from the point of sale to the warehouse is possible as the full return trip to the warehouse is attributed as an empty return trip to the examined system.

Table 23: Distribution distances in km for the examined packaging systems

segment	Distribution distance [km] as applied in this study			
	Distribution Step 1		Distribution step 2	
	filler > distribution centre (delivery)	**distribution centre > filler** (return trip)	**distribution centre > POS** (delivery)	**POS > distribution centre** (return trip)
all segments	300	90	100	100

3.14 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 or agglomerated into boards. 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.

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.

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% for white glass and 85.4% for green glass. 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 market related electricity grid mix.

Steel cans

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

Pouches

As multilayer films are currently not recycled [Niaounakis 2019] no recycling process for pouches is included in this study.

3.15 Background data

3.15.1 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 3.15.2).

3.15.2 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 2013]. It is based on national electricity mix data by the International Energy Agency (IEA)[2]. 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 all other processes. The applied shares of energy sources to the related market are given in Table 24.

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

Table 24: Share of energy source to specific energy mix, reference year 2015.

geographic scope / Energy source	Italy	EU 28	Sweden	Finland
Hard coal	14.86%	14.11%	0.23%	7.34%
Brown coal	0.30%	10.32%	0.00%	0.00%
Fuel oil	4.05%	1.65%	0.15%	0.30%
Natural gas	40.23%	16.51%	0.67%	12.65%
Nuclear energy	0.00%	26.70%	33.85%	33.66%
Hydropower/Wind/Solar /Geothermal	32.90%	24.50%	57.99%	29.14%
Hydropower	51.73%	45.74%	82.15%	87.77%
Wind power	16.86%	40.42%	17.75%	12.18%
Solar energy	24.74%	13.01%	0.10%	0.04%
Geothermal energy	6.67%	0.83%	0.00%	0.00%
Biomass energy	5.99%	4.84%	5.36%	15.69%
Waste	1.68%	1.35%	1.75%	1.23%

3.15.3 Municipal waste incineration

The electrical and thermal efficiencies of the municipal solid waste incineration plants (MSWI) are shown in Table 25.

Table 25: Electrical and thermal efficiencies of the incineration plants for Italy

Geographic Scope	Electrical efficiency	Thermal efficiency	Reference period	Source
Italy	21.2%	10.9%	2017	calculations based on [UTILITALIA 2019 and 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 latter mix of energy sources represents a European average. According to the knowledge of the authors of this study, official data regarding this aspect are not available.

3.15.4 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. It is assumed that 50% of methane generated is actually recovered via landfill gas capture systems. This assumption is based on data from National Inventory Reports (NIR) under consideration of different catchment efficiencies at different stages of landfill operation. The majority of captured methane is used for energy conversion. The remaining share is flared.

Regarding the degradation of the carton board under landfill conditions, it is assumed that it behaves like coated paper-based material in general. According to [Micales 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.

3.15.5 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 Italy are presented separately for the different categories in graphic form.

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

- production and transport of glass including converting to bottle (**'Glass'**)
- production and transport of PET, HDPE including additives, e.g. carbon black for the body of plastic bottles and pouches as well as steel for can bodies (**'Plastic/ Steel for body'**)
- production and transport of liquid packaging board **('LPB')**
- production and transport of plastics and additives for beverage and liquid food carton **('plastics for sleeve')**
- production and transport of aluminium & converting to foil for beverage and liquid food cartons **('aluminium foil for sleeve')**
- converting processes of cartons, plastic bottles, pouches and cans **('converting')**
- production, converting and transport of closures, tops, straws and labels and their base materials **('top, closure & label')**
- production of secondary and tertiary packaging: wooden pallets, LDPE shrink wrap and corrugated cardboard trays **('transport packaging')**
- filling process including packaging handling **('filling')**
- retail of the packages from filler to the point-of-sale including cooling during transport if relevant **('distribution')**
- sorting, recycling and disposal processes **('recycling & disposal')**
- CO_2 emissions from incineration of plant-based and renewable materials **('CO_2 reg. (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**')

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

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

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

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

The LCA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.
Each impact category diagram includes three bars per packaging system under investigation, which illustrate (from left to right):

- sectoral results of the packaging system itself (first stacked bar with positive values)
- credits given for secondary products leaving the system and CO_2 uptake (second stacked bar with negative values)
- net results as a results of the subtraction of credits from overall environmental burdens (grey bar)

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

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

4.1 Results allocation factor 50%; DAIRY FAMILY PACK AMBIENT

4.1.1 Presentation of results DAIRY FAMILY PACK AMBIENT

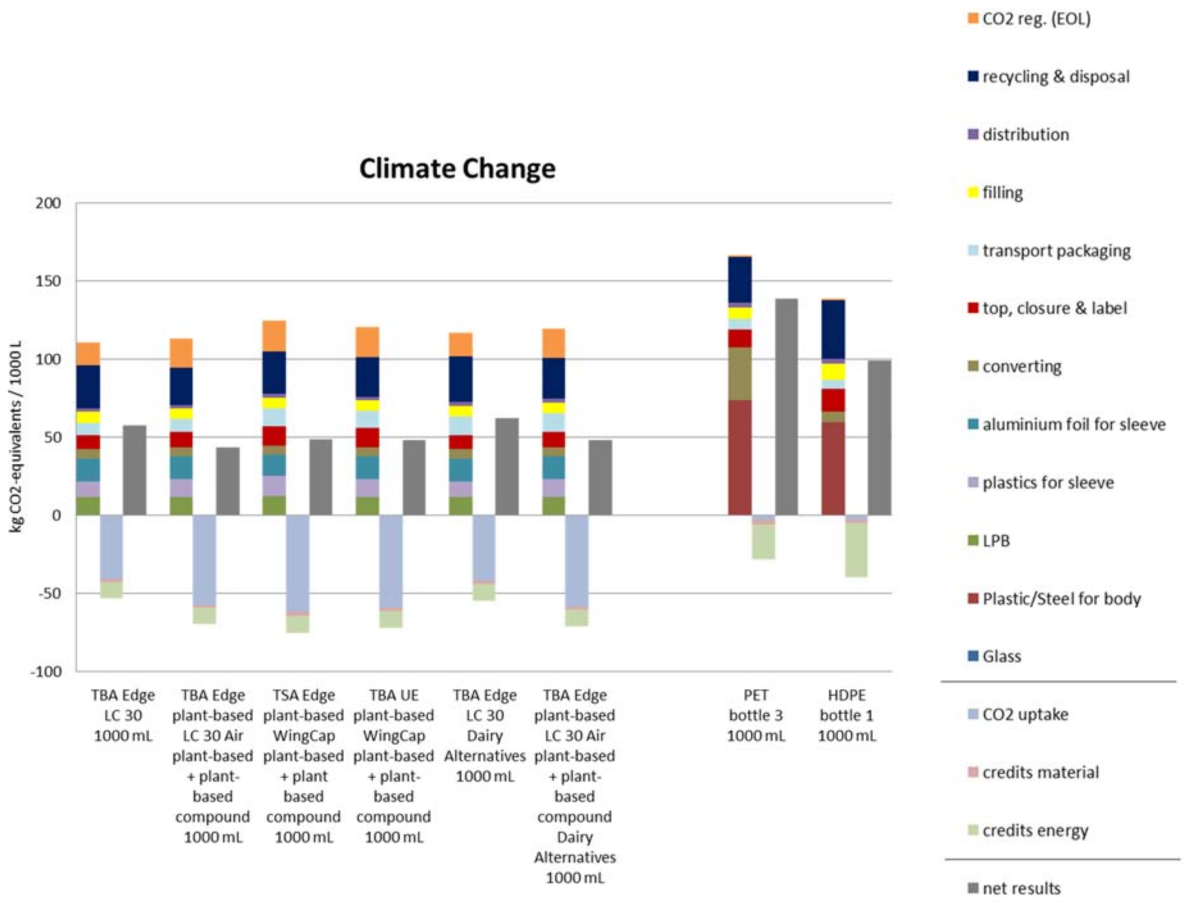

Figure 16: Climate Change results of segment DAIRY FAMILY PACK AMBIENT, allocation factor 50%

Table 26: Climate Change results of segment DAIRY FAMILY PACK AMBIENT - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL		PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	95.88	94.59	104.49	101.32	101.78	100.48		165.52	137.34
	CO2 (reg)	14.59	18.23	19.75	18.85	15.11	18.75		1.18	1.18
	Credits	-12.31	-12.32	-13.56	-12.85	-12.72	-12.73		-25.27	-36.84
	CO2 uptake	-40.60	-57.20	-62.08	-59.37	-41.78	-58.38		-2.77	-2.76
	net results	57.56	43.31	48.61	47.95	62.38	48.12		138.67	98.92

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 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%-11%), production of plastics for sleeves (8%-10%) and the production of aluminium foil for sleeve (11%-13%).

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

Also only minor shares (7%-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 7%-10% of the total burdens for 'Climate Change' for the beverage cartons.

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

The life cycle step 'distribution' shows up to 2% 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' (21%-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 these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 13%-16% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result from the recovery of energy in incineration plants. They sum up to 9% of the total burdens. Material credits for 'Climate Change' are low (2% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the

convention in this study which implies that no CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for 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 DAIRY FAMILY PACK AMBIENT segment, the biggest part (43%-44%) 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 (20%). The share of burdens for HDPE bottles (5%) is lower because the converting of HDPE bottles is done in one production step whereas the converting of PET bottles is done in two steps.

The life cycle step 'top, closure & label' shows small impacts shares (7%-11%) 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' (4%-8%) and 'distribution' (2%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares of burdens regarding 'Climate Change' (18%-27%). These result mainly from the incineration in cement kilns.

The influence of material credits on the net result is not relevant for 'Climate Change' as the white plastic bottles are not materially recycled. The influence of energy credits on the net result is high (13%-25%) mainly due to the substitution of fossil fuels in cement kilns.

4.1.3 Comparison between packaging systems

The following tables show the net results per FU 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 precentual comparison[1].

