INSTITUT FÜR ENERGIE-
UND UMWELTFORSCHUNG
HEIDELBERG

Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid dairy products on the Swiss and Austrian market

Final Report

commissioned by Tetra Pak (Switzerland) AG and Tetra Pak GmbH (Austria)

Heidelberg, October 2019

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

INSTITUT FÜR ENERGIE- UND UMWELTFORSCHUNG HEIDELBERG

Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid dairy products on the Swiss and Austrian market

Final Report

commissioned by Tetra Pak (Switzerland) AG and Tetra Pak GmbH (Austria)

Samuel Schlecht

Frank Wellenreuther

Mirjam Busch

Stefanie Markwardt

Heidelberg, October 2019

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

Table of contents

Table of content

Table of contents

Table of content

Table of contents

Table of content

Table of contents

Table of content

Abbreviations

ACE	Alliance for Beverage Cartons and the Environment
AT	Austria
bb	bio-based
BC	Beverage carton
CED	Cumulative energy demand
CH	Switzerland
CML	Centrum voor Milieukunde (Center of Environmental Science), Leiden University, Netherlands
COD	Chemical oxygen demand
CRD	Cumulative raw material demand
DE	Germany
EAA	European Aluminium Association
EEA	European Environment Agency
EU27+2	European Union & Switzerland and Norway
FEFCO	Fédération Européenne des Fabricants de Carton Ondulé (Brussels)
FP	Family pack
GWP	Global Warming Potential
HBEFA	Handbuch für Emissionsfaktoren (Handbook for Emission Factors)
ifeu	Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JN	Juice and Nectars
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
NMVOC	Non-methane volatile organic compounds

NO_X	Nitrogen oxides
ODP	Ozone Depletion Potential
OW	One way
pc	packs
PM2.5	Particulate matter with an aerodynamic diameter of 2.5 µm or smaller
PP	Polypropylene
PoP	Portion pack
PS	Polystyrene
RF	refillable
rPET	recycled PET
SBM	Stretch blow moulding
SD	Still drinks
TB	Tetra Brik
TBA	Tetra Brik Aseptic
TiO_2	Titanium dioxide
TPA	Tetra Prisma Aseptic
TR	Tetra Rex
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 2013]. 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 a global cooperation agreement with the WWF on issues concerning forestry and climate change.

Tetra Pak has recently finalized LCA studies for several packaging formats including bio-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. Therefore, Tetra Pak commissioned the Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research, ifeu) to conduct a comparative LCA study for key carton packages as well as key competing packages in different beverage segments covering the markets Switzerland and Austria.

The goal of the study is to conduct a LCA analysing the environmental performance of beverage carton systems compared to alternative beverage packaging systems.
Competing packaging systems on the Swiss and Austrian market include:

- PET bottles
- HDPE bottles and
- PP/PS cups.

Additionally,

- Glass bottles (one way) and
- Glass bottles (refillable)

are analysed for the Austrian market.
All analysed packaging systems are divided into the segments

- 'Family Packs' (FP) with volumes from 1000 mL to 2000 mL
- 'Portion Packs' (PoP) with volumes from 200 mL to 500 mL.

The analysed packaging systems contain the following chilled and ambient beverage segments:

- Juice and Nectars (JN)
- Still Drinks (SD)

- DAIRY products like milk or coffee drinks
- CREAM (whipping cream and coffee cream)
- still, unflavoured WATER

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 of carton packaging systems (partly with bio-based material) in the described segments and markets.

(2) to compare the environmental performance of these cartons with those of the competing packaging systems with high market relevance on the Swiss and Austrian markets.

Further objectives are addressed through sensitivity analyses and scenario variants:

(3) to provide knowledge regarding the environmental performance of carton packages, with future use of bio-based plastics.

(4) to provide knowledge regarding the environmental performance of carton packaging systems compared to HDPE bottles with bio-based material content

(5) to provide knowledge regarding the environmental performance of carton packaging systems compared to PET bottles with up to 100% recycled material content.

(6) to provide knowledge regarding the environmental performance of carton packaging systems compared to PET and HDPE bottles with reduced weights.

(7) to provide knowledge regarding the environmental performance of carton packaging systems compared to refillable glass bottles with lower or higher trip rates.

During the preparation of the study one bottle on the Austrian market got superseded by a new bottle. Therefore an additional scenario is added

(8) to provide knowledge regarding the change of a white opaque PET bottle to a clear PET bottle in the segment DAIRY FAMILY PACK in Austria.

The sensitivity analyses and scenario variants are conducted for selected packaging systems on selected markets chosen by Tetra Pak regarding their market relevance. (see Table 35-Table 37)

The results of this study for these scopes shall be used for internal and external communication.

The study will be critically reviewed according to ISO 14040/14044.

For the geographic scope of Switzerland the impact assessment method Umweltbelastungspunkte (UBPs) will be applied according to Frischknecht & Büsser Knöpfel (2013). The results will be included in a separate annex as well. It will not be part of this ISO compliant study due to the fact that weighting of different environmental impact indicators is not allowed according to ISO 14040/44. However, for the application of this method reviewed life cycle inventory of this study is used.

1.2 Organisation of the study

This study was commissioned by Tetra Pak in 2017. It is being conducted by the Institute for Energy and Environmental Research Heidelberg GmbH (ifeu).

The members of the project panel are:

- **Tetra Pak:** Katharina Schenk, Caroline Babendererde, Erika Kloow, Erik Lindroth
- **ifeu:** Samuel Schlecht, Frank Wellenreuther

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. The study and/or its results are therefore intended to be disclosed.
According to the ISO standards on LCA [ISO 14040 and 14044 (2006)], this requires a critical review process undertaken by a critical review panel. In the experience of Tetra Pak and ifeu the most cost- and time-efficient way to run the critical review is to have it as an accompanying process. Thus, the critical reviewers were able to comment on the project from the time the goal and scope description was available.

The members of the critical review panel are

- Harald Pilz (chair), to4to – together for tomorrow
- Jürgen Heinisch, Jürgen Heinisch consulting
- Andy Spörri, EBP Schweiz AG

1.4 Functional unit

The function examined in this LCA study is the packaging of beverages for retail. The functional unit for this study is the provision of 1000 L packaging volume for chilled or ambient beverage at the point of sale. The packaging of the beverages 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. Even though the shelf life of chilled packaging systems is only a few days, the function regarding food safety stays the same for all examined packaging solutions.

The primary packages examined are technically equivalent regarding the mechanical protection of the packaged beverage 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 regarded here, refers to the actually 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 foil, pallets), which are necessary for the packaging, filling and delivery of 1000 L beverage.

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:

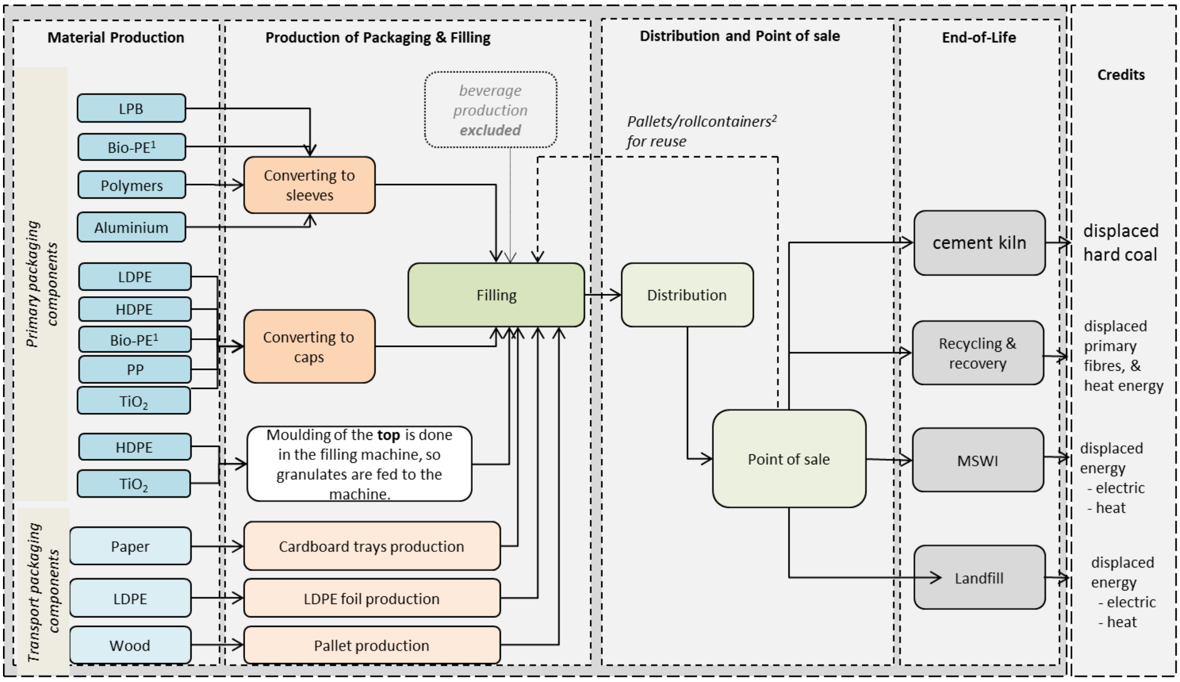
- production, converting, recycling and final disposal of the primary base materials used in the primary packaging elements from the studied systems including closures and straws.
- production, converting, recycling and final disposal of primary packaging elements and related transports
- production, 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 fillers
- filling processes, which are fully assigned to the packaging system
- transport from fillers to potential central warehouses and final distribution to the point of sale
- environmental effects of cooling during transport where relevant (chilled dairy and juice products).

Not included are:

- the production and disposal of the infrastructure (machines, transport media, roads, etc.) and their maintenance (spare parts, heating of production halls) as no significant impact is expected. To determine if infrastructure can be excluded the authors apply two criteria by Reinout Heijungs [Heijungs et al. 1992] and Rolf Frischknecht [Frischknecht et al. 2007]: Capital goods should be included if the costs of maintenance and depreciation are a substantial part of the product and if environmental hot spots within the supply chain can be identified. Considering relevant information about the supply chain from producers and retailers both criteria are considered to remain unfulfilled. An inclusion of capital goods might also lead to data asymmetries as data on infrastructure is not available for many production data sets. For some of the plastic bottles rollcontainer are used during the transport from fillers to the point of sale (see section 3). Rollcontainer have a weight of 38kg, mainly consist of steel and are reused between 200 to 500 times (IVL 2009; ERM 2010). As applied in Tetra Pak's LCA covering the Nordic market [ifeu 2017] rollcontainers are treated as transport media and therefore as part of the infrastructure for the used vehicles. Due to the high reuse rate the containers are not a substantial part of the products life cycle and are not identified as environmental hot spot within the supply chain. However, the weight of the rollcontainer itself will be considered for retail.

- production of beverage and transport to fillers as no relevant differences between the systems under examination are to be expected
- distribution of beverage from the filler to the point-of-sale (distribution of packages is included).
- environmental effects from accidents like breakages during transportation.
- losses of beverage 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 between the regarded 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 losses in households is available, these losses though cannot be allocated to the different beverage packaging systems. Further no data is available for losses at the point of sale. Therefore, possible beverage loss differences are not quantifiable. In consequence, a sensitivity analysis regarding beverage 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 waste treatment aspects.
- 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) 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 carton (Figure 1), PET bottle (Figure 2), HDPE bottle (Figure 3), PP cup (Figure 4), glass bottle one way (Figure 5) and glass bottle refillable (Figure 6).



¹ for selected beverage cartons
² weight of rollcontainers is considered for retail, production of rollcontainers is excluded

Figure 1: System boundaries of beverage cartons

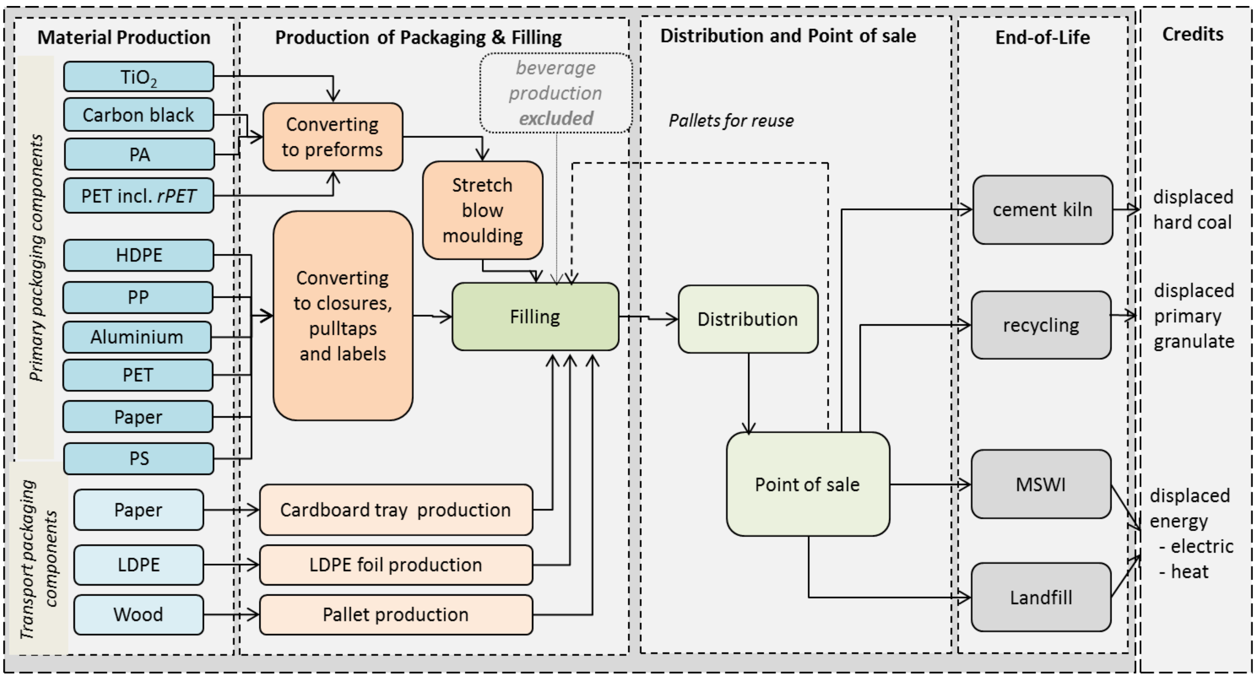
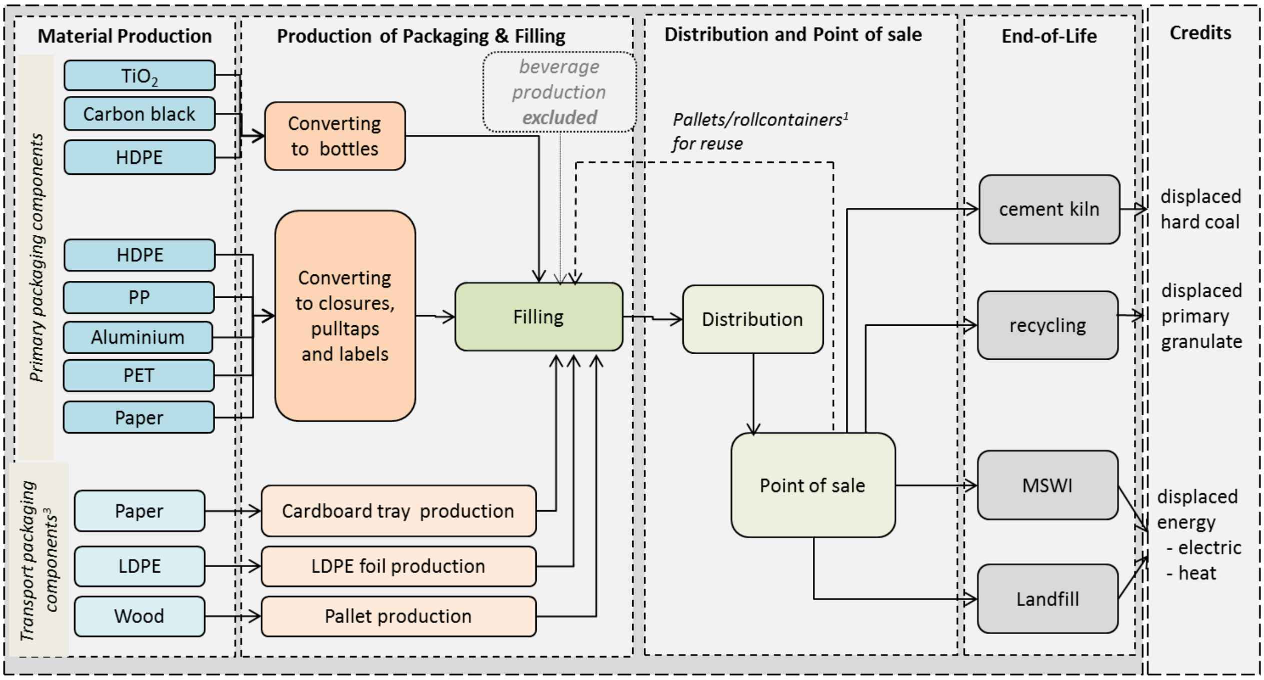


Figure 2: System boundaries of PET bottles



[1]weight of rollcontainers is considered for retail, production of rollcontainers is excluded

Figure 3: System boundaries of HDPE bottles

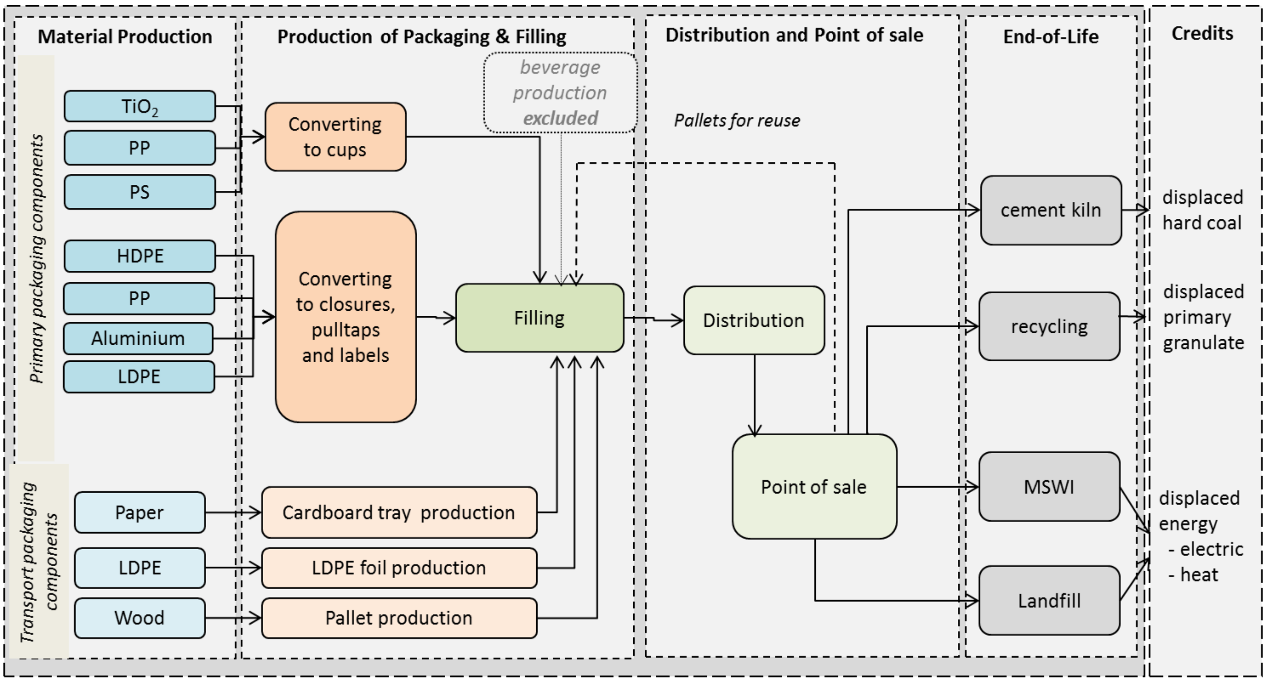


Figure 4: System boundaries of PP/PS cups

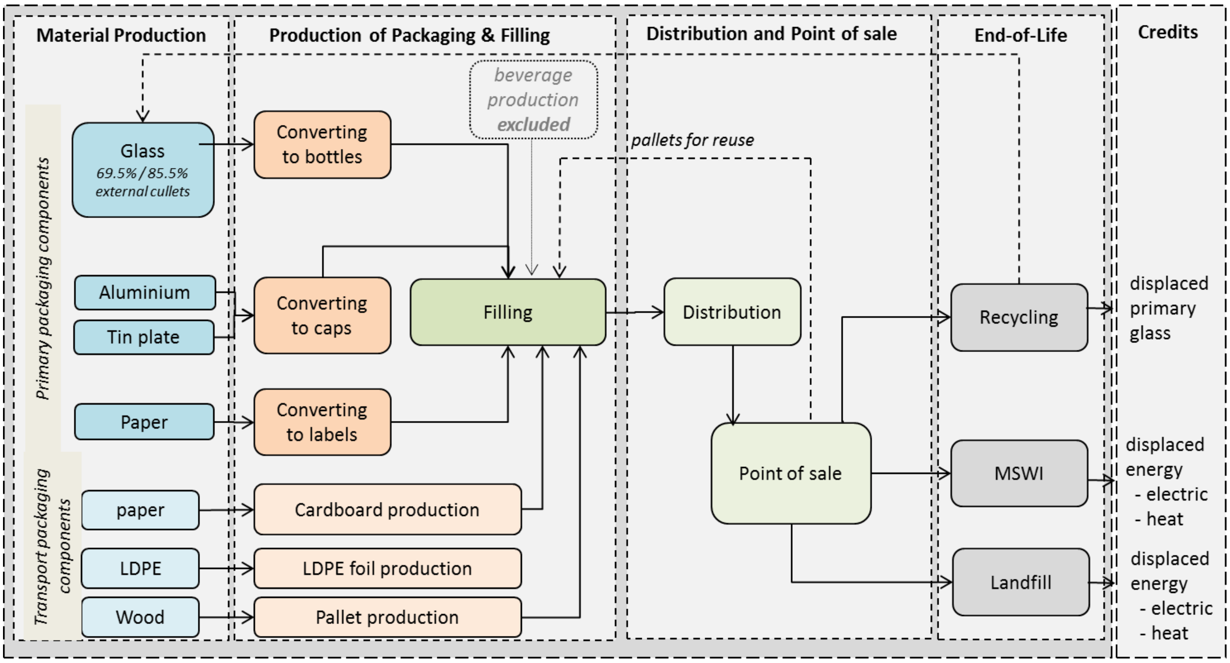


Figure 5: System boundaries of glass bottles one way

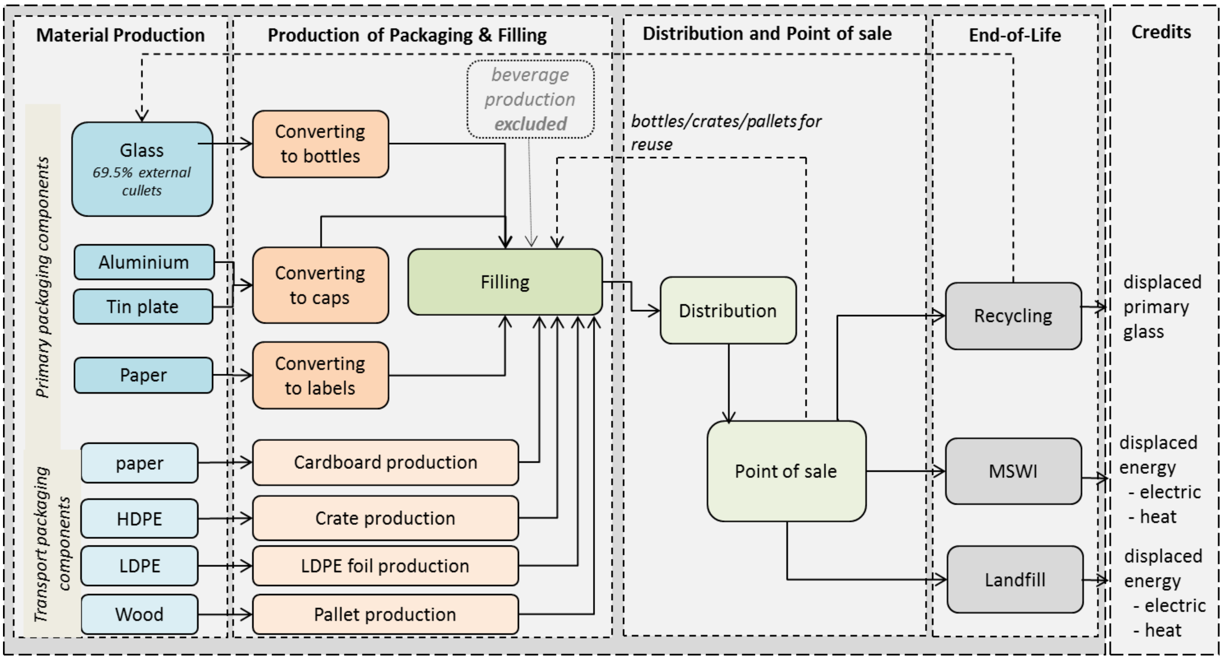


Figure 6: System boundaries glass bottle refillable

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 preceeding systems with an input material share of less than 1% of the total mass input of a considered process were excluded from the present study. However, total cut-off is not to surpass 5% of input materials as referred to the functional unit. In rare cases low input material shares may show environmental relevance, for example flows that include known toxic substances. In these cases no cut off of these low input materials is applied. Based on the mass-related cut-off the amount of printing ink used for the surface of beverage 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 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 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 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 Switzerland and Austria. 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 systems refer to 2017. Therefore, the reference time period for the comparison of packaging systems is 2017. 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 2002 and 2017 (see Table 39 in section 3). The datasets for transportation, energy generation and waste treatment processes (except recycling process for beverage 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 cartons	HDPE bottles	PET bottles	Glass bottle	PP/PS cups	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
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
Transportation of materials to the single production steps	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 39 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 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 is excluded. The allocation between package and filling goods is based on mass criterion. This allocation is applied as the functional unit of the study defines a fixed amount of beverage through all scenarios. Impacts related to transporting the beverage itself would be the same in all scenarios. There they don’t need to be included in this comparative study of beverage packaging systems.

System-related allocation

The approach chosen for system-related allocation is illustrated in Figure 8 and Figure 9. Both graphs 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 Figure 7 (upper graph) 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 of via MSWI. A virgin material in this case is to be understood as a material without recycled content. A different situation is shown in the lower graph of Figure 7. Here product A is recovered after use and supplied as a raw material to 'system B' avoiding thus the environmental loads related to the production ('MP-B') of the virgin materials, e.g. polymer and the disposal of product A ('MSWI-A'). Note: Avoided processes are indicated by dashed lines in the graphs.

Now, if the system boundaries of the LCA are such that only 'product system A' is examined it is necessary to decide how the possible environmental benefits and loads of the polymer material recovery and recycling shall be allocated (i.e. accounted) to 'system A'. In LCA practice, several allocation methods are found.

General notes regarding Figure 7 to Figure 9

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

- to illustrate the difference between the 50%:50% allocation method and the 100% allocation method
- to show which processes are allocated:
  - primary material production
  - recovery processes
  - waste treatment of final residues (here represented by MSWI)

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 (Figure 11 - Figure 16) as well as the actual substituted material including different substitution factors (section 3.14).

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 graphs, among them the following:

- Material losses occur in both 'systems A and B', but are not shown in the graphs. 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 graphs may imply. Consequently only the effectively recycled material's life cycle steps are allocated between 'systems A and B'.
- The graphs 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 graphs. 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'.
- The final waste treatment for the materials from both 'systems A and B' is represented in the graphs only as municipal solid waste incineration (MSWI). However, the LCA model implemented comprehends a final waste management 'mix' made up of both landfilling and MSWI processes.

Figure 7 illustrates the general allocation approach used for uncoupled systems and systems which are coupled through recycling. In order to do the allocation consistently, besides the virgin material production ('MP-A') already mentioned above and the disposal of product B ('MSWI-B'), also the recovery process 'Rec' has to be taken into consideration.

Furthermore, there is one important premise to be complied with by any allocation method chosen: the mass balance of all inputs and outputs of 'system A' and 'system B' after allocation must be the same as the inputs and outputs calculated for the sum of 'systems A and B' before allocation is performed.

Allocation with the 50% method (Figure 8)

In this method, benefits and loads of 'MP-A', 'Rec' and 'MSWI-B' are equally shared between 'system A and 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 (MSWI-B).

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 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).

The 50% allocation method was chosen as base scenario in the present study.

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 loads for producing the secondary raw material via ‘Rec-A’ are assigned to ‘system A’. In addition, also the loads that are generated by waste treatment of ‘product B’ in ‘MSWI-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’.

One should be aware that in such a case any LCA focusing on ‘system B’ would then have to assign the loads associated with the production process ‘MP-B’ to the ‘system B’ (otherwise the mass balance rule would be violated). However, ‘system B’ would not be charged with loads related to ‘Rec’ as the loads are already accounted for in ‘system A’. At the same time, ‘MSWI-B’ is not charged to ‘system B’ (again a requirement of the mass balance rule), as it is already assigned to ‘system A’.

The 100% allocation method was chosen as sensitivity analysis in the present study to verify the influence of the chosen allocation method in the base scenarios. This choice is considered as conservative approach from the view of the beverage carton.

It means that a comparatively unfavourable case for the beverage 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.

Application of allocation rules

The allocation factors have been applied on a mass basis (i.e. the environmental loads of the recycling process are charged with the total loads 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. This represents the substitution of amorphous PET instead of bottle grade PET.

The substitution factor of recycled fibres from beverage cartons has been set to 0.9. Further explanations on this issue can be found in section 3.14

- 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 or TiO_2: 0.9
- HDPE from closures: 0.9
- HDPE from bottles (substitutes PP): 0.9
- Glass from bottles: 1

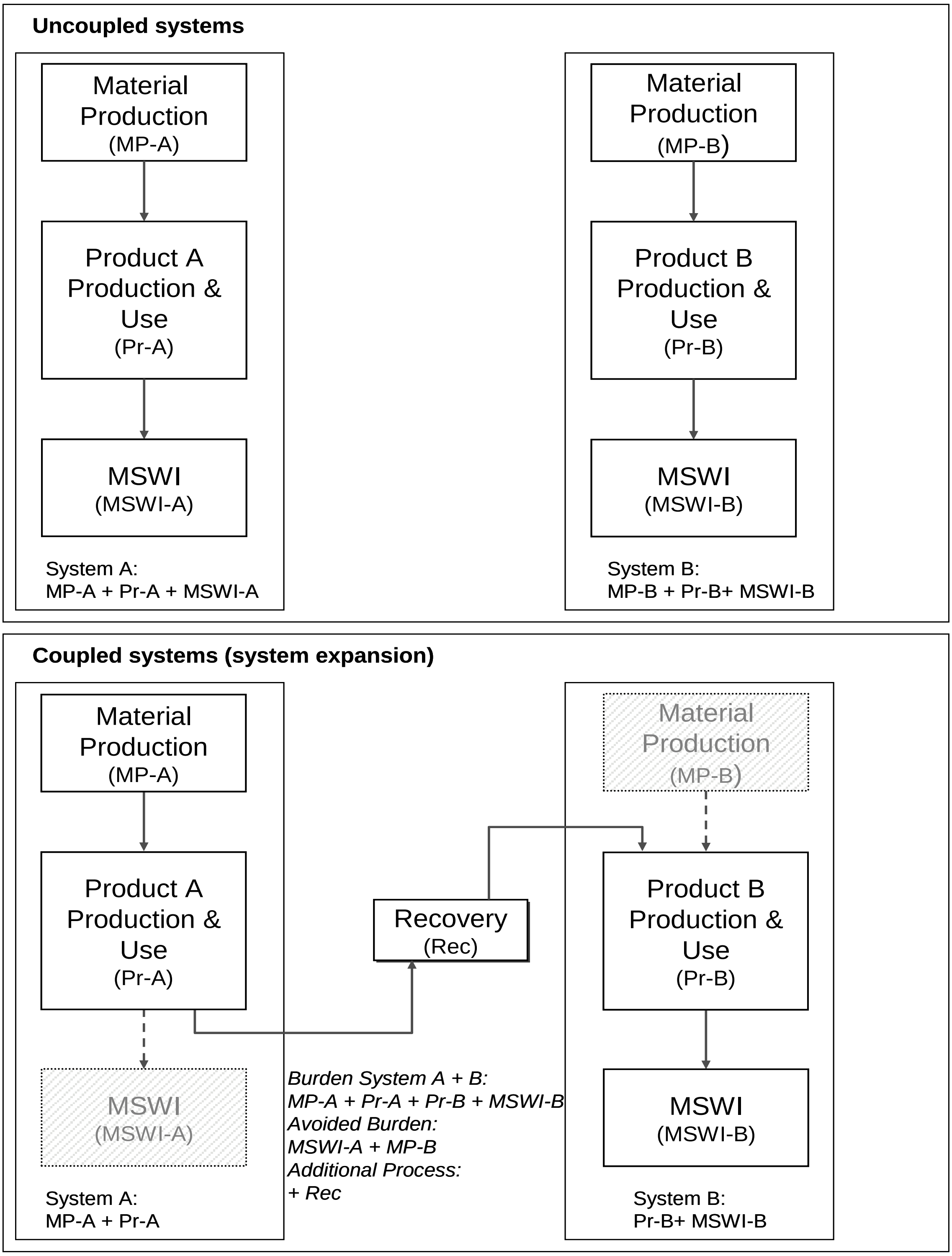


Figure 7: Additional system benefit/burden through recycling (schematic flow chart)

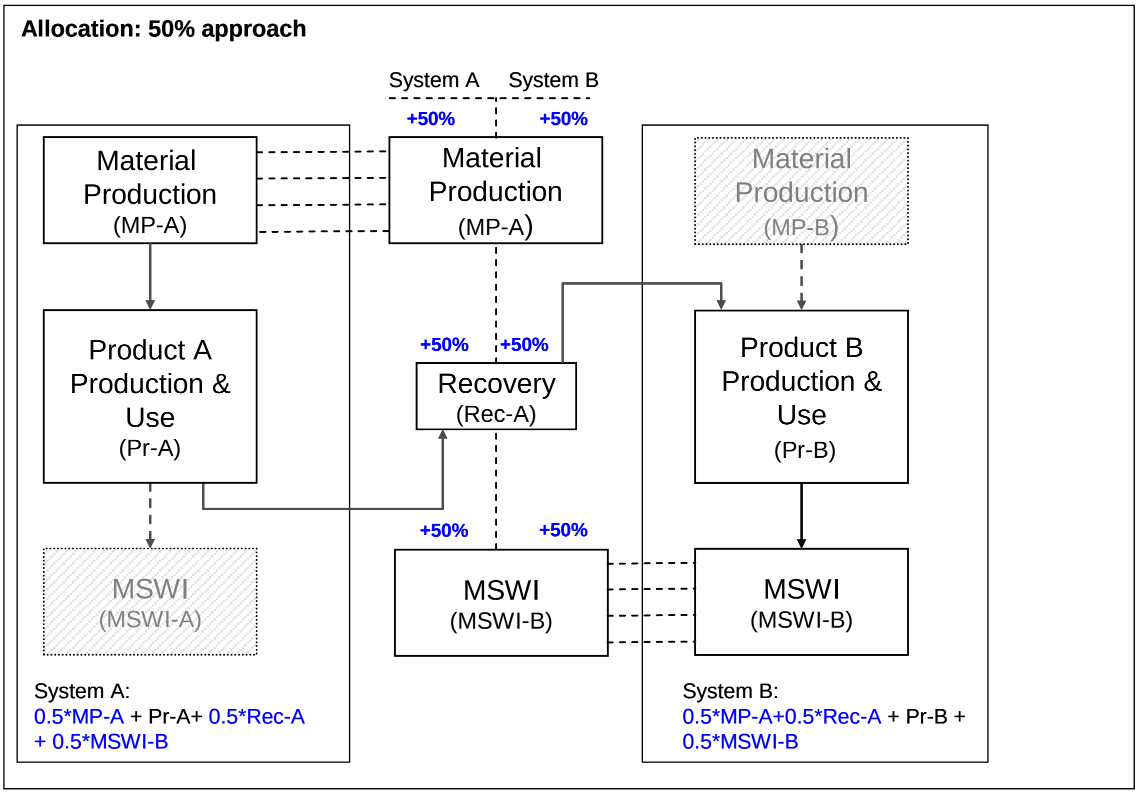


Figure 8: Principles of 50% allocation (schematic flow chart)

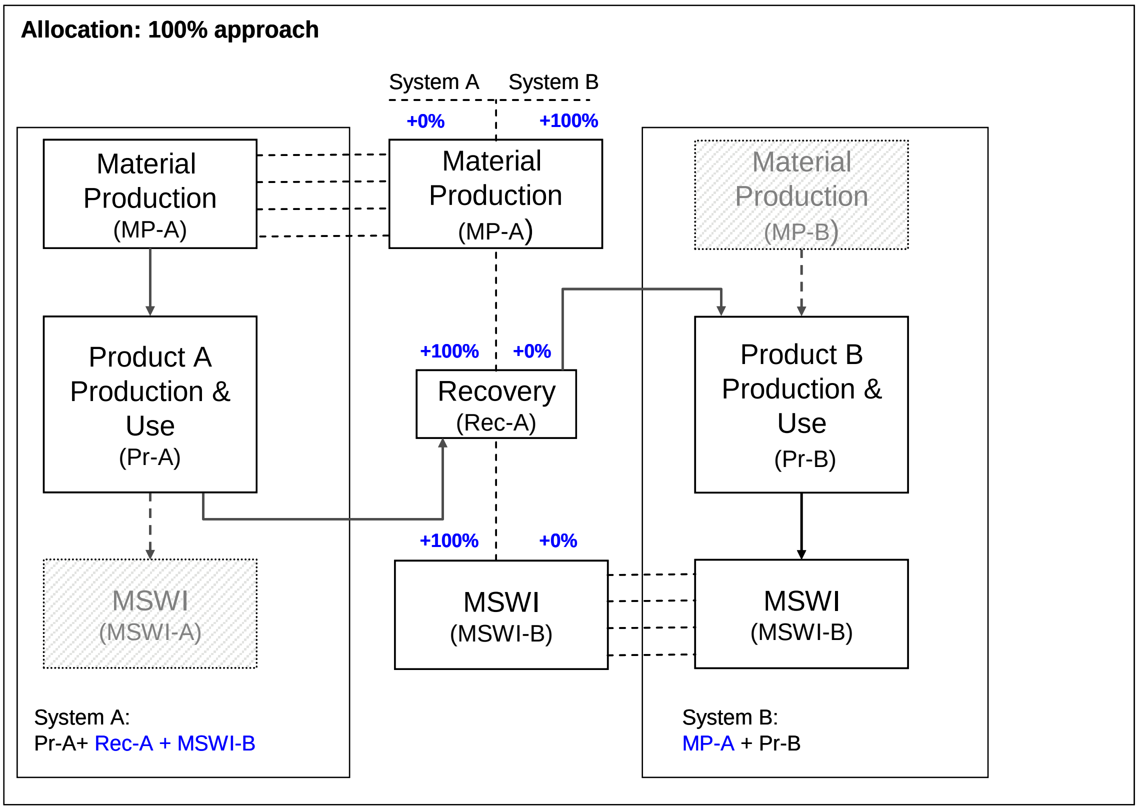


Figure 9: Principles of 100% allocation (schematic flow chart)

1.7.1 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.

The uptake of biogenic carbon is not affected by the system allocation. That means, if the 50% allocation method is applied, only 50% of the biogenic carbon emissions are attributed to the examined system, while the uptake is still attributed in full. This leads to a perceived imbalance of the carbon equation. This methodological approach has been developed for the minimum requirements for life cycle assessments of beverage packaging of the German Environment Agency [UBA 2016]. One of the reasons for this decision is the idea that the uptake should be attributed to the system causing it, instead of being considered as a property connected to a material. Another more practical reason is, when regarding bioplastics, especially so called drop-in bioplastics like Bio-PE, that it is only possible to differentiate between bio-based and fossil-based for primary materials, as these materials will be blended together in the recycling flow.

This approach bears the risk of over assessing the environmental performance of bio-based products due to the benefits from getting attributed 100% of the carbon uptake even in a scenario with an allocation factor of 50% for emissions and use of recycled content. For this reason it is especially important to consider the results of the 100% allocation approach alongside those of the base scenarios. All conclusions in this study will always be based on the outcomes of both assessments: the base scenarios and the sensitivity analyses.

To illustrate the effect of the above mentioned methodological choice for the base scenarios (with 50% allocation), an additional sensitivity scenario is presented in this study for the SD Family Pack segment in both markets. In this example the uptake as well as the emissions of biogenic CO_2 is not considered at all, as it was usually done in many LCA studies in the past.

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].

1.8.1 Mandatory elements

To assess the environmental performance of the examined packaging systems, a set of environmental impact categories is used. Related information as well as references of applied models is provided below. In the present study, midpoint categories are applied. 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.

The selection of the impact categories is based both on the current practice in LCA and the applicability of as less as uncertain characterisation models also with regard to the completeness and availability of the inventory data. The choice is also based on the German Federal Environmental Agency (UBA) approach 2016 [UBA 2016], which is fully consistent with the requirements of ISO 14040 and ISO 14044. However, it is nearly impossible to carry out an assessment in such a high level of detail, that all environmental issues are covered. A broad examination of as many environmental issues as possible is highly dependent on the quality of the available inventory datasets and of the scientific acceptance of the certain assessment methods.

The description of the different inventory categories and their indicators is based on the terminology by [ISO 14044]. It has to be noted that the impact categories, represent the environmental issues of concern, to which life cycle inventory analysis results per functional unit are assigned, but do not reflect actual environmental damages. The results of the impact categories are expressed by category indicators, which represent potential environmental impacts per functional unit. The category indicator results also do not quantify an actual environmental damage. Table 2 gives one example how the terms are applied in this study.

Table 2: Applied terms of ISO 14044 for the environmental impact assessment using the impact category stratospheric ozone depletion as example

Term	Example
Impact category	Stratospheric ozone depletion
LCI results	Amount of ozone depleting gases per functional unit
Characterisation model	Recent semi empirical steady-state model by the World Meteorological Organisation (WMO).
Category indicator	Ozone depletion potential (ODP)
Characterisation factor	Ozone depletion potential ODP_i [kg CFC-11eq. / kg emission i]
Category indicator result	Kilograms of CFC-11-equivalents per functional unit

Impact categories related to emissions

The selected impact categories related to emissions to be assessed in this study are listed and briefly addressed below. Table 3 includes an overview of elementary flows per category.

Table 3: Examples of elementary flows and their classification into impact categories

Impact categories	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
Stratospheric Ozone Depletion	CFC-11	N_2O	HBFC-123	HCFC-22	Halon-1211	Methyl Bromide	Methyl Chloride	Tetrachlor-methane	kg CFC-11-e
Photo-Oxidant Formation	CH_4	NMVOC	Benzene	Formal-dehyde	Ethyl acetate	VOC	TOC	Ethanol	kg O_3-e
Acidification	NOx	NH_3	SO_2	TRS***	HCl	H_2S	HF		kg SO_2-e
Terrestrial Eutrophication	NOx	NH_3							kg PO_4-e
Aquatic Eutrophication	COD	N	NH_4+	NO_3-	NO_2-	P			kg PO_4-e
Particulate Matter	PM2.5	SO_2	NOX	NH_3	NMVOC				kg PM2.5-e

* CO_2 fossil and biogenic / ** CH_4 fossil and CH_4 biogenic included / *** Total Reduced Sulphur

Climate change

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

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

Stratospheric Ozone Depletion

In the impact category the anthropogenic impact on the earth's atmosphere, which leads to the decomposition of naturally present ozone molecules, thus disturbing the molecular equilibrium in the stratosphere. The underlying chemical reactions are very slow processes and the actual impact, often referred to in a simplified way as the 'ozone hole', takes place only with considerable delay of several years after emission. The consequence of this disequilibrium is that an increased amount of UV-B radiation reaches the earth's surface, where it can cause damage to certain natural resources or human health. In this study, the ozone depletion potential (ODP) compiled by the World Meteorological Organisation (WMO) in 2011 [WMO 2011] is used as category indicator. In reference to the functional unit, the unit for Ozone Depletion Potential is kg CFC-11-e/fu.

Photo-Oxidant Formation

Photo-oxidant formation, also known as summer smog, is the photochemical creation of reactive substances (mainly ozone), which affect human health and ecosystems. This ground-level ozone is formed in the atmosphere by nitrogen oxides and volatile organic compounds in the presence of sunlight.

In this study, ‘Maximum Incremental Reactivity‘ (MIR) developed in the US by William P. L. Carter is applied as category indicator for the impact category photo-oxidant formation. MIRs expressed as kg O_3-equivalents are used in several reactivity-based VOC (Volatile Organic Compounds) regulations by the California Air Resources Board (CARB 1993, 2000). The recent approach of William P. L. Carter includes characterisation factors for individual VOC, unspecified VOC and NOx. The ‘Nitrogen-Maximum Incremental Reactivity‘ (NMIR) for NOx is introduced for the first time in 2008 (Carter 2008). The MIRs and NMIRs are calculated based on scenarios where ozone formation has maximum sensitivities either to VOC or NOx inputs. The recent factors applied in this study were published by [Carter 2010]. According to [Carter 2008], “MIR values may also be appropriate to quantify relative ozone impacts of VOCs for life cycle assessment analyses as well, particularly if the objective is to assess the maximum adverse impacts of the emissions of the compounds involved.” The results reflect the potential where VOC or NOx reductions are the most effective for reducing ozone.

The MIR+NMIR concept seems to be the most appropriate characterisation model for LCIA based on generic spatial independent global inventory data and combines following needs:

- Provision of characterisation factors for more than 1100 individual VOC, VOC mixtures, nitrogen oxides and nitrogen dioxides
- Consistent modelling of potential impacts for VOC and NOx
- Considering of the maximum formation potential by inclusion of most supporting background concentrations of the gas mixture and climatic conditions. This is in accordance with the precautionary principle.

Characterisation factors proposed by [CML 2002] and [ReCiPe 2008] are based on European conditions regarding background concentrations and climate conditions. The usage of this characterisation factors could lead to an underestimation of the photo-oxidant formation potential in regions with e.g. a high solar radiation.

The unit for Photo-Oxidant Formation Potential is kg O_3-e/fu.

Acidification

Acidification affects aquatic and terrestrial eco-systems by changing the acid-basic-equilibrium through the input of acidifying substances. The acidification potential expressed as SO_2-equivalents according to [Heijungs et al. 1992] is applied here as category indicator.

The characterisation model by [Heijungs et al. 1992] is chosen as the LCA framework addresses potential environmental impacts calculated based on generic spatial independent global inventory data. The method is based on the potential capacity of the pollutant to form hydrogen ions. The results of this indicator, therefore, represent the maximum acidification potential per substance without an undervaluation of potential impacts.

The method by [Heijungs et al. 1992] is, in contrast to methods using European dispersion models, applicable for emissions outside Europe. The authors of the method using accumulated exceedance note that “the current situation does not allow one to use these advanced characterisation methods, such as the AE method, outside of Europe due to a lack of suitable atmospheric dispersion models and/or measures of ecosystem sensitivity” ([Posch et al. 2008]).

The unit for the Acidification potential is kg SO_2-e/functional unit (fu).

Eutrophication and oxygen-depletion

Eutrophication means the excessive supply of nutrients and can apply to both surface waters and soils. As these two different media are affected in very different ways, a distinction is made between water-eutrophication and soil-eutrophication:

- ***Terrestrial Eutrophication*** (i.e., eutrophication of soils by atmospheric emissions)
- ***Aquatic Eutrophication*** (i.e., eutrophication of water bodies by effluent releases)

Compounds containing nitrogen and phosphorus are among the most eutrophicating elements. The eutrophication of surface waters also causes oxygen-depletion. A measure of the possible perturbation of the oxygen levels is given by the Chemical Oxygen Demand (COD). In order to quantify the magnitude of this undesired supply of nutrients and oxygen depletion substances, the eutrophication potential by [Heijungs et al. 1992, CML 2002] category was chosen as impact indicator.

The environmental impacts regarding eutrophication and oxygen depletion are therefore addressed by the following impact categories:

Terrestrial Eutrophication (including eutrophication of oligotrophic systems)

Category indicator: terrestrial eutrophication potential

Characterisation factors: EP_i [kg PO_4^{3-}-e/kg $emission_i$] based on [Heijungs et al. 1992]

Emissions to compartment: emissions to air

Aquatic Eutrophication

Category indicator: aquatic eutrophication potential

Characterisation factors: EP_i [kg PO_4^{3-}-e/kg $emission_i$] based on [Heijungs et al. 1992]

Emissions to compartment: emissions to water

Particulate matter

The category covers effects of fine particulates with an aerodynamic diameter of less than 2.5 µm (PM 2.5) emitted directly (primary particles) or formed from precursors as NO_x and SO_2 (secondary particles). Epidemiological studies have shown a correlation between the exposure to particulate matter and the mortality from respiratory diseases as well as a weakening of the immune system. Following an approach of [De Leeuw 2002], the category indicator aerosol formation potential (AFP) is applied. Within the characterisation model, secondary fine particulates are quantified and aggregated with primary fine particulates as PM2.5 equivalents. This approach addresses the potential impacts on human health and nature independent of the population density.

The characterisation models suggested by [ReCiPe 2008] and [JRC 2011] calculate intake fractions based on population densities. This means that emissions transported to rural areas are weighted lower than transported to urban areas. These approaches contradict the idea that all humans independent of their residence should be protected against potential impacts. Therefore, not the intake potential, but the formation potential is applied for the impact category particulate matter. In reference to the functional unit, the unit for Particulate Matter is kg PM 2.5-e/fu.

Note on human toxicity: The potential impacts of particulate matter on human health are part of the often addressed impact category "human toxicity". But, a generally accepted approach covering the whole range of toxicological concerns is not available. The inclusion of particulate matter in USEtox is desired but not existent. In general, LCA results on toxicity are often unreliable, mainly due to incomplete inventories, and also due to incomplete impact assessment methods and uncertainties in the characterisation factors. None of the available methods is clearly better than the others, although there is a slight preference for the consensus model USEtox. Based on comparisons among the different methods, the USEtox authors employ following residual errors (RE) related to the square geometric standard deviation (GSD^2):

Characterisation factor	GSD^2
Human health, emission to rural air	77
Human health, emission to freshwater	215
Human health, emission to agricultural soil	2,189
Freshwater ecotoxicity, emission to rural air	176
Freshwater ecotoxicity, emission to freshwater	18
Freshwater ecotoxicity, emission to agricultural soil	103

Figure 10: Model uncertainty estimates for USEtox characterisation factors (reference: [Rosenbaum et al. 2008])

To capture the 95 % confidence interval, the mean value of each substance would have to be divided and multiplied by the GSD^2. To draw comparative conclusions based on the existing characterisation models for toxicity categories is therefore not possible.

Impact categories related to the use/consumption of resources

Use of nature

The UNEP/SETAC Life Cycle Initiative Programme on Life Cycle Impact Assessment developed recommendations for the design of characterisation models for the impact category land use. Both biodiversity and ecosystem services are taken into account [Koellner et al. 2013]. However, neither low species diversity nor low productivity alone may be interpreted as a certain sign of poor ecosystem quality or performance. Biodiversity should always be defined in context with the biome, i.e. the natural potential for development, and the stage of succession. In consequence, an indicator for species quantification alone may not lead to correct interpretation. The choice and definition of indicators should be adapted to the conservation asset with a clear focus on the natural optimal output potential. The quantification of ecosystem services also requires a reduction of complexity, e.g. soil productivity may be quantified with the simplifying indicator soil carbon content ([Mila i Canals et al. 2007], [Brandao & Mila i Canals 2013]), which is directly correlated with the impact category indicator. Such reductions of complexity are always based on the assumption that no critical information is lost in the process of simplification.

Recently, [Fehrenbach et al. 2015] have developed the so called hemeroby concept in order to provide an applicable and meaningful impact category indicator for the integration of land use and biodiversity into the Life Cycle (Impact) Assessment. The central idea to the hemeroby concept follows the logic that intact ecosystems are not prone to higher levels of disturbance and negative impacts.

Within the hemeroby concept, the areas of concern are classified into seven hemeroby classes. The hemeroby approach is appropriate to be applied on any type of land-use type accountable in LCA. Particularly production systems for biomass (wood from forests, all kinds of biomass from agriculture) are assessed in a differentiated way:

To describe forest systems three criteria are defined: (1) natural character of the soil, (2) natural character of the forest vegetation, (3) natural character of the development conditions. The degree of performance is figured out by applying by 7 metrics for each criterion.

Agricultural systems are assessed by four criteria: (1) diversity of weeds, (2) Diversity of structures, (3) Soil conservation, (4) Material input. Three metrics are used for each criterion to calculate the grade of hemeroby.

The concept has been applied to almost any form of land use in central and northern Europe as well asfor individual agricultural productions in North- and South America (Kauertz et al. (2011), [Fehrenbach et al. 2016]). However data quality for its application in this study is considered to be not sufficient enough to deliver robust results. Due to the data uncertainties connected to forestry data and sugar cane cultivation, the results of this category in this study cannot be used without hesitation. Results for the base scenarios will be included in this report for transparency, but they will not be further interpreted for comparisons between systems and not considered for the final conclusions. The authors acknowledge though, that even without being able to assess the use of nature, on the inventory level the amount of land used is higher for wood based products like the beverage cartons compared to fossil based plastic packaging.

The used inventory data for paper production have been determined by Tiedemann 2000. Inventory data for the bio-PE dataset compiled by ifeu are based on [Fehrenbachet.al 2016], where sugar cane is classified in equal shares to class 5 and 6. As a conservative assumption, the land use for sugar cane cultivation is classified to class 6 in the bio-PE dataset from Braskem used in this study.

To address land use by a methodology without loosing crucial information, the impact category use of nature is addressed in this study by the category indicator 'Distance-to-Nature-Potential' (DNP) (m^2-e* 1a) based on the hemeroby concept by [Fehrenbach et al. 2015]. The DNP is a midpoint metric, focussing on the occupation impact. In reference to the functional unit (fu), the unit for use of nature is m^2-e*1a/fu.

Table 4: Examples of elementary flows and their classification into impact categories

Impact category	Elementary flows						Unit
Use of Nature	class 2	class 3	class 4	class 5	class 6	class 7	m^2-e*a

Raw materials

The published approaches addressing the impact on primary natural resources are currently limited to abiotic raw materials and energy. Currently there is no model applicable which addresses impacts for all types of primary natural resources (minerals and metals, biotic resources, energy carriers) [JRC 2016].

Even the complex models which refer to statistics on stock reserves do not cover all resources especially biotic ones. Furthermore, potential impacts on the environment are not addressed by the available LCIA models as required by ISO 14044.

The method proposed by Giegrich et al. (2012) aims to address potential impacts on the environment by introducing the safeguard subject *loss of material goods*. The approach covers the extraction of minerals, metals, fossil fuels and biotic materials. The category indicator is the loss potential of material resources. The required inventory to address this loss potential is the 'Cumulative raw material demand' (CRD). The CRD depicts the total of all material resources introduced into a system expressed in units of weight and takes the ore into account rather than just the refined metal. The unit for Cumulative raw material demand is kg. The proposed method by Giegrich et al. (2012) and recommended by UBA (2016) is still under development. Characterisation factors are not yet available for all materials to be considered.

Due to the lack of a comprehensive and applicable approach, the potential environmental impact on natural resources cannot be assessed on LCIA level. The CRD could be included on the inventory level only. A simple list of resources without an assessment will not add much value to this study, though. In fact, in the view of the authors, such inventory level results might even be misleading to readers. Inventory level information is not part of an environmental assessment and would not be used for the drawing of conclusions anyway.

Therefore, the Cumulative Energy Demand (CED) is included in the inventory categories as indication for the loss potential of energy resources (see below). It is included due to the fact, that the energy demand of the production of its materials and processes is one of Tetra Pak's priority areas of concern. Of course it also will not be considered for the drawing of conclusions within this study. The consequence of this methodological decision is, that there is an imbalance regarding the information on raw materials. While materials with an energy content like oil for plastics or wood for paperboard are inventoried in the CED, raw materials without energy content like silica and sodium carbonate for glass bottles are not considered. This has no influence on the final outcome of this study, though, as the CED, as an inventory level indicator is not considered for the drawing of conclusions within this study.

Additional categories at the inventory level

Inventory level categories differ from impact categories to the extent that no characterisation step using characterisation factors is used for assessment.

Water scarcity

Due to the growing water demand, increased water scarcity in many areas and degradation of water quality, water as a scarce natural resource has become increasingly central to the global debate on sustainable development. This drives the need for a better understanding of water related impacts as a basis for improved water management at local, regional, national and global levels (ISO 14046). To ensure consistency in assessing the so called water footprint ISO 14046 was published in 2014. It provides guidance in principles and requirements to assess water related impacts based on life cycle assessment (according to ISO 14044).

In general, the available methods to assess the impact of water consumption can be divided into volumetric and impact-oriented water footprints [Berger/Finkbeiner 2010]. The volumetric methods determine the freshwater consumption of products on an inventory level. The impact-based water footprints addressing the consequences resulting from water consumption and require a characterization of individual flows prior to aggregation [Berger/Finkbeiner 2010]. The safeguard subjects of most of the impact-oriented water footprint methods focussing on regional water scarcity.

According to ISO 14046, the consideration of spatial water scarcity is mandatory to assess the related environmental impacts of the water consumption. Water consumption occurs due to evaporation, transpiration, integration into a product, or release into a different drainage basin or the sea (ISO 14046). Thus information on the specific geographic location and quantity of water withdrawal and release is requisite.

In order to provide an ISO compliant method, the working group "Water Use in LCA (WULCA[1])" of the UNEP –SETAC Life Cycle Initiative was working on the development of a consensus-based water scarcity midpoint method for the use in LCA over the last three years. The working group recommended the method AWaRe [Boulay et al. 2017]: It is based on the quantification of the relative available water remaining per area once the demand of humans and aquatic ecosystems has been met. According to the authors this method represents the state of the art of the current knowledge on how to assess potential impacts from water use in LCA. However, most of the inventories applied in this study still do not include the water released from the technosphere. Therefore, the required amount of water consumed cannot be determined. For the inventory assessment of freshwater, a consistent differentiation and consistent water balance in the inventory data is requisite as basis for a subsequent impact assessment.

Due to the lack of mandatory information to assess the potential environmental impact, water scarcity cannot be assessed on LCIA level within this study. However, the use of water will be included in the inventory categories. A differentiation between process water, cooling water and water, unspecified is made. However, it includes neither any reference to the origin of this water, nor to its quality at the time of output/release. The respective results in this category are therefore of mere indicative nature and are not suited for conclusive quantitative statements related to either of the analysed packaging systems. The unit is m^3.

Primary Energy (Cumulative Energy Demand)

The *total Primary Energy Demand (CED total)* and the *non-renewable Primary Energy Demand (CED non-renewable)* serve primarily as a source of information regarding the energy intensity of a system.

Total Primary Energy (Cumulative Energy Demand, total)

The Total Cumulative Energy Demand is a parameter to quantify the primary energy consumption of a system. It is calculated by adding the energy content of all used fossil fuels, nuclear and renewable energy (including biomass). This category is described in [VDI 1997] and has not been changed considerably since then. It is a measure for the overall energy efficiency of a system, regardless the type of energy resource which is used. The calculation of the energy content of biomass, e.g. wood, is based on the lower heating value of the dry mass. The unit for Total Primary Energy is MJ.

Non-renewable Primary Energy (Cumulative Energy Demand, non-renewable)

The category non-renewable primary energy (CED non-renewable) considers the primary energy consumption based on non-renewable, i.e. fossil and nuclear energy sources. The unit for Non-renewable Primary Energy is MJ.

[1] http://wulca-waterlca.org

Table 5: Examples of elementary flows and their classification into inventory level categories

Categories at inventory level	Elementary Flows							Unit
Total Primary Energy	hard coal	brown coal	crude oil	natural gas	uranium ore	hydro energy	other renewable	MJ
Non-renewable Primary Energy	hard coal	brown coal	crude oil	natural gas	uranium ore			MJ
Freshwater Use	Process water	Cooling water	Water, unspecified					m^3

1.8.2 Optional elements

[ISO 14044] (§4.4.3) provides three optional elements for impact assessment which can be used depending on the goal and scope of the LCA:

1. Normalisation: calculating the magnitude of category results relative to reference information
2. Grouping: sorting and possibly ranking of the impact categories
3. Weighting: converting and possibly aggregating category results across impact categories using numerical factors based on value-choices (not allowed for comparative assertion disclosed to public)

In the present study none of the optional elements are applied.

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. Main function of the examined primary packaging is the packaging and protection of beverages. 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 settings (2.3). Section 2.4 provides information on all regarded scenarios, including those chosen for sensitivity analyses.

2.1 Selection of packaging systems

The focus of this study lies on the beverage cartons produced by Tetra Pak for which this study aims to provide knowledge of its strengths and weaknesses regarding environmental aspects. The beverage cartons are compared with corresponding competing packaging systems.

The selection of packaging systems can be done in two ways; by **typical packaging systems** or **average packaging systems**. Typical packaging systems are selected by taking into account the frequency distribution of the different brands in each segment. The most frequent Tetra Pak or competing packaging system are selected. Sometimes also several packaging systems are selected. All packaging systems are existing packaging systems. These packaging systems do not necessarily match the market average. In order to represent the market average an average packaging system has to be generated. In this case the average weight of different packaging systems of one type in each segment would be determined. Average packaging systems are typically used for life cycle assessments which cover the full market. For this study **typical packaging systems** are selected. Therefore the results cannot be used as a market wide comparison between beverage cartons and competing packaging systems. The results are to be used for direct comparison between specific beverage cartons and specific competing packaging systems.

The choice of beverage cartons has been made by Tetra Pak based on domestic relevance and new packaging types that should be compared with existing competitive packaging before market introduction. Cartons of different volumes for the packaging of dairy, cream, JN (Juice and Nectars), SD (Still Drinks) and still, unflavoured water have been chosen for examination. For each of these beverage categories typical competing packaging systems have been selected. The selection of these competing packaging systems was based on a market research commissioned by Tetra Pak to identify the packages with the highest market share on the Austrian and Swiss market in each category. The market research is based on the Nielsen market analysis for the two countries and internal sales data of Tetra Pak. The focus was on the direct comparison of alternative packaging materials to the dominant carton packaging from Tetra Pak. Beverage carton systems by Tetra Pak have been identified by Tetra Pak sales figures in each segment. Beverage carton systems from manufactures other than Tetra Pak have not been considered.

As a first step packaging types other than beverage cartons which have the highest market share in the two countries were identified. Reference year for all market analyses is 2017.

Of all JN and SD not packaged in beverage cartons the majority is packaged in PET bottles. In Austria second most important competitive packaging type are single use and refillable glass bottles. Other packaging alternatives as laminated pouches or cans do not play a significant role on the Austrian and Swiss JNSD market.

In the category DAIRY, the two markets differ from each other. In Austria PET bottles play a significant role apart from beverage cartons. The second most relevant competing package selected were glass bottles and plastic cups. In Switzerland HDPE bottles are the most relevant competitive package followed by plastic caps.

In the category CREAM, only the Austrian market is taken into account. The relevant competing packaging systems which are included are a one-way glass bottle, a PET bottle and a PS cup.

In the category still, unflavoured WATER only the size 500ml were looked at. Here in both countries the PET bottle is the most relevant competing packaging system.

Other competing packaging types as pouches or cans are not included in the study. Pouches are niche product with no Tetra Pak beverage carton as relevant competition. Cans are mostly used for carbonated drinks, which are not part of this study. Lightweight packaging solutions as produced by ECOLEAN AB are not included in the study as they have only a focus in regional markets like Basel.

For all categories in a second step individual packaging systems within the selected competing packaging types were identified. Again the ones with the highest relative market share were chosen.

In case of PET bottles for JN, SD and WATER a wide range of bottle designs exist on the markets. In order to classify the PET bottles chosen for this study in their markets the primary packaging weight of the PET bottles in the study is shown in Table 6 are compared to a second bottle with high market shares respectively. Effects of potentially lower PET bottle weights are calculated in the sensitivity analyses described in section 2.4.8.

Table 6: PET bottle (JN, SD and WATER) weights in study compared to other bottles on the market

PET bottle in study	segment	volume [mL]	market	primary packaging [g]	primary packaging other PET bottle [g]	difference other PET bottle to bottle in study
PET bottle 1	SD	1500	CH	36.49	41.94	15%
PET bottle 2	JN	1000	CH	38.14	37.59	-1%
PET bottle 3	SD	500	CH	24.84	29.18	17%
PET bottle 7	JN	1000	AT	33.84	37.16	10%
PET bottle 8	SD	1500	AT	39.87	33.34	-16%
PET bottle 9	SD	500	AT	23.31	22.26	-5%
PET bottle 10	SD	330	AT	17.81	n/a	n/a
PET bottle 11	WATER	500	CH	16.24	18.04	11%
PET bottle 12	WATER	500	AT	18.20	18.02	-1%
PET bottle 13	SD	1000	CH	41.07	32.19	-22%

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

- Only packaging systems in the same segment are compared to each other
- Chilled and ambient beverage packaging systems are not compared to each other.
- In one segment packaging systems with different volumes can be compared to each other

Table 7: List of beverage cartons in segment **DAIRY Family Pack** 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) Slim Perforation 1500 ml	A	CH	HDPE bottle 3 1500 ml	A	CH
Tetra Brik Aseptic (TBA) Edge Wingcap 30 1500 ml	A	CH	HDPE bottle 3 1500 ml	A	CH
Tetra Brik Aseptic (TBA) Edge Wingcap 30 1000 ml	A	CH, AT	HDPE bottle 2 1000 ml	A	CH
			-	-	AT
Tetra Brik Aseptic (TBA) Edge Wingcap 30 Biobased 1000 ml	A	CH, AT	HDPE bottle 2 1000 ml	A	CH
			-	-	AT
Tetra Brik Aseptic (TBA) Mid LightCap 24 1000 ml	A	CH	HDPE bottle 2 1000 ml	A	CH
Tetra Brik Aseptic (TBA) Edge LightCap 30 1000 ml	A	AT	-	-	AT
Tetra Rex (TR) OSO 34 1000 ml	C	CH, AT	HDPE bottle 1 1000 ml	C	CH
			PET bottle 4 1000 ml	C	AT
			Glass bottle (OW) 2 1000 ml	C	AT
			Glass bottle (RF) 2 1000 ml	C	AT
Tetra Rex (TR) OSO 34 Biobased 1000 ml	C	CH, AT	HDPE bottle 1 1000 ml	C	CH
			PET bottle 4 1000 ml	C	AT
			Glass bottle (OW) 2 1000 ml	C	AT
			Glass bottle (RF) 2 1000 ml	C	AT
Tetra Top (TT) C38 1000 ml	C	CH, AT	HDPE bottle 1 1000 ml	C	CH
			PET bottle 4 1000 ml	C	AT
			Glass bottle (OW) 2 1000 ml	C	AT

			Glass bottle (RF)2 1000 ml	C	AT
Tetra Top (TT) C38 Biobased 1000 ml	C	AT	PET bottle 4 1000 ml	C	AT
			Glass bottle (OW) 2 1000 ml	C	AT
			Glass bottle (RF) 2 1000 ml	C	AT

Table 8: List of beverage cartons in segment **JN Family Pack** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Rex (TR) Base Mini Plus TwistCap OSO Barrier 34 1000 ml	A	AT	PET bottle 7 1000 ml	A	AT
Tetra Brik Aseptic (TBA) Edge Wingcap 30 1000 ml	A	CH, AT	PET bottle 2 1000 ml	A	CH
			PET bottle 7 1000 ml	A	AT
			Glass bottle (RF) 1 1000 ml	A	AT
			Glass bottle (OW) 3 1000 ml	A	AT
Tetra Brik Aseptic (TBA) Edge Wingcap 30 Biobased 1000 ml	A	CH, AT	PET bottle 2 1000 ml	A	CH
			PET bottle 7 1000 ml	A	AT
Tetra Brik Aseptic (TBA) Slim Helicap 23 1000 ml	A	CH, AT	PET bottle 2 1000 ml	A	CH
			PET bottle 7 1000 ml	A	AT
			Glass bottle (RF) 1 1000 ml	A	AT
Tetra Prisma Aseptic (TPA) Square Helicap 27 1000 ml	A	AT	PET bottle 7 1000 ml	A	AT
			Glass bottle (RF) 1 1000 ml	A	AT

Table 9: List of beverage cartons in segment **SD Family Pack** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Rex (TR) Mid Twistcap Barrier 36 2000 ml	A	AT	PET bottle 8 1500 ml	A	AT
Tetra Brik Aseptic (TBA) Edge Wingcap 30 1500 ml	A	CH, AT	PET bottle 1 1500 ml	A	CH
			PET bottle 8 1500 ml	A	AT
Tetra Brik Aseptic (TBA) Edge Wingcap 30 1000 ml	A	CH	PET bottle 13 1000 ml	A	CH
Tetra Brik Aseptic (TBA) Edge Wingcap 30 Biobased 1000 ml	A	CH	PET bottle 13 1000 ml	A	CH
Tetra Brik Aseptic (TBA) Slim Helicap 23 1000 ml	A	CH	PET bottle 13 1000 ml	A	CH

Table 10: List of beverage cartons in segment **DAIRY Portion Pack** 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 Top (TT) Midi C38 500 ml	C	CH, AT	HDPE bottle 4 500 ml	C	CH
			PET bottle 5 500 ml	C	AT
Tetra Prisma Aseptic (TPA) Square DreamCap26 330 ml	A	CH	HDPE bottle 5 330 ml	A	CH
Tetra Top (TT) Midi C38 250 ml	C	CH, AT	PP cup 1 250 ml	C	CH
			PP cup 2 250 ml	C	AT

Table 11: List of beverage cartons in segment **CREAM Portion Pack** 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 Lightcap 30 500 ml	A	AT	Glass bottle (OW) 1 500 ml	A	AT
Tetra Top (TT) Midi Eifel O38 250 ml	C	AT	PS cup 1 250 ml	C	AT
			PET bottle 6 250 ml	C	AT

Table 12: List of beverage cartons in segment **SD Portion Pack** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Brik Aseptic (TBA) Edge WingCap 30 500 ml	A	CH	PET bottle 3 500 ml	A	CH
Tetra Prisma Aseptic (TPA) Edge DreamCap26 500 ml	A	AT	PET bottle 9 500 ml	A	AT
Tetra Prisma Aseptic (TPA) Edge DreamCap26 Biobased 500 ml	A	AT	PET bottle 9 500 ml	A	AT
Tetra Prisma Aseptic (TPA) Square DreamCap26 330 ml	A	AT	PET bottle 10 330 ml	A	AT

Table 13: List of beverage cartons in segment **Water Portion Pack** and corresponding competing packaging systems

Carton based packaging systems	chilled (C) / ambient (A)	Geographic scope	Competing packaging systems	chilled (C) / ambient (A)	Geographic scope
Tetra Prisma Aseptic (TPA) Edge DreamCap26 500 ml	A	CH, AT	PET bottle 11 500 ml	A	CH
			PET bottle 12 500 mL	A	AT
Tetra Prisma Aseptic (TPA) Edge DreamCap26 Biobased 500 ml	A	CH, AT	PET bottle 11 500 ml	A	CH
			PET bottle 12 500 mL	A	AT
Tetra Top (TT) Midi C38 500 ml	A	CH, AT	PET bottle 11 500 ml	A	CH
			PET bottle 12 500 mL	A	AT
Tetra Top (TT) Midi C38 Biobased 500 ml	A	CH, AT	PET bottle 11 500 ml	A	CH
			PET bottle 12 500 mL	A	AT

2.2 Packaging specifications

Specifications of beverage carton packaging systems to be listed are listed in Table 14 to Table 21 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 beverage carton system may vary over different production batches or production sites. To get the final specifications per beverage carton type the exact specifications of different batches were averaged taking into consideration the production volumes of each production batch.

Data on secondary and tertiary packaging for beverage cartons was also provided by Tetra Pak from its internal packaging system model. The data is periodically updated and the most recent data of 2017 is used in this LCA.

Specifications of the competing packaging systems are listed in Table 22 - Table 29. They were determined by ifeu in 2018. For each packaging system selected two sample bottles were bought by Tetra Pak at the point of sale and have been sent to ifeu. Specifications were determined by weighing the individual sample bottles. Even though slight variations in bottle weights are possible regarding different examples of a single packaging solution, these possible differences are considered to be low enough to derive the specifications from only a small amount of samples. Weight was determined for each material included in each system. Bottle and cap material of plastic bottles and cups were identified by its resin identification codes. The material of plastic labels was identified by floating experiments in water and vegetable oil. The barrier material included in the bottle bodies was identified as described in the following: All opaque bottles are assumed to contain a share of 1.6% TiO_2 as a colour medium [Robertson 2016]. Additionally all opaque bottles were cut open and checked for a black layer. If there was a black layer a 5% content of carbon black as barrier material was assumed. Ambient bottles in the segment JN are assumed to contain 8% of Polyamide (PA) as barrier material (average of communicated PA content of three bottle plastic producers[1]). Plastic bottles and cups containing carbon black were identified to be multi-layer, all other bottles and cups are identified as mono-layer.

Regarding the recycled content of PET bottles analysed in this study for both markets the specific rPET share is used. In case of PET bottle 8, PET bottle 9, PET bottle 10 and PET bottle 12 the participation in the pet2pet recycling group is communicated on the label of the bottles. For these bottles the average of 30% recycled content communicated by pet2pet is used [pet2pet 2019]. For bottles where no rPET share is known, no rPET is considered in the related model.

Data on secondary packaging for competing packaging systems was determined mainly from secondary packaging at hand. For some packaging systems the type and the package configuration was known. The weight of the packaging material was interpolated from similar secondary packaging.

Data on tertiary packaging was partially taken from previous studies conducted for Tetra Pak (i.e. weight of pallet).

Pallet configuration of beverage cartons as well as the information of shrink foil around the beverage carton pallets was provided by Tetra Pak.

The pallet configuration of competing packaging systems was calculated with the online tool *www.onpallet.com*. Europallets with a loading height of 1400mm were assumed for the calculation. The weight of shrink foil per pallets refers to the packaging height of 1400mm. Packaging dimension was taken from the earlier described calculation of secondary packaging. Pallet configuration depends on the size of the bottles as well as the amount and arrangement of bottles in each secondary packaging.

Data for refillable glass bottles, like trip rates of bottles and crates regarding the segment JN is based on expert judgment from the German market by Jürgen Heinisch and based on trip rates from Austrian water and lemonade bottles [Kauertz et al. 2011]. Regarding the segment Dairy data for trip rates is based on Berglandmilch [2019].

[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 carton systems

Table 14: Packaging specifications for regarded carton systems for the *packaging of dairy Family Packs (ambient)*

		DAIRY					
	Unit	TBA Slim Perforation	TBA Edge Wingcap 30	TBA Edge Wingcap 30	TBA Edge Wingcap 30 bb	TBA Mid LightCap 24	TBA Edge LightCap 30
Volume	ml	1500	1500	1000	1000	1000	1000
Geographic Scope	-	CH	CH	CH, AT	CH, AT	CH	AT
Chilled / ambient	-	ambient	ambient	ambient	ambient	ambient	ambient
primary packaging (sum)	**g**	**41.70**	**44.34**	**31.93**	**31.92**	**28.74**	**31.69**
composite material (sleeve)	**g**	**41.70**	**41.20**	**28.79**	**28.79**	**26.79**	**28.69**
- liquid packaging board	g	32.09	31.89	22.47	22.47	21.76	22.47
- polymer	g	7.80	7.51	4.90	2.20	3.66	4.81
- Biopolymer	g				2.70		
- Aluminium	g	1.81	1.81	1.42	1.42	1.37	1.42
Closure	**g**		**3.14**	**3.14**	**3.14**	**1.95**	**3.00**
- HDPE	g		1.30	1.30		1.05	1.40
- LDPE	g		1.80	1.80		0.90	1.60
- Bio-PE	g				3.10		
-Aluminium	g		0.04	0.04	0.04		
Top	**g**						
- PE	g						
- Bio-PE	g						
secondary packaging (sum)	**g**	**110.00**	**110.00**	**105.00**	**105.00**	**129.00**	**0**
tray/box/handle (corr.cardboard)	g	110.00	110.00	105.00	105.00	129.00	0
stretch foil (LDPE)	g						
tertiary packaging (sum)	**g**	**25170**	**25170**	**25170**	**25170**	**25170**	**38000**
pallet/rollcontainer	g	25000	25000	25000	25000	25000	38000
type of pallet	-	EURO	EURO	EURO	EURO	EURO	rollcontainer
number of use cycles	-	25	25	25	25	25	200
stretch foil (per pallet) (LDPE)	g	170	170	170	170	170	0
Pallet/rollcontainer configuration							
cartons per tray	pc	8	8	12	12	12	
trays / packs per layer	pc	16	16	13	13	12	36
layers per pallet/rollcontainer	pc	4	4	5	5	6	4
cartons per pallet/rollcontainer	pc	512	512	780	780	864	144

Table 15: Packaging specifications for regarded carton systems for the *packaging of dairy Family Packs (chilled)*

		DAIRY					
	Unit	TR OSO 34	TR OSO 34 bb	TT C38	TT C38	TT C38 bb	TT C38 bb
Volume	ml	1000	1000	1000	1000	1000	1000
Geographic Scope	-	CH, AT	CH, AT	CH, AT	AT	AT	AT
Chilled / ambient	-	chilled	chilled	chilled	chilled	chilled	chilled
primary packaging (sum)	g	30.39	31.00	31.15	31.15	31.15	31.15
composite material (sleeve)	g	27.79	28.40	23.12	23.12	23.12	23.12
- liquid packaging board	g	24.22	24.83	19.61	19.61	19.61	19.61
- polymer	g	3.57		3.51	3.51	1.43	1.43
- Biopolymer	g		3.57			2.08	2.08
- Aluminium	g						
Closure	g	2.60	2.60	2.90	2.90	2.90	2.90
- HDPE	g	1.40		2.90	2.90		
- LDPE	g	1.20					
- Bio-PE	g		2.60			2.90	2.90
-Aluminium	g						
Top	g			5.13	5.13	5.13	5.13
- PE	g			5.13	5.13	0.63	0.63
- Bio-PE	g					4.50	4.50
secondary packaging (sum)	g	165.00	165.00	0	121.52	0	121.52
tray/box/handle (corr.cardboard)	g	165.00	165.00	0	121.52	0	121.52
stretch foil (LDPE)	g						
tertiary packaging (sum)	g	25170	25170	38000	25170	38000	25170
pallet/rollcontainer	g	25000	25000	38000	25000	38000	25000
type of pallet	-	EURO	EURO	rollcontainer	EURO	rollcontainer	EURO
number of use cycles	-	25	25	200	25	200	25
stretch foil (per pallet) (LDPE)	g	170	170	0	170	0	170
Pallet/rollcontainer configuration							
cartons per tray	pc	10	10		10		10
trays / packs per layer	pc	15	15	40	15	40	15
layers per pallet/rollcontainer	pc	5	5	4	5	4	5
cartons per pallet/rollcontainer	pc	750	750	160	750	160	750

Table 16: Packaging specifications for regarded carton systems for the *packaging of JN Family Packs*:

		JN							
Packaging components	Unit	TR Base Mini Plus TwistCap OSO Barrier 34	TBA Edge Wingcap 30	TBA Edge Wingcap 30	TBA Edge Wingcap 30 bb	TBA Edge Wingcap 30 bb	TBA Slim Helicap 23	TBA Slim Helicap 23	TPA Square Helicap 27
Volume	ml	1000	1000	1000	1000	1000	1000	1000	1000
Geographic Scope	-	AT	AT	CH	AT	CH	CH	AT	AT
Chilled / ambient	-	ambient	ambient	ambient	ambient	ambient	ambient	ambient	ambient
primary packaging (sum)	g	**37.62**	**32.79**	**32.79**	**32.79**	**32.79**	**33.15**	**33.15**	**39.44**
composite material (sleeve)	g	**33.52**	**29.65**	**29.65**	**29.65**	**29.65**	**30.45**	**30.45**	**35.64**
- liquid packaging board	g	24.20	22.50	22.50	22.50	22.50	22.23	22.23	25.70
- polymer	g	7.84	5.73	5.73	3.03	3.03	6.82	6.82	8.01
- Biopolymer	g				2.70	2.70			
- Aluminium	g	1.48	1.42	1.42	1.42	1.42	1.40	1.40	1.93
Closure	g	**4.10**	**3.14**	**3.14**	**3.14**	**3.14**	**2.70**	**2.70**	**3.80**
- HDPE	g	2.00	1.30	1.30			1.31	1.31	3.20
- LDPE	g	2.10	1.80	1.80					
- Bio-PE	g				3.10	3.10			
- PP	g						1.39	1.39	0.60
- Aluminium	g		0.04	0.04	0.04	0.04			
secondary packaging (sum)	g	**133.28**	**101.92**	**10.00**	**101.92**	**10.00**		**156.80**	**167.00**
tray/box/handle (corr.cardboard)	g	133.28	101.92	0.70	101.92	0.70		**156.80**	**167.00**
stretch foil (LDPE)	g			9.30		9.30			
tertiary packaging (sum)	g	**25170**	**25170**	**25170**	**25170**	**25170**	**38000**	**25170**	**25170**
pallet/rollcontainer	g	25000	25000	25000	25000	25000	38000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO	EURO	roll-container	EURO	EURO
number of use cycles	-	25	25	25	25	25	200	25	25
stretch foil (per pallet) (LDPE)	g	170	170	170	170	170	0	170	170
Pallet/rollcontainer configuration									
cartons per tray	pc	8	8	4	8	4		12	12
trays / packs per layer	pc	17	23	35	23	35	40	12	13
layers per pallet/rollcontainer	pc	5	5	6	5	6	4	6	5
cartons per pallet/rollcontainer	pc	680	920	840	920	840	160	864	780

Table 17: Packaging specifications for regarded carton systems for the *packaging of SD Family Packs*:

		SD				
Packaging components	Unit	TR Mid Twistcap Barrier 36	TBA Edge Wingcap 30	TBA Edge Wingcap 30	TBA Edge Wingcap 30 bb	TBA Slim Helicap 23
Volume	ml	2000	1500	1000	1000	1000
Geographic Scope	-	AT	CH, AT	CH	CH	CH
Chilled / ambient	-	ambient	ambient	ambient	ambient	ambient
primary packaging (sum)	g	**65.70**	**44.74**	**32.79**	**32.79**	**33.15**
composite material (sleeve)	g	**61.60**	**41.60**	**29.65**	**29.65**	**30.45**
- liquid packaging board	g	46.68	32.09	22.50	22.50	22.23
- polymer	g	11.83	7.70	5.73	3.03	6.82
- Biopolymer	g				2.70	
- Aluminium	g	3.09	1.81	1.42	1.42	1.40
Closure	g	**4.10**	**3.14**	**3.14**	**3.14**	**2.70**
- HDPE	g	2.00	1.30	1.30		1.31
- LDPE	g	2.10	1.80	1.80		
- Bio-PE	g				3.10	
- PP	g					1.39
- Aluminium	g		0.04	0.04	0.04	
secondary packaging (sum)	g	**159.00**	**145.00**	**10.00**	**10.00**	
tray/box/handle (corr.cardboard)	g	159.00	145.00	0.70	0.70	
stretch foil (LDPE)	g			9.30	9.30	
tertiary packaging (sum)	g	**25170**	**25170**	**25170**	**25170**	**38000**
pallet/rollcontainer	g	25000	25000	25000	25000	38000
type of pallet	-	EURO	EURO	EURO	EURO	roll-container
number of use cycles	-	25	25	25	25	200
stretch foil (per pallet) (LDPE)	g	170	170	170	170	0
Pallet/rollcontainer configuration						
cartons per tray	pc	6	8	4	4	
trays / packs per layer	pc	16	16	35	35	40
layers per pallet/rollcontainer	pc	4	4	6	6	4
cartons per pallet/rollcontainer	pc	384	512	840	840	160

Table 18: Packaging specifications for regarded carton systems for the *packaging of DAIRY Portion Pack*:

		DAIRY				
Packaging components	Unit	TT Midi C38	TT Midi C38	TPA Square DreamCap26	TT Midi C38	TT Midi C38
Volume	ml	500	500	330	250	250
Geographic Scope	-	AT	CH	CH	AT	CH
Chilled / ambient	-	chilled	chilled	ambient	chilled	chilled
primary packaging (sum)	g	**20.84**	**20.84**	**16.64**	**15.98**	**15.98**
composite material (sleeve)	g	**13.89**	**13.89**	**12.92**	**9.03**	**9.03**
- liquid packaging board	g	11.56	11.56	8.79	7.51	7.51
- polymer	g	2.33	2.33	3.20	1.52	1.52
- Aluminium	g			0.93		
Closure	g	**2.90**	**2.90**	**3.72**	**2.90**	**2.90**
- HDPE	g	2.90	2.90	1.54	2.90	2.90
- LDPE	g					
- PP	g			2.18		
Top	g	**4.05**	**4.05**		**4.05**	**4.05**
- PE	g	4.05	4.05		4.05	4.05
secondary packaging (sum)	g	**86.24**	**70.56**	**58.00**	**58.80**	**50.96**
tray/box/handle (corr.cardboard)	g	86.24	70.56	58.00	58.80	50.96
tertiary packaging (sum)	g	**26920**	**26920**	**25170**	**26920**	**26920**
pallet/rollcontainer	g	25000	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO	EURO
number of use cycles	-	25	25	25	25	25
cardboard layer	g	218.75	218.75		218.75	218.75
number of cardboard layers		8	8		8	8
stretch foil (per pallet) (LDPE)	g	170	170	170	170	170
Pallet/rollcontainer configuration						
cartons per tray	pc	10	8	12	10	8
trays / packs per layer	pc	15	17	19	22	27
layers per pallet	pc	9	9	7	10	10
cartons per pallet	pc	1350	1224	1596	2200	2160

Table 19: Packaging specifications for regarded carton systems for the *packaging of CREAM Portion Pack*:

		CREAM	
Packaging components	Unit	TBA Edge Lightcap 30	TT Midi C38
Volume	ml	500	250
Geographic Scope	-	AT	AT
Chilled / ambient	-	ambient	chilled
primary packaging (sum)	g	**23.08**	**15.98**
composite material (sleeve)	g	**20.08**	**9.03**
- liquid packaging board	g	15.69	7.51
- polymer	g	3.40	1.52
- Biopolymer	g		
- Aluminium	g	0.99	
Closure	g	**3.00**	**2.90**
- HDPE	g	1.40	2.90
- LDPE	g	1.60	
- Bio-PE	g		
- PP	g		
Top	g		**4.05**
- PE	g		4.05
- Bio-PE	g		
secondary packaging (sum)	g	**66.64**	**58.80**
tray/box/handle (corr.cardboard)	g	66.64	58.80
stretch foil (LDPE)	g		
tertiary packaging (sum)	g	**25170**	**26920**
pallet/rollcontainer	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles	-	25	25
cardboard layer	g		218.75
number of cardboard layers			8
stretch foil (per pallet) (LDPE)	g	170	170
Pallet/rollcontainer configuration			
cartons per tray	pc	12	10
trays / packs per layer	pc	13	22
layers per pallet	pc	12	10
cartons per pallet	pc	1872	2200

Table 20: Packaging specifications for regarded carton systems for the *packaging of SD Portion Pack*:

		SD			
Packaging components	Unit	TBA Edge WingCap 30	TPA Edge DreamCap26	TPA Edge DreamCap26 Biobased	TPA Square DreamCap26
Volume	ml	500	500	500	330
Geographic Scope	-	CH	AT	AT	AT
Chilled / ambient	-	ambient	ambient	ambient	ambient
primary packaging (sum)	g	**23.24**	**23.03**	**23.03**	**16.64**
composite material (sleeve)	g	**20.10**	**19.31**	**19.31**	**12.92**
- liquid packaging board	g	15.69	13.20	13.20	8.79
- polymer	g	3.42	4.92	4.92	3.20
- Biopolymer	g				
- Aluminium	g	0.99	1.19	1.19	0.93
Closure	g	**3.14**	**3.72**	**3.72**	**3.72**
- HDPE	g	1.30	1.54		1.54
- LDPE	g	1.80			
- Bio-PE	g			1.54	
- PP	g		2.18	2.18	2.18
- Aluminium	g	0.04			
secondary packaging (sum)	g	**66.64**	**114.00**	**114.00**	**65.76**
tray/box/handle (corr.cardboard)	g	66.64	114.00	114.00	65.76
stretch foil (LDPE)	g				
tertiary packaging (sum)	g	**25170**	**25170**	**25170**	**25170**
pallet/rollcontainer	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/rollcontainer configuration					
cartons per tray	pc	12	12	12	12
trays / packs per layer	pc	13	18	18	19
layers per pallet	pc	12	6	6	7
cartons per pallet	pc	1872	1296	1296	1596

Table 21: Packaging specifications for regarded carton systems for the *packaging of Water Portion Pack*:

		Water					
Packaging components	Unit	TPA Edge DreamCap26	TPA Edge DreamCap26	TPA Edge DreamCap26 Biobased	TPA Edge DreamCap26 Biobased	TT Midi Eifel C38	TT Midi Eifel C38 Biobased
Volume	ml	500	500	500	500	500	500
Geographic Scope	-	CH	AT	CH	AT	CH, AT	CH, AT
Chilled / ambient	-	ambient	ambient	ambient	ambient	ambient	ambient
primary packaging (sum)	g	**22.10**	**22.10**	**22.10**	**22.10**	**21.75**	**21.76**
composite material (sleeve)	g	**18.38**	**18.38**	**18.38**	**18.38**	**14.96**	**14.96**
- liquid packaging board	g	13.24	13.24	13.24	13.24	11.56	11.56
- polymer	g	3.95	3.95	3.95	3.95	2.67	1.30
- Biopolymer	g						1.37
- Aluminium	g	1.19	1.19	1.19	1.19	0.73	0.73
Closure	g	**3.72**	**3.72**	**3.72**	**3.72**	**2.90**	**2.90**
- HDPE	g	1.54	1.54			2.90	
- LDPE	g						
- Bio-PE	g			1.54	1.54		2.90
- PP	g	2.18	2.18	2.18	2.18		
Top	g					**3.89**	**3.90**
- PE	g					3.89	0.47
- Bio-PE	g						3.43
secondary packaging (sum)	g	**129.36**	**202.78**	**129.36**	**202.78**	**110.54**	**110.54**
tray/box/handle (corr.cardboard)	g	129.36	202.78	129.36	202.78	110.54	110.54
stretch foil (LDPE)	g						
tertiary packaging (sum)	g	**25170**	**25170**	**25170**	**25170**	**25170**	**25170**
pallet/rollcontainer	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/rollcontainer configuration							
cartons per tray	pc	12	12	12	12	12	12
trays / packs per layer	pc	16	14	16	14	19	19
layers per pallet	pc	8	6	8	6	6	6
cartons per pallet	pc	1536	1008	1536	1008	1368	1368

2.2.2 Specifications of alternative packaging systems

Table 22: Packaging specifications for regarded alternative systems in the segment *DAIRY Family Pack (ambient)*

		DAIRY	
Packing components	Unit	HDPE bottle 3	HDPE bottle 2
Volume	ml	1500	1000
Geographic scope	-	CH	CH
Chilled / ambient	-	ambient	ambient
Clear / opaque	-	opaque	opaque
Layers	-	multi	multi
primary packaging (sum)	g	48.14	37.66
Bottle (sum)	g	43.84	32.73
- HDPE	g	40.95	30.57
- TiO2 (1.6%)	g	0.70	0.52
- Carbon black (5%)	g	2.19	1.64
Label	g	1.73	2.36
- paper	g		2.36
- PP	g	1.73	
closure	g	2.40	2.39
- HDPE	g	2.40	2.39
pull tap	g	0.17	0.18
- Aluminium	g	0.17	0.18
secondary packaging (sum)	g	17.05	17.72
- shrink pack (LDPE)	g	16.85	17.52
- paper handle	g	0.20	0.20
tertiary packaging (sum)	g	26570	26570
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles		25	25
cardboard layer	g	350	350
number of cardboard layers		4	4
stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
Bottles per pack	pc	6	6
packs per layer	pc	21	25
layers per pallet	pc	5	5
bottles per pallet	pc	630	750

Table 23: Packaging specifications for regarded alternative systems in the segment *DAIRY Family Pack (chilled)*

		DAIRY			
Packing components	Unit	HDPE bottle 1	PET bottle 4	Glass bottle (OW) 2	Glass bottle (RF) 2
Volume	ml	1000	1000	1000	1000
Geographic scope	-	CH	AT	AT	AT
Chilled / ambient	-	chilled	chilled	chilled	chilled
Clear / opaque; white/green glass	-	opaque	opaque	white glass	white glass
Layers	-	multi	mono	-	-
primary packaging (sum)	g	**38.82**	**27.63**	**430.99**[1]	**430.99**[1]
Bottle (sum)	g	**33.80**	**22.43**	**422.72**	**422.72**
- virgin PET	g		22.07		
- HDPE	g	31.57			
- TiO2 (1.6%)	g	0.54	0.36		
- Carbon black (5%)	g	1.69			
- Glass	g			422.72[2]	422.72[2]
- number of use cycles bottle					10
Label	g	**2.44**	**2.50**	**1.41**	**1.41**
- paper	g	2.44	0.09	0.74	0.74
- HDPE	g		2.41	0.67	0.67
closure	g	**2.41**	**2.70**	**6.86**	**6.86**
- HDPE	g	2.41	2.70		
- Tin plate	g			6.86	6.86
pull tap	g	**0.17**			
- Aluminium	g	0.17			
secondary packaging (sum)	g		**236.90**	**100.80**	**1100**
- tray (cardboard)	g		236.90	100.80	
- HDPE crate (reusable)	g				1100
tertiary packaging (sum)	g	**38700**	**26920**	**26570**	**25170**
roll container	g	38000			
pallet	g		25000	25000	25000
type of pallet	-		EURO	EURO	EURO
number of use cycles		200	25	25	25
cardboard layer	g		350	350	
number of cardboard layers			5	4	
stretch foil (per pallet) (LDPE)	g		170	170	170
pallet configuration					
Bottles per pack	pc	1	12	6	6
packs per layer	pc	35	8	21	21
layers per pallet/rollcontainer	pc	3	6	5	5
bottles per pallet/rollcontainer	pc	105	575	630	630

[1] Primary packaging of oneway and refillable bottle are the same. The one way bottle was introduced to the market in order to be changed into a refillable system in the near future [Berglandmilch 2019].
[2] external cullet rate: 69.5%

Table 24: Packaging specifications for regarded alternative systems in the segment *JN Family Pack*:

		JN			
Packing components	Unit	PET bottle 2	PET bottle 7	Glass bottle (RF) 1	Glass bottle (OW) 3
Volume	ml	1000	1000	1000	1000
Geographic scope	-	CH	AT	AT	AT
Chilled / ambient	-	ambient	ambient	ambient	ambient
Clear / opaque; white/green glass	-	clear	clear	white glass	green glass
Layers	-	mono	mono	-	-
primary packaging (sum)	**g**	**38.13**	**33.84**	**650.17**	**519.75**
Bottle (sum)	**g**	**33.42**	**29.28**	**647.00**	**516.77**
- virgin PET	g	30.75	26.94		
- recycled PET	g				
- PA (8%)	g	2.67	2.34		
- glass				647.00[1]	516.77[2]
- number of use cycles bottle				30	
Label	**g**	**1.05**	**0.82**	**1.69**	**1.47**
- paper	g	1.05		1.69	1.47
- PP	g		0.82		
- HDPE	g				
closure	**g**	**3.66**	**3.74**	**1.48**	**1.51**
- HDPE	g	3.66	3.74		
- Aluminium	g			1.48	1.51
secondary packaging (sum)	**g**	**15.25**	**17.91**	**1856**	**109.18**
- shrink pack (LDPE)	g	14.21	17.31		
- paper handle	g	1.04	0.60		
- tray (cardboard)	g				109.18
- crate (HDPE), 45 use cycles	g			1856	
tertiary packaging (sum)	**g**	**26570**	**26220**	**25170**	**26570**
roll container	g				
pallet	g	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO
number of use cycles		25	25	25	25
cardboard layer	g	350	350	350	350
number of cardboard layers		4	3	0	4
stretch foil (per pallet) (LDPE)	g	170	170	170	170
pallet configuration					
Bottles per pack	pc	6	6	12	6
packs per layer	pc	17	26	8	21
layers per pallet/rollcontainer	pc	5	4	4	5
bottles per pallet/rollcontainer	pc	510	624	384	630

[1] external cullet rate: 69.5%

[2] external cullet rate: 85.5%

Table 25: Packaging specifications for regarded alternative systems in the segment *SD Family Pack*:

		SD		
Packing components	Unit	PET bottle 1	PET bottle 8	PET bottle 13
Volume	ml	1500	1500	1000
Geographic scope	-	CH	AT	CH
Chilled / ambient	-	ambient	ambient	ambient
Clear / opaque	-	clear	clear	clear
Layers	-	mono	mono	mono
primary packaging (sum)	g	**36.50**	**39.87**	**41.08**
Bottle (sum)	g	**30.09**	**35.26**	**32.48**
- virgin PET	g	30.09	24.68	32.48
- recycled PET	g		10.58	
Label	g	**2.66**	**2.02**	**4.77**
- paper	g	2.66	2.02	
- PET	g			4.77
closure	g	**3.75**	**2.59**	**3.83**
- HDPE	g	3.75	2.59	3.83
secondary packaging (sum)	g	**14.90**	**25.86**	**14.52**
- shrink pack (LDPE)	g	14.18	25.05	13.70
- paper handle	g	0.72	0.81	0.82
tertiary packaging (sum)	g	**26220**	**26220**	**26220**
pallet	g	25000	25000	25000
type of pallet	-	EURO	EURO	EURO
number of use cycles		25	25	25
cardboard layer	g	350	350	350
number of cardboard layers		3	3	3
stretch foil (per pallet) (LDPE)	g	170	170	170
pallet configuration				
Bottles per pack	pc	6	6	6
packs per layer	pc	21	17	25
layers per pallet	pc	4	4	4
bottles per pallet	pc	504	408	600

Table 26: Packaging specifications for regarded alternative systems in the segment *DAIRY Portion Pack*:

		DAIRY				
Packing components	Unit	HDPE bottle 4	PET bottle 5	HDPE bottle 5	PP cup 2	PP cup 1
Volume	ml	500	500	330	250	230
Geographic scope	-	CH	AT	CH	AT	CH
Chilled / ambient	-	chilled	chilled	chilled	chilled	chilled
Clear / opaque	-	opaque	opaque	opaque	opaque	opaque
Layers	-	mono	mono	multi	mono	mono
primary packaging (sum)	g	**32.12**	**24.96**	**30.03**	**12.52**	**17.76**
Bottle (sum)	g	**26.52**	**20.05**	**24.64**	**7.43**	**12.43**
- virgin PET	g		19.73			
- HDPE	g	26.10		23.02		
- PP					7.31	12.23
- TiO2 (1.6%)	g	0.42	0.32	0.39	0.12	0.20
- Carbon black (5%)	g			1.23		
- glass	g					
Label	g	**2.67**	**2.21**	**1.55**	**1.39**	**1.34**
- paper	g		0.10			
- PET	g			1.55		1.34
- HDPE	g	2.67	2.11		1.39	
closure	g	**2.93**	**2.70**	**3.48**	**3.20**	**3.53**
- HDPE	g	2.93	2.70			
- PP	g			3.48	3.20	3.53
- Aluminium						
pull tap	g			**0.36**	**0.50**	**0.46**
- Aluminium	g			0.36	0.50	0.46
secondary packaging (sum)	g	**800.00**	**68.88**	**22.06**	**54.39**	**77.63**
- shrink pack (LDPE)	g			6.69		
- tray (cardboard)	g		68.88	15.37	54.39	77.63
- crate (HDPE), 45 use cycles	g	800.00				
tertiary packaging (sum)	g	**25170**	**26920**	**27620**	**28320**	**28320**
pallet	g	25000	25000	25000	25000	25000
type of pallet	-	EURO	EURO	EURO	EURO	EURO
number of use cycles		25	25	25	25	25
cardboard layer	g		350	350	350	350
number of cardboard layers			5	7	9	9
stretch foil (per pallet) (LDPE)	g	170	170	170	170	170
pallet configuration						
Bottles per pack	pc	6	8	6	10	10
packs per layer	pc	8	27	12	16	17
layers per pallet	pc	10	6	8	10	10
bottles per pallet	pc	480	1296	576	1600	1700

Table 27: Packaging specifications for regarded alternative systems in the segment *CREAM Portion Pack*:

		CREAM		
Packing components	Unit	Glass bottle (OW) 1	PET bottle 6	PS cup 1
Volume	ml	500	250	250
Geographic scope	-	AT	AT	AT
Chilled / ambient	-	ambient	chilled	chilled
Clear / opaque	-	clear	opaque	opaque
Layers	-	-	mono	mono
primary packaging (sum)	g	**232.69**	**19.32**	**7.24**
Bottle (sum)	g	**230.31**	**14.52**	**6.81**
- virgin PET	g		14.29	
- recycled PET	g			
- PS	g			6.70
- TiO2 (1.6%)	g		0.23	0.11
- glass	g	230.31[1]		
Label	g	**1.01**	**1.67**	
- paper	g	1.01		
- PET	g		1.67	
closure	g	**1.37**	**3.13**	**0.43**
- HDPE	g		3.13	
- PP	g			
- Aluminium	g	1.37		0.43
secondary packaging (sum)	g	**87.83**	**98.59**	**101.45**
- shrink pack (LDPE)	g			
- paper handle	g			
- tray (cardboard)	g	87.83	98.59	101.45
tertiary packaging (sum)	g	**27270**	**27620**	**29720**
pallet	g	25000	25000	25000
type of pallet	-	EURO	EURO	EURO
number of use cycles		25	25	25
cardboard layer	g	350	350	350
number of cardboard layers		6	7	13
stretch foil (per pallet) (LDPE)	g	170	170	170
pallet configuration				
Bottles per pack	pc	20	12	20
packs per layer	pc	8	20	8
layers per pallet	pc	7	8	14
bottles per pallet	pc	1120	1920	2240

[1] external cullet rate: 69.5%

Table 28: Packaging specifications for regarded alternative systems in the segment *SD Portion Pack*:

		SD		
Packing components	Unit	PET bottle 3	PET bottle 9	PET bottle 10
Volume	ml	500	500	330
Geographic scope	-	CH	AT	AT
Chilled / ambient	-	ambient	ambient	ambient
Clear / opaque	-	clear	clear	clear
Layers	-	mono	mono	mono
primary packaging (sum)	g	24.84	23.32	17.82
Bottle (sum)	g	18.16	19.56	13.61
- virgin PET	g	18.16	13.69	9.53
- recycled PET	g		5.87	4.08
Label	g	2.79	1.21	0.28
- paper	g		1.21	
- PP	g			0.28
- HDPE	g	2.79		
closure	g	3.89	2.55	3.93
- HDPE	g	3.89	2.55	1.53
- PP	g			2.40
secondary packaging (sum)	g	13.15	20.25	8.53
- shrink pack (LDPE)	g	13.15	19.53	8.35
- paper handle	g		0.72	0.18
- tray (cardboard)	g			
- crate (HDPE)	g			
- number of use cycles crate				
tertiary packaging (sum)	g	26920	26570	27620
roll container	g			
pallet	g	25000	25000	25000
type of pallet	-	EURO	EURO	EURO
number of use cycles		25	25	25
cardboard layer	g	350	350	350
number of cardboard layers		5	4	7
stretch foil (per pallet) (LDPE)	g	170	170	170
pallet configuration				
Bottles per pack	pc	12	12	6
packs per layer	pc	15	15	26
layers per pallet/rollcontainer	pc	6	5	8
bottles per pallet/rollcontainer	pc	1080	900	1248

Table 29: Packaging specifications for regarded alternative systems in the segment *Water Portion Pack*:

		Water	
Packing components	Unit	PET bottle 11	PET bottle 12
Volume	ml	500	500
Geographic scope	-	CH	AT
Chilled / ambient	-	ambient	ambient
Clear / opaque	-	clear	clear
Layers	-	mono	mono
primary packaging (sum)	g	16.24	18.20
Bottle (sum)	g	13.75	15.02
- virgin PET	g	13.75	10.51
- recycled PET	g		4.51
Label	g	0.41	0.23
- paper	g		
- PP	g	0.41	0.23
- HDPE	g		
closure	g	2.08	2.95
- HDPE	g	2.08	2.95
- PP	g		
secondary packaging (sum)	g	7.06	14.14
- shrink pack (LDPE)	g	7.06	14.14
- paper handle	g		
- tray (cardboard)	g		
tertiary packaging (sum)	g	26920	26920
pallet	g	25000	25000
type of pallet	-	EURO	EURO
number of use cycles		25	25
cardboard layer	g	350	350
number of cardboard layers		5	5
stretch foil (per pallet) (LDPE)	g	170	170
pallet configuration			
Bottles per pack	pc	6	8
packs per layer	pc	38	27
layers per pallet	pc	6	6
bottles per pallet	pc	1368	1296

2.3 End-of-life

For each packaging system regarded in the study, a base scenario is modelled and calculated assuming an average recycling rate for post-consumer packaging for the Swiss and Austrian markets. The applied recycling quotas are either based on published quotas or on quotas provided by Tetra Pak. The recycling quota represents the actual amount of material undergoing a recycling process after sorting took place, the collection quota before sorting. The applied quotas and the related references are given in Table 30. The collection and recycling quotas of beverage cartons in Switzerland are for the applied reference year very low. As the collection of beverage cartons in Switzerland is planned to be increased, base scenarios for beverage cartons in Switzerland are additionally calculated with an increased collection quota as shown in Table 30.

Table 30: Applied collection and recycling quotas for beverage cartons, plastic and glass bottles in Switzerland and Austria:

Country	Packaging system	Collection quota	Recycling quota[1]	Reference year	Source
Switzerland	Beverage carton	4.1%	2.4%	2016	[Tetra Pak 2016]
	Beverage carton	*75%*	*67.5%*	*Target value*	*[Dinkel & Kägi 2017]*
	PET bottles	90.6%	82%	2016	[BAFU 2017]
	HDPE bottles	66.93%	55%	2016	[BAFU 2016, Dinkel et al. 2017]
	Glass bottles	96%	96%	2016	[BAFU 2017]
	PP/PS cups	0%	0%	2016	[BAFU 2016]
Austria	Beverage carton	57%	34%	2016	[WKÖ 2017]
	PET bottles	73%	57%	2016	[WKÖ 2017]
	HDPE bottles	70%	54%	2016	[ARA 2018, WKÖ 2017]
	Glass bottles	81%	81%	2016	[WKÖ 2017]
	PP/PS cups	65%	25%	2016	[WKÖ 2017]

[1]based on input to recycling plant

The remaining part of the post-consumer packaging waste in Switzerland is incinerated in MSWI. In the case of Austria the remaining waste is incinerated in MSWI and cement kilns. The applied quotas and the related references are given in Table 31.

Table 31: Applied average rates for landfilling and incineration in Switzerland and Austria

Country	MSWI/Landfill/cement kiln	Quota	Reference year	Source
Switzerland	MSWI	100.00%	2016	calculated based on [Eurostat 2017]
Austria	MSWI	93.36%	2016	
	cement kiln	6.64%		

The following simplified flow charts Figure 11 to Figure 16 illustrate the applied end-of-life model of beverage cartons, PET and HDPE bottles, glass bottles as well as PP cups separated by country. The graphs illustrate only the end of life of one way packaging systems, as the end of life flow of refillable bottles is way smaller because of their multiple trip rates. The percentage going into the recycling path in each flowchart corresponds to the recycling quotas in Table 30.

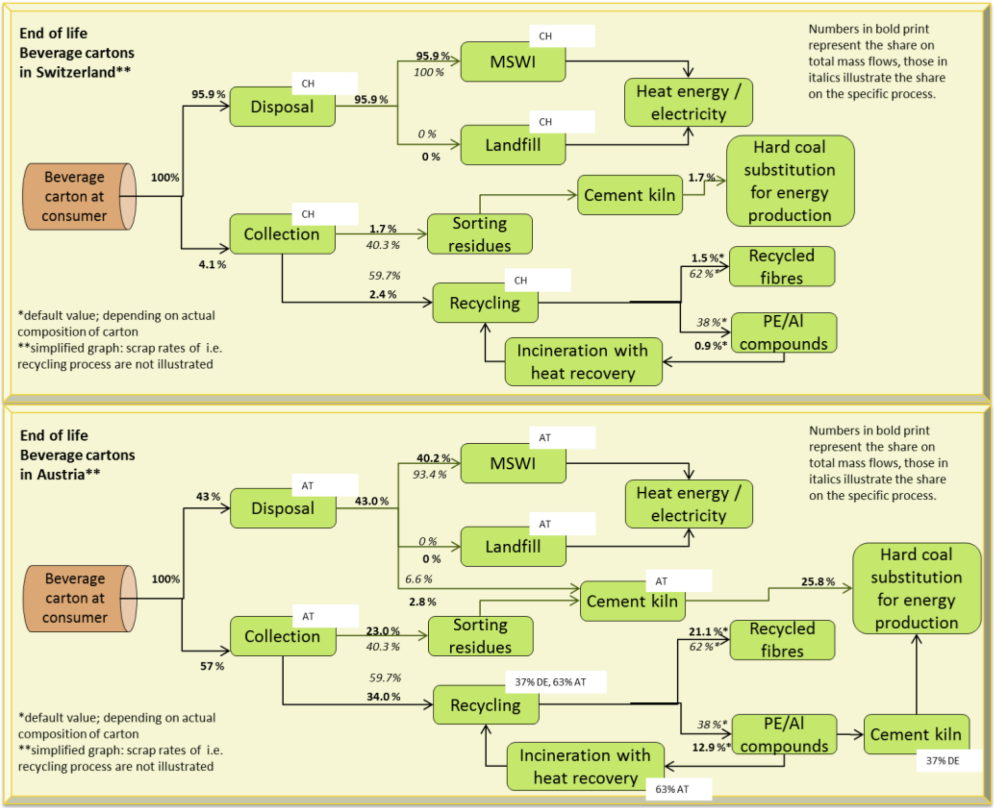


Figure 11: Applied average end-of-life quotas for beverage cartons in Switzerland and Austria. Numbers in bold print represent the share on total mass flow, those in italics illustrate the share on the specific process.

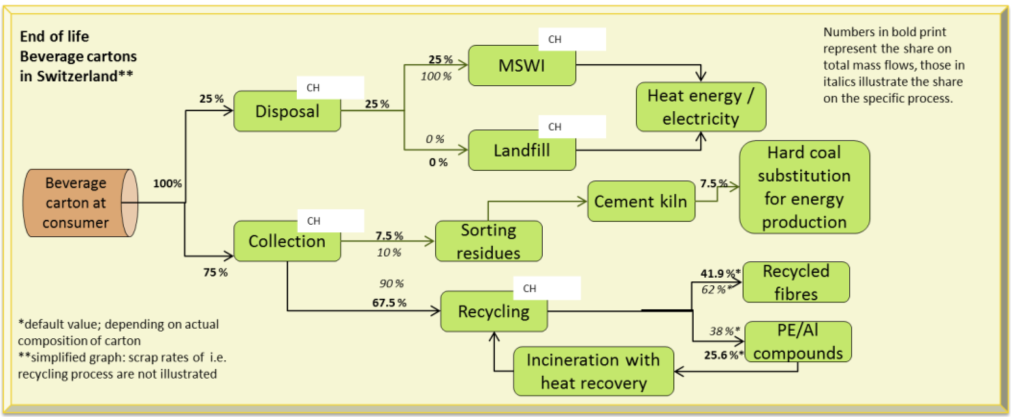


Figure 12: Applied target end-of-life quotas for beverage cartons in Switzerland. Numbers in bold print represent the share on total mass flow, those in italics illustrate the share on the specific process.

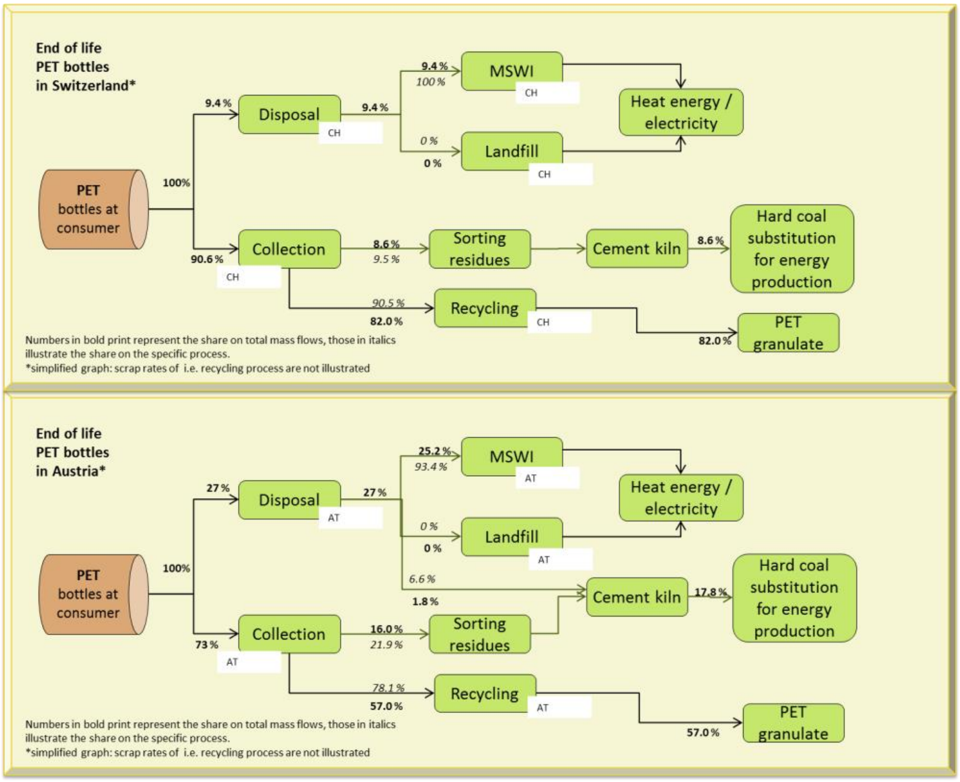


Figure 13: Applied average end-of-life quotas for PET bottles in Switzerland and Austria. Numbers in bold print represent the share on total mass flow, those in italics illustrate the share on the specific process.

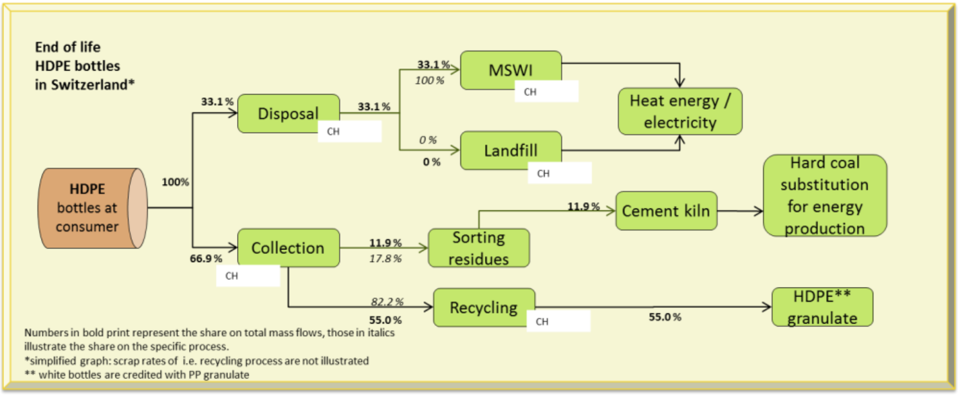


Figure 14: Applied average end-of-life quotas for HDPE bottles in Switzerland and Austria. Numbers in bold print represent the share on total mass flow, those in italics illustrate the share on the specific process.

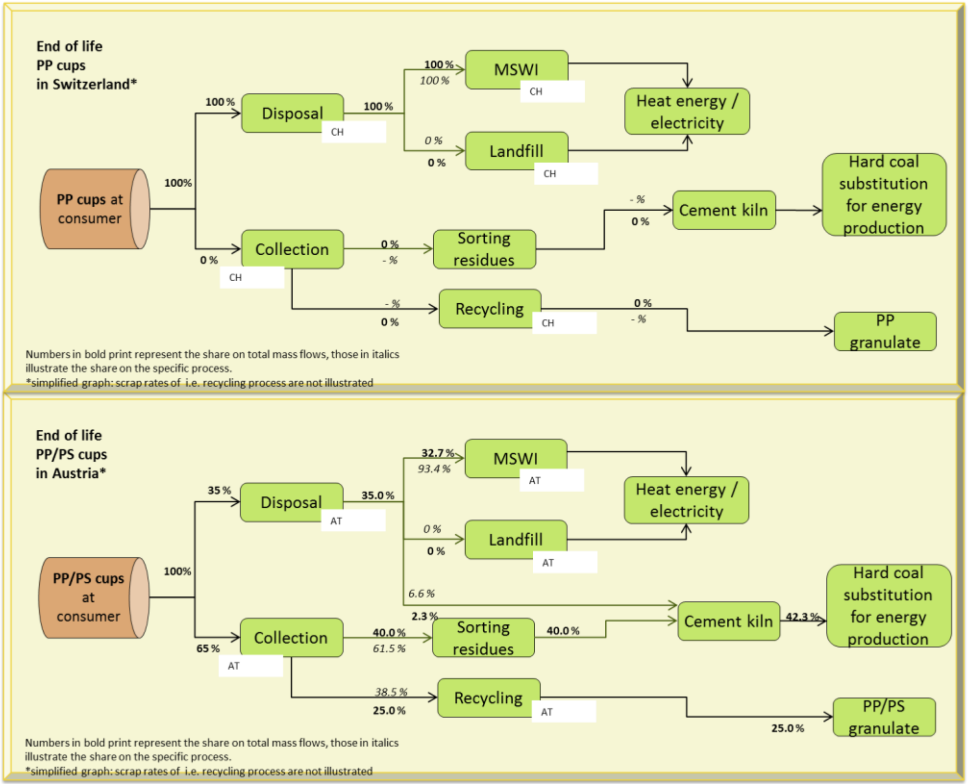


Figure 15: Applied average end-of-life quotas for PP/PS cups in Switzerland and Austria. Numbers in bold print represent the share on total mass flow, those in italics illustrate the share on the specific process.

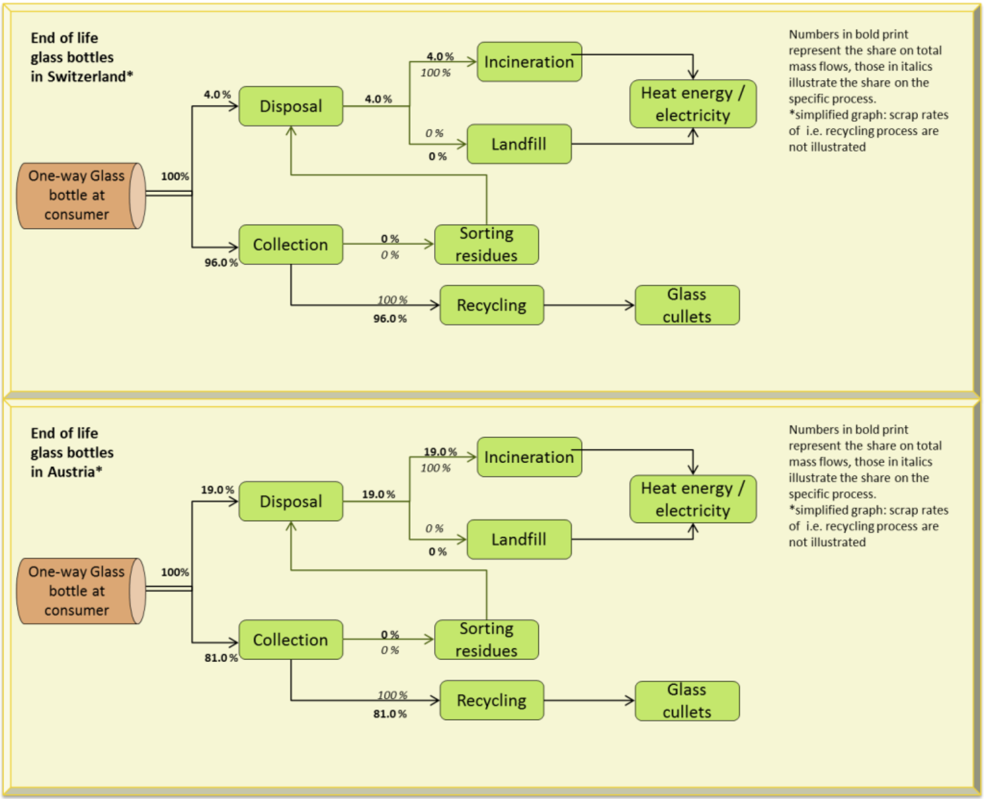


Figure 16: Applied average end-of-life quotas for one way glass bottles in Switzerland and Austria. Numbers in bold print represent the share on total mass flow, those in italics illustrate the share on the specific process.

2.4 Scenarios

2.4.1 Base scenarios

For each of the studied packaging systems a base scenario for the Swiss and Austrian markets is defined, which is intended to reflect the most realistic situation under the described scope. These base scenarios are clustered into groups within the same beverage segment and volume group. In these base scenarios, the allocation factor applied for open-loop-recycling is 50%. As the collection of beverage cartons in Switzerland is planned to be increased, base scenarios for beverage cartons in Switzerland are additionally calculated with an increased collection quota as shown in Table 30.

2.4.2 Sensitivity analysis with focus on the allocation factor

In the base scenarios of this study, open-loop allocation is performed with an allocation factor of 50%. Following the ISO norm's recommendation on subjective choices, one sensitivity analysis is conducted in this study to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% will be applied in a 'sensitivity analysis 100'. Beverage cartons in Switzerland are calculated with the base collection quota.

2.4.3 Sensitivity analysis regarding the consideration of regenerative carbon

In this 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 (please see section 1.7.1 for details).

To illustrate the effect of this approach for the base scenarios (with 50% allocation), an additional sensitivity scenario is presented in this study for the SD Family Pack segment in both markets. In this example the uptake as well as the emissions of biogenic CO_2 is not considered at all, as it was usually done in many LCA studies in the past.

2.4.4 Sensitivity analysis regarding recycled content in PET bottles

PET bottles in the base scenarios are modelled with their specific share of recycled PET (rPET). As PET bottles could be produced with 100% recycled content a sensitivity analysis is performed for the packaging systems listed in Table 32. In these analyses, the allocation factor applied for open-loop-recycling is 50%. Beverage cartons in Switzerland are calculated with the base collection quota.

Table 32: Sensitivity scenarios: recycled content in PET bottles

Base packaging system	Sensitivity	Comparing packaging systems	Geo-graphic scope	Volume	Beverage segment
PET bottle 2	30% and 100% recycled PET	TBA Edge Wingcap 30 TBA Edge Wingcap 30 biobased TBA Slim Helicap 23	CH	1000 ml	JN Family Pack (ambient)
PET bottle 13	30% and 100% recycled PET	TBA Edge Wingcap 30 TBA Edge Wingcap 30 biobased TBA Slim Helicap 23	CH	1000 ml	SD Family Pack (ambient)
PET bottle 11	30% and 100% recycled PET	TPA Square Dreamcap26 TPA Square Dreamcap26 biobased TT Midi C38 TT Midi C38 biobased	CH	500 ml	WATER Portion Pack (ambient)
PET bottle 4	30% and 100% recycled PET	TR OSO 34 TR OSO 34 biobased TT C38 (tray) TT C38 biobased (tray) TT C38 (rollcontainer) TT C38 biobased (rollcontainer)	AT	1000 ml	Dairy Family Pack (chilled)
PET bottle 7	30% and 100% recycled PET	TR Base Mini Plus TBA Edge Wingcap 30 TBA Edge Wingcap 30 biobased TBA Slim Helicap 23 TPA Square Helicap 27	AT	1000 ml	JN Family Pack (ambient)
PET bottle 9	30% and 100% recycled PET	TPA Edge Dreamcap26 TPA Edge Dreamcap26 biobased	AT	500 ml	SD Portion Pack (ambient)
PET bottle 12	30% and 100% recycled PET	TPA Square Dreamcap26 TPA Square Dreamcap26 biobased TT Midi C38 TT Midi C38 biobased	AT	500 ml	WATER Portion Pack (ambient)

2.4.5 Sensitivity analysis regarding trip rate of refillable glass bottles

In the base scenarios for refillable glass bottles in the segment JN Family Pack in Austria the trip rate of 30 refills is taken, based on expert judgment from the German market by Jürgen Heinisch and based on trip rates from Austrian water and lemonade bottles [Kauertz et al. 2011]. To consider also lower trip rates of these refillable glass bottles, a sensitivity analysis with trip rate of 20 is performed.

In the base scenarios for refillable glass bottles in the segment DAIRY Family Pack in Austria the trip rate of 10 refills is based on the press note of Berglandmilch [Berglandmilch 2019]. To consider also higher trip rates of this refillable glass bottles, a sensitivity analysis with trip rate of 20 is performed.

All sensitivity analyses on trip rates are listed in Table 33. In these analyses, the allocation factor applied for open-loop-recycling is 50%.

Table 33: Sensitivity scenarios: trip rate of refillable glass bottles

Base packaging system	Sensitivity	Comparing packaging systems	Geographic scope	Volume	Beverage segment
Glass bottle (RF) 1	Trip rate of 20	TBA Edge Wingcap 30 TBA Edge Wingcap 30 biobased TBA Slim Helicap 23 TPA Square Helicap 27	AT	1000 ml	JN Family Pack (ambient)
Glass bottle (RF) 2	Trip rate of 20	TR OSO 34 TR OSO 34 biobased TT C38 (tray) TT C38 biobased (tray) TT C38 (rollcontainer) TT C38 biobased (rollcontainer)	AT	1000 ml	DAIRY Family Pack (chilled)

2.4.6 Scenario variants regarding bio-based PE in beverage cartons

The base scenarios already include beverage cartons containing bio-based plastic materials. For some cartons the use of bio-based plastics is still in development. In order to take into account the further use of bio-based plastics in beverage cartons, a scenario variant with bio-based plastics is performed for the additional beverage cartons listed in Table 35. In these analyses, the allocation factor applied for open-loop-recycling is 50%. Beverage cartons in Switzerland are calculated with the base collection quota.

Table 34: Scenario variants: bio-based PE in beverage cartons

Base packaging system	Variant	Comparing packaging systems	Geographic scope	Volume	Beverage segment
TT C38	bio-based PE	HDPE bottle 1 HDPE bottle 1 biobased[1]	CH	1000 ml	DAIRY Family Pack (chilled)
TPA Square Dreamcap26	bio-based PE	HDPE bottle 5 HDPE bottle 5 biobased[1]	CH	330 ml	DAIRY Portion Pack (chilled)

[1]scenario variant described in section 2.4.7

2.4.7 Scenario variants regarding bio-based plastics in HDPE bottles

The study includes beverage cartons containing bio-based plastic materials. In order to take also bio-based material in plastic bottles into account a scenario variant is performed for the packaging systems listed in Table 35. In these analyses, the allocation factor applied for open-loop-recycling is 50%. Beverage cartons in Switzerland are calculated with the base collection quota.

Table 35: Scenario variants: bio-based PE in HDPE bottles

Base packaging system	Variants	Comparing packaging systems	Geographic scope	Volume	Beverage segment
HDPE bottle 1	100% bio-based PE	TR OSO 34 TR OSO 34 biobased TT C38 TT C38 biobased[1]	CH	1000 ml	DAIRY Family Pack (chilled)
HDPE bottle 2	100% bio-based PE	TBA edge Wingcap 30 TBA edge Wingcap 30 biobased TBA mid Lightcap	CH	1000 ml	DAIRY Family Pack (ambient)
HDPE bottle 5	100% bio-based PE	TPA Square Dreamcap26 TPA Square Dreamcap26 biobased[1]	CH	330 ml	DAIRY Portion Pack (chilled)

[1]scenario variant described in section 2.4.6

2.4.8 Scenario variants regarding plastic bottle weight

To consider potential future developments in terms of weight of the plastic bottles, a scenario variant with reduced bottle weight is performed for the packaging systems listed in and Table 36. In these analyses the allocation factor applied for open-loop-recycling is 50%. Beverage cartons in Switzerland are calculated with the base collection quota.

Table 36: Scenario variant: reduced weight of PET bottles

Base packaging system	Variants	Comparing packaging systems	Geographic scope	Volume	Beverage segment
PET bottle 13	10% and 30% reduced bottle weight	TBA Edge Wingcap 30 TBA Edge Wingcap 30 biobased TBA Slim Helicap 23	CH	1000 ml	SD Family Pack (ambient)
PET bottle 11	10% and 30% reduced bottle weight	TPA Square Dreamcap26 TPA Square Dreamcap26 biobased TT Midi C38 TT Midi C38 biobased	CH	500 ml	WATER Portion Pack (ambient)
PET bottle 12	10% and 30% reduced bottle weight	TPA Square Dreamcap26 TPA Square Dreamcap26 biobased TT Midi C38 TT Midi C38 biobased	AT	500 ml	WATER Portion Pack (ambient)

2.4.9 Additional scenarios regarding clear PET and recycled content in PET bottle 4

During the preparation of the study the opaque PET bottle 4 was superseded by a clear PET bottle with 25% recycled content. The recycled content is planned to be increased to 100%. Therefore additional scenarios are performed which includes the clear PET bottle 4 with 25% and 100% recycled content (Table 37). As the specification of mass has also changed, Table 38 shows the specifications of the PET bottle 4 in all variations.

Table 37: Additional scenarios: clear PET recycled content in chilled PET bottle 4

Base packaging system	Variant	Comparing packaging systems	Geo-graphic scope	Volume	Beverage segment
PET bottle 4	clear PET and 25% recycled PET clear PET and 100% recycled PET	TR OSO 34 TR OSO 34 biobased TT C38 (tray) TT C38 biobased (tray) TT C38 (rollcontainer) TT C38 biobased (rollcontainer)	AT	1000 ml	DAIRY Family Pack (chilled)

Table 38: Packaging specifications for additional scenarios of PET bottle 4 in the segment *DAIRY Family Pack*

		DAIRY		
Packing components	Unit	PET bottle 4	PET bottle 4	PET bottle 4
Volume	ml	1000	1000	1000
Geographic scope	-	AT	AT	AT
Chilled / ambient	-	chilled	chilled	chilled
Clear / opaque	-	opaque	clear	clear
Layers	-	mono	mono	mono
primary packaging (sum)	g	**27.63**	**31.20**	**31.20**
Bottle (sum)	g	**22.43**	**26.00**	**26.00**
- virgin PET	g	22.07	19.50	
- recycled PET	g		6.50	26.00
- TiO2 (1.6%)	g	0.36		
Label	g	**2.50**	**2.45**	**2.45**
- paper	g	0.09		
- PS	g		2.45	2.45
- HDPE	g	2.41		
closure	g	**2.70**	**2.75**	**2.75**
- HDPE	g	2.70	2.75	2.75
secondary packaging (sum)	g	**236.90**	**236.90**	**236.90**
- shrink pack (LDPE)	g			
- paper handle	g			
- tray (cardboard)	g	236.90	236.90	236.90
- HDPE crate (reuseable)	g			
tertiary packaging (sum)	g	**26920**	**26920**	**26920**
pallet	g	25000	25000	25000
type of pallet	-	EURO	EURO	EURO
number of use cycles		25	25	25
cardboard layer	g	350	350	350
number of cardboard layers		5	5	5
stretch foil (per pallet) (LDPE)	g	170	170	170
pallet configuration				
Bottles per pack	pc	12	12	12
packs per layer	pc	8	8	8
layers per pallet	pc	6	6	6
bottles per pallet	pc	576	576	576

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 39 gives an overview of important datasets applied in the current study.