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

Table 27: Comparison of net results: **TBA Edge LC 30 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA Edge LC 30 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	+33%	+18%	+20%	-8%	+20%	-58%	-42%

Table 28: Comparison of net results: **TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	-25%	-11%	-10%	-31%	-10%	-69%	-56%

Table 29: Comparison of net results: **TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Italy Allocation 50	The net results of **TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	-16%	+12%	+1%	-22%	+1%	-65%	-51%

Table 30: Comparison of net results: **TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	-17%	+11%	-1%	-23%	-0%	-65%	-52%

Table 31: Comparison of net results: **TBA Edge LC 30 Dairy Alternatives 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA Edge LC 30 Dairy Alternatives 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	+8%	+44%	+28%	+30%	+30%	-55%	-37%

Table 32: Comparison of net results: **TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	-16%	+11%	-1%	+0%	-23%	-65%	-51%

4.2 Results allocation factor 100%; DAIRY FAMILY PACK AMBIENT

4.2.1 Presentation of results DAIRY FAMILY PACK AMBIENT

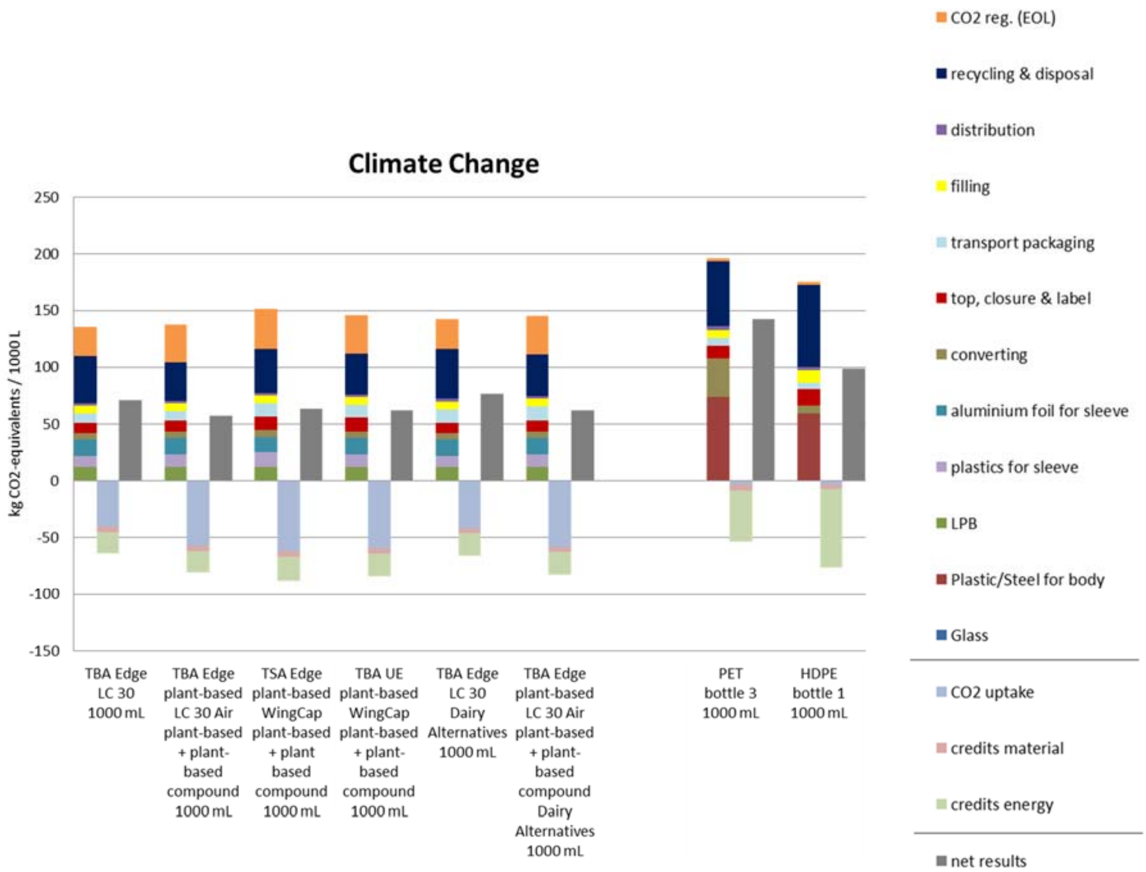

Figure 17: Climate Change results of **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

Table 33: Climate Change results of **segment DAIRY FAMILY PACK AMBIENT** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL		PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	109.56	104.63	115.97	112.03	116.16	111.23		193.70	173.12
	CO2 (reg)	25.74	33.03	35.74	34.10	26.56	33.86		2.37	2.36
	Credits	-23.56	-23.58	-25.98	-24.61	-24.35	-24.37		-50.57	-73.71
	CO2 uptake	-40.60	-57.20	-62.08	-59.37	-41.78	-58.38		-2.77	-2.76
	net results	71.14	56.89	63.65	62.15	76.59	62.34		142.72	99.01

4.2.2 Description and interpretation

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

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

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

In the cases of the plastic bottles, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits, resulting mainly from substituting coal fuel in cement kilns is similar than that of the burdens, resulting mainly from incinerating regardless of the allocation factor.

4.2.3 Comparison between packaging systems

The following tables show the net results per FU 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 precentual comparison[1].

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

Table 34: Comparison of net results: **TBA Edge LC 30 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA Edge LC 30 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	+25%	+12%	+14%	-7%	+14%	-50%	-28%

Table 35: Comparison of net results: **TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	-20%	-11%	-8%	-26%	-9%	-60%	-43%

Table 36: Comparison of net results: **TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Italy Allocation 100	The net results of **TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	-11%	+12%	+2%	-17%	+2%	-55%	-36%

Table 37: Comparison of net results: **TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	-13%	+9%	-2%	-19%	-0%	-56%	-37%

Table 38: Comparison of net results: **TBA Edge LC 30 Dairy Alternatives 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA Edge LC 30 Dairy Alternatives 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	+8%	+35%	+20%	+23%	+23%	-46%	-23%

Table 39: Comparison of net results: **TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL** versus competing cartons and alternative packaging systems in **segment DAIRY FAMILY PACK AMBIENT**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA Edge plant-based LC 30 Air plant-based + plant-based compound Dairy Alternatives 1000 mL** are lower (green)/ higher (orange) than those of						
	TBA Edge LC 30 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based compound 1000 mL	TSA Edge plant-based WingCap plant-based + plant based compound 1000 mL	TBA UE plant-based WingCap plant-based + plant-based compound 1000 mL	TBA Edge LC 30 Dairy Alternatives 1000 mL	PET bottle 3 1000 mL	HDPE bottle 1 1000 mL
Climate Change	-12%	+10%	-2%	+0%	-19%	-56%	-37%

4.3 Results allocation factor 50%; JNSD FAMILY PACK AMBIENT

4.3.1 Presentation of results JNSD FAMILY PACK AMBIENT

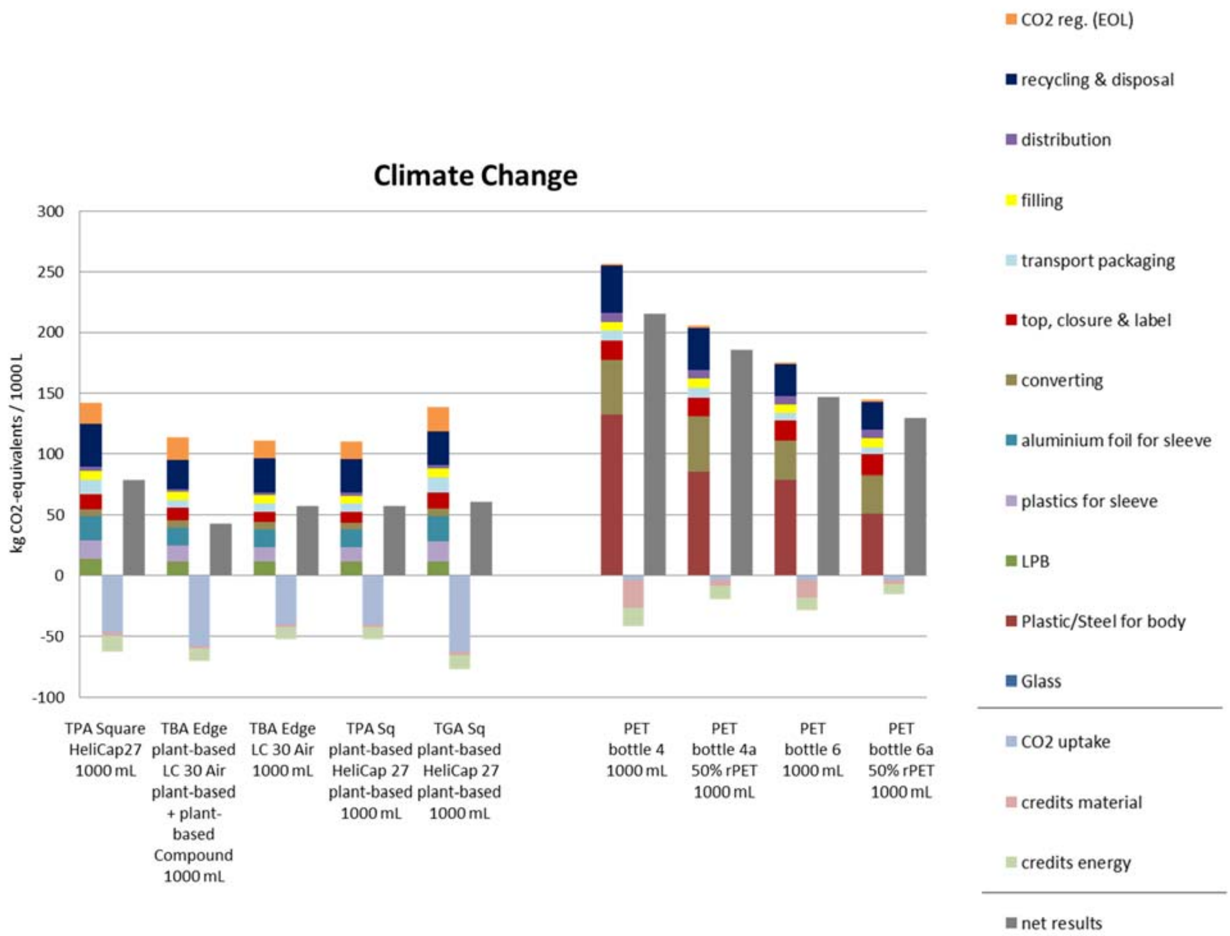

Figure 18: Climate Change results of **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

Table 40: Climate Change results of **segment JNSD FAMILY PACK AMBIENT** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Square HeliCap27 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TBA Edge LC 30 Air 1000 mL	TPA Sq plant-based HeliCap 27 plant-based 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL		PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	124.60	95.10	96.02	95.74	118.61		255.07	203.77	173.42	142.84
	CO2 (reg)	17.03	18.39	14.40	14.36	19.83		1.46	1.46	1.45	1.45
	Credits	-15.86	-12.65	-12.57	-12.52	-14.73		-38.03	-16.19	-24.86	-11.83
	CO2 uptake	-47.13	-58.28	-40.14	-40.01	-63.17		-3.40	-3.40	-3.39	-3.39
	net results	78.64	42.56	57.71	57.57	60.55		215.10	185.63	146.63	129.07

4.3.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

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

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

Also only minor shares (8%-10%) of total burdens for 'Climate Change' are caused from the production of closures.