Table 39: Overview on inventory/process datasets used in the current study

Material / Process step	Source	Reference period
Intermediate goods		
PP	Plastics Europe, published online April 2014	2011
PS	Plastics Europe, published online April 2012	2010
HDPE	Plastics Europe, published April 2014	2011
LDPE	Plastics Europe, published April 2014	2011
BioPE	[Braskem 2018]	2015
PET	Plastics Europe, published online June 2017	2015
PA6	Plastics Europe, last online retrieval in 2005	1999
Titanium dioxide	Ecoinvent V.3.4	2017
Carbon Black	Ecoinvent V.3.4	2011-2015
Tinplate	[APEAL 2015]	2012/2013
Aluminium (primary)	EAA Environmental Profile report 2018 [EAA 2018]	2015
Aluminium foil	EAA Environmental Profile report 2013 [EAA 2013]	2010
Corrugated cardboard	[FEFCO 2015]	2014
Liquid packaging board	ifeu data, obtained from ACE [ACE 2012]	2009
Production		
BC converting	Tetra Pak	2017
Glass bottle converting including glass production	UBA 2000 (bottle glass); energy prechains 2012	2000/2012
Preform production	Data provided by Tetra Pak, gathered in 2009, updated in 2016	2016
HDPE bottle production	Data provided by Tetra Pak, gathered in 2009, updated in	2016

Material / Process step	Source	Reference period
	2016	
Filling		
Filling of beverage cartons	Data provided by Tetra Pak	2017
Filling plastic bottles	Data provided by Tetra Pak, gathered in 2009, updated in 2016 for LCA Tetra Pak Nordics SBM is included in data for PET bottles	2016
Filling glass bottles	ifeu data obtained from various fillers	2012
Recovery		
Beverage carton recycling	ifeu database, based on data from various European recycling plants	2004
PET bottle	ifeu database, data collected from different recycles in Germany and Europe	2009
HDPE bottle	ifeu database, data collected from different recyclers in Germany and Europe	2008
Glass bottle	ifeu database, [FEVE 2006]	2004/2005
Background data		
electricity production CH, AT, DE & Europe	ifeu database, based on statistics and power plant models	2015
Municipal waste incineration	ifeu database, based on statistics and incineration plant models	2008
Landfill	ifeu database, based on statistics and landfill models	2008
lorry transport	ifeu database, based on statistics and transport models, emission factors based on HBEFA 3.3 [INFRAS 2017].	2009
rail transport	[EcoTransIT 2016]	2016
sea ship transport	[EcoTransIT 2016]	2016

3.1 Plastics

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

- Polypropylene (PP)
- Polystyrene (PS)
- High density polyethylene (HDPE)
- Low density polyethylene (LDPE)
- BioPE
- 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 Polystyrene (PS)

Polystyrene is produced by polymerisation of styrene monomer, a chain-growth reaction which is induced by any known initiation techniques such as heat, free radical organic initiator, anionic or cationic initiating systems, or coordination-insertion organo-metallic initiating complexes. The present LCA study uses the ecoprofile published on the website of Plastics Europe [PlasticsEurope 2012a].

3.1.3 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 ecoprofile 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).

3.1.4 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 ecoprofile 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).

3.1.5 Bio-based Polyethylene (Bio-PE)

All packaging systems analysed in this study, which contain bio-based Polyethylene (PE) are beverage carton systems. The only exceptions are the two sensitivity analyses with 100% bio-based HDPE bottles. The bio-based PE used by Tetra Pak in the regarded beverage carton systems is supplied by Braskem in Brazil. The PE is produced from ethanol based on sugar cane. This study uses two LCA datasets provided by Braskem, one for bio-based HDPE and one for bio-based LDPE [Braskem 2018]. In order to address co-products in the bio-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.

3.1.6 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 is 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).

3.1.7 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. Therefore impacts of caprolactam production are allocated between caprocaltam and ammonium sulphate. To the view of the authors, this approach is not consistent as other datasets of plastics are used alongside in this study, which don't allocate side products. 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 Association (EAA) covering the year 2015. The data is 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 EAA 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 EAA [EAA 2013], the foil production is modelled with 57% of the production done through strip casting technology and 43% through classical production route. The dataset includes the electricity prechains which are based on actual practice and are not a European average electricity mix.

3.3 Manufacture of tinplate

Data for the production of tinplate refer to the year 2012 and are published by APEAL [APEAL 2015]. 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 APEAL the dataset represent about 95% of the annual European supply or production volume.

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. This substitution follows a consequential LCA approach, whereas this LCA is conducted as an attributional LCA.

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.

Both data 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 2015 [FEFCO 2015] 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 2014. All corrugated board and cardboard trays are assumed to be sourced from European production.

In order to ensure stability, a fraction of fresh fibres is often used for the corrugated cardboard trays. According to [FEFCO 2015] this fraction on average is 12% 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 is 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 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 required additives, printing, 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 was 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. Data was gathered in 2009 from production plants, which are producing competing PET bottle systems, and was updated in 2016 for the Tetra Pak Nordics LCA study [ifeu 2017] and was crosschecked with the internal ifeu database. This data is also used in this study.

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 2016 for the Tetra Pak Nordics LCA study [ifeu 2017]. The data was also gathered from production plants, which are producing competing HDPE bottle systems. This data is also applied in this study.

3.10 Closure production

The closures made of fossil and bio-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.

3.11 Filling

Filling processes are similar for beverage cartons and alternative packaging systems regarding material and energy flows. The respective data for beverage cartons were provided by Tetra Pak in 2018 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 collected by Tetra Pak in 2009 and updated in 2016 for the Tetra Pak Nordics LCA [Tetra Pak 2017a] and was crosschecked for plausibility with the internal ifeu database. This data is also used in this study.

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 2017, as filling machines and technologies have not changed since then. Filling data for PP cups has been collected by [Tetra Pak 2017] for a competing PP cup filling line Electricity demands are supplied by the grid electricity of the country of filling.

3.12 Transport settings

Table 40 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 40: Transport distances and means: Transport defined by distance and mode [km/mode]

Packaging element	Material producer to converter	Converter to filler
HDPE, LDPE, PP, PET granulate for all packages	200 / road*	
Bio PE	10800 / sea* 500 / road*	
Aluminium	250 / road*	
Paper board for composite board	200 / road** 1300 / sea** 400 / 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 41 and Table 42 show the applied distribution distances in this study. Weighted average distances are applied for each of the segments JN/SD, DAIRY and WATER in the each of the two markets Austria and Switzerland. In both markets the average distances from the filling locations are based on the location of Tetra Pak's fillers weighted by their shares of production for Tetra Pak. In this study these distances apply for all packaging systems in each segment.

Table 41: Distribution distances in km for the examined packaging systems in Switzerland

Switzerland						
			lorry [km]	train [km]	lorry [km]	train [km]
			weighted averages		km applied	
JN/SD						
filling --> central distribution centre	3-stage distribution	83.9%	98	0	155	53
central distribution centre --> regional distribution centre			47	64		
regional distribution centre --> point of sale			30	0		
filling --> regional distribution centre	2-stage distribution	16.1%	19	0		
regional distribution centre --> point of sale			30	0		
DAIRY						
filling --> central distribution centre	3-stage distribution	84.2%	80	0	140	53
central distribution centre --> regional distribution centre			47	64		
regional distribution centre --> point of sale			30	0		
filling --> regional distribution centre	2-stage distribution	15.8%	19	0		
regional distribution centre --> point of sale			30	0		
WATER						
filling --> central distribution centre	3-stage distribution	46.4%	0	211	84	127
central distribution centre --> regional distribution centre			47	64		
regional distribution centre --> point of sale			30	0		
filling --> regional distribution centre	2-stage distribution	53.6%	61	0		
regional distribution centre --> point of sale			30	0		

Table 42: Distribution distances in km for the examined packaging systems in Austria

Austria			lorry [km]	train [km]	lorry [km]	train [km]
			weighted averages		km applied	
JN/SD						
filling --> regional distribution centre	2-stage distribution	100%	45	487	75	487
regional distribution centre --> point of sale			30	0		
DAIRY						
filling --> regional distribution centre	2-stage distribution	100%	185	20	215	20
regional distribution centre --> point of sale			30	0		
WATER						
filling --> regional distribution centre	2-stage distribution	100%	147	0	177	0
regional distribution centre --> point of sale			30	0		

The distribution model for Switzerland is based on the distribution net of the two largest supermarket chains with one central distribution centre and several regional distribution centres respectively. The average distances to and from the central distribution centres are weighted by the market share of the two supermarket chains. The average distances to the regional distribution centres are weighted by the amount of stores delivered from each regional distribution centres. No reliable data for the distances from regional distribution centres to the points of sale is available for Switzerland. Therefore the applied average distance of 30km is based on collected data from a supermarket chain in Austria. In this study a mix of a 3-stage distribution (filler → central distribution centre → regional distribution centre → point of sale) and 2-stage stage distribution (filler → regional distribution centre → point of sale) is applied. A 2-stage distribution is applied for the nearest regional distribution centre of each filling location. The distribution to the farer regional distribution centres is a 3-stage distribution. In case of the segment WATER the 2-stage distribution is applied for most of the regional distribution centres as distances from the only filling locations used in this study are closer to most regional distribution centres than through the central distribution centres. As mode of transportation, mostly lorry is applied due to the relatively short distances. In case of the distribution from central distribution centres to regional distribution centres one of the supermarket chains regarded uses almost completely trains for this step. Therefore the share of these distances is applied with train transport. In case of the segment WATER also the distribution from the filling location to the central distribution centre is applied with train transport as the regarded filler ships most of his products by train.

The distribution model of the Austrian market is based on regional distribution centres of the important supermarket chains in Austria. It is applied as a 2-stage distribution (filler → regional distribution centre → point of sale).
The average distances to the regional distribution centres are weighted by their sales from market data available at ifeu. The applied average distance of 30km distances from regional distribution centres to the points of sale is based on collected data from a supermarket chain in Austria. As Austria has a large east-west extension, transportation from east to west is predestined for train transport. Therefore distances from filler to regional distribution centres on the east-west line longer with more than 250km are applied by train. All shorter distances and routes off the east-west line are modelled with lorry transport.

It is assumed for one way packaging systems, that not the full return distance is driven with an empty load, as lorries and trains load other goods (outside the system boundaries of this study) for at least part of their journey. As these other goods usually cannot be loaded at the final point of the beverage packaging delivery it is assumed that a certain part of the return trip is made without any load and so has to be allocated to the distribution system. No primary data is available on average empty return distances. For this reason an estimation of 33% of the delivery distance is calculated as an empty return trip. 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. In case of trains an empty trip factor of 50% is applied. [EcoTransIT World 2016].
For refillable packaging systems no empty trip factor is applied as the lorries and trains have to transport the empty packaging back to the filler.

3.14 Recovery and recycling

Beverage cartons

The recycling of beverage cartons is taking place in the following countries:

- Cartons sold in Switzerland are recycled in Switzerland [Dinkel & Kägi 2014]
- Cartons sold in Austria are recycled to 63% in Austria and 37% in Germany [Tetra Pak 2016]

Food cartons are typically positively sorted into a beverage and food carton fraction, which subsequently is 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. In average 5% of the fibres are lost during the recycling process.

According to Tetra Pak plastics and aluminium compounds undergo thermal treatment with energy recovery. In the scope of Switzerland and the Austrian cartons which are recycled in Austria, the energy is recovered at the recycling plant and used internally for the recycling process. Plastic and aluminium compounds of cartons from the Austrian market which are recycled in Germany undergo thermal treatment in cement kilns. 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

A considerable share of plastic bottles is collected and sorted, 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.

According to Tetra Pak the recycling of plastic bottles takes place in the following countries:

- Plastic bottles sold in Switzerland are recycled in Switzerland
- Plastic bottles sold in Austria are recycled in Austria

Glass bottles

The glass of collected glass bottles 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 85.5% 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.

3.15 Background data

3.15.1 Transport processes

Lorry transport

The dataset used is based on standard emission data that were collated, validated, extrapolated and evaluated for the Austrian, German, French, Norwegian, Swedish and Swiss Environment Agencies in the 'Handbook of emission factors' [INFRAS 2017]. The 'Handbook' is a database application referring to the year 2017 and giving as a result the transport distance related fuel consumption and the emissions differentiated into lorry size classes and road categories**.** Data are based on average fleet compositions within several lorry size classes. 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. 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 a utilisation of capacity by 70%. 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 paperboard and the market related mix of energy suppliers in the year 2015 for all other processes depending on their location (e.g. energy for filling process: either Switzerland or Austria; energy for corrugated cardboard production: European). The applied shares of energy sources to the related market are given in Table 43. All applied electricity mixes are production mixes of the specific country. Electricity import and exports are therefore not considered.

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

Table 43: Share of energy source to specific energy mix, reference year 2015.

country Energy source	EU 28	Switzerland	Austria	Germany
Hard coal	14.11%	0.00%	4.62%	18.22%
Brown coal	10.32%	0.00%	0.00%	23.90%
Fuel oil	1.65%	0.07%	1.20%	0.86%
Natural gas	16.51%	0.96%	15.47%	11.53%
Nuclear energy	26.70%	33.90%	0.00%	14.36%
Hydropower/Wind/Solar /Geothermal	24.50%	60.98%	70.66%	22.25%
Hydropower	45.74%	97.03%	86.61%	14.05%
Windpower	40.42%	0.28%	11.31%	58.64%
Solar energy	13.01%	2.69%	2.08%	27.22%
Geothermal energy	0.83%	0.00%	0.00%	0.09%
Biomass energy	4.84%	0.75%	6.39%	6.90%
Waste	1.35%	3.34%	1.66%	1.98%

3.15.3 Municipal waste incineration

The electrical and thermal efficiencies of the municipal solid waste incineration plants (MSWI) are shown in Table 44. These refer to the years 2015 and 2016. Especially for Switzerland an increase in both efficiencies can be expected in the near future.

Table 44: Electrical and thermal efficiencies of the incineration plants in the two studied markets.

Country	Electrical efficiency	Thermal efficiency	Reference period	Source
Switzerland	14%	27%	2016	[VBSA 2018]
Austria	17%	37%	2015	[bmnt 2017], [Umweltbundesamt 2007]

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 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. Emissions of methane from biogenic materials (e.g. during landfill) are always accounted at the inventory level AND in form of GWP.

4 Results Austria

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

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

- production and transport of glass including converting to bottle (**'Glass'**)
- production and transport of PET including additives, e.g. carbon black (**'PET/HDPE'**)
- production and transport of liquid packaging board **('LPB')**
- production and transport of plastics and additives for beverage carton **('plastics for sleeve')**
- production and transport of aluminium & converting to foil **('aluminium foil')**
- converting processes of cartons **('converting')**
- production and transport of base materials for closures, top and label **('top, closure & label')**
- production of secondary and tertiary packaging: wooden pallets, LDPE shrink foil 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 biobased and renewable materials **('CO_2 reg. (EOL)')**; in the following also the term regenerative CO_2 emissions is used

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 loads of the substituted material. The so-called 50% allocation method has been used for the crediting procedure (see section1.7) in the base scenarios.

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

- credits for material recycling **('credits material')**
- credits for energy recovery (replacing e.g. grid electricity) **('credits energy')**
- Uptake of atmospheric CO_2 during the plant growth phase ('**CO_2-uptake**')

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 graph includes three bars per packaging system under investigation, which illustrate (from left to right):

- sectoral results of the packaging system itself (stacked bar 'environmental burdens')
- credits given for secondary products leaving the system (negative stacked bar 'credits')
- net results as a results of the subtraction of credits from overall environmental loads (grey bar 'net results')

All category results refer to the primary and transport packaging material flows required for the delivery of 1000 L beverage to the point of sale including the end-of-life of the packaging materials.
The results for *water use* are shown on the inventory level. Due to the lack of mandatory information to assess the potential environmental impact, water scarcity cannot be assessed on LCIA level within this study. However, the use of freshwater is included in the inventory categories. A differentiation between process water, cooling water and water, unspecified is made. However, it includes neither any reference to the origin of this water, nor to its quality at the time of output/release. The respective results in this category are therefore of mere indicative nature and are not suited for conclusive quantitative statements related to either of the analysed packaging systems.

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 base scenarios DAIRY FAMILY PACK AUSTRIA

4.1.1 Presentation of results DAIRY FAMILY PACK Austria

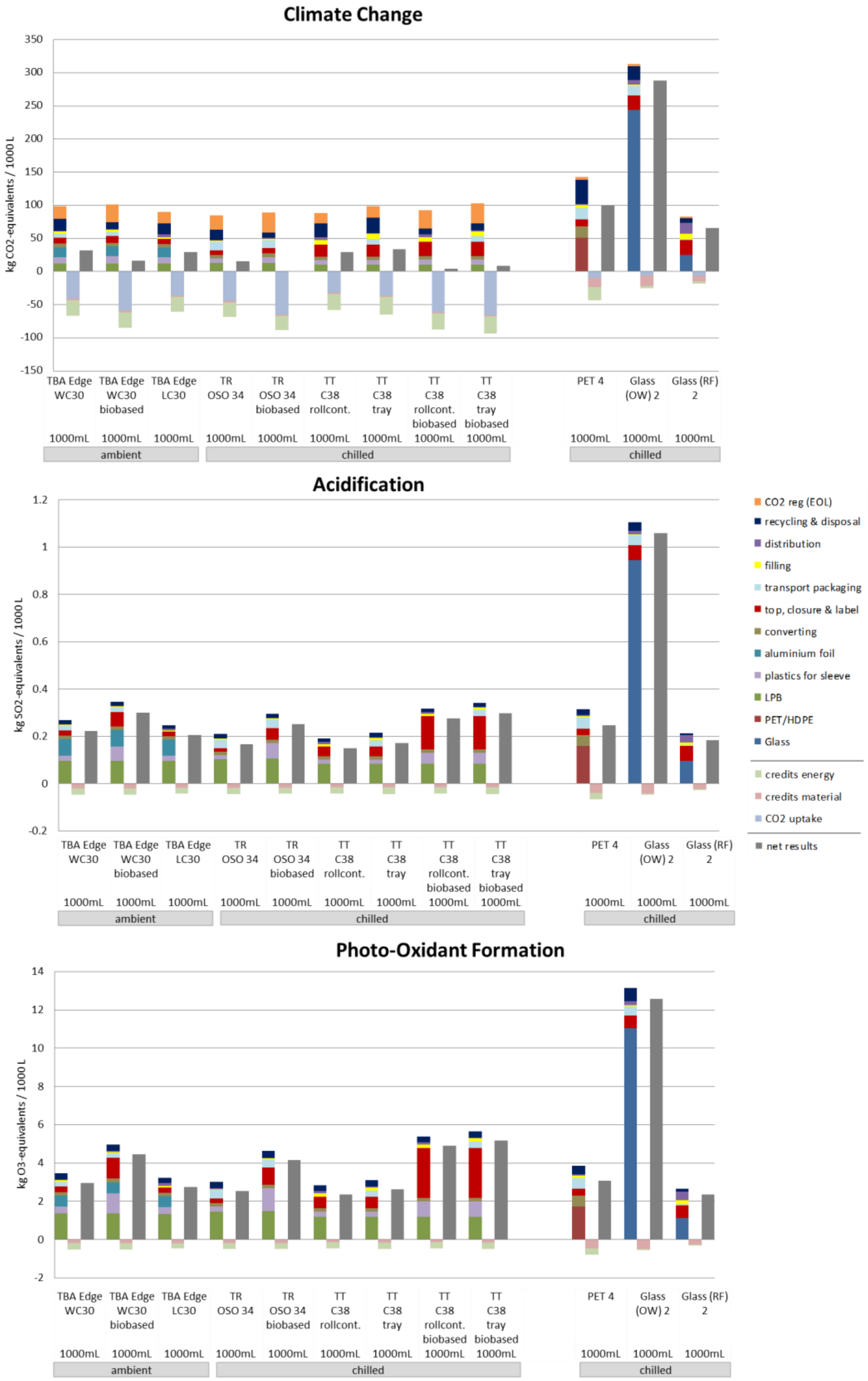


Figure 17: Indicator results for base scenarios of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 1)

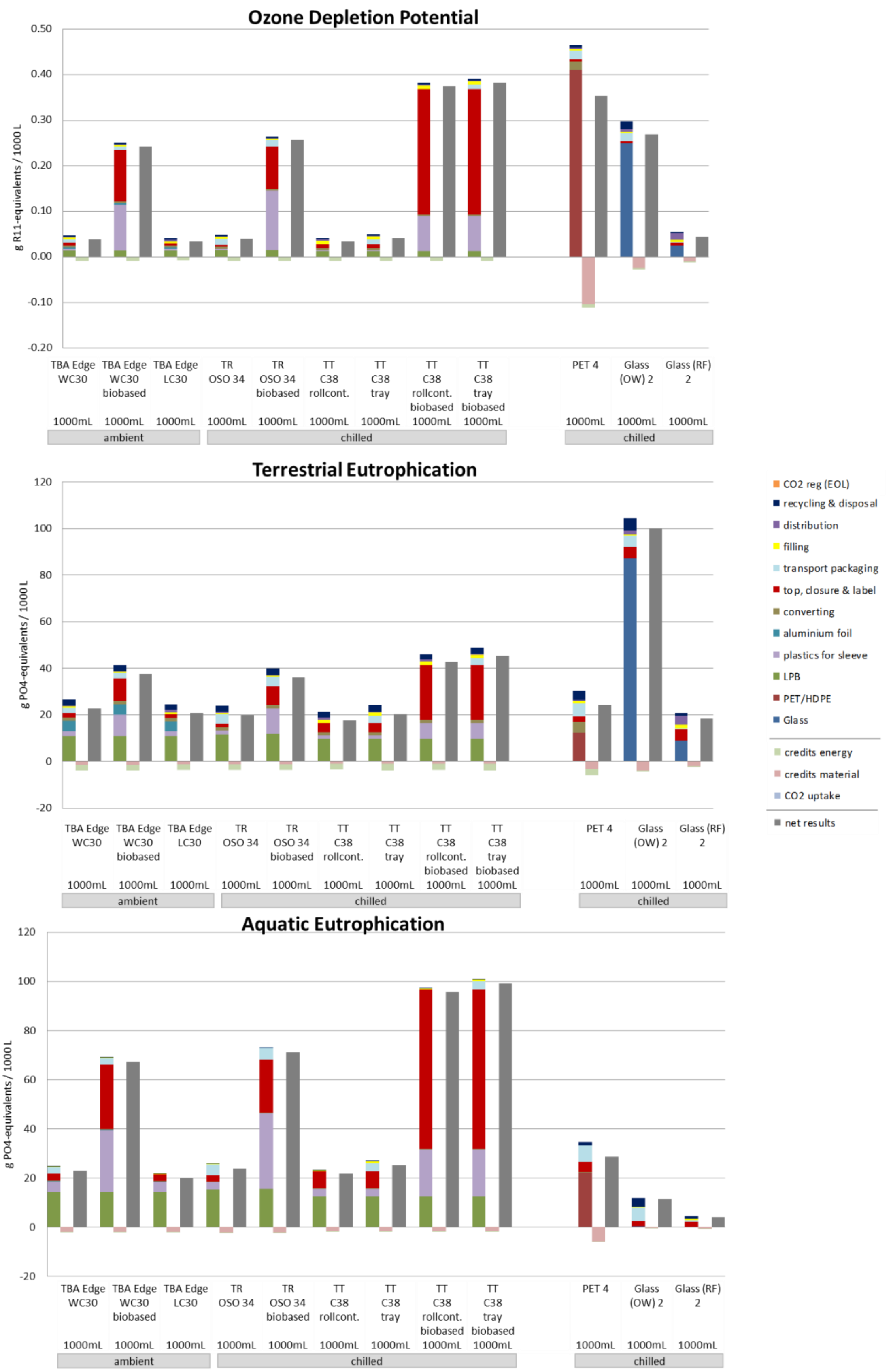


Figure 18 Indicator results for base scenarios of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 2)

Figure 19: Indicator results for base scenarios of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 3)

Figure 20: Indicator results for base scenarios of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 4)

Table 45: Category indicator results per impact category for base scenarios of **segment DAIRY FAMILY PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Edge LC30 1000mL	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL		PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	79.70	74.45	72.73	63.02	58.96	72.93	81.19	64.56	72.81		138.35	310.16	80.47
	CO2 (reg)	19.23	27.07	17.10	21.51	29.97	15.08	17.43	27.77	30.12		4.66	3.06	2.88
	Credits	-26.21	-26.24	-24.57	-24.05	-23.94	-26.52	-27.86	-26.59	-27.94		-33.69	-18.37	-12.08
	CO2 uptake	-40.48	-58.61	-36.13	-44.60	-64.76	-31.86	-36.66	-61.19	-66.00		-9.83	-6.34	-5.82
	net results	32.24	16.66	29.13	15.88	0.24	29.63	34.09	4.54	9.00		99.49	288.52	65.44
Acidification [kg SO2-e/1000 L[	Burdens	0.27	0.35	0.25	0.21	0.29	0.19	0.21	0.32	0.34		0.31	1.11	0.21
	Credits	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04		-0.07	-0.05	-0.03
	Net results	0.22	0.30	0.20	0.17	0.25	0.15	0.17	0.28	0.30		0.25	1.06	0.18
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.46	4.95	3.23	3.01	4.62	2.83	3.11	5.37	5.66		3.86	13.13	2.66
	Credits	-0.51	-0.51	-0.47	-0.49	-0.48	-0.46	-0.49	-0.46	-0.49		-0.79	-0.55	-0.32
	Net results	2.95	4.44	2.76	2.53	4.14	2.37	2.62	4.91	5.17		3.07	12.57	2.35
Ozone Depletion [g R11/1000 L]	Burdens	0.05	0.25	0.04	0.05	0.26	0.04	0.05	0.38	0.39		0.47	0.30	0.06
	Credits	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01		-0.11	-0.03	-0.01
	Net results	0.04	0.24	0.03	0.04	0.26	0.03	0.04	0.37	0.38		0.35	0.27	0.04
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	26.64	41.45	24.42	23.90	39.86	21.27	24.15	46.10	48.98		30.12	104.39	20.75
	Credits	-3.93	-3.93	-3.65	-3.77	-3.76	-3.57	-3.83	-3.58	-3.83		-5.83	-4.46	-2.48
	Net results	22.71	37.51	20.77	20.13	36.10	17.70	20.33	42.52	45.15		24.28	99.93	18.26
Aquatic Eutrophication [g PO4/1000 L]	Burdens	24.87	69.19	21.86	25.81	73.21	23.30	26.88	97.35	100.93		34.45	11.69	4.50
	Credits	-2.04	-2.04	-1.94	-2.16	-2.21	-1.72	-1.80	-1.72	-1.80		-5.92	-0.46	-0.53
	Net results	22.82	67.14	19.92	23.65	71.00	21.58	25.08	95.63	99.14		28.53	11.23	3.97
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	251.77	366.25	233.74	202.61	326.26	188.24	209.92	378.31	399.98		289.55	1086.54	205.61
	Credits	-41.42	-41.45	-38.75	-38.53	-38.43	-36.59	-38.94	-36.66	-39.01		-60.57	-55.60	-29.76
	Net results	210.36	324.81	194.99	164.08	287.83	151.65	170.97	341.65	360.97		228.99	1030.94	175.85
Total Primary Energy [GJ]	Burdens	2.19	2.18	2.03	1.90	1.91	2.05	2.21	2.04	2.20		3.01	4.11	1.23
	Credits	-0.53	-0.53	-0.50	-0.52	-0.52	-0.50	-0.53	-0.50	-0.53		-0.77	-0.23	-0.18
	Net results	1.66	1.65	1.54	1.38	1.39	1.55	1.68	1.54	1.67		2.25	3.88	1.05
Non-renewable Primary Energy [GJ]	Burdens	1.41	1.07	1.30	1.15	0.80	1.42	1.54	0.87	0.99		2.68	3.85	1.11
	Credits	-0.33	-0.33	-0.30	-0.31	-0.30	-0.32	-0.35	-0.33	-0.35		-0.69	-0.22	-0.16
	Net results	1.08	0.74	1.00	0.85	0.50	1.09	1.19	0.54	0.64		1.98	3.64	0.95
Use of Nature [m²*year]	Burdens	21.90	35.10	20.48	24.21	38.72	18.08	19.74	39.85	41.51		3.27	3.02	0.39
	Credits	-2.87	-2.87	-2.81	-3.04	-3.12	-2.50	-2.52	-2.50	-2.52		-0.06	-0.03	-0.03
	Net results	19.03	32.23	17.67	21.17	35.60	15.58	17.23	37.35	38.99		3.20	0.00	0.00
Water use [m³/1000 L]	water cool	1.33	1.37	1.22	1.35	1.40	1.27	1.38	1.18	1.29		2.52	0.65	0.28
	water process	2.17	2.16	2.14	1.93	1.97	1.89	1.90	1.87	1.88		0.18	4.90	5.16
	water unspecified	0.69	0.81	0.55	0.47	0.61	0.29	0.45	0.33	0.50		0.86	0.54	0.29

4.1.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the DAIRY FAMILY PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories 'Aquatic Eutrophication' (12%-64%) and 'Use of Nature' (43%-98%). It is also relevant regarding 'Photo-Oxidant Formation' (21%-48%) 'Acidification' (25%-49%), 'Terrestrial Eutrophication' (19%-49%), 'Particulate Matter' (20%-49%) and also the consumption of 'Total Primary Energy' (33%-48%). Regarding 'Climate Change' the production of LPB is responsible for only 10%-15% of the burdens.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (20%-28%) and 'Particulate Matter' (16%-25%). These result from SO2 and NOx emissions from the aluminium production.

The production of 'plastics for sleeve' of the beverage cartons shows considerable burdens in most impact categories (up to 49%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (7%-11%) and LPB (10%-15%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (15%-36%) and LPB (9%-30%) contribute about the same of the total burdens. If 'plastics for sleeve' contains bio-based plastics, this life cycle step plays a major role (9%-49%) for the overall burdens in all categories apart from 'Climate Change' (8%-11%), and 'Total Primary Energy' (13%-18%).

The life cycle step 'top, closure & label' for TBA and TR cartons contributes to a considerable amount in almost all impact categories (0%-45%). In case of TT cartons this life cycle step contributes to a substantial share in almost all impact categories (1%-72%). In case the plastics used for 'top, closure & label' are bio-based, the results are considerably higher than cartons with fossil based plastics in all categories except 'Climate Change', 'Total Primary Energy Demand' and 'Non-renewable Primary Energy'.

The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

The converting process generally plays a minor role (0%-11%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (4%-25%). The exception is 'Ozone Depletion Potential' for the cartons with fossil based plastics. In these cases 'transport packaging' has a higher share of 16%-29% of the burdens due to the low share of the categories 'top, closure & label' and 'plastics for sleeve'. If rollcontainers are used, this lifecycle step shows no impacts, as the production of rollcontainers is neglected due to their high reusability.

The life cycle step 'filling' shows only minor shares of burdens (up to 8%) for all TBA and TR beverage carton systems in all impact categories In case of TT beverage carton systems the shares are higher (up to 17%) due to the additional moulding process of the top.

The life cycle step 'distribution' shows only minor burdens in all impact categories for all beverage carton systems with rollcontainers (max. 9%). In case of beverage cartons with trays this step contributes only up to 2% of the total burdens.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (37%-44%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are lower than energy credits in almost all impact categories as in Austria only 34% of the beverage cartons are recycled. Exceptions are 'Aquatic Eutrophication' and 'Use of Nature' which have higher material credits caused by the substitution of fresh fibres. Material credits for 'Climate Change' are low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play an important role on the net results in all categories apart of 'Ozone Depletion Potential'.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the DAIRY FAMILY PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a considerable share of burdens (4%-15%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (1%-15%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show relevant impact shares (4%-19%) in most categories. The exception is 'Use of Nature' for which 93% of the burdens are caused from 'transport packaging' resulting from the used cardboard.

The life cycle step 'filling' shows only small shares of burdens (max. 3%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 2%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (28%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 20% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Glass bottles (specifications see section 2.2.2)

In case of the one way glass bottle even more than for the other regarded packaging systems, the production of the 'glass' material is the main contributor to the overall burdens . The production of glass clearly dominates the results (74%-86%) in all categories apart from 'Aquatic Eutrophication' and 'Use of Nature'.

All other life cycle steps play only a minor role compared to the glass production. For the impact categories, 'Aquatic Eutrophication' (47%) and 'Use of Nature' (84%) transport packaging also plays an important role.

Energy credits play only a minor role for the one-way glass bottle, as the little energy that can be generated in end-of-life mainly comes from the incineration of secondary and tertiary packaging.

Material credits from glass recycling, compared to energy credits have a higher impact on the overall net results apart from 'Aquatic Eutrophication' and 'Use of Nature'. The Impact is still small as most of the glass cullet is used in a closed loop for the production of the glass bottle.

In case of the refillable glass bottle the burdens of 'glass' production are considerably lower than for one way glass bottle. Therefore the share of 'glass' production for the refillable bottle are only (27%-46%) in all categories apart from 'Aquatic Eutrophication' (0%) and 'Use of Nature' (8%).

The lifecycle step 'top, closure & label' contributes with considerable shares (11%-49%) to the total burdens as the closure and label are in opposite of the bottle one way products.

The lifecycle step 'transport packaging' contributes with only minor shares (2%-10%) in most categories to the total burdens due to the reusability of the secondary packaging.

The lifecycle step 'filling' contributes with minor shares (5%-15%) in all categories to the total burdens

In comparison to the one-way bottle the lifecycle step 'distribution' contributes with more considerable shares (11%-26%) in all categories apart from 'Aquatic Eutrophication' (0%) due to the additional transportation of empty bottles.

The impact of the refillable glass bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Aquatic Eutrophication' (26%) and 'Climate Change' (11%).

Material credits from glass recycling play a minor role on the overall net results due to the reusability of the glass bottle.

Energy credits play only a minor role for the refillable glass bottle, as the little energy that can be generated in end-of-life mainly comes from the incineration of secondary and tertiary packaging.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

4.1.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging

systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

DAIRY FAMILY PACK (chilled), Austria	The net results of **TR OSO 34 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	6581%	-46%	-53%	250%	76%	-84%	-94%	-76%
Acidification	-34%	11%	-3%	-40%	-44%	-33%	-84%	-10%
Photo-Oxidant Formation	-39%	7%	-4%	-49%	-51%	-18%	-80%	8%
Ozone Depletion Potential	-84%	20%	-3%	-89%	-89%	-89%	-85%	-6%
Terrestrial Eutrophication	-44%	14%	-1%	-53%	-55%	-17%	-80%	10%
Aquatic Eutrophication	-67%	10%	-6%	-75%	-76%	-17%	111%	496%
Particulate Matter	-43%	8%	-4%	-52%	-55%	-28%	-84%	-7%

Table 47: Comparison of net results: **TR OSO 34 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Austria**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TR OSO 34 biobased 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	-99%	-99%	-99%	-95%	-97%	-100%	-100%	-100%
Acidification	51%	69%	47%	-9%	-16%	2%	-76%	37%
Photo-Oxidant Formation	64%	75%	58%	-16%	-20%	35%	-67%	77%
Ozone Depletion Potential	534%	661%	516%	-31%	-33%	-28%	-5%	495%
Terrestrial Eutrophication	79%	104%	78%	-15%	-20%	49%	-64%	98%
Aquatic Eutrophication	200%	229%	183%	-26%	-28%	149%	532%	1689%
Particulate Matter	75%	90%	68%	-16%	-20%	26%	-72%	64%

Table 48: Comparison of net results: **TT C38 rollcont. 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Austria**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TT C38 rollcont. 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	87%	12369%	-13%	553%	229%	-70%	-90%	-55%
Acidification	-10%	-41%	-13%	-46%	-50%	-40%	-86%	-19%
Photo-Oxidant Formation	-6%	-43%	-10%	-52%	-54%	-23%	-81%	1%
Ozone Depletion Potential	-17%	-87%	-19%	-91%	-91%	-90%	-88%	-22%
Terrestrial Eutrophication	-12%	-51%	-13%	-58%	-61%	-27%	-82%	-3%
Aquatic Eutrophication	-9%	-70%	-14%	-77%	-78%	-24%	92%	444%
Particulate Matter	-8%	-47%	-11%	-56%	-58%	-34%	-85%	-14%

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

Table 49: Comparison of net results: **TT C38 tray 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Austria**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TT C38 tray 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	115%	14246%	15%	651%	279%	-66%	-88%	-48%
Acidification	3%	-32%	15%	-38%	-43%	-31%	-84%	-7%
Photo-Oxidant Formation	4%	-37%	11%	-47%	-49%	-15%	-79%	12%
Ozone Depletion Potential	3%	-84%	24%	-89%	-89%	-88%	-85%	-3%
Terrestrial Eutrophication	1%	-44%	15%	-52%	-55%	-16%	-80%	11%
Aquatic Eutrophication	6%	-65%	16%	-74%	-75%	-12%	123%	532%
Particulate Matter	4%	-41%	13%	-50%	-53%	-25%	-83%	-3%

Table 50: Comparison of net results: **TT C38 rollcont. biobased 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Austria**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TT C38 rollcont. biobased 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	-71%	1809%	-85%	-87%	-50%	-95%	-98%	-93%
Acidification	66%	10%	85%	62%	-7%	12%	-74%	50%
Photo-Oxidant Formation	94%	19%	108%	87%	-5%	60%	-61%	110%
Ozone Depletion Potential	826%	46%	1011%	798%	-2%	6%	39%	768%
Terrestrial Eutrophication	111%	18%	140%	109%	-6%	75%	-57%	133%
Aquatic Eutrophication	304%	35%	343%	281%	-4%	235%	752%	2310%
Particulate Matter	108%	19%	125%	100%	-5%	49%	-67%	94%

Table 51: Comparison of net results: **TT C38 tray biobased 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Austria**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TT C38 tray biobased** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	-43%	3687%	-70%	-74%	98%	-91%	-97%	-86%
Acidification	79%	18%	100%	74%	8%	21%	-72%	62%
Photo-Oxidant Formation	105%	25%	118%	97%	5%	69%	-59%	120%
Ozone Depletion Potential	846%	49%	1035%	818%	2%	8%	42%	786%
Terrestrial Eutrophication	124%	25%	155%	122%	6%	86%	-55%	147%
Aquatic Eutrophication	319%	40%	359%	295%	4%	247%	783%	2398%
Particulate Matter	120%	25%	138%	111%	6%	58%	-65%	105%

4.2 Results base scenarios JN FAMILY PACK AUSTRIA

4.2.1 Presentation of results JN FAMILY PACK Austria

Figure 21: Indicator results for base scenarios of segment JN FAMILY PACK, Austria, allocation factor 50% (Part 1)

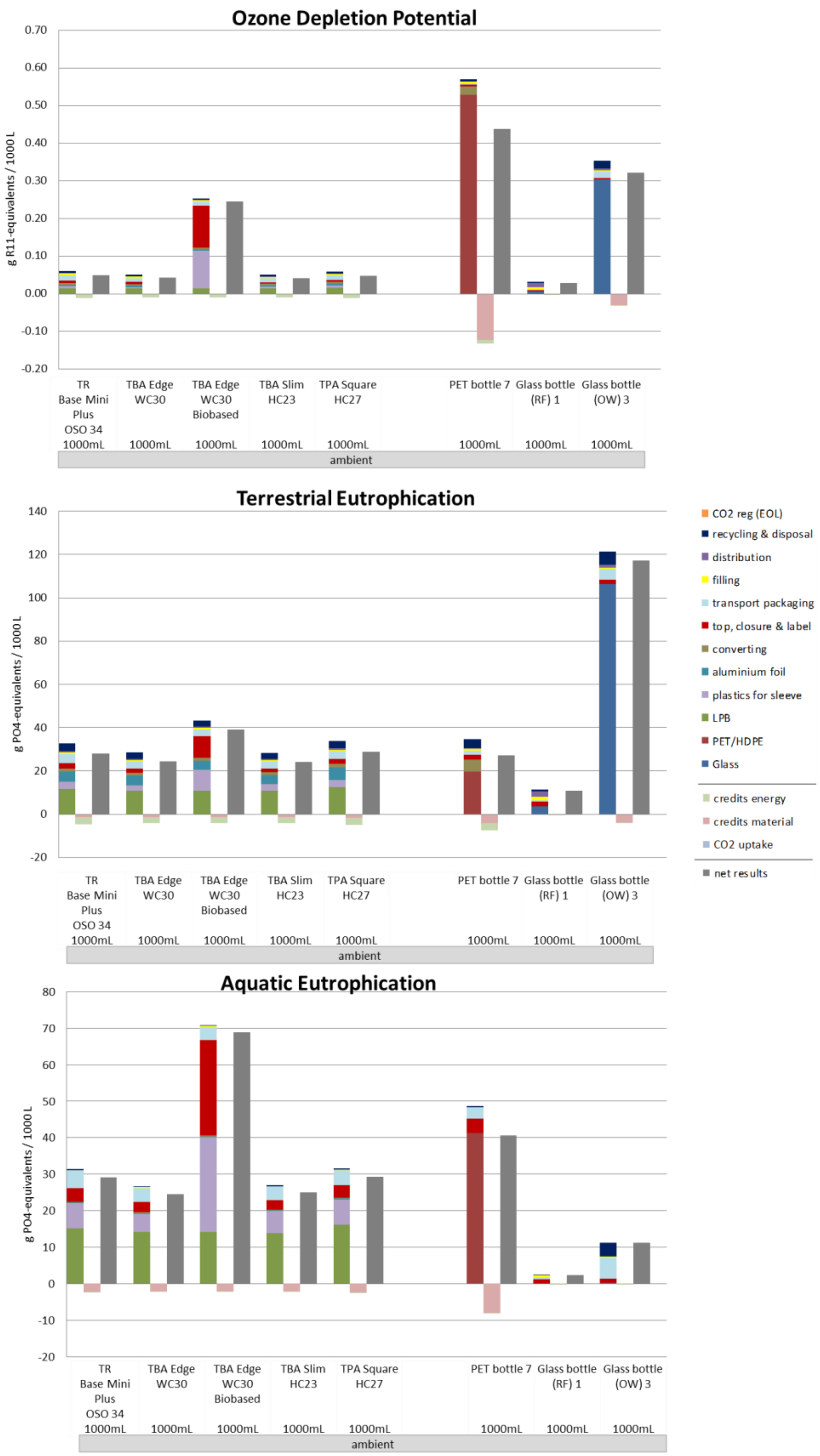


Figure 22: Indicator results for base scenarios of **segment JN FAMILY PACK, Austria**, allocation factor 50% (Part 2)

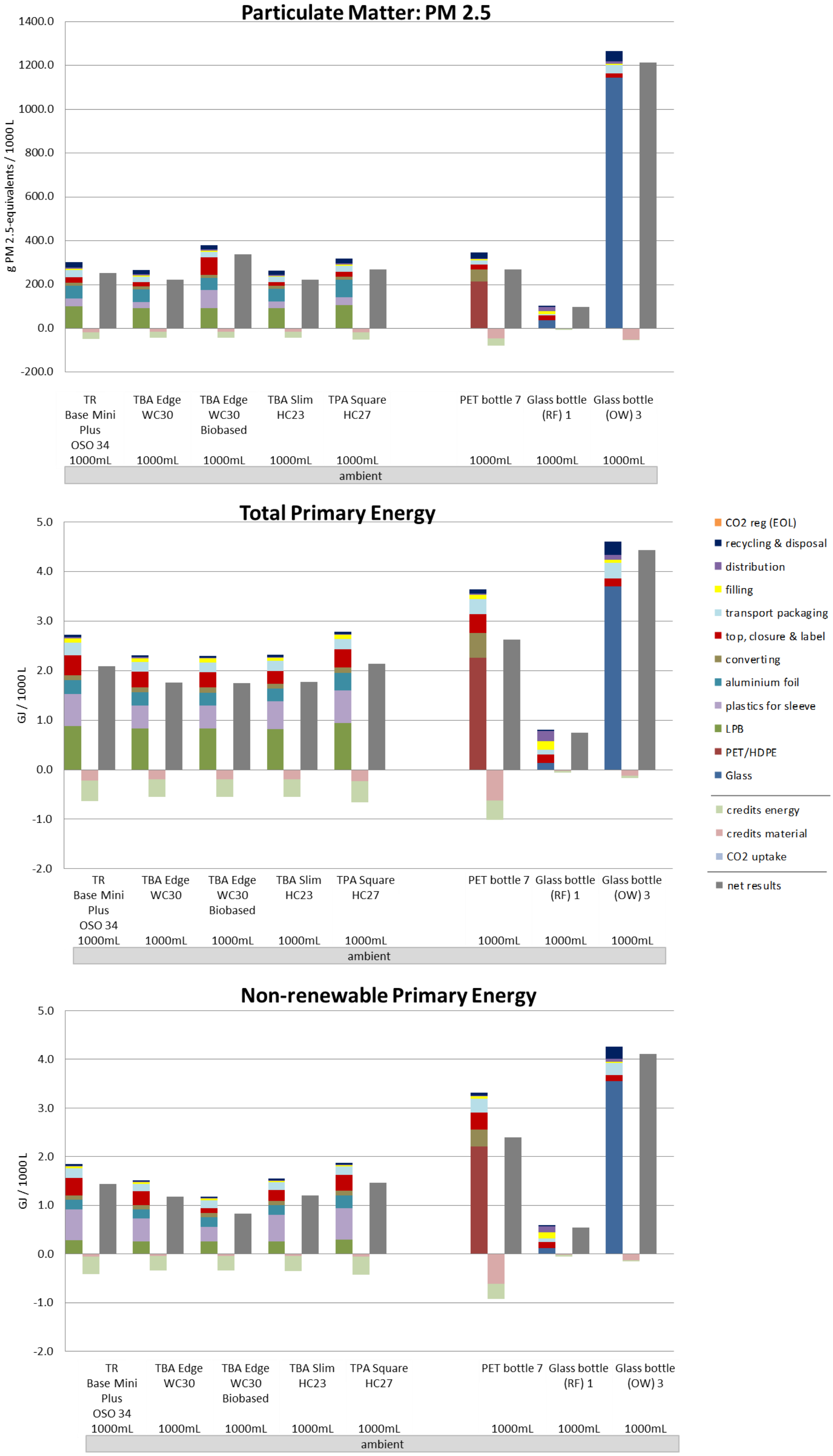
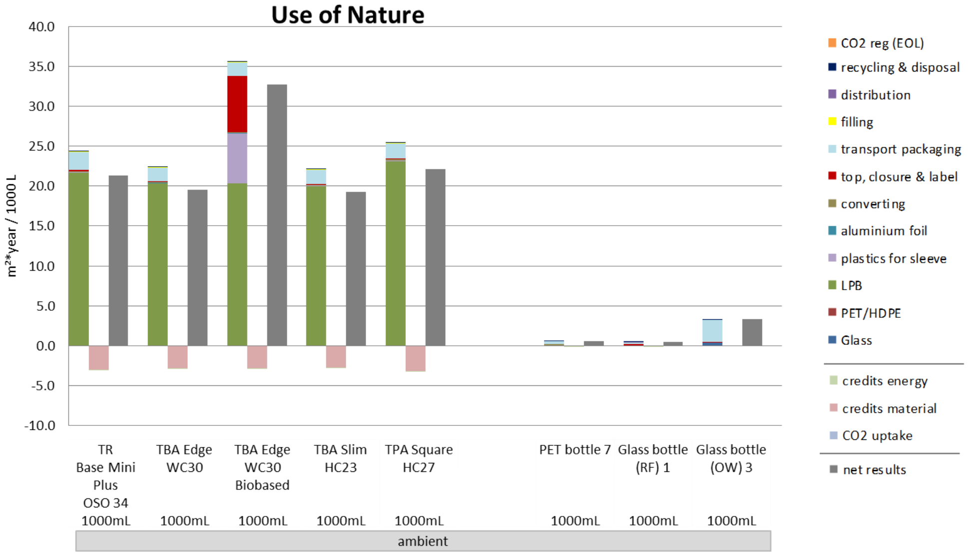


Figure 23: Indicator results for base scenarios of **segment JN FAMILY PACK, Austria**, allocation factor 50% (Part 3)



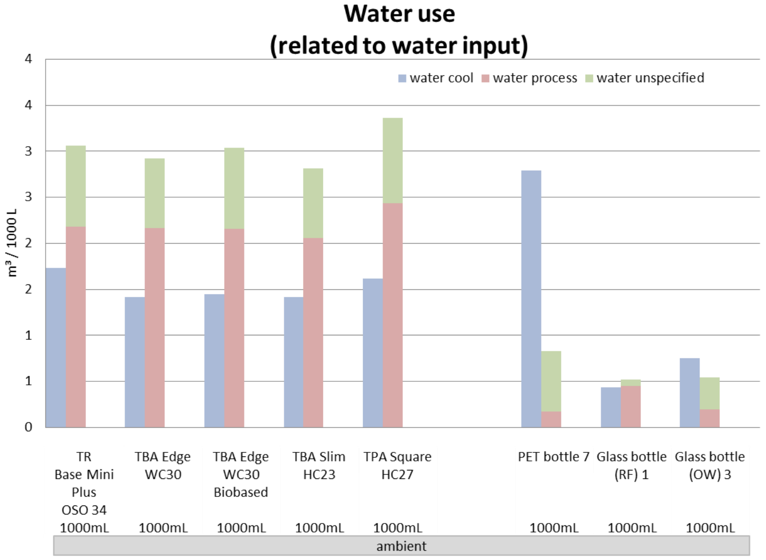


Figure 24: Indicator results for base scenarios of **segment JN FAMILY PACK, Austria**, allocation factor 50% (Part 4)

Table 52: Category indicator results per impact category for base scenarios of segment JN FAMILY PACK, Austria- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places)

Allocation 50		TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	TPA Square HC27 1000mL		PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	102.55	85.68	80.44	86.42	104.94		167.82	41.36	347.74
	CO2 (reg)	21.34	19.44	27.27	19.26	22.10		1.60	3.71	3.77
	Credits	-32.70	-27.38	-27.41	-28.11	-33.69		-42.61	-2.91	-14.56
	CO2 uptake	-44.88	-40.92	-59.01	-40.54	-46.51		-3.29	-7.49	-7.78
	net results	46.31	36.82	21.29	37.04	46.83		123.52	34.67	329.17
Acidification [kg SO2-e/1000 L[	Burdens	0.32	0.28	0.36	0.28	0.34		0.38	0.11	1.28
	Credits	-0.05	-0.05	-0.05	-0.05	-0.06		-0.08	-0.01	-0.04
	Net results	0.27	0.24	0.31	0.23	0.29		0.30	0.10	1.24
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	4.25	3.68	5.16	3.67	4.38		4.56	1.44	15.25
	Credits	-0.60	-0.52	-0.52	-0.53	-0.63		-1.03	-0.07	-0.52
	Net results	3.64	3.16	4.64	3.14	3.76		3.52	1.37	14.74
Ozone Depletion [g R11/1000 L]	Burdens	0.06	0.05	0.25	0.05	0.06		0.57	0.03	0.35
	Credits	-0.01	-0.01	-0.01	-0.01	-0.01		-0.13	0.00	-0.03
	Net results	0.05	0.04	0.25	0.04	0.05		0.44	0.03	0.32
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	32.57	28.41	43.18	28.33	33.75		34.51	11.26	121.42
	Credits	-4.68	-4.04	-4.04	-4.09	-4.86		-7.48	-0.57	-4.22
	Net results	27.90	24.37	39.14	24.25	28.90		27.03	10.69	117.20
Aquatic Eutrophication [g PO4/1000 L]	Burdens	31.38	26.65	70.85	26.95	31.54		48.72	2.48	11.32
	Credits	-2.18	-2.03	-2.03	-2.00	-2.31		-8.01	-0.16	-0.10
	Net results	29.20	24.62	68.83	24.95	29.23		40.71	2.33	11.22
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	301.15	265.73	379.93	264.80	319.95		346.39	104.07	1265.44
	Credits	-48.88	-42.52	-42.54	-42.92	-51.25		-77.50	-5.89	-53.49
	Net results	252.27	223.22	337.39	221.89	268.70		268.88	98.19	1211.95
Total Primary Energy [GJ]	Burdens	2.72	2.31	2.30	2.32	2.79		3.63	0.81	4.60
	Credits	-0.63	-0.55	-0.55	-0.55	-0.66		-1.01	-0.06	-0.17
	Net results	2.08	1.76	1.75	1.77	2.13		2.62	0.75	4.43
Non-renewable Primary Energy [GJ]	Burdens	1.85	1.52	1.18	1.55	1.88		3.31	0.60	4.26
	Credits	-0.41	-0.34	-0.34	-0.35	-0.42		-0.92	-0.05	-0.15
	Net results	1.44	1.18	0.84	1.20	1.46		2.39	0.55	4.11
Use of Nature [m²*year]	Burdens	24.35	22.38	35.55	22.09	25.39		0.61	0.46	3.34
	Credits	-3.05	-2.86	-2.86	-2.81	-3.25		-0.08	-0.03	-0.02
	Net results	21.29	19.52	32.69	19.28	22.14		0.53	0.43	3.32
Water use [m³/1000 L]	water cool	1.73	1.42	1.45	1.41	1.61		2.79	0.44	0.75
	water process	2.18	2.17	2.16	2.06	2.44		0.17	0.45	0.20
	water unspecified	0.88	0.75	0.88	0.75	0.93		0.66	0.07	0.34

4.2.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the JN FAMILY PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories 'Aquatic Eutrophication' (20%-53%) and 'Use of Nature' (57%-91%). It is also relevant regarding 'Photo-Oxidant Formation' (26%-37%) 'Acidification' (27%-34%), 'Terrestrial Eutrophication' (25%-38%), 'Particulate Matter' (25%-35%) and also the consumption of 'Total Primary Energy' (33%-36%). Regarding 'Climate Change' the production of LPB contributes only to 10%-11%.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (19%-27%) and 'Particulate Matter' (15%-25%). These result from SO2 and NOx emissions from the aluminium production.

The production of 'plastics for sleeve' of the beverage cartons with fossil plastics shows considerable burdens in most impact categories (up to 40%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (11%-13%) and LPB (10%-11%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (25%-35%) contribute almost twice as much as LPB (15%-22%) to the total burdens. If 'plastics for sleeve' contains bio-based plastics, this life cycle step plays a major role (20%-40%) for the overall burdens in all categories apart from 'Climate Change' (12%), 'Acidification' (18%) and 'Use of Nature (18%).

The life cycle step 'top, closure & label' for the cartons contributes to a small amount in almost all impact categories (0%-19%). In case the plastics used for 'top, closure & label' are bio-based, the results are considerably higher than cartons with fossil based plastics in all categories except 'Climate Change', 'Total Primary Energy Demand' and 'Non-renewable Primary Energy'.

The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

The converting process generally plays a minor role (0%-9%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (4%-15%). The exception is 'Ozone Depletion Potential' for the cartons with fossil based plastics. In these cases 'transport packaging' has a higher share of 20%-24% of the burdens due to the low share of the categories 'top, closure & label' and 'plastics for sleeve'.

The life cycle step 'filling' shows only minor burdens for all beverage carton systems in all impact categories (max. 7%).

The life cycle step 'distribution' shows only very minor burdens in all impact categories for all beverage carton systems 2%.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (37%-38%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are lower than energy credits in almost all impact categories as in Austria only 34% of the beverage cartons are recycled. Exceptions are 'Aquatic Eutrophication' and 'Use of Nature' which have higher material credits caused by the substitution of fresh fibres. Material credits for 'Climate Change' are low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play an important role on the net results in all categories apart of 'Ozone Depletion Potential'.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the JN FAMILY PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a considerable share of burdens (4%-27%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (1%-11%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (1%-8%) in most categories. The exception is 'Use of Nature' for which 58% of the burdens are caused from 'transport packaging' resulting from the used cardboard slip sheets.

The life cycle step 'filling' shows only small shares of burdens (max. 5%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 1%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (27%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 20% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Glass bottles (specifications see section 2.2.2)

In case of the one way glass bottle even more than for the other regarded packaging systems, the production of the 'glass' material is the main contributor to the overall burdens . The production of glass clearly dominates the results (83%-90%) in all categories apart from 'Aquatic Eutrophication' and 'Use of Nature'.

All other life cycle steps play only a minor role compared to the glass production. For the impact categories, 'Aquatic Eutrophication' (52%) and 'Use of Nature' (81%) transport packaging also plays an important role.

Energy credits play only a minor role for the one-way glass bottle, as the little energy that can be generated in end-of-life mainly comes from the incineration of secondary and tertiary packaging.

Material credits from glass recycling, compared to energy credits have a higher impact on the overall net results apart from 'Aquatic Eutrophication' and 'Use of Nature'. The Impact is still small as most of the glass cullet is used in a closed loop for the production of the glass bottle.

In case of the refillable glass bottle the burdens of 'glass' production are considerably lower than for one way glass bottle. Therefore the share of 'glass' production for the refillable bottle are only (16%-39%) in all categories apart from 'Aquatic Eutrophication' (0%) and 'Use of Nature' (3%).

The lifecycle step 'top, closure & label' contributes with considerable shares (12%-50%) to the total burdens as the closure and label are in opposite of the bottle one way products.

The lifecycle step 'transport packaging' contributes with only minor shares (6%-20%) in most categories to the total burdens due to the reusability of the secondary packaging.

The lifecycle step 'filling' contributes with considerable shares (8%-26%) in all categories to the total burdens

In comparison to the one-way bottle the lifecycle step 'distribution' contributes with considerable shares (13%-37%) in all categories apart from 'Aquatic Eutrophication' (0%) due to the additional transportation of empty bottles.

The impact of the refillable glass bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (15%).

Material credits from glass recycling play a minor role on the overall net results due to the reusability of the glass bottle.

Energy credits play only a minor role for the refillable glass bottle, as the little energy that can be generated in end-of-life mainly comes from the incineration of secondary and tertiary packaging.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

4.2.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 53: Comparison of net results: **TR Base Mini Plus OSO 34 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 50%

JN FAMILY PACK (ambient), Austria	The net results of **TR Base Mini Plus OSO 34 1000mL** are lower (green)/ higher (orange) than those of						
	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	TPA Square HC27 1000ML	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	26%	118%	25%	-1%	-63%	34%	-86%
Acidification	13%	-15%	13%	-7%	-10%	165%	-79%
Photo-Oxidant Formation	15%	-21%	16%	-3%	3%	167%	-75%
Ozone Depletion Potential	18%	-80%	20%	3%	-89%	75%	-84%
Terrestrial Eutrophication	14%	-29%	15%	-3%	3%	161%	-76%
Aquatic Eutrophication	19%	-58%	17%	0%	-28%	1156%	160%
Particulate Matter	13%	-25%	14%	-6%	-6%	157%	-79%

Table 54: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 50%

JN FAMILY PACK (ambient), Austria	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of						
	TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	TPA Square HC27 1000ML	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	-20%	73%	-1%	-21%	-70%	6%	-89%
Acidification	-11%	-25%	0%	-17%	-20%	136%	-81%
Photo-Oxidant Formation	-13%	-32%	0%	-16%	-10%	131%	-79%
Ozone Depletion Potential	-15%	-83%	2%	-13%	-90%	48%	-87%
Terrestrial Eutrophication	-13%	-38%	0%	-16%	-10%	128%	-79%
Aquatic Eutrophication	-16%	-64%	-1%	-16%	-40%	959%	119%
Particulate Matter	-12%	-34%	1%	-17%	-17%	127%	-82%

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

Table 55: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 50%

JN FAMILY PACK (ambient), Austria	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of						
	TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 1000mL	TBA Slim HC23 1000mL	TPA Square HC27 1000ML	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	-54%	-42%	-43%	-55%	-83%	-39%	-94%
Acidification	18%	33%	34%	10%	6%	214%	-75%
Photo-Oxidant Formation	27%	47%	48%	24%	32%	240%	-69%
Ozone Depletion Potential	390%	477%	487%	404%	-44%	757%	-24%
Terrestrial Eutrophication	40%	61%	61%	35%	45%	266%	-67%
Aquatic Eutrophication	136%	180%	176%	135%	69%	2860%	514%
Particulate Matter	34%	51%	52%	26%	25%	244%	-72%

Table 56: Comparison of net results: **TBA Slim HC23 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 50%

JN FAMILY PACK (ambient), Austria	The net results of **TBA Slim HC23 1000mL** are lower (green)/ higher (orange) than those of						
	TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TPA Square HC27 1000ML	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	-20%	1%	74%	-21%	-70%	7%	-89%
Acidification	-12%	0%	-25%	-18%	-21%	135%	-81%
Photo-Oxidant Formation	-14%	0%	-32%	-16%	-11%	130%	-79%
Ozone Depletion Potential	-17%	-2%	-83%	-14%	-90%	46%	-87%
Terrestrial Eutrophication	-13%	0%	-38%	-16%	-10%	127%	-79%
Aquatic Eutrophication	-15%	1%	-64%	-15%	-39%	973%	122%
Particulate Matter	-12%	-1%	-34%	-17%	-17%	126%	-82%

Table 57: Comparison of net results: **TBA Square HC27 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 50%

JN FAMILY PACK (ambient), Austria	The net results of **TPA Square HC27 1000mL** are lower (green)/ higher (orange) than those of						
	TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	1%	27%	120%	26%	-62%	35%	-86%
Acidification	8%	21%	-9%	22%	-3%	185%	-77%
Photo-Oxidant Formation	3%	19%	-19%	20%	7%	175%	-75%
Ozone Depletion Potential	-3%	15%	-80%	17%	-89%	70%	-85%
Terrestrial Eutrophication	4%	19%	-26%	19%	7%	170%	-75%
Aquatic Eutrophication	0%	19%	-58%	17%	-28%	1157%	161%
Particulate Matter	7%	20%	-20%	21%	0%	174%	-78%

4.3 Results base scenarios *SD FAMILY PACK AUSTRIA*

4.3.1 Presentation of results SD FAMILY PACK Austria

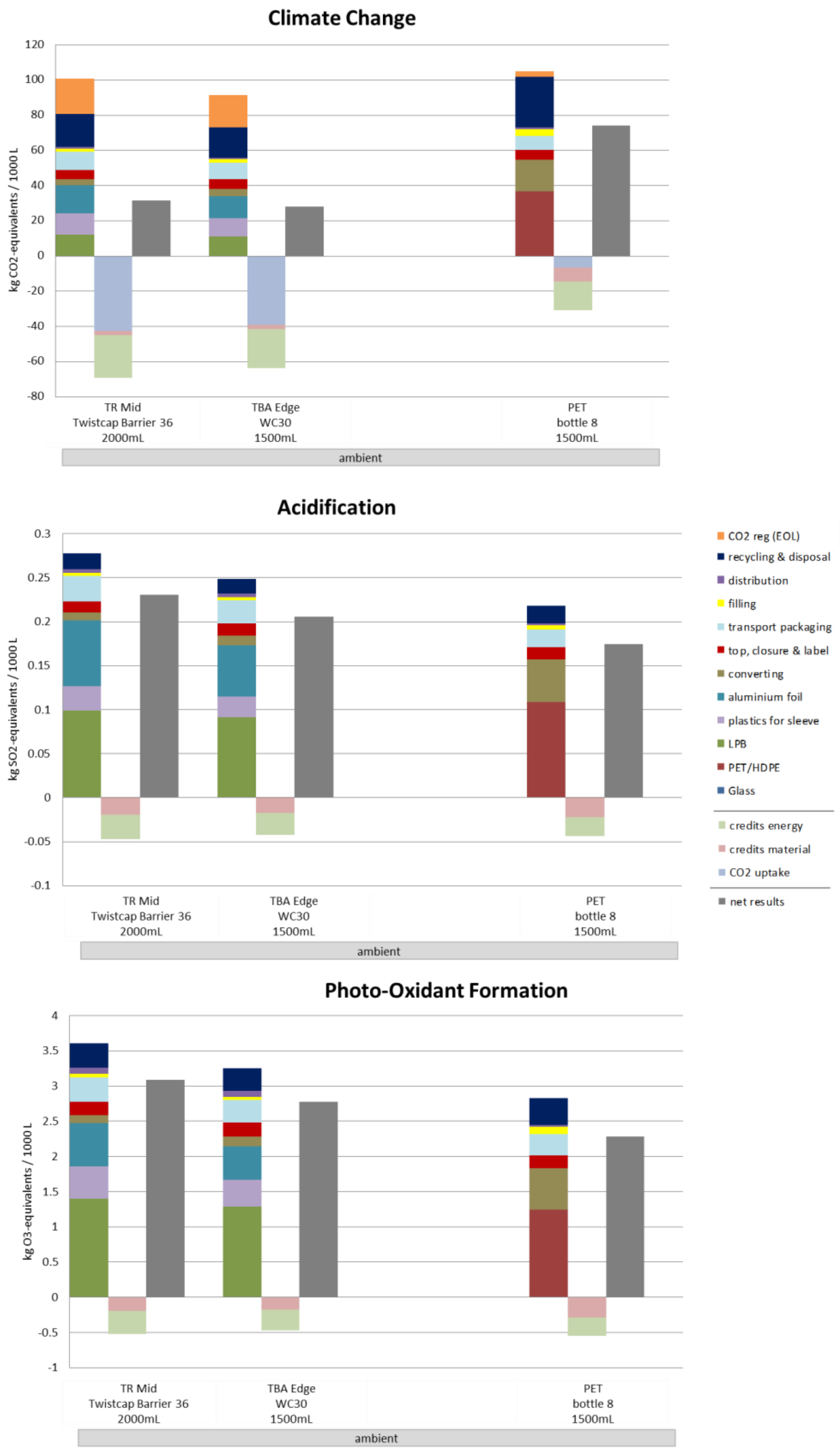


Figure 25: Indicator results for base scenarios of **segment SD FAMILY PACK, Austria**, allocation factor 50% (Part 1)

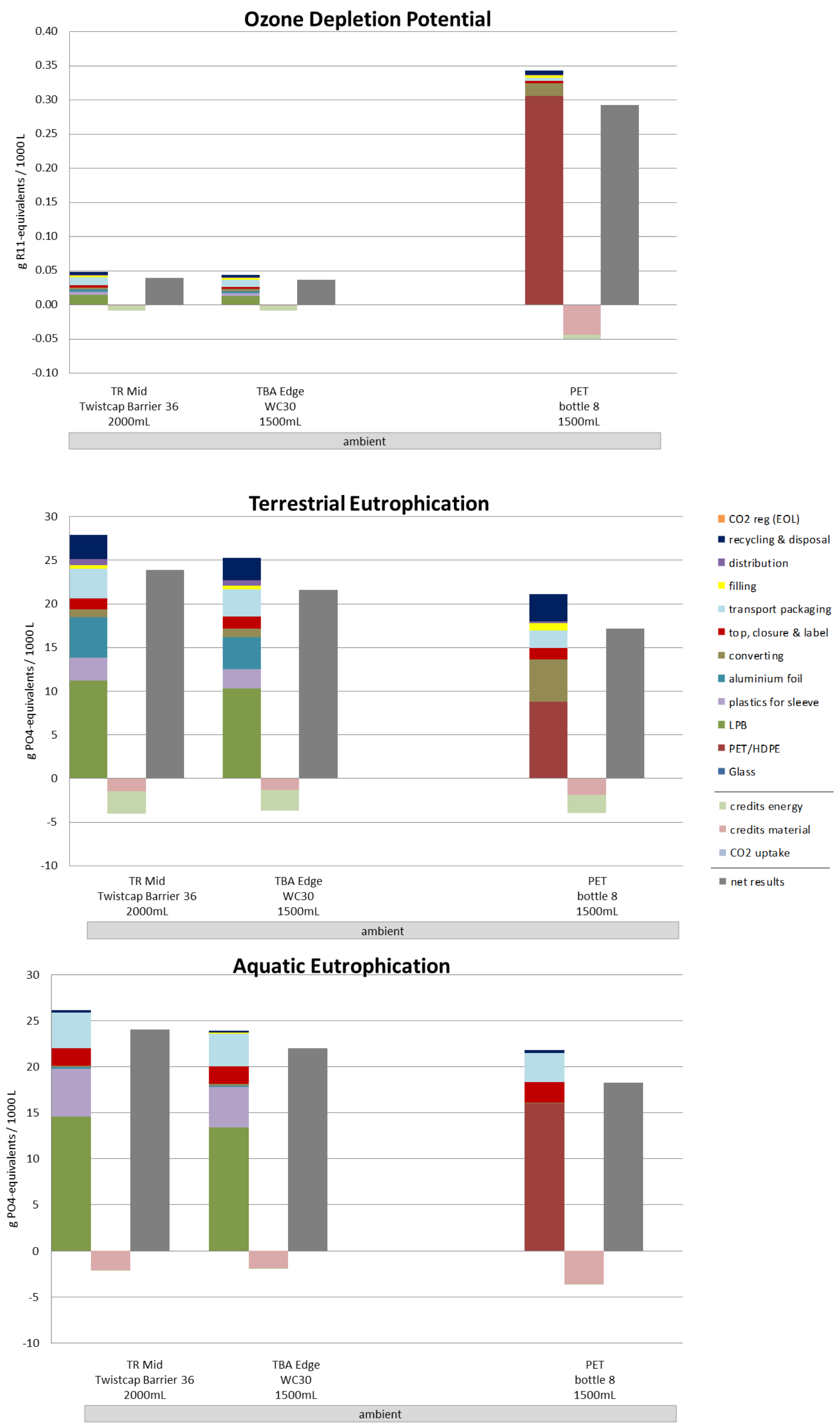


Figure 26: Indicator results for base scenarios of **segment SD FAMILY PACK, Austria**, allocation factor 50% (Part 2)

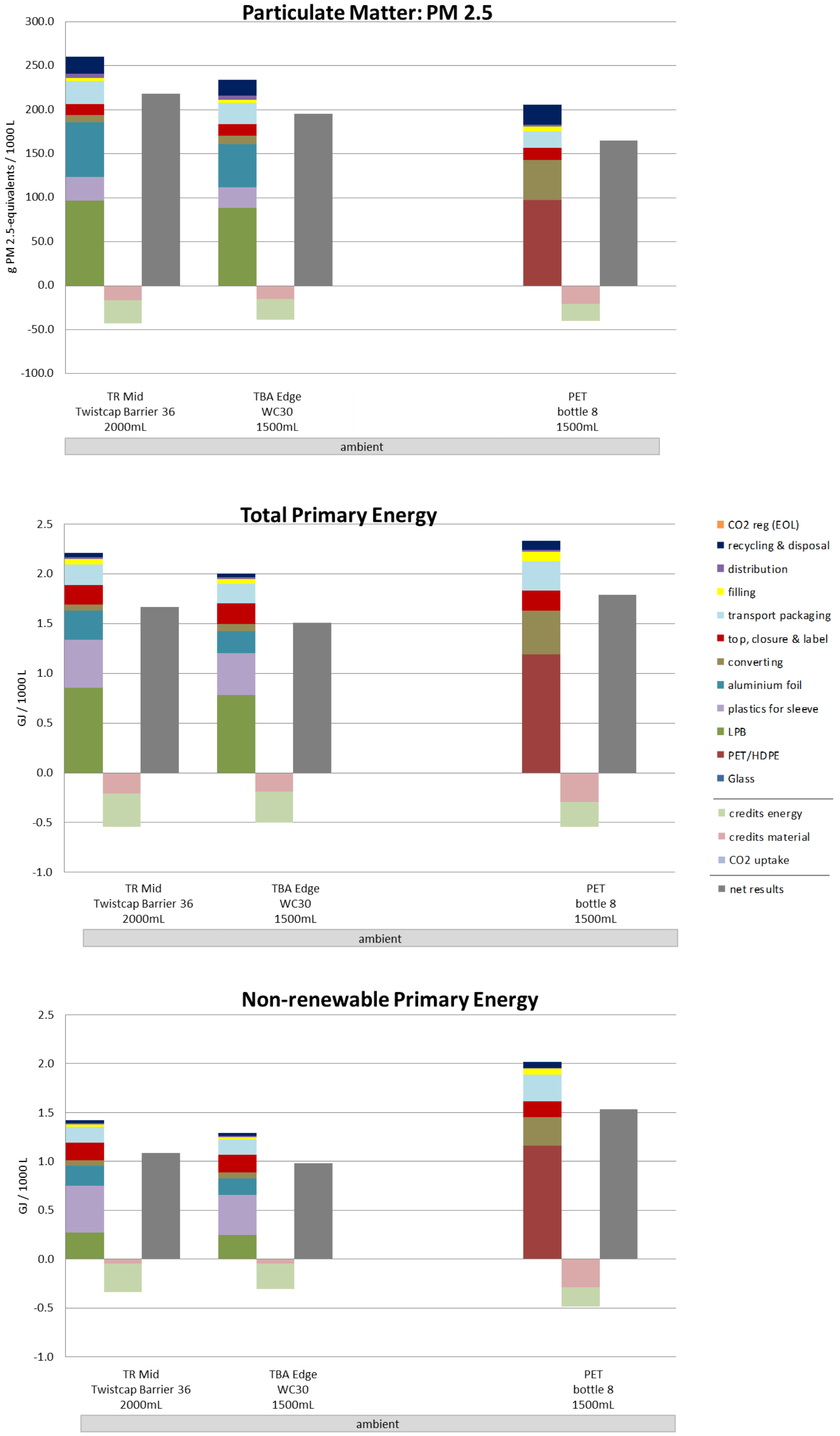
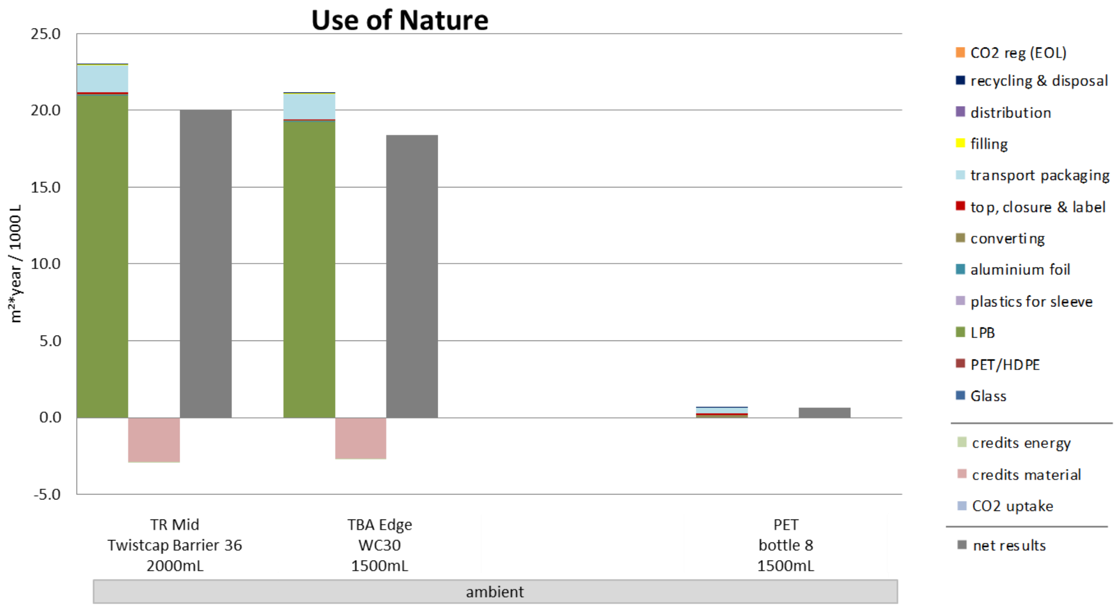


Figure 27: Indicator results for base scenarios of **segment SD FAMILY PACK, Austria**, allocation factor 50% (Part 3)



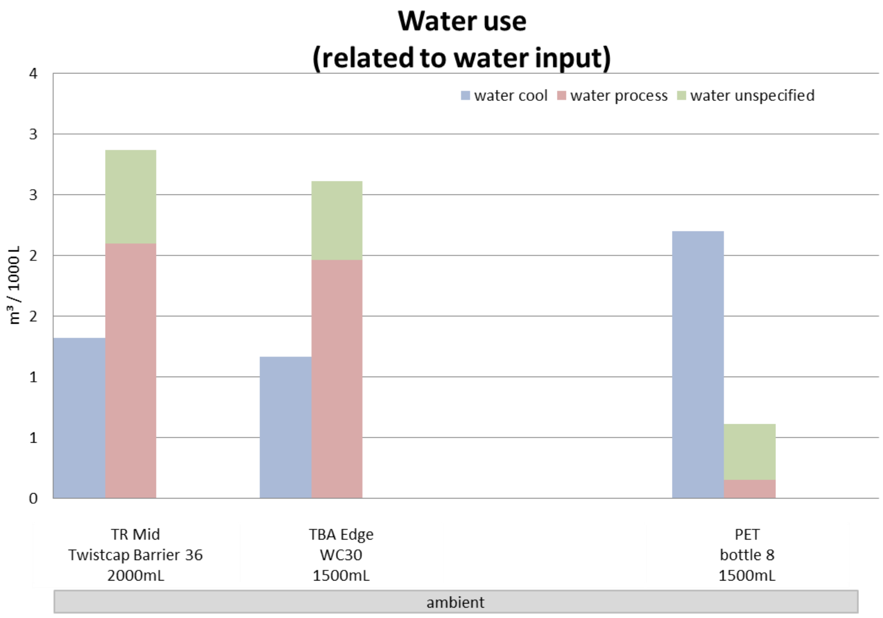


Figure 28: Indicator results for base scenarios of **segment SD FAMILY PACK, Austria**, allocation factor 50% (Part 4)

Table 58: Category indicator results per impact category for base scenarios of **segment SD FAMILY PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TR Mid Twistcap Barrier 36 2000mL	TBA Edge WC30 1500mL		PET bottle 8 1500mL
Climate Change [kg CO2-e/1000 L[	Burdens	80.76	73.00		101.92
	CO2 (reg)	20.16	18.60		3.15
	Credits	-26.85	-24.36		-24.19
	CO2 uptake	-42.42	-39.13		-6.55
	net results	31.64	28.11		74.32
Acidification [kg SO2-e/1000 L[	Burdens	0.28	0.25		0.22
	Credits	-0.05	-0.04		-0.04
	Net results	0.23	0.21		0.17
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.61	3.25		2.83
	Credits	-0.52	-0.47		-0.55
	Net results	3.09	2.78		2.28
Ozone Depletion [g R11/1000 L]	Burdens	0.05	0.04		0.34
	Credits	-0.01	-0.01		-0.05
	Net results	0.04	0.04		0.29
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	27.92	25.28		21.09
	Credits	-4.03	-3.67		-3.93
	Net results	23.89	21.61		17.16
Aquatic Eutrophication [g PO4/1000 L]	Burdens	26.12	23.93		21.82
	Credits	-2.08	-1.92		-3.59
	Net results	24.04	22.01		18.23
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	260.47	234.07		205.37
	Credits	-42.53	-38.52		-40.05
	Net results	217.94	195.54		165.31
Total Primary Energy [GJ]	Burdens	2.21	2.00		2.33
	Credits	-0.54	-0.50		-0.54
	Net results	1.66	1.51		1.79
Non-renewable Primary Energy [GJ]	Burdens	1.42	1.29		2.02
	Credits	-0.34	-0.31		-0.49
	Net results	1.09	0.98		1.53
Use of Nature [m²*year]	Burdens	22.98	21.11		0.69
	Credits	-2.94	-2.70		-0.06
	Net results	20.04	18.41		0.63
Water use [m³/1000 L]	water cool	1.32	1.17		2.20
	water process	2.10	1.96		0.15
	water unspecified	0.77	0.65		0.46

4.3.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the SD FAMILY PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories 'Aquatic Eutrophication' (56%-56%) and 'Use of Nature' (91%-91%). It is also relevant regarding 'Photo-Oxidant Formation' (39%-40%) 'Acidification' (36%-37%), 'Terrestrial Eutrophication' (40%-41%), 'Particulate Matter' (37%-38%) and also the consumption of 'Total Primary Energy' (39%-39%). Regarding 'Climate Change' the production of LPB contributes only to 12%-12%.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (24%-27%) and 'Particulate Matter' (21%-24%). These result from SO2 and NOx emissions from the aluminium production.

The production of 'plastics for sleeve' of the beverage cartons with fossil plastics shows considerable burdens in most impact categories (up to 34%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (11%-12%) and LPB (12%-12%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (32%-34%) contribute more than LPB (19%-19%) to the total burdens.

The life cycle step 'top, closure & label' for TBA and TR cartons contributes to a small amount in almost all impact categories (0%-14%).

The converting process generally plays a minor role (0%-7%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of ‘transport packaging’ for the beverage carton systems show minor impacts in most categories (8%-15%). The exception is ‘Ozone Depletion Potential’ for these cartons with fossil based plastics. In these cases ‘transport packaging’ has a higher share of 24% of the burdens due to the low share of the categories ‘top, closure & label’ and ‘plastics for sleeve’.

The life cycle step ‘filling’ shows only minor burdens for all beverage carton systems in all impact categories (max. 6%).

The life cycle step ‘distribution’ shows only very minor burdens in all impact categories for all beverage carton systems 3%.

The life cycle step ‘recycling & disposal’ of the regarded beverage cartons is most relevant in the impact category ‘Climate Change’. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

‘CO2 reg. (recycling & disposal)’ describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of paper. They play an important role for the results of all beverage carton systems in the impact category ‘Climate Change’. Together with the fossil-based CO2 emissions of the life cycle step ‘recycling & disposal’, they represent the total CO2 emissions from the packaging’s end-of-life (39%-39%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are lower than energy credits in almost all impact categories as in Austria only 34% of the beverage cartons are recycled. Exceptions are ‘Aquatic Eutrophication’ and ‘Use of Nature’ which have higher material credits caused by the substitution of fresh fibres. Material credits for ‘Climate Change’ are low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play an important role on the net results in all categories apart of ‘Ozone Depletion Potential’.

The uptake of CO2 by trees harvested for the production of paperboard 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. 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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the JN FAMILY PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a considerable share of burdens (5%-23%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (1%-17%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (1%-15%) in most categories. The exception is 'Use of Nature' for which 52% of the burdens are caused from 'transport packaging' resulting from the used cardboard slip sheets.

The life cycle step 'filling' shows only small shares of burdens (max. 4%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 1%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (30%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 20% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

4.3.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 59: Comparison of net results: **TR Mid Twistcap Barrier 36 2000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Austria**, allocation factor 50%

SD FAMILY PACK (ambient), Austria	The net results of **TR Mid Twistcap Barrier 36 2000mL** are lower (green)/ higher (orange) than those of	
	TBA Edge WC30 1500mL	PET bottle 8 1500mL
Climate Change	13%	-57%
Acidification	12%	32%
Photo-Oxidant Formation	11%	35%
Ozone Depletion Potential	9%	-86%
Terrestrial Eutrophication	11%	39%
Aquatic Eutrophication	9%	32%
Particulate Matter	11%	32%

Table 60: Comparison of net results: **TBA Edge WC30 1500mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Austria**, allocation factor 50%

SD FAMILY PACK (ambient), Austria	The net results of **TBA Edge WC30 1500mL** are lower (green)/ higher (orange) than those of	
	TR Mid Twistcap Barrier 36 2000mL	PET bottle 8 1500mL
Climate Change	-11%	-62%
Acidification	-11%	18%
Photo-Oxidant Formation	-10%	22%
Ozone Depletion Potential	-8%	-88%
Terrestrial Eutrophication	-10%	26%
Aquatic Eutrophication	-8%	21%
Particulate Matter	-10%	18%

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

4.4 Results base scenarios DAIRY PORTION PACK AUSTRIA

4.4.1 Presentation of results DAIRY PORTION PACK Austria

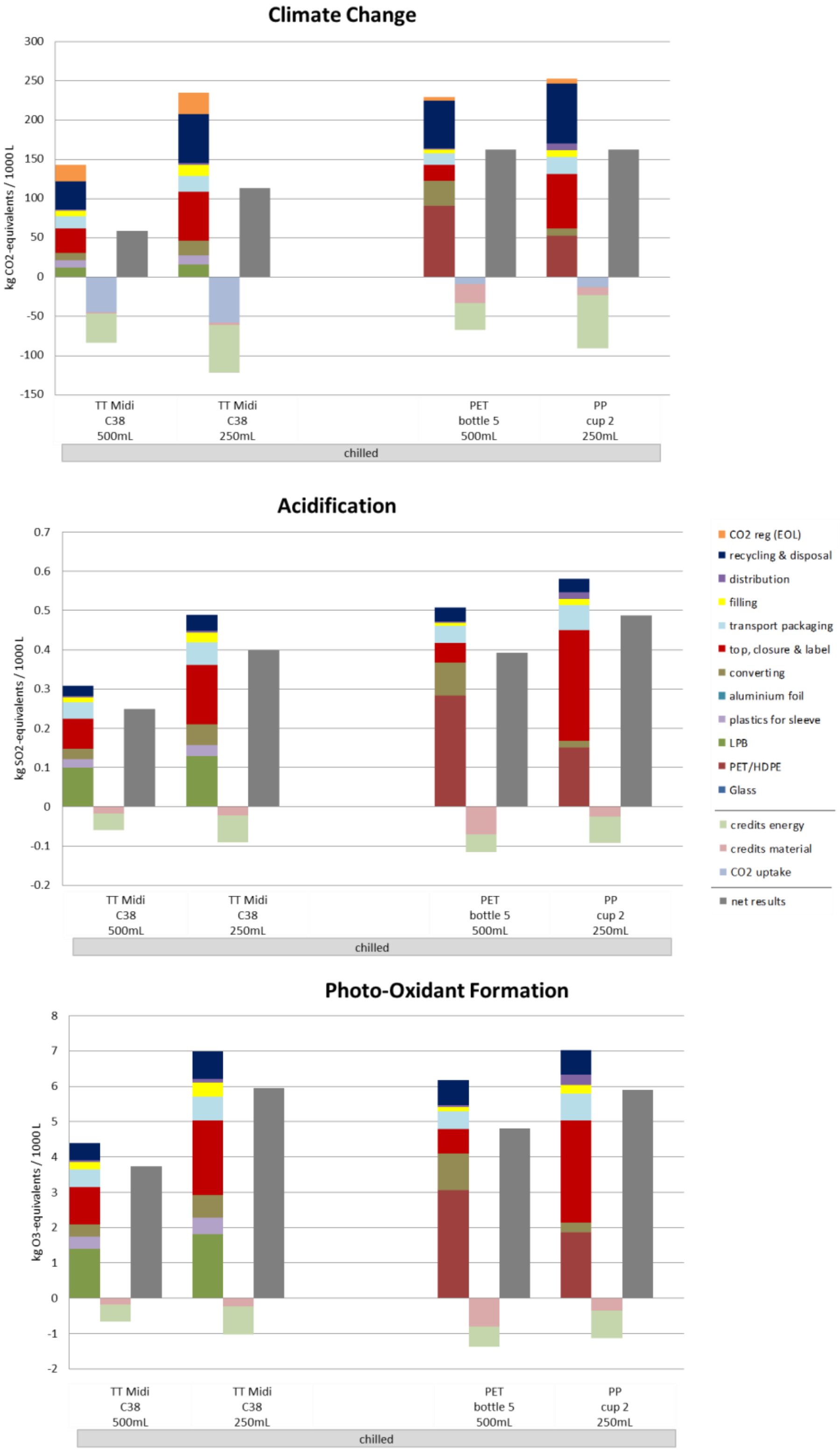


Figure 29: Indicator results for base scenarios of **segment DAIRY PORTION PACK, Austria**, allocation factor 50% (Part 1)

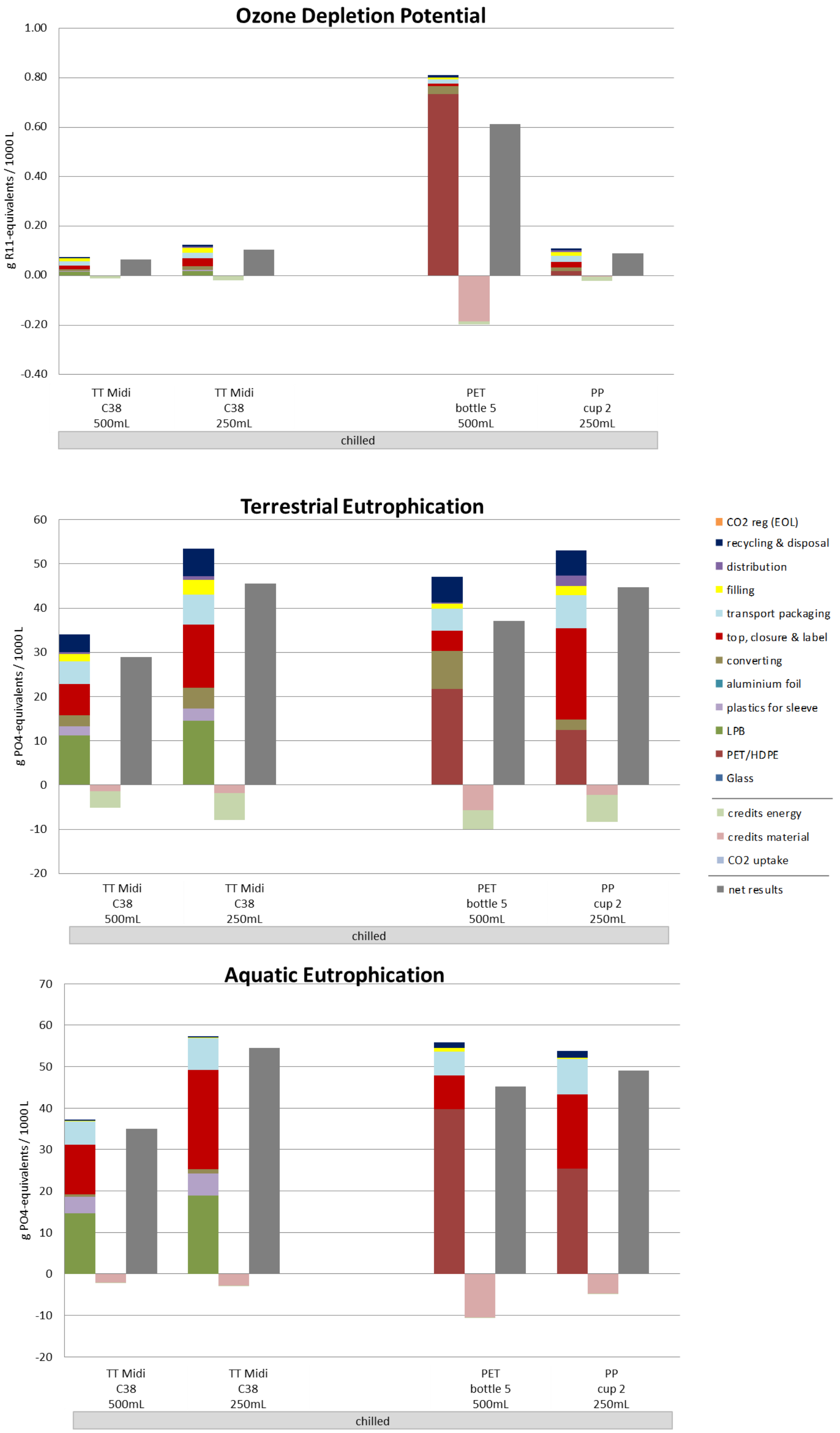


Figure 30 Indicator results for base scenarios of **segment DAIRY PORTION PACK, Austria**, allocation factor 50% (Part 2)

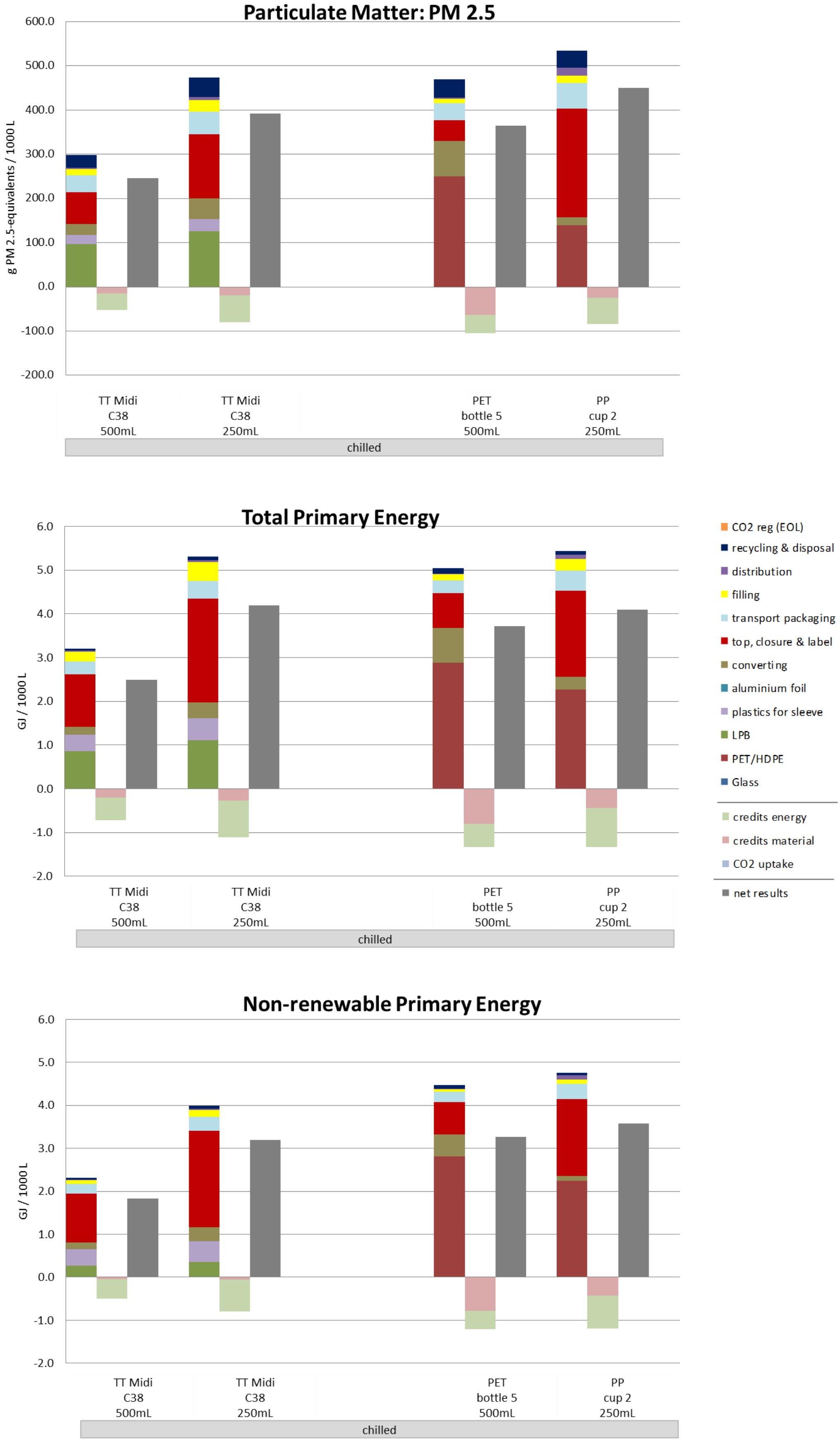
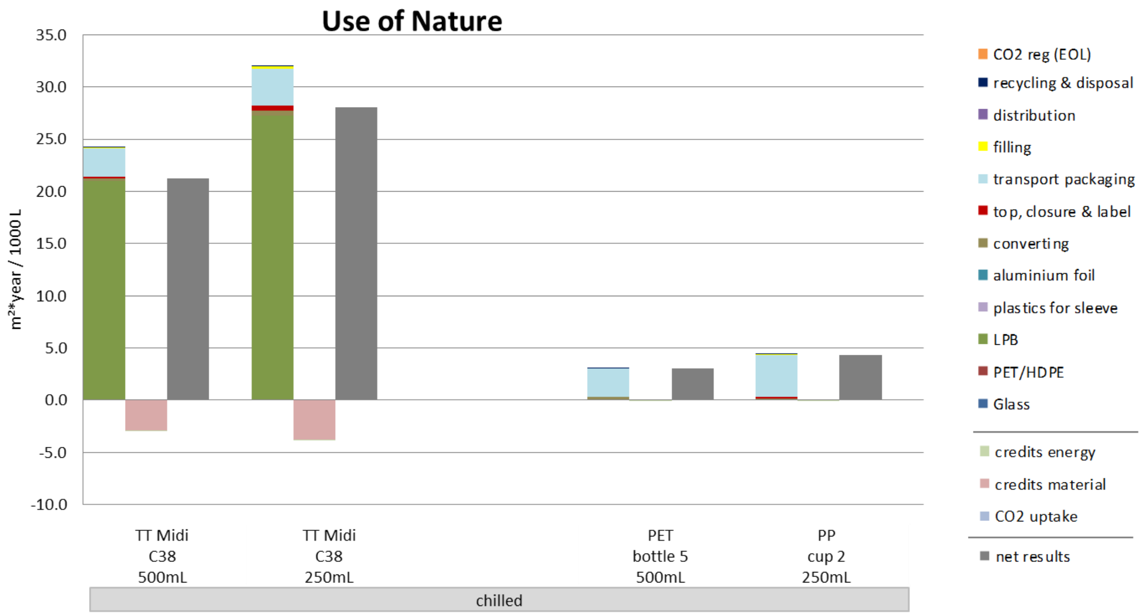


Figure 31: Indicator results for base scenarios of segment DAIRY PORTION PACK, Austria, allocation factor 50% (Part 3)



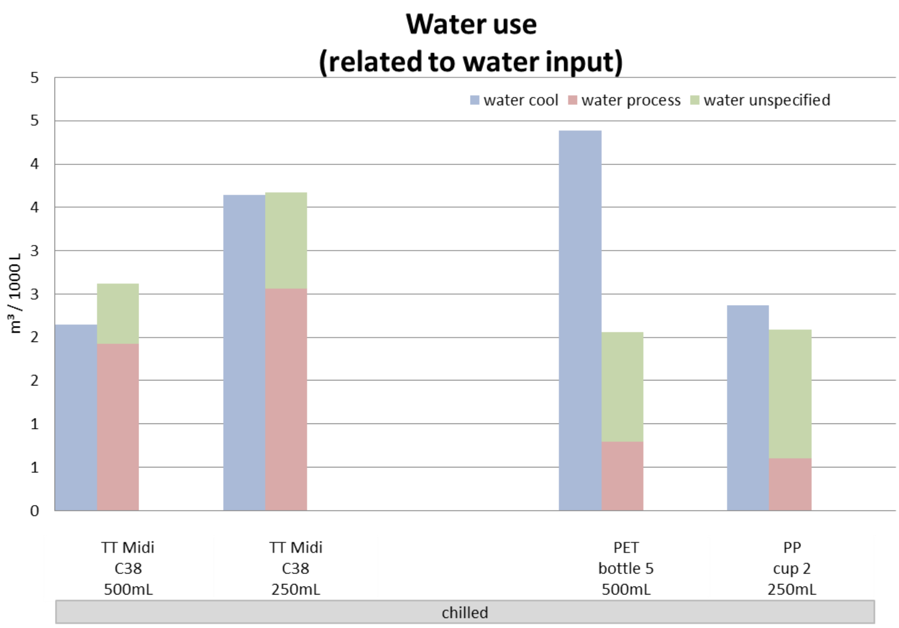


Figure 32: Indicator results for base scenarios of segment DAIRY PORTION PACK, Austria, allocation factor 50% (Part 4)

Table 61: Category indicator results per impact category for base scenarios of **segment DAIRY PORTION PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TT Midi C38 500mL	TT Midi C38 250mL		PET bottle 5 500mL	PP cup 2 250mL
Climate Change [kg CO2-e/1000 L[	Burdens	121.98	207.71		225.27	246.62
	CO2 (reg)	21.10	27.54		4.20	6.17
	Credits	-39.47	-63.78		-58.09	-77.32
	CO2 uptake	-44.33	-57.86		-8.85	-12.99
	net results	59.28	113.61		162.52	162.47
Acidification [kg SO2-e/1000 L[	Burdens	0.31	0.49		0.51	0.58
	Credits	-0.06	-0.09		-0.12	-0.09
	Net results	0.25	0.40		0.39	0.49
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	4.40	6.98		6.18	7.02
	Credits	-0.67	-1.03		-1.36	-1.12
	Net results	3.73	5.96		4.81	5.90
Ozone Depletion [g R11/1000 L]	Burdens	0.08	0.12		0.81	0.11
	Credits	-0.01	-0.02		-0.20	-0.02
	Net results	0.06	0.11		0.61	0.09
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	34.06	53.48		47.08	53.05
	Credits	-5.19	-7.96		-10.03	-8.36
	Net results	28.87	45.52		37.04	44.69
Aquatic Eutrophication [g PO4/1000 L]	Burdens	37.17	57.39		55.83	53.71
	Credits	-2.14	-2.81		-10.55	-4.71
	Net results	35.03	54.57		45.27	49.00
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	297.71	472.96		469.03	534.13
	Credits	-52.57	-80.49		-104.56	-84.57
	Net results	245.14	392.47		364.48	449.56
Total Primary Energy [GJ]	Burdens	3.21	5.30		5.04	5.43
	Credits	-0.72	-1.11		-1.33	-1.33
	Net results	2.49	4.20		3.71	4.10
Non-renewable Primary Energy [GJ]	Burdens	2.32	3.99		4.47	4.76
	Credits	-0.49	-0.79		-1.21	-1.19
	Net results	1.83	3.20		3.27	3.57
Use of Nature [m²*year]	Burdens	24.20	31.96		3.09	4.45
	Credits	-2.97	-3.88		-0.09	-0.13
	Net results	21.23	28.08		3.00	4.32
Water use [m³/1000 L]	water cool	2.14	3.65		4.39	2.37
	water process	1.92	2.56		0.80	0.60
	water unspecified	0.70	1.10		1.27	1.49

4.4.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the DAIRY PORTION PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories ‘Aquatic Eutrophication’ (33%-39%) and ‘Use of Nature’ (85%-87%). It is also relevant regarding ‘Photo-Oxidant Formation’ (26%-32%) ‘Acidification’ (26%-32%), ‘Terrestrial Eutrophication’ (27%-33%), ‘Particulate Matter’ (27%-32%) and also the consumption of ‘Total Primary Energy’ (21%-27%). Regarding ‘Climate Change’ the production of LPB is responsible for only 7%-9% of the burdens.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both ‘Aquatic Eutrophication’ and ‘Terrestrial Eutrophication’, the latter to a lesser extent. Approximately half of the ‘Aquatic Eutrophication Potential’ is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the ‘Terrestrial Eutrophication Potential’, nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called ‘Kraft process’ is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories ‘Total Primary Energy’ and ‘Non-renewable Primary Energy’.

The production of ‘aluminium foil’ for the sleeves of chilled beverage cartons shows no burdens in all impact categories as the chilled beverage cartons don’t have an aluminium foil layer.

The production of ‘plastics for sleeve’ of the beverage cartons shows considerable burdens in most impact categories (up to 16%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (5%-7%) and LPB (7%-9%) contribute about the same and the inventory category ‘Non-renewable Primary Energy’, where the plastics (12%-16%) contribute more than LPB (9%-12%) to the total burdens.

The life cycle step ‘top, closure & label’ for the TT cartons contributes to a substantial amount in almost all impact categories (21%-57%).

The converting process generally plays a minor role (1%-11%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of ‘transport packaging’ for the beverage carton systems show minor impacts in most categories (8%-15%). The exception is ‘Ozone Depletion Potential’ for the cartons with fossil based plastics. In these cases ‘transport packaging’ has a higher share of 18%-22% of the burdens due to the low share of the categories ‘top, closure & label’ and ‘plastics for sleeve’.

The life cycle step ‘filling’ shows only considerable shares of burdens (up to 17%) for all TT beverage carton systems due to the additional moulding process of the top.

The life cycle step ‘distribution’ shows only very minor burdens in all impact categories for all beverage carton systems 2%.

The life cycle step ‘recycling & disposal’ of the regarded beverage cartons is most relevant in the impact category ‘Climate Change’. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

‘CO2 reg. (recycling & disposal)’ describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of paper. They play an important role for the results of all beverage carton systems in the impact category ‘Climate Change’. Together with the fossil-based CO2 emissions of the life cycle step ‘recycling & disposal’, they represent the total CO2 emissions from the packaging’s end-of-life (38%-40%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are lower than energy credits in almost all impact categories as in Austria only 34% of the beverage cartons are recycled. Exceptions are ‘Aquatic Eutrophication’ and ‘Use of Nature’ which have higher material credits caused by the substitution of fresh fibres. Material credits for ‘Climate Change’ are low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play an important role on the net results in all categories apart of ‘Ozone Depletion Potential’.

The uptake of CO2 by trees harvested for the production of paperboard 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. 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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the DAIRY PORTION PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a minor share of burdens (4%-18%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (1%-17%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (2%-11%) in most categories. The exception is 'Use of Nature' for which 86% of the burdens are caused from 'transport packaging' resulting from the used cardboard.

The life cycle step 'filling' shows only small shares of burdens (max. 3%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 1%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (29%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 20%-30% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

PP cups (specifications see section 2.2.2)

In the regarded PP cup system in the DAIRY PORTION PACK segment, the major shares of the environmental burdens are caused by the production of the base materials of the cups (1%-47%), the life cycle step 'top, closure & label' (3%-48%) and 'Transport Packaging' (8%-89%).

The 'converting' process of the regarded PP Cup shows a small share of impacts (max 13%) in all categories apart from 'Aquatic Eutrophication' with less than 1% share of burdens. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows high impacts (3%-48%) in most categories attributed to the used plastics in cap and label as well as to the aluminium used for the pull taps.

The production and provision of 'transport packaging' for the PP cups shows high shares of impacts (8%-89%) in all categories. The relevant emissions derive from the production of paper for trays and slipsheets.

The life cycle step 'filling' shows only minor shares of burdens (max. 12%) for the PP cup in all categories.

The life cycle step 'distribution' shows minor shares of burdens (max. 8%) in all impact categories.

The impact of the PP Cup's 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (33%). The incineration of cups in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. Energy credits reduce the overall burdens by 2%-27% in most categories. The energy credits mainly originate from the incineration plants and cement kilns. Material credits reduce the overall burdens by 1%-9%. Material credits originate mainly from the substitution of virgin PP with recycled PP from the bottle.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

4.4.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 62: Comparison of net results: **TT Midi C38 500mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (chilled), Austria**, allocation factor 50%

DAIRY PORTION PACK (chilled), Austria	The net results of **TT Midi C38 500mL** are lower (green)/ higher (orange) than those of		
	TT Midi C38 250mL	PET bottle 5 500mL	PP cup 2 250mL
Climate Change	-48%	-64%	-64%
Acidification	-38%	-37%	-49%
Photo-Oxidant Formation	-37%	-22%	-37%
Ozone Depletion Potential	-39%	-90%	-29%
Terrestrial Eutrophication	-37%	-22%	-35%
Aquatic Eutrophication	-36%	-23%	-29%
Particulate Matter	-38%	-33%	-45%

Table 63: Comparison of net results: **TT Midi C38 250mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (chilled), Austria**, allocation factor 50%

DAIRY PORTION PACK (chilled), Austria	The net results of **TT Midi C38 250mL** are lower (green)/ higher (orange) than those of		
	TT Midi C38 500mL	PET bottle 5 500mL	PP cup 2 250mL
Climate Change	92%	-30%	-30%
Acidification	60%	2%	-18%
Photo-Oxidant Formation	60%	24%	1%
Ozone Depletion Potential	65%	-83%	18%
Terrestrial Eutrophication	58%	23%	2%
Aquatic Eutrophication	56%	21%	11%
Particulate Matter	60%	8%	-13%

4.5 Results base scenarios CREAM PORTION PACK AUSTRIA

4.5.1 Presentation of results CREAM PORTION PACK Austria

Figure 33: Indicator results for base scenarios of segment CREAM PORTION PACK, Austria, allocation factor 50% (Part 1)

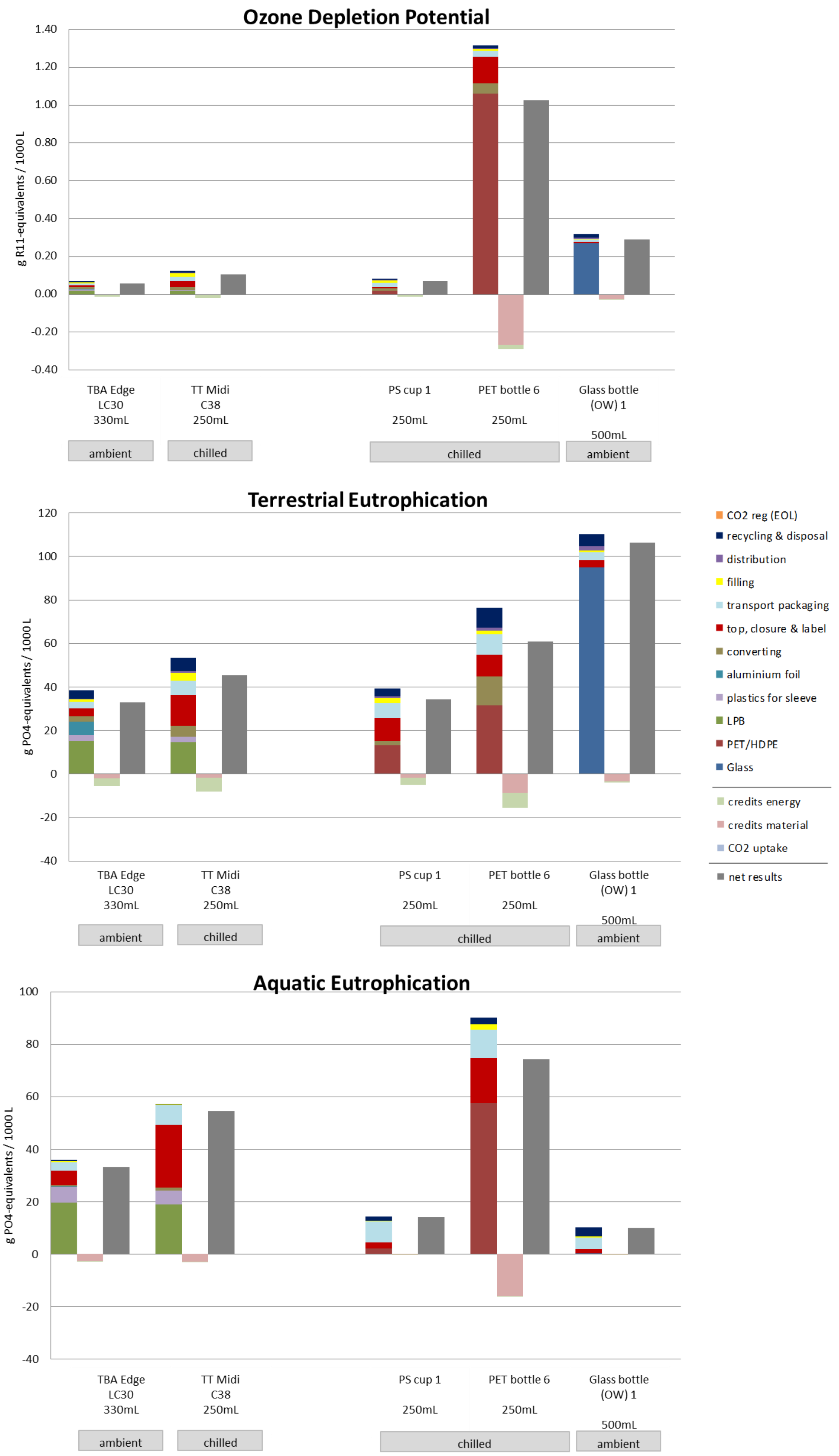


Figure 34 Indicator results for base scenarios of **segment CREAM PORTION PACK, Austria**, allocation factor 50% (Part 2)

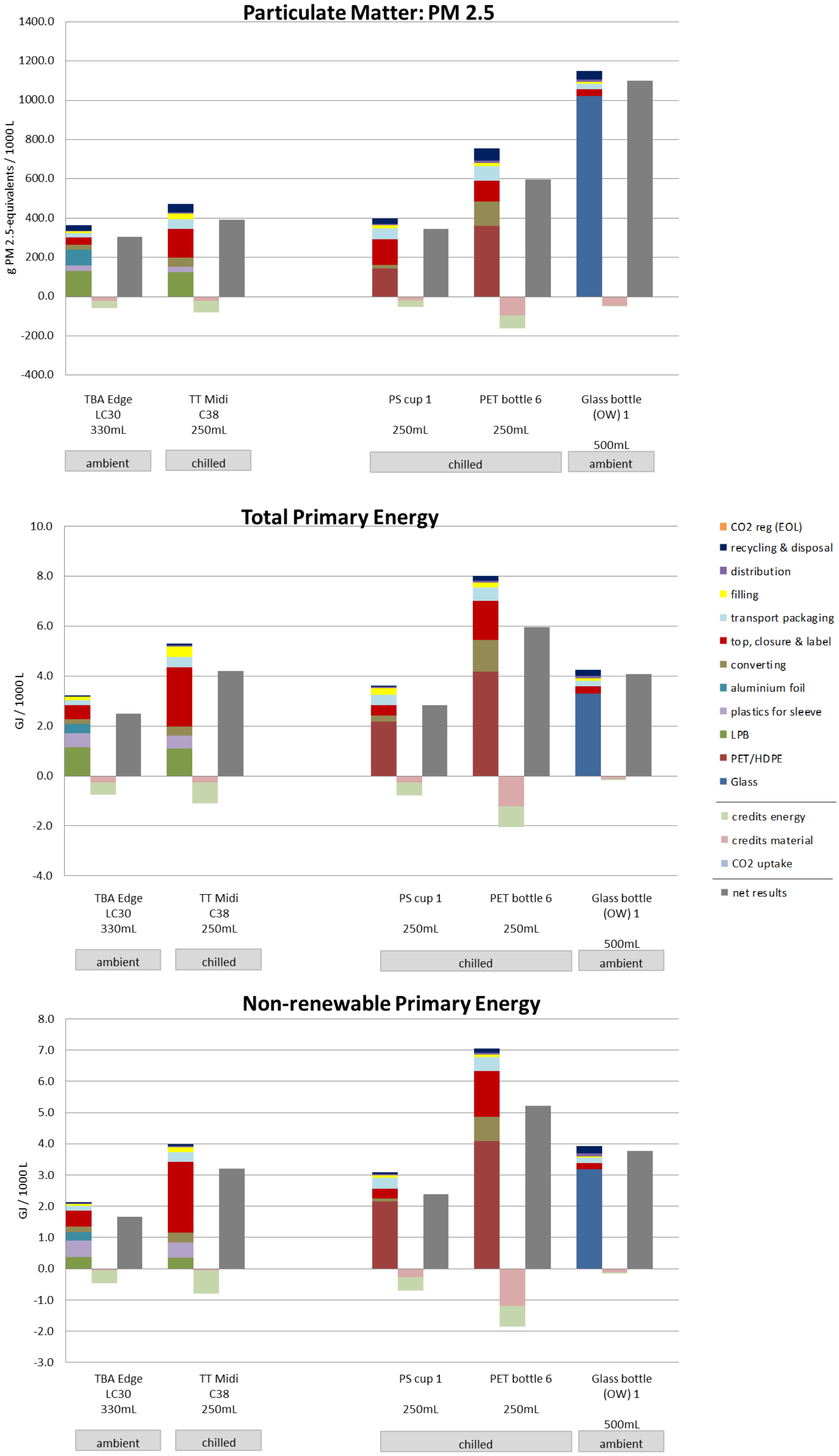
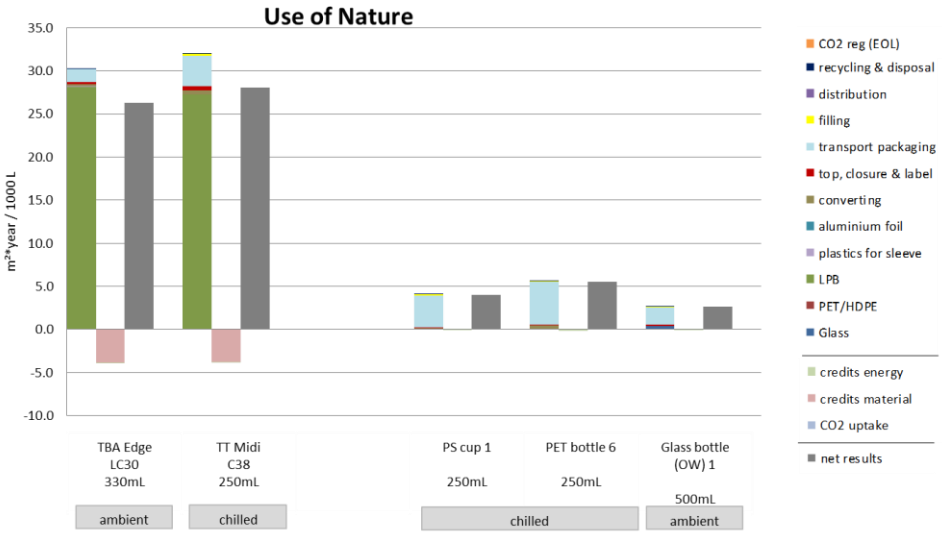


Figure 35: Indicator results for base scenarios of **segment CREAM PORTION PACK, Austria**, allocation factor 50% (Part 3)



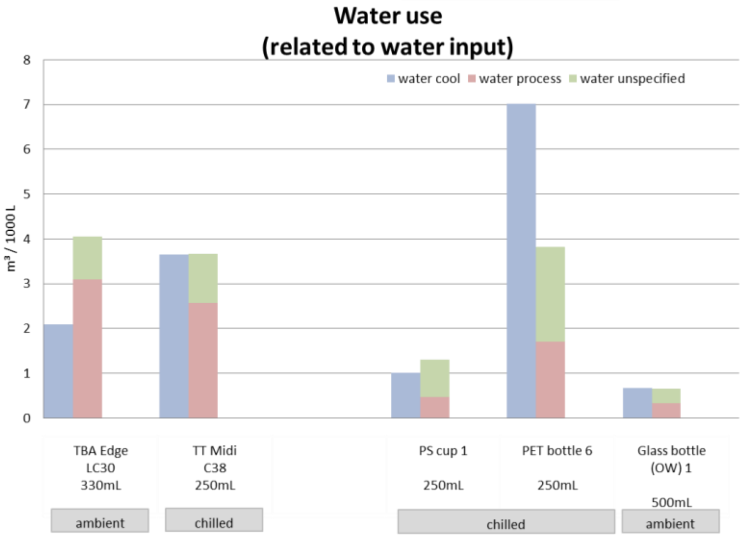


Figure 36: Indicator results for base scenarios of **segment CREAM PORTION PACK, Austria**, allocation factor 50% (Part 4)

Table 64: Category indicator results per impact category for base scenarios of **segment CREAM PORTION PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

	Allocation 50	TBA Edge LC30 330mL	TT Midi C38 250mL	PS cup 1 250mL	PET bottle 6 250mL	Glass bottle (OW) 1 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	119.01	207.71	187.56	360.10	317.79
	CO2 (reg)	25.95	27.54	5.40	6.96	4.13
	Credits	-37.86	-63.78	-45.56	-88.25	-13.72
	CO2 uptake	-54.68	-57.86	-11.40	-14.71	-8.48
	net results	52.41	113.61	135.99	264.09	299.73
Acidification [kg SO2-e/1000 L[	Burdens	0.39	0.49	0.45	0.82	1.16
	Credits	-0.06	-0.09	-0.06	-0.18	-0.04
	Net results	0.32	0.40	0.39	0.64	1.12
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.01	6.98	4.93	9.94	13.87
	Credits	-0.72	-1.03	-0.66	-2.10	-0.48
	Net results	4.29	5.96	4.27	7.84	13.39
Ozone Depletion [g R11/1000 L]	Burdens	0.07	0.12	0.08	1.32	0.32
	Credits	-0.01	-0.02	-0.01	-0.29	-0.03
	Net results	0.06	0.11	0.07	1.03	0.29
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	38.36	53.48	39.42	76.35	110.10
	Credits	-5.57	-7.96	-5.05	-15.42	-3.89
	Net results	32.79	45.52	34.37	60.93	106.20
Aquatic Eutrophication [g PO4/1000 L]	Burdens	35.86	57.39	14.26	90.18	10.15
	Credits	-2.79	-2.81	-0.25	-15.95	-0.11
	Net results	33.07	54.57	14.01	74.23	10.04
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	363.07	472.96	397.07	755.48	1148.57
	Credits	-58.66	-80.49	-50.99	-160.08	-49.04
	Net results	304.41	392.47	346.08	595.40	1099.53
Total Primary Energy [GJ]	Burdens	3.24	5.30	3.61	8.00	4.25
	Credits	-0.75	-1.11	-0.77	-2.04	-0.17
	Net results	2.48	4.20	2.84	5.96	4.08
Non-renewable Primary Energy [GJ]	Burdens	2.13	3.99	3.08	7.06	3.92
	Credits	-0.47	-0.79	-0.69	-1.85	-0.15
	Net results	1.65	3.20	2.39	5.21	3.77
Use of Nature [m²*year]	Burdens	30.27	31.96	4.09	5.69	2.69
	Credits	-3.95	-3.88	-0.07	-0.15	-0.03
	Net results	26.32	28.08	4.01	5.54	2.67
Water use [m³/1000 L]	water cool	2.09	3.65	1.00	7.02	0.67
	water process	3.09	2.56	0.46	1.70	0.33
	water unspecified	0.97	1.10	0.84	2.11	0.32

4.5.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the CREAM PORTION PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories 'Aquatic Eutrophication' (33%-55%) and 'Use of Nature' (85%-93%). It is also relevant regarding 'Photo-Oxidant Formation' (26%-38%) 'Acidification' (26%-35%), 'Terrestrial Eutrophication' (27%-39%), 'Particulate Matter' (27%-36%) and also the consumption of 'Total Primary Energy' (21%-35%). Regarding 'Climate Change' the production of LPB is responsible for only 7%-11% of the burdens.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of the ambient beverage carton shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (25%) and 'Particulate Matter' (22%). These result from SO2 and NOx emissions from the aluminium production. The production of 'aluminium foil' for the sleeves of the chilled beverage carton shows no burdens in all impact categories as the chilled beverage carton doesn't have an aluminium foil layer.

The production of 'plastics for sleeve' of the beverage cartons shows considerable burdens in most impact categories (up to 26%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (5%-9%) and LPB (7%-11%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (12%-26%) contribute a bit more than LPB (9%-17%) to the total burdens.

The life cycle step 'top, closure & label' for the TT cartons contributes to a substantial amount in almost all impact categories (9%-57%).

The converting process generally plays a minor role (1%-11%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (5%-18%).

The life cycle step 'filling' shows only minor shares of burdens (up to 10%) for the beverage carton system in all impact categories In case of TT beverage carton systems the shares are higher (up to 17%) due to the additional moulding process of the top.

The life cycle step 'distribution' shows only very minor burdens in all impact categories for all beverage carton systems 2%.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (37%-38%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are lower than energy credits in almost all impact categories as in Austria only 34% of the beverage cartons are recycled. Exceptions are 'Aquatic Eutrophication' and 'Use of Nature' which have higher material credits caused by the substitution of fresh fibres. Material credits for 'Climate Change' are low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play an important role on the net results in all categories apart of 'Ozone Depletion Potential'.

The uptake of CO2 by trees harvested for the production of paperboard 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. 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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the CREAM PORTION PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a minor share of burdens (4%-17%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (2%-21%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (2%-12%) in most categories. The exception is 'Use of Nature' for which 88% of the burdens are caused from 'transport packaging' resulting from the used cardboard.

The life cycle step 'filling' shows only small shares of burdens (max. 2%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 2%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (28%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is very low in most categories. The exception is 'Climate Change', where the credits reduce the overall burdens by around 20%. The energy credits mainly originate from the incineration plants. Since no primary granulate is credited as the used white PET bottles are incinerated in MSWIs, the received material credits are negligible compared to the credits for energy.

PS cup (specifications see section 2.2.2)

In the regarded PS cup system in the CREAM PORTION PACK segment, the major shares of the environmental burdens are caused by the production of the base materials of the cups (0%-70%), the life cycle step 'top, closure & label' (2%-35%) and 'Transport Packaging' (11%-92%).

The 'converting' process of the regarded PS Cup shows a minor share of impacts (3%-15%) in all categories apart from 'Aquatic Eutrophication' with less than 1% share of burdens. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows high impacts (2%-35%) in most categories attributed to the aluminium used for the pull taps.

The production and provision of 'transport packaging' for the PS cups shows high shares of impacts (11%-92%) in all categories. The relevant emissions derive from the production of paper for trays and slip sheets.

The life cycle step 'filling' shows only minor shares of burdens (max. 7%) for the PS cup in most categories. The exception is 'Ozone Depletion Potential' where 'transport packaging' has a higher share of 16% of the burdens

The life cycle step 'distribution' shows minor shares of burdens (max. 3%) in all impact categories.

The impact of the PS Cup's 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (29%). The incineration of cups in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. Energy credits reduce the overall burdens by 9%-19% in most categories. The energy credits originate from the incineration plants and cement kilns. Material credits reduce the overall burdens by 0%-9%. Material credits originate mainly from the substitution of virgin PS with recycled PS from the cup.

Glass bottles (specifications see section 2.2.2)

In case of the one way glass bottle even more than for the other regarded packaging systems, the production of the 'glass' material is the main contributor to the overall burdens . The production of glass clearly dominates the results (78%-89%) in all categories apart from 'Aquatic Eutrophication' and 'Use of Nature'.

All other life cycle steps play only a minor role compared to the glass production. For the impact categories, 'Aquatic Eutrophication' (42%) and 'Use of Nature' (74%) transport packaging also plays an important role.

Energy credits play only a minor role for the one-way glass bottle, as the little energy that can be generated in end-of-life mainly comes from the incineration of secondary and tertiary packaging.