The production and provision of 'transport packaging' for the beverage carton systems shows 6%-9% of the total burdens for 'Climate Change' for all beverage cartons.

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

The life cycle step 'distribution' shows 2%-3% 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' (20%-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 these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 12%-16% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result from the recovery of energy in incineration plants. They sum up to 9% of the total burdens. Material credits for 'Climate Change' are low (2% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the

convention in this study which implies that no CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for 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 AMBIENT segment, the biggest part (35%-51%) 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 a considerable share of burdens for 'Climate Change' (18%-22%).

The life cycle step 'top, closure & label' shows minor impacts shares (6%-12%) mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle systems show small impact shares (3%-4%) for 'Climate Change'.

The life cycle steps 'filling' (3%-5%) and 'distribution' (3%-5%) show only small shares of burdens for all bottle systems.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares of burdens regarding 'Climate Change' (15%-17%). These result mainly from the incineration in MSWI plants.

The influence of material credits on the net result is relevant for 'Climate Change'. They reduce the overall burdens by around 9% due to the substitution of virgin plastic with recycled PET from the bottles. In case of the PET bottles 4a and 6a with 50% recycled content the material credits are lower as most of the recycled material is used in a closed loop in the assessed systems. Energy credits, resulting mainly from incineration reduce the overall burdens by 5%-6%.

4.3.3 Comparison between packaging systems

The following tables show the net results per FU 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 precentual comparison[1].

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

Table 41: Comparison of net results: **TPA Square HeliCap27 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT-**, allocation factor 50%

JNSD FAMILY PACK (ambient), Italy Allocation 50	The net results of **TPA Square HeliCap27 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TBA Edge LC 30 Air 1000 mL	TPA Sq plant-based HeliCap 27 plant-based 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	+85%	+36%	+37%	+30%	-63%	-58%	-46%	-39%

Table 42: Comparison of net results: **TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA Edge plant-based LC 30 Air plant-based + plant-based Compound1000 mL** are lower (green)/ higher (orange) than those of							
	TPA Square HeliCap27 1000 mL	TBA Edge LC 30 Air 1000 mL	TPA Sq plant-based HeliCap 27 plant-based 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	-46%	-26%	-26%	-30%	-80%	-77%	-71%	-67%

Table 43: Comparison of net results: **TBA Edge LC 30 Air 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA Edge LC 30 Air 1000 mL** are lower (green)/ higher (orange) than those of							
	TPA Square HeliCap27 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TPA Sq plant-based HeliCap 27 plant-based 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	-27%	+36%	+0%	-5%	-73%	-69%	-61%	-55%

Table 44: Comparison of net results: **TPA Sq plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Italy Allocation 50	The net results of **TPA Sq plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TPA Square HeliCap27 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TBA Edge LC 30 Air 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	-27%	+35%	-0%	-5%	-73%	-69%	-61%	-55%

Table 45: Comparison of net results: **TGA 1000 Sq plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 50%

JNSD FAMILY PACK (ambient), Italy Allocation 50	The net results of **TGA 1000 Sq plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TPA Square HeliCap27 1000 mL	TBA 1000 Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TBA 1000 Edge LC 30 Air 1000 mL	TPA 1000 Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	-23%	+42%	+5%	+5%	-72%	-67%	-59%	-53%

4.4 Results allocation factor 100%; JNSD FAMILY PACK AMBIENT

4.4.1 Presentation of results JNSD FAMILY PACK AMBIENT

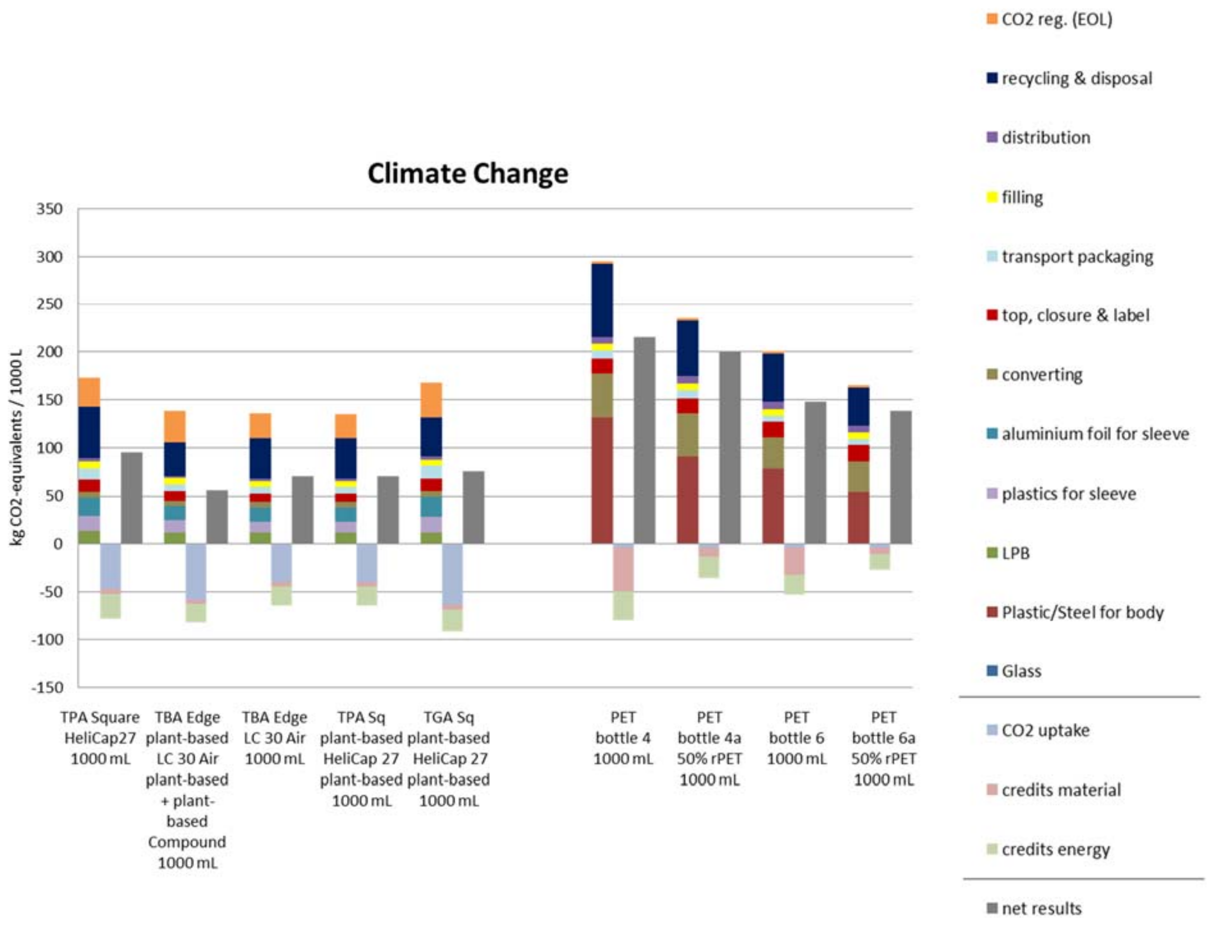

Figure 19: Climate Change results of segment JNSD FAMILY PACK AMBIENT, allocation factor 100%

Table 46: Climate Change results of segment JNSD FAMILY PACK AMBIENT - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Square HeliCap27 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TBA Edge LC 30 Air 1000 mL	TPA Sq plant-based HeliCap 27 plant-based 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL		PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	143.09	105.35	110.14	109.78	131.49		292.12	232.59	197.85	162.33
	CO2 (reg)	30.01	33.42	25.45	25.36	35.97		2.91	2.91	2.91	2.91
	Credits	-30.49	-24.25	-24.10	-24.00	-28.36		-76.10	-32.43	-49.75	-23.70
	CO2 uptake	-47.13	-58.28	-40.14	-40.01	-63.17		-3.40	-3.40	-3.39	-3.39
	net results	95.47	56.24	71.34	71.13	75.93		215.54	199.68	147.62	138.15

4.4.2 Description and interpretation

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 case of the plastic bottles, similar net results for 'Climate Change' are shown for PET bottle 4 and 6 when applying the allocation factor 100% instead of 50% as the absolute value of the credits (mainly material credits) is similar than that of the burdens from recycling and disposal regardless of the allocation factor. In case of PET bottles 4a and 6a with 50% recycled content higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the lower benefit from providing recycled material than using recycled material due the PA content shows more with allocation 100%.

4.4.3 Comparison between packaging systems

The following tables show the net results per FU 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 precentual comparison[1].

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

Table 47: Comparison of net results: **TPA Square HeliCap27 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT-**, allocation factor 100%

JNSD FAMILY PACK (ambient), Italy Allocation 100	The net results of **TPA Square HeliCap27 1000 mL** are lower (green)/ higher (orange) than those of							
	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TBA Edge LC 30 Air 1000 mL	TPA Sq plant-based HeliCap 27 plant-based 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	+70%	+34%	+34%	+26%	-56%	-52%	-35%	-31%

Table 48: Comparison of net results: **TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA Edge plant-based LC 30 Air plant-based + plant-based Compound1000 mL** are lower (green)/ higher (orange) than those of							
	TPA Square HeliCap27 1000 mL	TBA Edge LC 30 Air 1000 mL	TPA Sq plant-based HeliCap 27 plant-based 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	-41%	-21%	-21%	-26%	-74%	-72%	-62%	-59%

Table 49: Comparison of net results: **TBA Edge LC 30 Air 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA Edge LC 30 Air 1000 mL** are lower (green)/ higher (orange) than those of							
	TPA Square HeliCap27 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TPA Sq plant-based HeliCap 27 plant-based 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	-25%	+27%	+0%	-6%	-67%	-64%	-52%	-48%

Table 50: Comparison of net results: **TPA Sq plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Italy Allocation 100	The net results of **TPA Sq plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TPA Square HeliCap27 1000 mL	TBA Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TBA Edge LC 30 Air 1000 mL	TGA Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	-25%	+26%	-0%	-6%	-67%	-64%	-52%	-49%

Table 51: Comparison of net results: **TGA 1000 Sq plant-based HeliCap 27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment JNSD FAMILY PACK AMBIENT**, allocation factor 100%

JNSD FAMILY PACK (ambient), Italy Allocation 100	The net results of **TGA 1000 Sq plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of							
	TPA Square HeliCap27 1000 mL	TBA 1000 Edge plant-based LC 30 Air plant-based + plant-based Compound 1000 mL	TBA 1000 Edge LC 30 Air 1000 mL	TPA 1000 Sq plant-based HeliCap 27 plant-based 1000 mL	PET bottle 4 1000 mL	PET bottle 4a 50% rPET 1000 mL	PET bottle 6 1000 mL	PET bottle 6a 50% rPET 1000 mL
Climate Change	-20%	+35%	+6%	+7%	-65%	-62%	-49%	-45%

4.5 Results allocation factor 50%; WINE FAMILY PACK AMBIENT

4.5.1 Presentation of results WINE FAMILY PACK AMBIENT

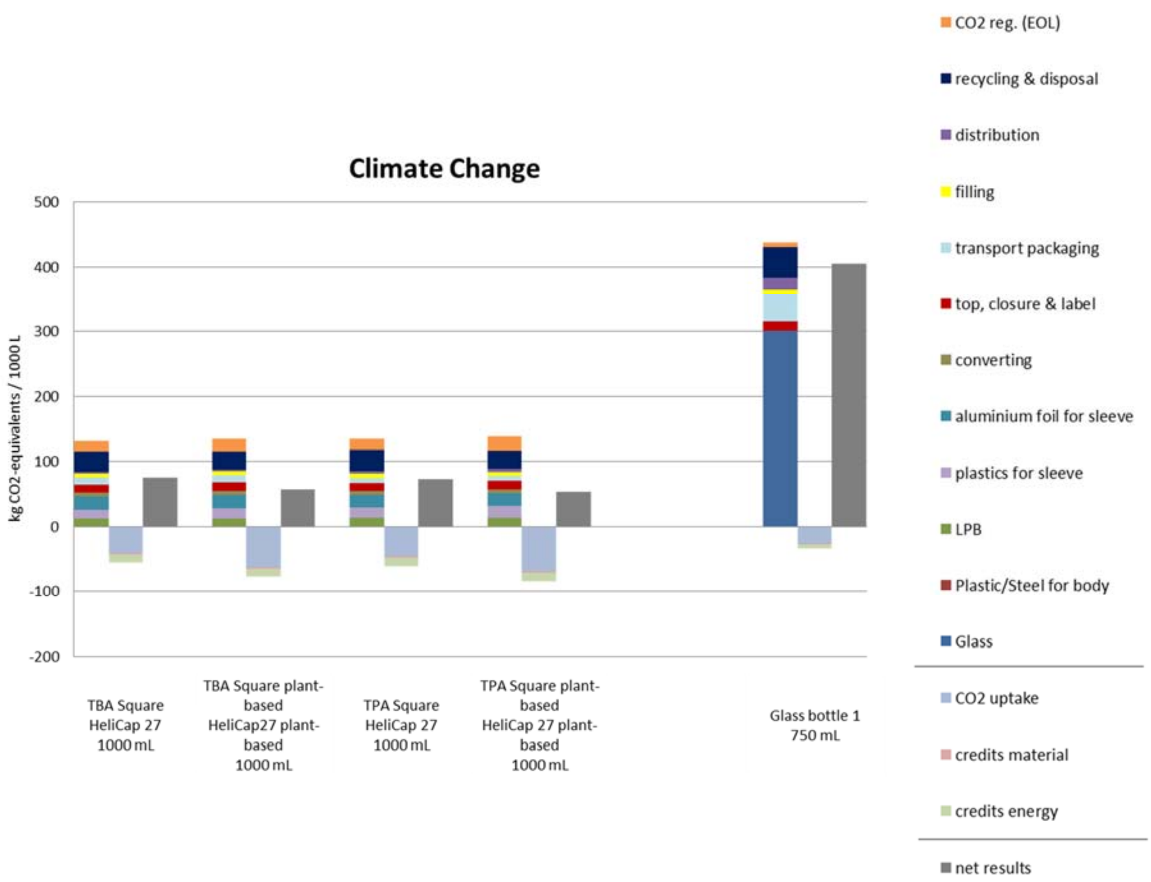

Figure 20: Climate Change results of **segment WINE FAMILY PACK AMBIENT**, allocation factor 50%

Table 52: Climate Change results of **segment WINE FAMILY PACK AMBIENT** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Square HeliCap 27 1000 mL	TBA Square plant-based HeliCap27 plant-based 1000 mL	TPA Square HeliCap 27 1000 mL	TPA Square plant-based HeliCap 27 plant-based 1000 mL		Glass bottle 1 750 mL
Climate Change [kg CO2-e/1000 L]	Burdens	115.73	115.04	117.85	116.39		430.64
	CO2 (reg)	14.95	19.54	16.48	21.55		7.63
	Credits	-14.34	-14.50	-15.40	-15.47		-6.53
	CO2 uptake	-41.37	-62.39	-45.87	-69.11		-26.97
	net results	74.98	57.69	73.06	53.36		404.77

4.5.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems considered in the WINE FAMILY PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (9%-10%), production of plastics for sleeves (10%-13%) and the production of aluminium foil for sleeve (14%-16%).

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

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

The production and provision of 'transport packaging' for the beverage carton systems shows 5%-8% of the total burdens for 'Climate Change' for the beverage cartons.

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

The life cycle step 'distribution' shows 2%-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' (20%-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 these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 11%-16% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result from the recovery of energy in incineration plants. They sum up to 9% of the total burdens. Material credits for 'Climate Change' are low (2% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the

convention in this study which implies that no CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for of the assessed system. (see section 1.7.2)

Glass bottle (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' (69%), due to the energy intensive glass bottle production process and the high weight of the bottle.

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

The influence of energy credits on the net result is low (1%) due to the low heating value of glass in MSWI plants.

The influence of material credits on the net result is also small for 'Climate Change'. They reduce the overall burdens by less than 1% as most of the glass is being recycled in a closed loop.

4.5.3 Comparison between packaging systems

The following tables show the net results per FU 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 precentual comparison[1].

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

Table 53: Comparison of net results: **TBA Square HeliCap 27 1000 mL** versus competing cartons and alternative packaging systems in **segment WINE FAMILY PACK AMBIENT-**, allocation factor 50%

WINE FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA Square HeliCap 27 1000 mL** are lower (green)/ higher (orange) than those of			
	TBA Square plant-based HeliCap27 plant-based 1000 mL	TPA Square HeliCap 27 1000 mL	TPA Square plant-based HeliCap 27 plant-based 1000 mL	Glass bottle 1 750 mL
Climate Change	+30%	+3%	+41%	-81%

Table 54: Comparison of net results: **TBA Square plant-based HeliCap27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment WINE FAMILY PACK AMBIENT-**, allocation factor 50%

WINE FAMILY PACK (ambient), Italy Allocation 50	The net results of **TBA Square plant-based HeliCap27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of			
	TBA Square HeliCap 27 1000 mL	TPA Square HeliCap 27 1000 mL	TPA Square plant-based HeliCap 27 plant-based 1000 mL	Glass bottle 1 750 mL
Climate Change	-23%	-21%	+8%	-86%

Table 55: Comparison of net results: **TPA Square HeliCap 27 1000 mL** versus competing cartons and alternative packaging systems in **segment WINE FAMILY PACK AMBIENT-**, allocation factor 50%

WINE FAMILY PACK (ambient), Italy Allocation 50	The net results of **TPA Square HeliCap 27 1000 mL** are lower (green)/ higher (orange) than those of			
	TBA Square HeliCap 27 1000 mL	TBA Square plant-based HeliCap27 plant-based 1000 mL	TPA Square plant-based HeliCap 27 plant-based 1000 mL	Glass bottle 1 750 mL
Climate Change	-3%	+27%	+37%	-82%

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

WINE FAMILY PACK (ambient), Italy Allocation 50	The net results of **TPA Square plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of			
	TBA Square HeliCap 27 1000 mL	TBA Square plant-based HeliCap27 plant-based 1000 mL	TPA Square HeliCap 27 1000 mL	Glass bottle 1 750 mL
Climate Change	-29%	-8%	-27%	-87%