Material credits from glass recycling, compared to energy credits have a higher impact on the overall net results apart from 'Aquatic Eutrophication' and 'Use of Nature'. The Impact is still small as most of the glass cullet is used in a closed loop for the production of the glass bottle.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

4.5.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging

systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 65: Comparison of net results: **TBA Edge LC30 330mL** versus competing carton based and alternative packaging systems in **segment CREAM Portion Pack (ambient), Austria**, allocation factor 50%

CREAM Portion Pack (ambient), Austria	The net results of **TBA Edge LC30 330mL** are lower (green)/ higher (orange) than those of
	Glass bottle (OW) 1 500mL
Climate Change	-54%
Acidification	-20%
Photo-Oxidant Formation	-28%
Ozone Depletion Potential	-45%
Terrestrial Eutrophication	-28%
Aquatic Eutrophication	-39%
Particulate Matter	-22%

Table 66: Comparison of net results: **TBA Edge LC30 330mL** versus competing carton based and alternative packaging systems in **segment CREAM Portion Pack (chilled), Austria**, allocation factor 50%

CREAM Portion Pack (chilled), Austria	The net results of **TT Midi C38 250mL** are lower (green)/ higher (orange) than those of	
	PS cup 1 250mL	PET bottle 6 250mL
Climate Change	-16%	-57%
Acidification	1%	-38%
Photo-Oxidant Formation	39%	-24%
Ozone Depletion Potential	48%	-90%
Terrestrial Eutrophication	32%	-25%
Aquatic Eutrophication	290%	-26%
Particulate Matter	13%	-34%

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

4.6 Results base scenarios SD PORTION PACK AUSTRIA

4.6.1 Presentation of results SD PORTION PACK Austria

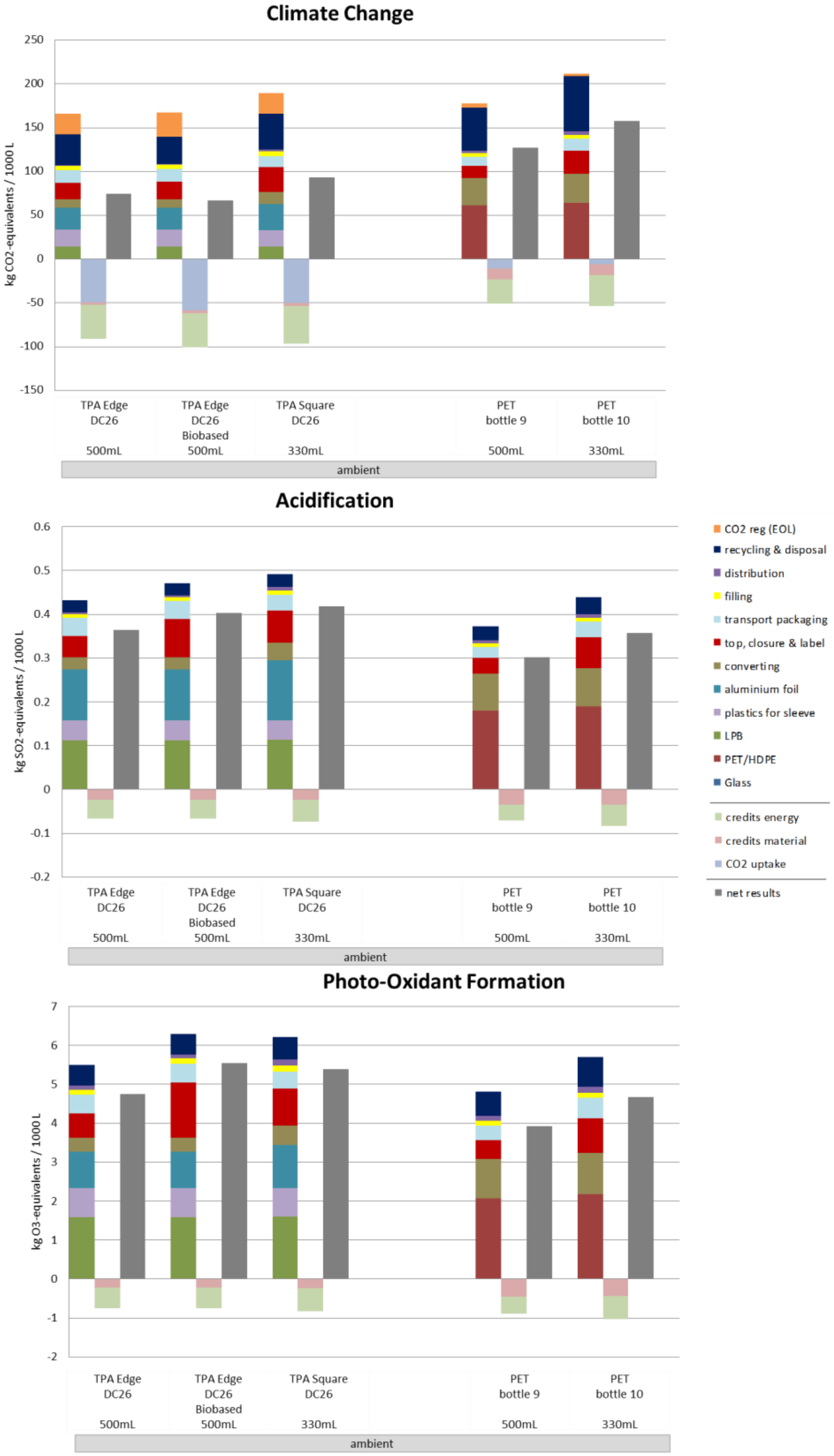


Figure 37: Indicator results for base scenarios of segment SD PORTION PACK, Austria, allocation factor 50% (Part 1)

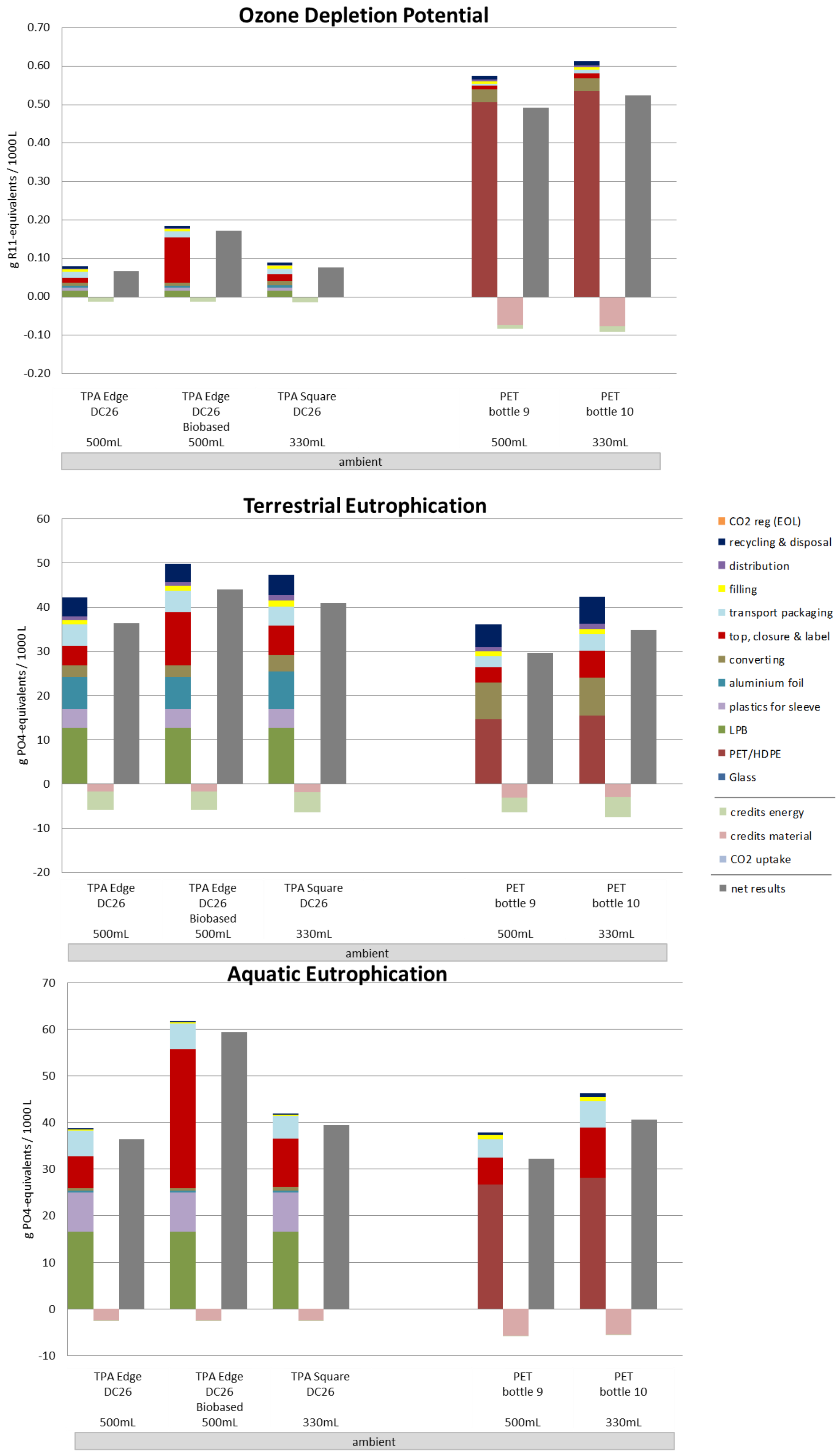


Figure 38 Indicator results for base scenarios of **segment SD PORTION PACK, Austria**, allocation factor 50% (Part 2)

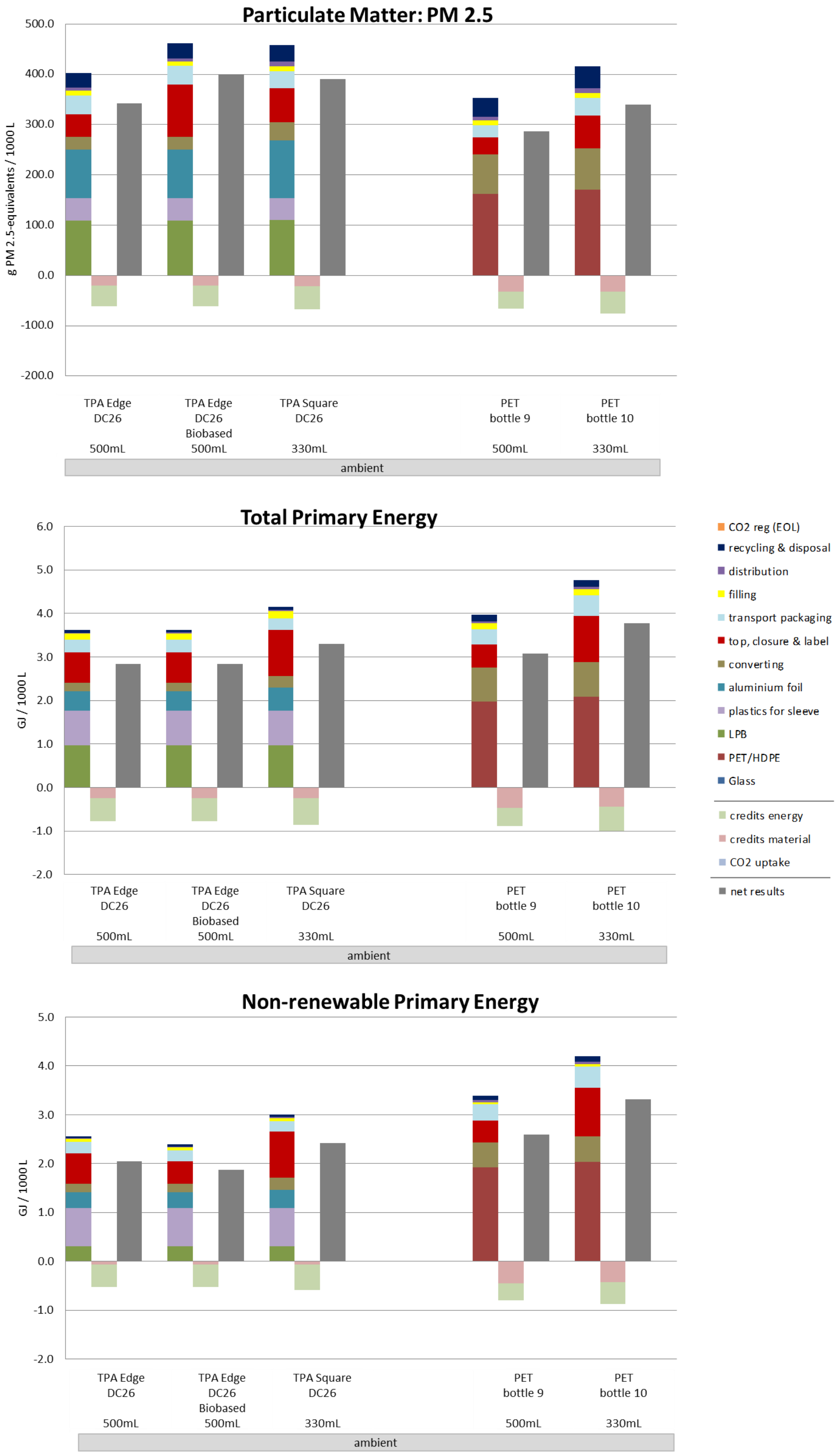
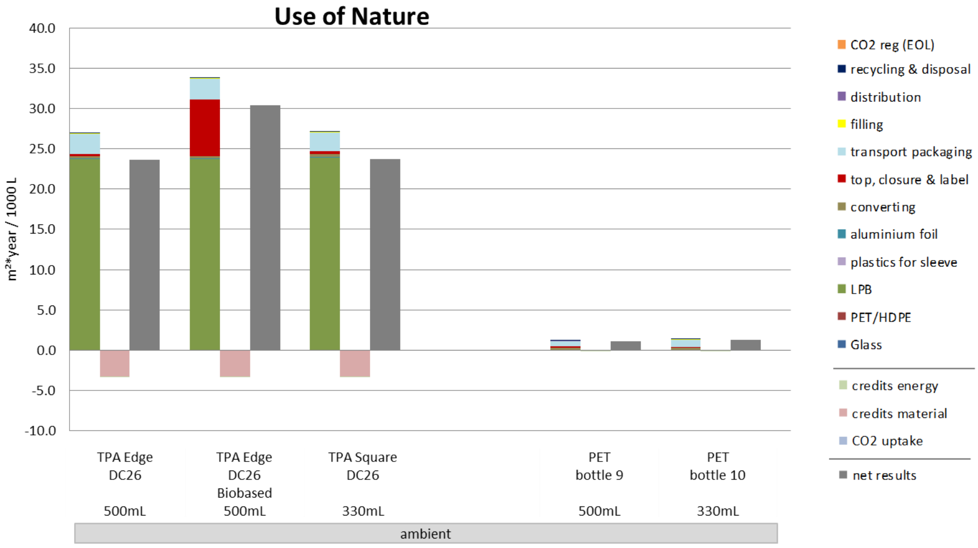


Figure 39: Indicator results for base scenarios of **segment SD PORTION PACK, Austria**, allocation factor 50% (Part 3)



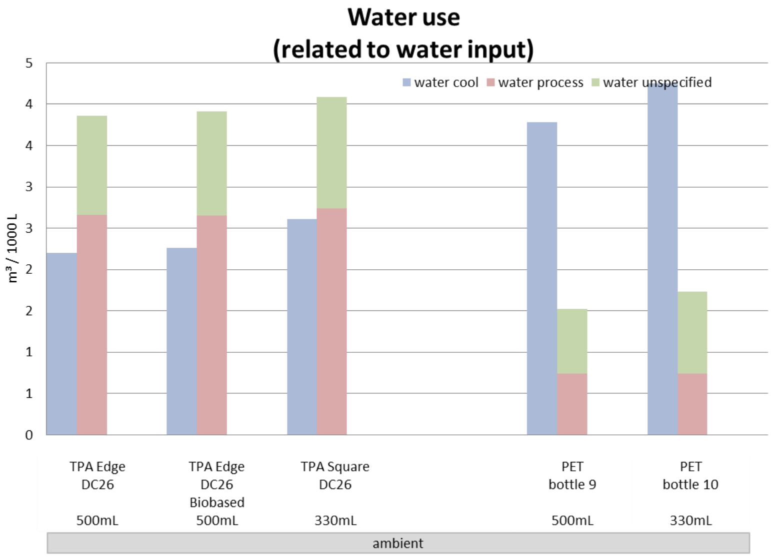


Figure 40: Indicator results for base scenarios of **segment SD PORTION PACK, Austria**, allocation factor 50% (Part 4)

Table 67: Category indicator results per impact category for base scenarios of segment SD PORTION PACK, Austria- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TPA Square DC26 330mL		PET bottle 9 500mL	PET bottle 10 330mL
Climate Change [kg CO2-e/1000 L[	Burdens	142.27	139.64	166.04		172.83	208.76
	CO2 (reg)	23.42	27.54	23.71		5.04	2.89
	Credits	-41.87	-41.94	-46.98		-40.43	-47.91
	CO2 uptake	-49.25	-58.63	-49.83		-10.53	-5.96
	net results	74.58	66.60	92.94		126.92	157.77
Acidification [kg SO2-e/1000 L[	Burdens	0.43	0.47	0.49		0.37	0.44
	Credits	-0.07	-0.07	-0.07		-0.07	-0.08
	Net results	0.36	0.40	0.42		0.30	0.36
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.49	6.29	6.21		4.82	5.70
	Credits	-0.75	-0.75	-0.82		-0.89	-1.03
	Net results	4.75	5.54	5.39		3.93	4.67
Ozone Depletion [g R11/1000 L]	Burdens	0.08	0.18	0.09		0.58	0.61
	Credits	-0.01	-0.01	-0.01		-0.08	-0.09
	Net results	0.07	0.17	0.08		0.49	0.52
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	42.19	49.88	47.38		36.08	42.40
	Credits	-5.79	-5.80	-6.39		-6.44	-7.53
	Net results	36.40	44.08	41.00		29.63	34.87
Aquatic Eutrophication [g PO4/1000 L]	Burdens	38.79	61.76	41.97		37.86	46.21
	Credits	-2.41	-2.41	-2.48		-5.72	-5.55
	Net results	36.37	59.35	39.49		32.14	40.66
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	402.94	461.52	458.15		352.56	415.57
	Credits	-60.86	-60.93	-67.13		-65.65	-75.87
	Net results	342.08	400.59	391.02		286.91	339.69
Total Primary Energy [GJ]	Burdens	3.62	3.62	4.15		3.96	4.77
	Credits	-0.78	-0.78	-0.85		-0.89	-1.00
	Net results	2.84	2.84	3.30		3.08	3.77
Non-renewable Primary Energy [GJ]	Burdens	2.56	2.39	3.01		3.39	4.19
	Credits	-0.52	-0.52	-0.59		-0.79	-0.88
	Net results	2.04	1.87	2.42		2.60	3.32
Use of Nature [m²*year]	Burdens	26.95	33.78	27.10		1.19	1.43
	Credits	-3.34	-3.35	-3.37		-0.09	-0.11
	Net results	23.60	30.44	23.72		1.10	1.32
Water use [m³/1000 L]	water cool	2.20	2.26	2.61		3.78	4.25
	water process	2.66	2.65	2.74		0.74	0.74
	water unspecified	1.20	1.26	1.35		0.78	0.98

4.6.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the SD PORTION PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories 'Aquatic Eutrophication' (27%-43%) and 'Use of Nature' (70%-88%). It is also relevant regarding 'Photo-Oxidant Formation' (25%-29%) 'Acidification' (23%-26%), 'Terrestrial Eutrophication' (25%-30%), 'Particulate Matter' (24%-27%) and also the consumption of 'Total Primary Energy' (23%-27%). Regarding 'Climate Change' the production of LPB contributes only to 7%-8%.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (25%-28%) and 'Particulate Matter' (21%-25%). These result from SO2 and NOx emissions from the aluminium production.

The production of 'plastics for sleeve' of the beverage cartons with fossil plastics shows considerable burdens in most impact categories (up to 33%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (10%-12%) and LPB (7%-8%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (26%-33%) contribute about twice as much as LPB (10%-13%) to the total burdens.

The life cycle step 'top, closure & label' for the cartons contributes to a considerable amount in almost all impact categories (0%-31%). In case the plastics used for 'top, closure & label' are bio-based, the results are considerably higher than cartons with fossil based plastics in all categories except 'Climate Change', 'Total Primary Energy Demand' and 'Non-renewable Primary Energy'.

The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

The converting process generally plays a minor role (1%-12%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (6%-14%). The exception is 'Ozone Depletion Potential' for the cartons with fossil based plastics. In these cases 'transport packaging' has a higher share of 16%-21% of the burdens due to the low share of the categories 'top, closure & label' and 'plastics for sleeve'.

The life cycle step 'filling' shows only minor burdens for all beverage carton systems in all impact categories (max. 8%).

The life cycle step 'distribution' shows only very minor burdens in all impact categories for all beverage carton systems 3%.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (34%-35%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are lower than energy credits in almost all impact categories as in Austria only 34% of the beverage cartons are recycled. Exceptions are 'Aquatic Eutrophication' and 'Use of Nature' which have higher material credits caused by the substitution of fresh fibres. Material credits for 'Climate Change' are low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play an important role on the net results in all categories apart of 'Ozone Depletion Potential'.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the SD PORTION PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a considerable share of burdens (6%-23%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (1%-24%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (1%-12%) in most categories. The exception is 'Use of Nature' for which 49%-67% of the burdens are caused from 'transport packaging' resulting from the used cardboard slip sheets.

The life cycle step 'filling' shows only small shares of burdens (max. 5%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 3%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (30%-31%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 20% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

4.6.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 68: Comparison of net results: **TPA Edge DC26 500mL** versus competing carton based and alternative packaging systems in **segment SD PORTION PACK (ambient), Austria**, allocation factor 50%

SD PORTION PACK (ambient), Austria	The net results of **TPA Edge DC26 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 biobased 500mL	TPA Square DC26 330mL	PET bottle 9 500mL	PET bottle 10 330mL
Climate Change	12%	-20%	-41%	-53%
Acidification	-10%	-13%	21%	2%
Photo-Oxidant Formation	-14%	-12%	21%	2%
Ozone Depletion Potential	-61%	-12%	-86%	-87%
Terrestrial Eutrophication	-17%	-11%	23%	4%
Aquatic Eutrophication	-39%	-8%	13%	-11%
Particulate Matter	-15%	-13%	19%	1%

Table 69: Comparison of net results: **TPA Edge DC26 biobased 500mL** versus competing carton based and alternative packaging systems in **segment SD PORTION PACK (ambient), Austria**, allocation factor 50%

SD PORTION PACK (ambient), Austria	The net results of **TPA Edge DC26 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Square DC26 330mL	PET bottle 9 500mL	PET bottle 10 330mL
Climate Change	-11%	-28%	-48%	-58%
Acidification	11%	-3%	34%	13%
Photo-Oxidant Formation	17%	3%	41%	19%
Ozone Depletion Potential	159%	126%	-65%	-67%
Terrestrial Eutrophication	21%	8%	49%	26%
Aquatic Eutrophication	63%	50%	85%	46%
Particulate Matter	17%	2%	40%	18%

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

Table 70: Comparison of net results: **TPA Square DC26 330mL** versus competing carton based and alternative packaging systems in **segment SD PORTION PACK (ambient), Austria**, allocation factor 50%

SD PORTION PACK (ambient), Austria	The net results of **TPA Square DC26 330mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	PET bottle 9 500mL	PET bottle 10 330mL
Climate Change	25%	40%	-27%	-41%
Acidification	15%	4%	39%	17%
Photo-Oxidant Formation	14%	-3%	37%	15%
Ozone Depletion Potential	14%	-56%	-85%	-85%
Terrestrial Eutrophication	13%	-7%	38%	18%
Aquatic Eutrophication	9%	-33%	23%	-3%
Particulate Matter	14%	-2%	36%	15%

4.7 Results base scenarios *WATER PORTION PACK AUSTRIA*

4.7.1 Presentation of results WATER PORTION PACK Austria

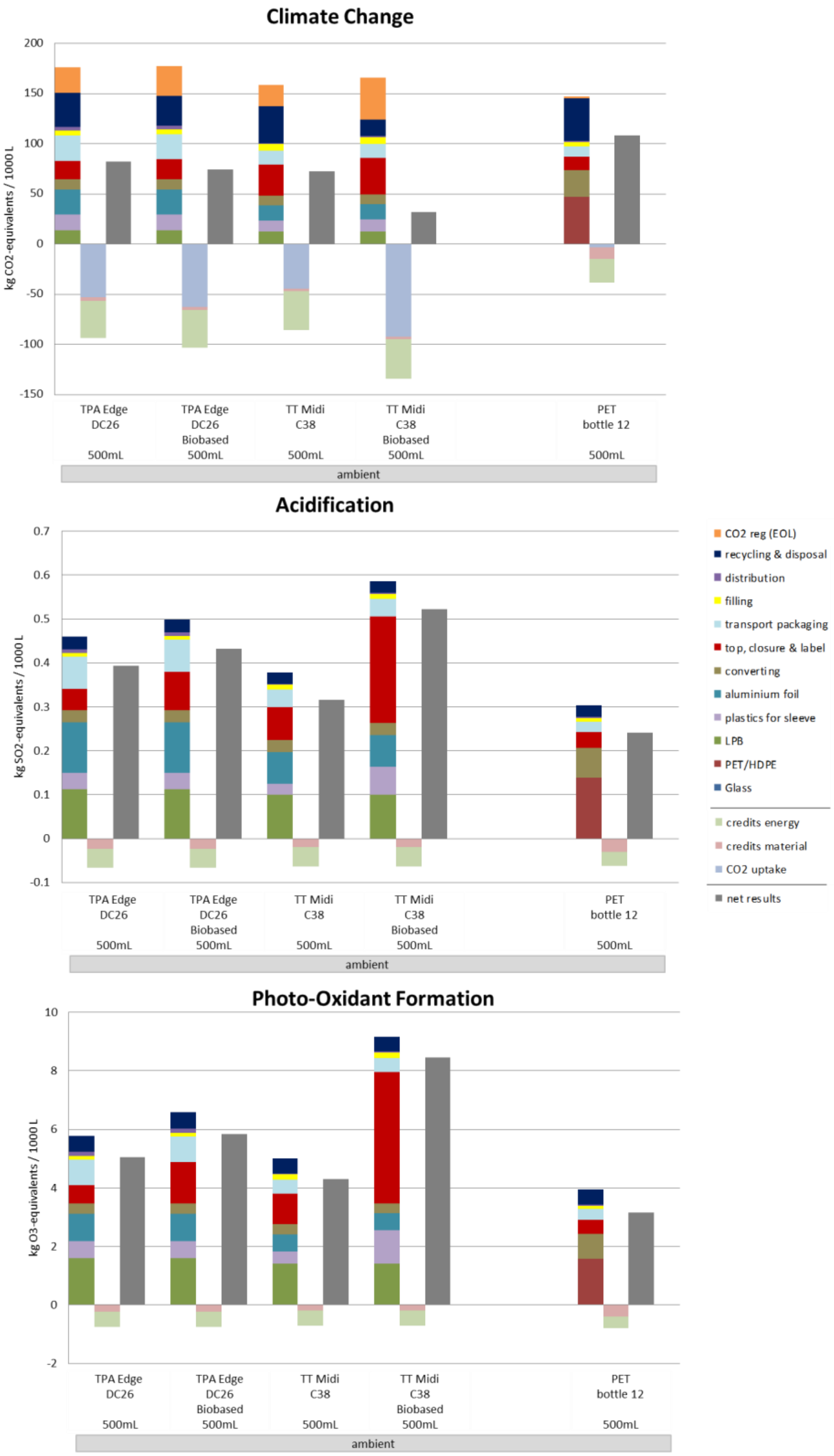


Figure 41: Indicator results for base scenarios of **segment WATER PORTION PACK, Austria**, allocation factor 50% (Part 1)

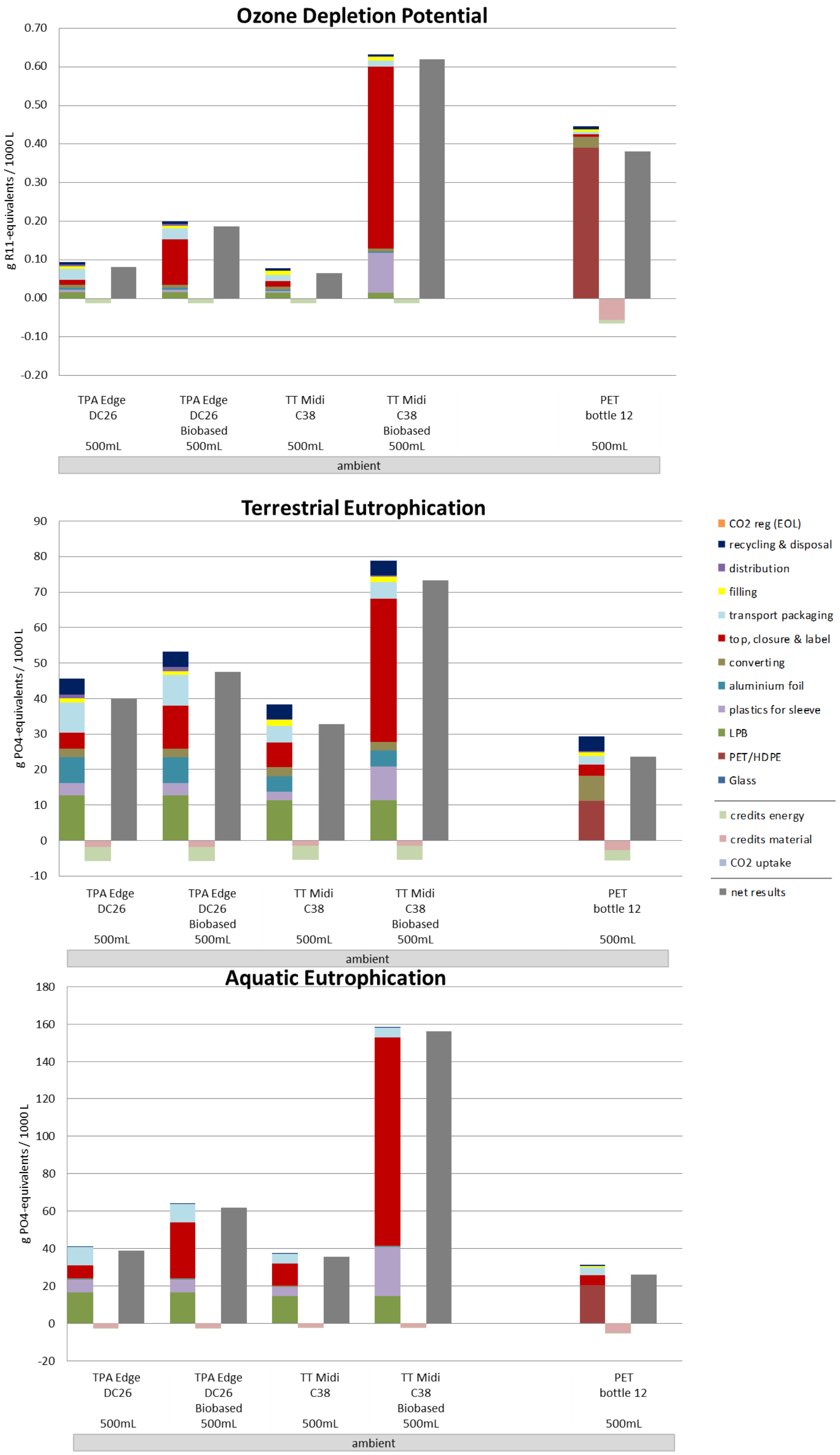


Figure 42: Indicator results for base scenarios of **segment WATER PORTION PACK, Austria**, allocation factor 50% (Part 2)

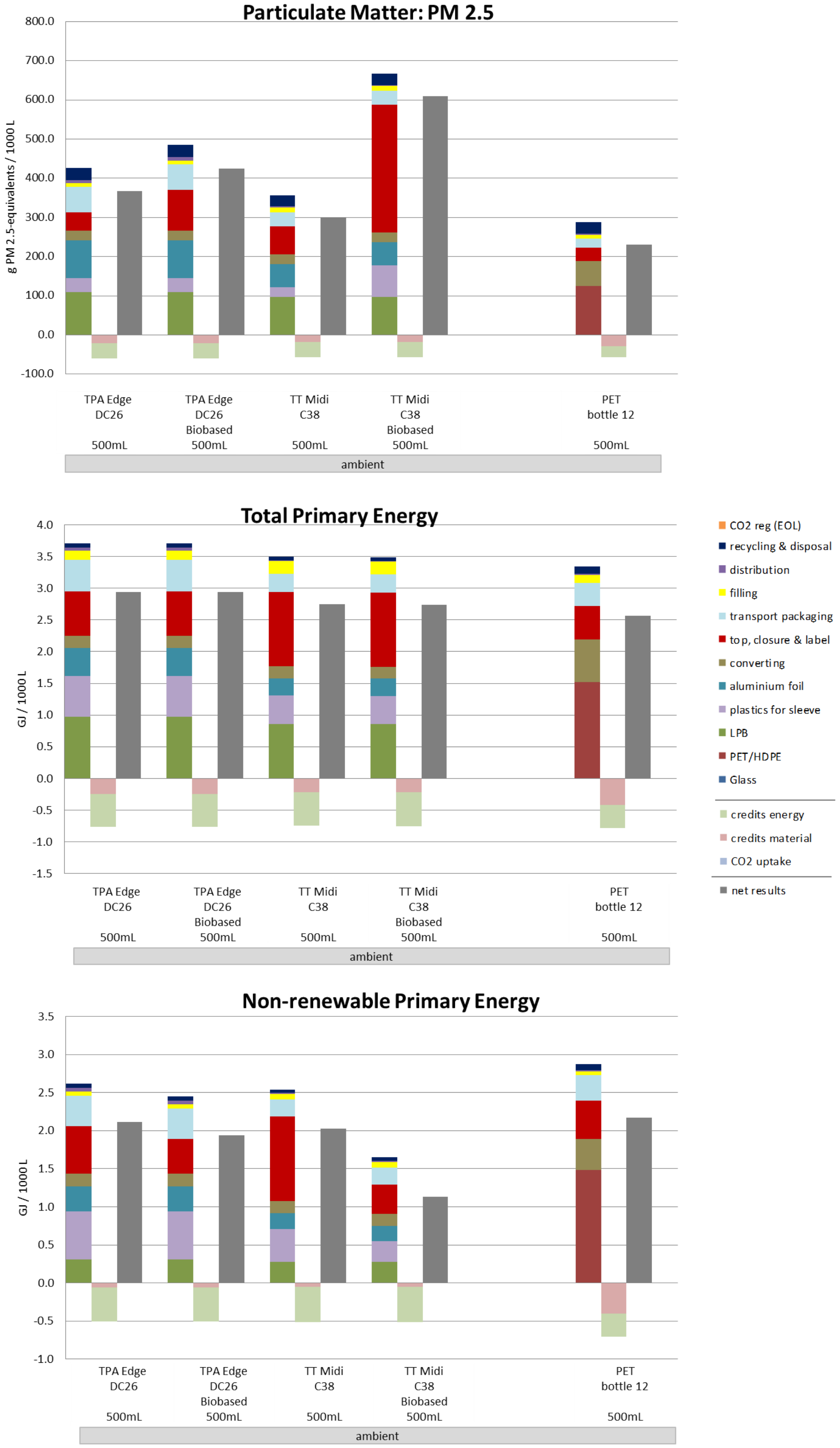
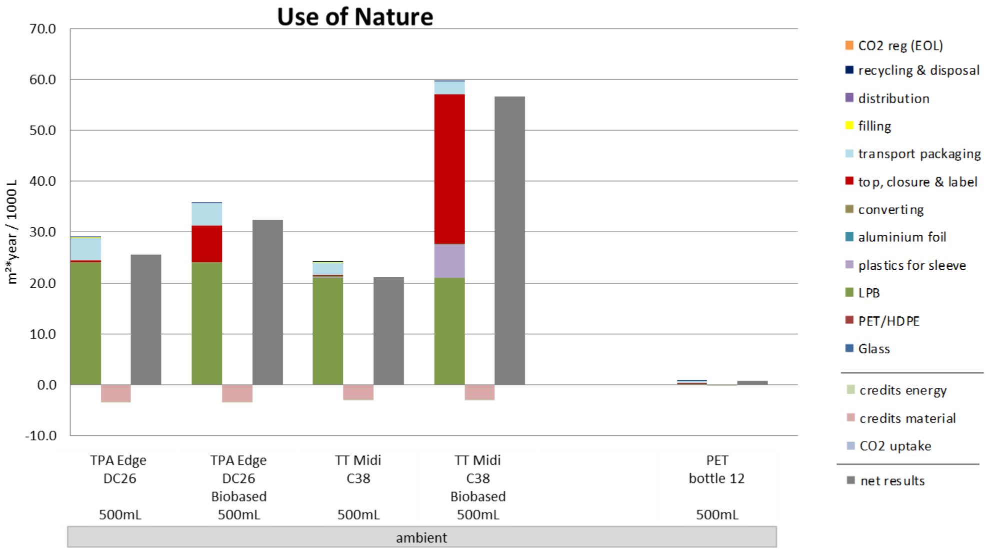


Figure 43: Indicator results for base scenarios of **segment WATER PORTION PACK, Austria**, allocation factor 50% (Part 3)



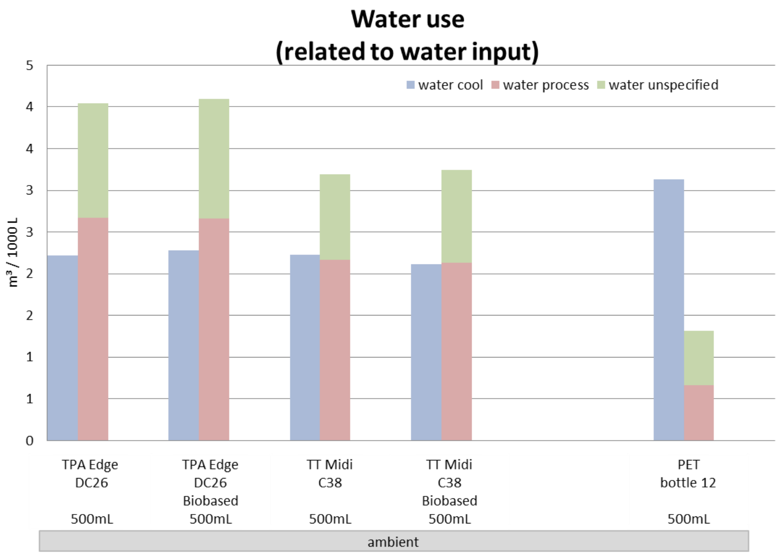


Figure 44: Indicator results for base scenarios of **segment WATER PORTION PACK, Austria**, allocation factor 50% (Part 4)

Table 71: Category indicator results per impact category for base scenarios of **segment WATER PORTION PACK, Austria** - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL		PET bottle 12 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	150.53	147.89	137.33	123.82		145.39
	CO2 (reg)	25.34	29.45	21.05	41.73		1.68
	Credits	-40.29	-40.36	-41.59	-41.76		-35.18
	CO2 uptake	-53.18	-62.56	-44.23	-92.13		-3.46
	net results	82.40	74.42	72.55	31.65		108.43
Acidification [kg SO2-e/1000 L[	Burdens	0.46	0.50	0.38	0.59		0.30
	Credits	-0.07	-0.07	-0.06	-0.06		-0.06
	Net results	0.39	0.43	0.32	0.52		0.24
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.78	6.58	5.00	9.16		3.95
	Credits	-0.74	-0.74	-0.71	-0.71		-0.78
	Net results	5.04	5.84	4.29	8.45		3.17
Ozone Depletion [g R11/1000 L]	Burdens	0.09	0.20	0.08	0.63		0.45
	Credits	-0.01	-0.01	-0.01	-0.01		-0.07
	Net results	0.08	0.19	0.07	0.62		0.38
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	45.62	53.31	38.35	78.83		29.33
	Credits	-5.74	-5.75	-5.49	-5.51		-5.62
	Net results	39.88	47.56	32.86	73.32		23.71
Aquatic Eutrophication [g PO4/1000 L]	Burdens	41.31	64.28	37.60	158.31		31.23
	Credits	-2.44	-2.44	-2.16	-2.16		-5.03
	Net results	38.86	61.83	35.44	156.15		26.20
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	427.05	485.62	357.14	666.77		287.78
	Credits	-60.21	-60.28	-57.00	-57.16		-57.07
	Net results	366.83	425.34	300.13	609.60		230.71
Total Primary Energy [GJ]	Burdens	3.70	3.71	3.50	3.49		3.34
	Credits	-0.76	-0.77	-0.75	-0.75		-0.78
	Net results	2.94	2.94	2.75	2.74		2.56
Non-renewable Primary Energy [GJ]	Burdens	2.62	2.45	2.54	1.65		2.87
	Credits	-0.51	-0.51	-0.51	-0.52		-0.70
	Net results	2.11	1.94	2.03	1.13		2.17
Use of Nature [m²*year]	Burdens	28.94	35.78	24.18	59.68		0.85
	Credits	-3.36	-3.36	-3.00	-3.00		-0.07
	Net results	25.58	32.42	21.18	56.68		0.77
Water use [m³/1000 L]	water cool	2.22	2.28	2.23	2.12		3.13
	water process	2.67	2.66	2.17	2.14		0.67
	water unspecified	1.37	1.43	1.03	1.11		0.65

4.7.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the WATER PORTION PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories ‘Aquatic Eutrophication’ (9%-40%) and ‘Use of Nature’ (35%-87%). It is also relevant regarding ‘Photo-Oxidant Formation’ (15%-28%) ‘Acidification’ (17%-26%), ‘Terrestrial Eutrophication’ (14%-29%), ‘Particulate Matter’ (15%-27%) and also the consumption of 'Total Primary Energy' (25%-26%). Regarding 'Climate Change' the production of LPB contributes only to 7%-8%.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (12%-25%) and 'Particulate Matter' (9%-23%). These result from SO2 and NOx emissions from the aluminium production.

The production of 'plastics for sleeve' of the beverage cartons with fossil plastics shows considerable burdens in most impact categories (up to 26%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (7%-9%) and LPB (7%-8%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (16%-26%) contribute more than LPB (11%-17%) to the total burdens.

The life cycle step 'top, closure & label' for the cartons contributes to a small amount in almost all impact categories (1%-44%). In case the plastics used for 'top, closure & label' are bio-based, the results are considerably higher than cartons with fossil based plastics in all categories except 'Climate Change', 'Total Primary Energy Demand' and 'Non-renewable Primary Energy'.

The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

The converting process generally plays a minor role (up to 10%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show considerable impacts in most categories (3%-23%). The exception is 'Ozone Depletion Potential' for the cartons with fossil based plastics. In these cases 'transport packaging' has a higher share of 20%-31% of the burdens due to the low share of the categories 'top, closure & label' and 'plastics for sleeve'.

The life cycle step 'filling' shows only minor burdens for all beverage carton systems in all impact categories (max. 13%).

The life cycle step 'distribution' shows only very minor burdens in all impact categories for all beverage carton systems 4%.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (33%-36%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are lower than energy credits in almost all impact categories as in Austria only 34% of the beverage cartons are recycled. Exceptions are 'Aquatic Eutrophication' and 'Use of Nature' which have higher material credits caused by the substitution of fresh fibres. Material credits for 'Climate Change' are low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play an important role on the net results in all categories apart of 'Ozone Depletion Potential'.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the WATER PORTION PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a considerable share of burdens (7%-28%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (1%-17%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (1%-13%) in most categories. The exception is 'Use of Nature' for which 55% of the burdens are caused from 'transport packaging' resulting from the used cardboard slip sheets.

The life cycle step 'filling' shows only small shares of burdens (max. 7%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 1%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (30%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 20% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

4.7.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 72: Comparison of net results: **TBA Edge DC26 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Austria**, allocation factor 50%

WATER PORTION PACK (ambient), Austria	The net results of **TPA Edge DC26 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL	PET bottle 12 500mL
Climate Change	11%	14%	160%	-24%
Acidification	-9%	25%	-25%	63%
Photo-Oxidant Formation	-14%	17%	-40%	59%
Ozone Depletion Potential	-56%	23%	-87%	-79%
Terrestrial Eutrophication	-16%	21%	-46%	68%
Aquatic Eutrophication	-37%	10%	-75%	48%
Particulate Matter	-14%	22%	-40%	59%

Table 73: Comparison of net results: **TBA Edge DC26 biobased 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Austria**, allocation factor 50%

WATER PORTION PACK (ambient), Austria	The net results of **TPA Edge DC26 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL	PET bottle 12 500mL
Climate Change	-10%	3%	135%	-31%
Acidification	10%	37%	-17%	79%
Photo-Oxidant Formation	16%	36%	-31%	84%
Ozone Depletion Potential	130%	183%	-70%	-51%
Terrestrial Eutrophication	19%	45%	-35%	101%
Aquatic Eutrophication	59%	74%	-60%	136%
Particulate Matter	16%	42%	-30%	84%

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

Table 74: Comparison of net results: **TT Midi C38 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Austria**, allocation factor 50%

WATER PORTION PACK (ambient), Austria	The net results of **TT Midi C38 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 biobased 500mL	PET bottle 12 500mL
Climate Change	-12%	-3%	129%	-33%
Acidification	-20%	-27%	-40%	31%
Photo-Oxidant Formation	-15%	-26%	-49%	36%
Ozone Depletion Potential	-19%	-65%	-89%	-83%
Terrestrial Eutrophication	-18%	-31%	-55%	39%
Aquatic Eutrophication	-9%	-43%	-77%	35%
Particulate Matter	-18%	-29%	-51%	30%

Table 75: Comparison of net results: **TT Midi C38 biobased 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Austria**, allocation factor 50%

WATER PORTION PACK (ambient), Austria	The net results of **TT Midi C38 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	PET bottle 12 500mL
Climate Change	-62%	-57%	-56%	-71%
Acidification	33%	21%	66%	116%
Photo-Oxidant Formation	68%	45%	97%	167%
Ozone Depletion Potential	664%	232%	842%	63%
Terrestrial Eutrophication	84%	54%	123%	209%
Aquatic Eutrophication	302%	153%	341%	496%
Particulate Matter	66%	43%	103%	164%

5 Sensitivity Analyses Austria

5.1 DAIRY FAMILY PACK AUSTRIA

5.1.1 Sensitivity analysis on system allocation DAIRY FAMILY PACK Austria

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

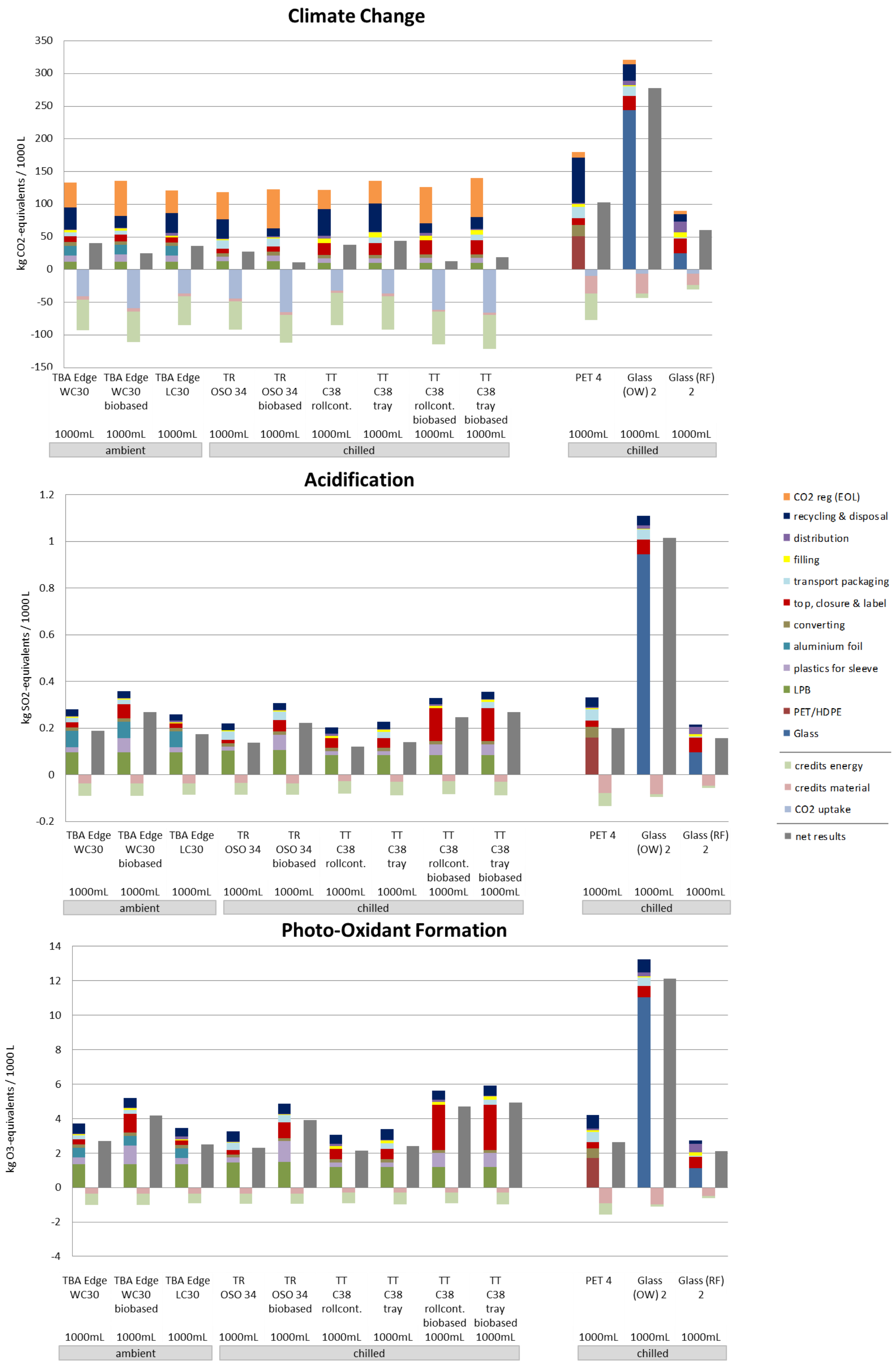


Figure 45: Indicator results for sensitivity analysis on system allocation of **segment DAIRY FAMILY PACK, Austria**, allocation factor 100% (Part 1)

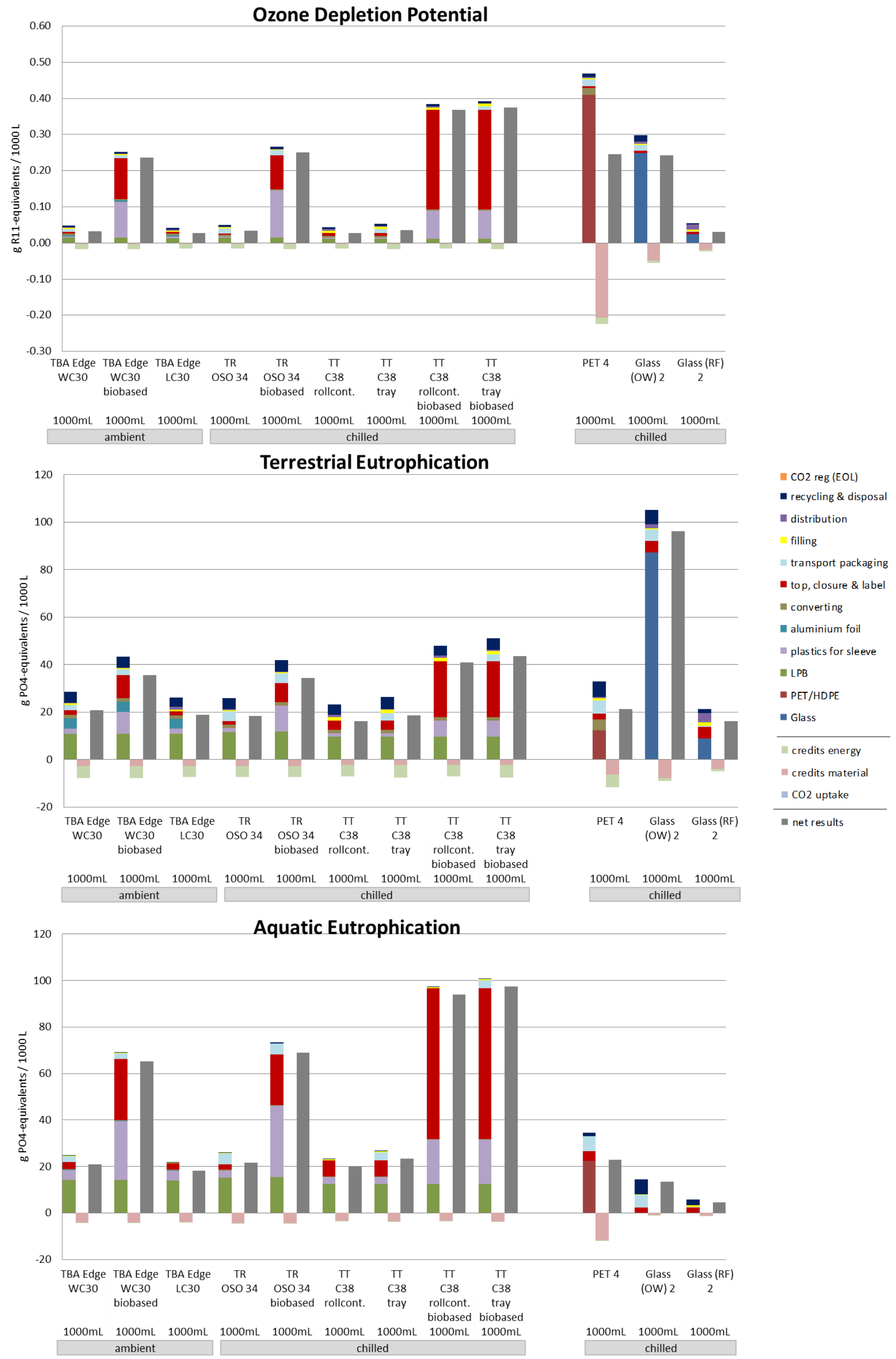


Figure 46: Indicator results for sensitivity analysis on system allocation of **segment DAIRY FAMILY PACK, Austria**, allocation factor 100% (Part 2)

Figure 47: Indicator results for sensitivity analysis on system allocation of **segment DAIRY FAMILY PACK, Austria**, allocation factor 100% (Part 3)

Table 76: Category indicator results per impact category for sensitivity analysis on system allocation scenarios of **segment DAIRY FAMILY PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Edge LC30 1000mL	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL		PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	94.86	81.80	86.74	76.65	63.29	92.18	101.34	71.20	80.36		171.05	314.55	84.43
	CO2 (reg)	38.25	53.93	34.03	42.14	59.69	30.01	34.67	55.39	60.05		9.32	6.13	5.75
	Credits	-51.93	-51.99	-48.65	-46.82	-47.34	-52.61	-55.30	-52.76	-55.45		-67.38	-36.74	-24.17
	CO2 uptake	-40.48	-58.61	-36.13	-44.60	-64.76	-31.86	-36.66	-61.19	-66.00		-9.83	-6.34	-5.82
	net results	40.69	25.12	35.99	27.37	10.89	37.72	44.05	12.64	18.96		103.17	277.61	60.19
Acidification [kg SO2-e/1000 L[	Burdens	0.28	0.36	0.26	0.22	0.31	0.20	0.23	0.33	0.35		0.33	1.11	0.21
	Credits	-0.09	-0.09	-0.09	-0.08	-0.09	-0.08	-0.09	-0.08	-0.09		-0.13	-0.10	-0.06
	Net results	0.19	0.27	0.17	0.14	0.22	0.12	0.14	0.25	0.27		0.20	1.01	0.16
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.70	5.18	3.44	3.24	4.86	3.05	3.37	5.60	5.92		4.20	13.22	2.72
	Credits	-1.00	-1.00	-0.93	-0.94	-0.96	-0.91	-0.98	-0.91	-0.98		-1.58	-1.11	-0.63
	Net results	2.69	4.18	2.51	2.29	3.90	2.14	2.39	4.69	4.94		2.61	12.11	2.09
Ozone Depletion [g R11/1000 L]	Burdens	0.05	0.25	0.04	0.05	0.27	0.04	0.05	0.38	0.39		0.47	0.30	0.06
	Credits	-0.02	-0.02	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02		-0.22	-0.06	-0.02
	Net results	0.03	0.24	0.03	0.03	0.25	0.03	0.04	0.37	0.38		0.25	0.24	0.03
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	28.58	43.40	26.16	25.75	41.79	23.15	26.26	47.99	51.09		32.92	105.15	21.23
	Credits	-7.78	-7.79	-7.22	-7.33	-7.43	-7.08	-7.58	-7.09	-7.60		-11.67	-8.92	-4.97
	Net results	20.80	35.61	18.93	18.42	34.35	16.08	18.67	40.90	43.49		21.25	96.22	16.26
Aquatic Eutrophication [g PO4/1000 L]	Burdens	24.93	69.25	21.92	26.00	73.27	23.35	26.93	97.40	100.99		34.60	14.35	5.65
	Credits	-4.09	-4.09	-3.88	-4.31	-4.42	-3.44	-3.59	-3.44	-3.59		-11.84	-0.92	-1.06
	Net results	20.84	65.16	18.04	21.68	68.85	19.92	23.34	93.97	97.39		22.77	13.44	4.59
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	265.19	379.68	245.74	215.28	339.44	201.23	224.35	391.33	414.45		308.85	1091.72	208.74
	Credits	-82.30	-82.36	-76.96	-75.22	-76.29	-72.71	-77.42	-72.85	-77.56		-121.15	-111.21	-59.52
	Net results	182.89	297.32	168.78	140.06	263.15	128.52	146.93	318.48	336.89		187.70	980.51	149.22
Total Primary Energy [GJ]	Burdens	2.20	2.19	2.05	1.91	1.92	2.06	2.22	2.05	2.21		3.06	4.11	1.23
	Credits	-1.06	-1.06	-0.98	-1.02	-1.03	-1.00	-1.06	-1.00	-1.06		-1.53	-0.47	-0.36
	Net results	1.15	1.13	1.06	0.89	0.89	1.06	1.16	1.05	1.15		1.52	3.65	0.88
Non-renewable Primary Energy [GJ]	Burdens	1.42	1.08	1.31	1.16	0.81	1.43	1.55	0.88	1.00		2.71	3.85	1.11
	Credits	-0.65	-0.65	-0.60	-0.60	-0.60	-0.64	-0.69	-0.64	-0.69		-1.39	-0.43	-0.32
	Net results	0.77	0.43	0.71	0.57	0.21	0.78	0.86	0.23	0.31		1.32	3.42	0.79
Use of Nature [m²*year]	Burdens	21.91	35.10	20.49	24.21	38.72	18.09	19.75	39.85	41.51		3.28	3.02	0.35
	Credits	-5.74	-5.74	-5.63	-6.08	-6.24	-5.00	-5.03	-5.00	-5.03		-0.13	-0.05	-0.06
	Net results	16.17	29.37	14.86	18.13	32.49	13.09	14.72	34.85	36.48		3.15	0.00	0.00
Water use [m³/1000 L]	water cool	1.15	1.18	1.06	1.17	1.22	1.11	1.20	1.02	1.11		2.04	0.55	0.19
	water process	2.05	2.04	2.02	1.82	1.85	1.79	1.80	1.78	1.78		0.16	4.87	5.15
	water unspecified	0.64	0.77	0.51	0.47	0.60	0.28	0.45	0.33	0.49		0.71	0.53	0.28

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 regarded system.

In the cases of beverage cartons in the Austrian segment DAIRY FAMILY PACK applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories. This is because the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. In case of beverage cartons with bio-based plastics, net results stay similar in the categories which have high burdens from the production of bio-based plastics. In case of ‘Climate Change’, applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don’t increase when applying the 100% allocation factor.

In the cases of the plastic bottle, lower net results in almost all impact categories are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The exception is 'Climate Change'. For 'Climate Change' net results stay about the same when applying the 100% allocation factor, as the additionally allocated credits and burdens show similar absolute values.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

In the cases of one-way and refillable glass bottles net results of all categories except 'Aquatic Eutrophication' decrease a bit when applying the 100% allocation factor as burdens from recycling and disposal are a bit lower than energy and material credits.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 77: Comparison of net results: **TR OSO 34 1000mL** versus competing carton based and alternative packaging systems in **segment DAIRY Family Pack (ambient), Austria**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TR OSO 34 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	151%	-27%	-38%	117%	44%	-73%	-90%	-55%
Acidification	-38%	13%	-3%	-45%	-49%	-31%	-87%	-14%
Photo-Oxidant Formation	-41%	7%	-4%	-51%	-54%	-12%	-81%	10%
Ozone Depletion Potential	-86%	24%	-1%	-91%	-91%	-86%	-86%	10%
Terrestrial Eutrophication	-46%	15%	-1%	-55%	-58%	-13%	-81%	13%
Aquatic Eutrophication	-69%	9%	-7%	-77%	-78%	-5%	61%	373%
Particulate Matter	-47%	9%	-5%	-56%	-58%	-25%	-86%	-6%

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

Table 78: Comparison of net results: **TR OSO 34 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment DAIRY Family Pack (chilled), Austria**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TR OSO 34 biobased 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	-60%	-71%	-75%	-14%	-43%	-89%	-96%	-82%
Acidification	62%	84%	57%	-11%	-18%	12%	-78%	40%
Photo-Oxidant Formation	70%	82%	63%	-17%	-21%	49%	-68%	87%
Ozone Depletion Potential	622%	798%	611%	-32%	-33%	2%	3%	696%
Terrestrial Eutrophication	86%	114%	84%	-16%	-21%	62%	-64%	111%
Aquatic Eutrophication	218%	246%	195%	-27%	-29%	202%	412%	1401%
Particulate Matter	88%	105%	79%	-17%	-22%	40%	-73%	76%

Table 79: Comparison of net results: **TT C38 rollcont. 1000mL** versus competing carton based and alternative packaging systems in **segment DAIRY Family Pack (ambient), Austria**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TT C38 rollcont. 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	38%	246%	-14%	199%	99%	-63%	-86%	-37%
Acidification	-12%	-46%	-15%	-51%	-55%	-39%	-88%	-24%
Photo-Oxidant Formation	-6%	-45%	-10%	-54%	-57%	-18%	-82%	3%
Ozone Depletion Potential	-20%	-89%	-21%	-92%	-93%	-89%	-88%	-11%
Terrestrial Eutrophication	-13%	-53%	-14%	-61%	-63%	-24%	-83%	-1%
Aquatic Eutrophication	-8%	-71%	-15%	-79%	-80%	-13%	48%	334%
Particulate Matter	-8%	-51%	-13%	-60%	-62%	-32%	-87%	-14%

Table 80: Comparison of net results: **TT C38 tray 1000mL** versus competing carton based and alternative packaging systems in **segment DAIRY Family Pack (chilled), Austria**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TT C38 tray 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 rollcont. biobased 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	61%	305%	17%	249%	132%	-57%	-84%	-27%
Acidification	3%	-36%	17%	-43%	-47%	-29%	-86%	-11%
Photo-Oxidant Formation	4%	-39%	12%	-49%	-52%	-8%	-80%	15%
Ozone Depletion Potential	2%	-86%	26%	-90%	-91%	-86%	-85%	12%
Terrestrial Eutrophication	1%	-46%	16%	-54%	-57%	-12%	-81%	15%
Aquatic Eutrophication	8%	-66%	17%	-75%	-76%	3%	74%	409%
Particulate Matter	5%	-44%	14%	-54%	-56%	-22%	-85%	-2%

Table 81: Comparison of net results: **TT C38 rollcont. biobased 1000mL** versus competing carton based and alternative packaging systems in **segment DAIRY Family Pack (ambient), Austria**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TT C38 rollcont. biobased 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 tray biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	-54%	16%	-67%	-71%	-33%	-88%	-95%	-79%
Acidification	81%	12%	106%	76%	-8%	25%	-76%	57%
Photo-Oxidant Formation	105%	20%	119%	96%	-5%	80%	-61%	125%
Ozone Depletion Potential	963%	47%	1221%	947%	-2%	50%	52%	1071%
Terrestrial Eutrophication	122%	19%	154%	119%	-6%	93%	-57%	152%
Aquatic Eutrophication	333%	36%	372%	303%	-4%	313%	599%	1948%
Particulate Matter	127%	21%	148%	117%	-5%	70%	-68%	113%

Table 82: Comparison of net results: **TT C38 tray biobased 1000mL** versus competing carton based and alternative packaging systems in **segment DAIRY Family Pack (chilled), Austria**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Austria	The net results of **TT C38 tray biobased 1000mL** are lower (green)/ higher (orange) than those of							
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 rollcont. 1000mL	TT C38 tray 1000mL	TT C38 rollcont. biobased 1000mL	PET 4 1000mL	Glass (OW) 2 1000mL	Glass (RF) 2 1000mL
Climate Change	-31%	74%	-50%	-57%	50%	-82%	-93%	-68%
Acidification	96%	21%	123%	90%	8%	36%	-74%	70%
Photo-Oxidant Formation	115%	27%	130%	107%	5%	89%	-59%	137%
Ozone Depletion Potential	984%	50%	1247%	968%	2%	53%	55%	1094%
Terrestrial Eutrophication	136%	27%	171%	133%	6%	105%	-55%	167%
Aquatic Eutrophication	349%	41%	389%	317%	4%	328%	625%	2023%
Particulate Matter	141%	28%	162%	129%	6%	79%	-66%	126%

5.1.2 Sensitivity analysis regarding recycled PET in PET bottles

To consider potential future developments in terms of the share of recyclate of the plastic bottles, two additional scenarios for plastic bottles with a recycled content of PET of 30% and 100% are analysed and illustrated in this sensitivity analysis (for details please see section 2.4.4). Results are shown in the following break even graphs.

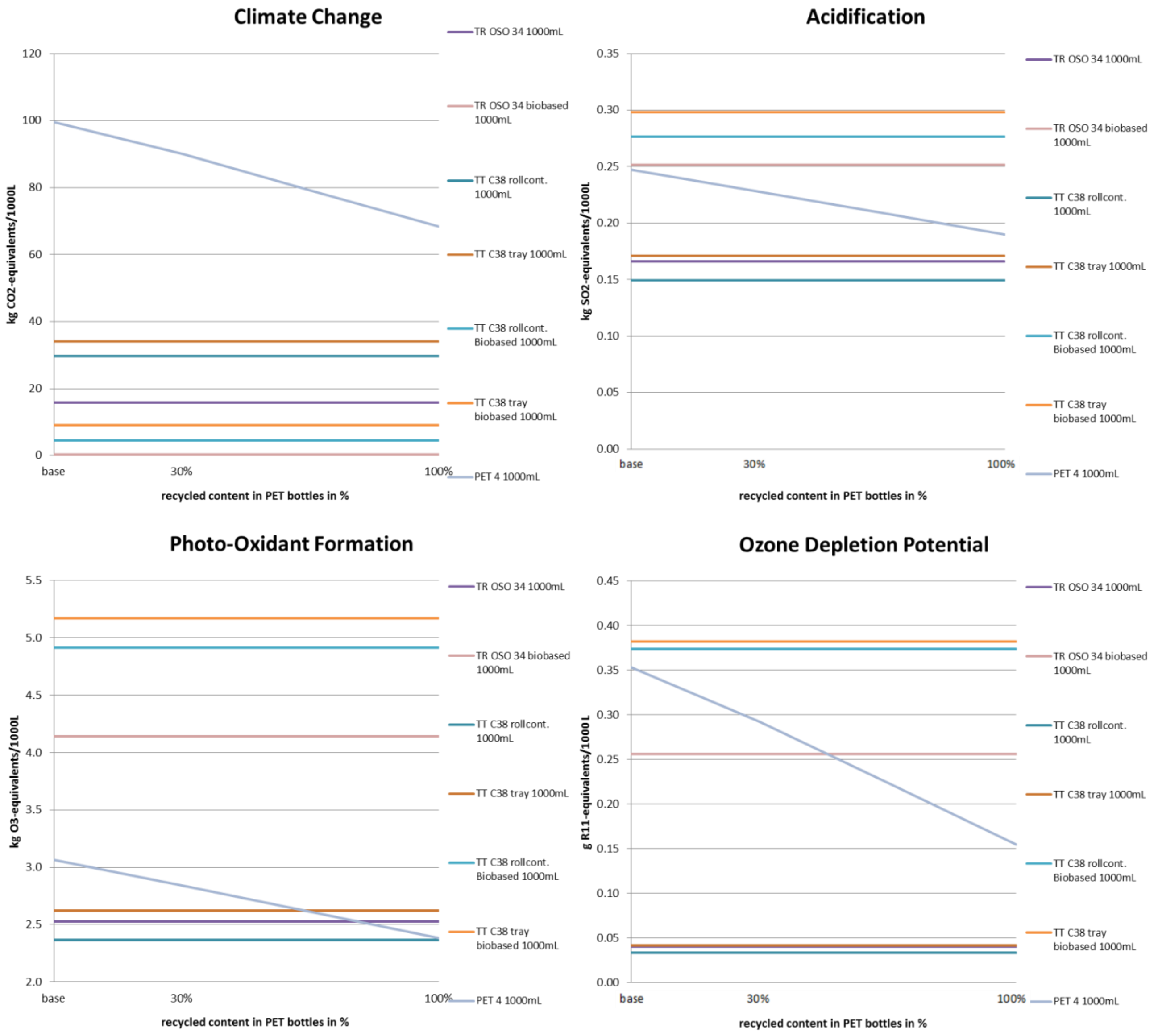


Figure 48: Indicator results for sensitivity analysis recycled PET of **segment DAIRY Family Pack, Austria**, allocation factor 50% (Part 1)

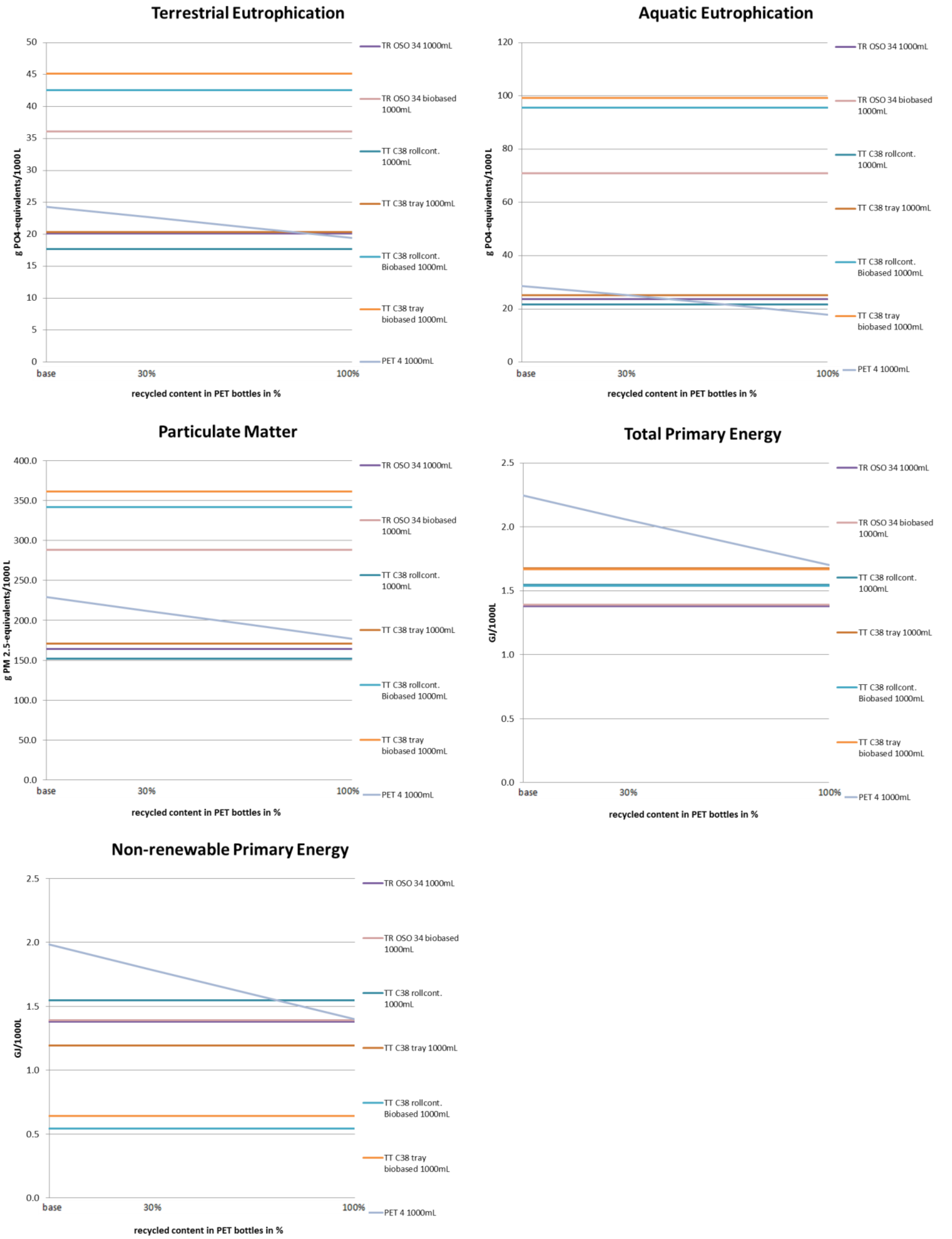


Figure 49: Indicator results for sensitivity analysis recycled PET of segment DAIRY Family Pack, Austria, allocation factor 50% (Part 2)

Description and Interpretation

In most categories, the PET bottle with an increasing recycled content will break even with at least some beverage cartons. The exceptions are ‘Climate Change’ and ‘Total Primary Energy’, for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

5.1.3 Sensitivity analysis regarding trip rates of refillable glass bottles

In the base scenarios for refillable glass bottles in the segment DAIRY Family Pack in Austria the trip rate of 10 refills is based on the press note of Berglandmilch [Berglandmilch 2019]. To consider also higher trip rates of this refillable glass bottles, a sensitivity analysis is performed (for details please see section 2.4.5). Results are shown in the following figures.

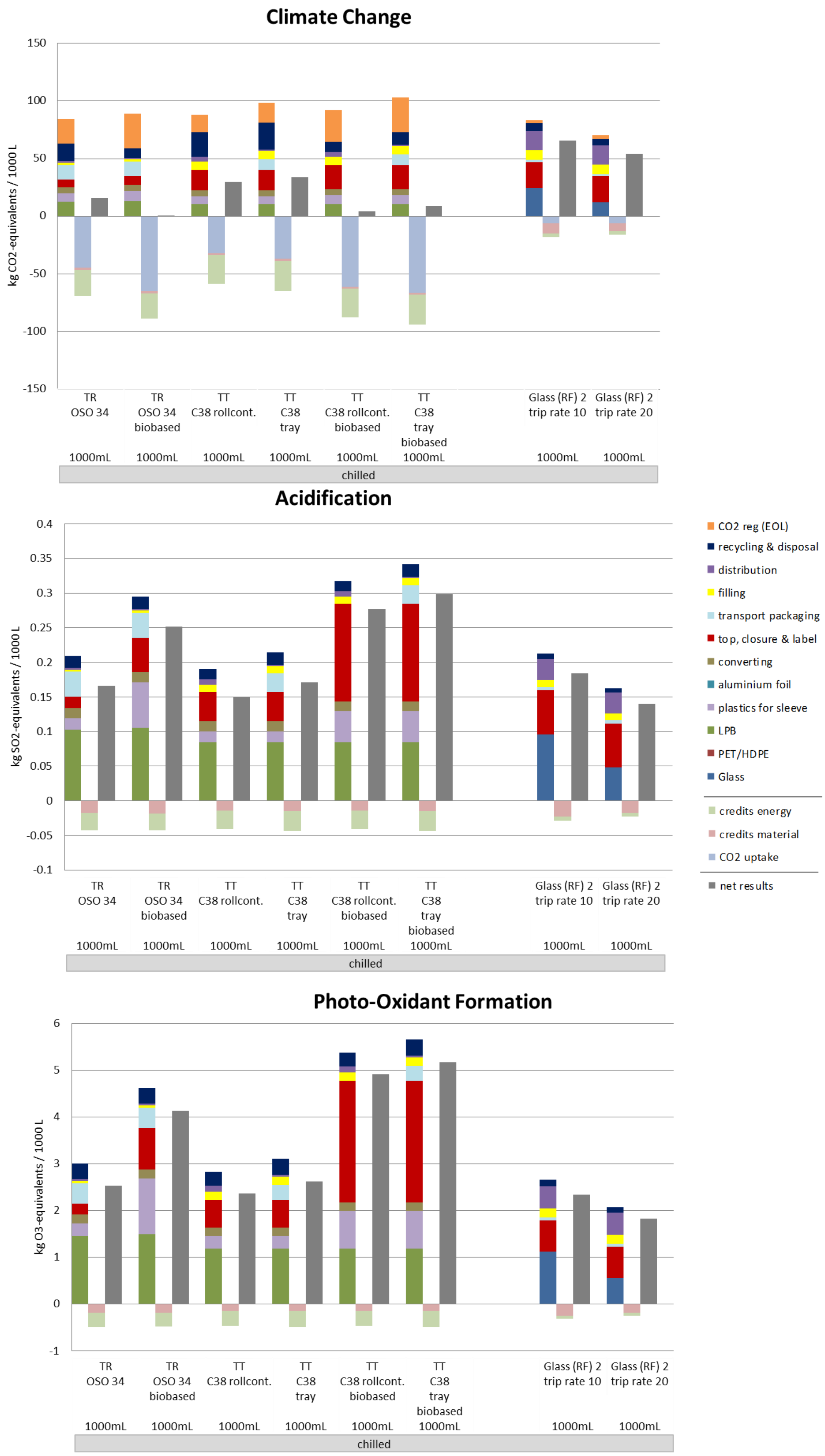


Figure 50: Indicator results for sensitivity analysis regarding trip rates of refillable glass bottles of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 1)

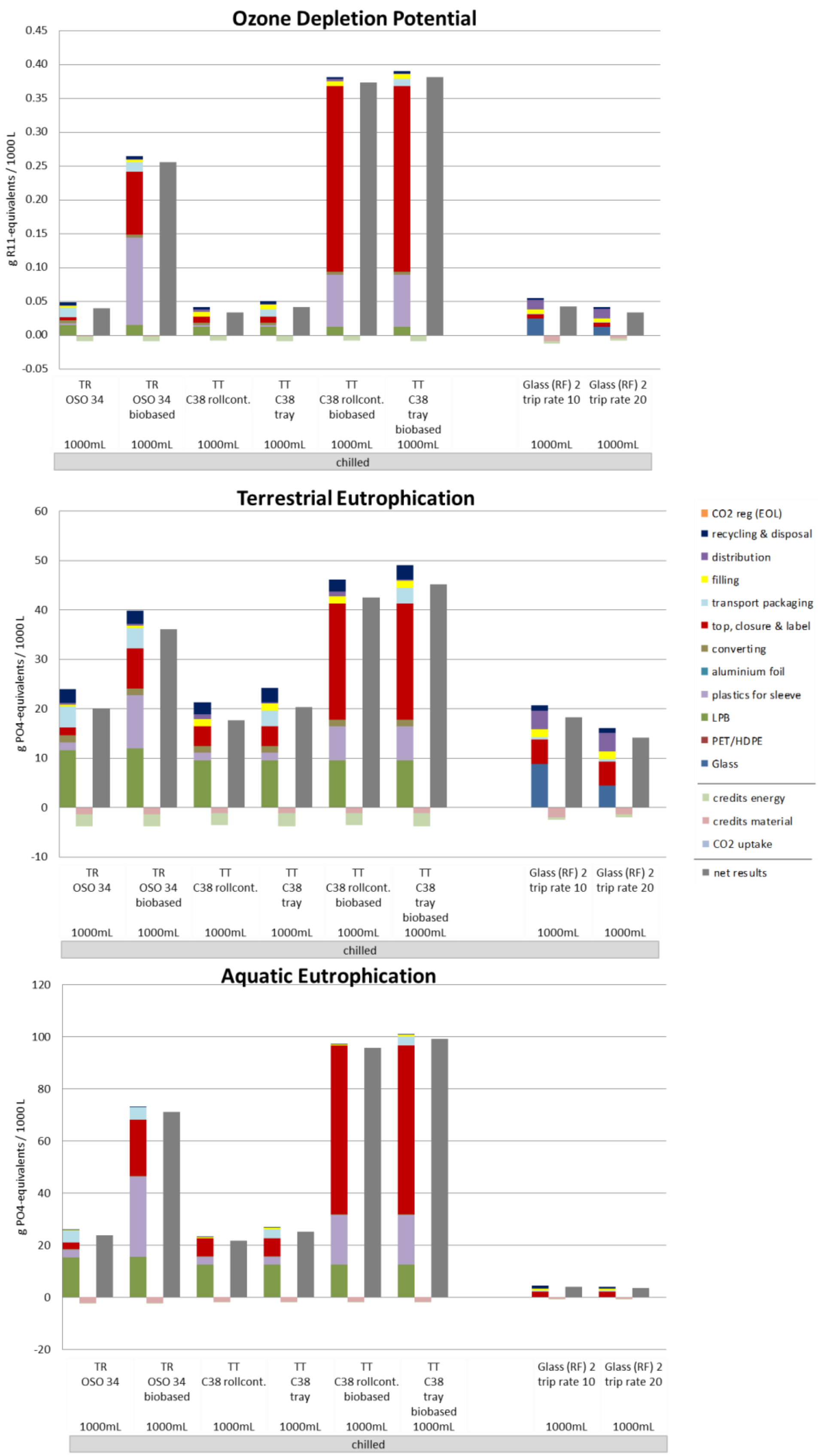


Figure 51 Indicator results for sensitivity analysis regarding trip rates of refillable glass bottles of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 2)

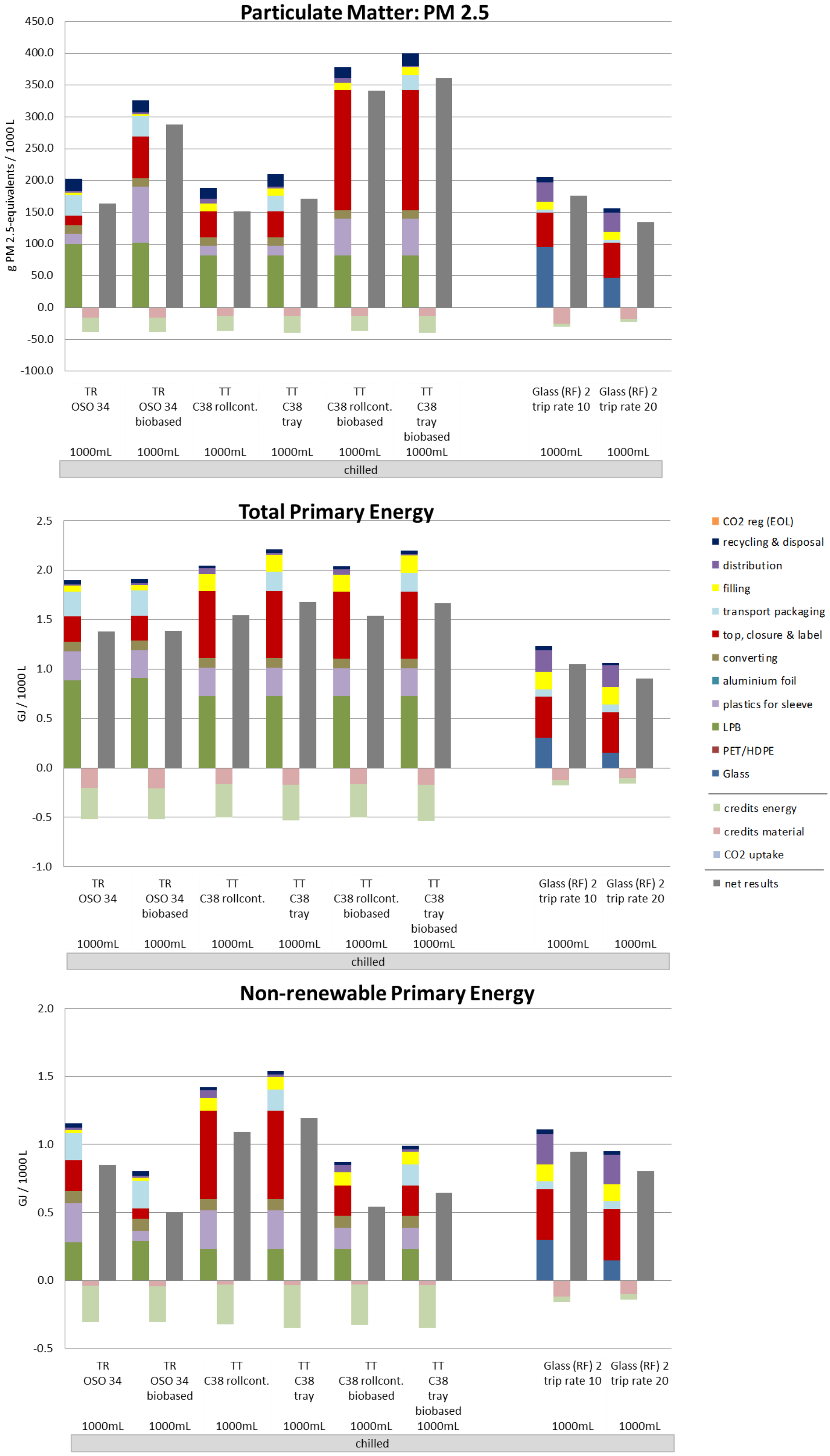


Figure 52: Indicator results for sensitivity analysis regarding trip rates of refillable glass bottles of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 3)

Description and Interpretation

The increase of the trip rate of the refillable glass bottle from 10 to 20 reduces the net results by 10%-24%. This leads to lower net results of the refillable glass bottle than all beverage carton systems in most impact categories. An exception is ‘Climate Change’. For ‘Climate Change’ the net results of beverage cartons stay lower than the net results of the refillable glass bottle with an increased trip rate.

5.2 JN FAMILY PACK AUSTRIA

5.2.1 Sensitivity analysis on system allocation JN FAMILY PACK Austria

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard’s recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

Figure 53: Indicator results for sensitivity analysis on system allocation of **segment JN FAMILY PACK, Austria**, allocation factor 100% (Part 1)

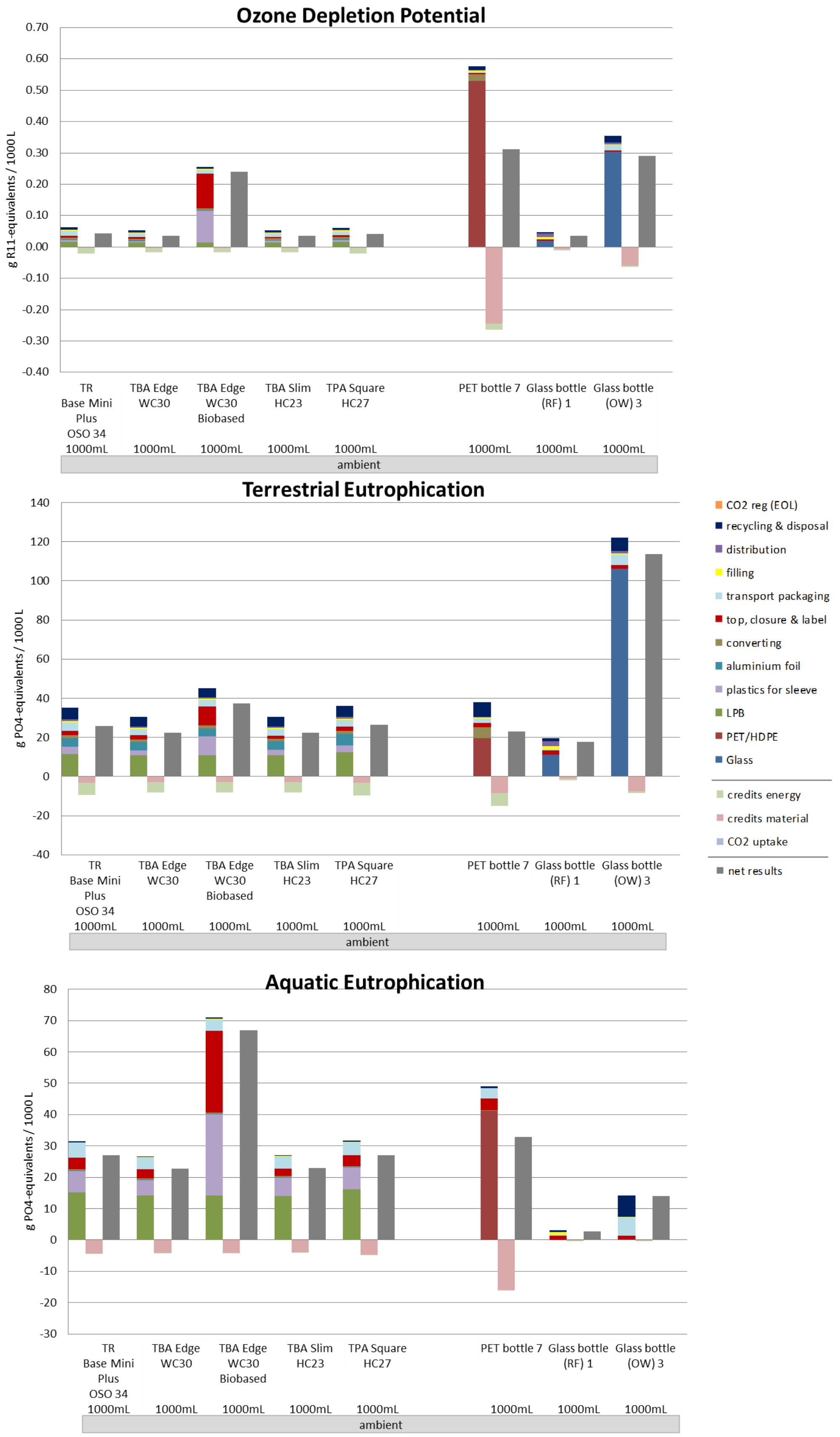


Figure 54: Indicator results for sensitivity analysis on system allocation of **segment JN FAMILY PACK, Austria** , allocation factor 100% (Part 2)

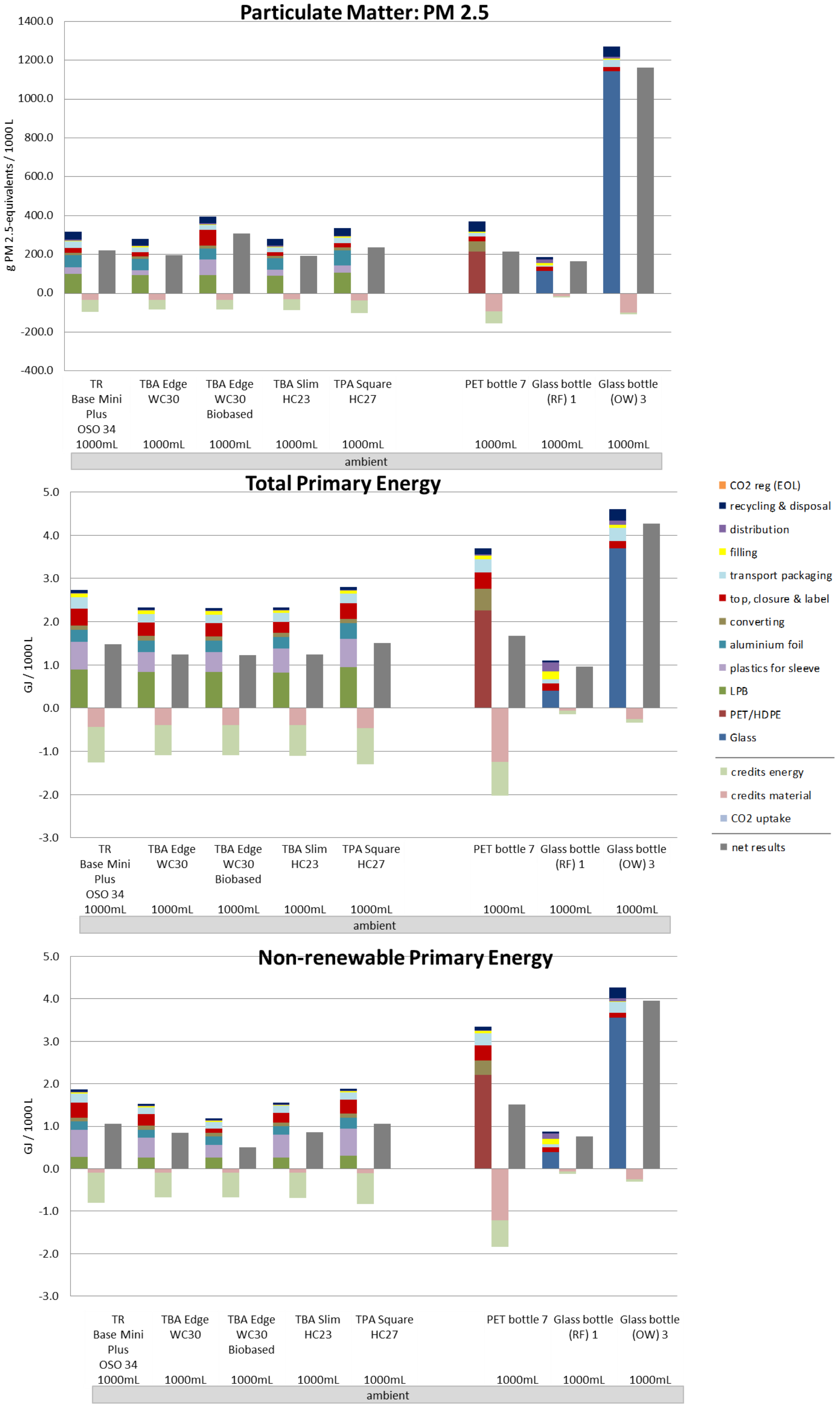


Figure 55: Indicator results for sensitivity analysis on system allocation of **segment JN FAMILY PACK, Austria**, allocation factor 100% (Part 3)

Table 83: Category indicator results per impact category for sensitivity analysis on system allocation of **segment JN FAMILY PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	TPA Square HC27 1000mL		PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	124.24	102.24	89.20	103.99	126.43		210.98	64.97	349.68
	CO2 (reg)	42.43	38.66	54.32	38.30	43.95		3.21	7.43	7.55
	Credits	-64.88	-54.28	-54.34	-55.74	-66.84		-85.29	-8.12	-29.12
	CO2 uptake	-44.88	-40.92	-59.01	-40.54	-46.51		-3.29	-7.50	-7.78
	net results	56.92	45.70	30.18	46.02	57.03		125.61	56.79	320.33
Acidification [kg SO2-e/1000 L[	Burdens	0.33	0.30	0.37	0.29	0.36		0.40	0.19	1.28
	Credits	-0.11	-0.09	-0.09	-0.09	-0.11		-0.17	-0.02	-0.08
	Net results	0.23	0.20	0.28	0.20	0.24		0.23	0.17	1.20
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	4.54	3.92	5.41	3.92	4.68		4.97	2.49	15.33
	Credits	-1.19	-1.03	-1.03	-1.04	-1.24		-2.07	-0.24	-1.03
	Net results	3.35	2.89	4.38	2.88	3.44		2.90	2.26	14.30
Ozone Depletion [g R11/1000 L]	Burdens	0.06	0.05	0.26	0.05	0.06		0.58	0.05	0.35
	Credits	-0.02	-0.02	-0.02	-0.02	-0.02		-0.26	-0.01	-0.06
	Net results	0.04	0.04	0.24	0.04	0.04		0.31	0.04	0.29
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	35.02	30.45	45.23	30.42	36.23		37.90	19.54	122.07
	Credits	-9.27	-8.00	-8.01	-8.09	-9.63		-14.97	-1.86	-8.43
	Net results	25.76	22.45	37.22	22.32	26.60		22.93	17.68	113.64
Aquatic Eutrophication [g PO4/1000 L]	Burdens	31.44	26.71	70.92	27.01	31.61		48.93	3.06	14.10
	Credits	-4.36	-4.06	-4.06	-3.99	-4.61		-16.02	-0.32	-0.20
	Net results	27.09	22.65	66.86	23.02	26.99		32.92	2.75	13.90
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	318.02	279.80	394.00	279.18	337.02		369.80	186.72	1269.99
	Credits	-97.20	-84.50	-84.56	-85.31	-101.88		-155.12	-21.19	-106.99
	Net results	220.82	195.30	309.45	193.87	235.13		214.68	165.53	1163.00
Total Primary Energy [GJ]	Burdens	2.73	2.32	2.31	2.33	2.80		3.69	1.10	4.60
	Credits	-1.26	-1.09	-1.09	-1.10	-1.30		-2.02	-0.14	-0.34
	Net results	1.48	1.24	1.22	1.23	1.50		1.67	0.96	4.26
Non-renewable Primary Energy [GJ]	Burdens	1.86	1.53	1.19	1.56	1.89		3.35	0.88	4.26
	Credits	-0.81	-0.68	-0.68	-0.69	-0.83		-1.84	-0.12	-0.31
	Net results	1.05	0.85	0.51	0.87	1.06		1.51	0.76	3.95
Use of Nature [m²*year]	Burdens	24.35	22.39	35.55	22.10	25.40		0.62	0.50	3.35
	Credits	-6.10	-5.72	-5.72	-5.63	-6.51		-0.15	-0.05	-0.05
	Net results	18.25	16.66	29.83	16.47	18.89		0.47	0.44	3.30
Water use [m³/1000 L]	water cool	1.52	1.23	1.27	1.23	1.39		2.17	0.40	0.68
	water process	2.06	2.05	2.04	1.94	2.30		0.15	0.44	0.17
	water unspecified	0.83	0.71	0.83	0.71	0.87		0.46	0.06	0.34

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 regarded system.

In the cases of beverage cartons in the Austrian segment JN FAMILY PACK applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories. This is because the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The only exception is 'Climate Change'. For 'Climate Change' applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of plastic bottles the net results also decrease when applying the 100% allocation factor in most impact categories as the additionally allocated credits are higher than the additionally allocated. The exception is 'Climate Change'. For 'Climate Change' net results stay about the same when applying the 100% allocation factor as burdens from incineration are similar than energy and material credits.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

In the case of the one-way glass bottle net results of all categories except 'Aquatic Eutrophication' decrease when applying the 100% allocation factor as burdens from recycling and disposal are lower than energy and material credits.

In the case of the refillable glass bottle net results of all categories increase when applying the 100% allocation factor as burdens from recycling and disposal are higher than energy and material credits. The lower material credits result from the high trip rates.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 84: Comparison of net results: **TR Base Mini Plus OSO 34 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 100%

JN FAMILY PACK (ambient), Austria	The net results of **TR Base Mini Plus OSO 34 1000mL** are lower (green)/ higher (orange) than those of						
	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	TPA Square HC27 1000ML	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	25%	89%	24%	0%	-55%	0%	-82%
Acidification	12%	-19%	13%	-7%	-2%	30%	-81%
Photo-Oxidant Formation	16%	-23%	16%	-3%	16%	48%	-77%
Ozone Depletion Potential	18%	-82%	20%	4%	-86%	19%	-85%
Terrestrial Eutrophication	15%	-31%	15%	-3%	12%	46%	-77%
Aquatic Eutrophication	20%	-59%	18%	0%	-18%	886%	95%
Particulate Matter	13%	-29%	14%	-6%	3%	33%	-81%

Table 85: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 100%

JN FAMILY PACK (ambient), Austria	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of						
	TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	TPA Square HC27 1000ML	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	-20%	51%	-1%	-20%	-64%	-20%	-86%
Acidification	-11%	-28%	1%	-18%	-13%	15%	-83%
Photo-Oxidant Formation	-14%	-34%	0%	-16%	0%	28%	-80%
Ozone Depletion Potential	-15%	-85%	2%	-12%	-88%	1%	-88%
Terrestrial Eutrophication	-13%	-40%	1%	-16%	-2%	27%	-80%
Aquatic Eutrophication	-16%	-66%	-2%	-16%	-31%	725%	63%
Particulate Matter	-12%	-37%	1%	-17%	-9%	18%	-83%

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

Table 86: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 100%

JN FAMILY PACK (ambient), Austria	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of						
	TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 1000mL	TBA Slim HC23 1000mL	TPA Square HC27 1000ML	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	-47%	-34%	-34%	-47%	-76%	-47%	-91%
Acidification	23%	39%	39%	14%	21%	60%	-77%
Photo-Oxidant Formation	31%	51%	52%	27%	51%	94%	-69%
Ozone Depletion Potential	462%	561%	577%	482%	-23%	568%	-18%
Terrestrial Eutrophication	44%	66%	67%	40%	62%	110%	-67%
Aquatic Eutrophication	147%	195%	190%	148%	103%	2335%	381%
Particulate Matter	40%	58%	60%	32%	44%	87%	-73%

Table 87: Comparison of net results: **TBA Slim HC23 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 100%

JN FAMILY PACK (ambient), Austria	The net results of **TBA Slim HC23 1000mL** are lower (green)/ higher (orange) than those of						
	TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TPA Square HC27 1000ML	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	-19%	1%	53%	-19%	-63%	-19%	-86%
Acidification	-12%	-1%	-28%	-18%	-13%	15%	-83%
Photo-Oxidant Formation	-14%	0%	-34%	-16%	-1%	28%	-80%
Ozone Depletion Potential	-17%	-2%	-85%	-14%	-89%	-1%	-88%
Terrestrial Eutrophication	-13%	-1%	-40%	-16%	-3%	26%	-80%
Aquatic Eutrophication	-15%	2%	-66%	-15%	-30%	738%	66%
Particulate Matter	-12%	-1%	-37%	-18%	-10%	17%	-83%

Table 88: Comparison of net results: **TBA Square HC27 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Austria**, allocation factor 100%

JN FAMILY PACK (ambient), Austria	The net results of **TPA Square HC27 1000mL** are lower (green)/ higher (orange) than those of						
	TR Base Mini Plus OSO 34 1000mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 7 1000mL	Glass bottle (RF) 1 1000mL	Glass bottle (OW) 3 1000mL
Climate Change	0%	25%	89%	24%	-55%	0%	-82%
Acidification	8%	21%	-12%	22%	6%	40%	-80%
Photo-Oxidant Formation	3%	19%	-21%	20%	19%	53%	-76%
Ozone Depletion Potential	-3%	14%	-83%	16%	-87%	15%	-86%
Terrestrial Eutrophication	3%	19%	-29%	19%	16%	50%	-77%
Aquatic Eutrophication	0%	19%	-60%	17%	-18%	883%	94%
Particulate Matter	6%	20%	-24%	21%	10%	42%	-80%

5.2.2 Sensitivity analysis regarding recycled PET in PET bottles

To consider potential future developments in terms of the share of recyclate of the plastic bottles, two additional scenarios for plastic bottles with a recycled content of PET of 30% and 100% are analysed and illustrated in this sensitivity analysis (for details please see section 2.4.4). Results are shown in the following break even graphs.

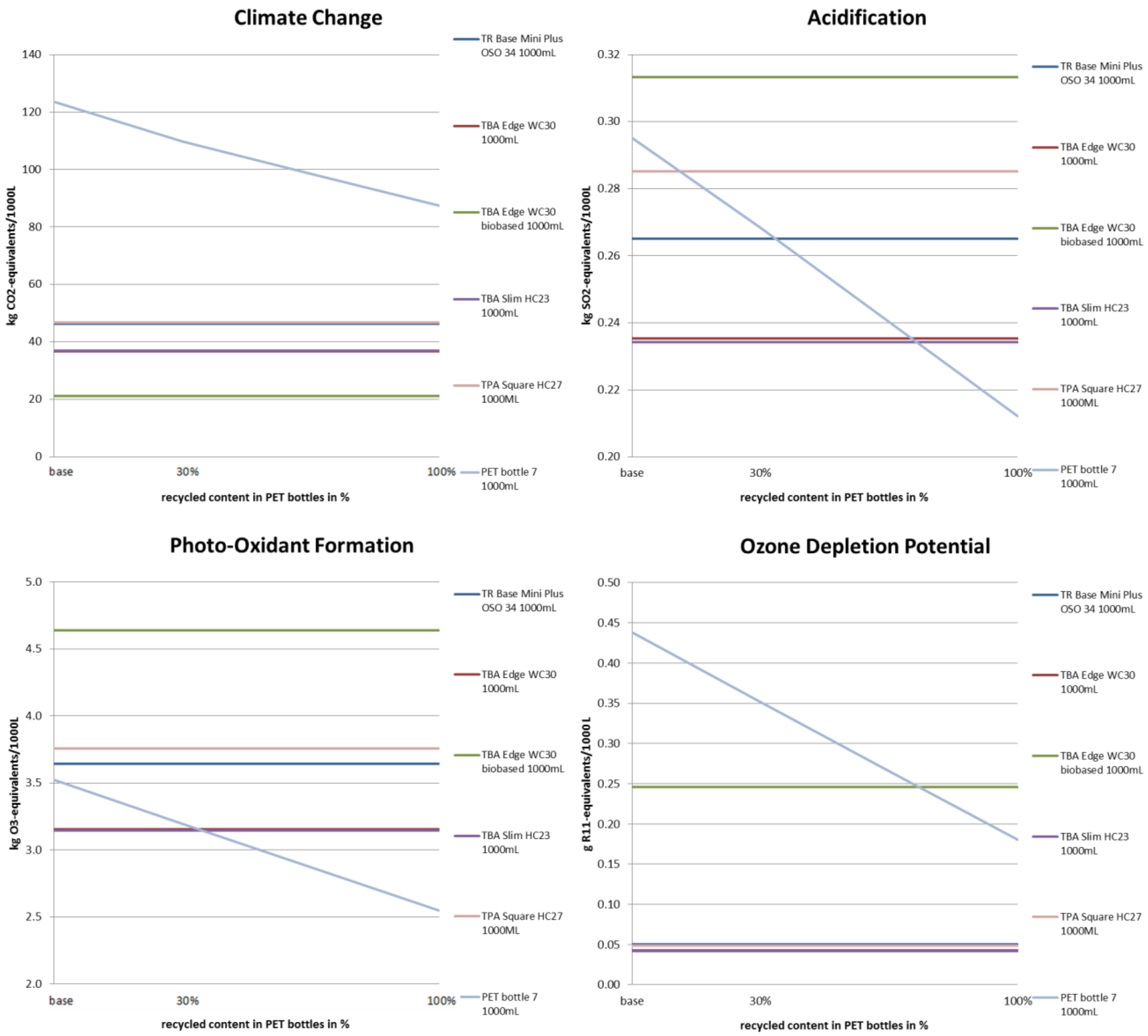


Figure 56: Indicator results for sensitivity analysis recycled PET of **segment JN Family Pack, Austria**, allocation factor 50% (Part 1)

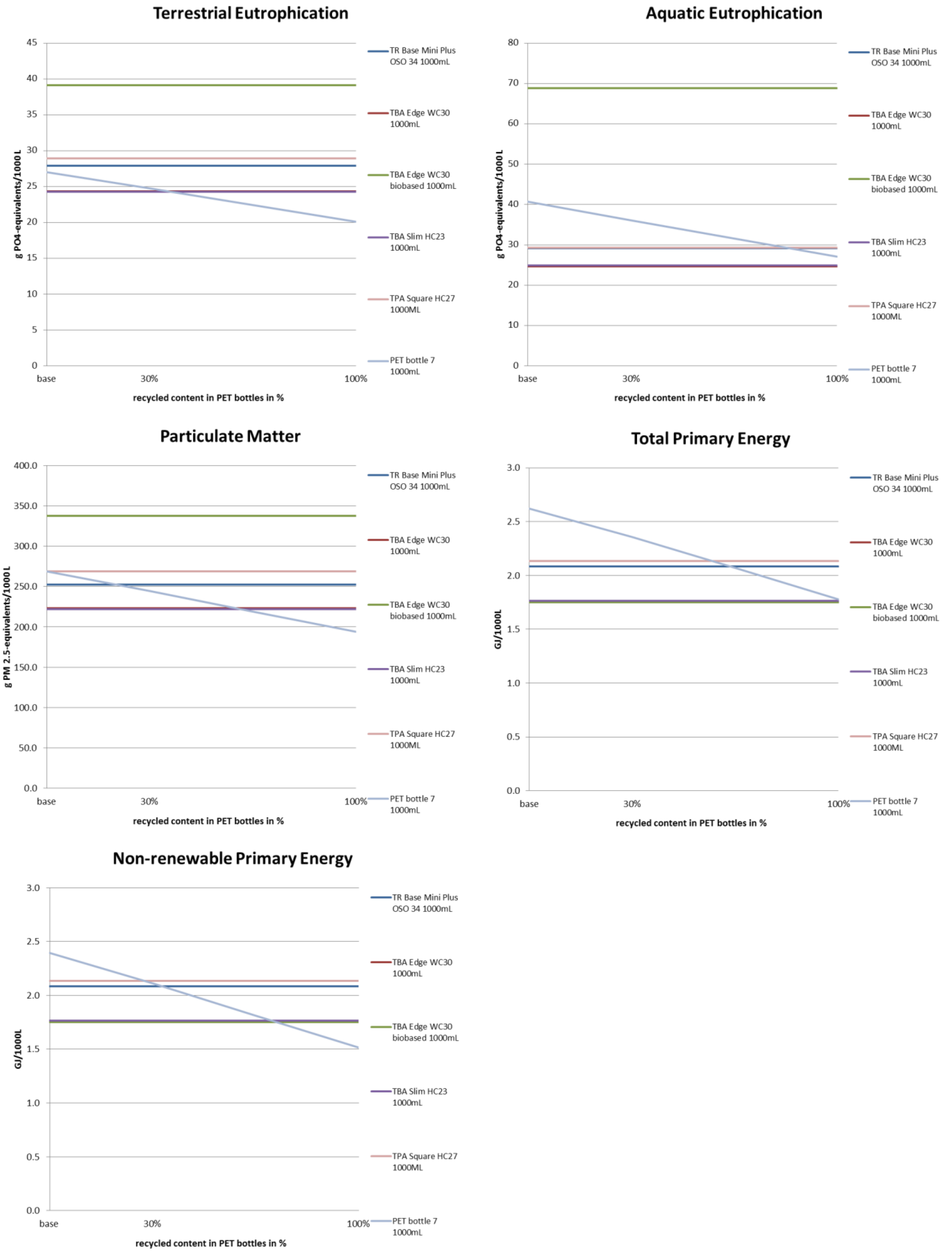


Figure 57: Indicator results for sensitivity analysis recycled PET of **segment JN Family Pack, Austria**, allocation factor 50% (Part 2)

Description and Interpretation

In most categories, the PET bottle with an increasing recycled content will break even with at least some beverage cartons. The exception is 'Climate Change', for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

5.2.3 Sensitivity analysis regarding trip rates of refillable glass bottles

In the base scenarios for refillable glass bottles in the segment JN Family Pack in Austria the trip rate of 30 refills is taken from [Kauertz et al. 2011]. To consider also lower trip rates of this refillable glass bottles, a sensitivity analysis is performed (for details please see section 2.4.5). Results are shown in the following figures.

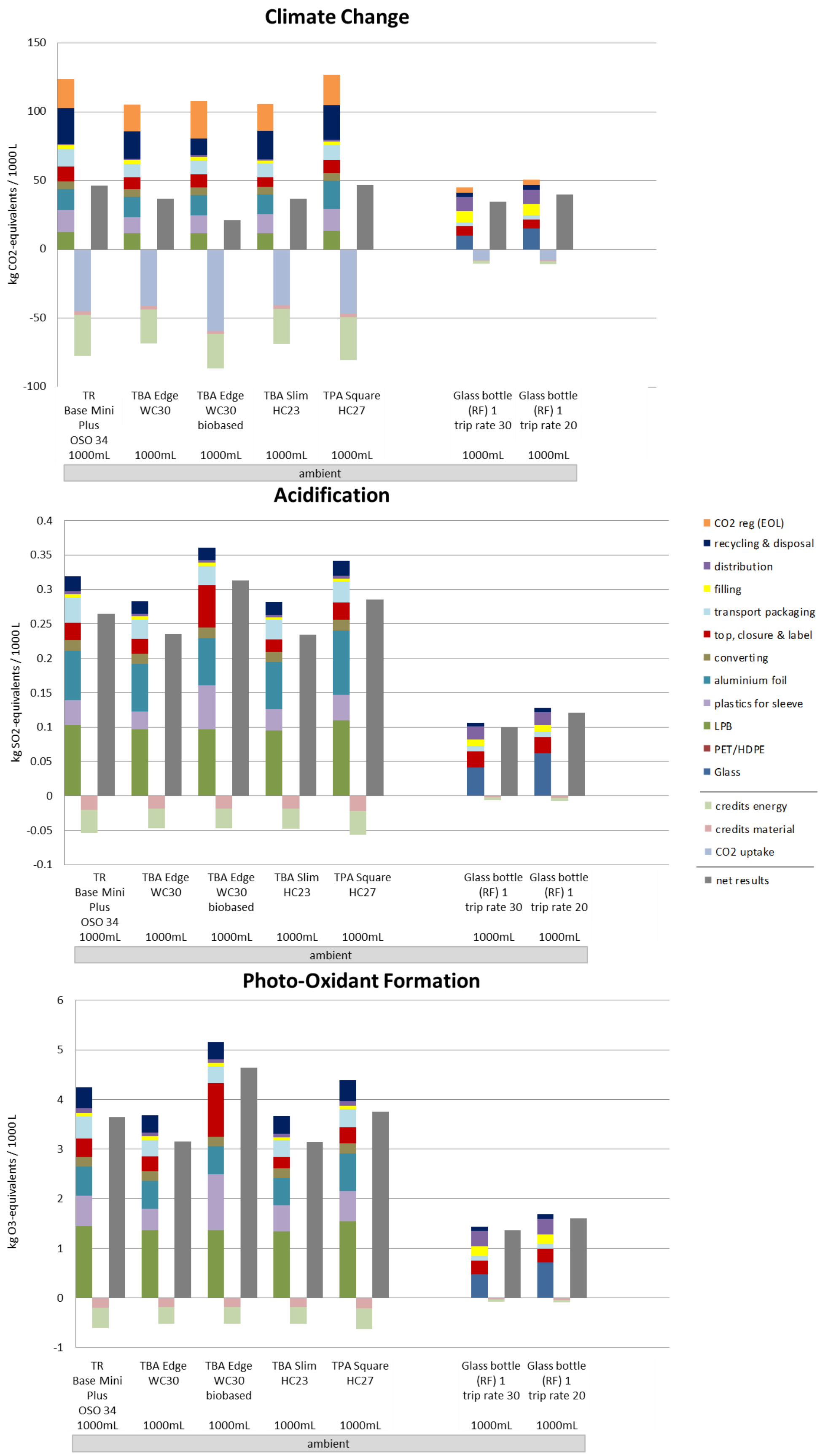


Figure 58: Indicator results for sensitivity analysis regarding trip rates of refillable glass bottles of **segment JN FAMILY PACK, Austria**, allocation factor 50% (Part 1)

Figure 59 Indicator results for sensitivity analysis regarding trip rates of refillable glass bottles of **segment JN FAMILY PACK, Austria**, allocation factor 50% (Part 2)

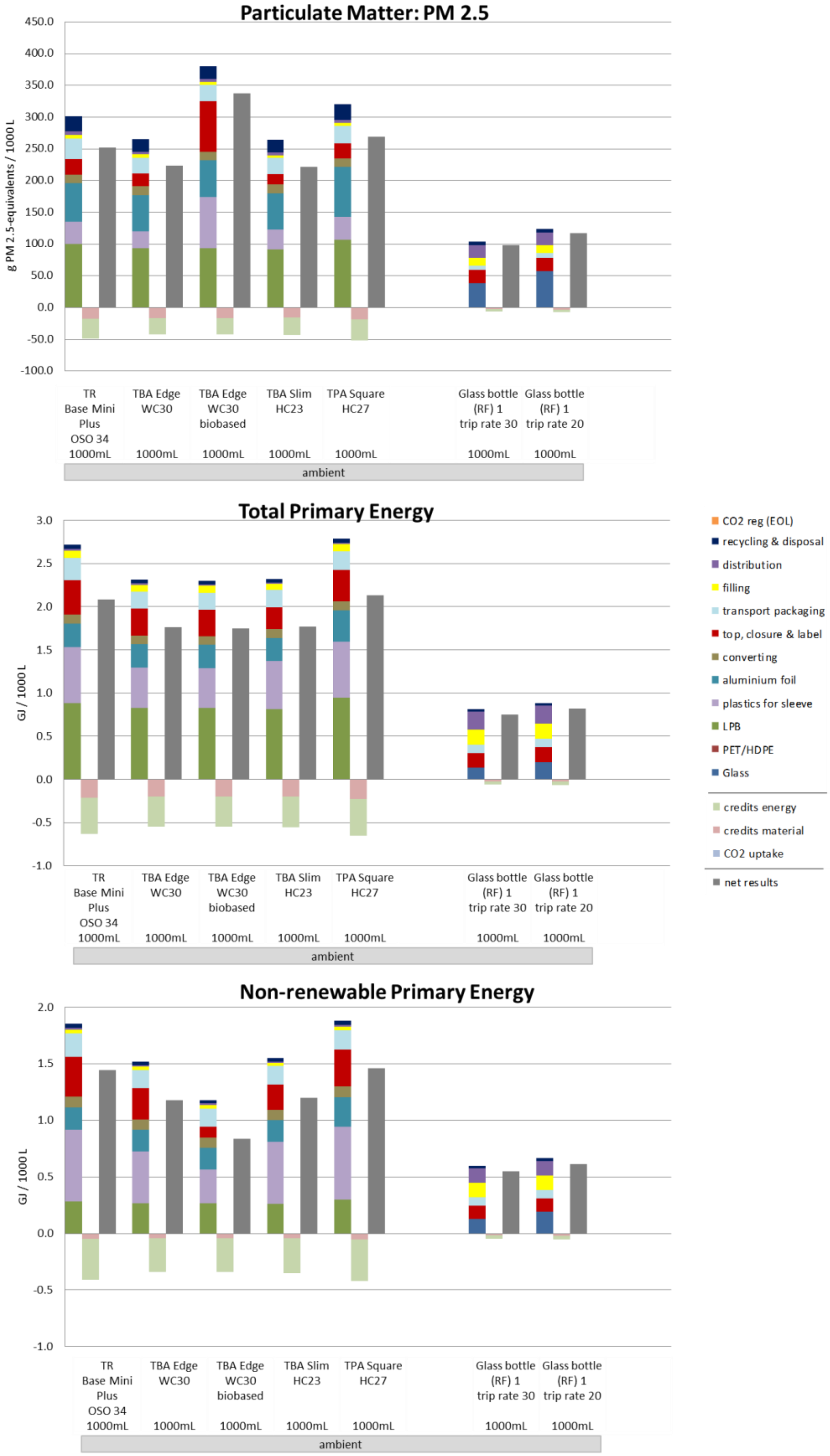


Figure 60: Indicator results for sensitivity analysis regarding trip rates of refillable glass bottles of **segment JN FAMILY PACK, Austria**, allocation factor 50% (Part 3)

Description and Interpretation

The decrease of the trip rate of the refillable glass bottle from 30 to 20 increases the net results by 3%-21%. Also with this increase, the net results of the refillable glass bottle stay lower than most beverage cartons in most categories. The exception is the 'TBA Edge WC30 bio-based 1000mL' which shows lower net results for 'Climate Change' than the refillable glass bottle with the base trip rate and the reduced trip rate. The 'TBA Edge WC 30 1000mL' and the 'TBA Slim HC23 1000mL' show lower net results than the refillable glass bottle with the reduced trip rate.

5.3 SD FAMILY PACK AUSTRIA

5.3.1 Sensitivity analysis on system allocation SD FAMILY PACK Austria

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

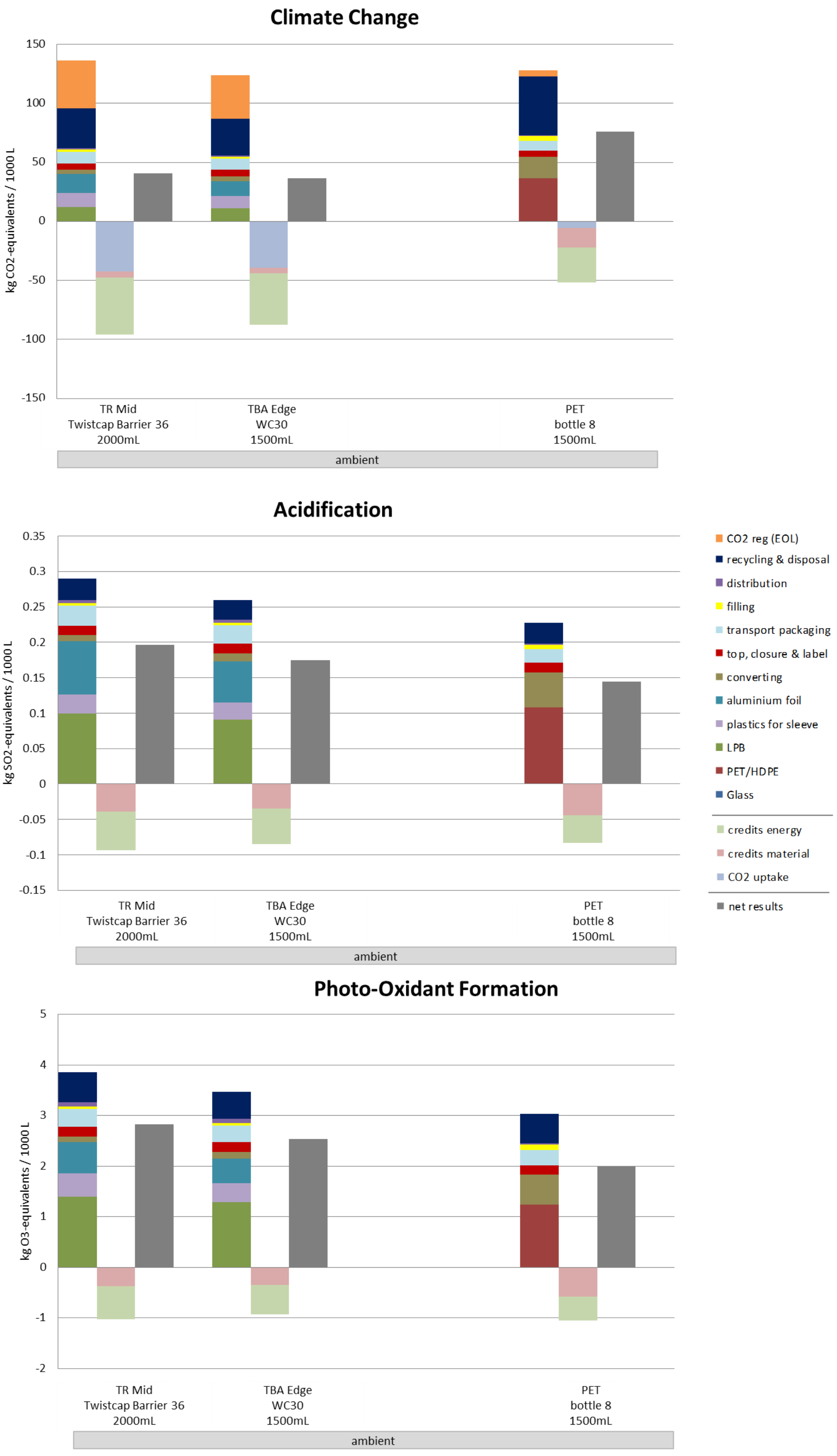


Figure 61: Indicator results on system allocation of **segment SD FAMILY PACK, Austria**, allocation factor 100% (Part 1)

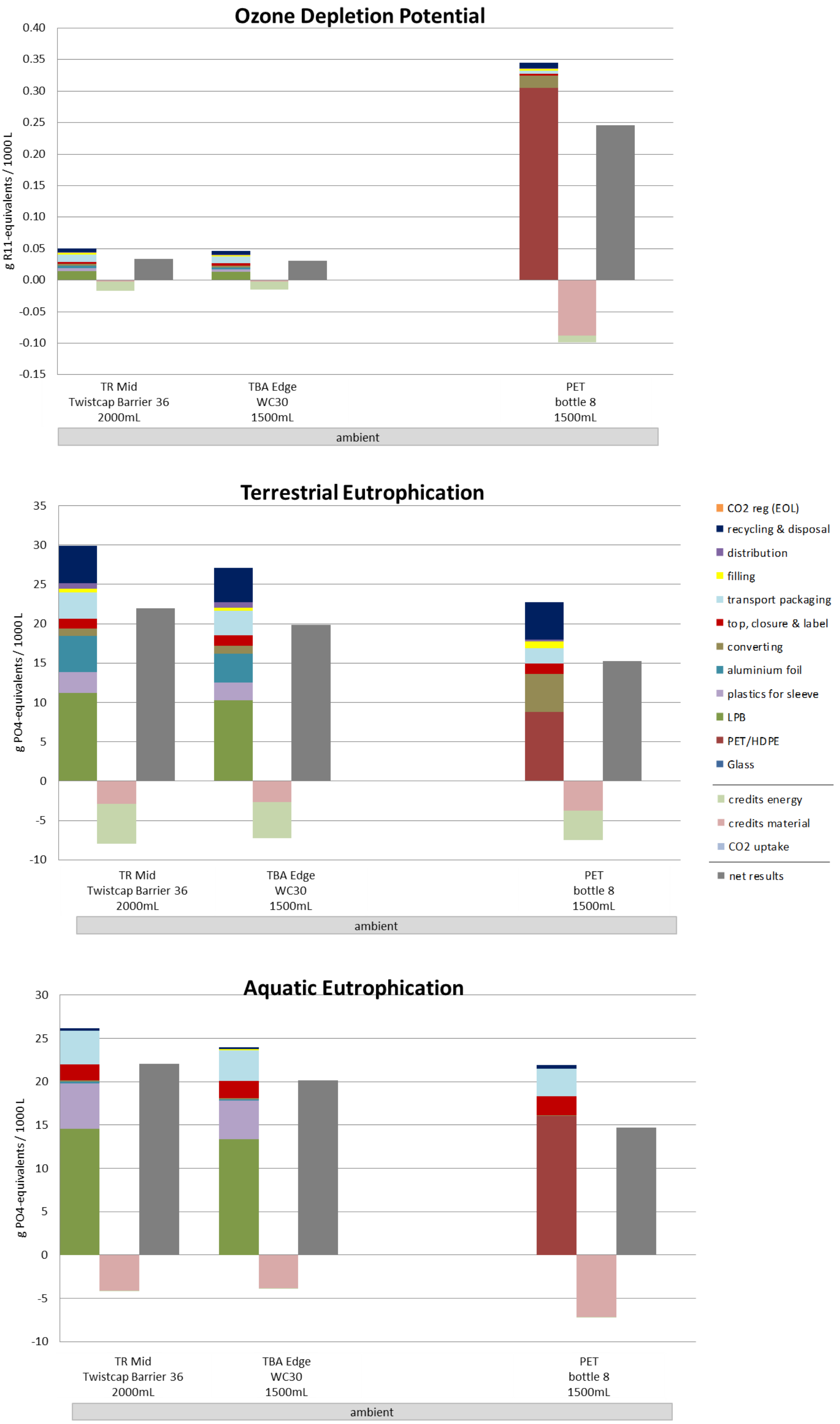


Figure 62: Indicator results on system allocation of **segment SD FAMILY PACK, Austria**, allocation factor 100% (Part 2)

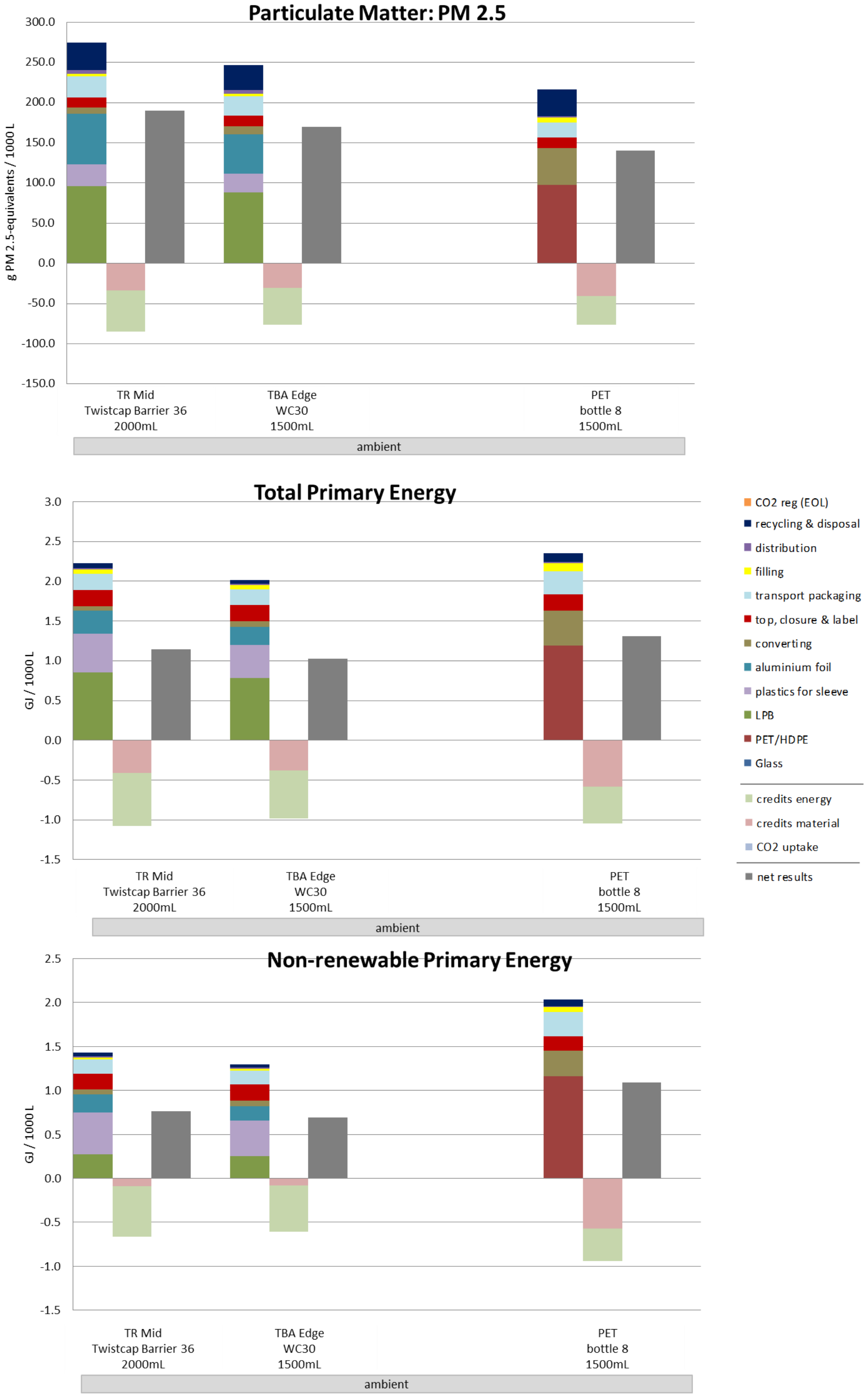


Figure 63: Indicator results on system allocation of **segment SD FAMILY PACK, Austria**, allocation factor 100% (Part 3)

Table 89: Category indicator results per impact category on system allocation of **segment SD FAMILY PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TR Mid Twistcap Barrier 36 2000mL	TBA Edge WC30 1500mL		PET bottle 8 1500mL
Climate Change [kg CO2-e/1000 L[	Burdens	96.03	86.88		122.61
	CO2 (reg)	40.09	36.98		5.52
	Credits	-53.21	-48.26		-46.14
	CO2 uptake	-42.42	-39.13		-5.72
	net results	40.49	36.48		76.26
Acidification [kg SO2-e/1000 L[	Burdens	0.29	0.26		0.23
	Credits	-0.09	-0.08		-0.08
	Net results	0.20	0.17		0.14
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.85	3.47		3.03
	Credits	-1.03	-0.94		-1.05
	Net results	2.82	2.54		1.98
Ozone Depletion [g R11/1000 L]	Burdens	0.05	0.05		0.34
	Credits	-0.02	-0.02		-0.10
	Net results	0.03	0.03		0.25
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	29.92	27.11		22.74
	Credits	-7.98	-7.26		-7.48
	Net results	21.94	19.85		15.27
Aquatic Eutrophication [g PO4/1000 L]	Burdens	26.18	23.98		21.89
	Credits	-4.16	-3.84		-7.18
	Net results	22.02	20.15		14.70
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	274.29	246.71		216.71
	Credits	-84.51	-76.54		-76.44
	Net results	189.78	170.17		140.27
Total Primary Energy [GJ]	Burdens	2.22	2.02		2.35
	Credits	-1.08	-0.99		-1.04
	Net results	1.14	1.03		1.31
Non-renewable Primary Energy [GJ]	Burdens	1.43	1.30		2.03
	Credits	-0.66	-0.60		-0.94
	Net results	0.77	0.69		1.09
Use of Nature [m²*year]	Burdens	22.98	21.11		0.69
	Credits	-5.87	-5.40		-0.10
	Net results	17.11	15.72		0.59
Water use [m³/1000 L]	water cool	1.14	1.00		1.91
	water process	1.98	1.85		0.14
	water unspecified	0.72	0.61		0.38

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 regarded system.

In the cases of beverage cartons in the Austrian segment SD FAMILY PACK applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories. This is because the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The only exception is 'Climate Change'. For 'Climate Change' applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of plastic bottles the net results also decrease when applying the 100% allocation factor in most impact categories as the additionally allocated credits are higher than the additionally allocated. The exception is 'Climate Change'. For 'Climate Change' net results stay about the same when applying the 100% allocation factor as burdens from incineration are similar than energy and material credits.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 90: Comparison of net results: **TR Mid Twistcap Barrier 36 2000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Austria**, allocation factor 100%

SD FAMILY PACK (ambient), Austria	The net results of **TR Mid Twistcap Barrier 36 2000mL** are lower (green)/ higher (orange) than those of	
	TBA Edge WC30 1500mL	PET bottle 8 1500mL
Climate Change	11%	-47%
Acidification	12%	36%
Photo-Oxidant Formation	11%	42%
Ozone Depletion Potential	9%	-86%
Terrestrial Eutrophication	11%	44%
Aquatic Eutrophication	9%	50%
Particulate Matter	12%	35%

Table 91: Comparison of net results: **TBA Edge WC30 1500mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Austria**, allocation factor 100%

SD FAMILY PACK (ambient), Austria	The net results of **TBA Edge WC30 1500mL** are lower (green)/ higher (orange) than those of	
	TR Mid Twistcap Barrier 36 2000mL	PET bottle 8 1500mL
Climate Change	-10%	-52%
Acidification	-11%	21%
Photo-Oxidant Formation	-10%	28%
Ozone Depletion Potential	-8%	-87%
Terrestrial Eutrophication	-10%	30%
Aquatic Eutrophication	-9%	37%
Particulate Matter	-10%	21%

5.3.2 Sensitivity analysis regarding the consideration of regenerative carbon

To illustrate the effect of the choice the consideration of regenerative carbon has on the results of the environmental impact category ‘Climate Change’ while allocation factor of 50% is applied, a sensitivity analysis in which neither uptake nor emissions of regenerative carbon is considered, is conducted. In the following graphs the results of this sensitivity analysis is presented.