4.6 Results allocation factor 100%; WINE FAMILY PACK AMBIENT

4.6.1 Presentation of results WINE FAMILY PACK AMBIENT

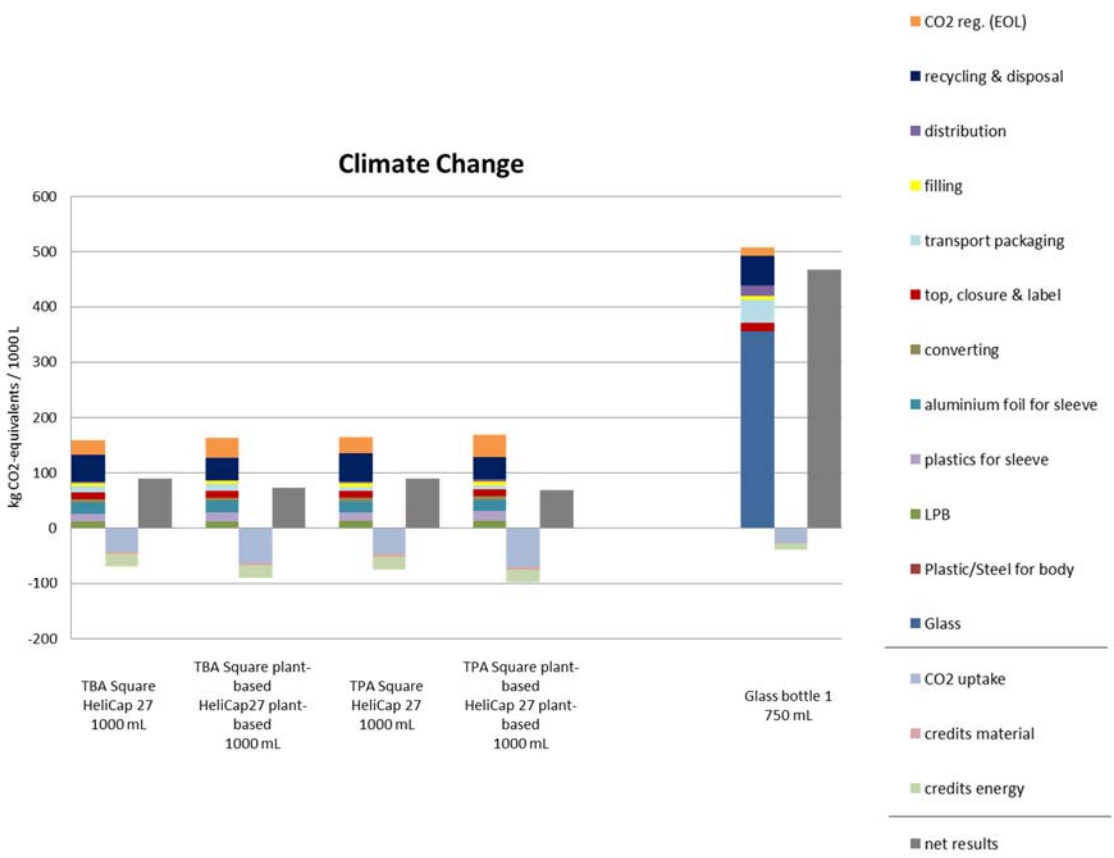

Figure 21: Climate Change results of **segment WINE FAMILY PACK AMBIENT**, allocation factor 100%

Table 57: Climate Change results of **segment WINE FAMILY PACK AMBIENT** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Square HeliCap 27 1000 mL	TBA Square plant-based HeliCap27 plant-based 1000 mL	TPA Square HeliCap 27 1000 mL	TPA Square plant-based HeliCap 27 plant-based 1000 mL		Glass bottle 1 750 mL
Climate Change [kg CO2-e/1000 L]	Burdens	132.60	127.59	135.50	129.08		492.33
	CO2 (reg)	26.29	35.47	29.16	39.30		15.26
	Credits	-27.59	-27.92	-29.62	-29.75		-12.63
	CO2 uptake	-41.37	-62.39	-45.87	-69.11		-26.97
	net results	89.93	72.76	89.17	69.51		467.99

4.6.2 Description and interpretation

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 carton in the segment WINE 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 case of the glass bottle, higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. The reason is that most of the glass cullet is closed loop material, which is not affected by the allocation factor.

4.6.3 Comparison between packaging systems

The following tables show the net results per FU 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 precentual comparison[1].

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

Table 58: Comparison of net results: **TBA Square HeliCap 27 1000 mL** versus competing cartons and alternative packaging systems in **segment WINE FAMILY PACK AMBIENT-**, allocation factor 100%

WINE FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA Square HeliCap 27 1000 mL** are lower (green)/ higher (orange) than those of			
	TBA Square plant-based HeliCap27 plant-based 1000 mL	TPA Square HeliCap 27 1000 mL	TPA Square plant-based HeliCap 27 plant-based 1000 mL	Glass bottle 1 750 mL
Climate Change	+24%	+1%	+29%	-81%

Table 59: Comparison of net results: **TBA Square plant-based HeliCap27 plant-based 1000 mL** versus competing cartons and alternative packaging systems in **segment WINE FAMILY PACK AMBIENT-**, allocation factor 100%

WINE FAMILY PACK (ambient), Italy Allocation 100	The net results of **TBA Square plant-based HeliCap27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of			
	TBA Square HeliCap 27 1000 mL	TPA Square HeliCap 27 1000 mL	TPA Square plant-based HeliCap 27 plant-based 1000 mL	Glass bottle 1 750 mL
Climate Change	-19%	-18%	+5%	-84%

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

WINE FAMILY PACK (ambient), Italy Allocation 100	The net results of **TPA Square HeliCap 27 1000 mL** are lower (green)/ higher (orange) than those of			
	TBA Square HeliCap 27 1000 mL	TBA Square plant-based HeliCap27 plant-based 1000 mL	TPA Square plant-based HeliCap 27 plant-based 1000 mL	Glass bottle 1 750 mL
Climate Change	-1%	+23%	+28%	-81%

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

WINE FAMILY PACK (ambient), Italy Allocation 100	The net results of **TPA Square plant-based HeliCap 27 plant-based 1000 mL** are lower (green)/ higher (orange) than those of			
	TBA Square HeliCap 27 1000 mL	TBA Square plant-based HeliCap27 plant-based 1000 mL	TPA Square HeliCap 27 1000 mL	Glass bottle 1 750 mL
Climate Change	-23%	-4%	-22%	-85%

4.7 Results allocation factor 50%; OIL FAMILY PACK AMBIENT

4.7.1 Presentation of results OIL FAMILY PACK AMBIENT

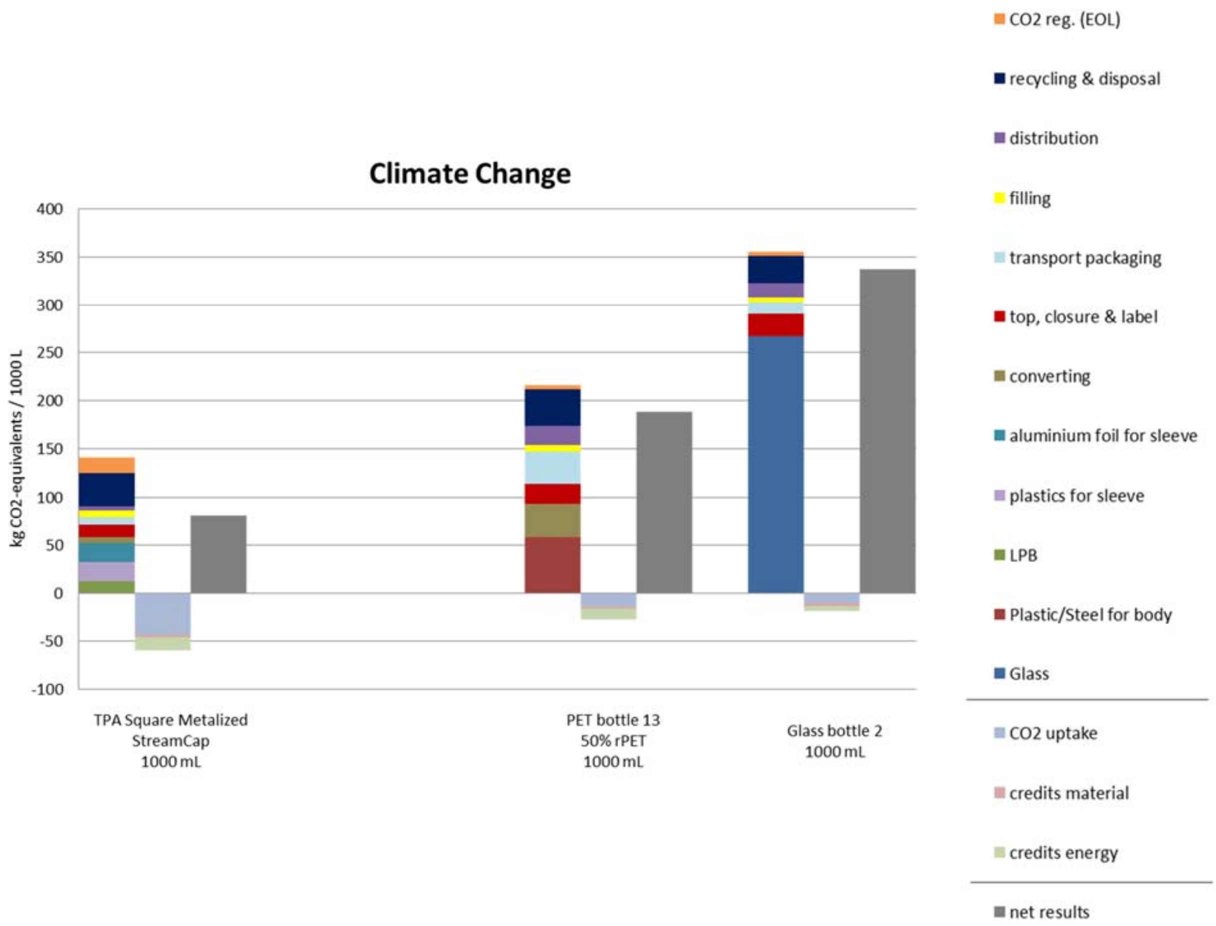

Figure 22: Climate Change results of **segment OIL FAMILY PACK AMBIENT**, allocation factor 50%

Table 62: Climate Change results of **segment OIL FAMILY PACK AMBIENT** - burdens, credits and net results per FU of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Sq Metalized StreamCap 1000 mL		PET bottle 13 50% rPET 1000 mL	Glass bottle 2 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	125.02		211.63	351.34
	CO2 (reg)	15.71		4.13	3.96
	Credits	-16.29		-13.49	-8.71
	CO2 uptake	-43.55		-13.62	-9.46
	net results	80.90		188.65	337.12

4.7.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton system considered in the 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 (9%), production of plastics for sleeves (14%) and the production of aluminium foil for sleeve (14%).