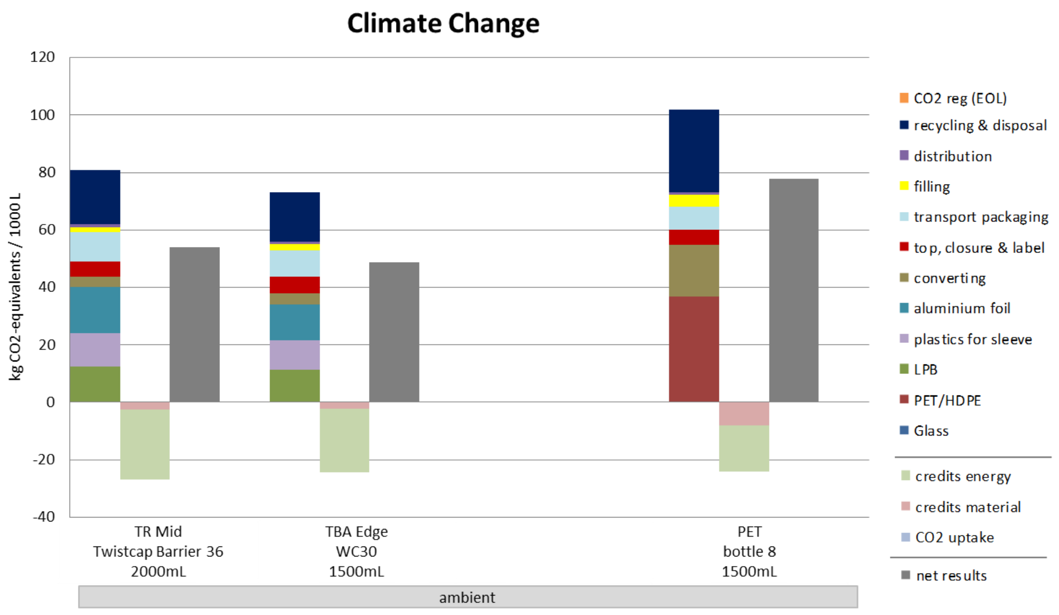


Figure 64: Indicator results 'Climate Change' of **segment SD FAMILY PACK, Austria**, regenerative carbon (Part 1)

Table 92: Category indicator results for 'Climate Change' for sensitivity on regenerative carbon of **segment SD FAMILY PACK, Austria**-burdens, credits and net results per functional unit of 1000 L. (All figures are rounded to two decimal places.)

Allocation 50		TR Mid Twistcap Barrier 36 2000mL	TBA Edge WC30 1500mL		PET bottle 8 1500mL
Climate Change [kg CO2-e/1000 L[	Burdens	80.76	73.00		101.92
	CO2 (reg)	0.00	0.00		0.00
	Credits	-26.85	-24.36		-24.19
	CO2 uptake	0.00	0.00		0.00
	net results	53.91	48.64		77.73

Description and interpretation

The non-consideration of regenerative carbon leads to lower burdens as the regenerative CO2 emissions, which are allocated in the base scenario (50%) are no longer considered. As the uptake which is not allocated in the base scenario is also not considered anymore, the net results increase for all packaging systems. The effect is significantly higher for the beverage cartons as they contain much more bio-based material than the plastic bottle (only in label and secondary/tertiary packaging). Nevertheless Climate Change results of both beverage cartons are still significantly lower than the PET bottle, as shown in the tables of the following section.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for 'Climate Change' compared to those of the other regarded packaging system 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 93: Comparison of net results: **TR Mid Twistcap Barrier 36 2000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Austria**, regenerative carbon

SD FAMILY PACK (ambient), Austria	The net results of **TR Mid Twistcap Barrier 36 2000mL** are lower (green)/ higher (orange) than those of	
	TBA Edge WC30 1500mL	PET bottle 8 1500mL
Climate Change	11%	-31%

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

Table 94: Comparison of net results: **TBA Edge WC30 1500mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Austria**, regenerative carbon

SD FAMILY PACK (ambient), Austria	The net results of **TBA Edge WC30 1500mL** are lower (green)/ higher (orange) than those of	
	TR Mid Twistcap Barrier 36 2000mL	PET bottle 8 1500mL
Climate Change	-10%	-37%

5.4 DAIRY PORTION PACK AUSTRIA

5.4.1 Sensitivity analysis on system allocation DAIRY PORTION PACK Austria

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

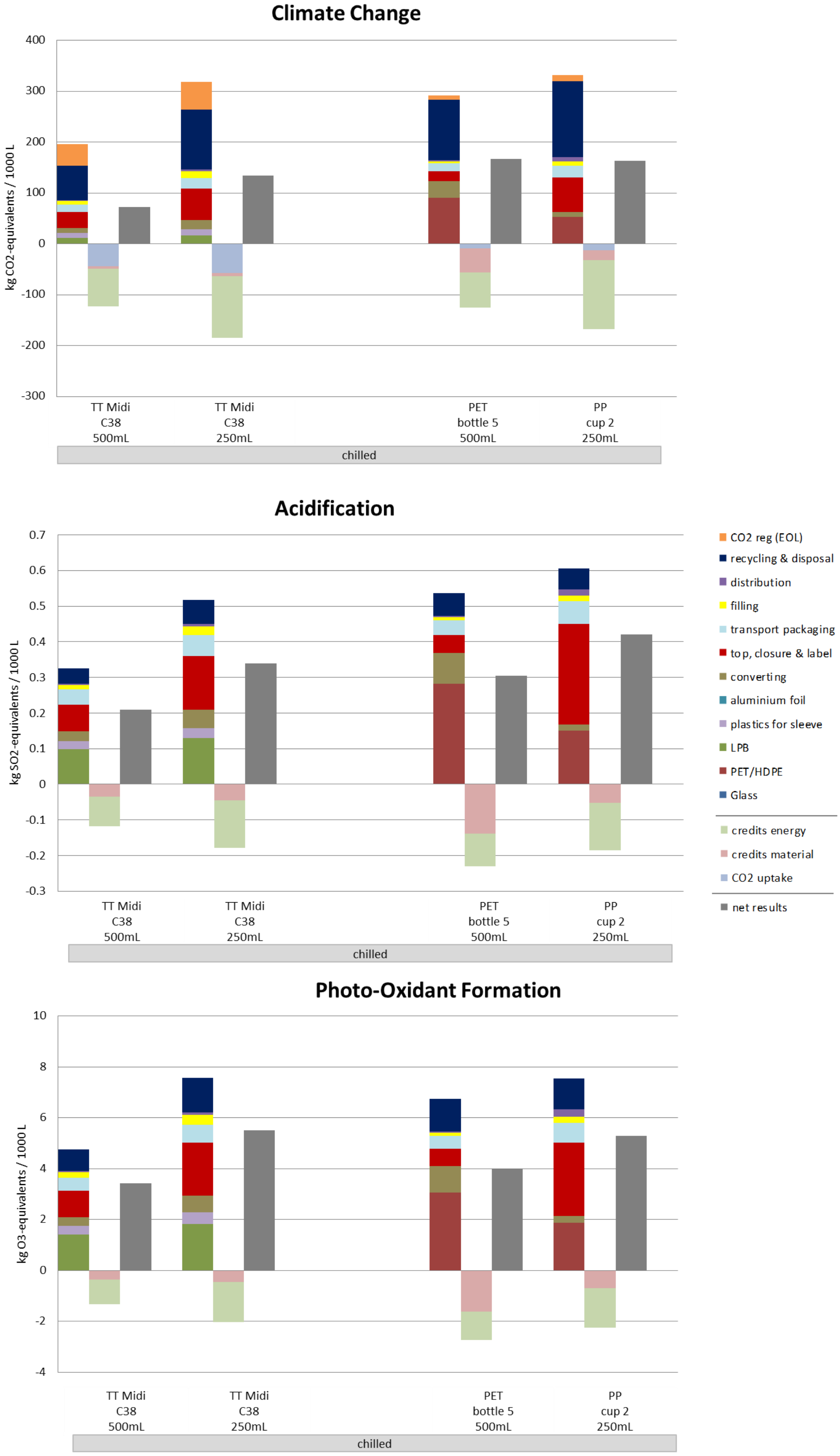
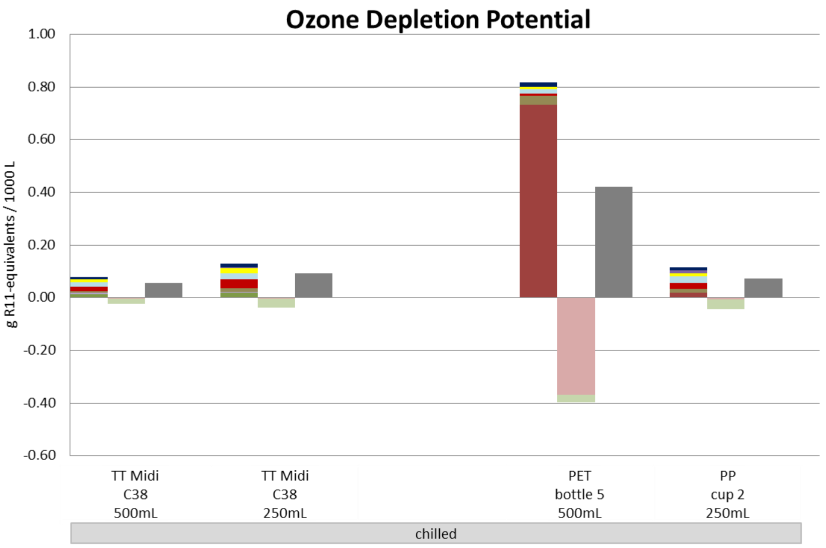
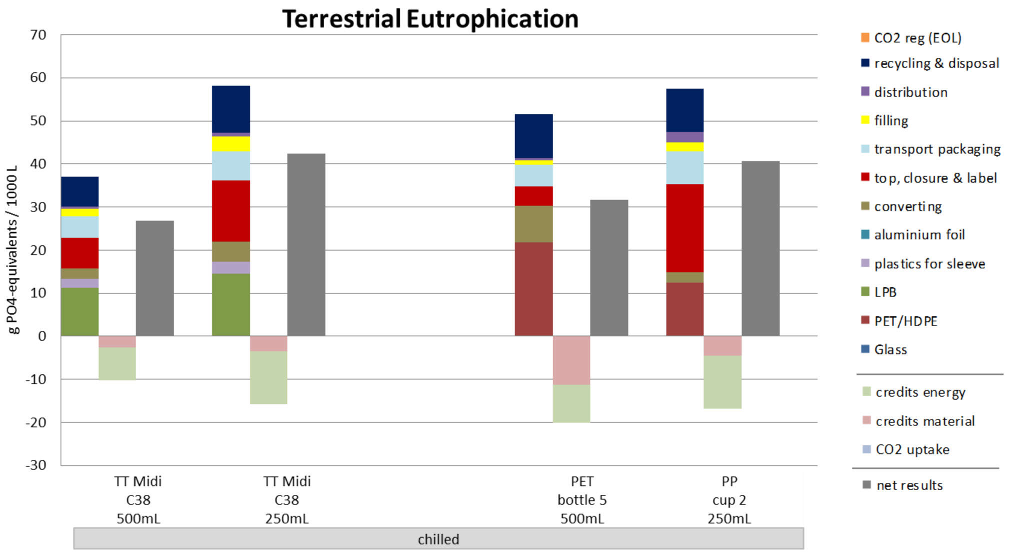


Figure 65: Indicator results on system allocation of segment DAIRY PORTION PACK, Austria, allocation factor 100% (Part 1)





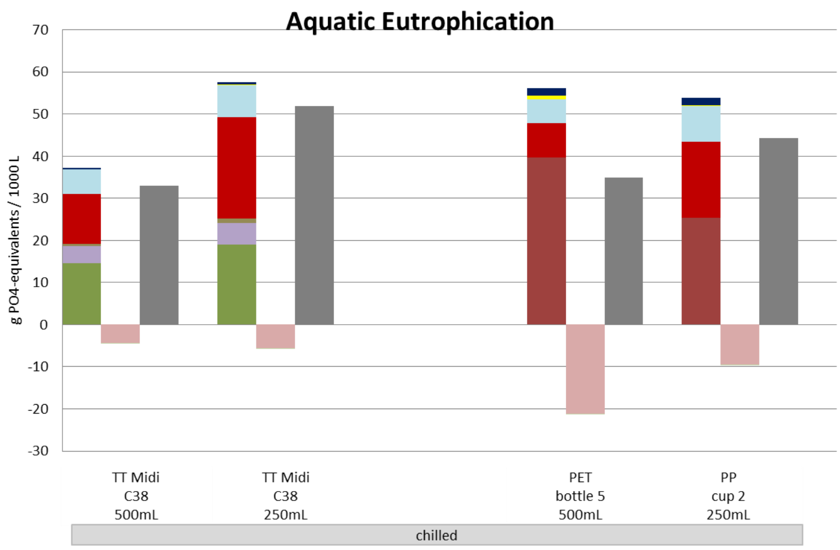


Figure 66 Indicator results on system allocation of **segment DAIRY PORTION PACK, Austria**, allocation factor 100% (Part 2)

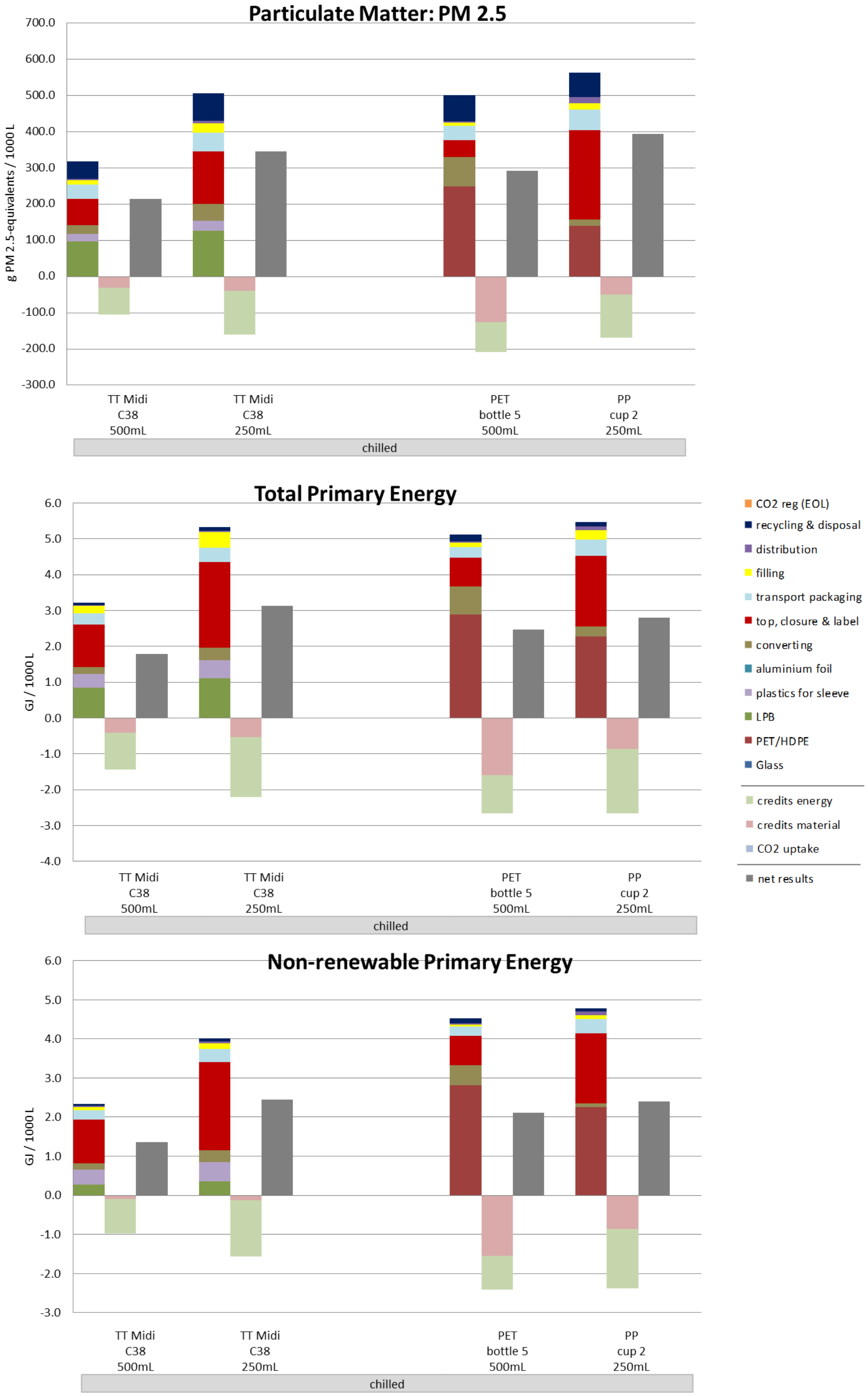


Figure 67: Indicator results on system allocation of **segment DAIRY PORTION PACK, Austria**, allocation factor 100% (Part 3)

Table 95: Category indicator results per impact category for sensitivity analysis on system allocation scenarios of **segment DAIRY PORTION PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TT Midi C38 500mL	TT Midi C38 250mL		PET bottle 5 500mL	PP cup 2 250mL
Climate Change [kg CO2-e/1000 L[	Burdens	153.57	263.59		283.19	318.94
	CO2 (reg)	41.94	54.75		8.40	12.34
	Credits	-78.44	-126.92		-116.19	-154.67
	CO2 uptake	-44.33	-57.86		-8.85	-12.99
	net results	72.74	133.55		166.55	163.61
Acidification [kg SO2-e/1000 L[	Burdens	0.33	0.52		0.54	0.61
	Credits	-0.12	-0.18		-0.23	-0.18
	Net results	0.21	0.34		0.31	0.42
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	4.76	7.56		6.73	7.53
	Credits	-1.33	-2.04		-2.73	-2.24
	Net results	3.43	5.52		4.01	5.29
Ozone Depletion [g R11/1000 L]	Burdens	0.08	0.13		0.82	0.12
	Credits	-0.02	-0.04		-0.40	-0.04
	Net results	0.06	0.09		0.42	0.07
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	37.03	58.21		51.66	57.39
	Credits	-10.29	-15.82		-20.07	-16.73
	Net results	26.74	42.39		31.59	40.66
Aquatic Eutrophication [g PO4/1000 L]	Burdens	37.23	57.49		56.10	53.78
	Credits	-4.27	-5.63		-21.11	-9.42
	Net results	32.96	51.86		35.00	44.36
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	318.09	505.36		500.63	562.58
	Credits	-104.60	-160.27		-209.12	-169.18
	Net results	213.49	345.09		291.51	393.40
Total Primary Energy [GJ]	Burdens	3.22	5.33		5.12	5.46
	Credits	-1.43	-2.20		-2.66	-2.66
	Net results	1.79	3.13		2.46	2.80
Non-renewable Primary Energy [GJ]	Burdens	2.33	4.00		4.53	4.78
	Credits	-0.97	-1.57		-2.41	-2.38
	Net results	1.36	2.44		2.12	2.40
Use of Nature [m²*year]	Burdens	24.21	31.97		3.11	4.46
	Credits	-5.95	-7.76		-0.19	-0.26
	Net results	18.26	24.21		2.92	4.19
Water use [m³/1000 L]	water cool	1.89	3.26		3.57	1.93
	water process	1.81	2.42		0.77	0.59
	water unspecified	0.70	1.10		1.00	1.42

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 regarded system.

In the cases of beverage cartons in the Austrian segment DAIRY PORTION PACK applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories. This is because the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The only exception is 'Climate Change'. For 'Climate Change' applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of the plastic bottle and the PP cup, lower net results in almost all impact categories are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The exception is 'Climate Change'. For 'Climate Change' net results stay about the same when applying the 100% allocation factor, as the additionally allocated credits and burdens show similar absolute values.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons, the plastic bottle and the PP cup in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 96: Comparison of net results: **TT Midi C38 500mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (chilled), Austria**, allocation factor 100%

DAIRY PORTION PACK (chilled), Austria	The net results of **TT Midi C38 500mL** are lower (green)/ higher (orange) than those of		
	TT Midi C38 250mL	PET bottle 5 500mL	PP cup 2 250mL
Climate Change	-46%	-56%	-56%
Acidification	-38%	-31%	-50%
Photo-Oxidant Formation	-38%	-14%	-35%
Ozone Depletion Potential	-40%	-87%	-25%
Terrestrial Eutrophication	-37%	-15%	-34%
Aquatic Eutrophication	-36%	-6%	-26%
Particulate Matter	-38%	-27%	-46%

Table 97: Comparison of net results: **TT Midi C38 250mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (chilled), Austria**, allocation factor 100%

DAIRY PORTION PACK (chilled), Austria	The net results of **TT Midi C38 250mL** are lower (green)/ higher (orange) than those of		
	TT Midi C38 500mL	PET bottle 5 500mL	PP cup 2 250mL
Climate Change	84%	-20%	-18%
Acidification	62%	11%	-19%
Photo-Oxidant Formation	61%	38%	4%
Ozone Depletion Potential	66%	-78%	25%
Terrestrial Eutrophication	58%	34%	4%
Aquatic Eutrophication	57%	48%	17%
Particulate Matter	62%	18%	-12%

5.5 CREAM PORTION PACK AUSTRIA

5.5.1 Sensitivity analysis on system allocation CREAM PORTION PACK Austria

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard’s recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

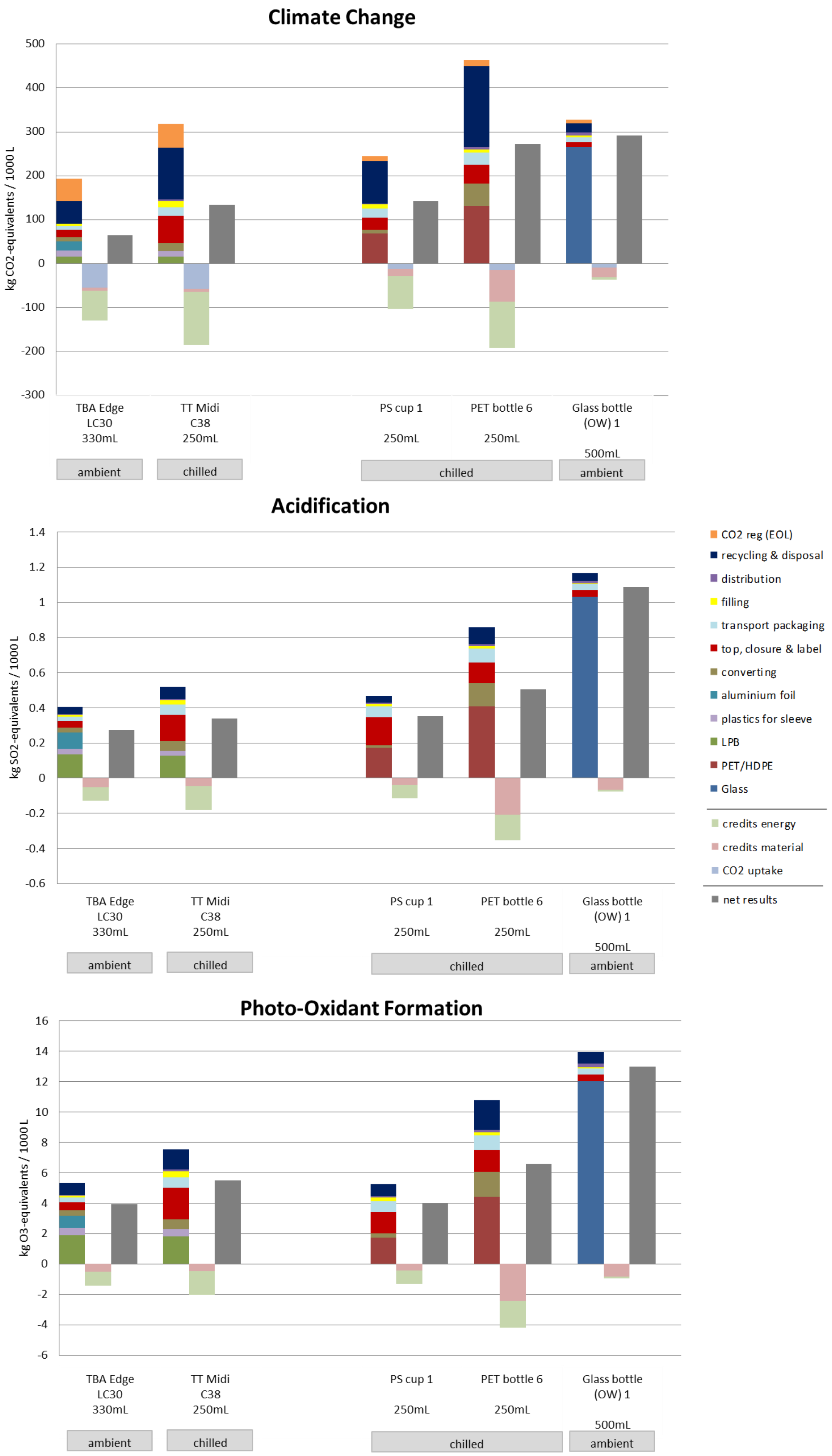


Figure 68: Indicator results for sensitivity analysis on system allocation of **segment CREAM PORTION PACK, Austria**, allocation factor 100% (Part 1)

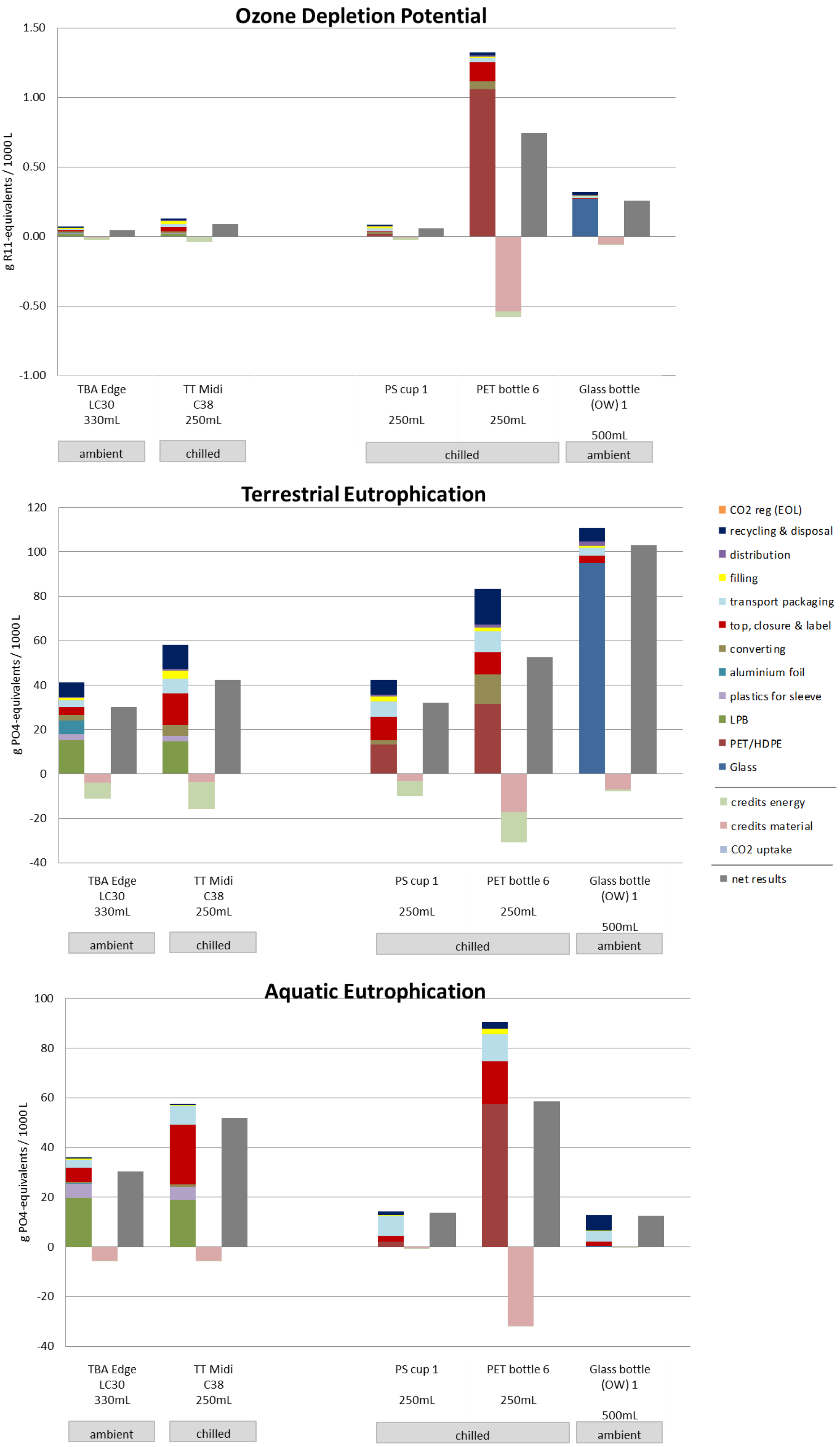


Figure 69: Indicator results for sensitivity analysis on system allocation of **segment CREAM PORTION PACK, Austria**, allocation factor 100% (Part 2)

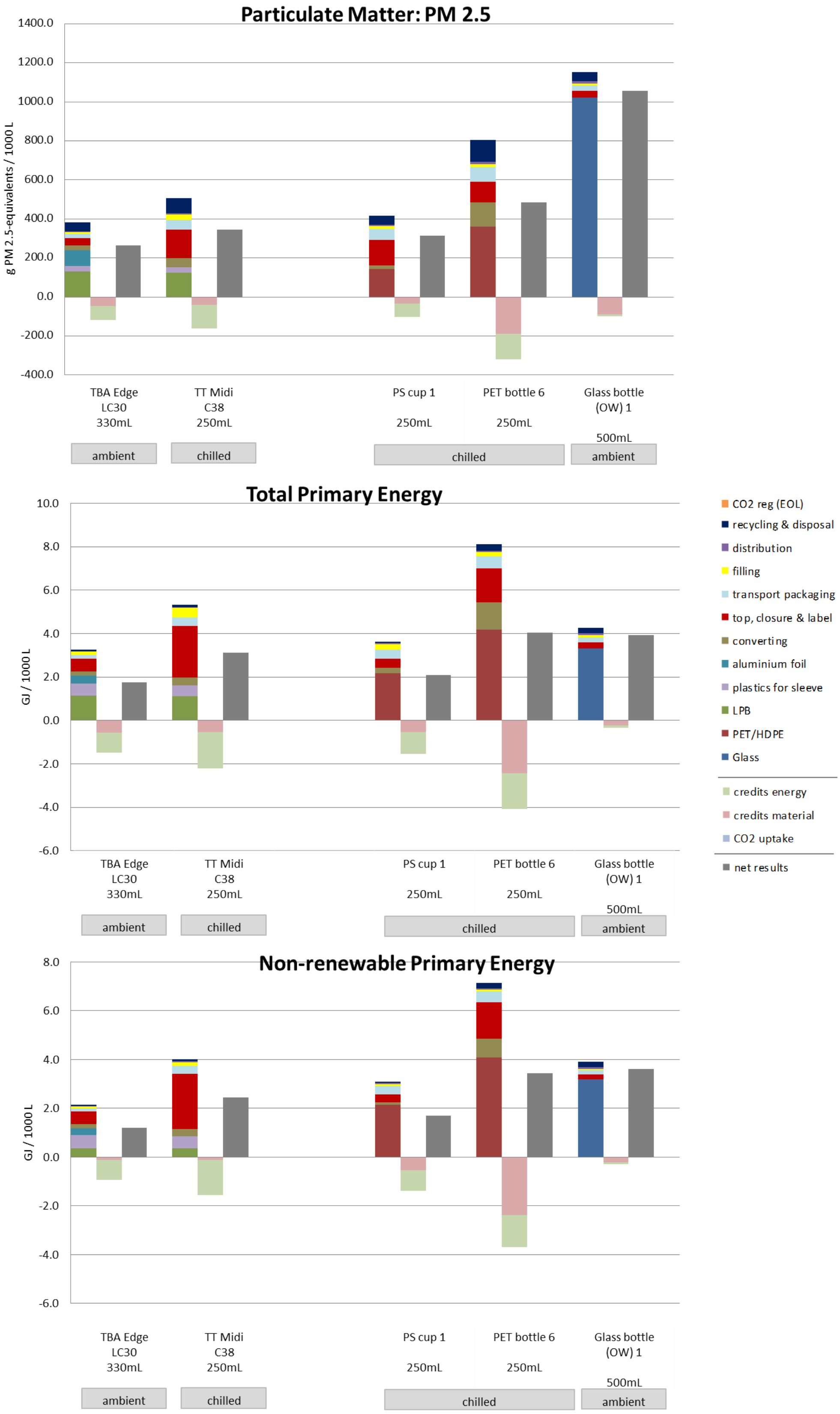


Figure 70: Indicator results for sensitivity analysis on system allocation of **segment CREAM PORTION PACK, Austria**, allocation factor 100% (Part 3)

Table 98: Category indicator results per impact category for sensitivity analysis on system allocation scenarios of segment CREAM PORTION PACK, Austria- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Edge LC30 330mL	TT Midi C38 250mL		PS cup 1 250mL	PET bottle 6 250mL	Glass bottle (OW) 1 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	142.32	263.59		234.04	449.41	320.03
	CO2 (reg)	51.62	54.75		10.80	13.91	8.27
	Credits	-75.05	-126.92		-91.14	-176.52	-27.44
	CO2 uptake	-54.68	-57.86		-11.40	-14.71	-8.48
	net results	64.21	133.55		142.29	272.09	292.38
Acidification [kg SO2-e/1000 L[	Burdens	0.40	0.52		0.47	0.86	1.17
	Credits	-0.13	-0.18		-0.12	-0.35	-0.08
	Net results	0.27	0.34		0.35	0.51	1.09
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.35	7.56		5.27	10.80	13.95
	Credits	-1.42	-2.04		-1.31	-4.20	-0.95
	Net results	3.93	5.52		3.96	6.60	12.99
Ozone Depletion [g R11/1000 L]	Burdens	0.07	0.13		0.09	1.33	0.32
	Credits	-0.02	-0.04		-0.03	-0.58	-0.06
	Net results	0.05	0.09		0.06	0.75	0.26
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	41.15	58.21		42.27	83.43	110.75
	Credits	-11.04	-15.82		-10.11	-30.85	-7.79
	Net results	30.12	42.39		32.17	52.58	102.96
Aquatic Eutrophication [g PO4/1000 L]	Burdens	35.94	57.49		14.31	90.58	12.63
	Credits	-5.58	-5.63		-0.51	-31.89	-0.22
	Net results	30.36	51.86		13.80	58.69	12.41
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	382.33	505.36		416.10	803.95	1153.06
	Credits	-116.58	-160.27		-102.02	-320.19	-98.08
	Net results	265.76	345.09		314.08	483.77	1054.98
Total Primary Energy [GJ]	Burdens	3.25	5.33		3.63	8.12	4.25
	Credits	-1.50	-2.20		-1.55	-4.08	-0.33
	Net results	1.76	3.13		2.08	4.04	3.92
Non-renewable Primary Energy [GJ]	Burdens	2.14	4.00		3.09	7.14	3.92
	Credits	-0.93	-1.57		-1.39	-3.70	-0.30
	Net results	1.20	2.44		1.70	3.44	3.62
Use of Nature [m²*year]	Burdens	30.27	31.97		4.09	5.72	2.70
	Credits	-7.89	-7.76		-0.15	-0.29	-0.05
	Net results	22.38	24.21		3.95	5.43	2.64
Water use [m³/1000 L]	water cool	1.84	3.26		0.84	5.77	0.59
	water process	2.93	2.42		0.46	1.66	0.30
	water unspecified	0.91	1.10		0.84	1.71	0.32

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 regarded system.

In the cases of beverage cartons in the Austrian segment CREAM PORTION PACK applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories. This is because the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The only exception is 'Climate Change'. For 'Climate Change' applying the allocation factor 100% instead of

50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of the plastic bottle and the PS cup, lower net results in almost all impact categories are shown when applying the allocation factor 100% instead of 50% as the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The exception is 'Climate Change'. For 'Climate Change' net results stay about the same when applying the 100% allocation factor, as the additionally allocated credits and burdens show similar absolute values.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons, the plastic bottle and the PS cup in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

In the case of the one-way glass bottle net results of all categories except 'Aquatic Eutrophication' stay about the same when applying the 100% allocation factor as burdens from recycling and disposal are similar than energy and material credits.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 99: Comparison of net results: **TBA Edge LC30 330mL** versus competing carton based and alternative packaging systems in **segment CREAM Portion Pack (ambient), Austria**, allocation factor 100%

CREAM Portion Pack (ambient), Austria	The net results of **TBA Edge LC30 330mL** are lower (green)/ higher (orange) than those of
	Glass bottle (OW) 1 500mL
Climate Change	-78%
Acidification	-75%
Photo-Oxidant Formation	-70%
Ozone Depletion Potential	-81%
Terrestrial Eutrophication	-71%
Aquatic Eutrophication	145%
Particulate Matter	-75%

Table 100: Comparison of net results: **TBA Edge LC30 330mL** versus competing carton based and alternative packaging systems in **segment CREAM Portion Pack (chilled), Austria**, allocation factor 100%

CREAM Portion Pack (chilled), Austria	The net results of **TT Midi C38 250mL** are lower (green)/ higher (orange) than those of	
	PS cup 1 250mL	PET bottle 6 250mL
Climate Change	-6%	-51%
Acidification	-4%	-33%
Photo-Oxidant Formation	39%	-16%
Ozone Depletion Potential	48%	-88%
Terrestrial Eutrophication	32%	-19%
Aquatic Eutrophication	276%	-12%
Particulate Matter	10%	-29%

5.6 SD PORTION PACK AUSTRIA

5.6.1 Sensitivity analysis on system allocation SD PORTION PACK Austria

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

Figure 71: Indicator results on system allocation of **segment SD PORTION PACK, Austria**, allocation factor 100% (Part 1)

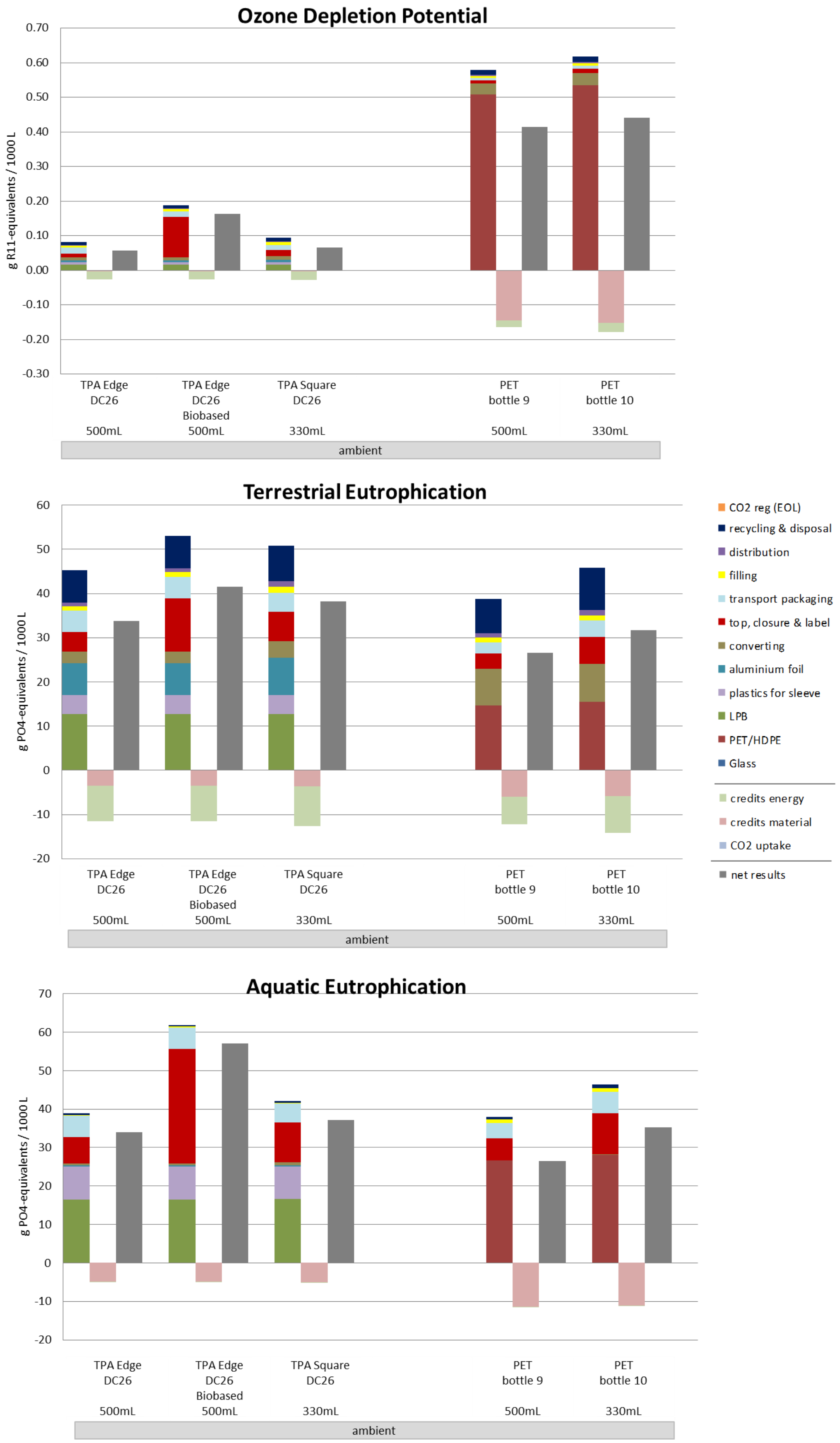


Figure 72 Indicator results on system allocation of **segment SD PORTION PACK, Austria**, allocation factor 100% (Part 2)

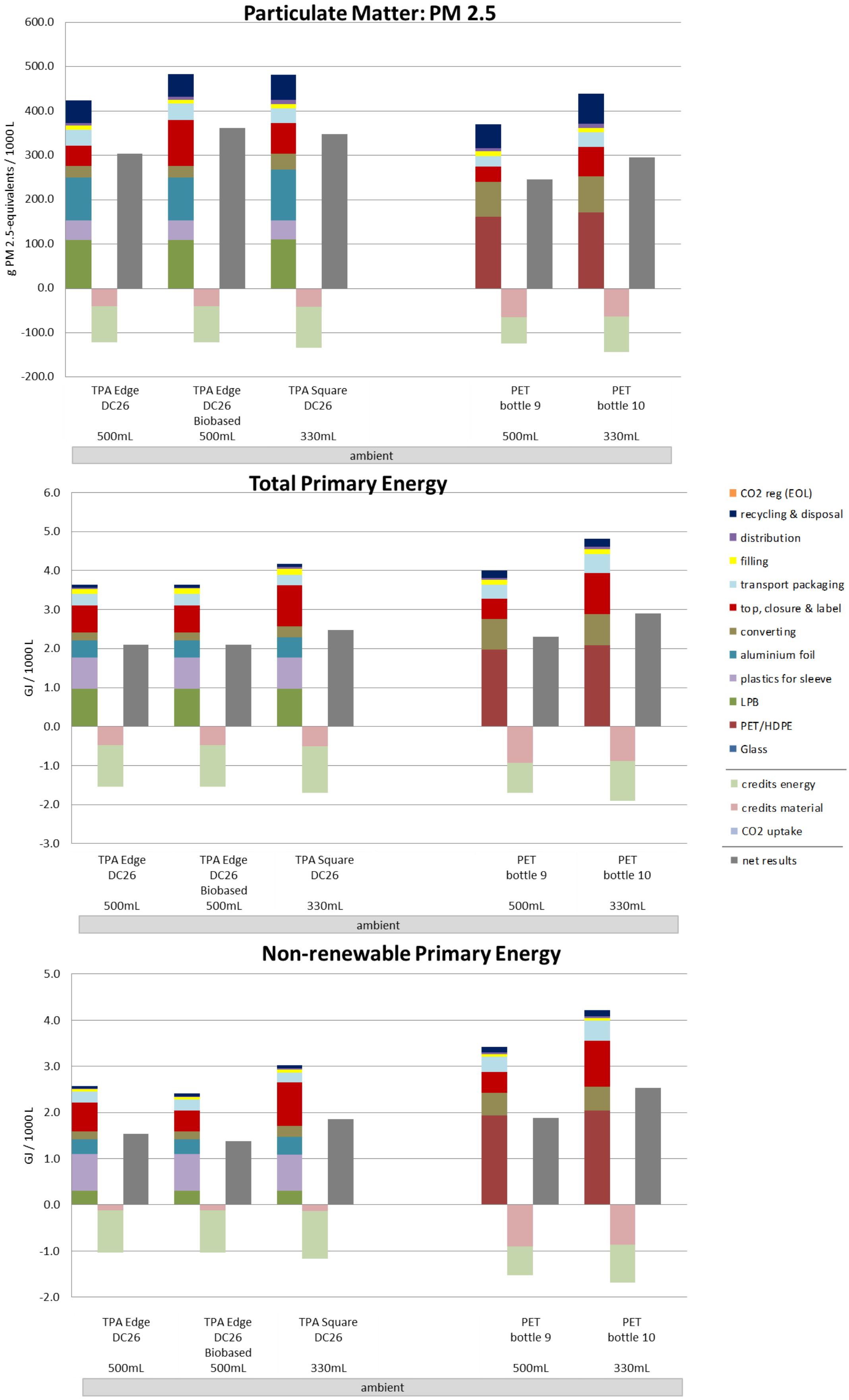


Figure 73: Indicator results on system allocation of segment SD PORTION PACK, Austria, allocation factor 100% (Part 3)

Table 101: Category indicator results per impact category on system allocation of **segment SD PORTION PACK, Austria**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TPA Square DC26 330mL		PET bottle 9 500mL
Climate Change [kg CO_2-e/1000 L[	Burdens	172.56	165.89	201.98		207.87
	CO_2 (reg)	46.57	54.80	47.15		8.70
	Credits	-83.18	-83.32	-93.41		-76.81
	CO_2 uptake	-49.25	-58.63	-49.83		-9.04
	net results	86.70	78.74	105.89		130.71
Acidification [kg SO_2-e/1000 L[	Burdens	0.45	0.49	0.51		0.39
	Credits	-0.13	-0.13	-0.15		-0.14
	Net results	0.32	0.36	0.37		0.25
Photo-Oxidant Formation [kg O_3 e/1000 L]	Burdens	5.87	6.66	6.63		5.13
	Credits	-1.48	-1.48	-1.64		-1.69
	Net results	4.39	5.18	5.00		3.44
Ozone Depletion [g R11/1000 L]	Burdens	0.08	0.19	0.09		0.58
	Credits	-0.03	-0.03	-0.03		-0.16
	Net results	0.06	0.16	0.07		0.41
Terrestrial Eutrophication [g PO_4/1000 L]	Burdens	45.28	52.97	50.85		38.70
	Credits	-11.49	-11.50	-12.68		-12.18
	Net results	33.80	41.47	38.17		26.52
Aquatic Eutrophication [g PO_4/1000 L]	Burdens	38.86	61.83	42.05		37.96
	Credits	-4.82	-4.82	-4.96		-11.44
	Net results	34.04	57.01	37.09		26.52
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	424.23	482.84	481.99		370.43
	Credits	-121.10	-121.24	-133.65		-124.65
	Net results	303.12	361.59	348.35		245.78
Total Primary Energy [GJ]	Burdens	3.64	3.64	4.17		4.00
	Credits	-1.54	-1.55	-1.70		-1.70
	Net results	2.09	2.09	2.47		2.30
Non-renewable Primary Energy [GJ]	Burdens	2.58	2.41	3.02		3.42
	Credits	-1.03	-1.03	-1.16		-1.53
	Net results	1.54	1.37	1.86		1.89
Use of Nature [m²*year]	Burdens	26.95	33.79	27.10		1.20
	Credits	-6.69	-6.69	-6.74		-0.16
	Net results	20.26	27.10	20.36		1.04
Water use [m³/1000 L]	water cool	1.94	2.00	2.32		3.32
	water process	2.52	2.51	2.60		0.72
	water unspecified	1.13	1.19	1.26		0.65

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 regarded system.

In the cases of beverage cartons in the Austrian segment SD PORTION PACK applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories. This is because the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The main exception is ‘Climate Change’. For ‘Climate Change’ applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don’t increase when applying the 100% allocation factor.

In the cases of plastic bottles the net results also decrease when applying the 100% allocation factor in most impact categories as the additionally allocated credits are higher than the additionally allocated. The exception is ‘Climate Change’. For ‘Climate Change’ net results stay about the same when applying the 100% allocation factor as burdens from incineration are similar than energy and material credits.

For the inventory categories ‘Total Primary Energy’ and ‘Non-renewable Energy’ net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 102: Comparison of net results: **TPA Edge DC26 500mL** versus competing carton based and alternative packaging systems in **segment SD PORTION PACK (ambient), Austria**, allocation factor 100%

SD PORTION PACK (ambient), Austria	The net results of **TPA Edge DC26 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 biobased 500mL	TPA Square DC26 330mL	PET bottle 9 500mL	PET bottle 10 330mL
Climate Change	10%	-18%	-34%	-47%
Acidification	-11%	-13%	26%	5%
Photo-Oxidant Formation	-15%	-12%	27%	5%
Ozone Depletion Potential	-65%	-13%	-86%	-87%
Terrestrial Eutrophication	-19%	-11%	27%	7%
Aquatic Eutrophication	-40%	-8%	28%	-3%
Particulate Matter	-16%	-13%	23%	3%

Table 103: Comparison of net results: **TPA Edge DC26 biobased 500mL** versus competing carton based and alternative packaging systems in **segment SD PORTION PACK (ambient), Austria**, allocation factor 100%

SD PORTION PACK (ambient), Austria	The net results of **TPA Edge DC26 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Square DC26 330mL	PET bottle 9 500mL	PET bottle 10 330mL
Climate Change	-9%	-26%	-40%	-52%
Acidification	12%	-3%	41%	18%
Photo-Oxidant Formation	18%	4%	50%	24%
Ozone Depletion Potential	185%	149%	-61%	-63%
Terrestrial Eutrophication	23%	9%	56%	31%
Aquatic Eutrophication	67%	54%	115%	62%
Particulate Matter	19%	4%	47%	23%

Table 104: Comparison of net results: **TPA Square DC26 330mL** versus competing carton based and alternative packaging systems in **segment SD PORTION PACK (ambient), Austria**, allocation factor 100%

SD PORTION PACK (ambient), Austria	The net results of **TPA Square DC26 330mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	PET bottle 9 500mL	PET bottle 10 330mL
Climate Change	22%	34%	-19%	-36%
Acidification	15%	3%	45%	21%
Photo-Oxidant Formation	14%	-4%	45%	20%
Ozone Depletion Potential	15%	-60%	-84%	-85%
Terrestrial Eutrophication	13%	-8%	44%	21%
Aquatic Eutrophication	9%	-35%	40%	5%
Particulate Matter	15%	-4%	42%	18%

5.6.2 Sensitivity analysis regarding recycled PET in PET bottles

To consider potential future developments in terms of the share of recyclate of the plastic bottles, two additional scenarios for plastic bottles with a recycled content of PET of 30% and 100% are analysed and illustrated in this sensitivity analysis (for details please see section 2.4.4). Results are shown in the following break even graphs.

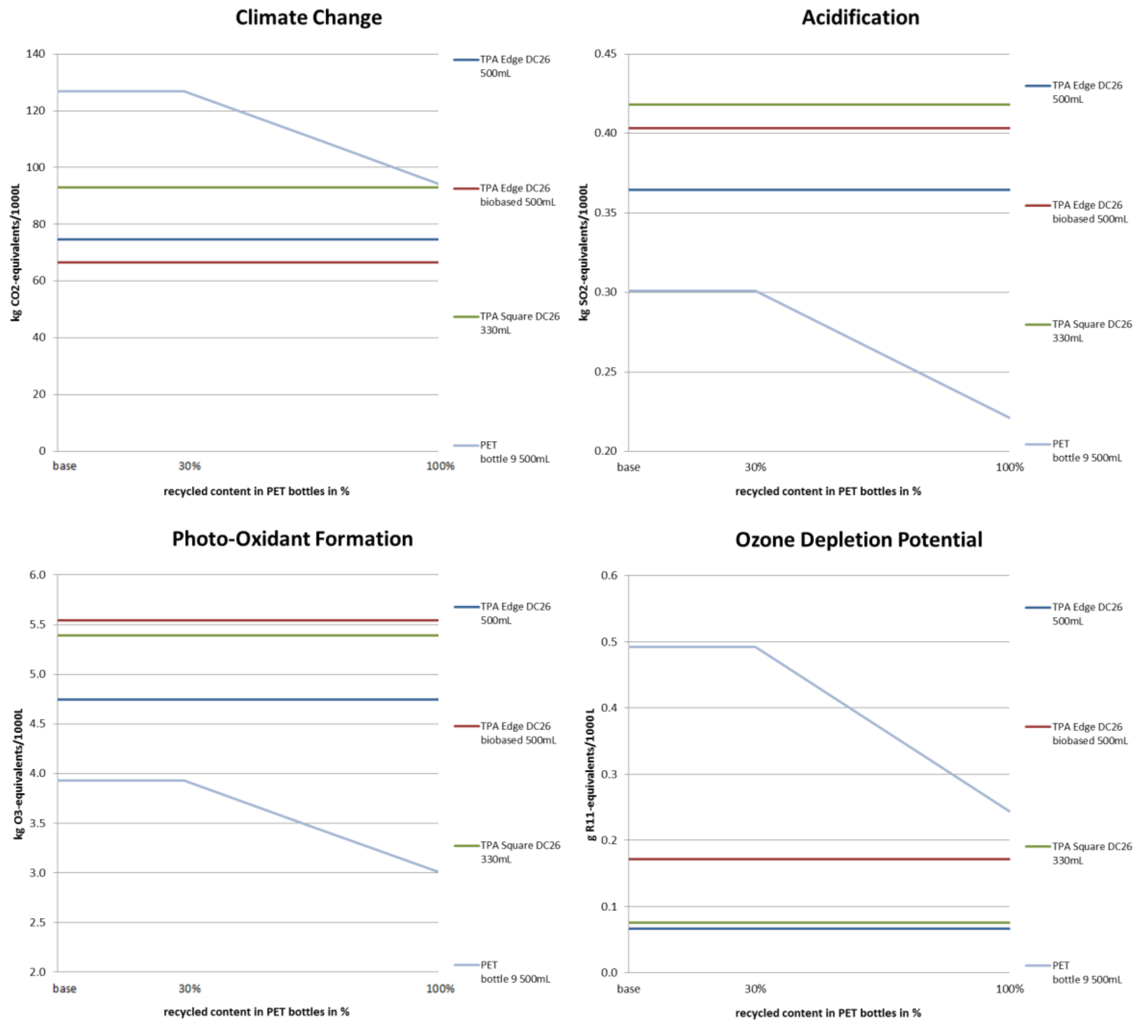


Figure 74: Indicator results for sensitivity analysis recycled PET of **segment SD Portion Pack, Austria**, allocation factor 50% (Part 1)

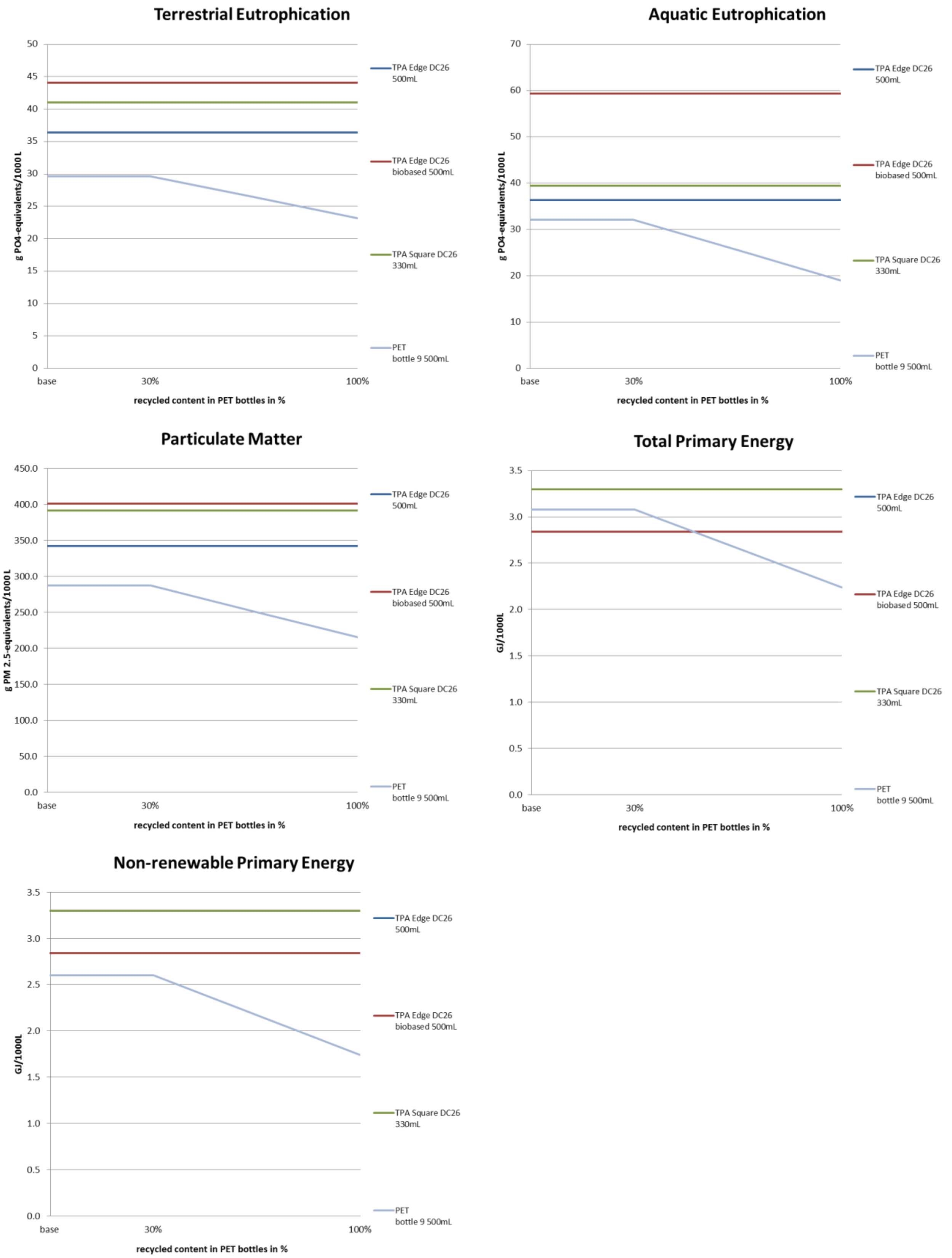


Figure 75: Indicator results for sensitivity analysis recycled PET of **segment SD Portion Pack, Austria**, allocation factor 50% (Part 2)

Description and Interpretation

The regarded PET bottle in this sensitivity analysis has already a recycled content of 30% in its base scenario. The PET bottle with an increasing recycled content will break even with or shows lower results than all compared beverage cartons in many categories regardless the PET bottles' recycled content. The exceptions are 'Climate Change' and 'Ozone Depletion Potential' for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

5.7 WATER PORTION PACK AUSTRIA

5.7.1 Sensitivity analysis on system allocation WATER PORTION PACK Austria

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

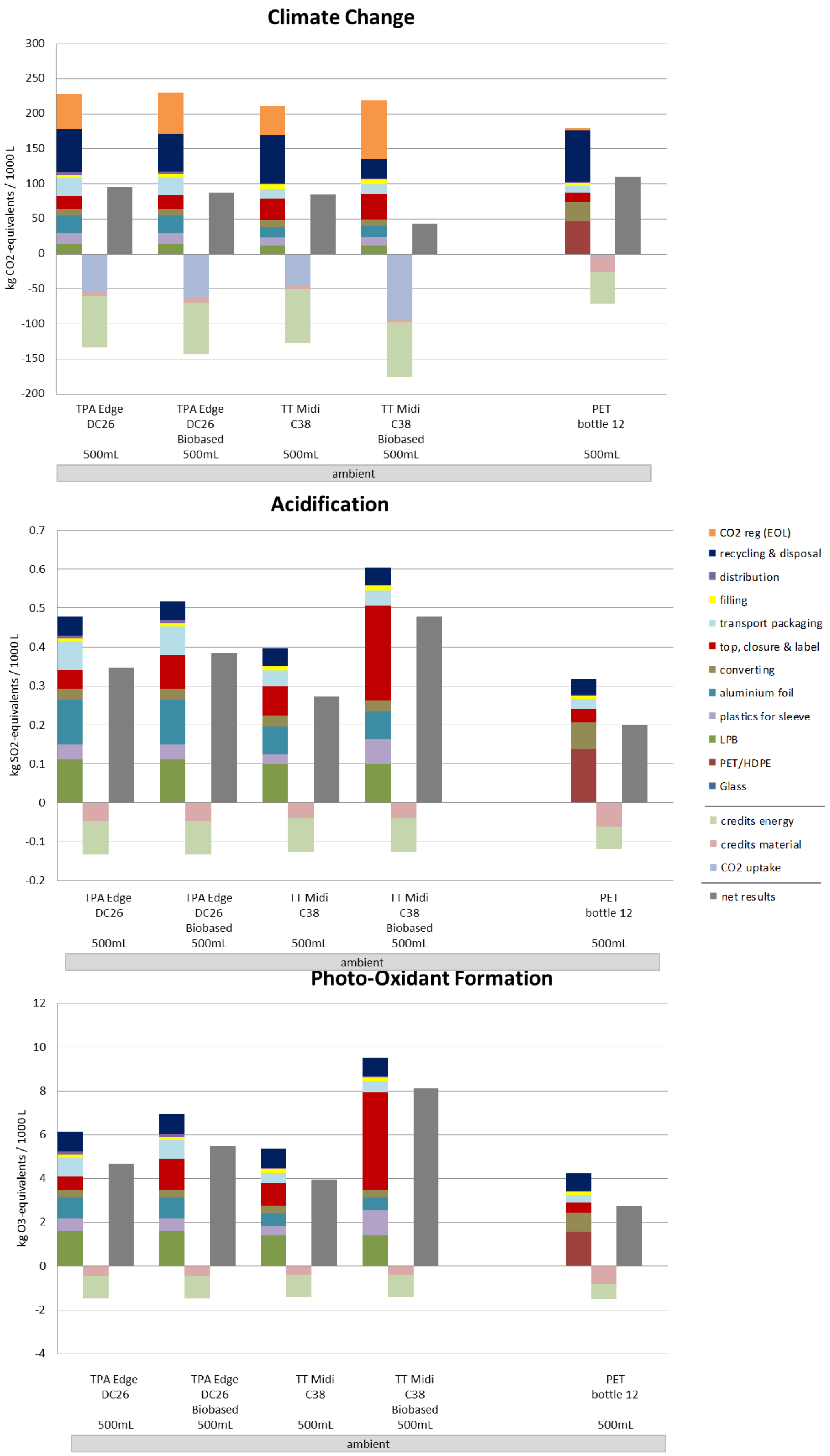


Figure 76: Indicator results on system allocation of **segment WATER PORTION PACK, Austria**, allocation factor 100% (Part 1)

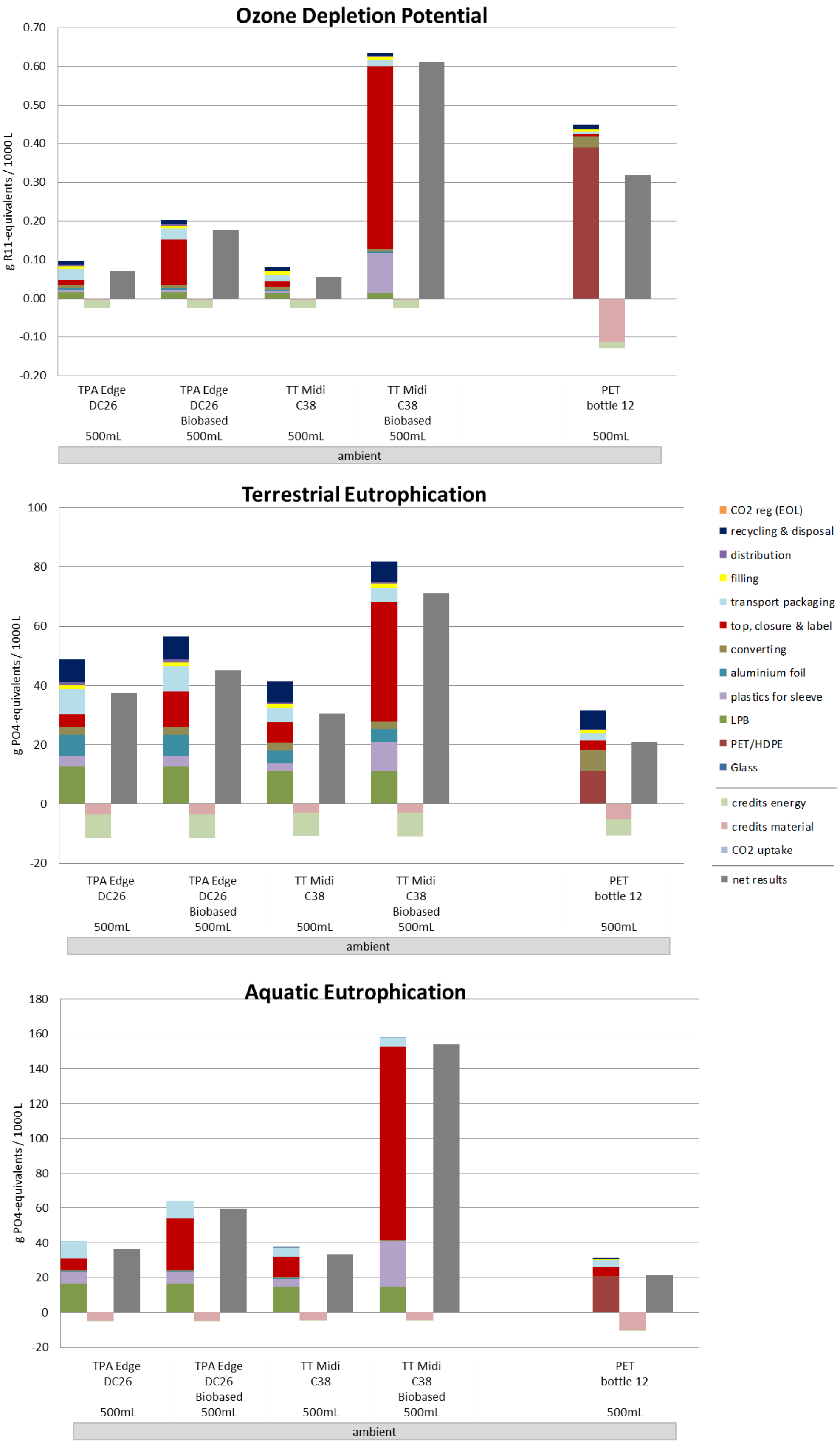


Figure 77: Indicator results on system allocation of **segment WATER PORTION PACK, Austria**, allocation factor 100% (Part 2)

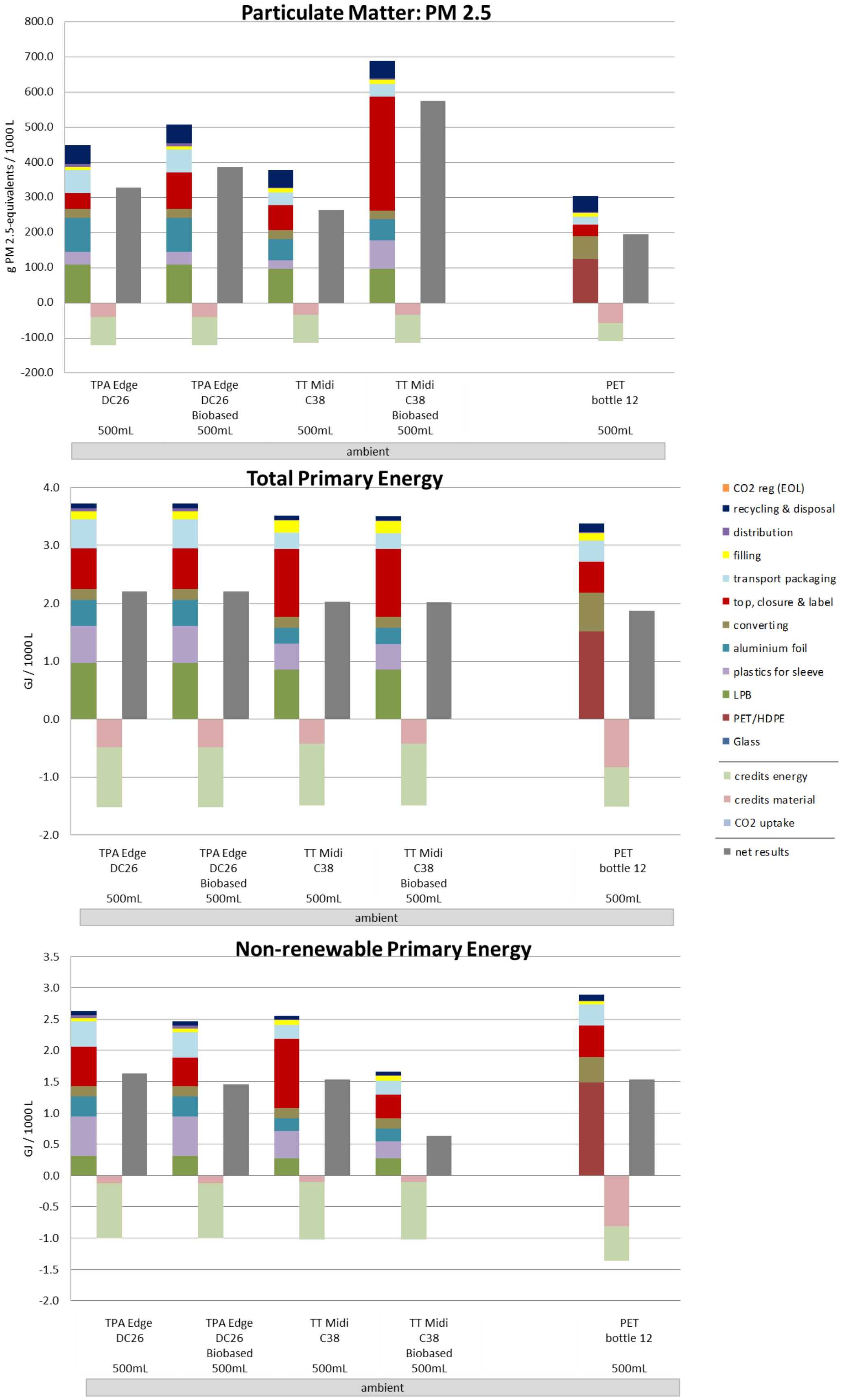


Figure 30: Indicator results on system allocation of **segment WATER PORTION PACK, Austria**, allocation factor 100% (Part 3)

Table 105: Category indicator results per impact category on system allocation of **segment WATER PORTION PACK, Austria** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL		PET bottle 12 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	178.57	171.91	169.71	135.71		177.13
	CO2 (reg)	50.34	58.57	41.84	83.20		3.36
	Credits	-80.01	-80.15	-82.68	-83.03		-67.23
	CO2 uptake	-53.18	-62.56	-44.23	-92.13		-3.46
	net results	95.72	87.76	84.63	43.76		109.80
Acidification [kg SO2-e/1000 L[	Burdens	0.48	0.52	0.40	0.60		0.32
	Credits	-0.13	-0.13	-0.13	-0.13		-0.12
	Net results	0.35	0.39	0.27	0.48		0.20
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	6.16	6.95	5.37	9.53		4.22
	Credits	-1.47	-1.47	-1.40	-1.41		-1.49
	Net results	4.69	5.48	3.96	8.12		2.73
Ozone Depletion [g R11/1000 L]	Burdens	0.10	0.20	0.08	0.64		0.45
	Credits	-0.03	-0.03	-0.02	-0.02		-0.13
	Net results	0.07	0.18	0.06	0.61		0.32
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	48.73	56.42	41.39	81.88		31.63
	Credits	-11.39	-11.40	-10.90	-10.93		-10.69
	Net results	37.34	45.02	30.49	70.95		20.94
Aquatic Eutrophication [g PO4/1000 L]	Burdens	41.38	64.35	37.67	158.38		31.32
	Credits	-4.89	-4.89	-4.32	-4.32		-10.06
	Net results	36.50	59.47	33.35	154.06		21.26
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	448.36	506.97	378.02	687.73		303.46
	Credits	-119.80	-119.94	-113.46	-113.78		-109.00
	Net results	328.56	387.03	264.56	573.94		194.46
Total Primary Energy [GJ]	Burdens	3.72	3.72	3.51	3.50		3.37
	Credits	-1.52	-1.52	-1.49	-1.49		-1.51
	Net results	2.20	2.20	2.03	2.01		1.87
Non-renewable Primary Energy [GJ]	Burdens	2.63	2.46	2.55	1.66		2.89
	Credits	-1.00	-1.00	-1.02	-1.02		-1.36
	Net results	1.63	1.46	1.53	0.63		1.53
Use of Nature [m²*year]	Burdens	28.95	35.78	24.19	59.68		0.86
	Credits	-6.72	-6.72	-6.01	-6.01		-0.14
	Net results	22.23	29.06	18.18	53.68		0.72
Water use [m³/1000 L]	water cool	1.96	2.01	1.98	1.87		2.73
	water process	2.53	2.52	2.04	2.01		0.65
	water unspecified	1.30	1.36	0.98	1.06		0.54

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 regarded system.