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

Also only small shares (9%) of total burdens for 'Climate Change' are caused from the production of closures.

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

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

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

The life cycle step 'recycling & disposal' of the assessed beverage carton is the most relevant life cycle step for 'Climate Change' (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 these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 11% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result from the recovery of energy in incineration plants. They sum up to 10% of the total burdens. Material credits for 'Climate Change' are low (2% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. Due to the

convention in this study which implies that no CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for 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 OIL FAMILY PACK AMBIENT segment, the biggest part (27%) 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' (16%).

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

The production and provision of 'transport packaging' for the bottle system show considerable impact shares (15%-15%) for 'Climate Change' due to the large amount of cardboard used for the secondary packaging.

The life cycle step 'filling' shows only small shares of burdens (3%) for the PET bottle system.

The life cycle step 'distribution' shows considerable shares of burdens (9%) due to the small amount of packs per pallets.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares of burdens regarding 'Climate Change' (18%). These result mainly from the incineration in MSWI plants.

The influence of material credits on the net result is low for 'Climate Change'. Because its 50% recycled content the material credits are low (1% of total burdens) as most of the recycled material is used in a closed loop in the assessed system. Energy credits, resulting mainly from incineration reduce the overall burdens by 5%.

Glass bottle (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' (75%), due to the energy intensive glass bottle production process and the high weight of the bottle.

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

The influence of energy credits on the net result is low (1%) due to the low the low heating value of glass in MSWI plants.

The influence of material credits on the net result is also small for 'Climate Change'. They reduce the overall burdens by 1% as most of the glass is being recycled in a closed loop.

4.7.3 Comparison between packaging systems

The following tables show the net results per FU 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 precentual comparison[1].

Table 63: Comparison of net results: **TPA Square Metalized StreamCap 1000 mL** versus competing cartons and alternative packaging systems in **segment OIL FAMILY PACK AMBIENT-**, allocation factor 50%

OIL FAMILY PACK (ambient), Italy Allocation 50	The net results of **TPA Sq Metalized StreamCap 1000 mL** are lower (green)/ higher (orange) than those of	
	PET bottle 13 50% rPET 1000 mL	Glass bottle 2 1000 mL
Climate Change	-57%	-76%

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

4.8 Results allocation factor 100%; OIL FAMILY PACK AMBIENT

4.8.1 Presentation of results OIL FAMILY PACK AMBIENT

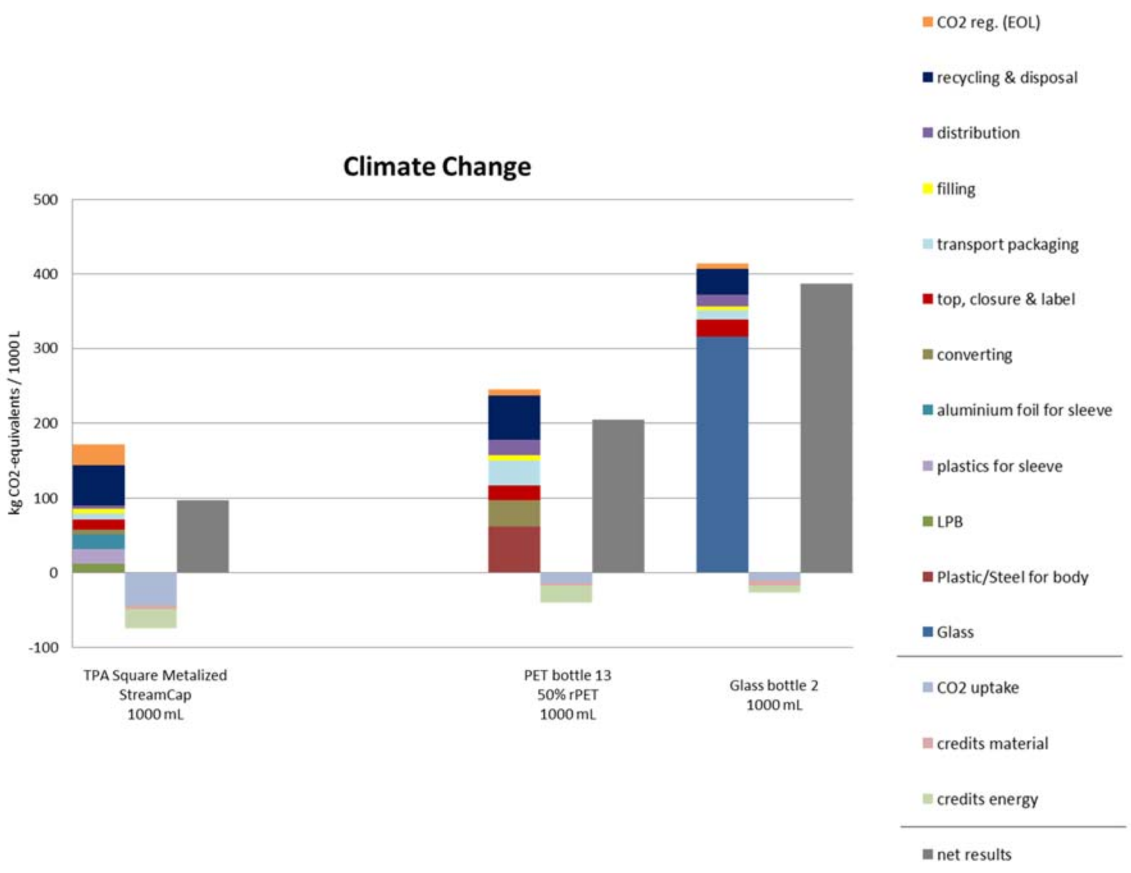

Figure 23: Climate Change results of **segment OIL FAMILY PACK AMBIENT**, allocation factor 100%

Table 64: Climate Change results of **segment OIL FAMILY PACK AMBIENT** - burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Square Metalized StreamCap 1000 mL		PET bottle 13 50% rPET 1000 mL	Glass bottle 2 1000 mL
Climate Change [kg CO2-e/1000 L]	Burdens	144.68		236.67	406.76
	CO2 (reg)	27.76		8.27	7.92
	Credits	-31.45		-26.69	-17.42
	CO2 uptake	-43.55		-13.62	-9.46
	net results	97.45		204.62	387.79

4.8.2 Description and interpretation

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 carton in the segment 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 case of the plastic bottle with 50% recycled PET content, higher net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the lower benefit from providing recycled material than using recycled material due the PA content shows more with allocation 100%.

In the case of the glass bottle, higher net results net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. The reason is that most of the glass cullet is closed loop material, which is not affected by the allocation factor.

4.8.3 Comparison between packaging systems

The following tables show the net results per FU 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 precentual comparison[1].

Table 65: Comparison of net results: **TPA Square Metalized StreamCap 1000 mL** versus competing cartons and alternative packaging systems in **segment OIL FAMILY PACK AMBIENT-**, allocation factor 100%

OIL FAMILY PACK (ambient), *Italy* *Allocation 100*	The net results of **TPA Square Metalized StreamCap 1000 mL** are lower (green)/ higher (orange) than those of	
	PET bottle 13 50% rPET 1000 mL	Glass bottle 2 1000 mL
Climate Change	-52%	-75%

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

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

4.9.1 Presentation of results LIQUID FOOD PORTION PACK AMBIENT

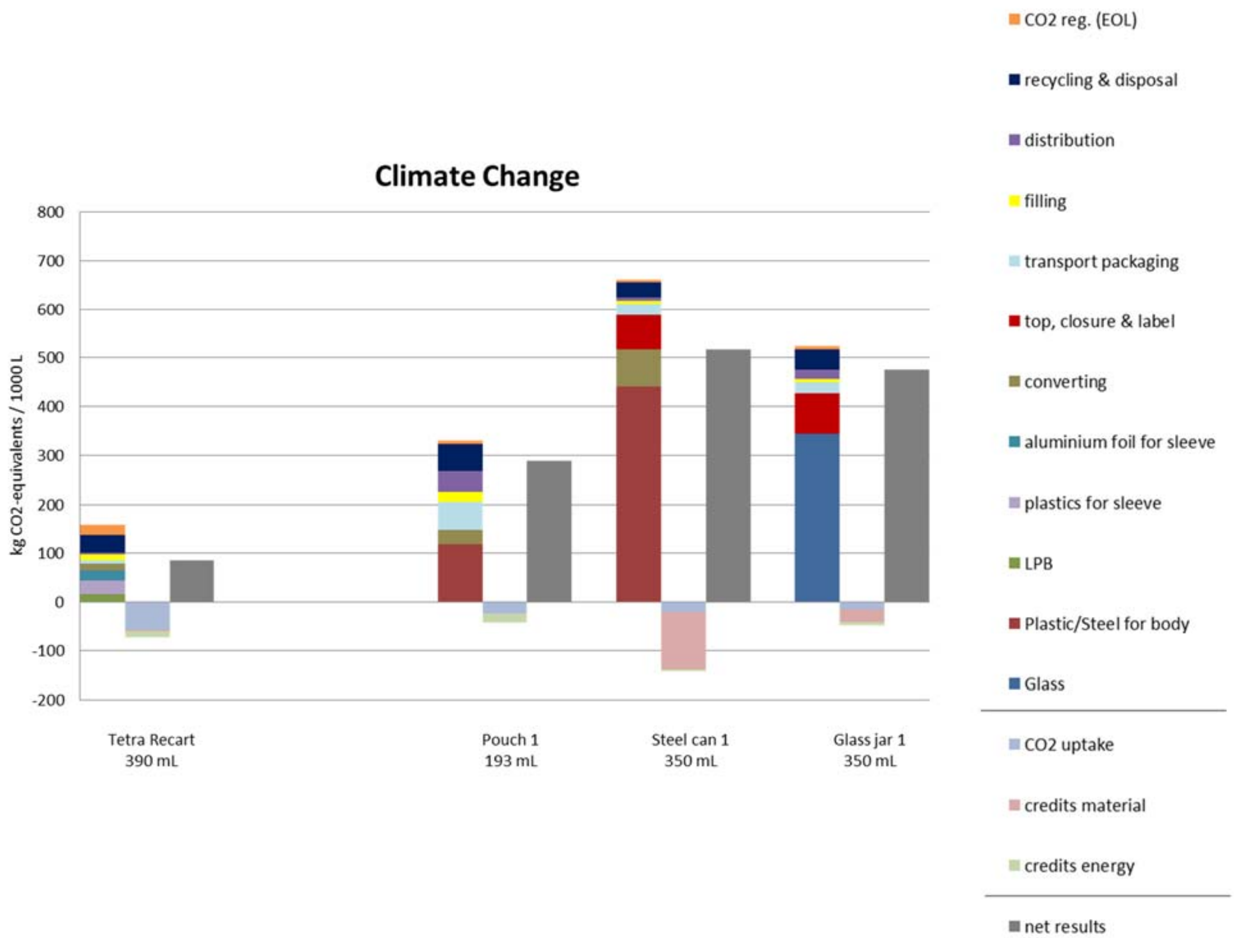

Figure 24: Climate Change results of **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 50%

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

Allocation 50		Tetra Recart 390 mL		Pouch 1 193 mL	Steel can 1 350 mL	Glass jar 1 350 mL
Climate Change [kg CO2-e/1000 L]	Burdens	138.59		323.67	655.45	517.89
	CO2 (reg)	19.93		6.76	4.97	5.55
	Credits	-16.95		-19.99	-123.32	-33.99
	CO2 uptake	-55.95		-22.68	-19.27	-13.68
	net results	85.61		287.76	517.83	475.76

4.9.2 Description and interpretation

Liquid food carton systems (specifications see section 2.2.1)

For the liquid food carton system considered in the LIQUID FOOD PORTION PACK AMBIENT segment, a considerable part of the environmental burdens for 'Climate Change' is caused by the production of the material components of the beverage carton. This includes the following life cycle steps with their corresponding shares of the total burdens regarding: Production of LPB (11%), production of plastics for sleeves (18%) and the production of aluminium foil for sleeve (13%).

The converting to sleeves accounts only small shares (9%) of the total burdens for 'Climate Change'.

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

The production and provision of 'transport packaging' for the beverage carton systems shows small shares (4%) of the total burdens for 'Climate Change' for the liquid food carton.

The life cycle step 'filling' shows minor shares of burdens (8%) for the liquid food carton system.

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

The life cycle step 'recycling & disposal' of the assessed liquid food carton is the most relevant life cycle step for 'Climate Change' (23%). 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 these derive mainly from the incineration of plant-based plastics and paper as well as from landfills. Together they contribute to 13% of the total burdens for 'Climate Change'. For thermal recovery system-related allocation is applied. In this case system-related allocation is applied with the allocation factor 50%.

Energy credits result from the recovery of energy in incineration plants. They sum up to 9% of the total burdens. Material credits for 'Climate Change' are low (2% of the total burdens) as the production of substituted primary paper fibres has low greenhouse gas emissions. System-related allocation (in this case with allocation factor 50%) is applied for energy and material credits.

The uptake of CO_2 by trees harvested for the production of paperboard and by sugarcane for plant-based plastics plays an important role in the impact category 'Climate Change'. The carbon uptake refers to the conversion process of carbon dioxide to organic compounds by trees and sugarcane. The assimilated carbon is then used to produce energy and to build body structures. However, the carbon uptake in this context describes only the amount of carbon which is stored in the product under study. This amount of carbon can be re-emitted in the end-of-life either by landfilling or incineration. Due to the convention in this study which implies that no CO_2 uptake is considered in credits, only for the assessed system, the producer of biogenic material, the CO_2 uptake is applied and seen in the results. In case of allocation factor 50% this leads to a benefit in 'Climate Change' for of the assessed system. (see section 1.7.2)

Pouch (specifications see section 2.2.2)

In the assessed pouch system in the LIQUID FOOD PORTION PACK AMBIENT segment, the major part (36%) of the environmental burdens for 'Climate Change' is caused by the production of the plastics of the pouch.

The 'converting' process shows for the pouch in this segment a small share of burdens for 'Climate Change' (9%).

The life cycle step 'top, closure & label' shows no impacts shares as the pouch systems does not include a closure.

The production and provision of 'transport packaging' for the bottle system show considerable impact shares (17%) for 'Climate Change' due to the large amount of cardboard used for the secondary packaging.

The life cycle step 'filling' shows only small shares of burdens (6%) for the pouch system.

The life cycle step 'distribution' shows considerable shares of burdens (13%) due to the small amount of packs per pallets.

The plastic bottles' 'recycling & disposal' life cycle step shows considerable shares of burdens regarding 'Climate Change' (17%). These result mainly from the incineration in MSWI plants.

The influence of material credits on the net result is low for 'Climate Change' as the pouches are not materially recycled. Energy credits, resulting mainly from incineration reduce the overall burdens by 6%.

Steel can (specifications see section 2.2.2)

In the assessed steel can system in the LIQUID FOOD PORTION PACK AMBIENT segment, the biggest part (67%) 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 considerable share of burdens for 'Climate Change (11%).

The life cycle step 'top, closure & label' shows also considerable 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 (3%, 1% and 1%) for the can.

The steel cans' 'recycling & disposal' life cycle step shows minor shares of burdens regarding 'Climate Change' (5%). 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 18% due to the substitution of raw steel with recycled steel from the cans. The influence of energy credits on the net result is low (less than 1% of total burdens) due to the low heating value of steel in MSWI plants

Glass jar (specifications see section 2.2.2)

Similar to the steel can, the production of the 'glass' material is the main contributor to the overall burdens for the glass jar. The production of glass clearly dominates the results for 'Climate Change' (66%), due to the energy intensive glass bottle production process and the high weight of the bottle.

Most other life cycle steps play only a minor role compared to the glass production. The exception is 'top, closure & label' which shows 16% of the total burdens resulting from the production of the tin plate closure.

The influence of energy credits on the net result is low (1%) due to the low the low heating value of glass in MSWI plants.

The influence of material credits on the net result is also small for 'Climate Change'. They reduce the overall burdens by 5% as most of the glass is being recycled in a closed loop.

4.9.3 Comparison between packaging systems

The following table shows the net results per FU 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 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 precentual comparison[1].

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

Table 67: Comparison of net results: **Tetra Recart 390mL** versus competing cartons and alternative packaging systems in **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 50%

FOOD PORTION PACK (ambient), Italy Allocation 50	The net results of **Tetra Recart 390 mL** are lower (green)/ higher (orange) than those of		
	Pouch 1 193 mL	Steel can 1 350 mL	Glass jar 1 350 mL
Climate Change	-70%	-83%	-82%

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

4.10.1 Presentation of results LIQUID FOOD PORTION PACK AMBIENT

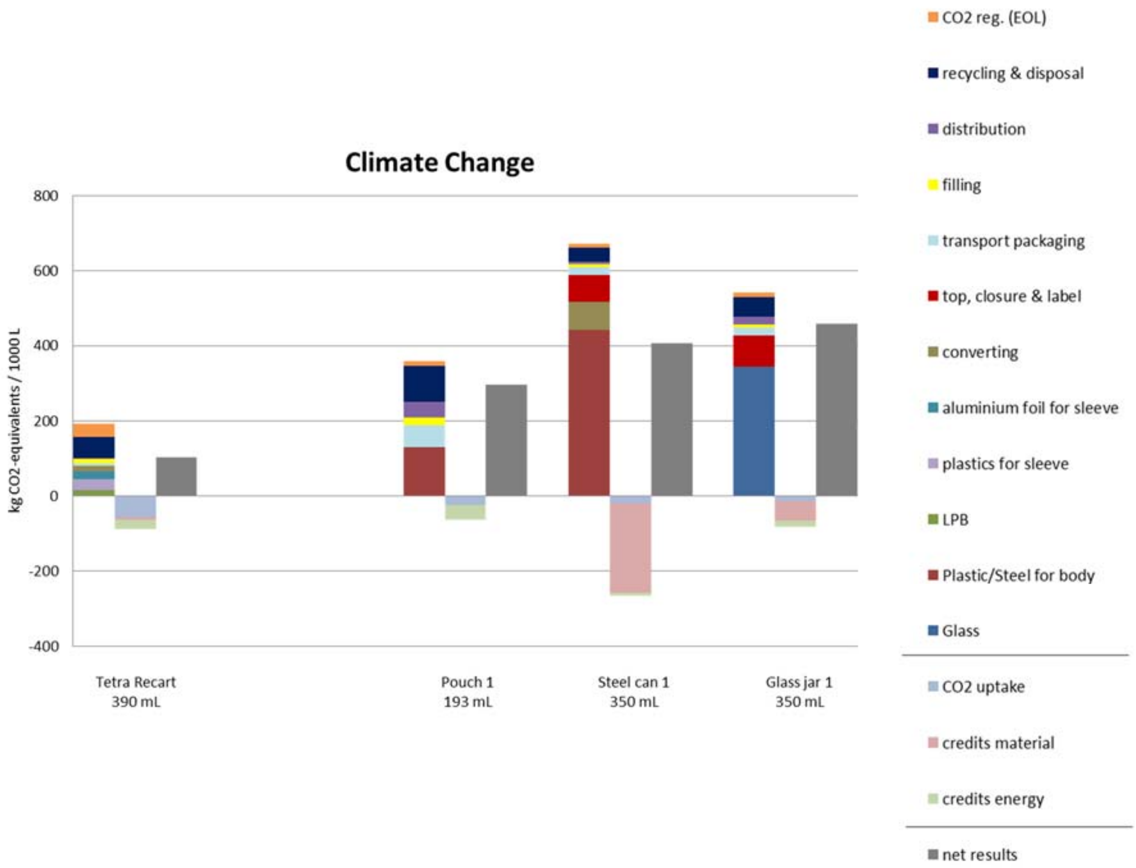

Figure 25: Climate Change results of **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 100%

Table 68: Climate Change results of **segment LIQUID FOOD PORTION PACK AMBIENT** burdens, credits and net results per FU of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		Tetra Recart 390 mL		Pouch 1 193 mL	Steel can 1 350 mL	Glass jar 1 350 mL
Climate Change [kg CO2-e/1000 L]	Burdens	157.13		345.36	662.57	529.62
	CO2 (reg)	35.18		13.52	10.05	11.09
	Credits	-32.42		-39.47	-246.20	-67.94
	CO2 uptake	-55.95		-22.68	-19.27	-13.68
	net results	103.94		296.73	407.14	459.10

4.10.2 Description and interpretation

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 pouch, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits (mainly from energy recovery in incineration) is similar as that of the burdens from recycling and disposal (mainly from incineration) regardless of the allocation factor.

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

In the case of the glass jar, similar net results for 'Climate Change' are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits is similar than that of the burdens from recycling and disposal regardless of the allocation factor. The reason is that most of the glass cullet is closed loop material, which is not affected by the allocation factor.

4.10.3 Comparison between packaging systems

The following table shows the net results per FU 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 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 precentual comparison[1].

Table 69: Comparison of net results: **Tetra Recart 390mL** versus competing cartons and alternative packaging systems in **segment LIQUID FOOD PORTION PACK AMBIENT**, allocation factor 100%

FOOD PORTION PACK (ambient), Italy Allocation 100	The net results of **Tetra Recart 390 mL** are lower (green)/ higher (orange) than those of		
	Pouch 1 193 mL	Steel can 1 350 mL	Glass jar 1 350 mL
Climate Change	-65%	-74%	-77%

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

5 Conclusions

In the following sections, results are summarised and conclusions are drawn regarding the environmental impact assessment of the packaging systems in the different segments on the Italian market. This section addresses all sensitivity analyses. In doing so, results with the 50% allocation factor and the 100% allocation factor are taken into account to the same degree. For comparative conclusions differences lower than 10% are considered to be insignificant in order to take into account data uncertainties (please see section 1.6 on precision and uncertainty).

5.1 DAIRY FAMILY PACK AMBIENT

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

As the net results of compared beverage cartons and competing packaging systems show wide enough differences, the choice of allocation factor has no influence on the comparative assessment of the environmental impacts in this segment. Therefore in this segment, a clear conclusion for the impact category 'Climate Change' can be drawn which shows lower impacts for the assessed beverage cartons than the compared PET bottle and HDPE bottle.

5.2 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 bottles.

As the net results of compared beverage cartons and competing packaging systems show wide enough differences, the choice of allocation factor has no influence on the comparative assessment of the environmental impacts in this segment. Therefore in this segment, a clear conclusion for the impact category 'Climate Change' can be drawn which shows lower impacts for the assessed beverage cartons than the compared PET bottles.

5.3 WINE 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 single glass bottle.

As the net results of compared beverage cartons and competing packaging systems show wide enough differences, the choice of allocation factor has no influence on the comparative assessment of the environmental impacts in this segment. Therefore in this segment, a clear conclusion for the impact category 'Climate Change' can be drawn which shows lower impacts for the assessed beverage cartons than the compared glass bottle.

5.4 OIL FAMILY PACK AMBIENT

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

As the net results of compared beverage cartons and competing packaging systems show wide enough differences, the choice of allocation factor has no influence on the comparative assessment of the environmental impacts in this segment. Therefore in this segment, a clear conclusion for the impact category 'Climate Change' can be drawn which shows lower impacts for the assessed beverage carton than the compared PET bottle and glass bottle.

5.5 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 pouch, steel can and glass jar.

As the net results of compared liquid food cartons and competing packaging systems show wide enough differences, the choice of allocation factor has no influence on the comparative assessment of the environmental impacts in this segment. Therefore in this segment, a clear conclusion for the impact category 'Climate Change' can be drawn which shows lower impacts for the liquid food carton than the compared pouch, 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 ambient, JNSD ambient, wine ambient, 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 Italian 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 environmental 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 environmental 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 Italy, 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 time scope and 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 calculation of environmental categories.

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 environmental performances depending on different segments as well as their packaging specifications. They generally show slightly higher results than similar cartons on the European market as presented in the European baseline study. The main reasons are the lower recycling rate and the slightly lower efficiency of MSWI plants in Italy.

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 environmental impact, as its production utilises mainly renewable energy leading to lower environmental impacts.

In all beverage and food segments assessed in this report, the beverage and food cartons show lower climate change impacts than the compared glass and plastic bottles as well as the cans and the pouch.

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.
- Regarding Climate Change it is recommended to prefer beverage cartons over the compared alternative packaging systems in the segments Dairy Family Pack Ambient, JNSD Family Pack, Wine Family pack, Oil Family pack and liquid food.
- 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.
- It is shown in this study that the closures can contribute a considerable amount to the overall life cycle impacts of beverage cartons with smaller volumes. To improve the overall environmental performance it is recommended to assess the

possibilities of using smaller and lighter closures for beverage cartons, especially for the ones with a filling volume below 500mL.

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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:

$$GWP = \sum_i (m_i \times GWP_i)$$

Note on biogenic carbon:

At the impact assessment level, it must be decided how to model and calculate CO_2-based GWP. In this context, biogenic carbon (the carbon content of renewable biomass resources) plays a special role: as they grow, plants absorb carbon from the air, thus reducing the amounts of carbon dioxide in the atmosphere. The question is how this uptake should be valued in relation to the (re-)emission of CO_2 at the material's end of life, for example CO_2 fixation in biogenic materials such as growing trees versus the greenhouse gas's release from thermal treatment of cardboard waste.

In the life cycle community two approaches are common. CO_2 may be 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.

[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.

Alternatively, neither the uptake of non-fossil CO_2 by the plant during its growth nor the corresponding CO_2 emissions are taken into account in the GWP calculation.

In the present study, the first approach has been applied for the impact assessment.

Methane emissions originating from any life cycle step of biogenic materials (e.g. their landfilling at end of life) are always accounted for both at the inventory level and in the impact assessment (in form of GWP).

A.2 References (for Appendix A)

[CML 2002]: Guinée. J.B. (Ed.) – Centre of Environmental Science – Leiden University (CML). de Bruijn. H.. van Duin. R.. Huijbregts. M.. Lindeijer. E.. Roorda. A.. van der Ven. B.. Weidema. B.: Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards, Eco-Efficiency in Industry and Science Vol. 7, Kluwer Academic Publishers.,Netherlands 2002.

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

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

[Klöpffer & Renner 1995]: Methodik der Wirkungsbilanz im Rahmen von Produkt-Ökobilanzen unter Berücksichtigung nicht oder nur schwer quantifizierbarer Umwelt-Kategorien. UBA-Texte 23/95. Berlin. 1995.

Appendix B:

Critical Review Report

Supplement Critical Review Statement according to ISO 14040 and 14044

of the study

“Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the Italian market -
for the segments: Dairy (ambient), JNSD, wine, oil and liquid food”

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
Alessandra Zamagni

4.11. 2020

Content

1. Procedural Aspects of the Critical Review

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

There was no First Draft Report of the Italian study. A first version of the Final Report was submitted on 14th September 2020, commented by the panel, and discussed in the telephone conference on 14th October 2020. During the conference calls the comments were elaborated by the panel members and discussed with the practitioner in detail.

The review panel received the second version of the Final Report of the study 27th October 2020. After a few minor changes based on comments from the review panel this version was transferred into the Final Report 4th November 2020. The statements and comments in the supplement CR-statement dated 4th November 2020 are based on this final version.

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

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

The reviewers emphasise the open and constructive atmosphere of the project. All necessary data 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 studies "Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid food on the Italian 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 – 4.11.2020" 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 which has been 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 Italian market is a 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 Italian study the same LCA model is used as in the European baseline study, but region-specific data like packaging solutions 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 Italian 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 taken into account, 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 Italian 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. This aspect is 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 Italian market. In this context, the panel warns against emphasizing the 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 Italian 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 Italian 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 Italian 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 Italian 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]. Comparability was ensured by Tetra Pak, based on product and market characteristics.
- Specified are the Italian 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 Italian 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 Italian 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.

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

The assumptions of the EoL management in Italy are comprehensibly derived and plausible.

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 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 Italian 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 Italian 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 Italian 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 Italian study. However, caution is advised here, and the panel warns against emphasizing the 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

Heidekamp, 4.11.2020	Bologna, 4.11.2020	Ashby de la Zouch, 4.11.2020
Prof. Dr. Birgit Grahl (Chair)	Dr. Alessandra Zamagni	Dr. Leigh Holloway

Addresses of the reviewers:

Prof. Dr. Birgit Grahl
Industrielle Ökologie
Schuhwiese 6
23838 Heidekamp
Germany
Tel: +49(0)4533 - 4110
Email: integrahl@t-online.de

Dr. Alessandra Zamagni
Ecoinnovazione srl spin-off ENEA
Via Ferrarese 3
40128 Bologna
Italy
Tel: +39 338 7531665Email: a.zamagni@ecoinnovazione.it

Dr. Leigh Holloway
Eco3 Design Ltd
The Old Bank
Kilwardby Street
Ashby de la Zouch
Leicestershire
LE652FR
United Kingdom
Tel: +44(0)1530563330
Email: leigh@eco3.co.uk