In the cases of beverage cartons in the Austrian segment SD PORTION PACK applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories. This is because the absolute value of the credits is higher than that of the burdens from recycling and disposal regardless of the allocation factor. The only exception is ‘Climate Change’. For ‘Climate Change’ applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don’t increase when applying the 100% allocation factor.

In the cases of plastic bottles the net results also decrease when applying the 100% allocation factor in most impact categories as the additionally allocated credits are higher than the additionally allocated. The exception is ‘Climate Change’. For ‘Climate Change’ net results stay about the same when applying the 100% allocation factor as burdens from incineration are similar than energy and material credits.

For the inventory categories ‘Total Primary Energy’ and ‘Non-renewable Energy’ net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 106: Comparison of net results: **TBA Edge DC26 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Austria**, allocation factor 100%

WATER PORTION PACK (ambient), Austria	The net results of **TPA Edge DC26 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL	PET bottle 12 500mL
Climate Change	9%	13%	119%	-13%
Acidification	-10%	27%	-28%	74%
Photo-Oxidant Formation	-14%	18%	-42%	72%
Ozone Depletion Potential	-60%	27%	-88%	-78%
Terrestrial Eutrophication	-17%	22%	-47%	78%
Aquatic Eutrophication	-39%	9%	-76%	72%
Particulate Matter	-15%	24%	-43%	69%

Table 107: Comparison of net results: **TBA Edge DC26 biobased 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Austria**, allocation factor 100%

WATER PORTION PACK (ambient), Austria	The net results of **TPA Edge DC26 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL	PET bottle 12 500mL
Climate Change	-8%	4%	101%	-20%
Acidification	11%	42%	-19%	94%
Photo-Oxidant Formation	17%	38%	-32%	101%
Ozone Depletion Potential	147%	213%	-71%	-45%
Terrestrial Eutrophication	21%	48%	-37%	115%
Aquatic Eutrophication	63%	78%	-61%	180%
Particulate Matter	18%	46%	-33%	99%

Table 108: Comparison of net results: **TT Midi C38 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Austria**, allocation factor 100%

WATER PORTION PACK (ambient), Austria	The net results of **TT Midi C38 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 biobased 500mL	PET bottle 12 500mL
Climate Change	-12%	-4%	93%	-23%
Acidification	-22%	-29%	-43%	37%
Photo-Oxidant Formation	-15%	-28%	-51%	45%
Ozone Depletion Potential	-21%	-68%	-91%	-82%
Terrestrial Eutrophication	-18%	-32%	-57%	46%
Aquatic Eutrophication	-9%	-44%	-78%	57%
Particulate Matter	-19%	-32%	-54%	36%

Table 109: Comparison of net results: **TT Midi C38 biobased 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Austria**, allocation factor 100%

WATER PORTION PACK (ambient), Austria	The net results of **TT Midi C38 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	PET bottle 12 500mL
Climate Change	-54%	-50%	-48%	-60%
Acidification	38%	24%	76%	141%
Photo-Oxidant Formation	73%	48%	105%	197%
Ozone Depletion Potential	752%	245%	979%	91%
Terrestrial Eutrophication	90%	58%	133%	239%
Aquatic Eutrophication	322%	159%	362%	625%
Particulate Matter	75%	48%	117%	195%

5.7.2 Sensitivity analysis regarding recycled PET in PET bottles

To consider potential future developments in terms of the share of recyclate of the plastic bottles, two additional scenarios for plastic bottles with a recycled content of PET of 30% and 100% are analysed and illustrated in this sensitivity analysis (for details please see section 2.4.4). Results are shown in the following break even graphs.

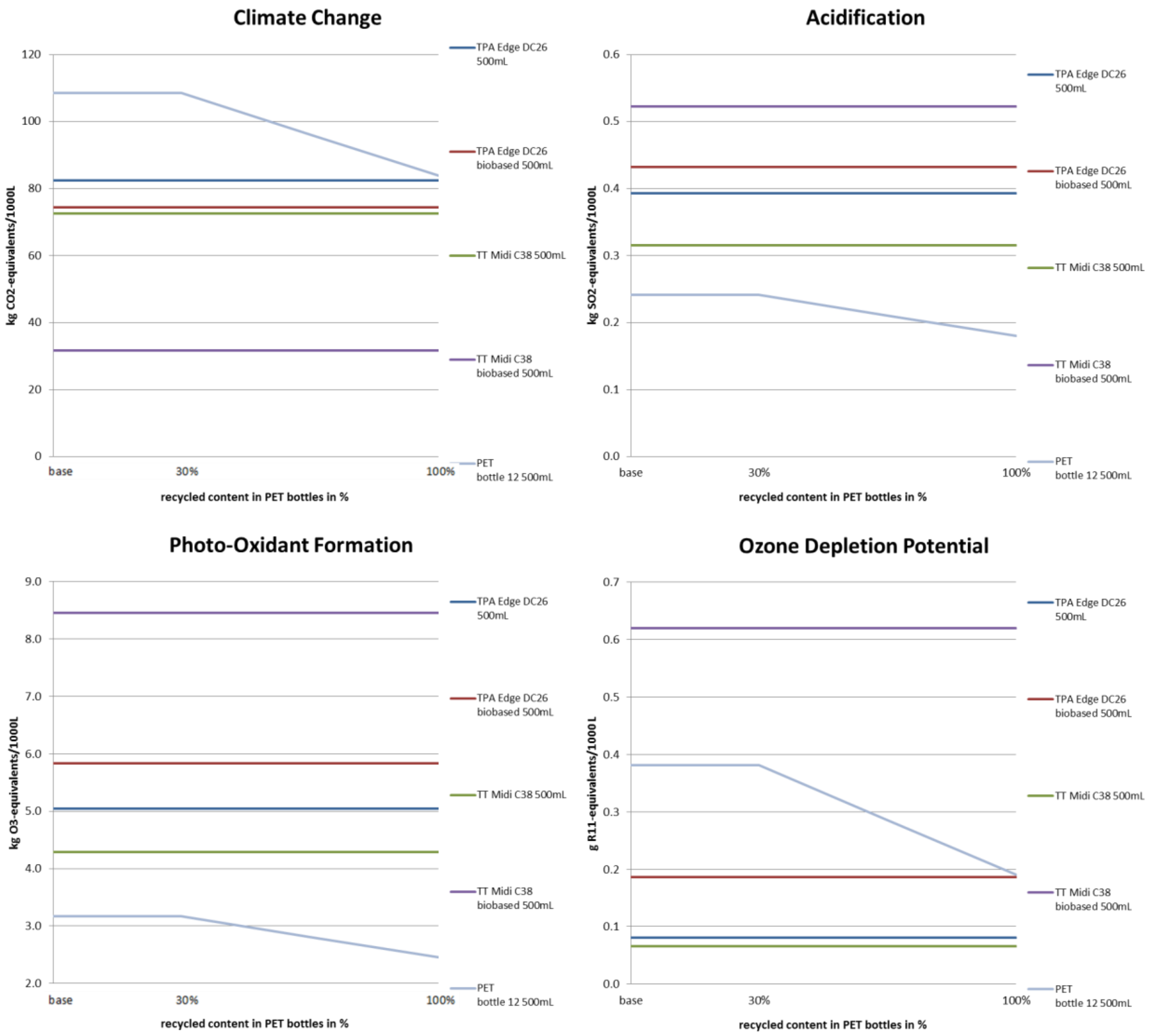
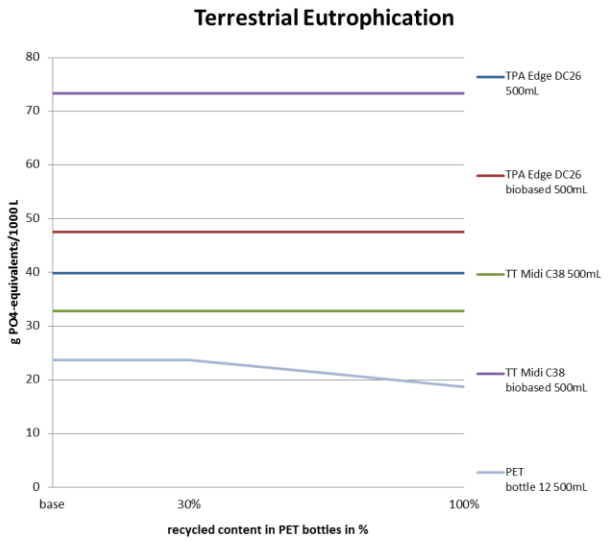
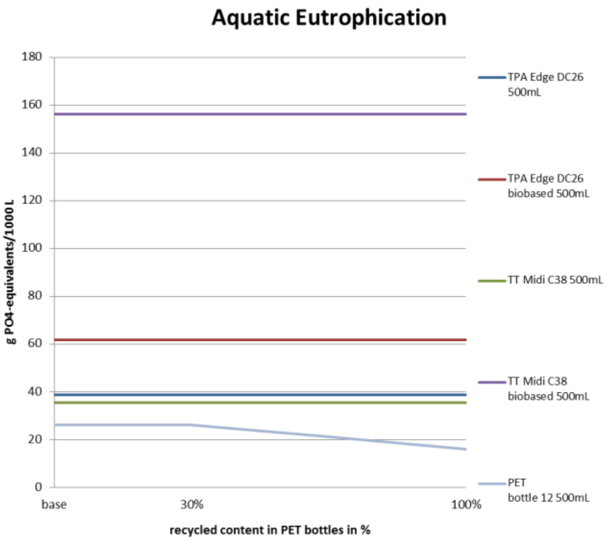
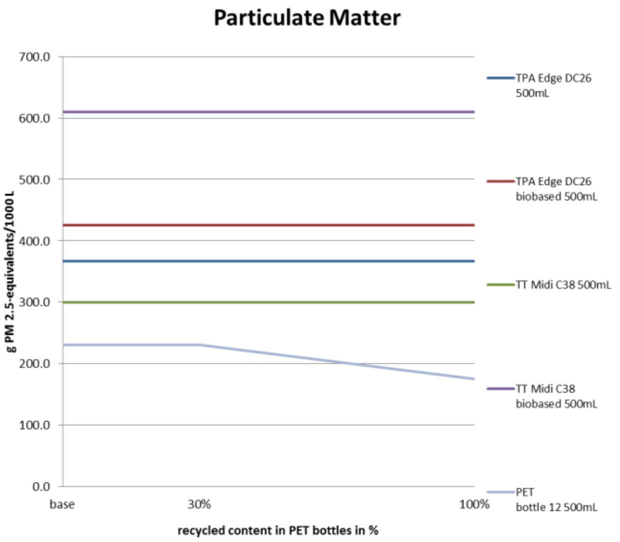
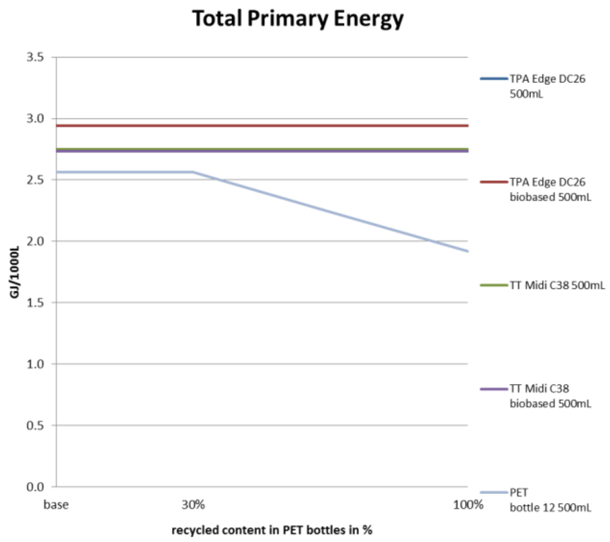


Figure 78: Indicator results for sensitivity analysis recycled PET of **segment WATER Portion Pack, Austria**, allocation factor 50% (Part 1)









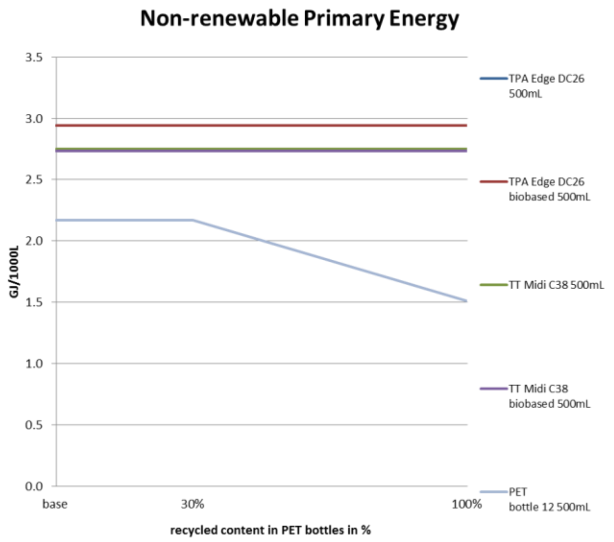


Figure 79: Indicator results for sensitivity analysis recycled PET of **segment WATER Portion Pack, Austria**, allocation factor 50% (Part 2)

Description and Interpretation

The regarded PET bottle in this sensitivity analysis has already a recycled content of 30% in its base scenario. The ranking between the PET bottle with increased recycled content and the compared beverage cartons stays mostly the same with the regarded increase of recycled content.

6 Scenario Variants Austria

6.1 DAIRY FAMILY PACK AUSTRIA

6.1.1 Additional scenarios regarding clear PET and recycled content in PET bottle 4

During the preparation of the study the opaque PET bottle 4 was superseded by a clear PET bottle with 25% recycled content. The recycled content is planned to be increased to 100%. Therefore an additional scenario is performed which includes the clear PET bottle 4 with 25% and 100% recycled content (Table 37). As the specification of mass has also changed, Table 38 shows the specifications of the PET bottle 4 in all variations (see section 2.4.9). Results are shown in the following figures.

Figure 80: Indicator results for scenario variants regarding clear PET and recycled content in chilled PET bottle 4 of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 1)

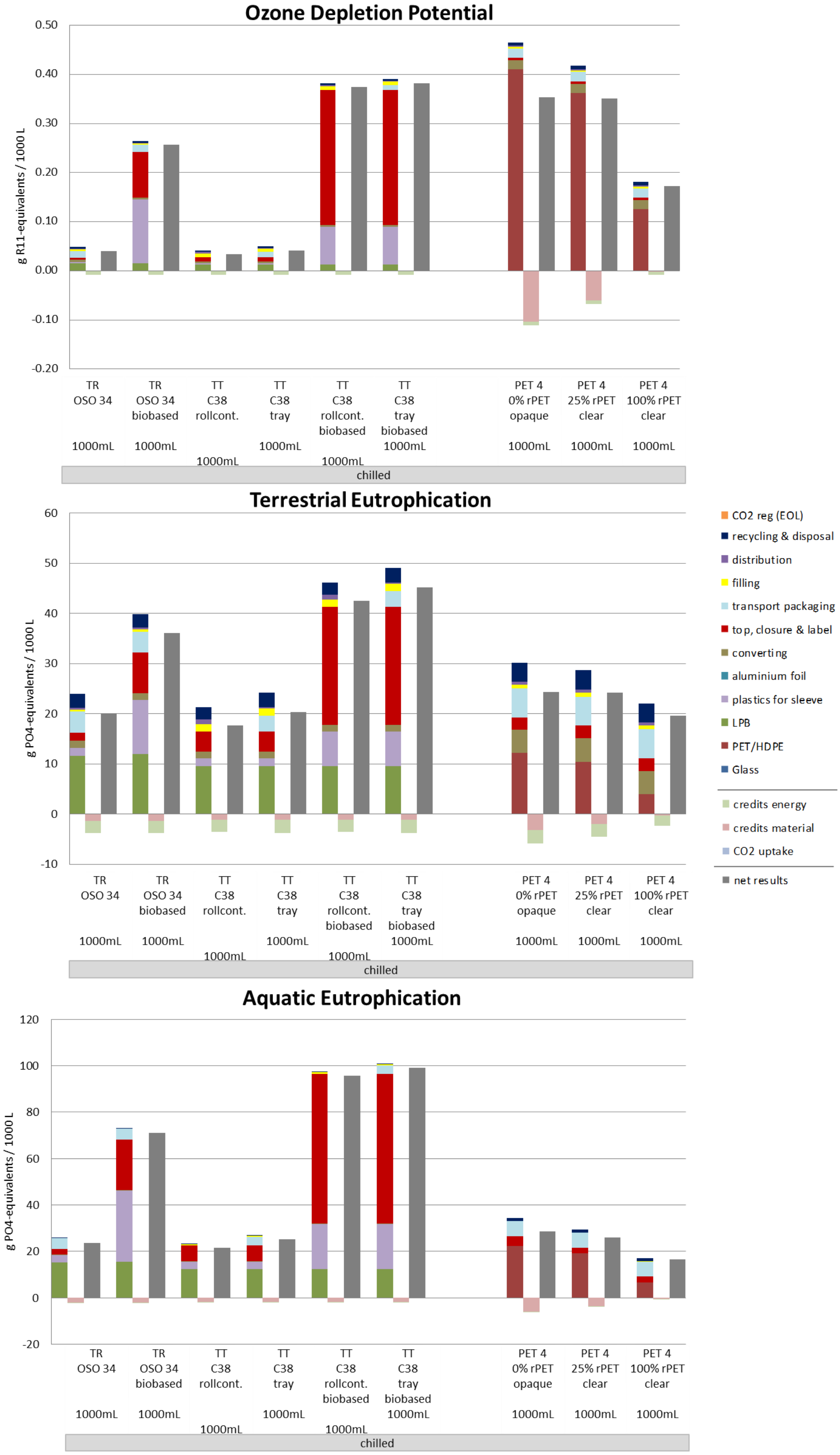


Figure 81 Indicator results for scenario variants regarding clear PET and recycled content in chilled PET bottle 4 of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 2)

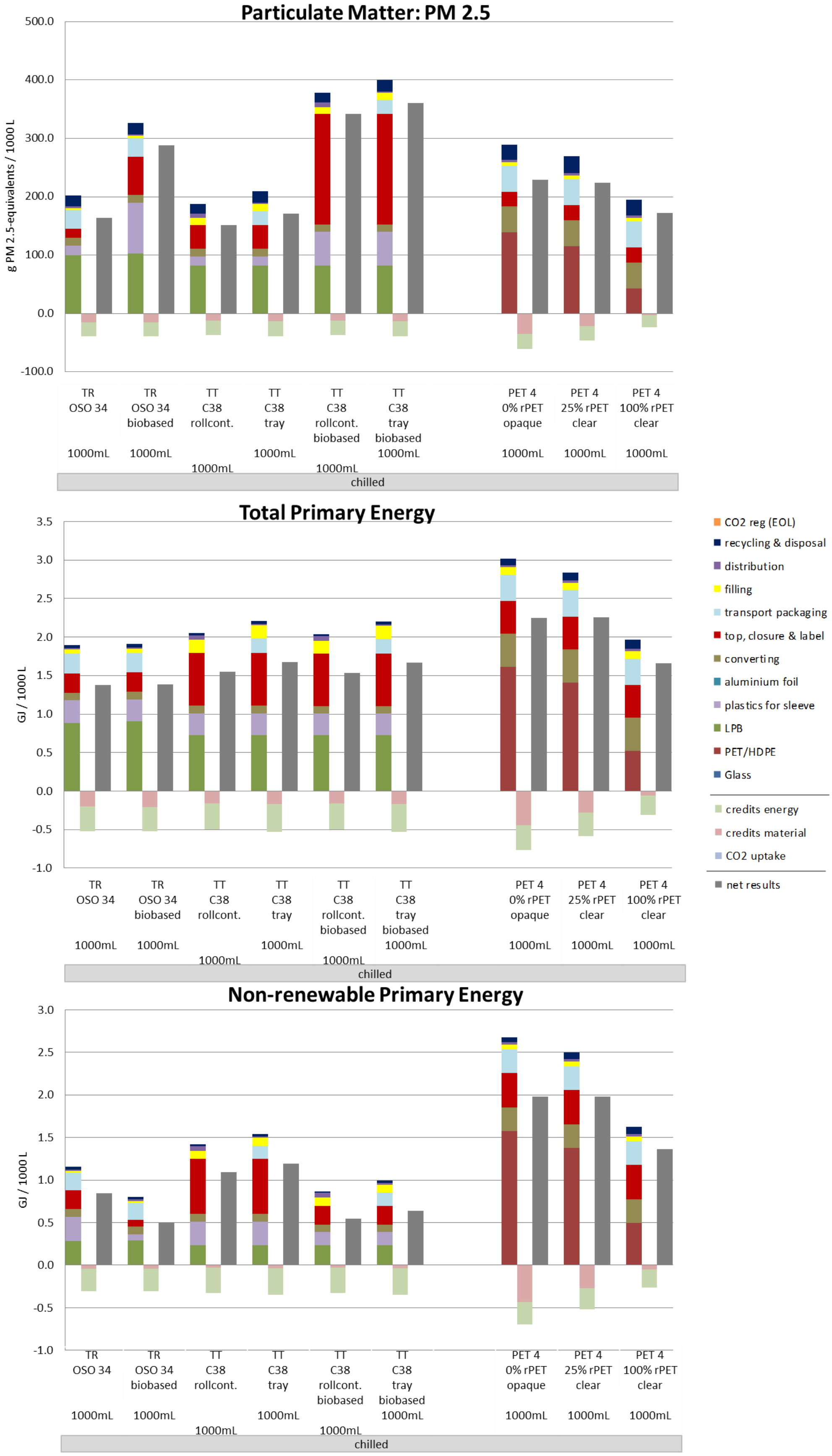


Figure 82: Indicator results for scenario variants regarding clear PET and recycled content in chilled PET bottle 4 of **segment DAIRY FAMILY PACK, Austria**, allocation factor 50% (Part 3)

Description and Interpretation

The new clear PET bottle 4 with 25% rPET reduces the net results by 0%-9%. The overall comparison with the beverage cartons does change only in a few cases. For ‘Climate Change’ the net results of beverage cartons stay lower than the net results of the clear PET bottle 4 with 25% rPET.

The new clear PET bottle 4 with 100% rPET reduces the net results by 19%-51%. This leads to lower net results of the clear PET bottle 4 with 100%rPET than most beverage carton systems in several impact categories except ‘Climate Change’ For ‘Climate Change’ the net results of beverage cartons stay lower than the net results of the clear PET bottle 4 with 100% rPET.

6.2 WATER PORTION PACK AUSTRIA

6.2.1 Scenario variants regarding plastic bottle weights

To consider potential future developments in terms of weight of the plastic bottles, two additional weights of plastic bottles are analysed and illustrated in these scenario variants (for details please see section 2.4.8). Results are shown in the following break even graphs.

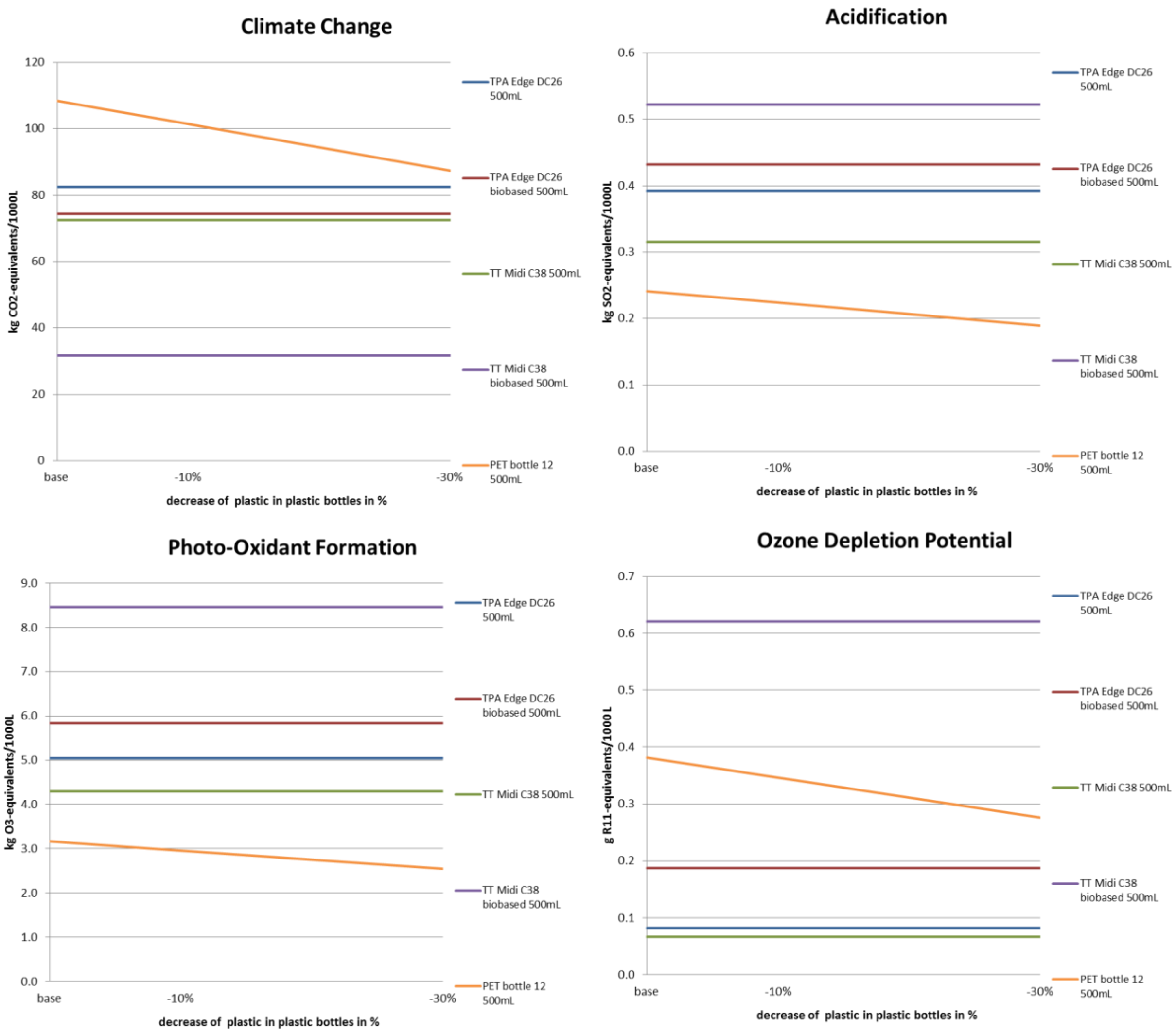


Figure 83: Indicator results for scenario variants on plastic bottle weight of **segment WATER Portion Pack, Austria**, allocation factor 50% (Part 1)

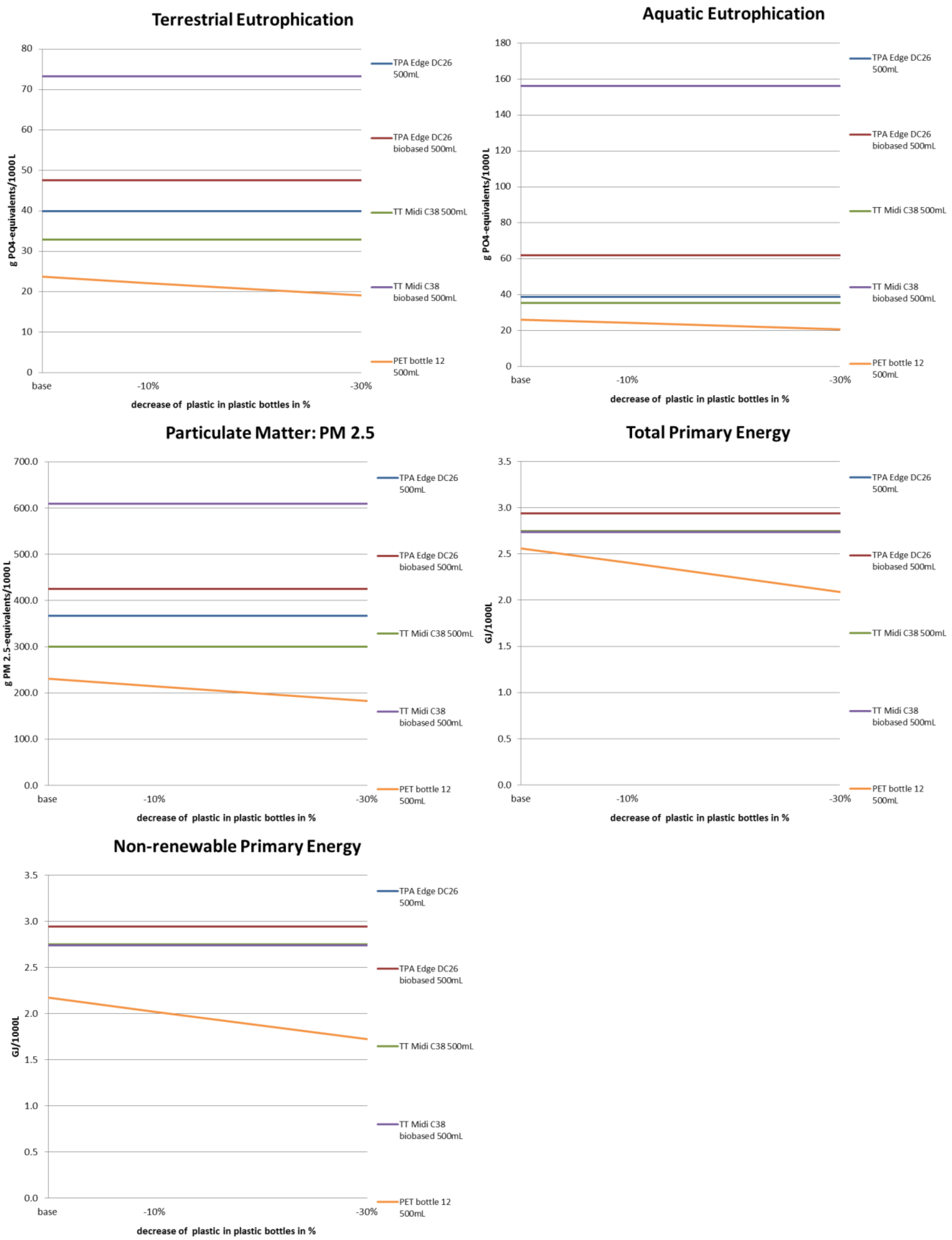


Figure 84: Indicator results for scenario variants on plastic bottle weight of **segment WATER Portion Pack, Austria**, allocation factor 50% (Part 2)

Description and interpretation

The recalculation of the PET bottle with reduced weights shows that the impacts in all categories are lower if less material is used. Nevertheless the ranking between the PET bottle and the compared beverage cartons stays mostly the same with the regarded decrease of weight.

7 Conclusions AUSTRIA

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 Austrian market. This section addresses all sensitivity analyses. In doing so, results of the 50% allocation (base) scenarios and the 100% allocation sensitivity analysis are taken into account to the same degree.

7.1 DAIRY FAMILY PACK AUSTRIA

In case of 'Climate Change' all beverage cartons in this segment show lower impacts than the compared PET bottle as well as refillable and one-way glass bottles regardless of the allocation factor.

Regarding the other categories, the examined beverage carton systems with fossil based plastics show lower or similar impacts than the compared PET bottle depending on the allocation factor. Compared with the one-way glass bottle the examined beverage carton systems with fossil based plastics show lower impacts in all other categories except 'Aquatic Eutrophication' regardless of the allocation factor. Compared with the refillable glass bottle, no unambiguous conclusion can be drawn. The examined beverage carton systems with fossil based plastics show higher, lower or similar impacts depending on the category and the allocation factor.

In case of the beverage cartons containing bio-based plastics, environmental impacts in the category 'Climate Change' are lower than those of cartons with fossil based plastics. However, the use of bio-based plastics also leads to higher environmental impacts in all other impact categories examined. This leads to the beverage carton showing higher impacts in most categories than the compared bottles.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has only minor influence on the assessment of the environmental impacts in this segment.

The sensitivity analysis regarding recycled PET in the PET bottle shows that the PET bottle with an increasing recycled content will break even with at least some beverage cartons. The exception is 'Climate Change', for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

The sensitivity analysis regarding the increased trip rate of the refillable glass bottle shows lower net results of the refillable glass bottle than all beverage carton systems in most impact categories. An exception is 'Climate Change'. For 'Climate Change' the net results of beverage cartons stay lower than the net results of the refillable glass bottle with an increased trip rate.

7.2 JN FAMILY PACK AUSTRIA

In case of ‘Climate Change’ all beverage cartons in this segment show lower impacts than the compared PET and one-way glass bottle regardless of the allocation factor. Compared with the refillable glass bottle, the ‘TR Base Mini Plus OSO 34 1000mL’ and ‘TPA Square HC27 1000mL’ show higher or similar impacts depending on the allocation factor. The ‘TBA Edge WC30 1000mL’ and ‘TBA Slim HC23 1000mL’ show lower or similar impacts depending on the allocation factor. Only the ‘TBA Edge WC30 biobased 1000mL’ shows lower impacts for ‘Climate Change’ than the refillable glass bottle regardless of the allocation factor.

Regarding the other categories, some of the examined beverage carton systems with fossil based plastics show lower or similar impacts than the compared PET bottle regardless of the allocation factor. The exceptions are the ‘TPA Square HC27 1000mL’ and the ‘TR Base Mini Plus OSO 34 1000mL’ which show lower, similar and higher impacts than the compared PET bottle depending of the allocation factor. Compared with the one-way glass bottle the examined beverage carton systems with fossil based plastics show lower impacts in all other categories except ‘Aquatic Eutrophication’ regardless of the allocation factor. Compared with the refillable glass bottle, the examined beverage carton systems with fossil based plastics show higher impacts in almost all other categories regardless of the allocation factor.

In case of the beverage carton containing bio-based plastics, environmental impacts in the category ‘Climate Change’ are lower than those of cartons with fossil based plastics. However, the use of bio-based plastics also leads to higher environmental impacts in all other impact categories examined. This leads to the beverage carton showing higher impacts in most categories than the compared PET and refillable Glass bottles. Compared with the one-way glass bottle the examined beverage carton systems with bio-based plastics shows lower impacts in all other categories except ‘Aquatic Eutrophication’ regardless of the allocation factor

The sensitivity analysis on system allocation shows, that the choice of allocation factor has some influence on the assessment of the environmental impacts in this segment. Especially the results of the comparisons between the beverage cartons and the PET bottle depend on the allocation factor.

The sensitivity analysis regarding recycled PET in PET bottles shows that the PET bottle with an increasing recycled content will break even with at least some beverage cartons. The exception is ‘Climate Change’, for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

The sensitivity analysis regarding the decreased trip rate of the refillable glass bottle shows still lower impacts than most beverage cartons in most categories. The exception is the ‘TBA Edge WC30 biobased 1000mL’ which shows lower net results for ‘Climate Change’ than the refillable glass bottle with the base trip rate and the reduced trip rate. The ‘TBA

Edge WC 30 1000mL' and the 'TBA Slim HC23 1000mL' show lower net results than the refillable glass bottle with the reduced trip rate.

7.3 SD FAMILY PACK AUSTRIA

In case of 'Climate Change' all beverage cartons in this segment show lower impacts than the compared PET bottles regardless the allocation factor.

For the other categories, the comparisons of the examined beverage carton systems to the 1500 mL PET bottle show higher impacts for the beverage cartons in most of the other categories.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has only a small influence on the assessment of the environmental impacts in this segment.

As the sensitivity on regenerative carbon still shows lower net results for the beverage cartons than the compared bottles it confirms that the choice of methodology for consideration of regenerative carbon does not affect the comparisons.

7.4 DAIRY PORTION PACK AUSTRIA

In case of 'Climate Change' all beverage cartons in this segment show lower impacts than the compared PET bottle and PP cup regardless of the allocation factor.

The comparisons of the TT Midi C38 500mL and the PET bottle 5 500mL and the PP cup 2 250mL show in almost all of the other categories lower impacts for the beverage cartons. The comparisons of the TT Midi C38 250mL and the PET bottle 5 500mL shows in most of the other categories higher impacts for the beverage cartons. The comparisons of the TT Midi C38 250mL and the PP cup 2 250mL shows in the other categories no unambiguous result.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has only a small influence on the assessment of the environmental impacts in this segment.

7.5 CREAM PORTION PACK AUSTRIA

In case of 'Climate Change' all beverage cartons in this segment show lower impacts than the compared one-way glass bottle and PET bottle regardless of the allocation factor. Compared to the PS cup the beverage carton shows lower or similar impacts depending on the allocation factor.

The comparisons of the chilled TBA Edge LC30 330mL with the chilled Glass bottle 1 (OW) shows lower impacts for the beverage carton in all other categories except ‘Aquatic Eutrophication’. The comparison of the ambient TT Midi C38 250mL with the PET bottle 6 250mL shows in all other categories lower impacts for the beverage carton. Compared with the PS cup 1 the TT Midi C38 250mL shows higher impacts in most of the other categories.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has only a small influence on the assessment of the environmental impacts in this segment.

7.6 SD PORTION PACK AUSTRIA

In case of ‘Climate Change’ the beverage carton in this segment shows lower impacts than the compared PET regardless of the allocation factor.

For the other categories the comparison of the examined beverage carton systems with fossil based plastics to the PET bottles in this segment, no unambiguous result can be observed.

In case of the beverage carton containing bio-based plastics, environmental impacts in the category ‘Climate Change’ are lower than those of cartons with fossil based plastics. However, the use of bio-based plastics also leads to higher environmental impacts in all other impact categories examined. This leads to the beverage carton showing higher impacts in most categories than the compared PET bottles.

Regarding the sensitivity analysis on recycled content of the PET bottle, the ranking between the PET bottle with increased recycled content and the compared beverage cartons stays the same with the regarded increase of recycled content for all impact categories.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has only a small influence on the assessment of the environmental impacts in this segment.

7.7 WATER PORTION PACK AUSTRIA

In case of ‘Climate Change’ all of the beverage cartons in this segment show lower impacts than the compared PET bottle regardless of the allocation factor.

Regarding the comparison of the examined beverage carton systems and the PET bottles for the other categories in this segment, the beverage cartons show mostly higher impacts than the PET bottle regardless of the allocation factor.

In case of the beverage carton containing bio-based plastics, environmental impacts in the category ‘Climate Change’ are lower than those of cartons with fossil based plastics. However, the use of bio-based plastics also leads to higher environmental impacts in all other impact categories examined. This leads to the beverage carton showing even higher impacts in most categories than the compared bottles.

Regarding the sensitivity analysis on recycled content of the PET bottle, the ranking between the PET bottle with increased recycled content and the compared beverage cartons stays the same with the regarded increase of recycled content.

Regarding the scenario variants on reduced bottle weight of the PET bottle, the ranking between the PET bottle and the compared beverage cartons stays the same with the regarded decrease of weight.

8 Results Switzerland

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

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

- production and transport of glass including converting to bottle (**'Glass'**)
- production and transport of PET including additives, e.g. carbon black (**'PET/HDPE'**)
- production and transport of liquid packaging board **('LPB')**
- production and transport of plastics and additives for beverage carton **('plastics for sleeve')**
- production and transport of aluminium & converting to foil **('aluminium foil')**
- converting processes of cartons **('converting')**
- production and transport of base materials for closures, top and label **('top, closure & label')**
- production of secondary and tertiary packaging: wooden pallets, LDPE shrink foil 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 biobased and renewable materials **('CO_2 reg. (EOL)')**; in the following also the term regenerative CO_2 emissions is used

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 loads of the substituted material. The so-called 50% allocation method has been used for the crediting procedure (see section1.7) in the base scenarios.

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

- credits for material recycling **('credits material')**
- credits for energy recovery (replacing e.g. grid electricity) **('credits energy')**
- Uptake of atmospheric CO_2 during the plant growth phase (**'CO_2-uptake'**)

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 graph includes three bars per packaging system under investigation, which illustrate (from left to right):

- sectoral results of the packaging system itself (stacked bar ‘environmental burdens’)
- credits given for secondary products leaving the system (negative stacked bar ‘credits’)
- net results as a results of the subtraction of credits from overall environmental loads (grey bar ‘net results’)

All category results refer to the primary and transport packaging material flows required for the delivery of 1000 L beverage to the point of sale including the end-of-life of the packaging materials.
The results for *water use* are shown on the inventory level. Due to the lack of mandatory information to assess the potential environmental impact, water scarcity cannot be assessed on LCIA level within this study. However, the use of freshwater is included in the inventory categories. A differentiation between process water, cooling water and water, unspecified is made. However, it includes neither any reference to the origin of this water, nor to its quality at the time of output/release. The respective results in this category are therefore of mere indicative nature and are not suited for conclusive quantitative statements related to either of the analysed packaging systems.

<u>A note on significance:</u> 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.

8.1 Results base scenarios DAIRY FAMILY PACK SWITZERLAND

8.1.1 Presentation of results DAIRY FAMILY PACK Switzerland, base collection quota of beverage cartons

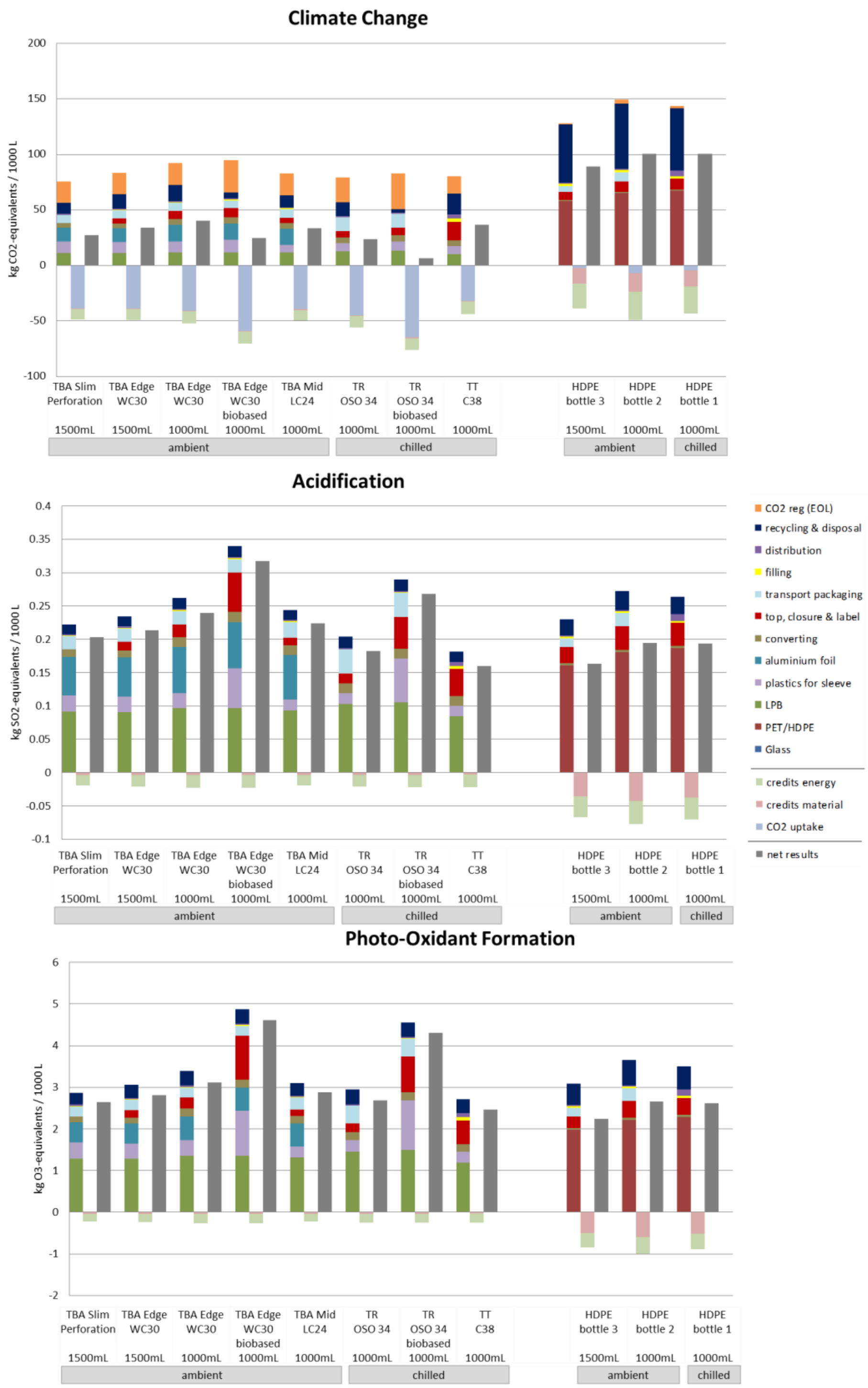


Figure 85: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)

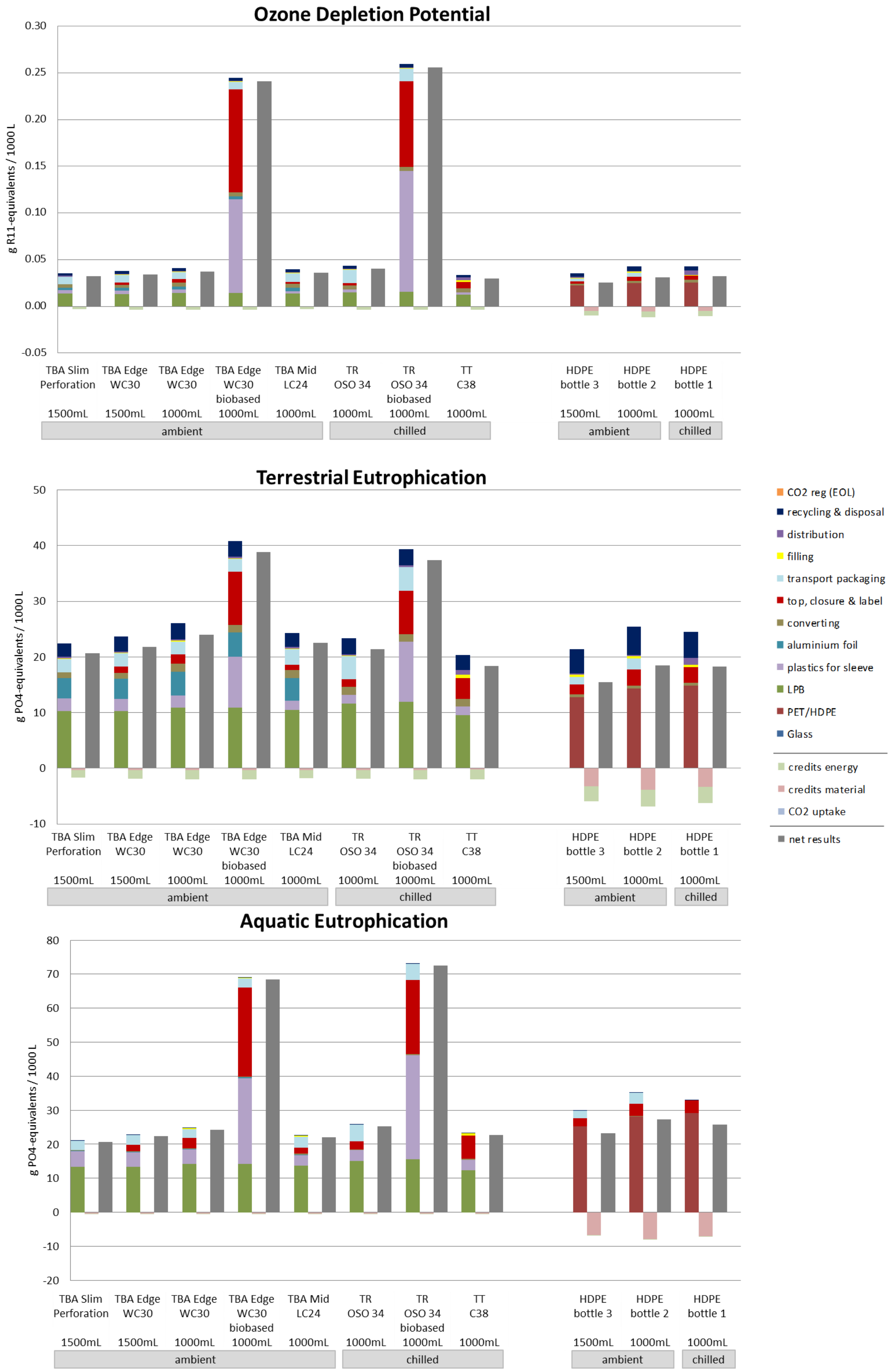


Figure 86 Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 2)

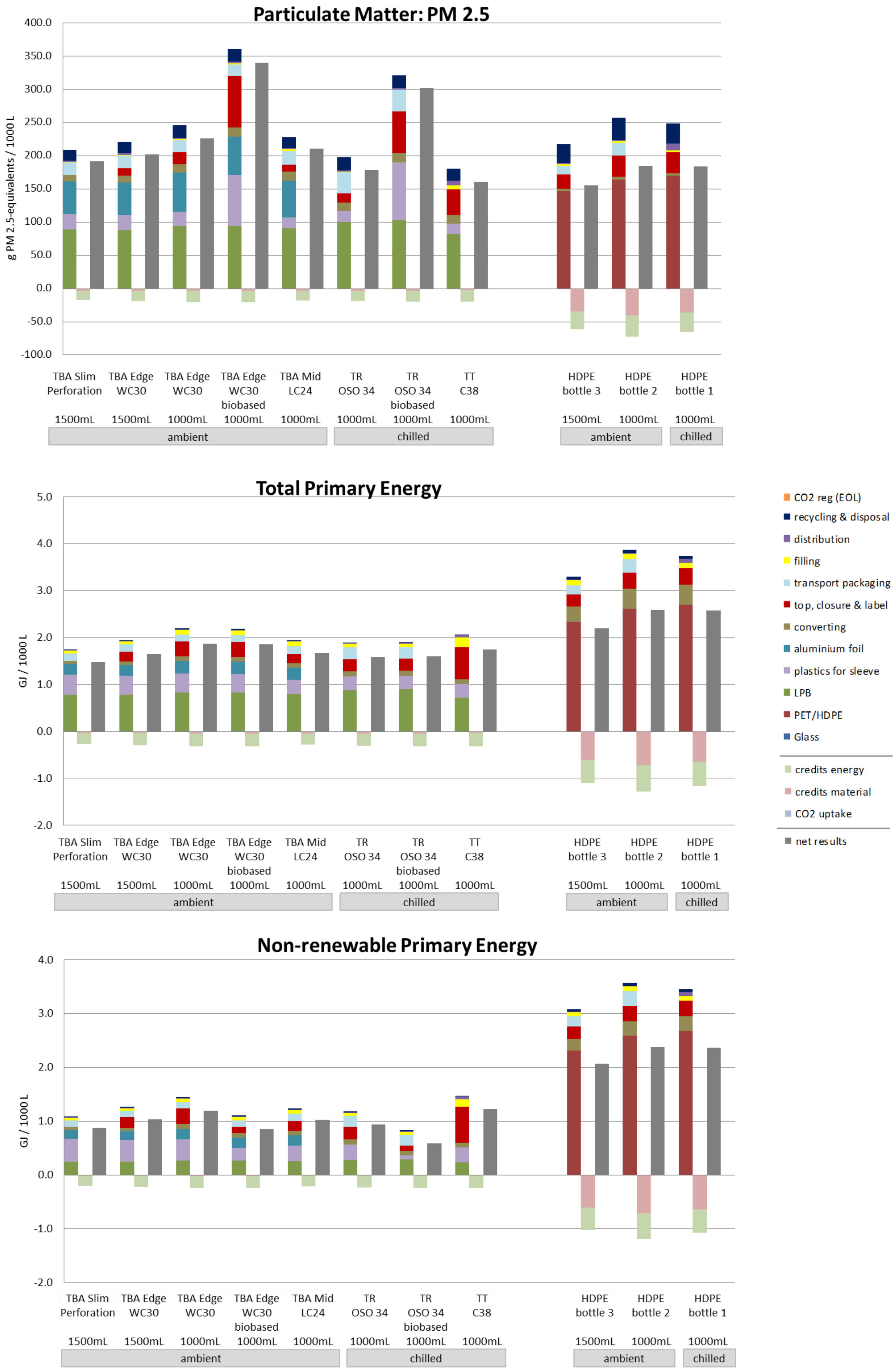
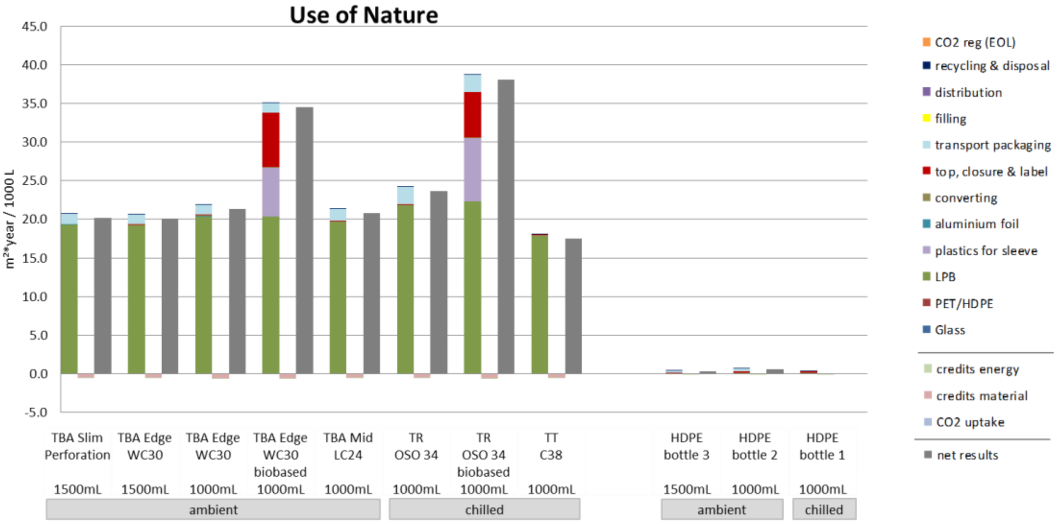


Figure 87: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 3)



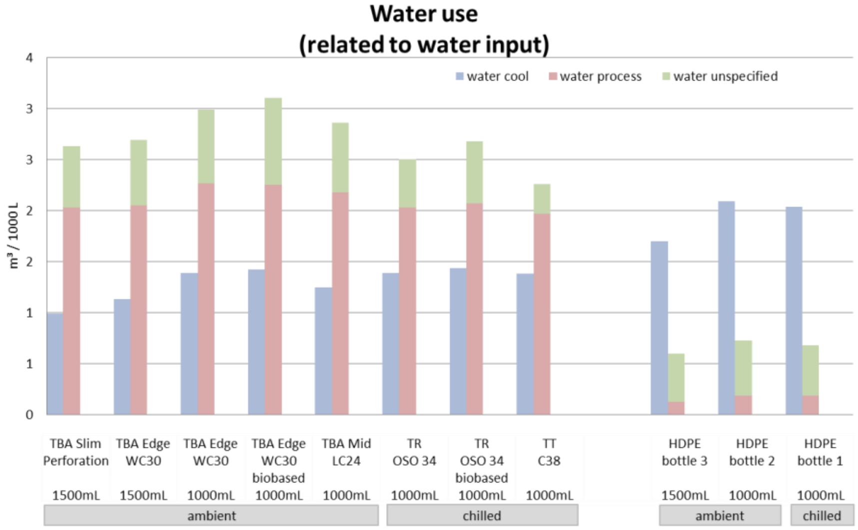


Figure 88: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 4)

Table 110: Category indicator results per impact category for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 1000mL		HDPE bottle 3 1500mL	HDPE bottle 2 1000mL	HDPE bottle 1 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	56.65	64.21	72.34	66.04	63.32	56.97	50.62	64.68		126.83	145.99	141.38
	CO2 (reg)	19.23	19.14	20.17	29.07	19.59	22.23	32.17	15.87		1.13	3.51	2.15
	Credits	-9.78	-10.78	-11.76	-11.78	-10.10	-11.08	-11.26	-11.88		-36.34	-42.04	-38.87
	CO2 uptake	-38.57	-38.40	-40.48	-58.61	-39.31	-44.60	-64.76	-31.86		-2.27	-7.01	-4.29
	net results	27.53	34.16	40.27	24.71	33.50	23.52	6.78	36.80		89.36	100.44	100.36
Acidification [kg SO2-e/1000 L[	Burdens	0.22	0.23	0.26	0.34	0.24	0.20	0.29	0.18		0.23	0.27	0.26
	Credits	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02		-0.07	-0.08	-0.07
	Net results	0.20	0.21	0.24	0.32	0.22	0.18	0.27	0.16		0.16	0.19	0.19
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	2.87	3.06	3.38	4.87	3.10	2.94	4.56	2.72		3.09	3.66	3.51
	Credits	-0.22	-0.24	-0.26	-0.26	-0.23	-0.25	-0.26	-0.26		-0.85	-0.99	-0.88
	Net results	2.65	2.82	3.12	4.61	2.87	2.69	4.30	2.46		2.24	2.66	2.62
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.04	0.04	0.24	0.04	0.04	0.26	0.03		0.04	0.04	0.04
	Credits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		-0.01	-0.01	-0.01
	Net results	0.03	0.03	0.04	0.24	0.04	0.04	0.26	0.03		0.03	0.03	0.03
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	22.38	23.65	26.03	40.84	24.28	23.34	39.35	20.39		21.36	25.40	24.53
	Credits	-1.69	-1.84	-2.01	-2.01	-1.74	-1.91	-1.94	-1.97		-5.89	-6.90	-6.23
	Net results	20.70	21.81	24.02	38.83	22.53	21.43	37.41	18.42		15.46	18.50	18.29
Aquatic Eutrophication [g PO4/1000 L]	Burdens	21.09	22.80	24.69	69.00	22.48	25.75	73.02	23.15		29.94	35.19	32.88
	Credits	-0.43	-0.44	-0.49	-0.49	-0.45	-0.48	-0.49	-0.37		-6.71	-7.91	-7.03
	Net results	20.65	22.35	24.19	68.51	22.03	25.26	72.52	22.78		23.23	27.28	25.85
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	208.47	220.91	245.99	360.47	228.01	197.38	321.33	180.17		217.09	256.84	248.69
	Credits	-17.06	-18.63	-20.33	-20.35	-17.64	-19.15	-19.47	-19.82		-61.59	-71.99	-65.31
	Net results	191.41	202.27	225.65	340.12	210.37	178.23	301.86	160.35		155.50	184.85	183.38
Total Primary Energy [GJ]	Burdens	1.75	1.94	2.19	2.18	1.95	1.90	1.91	2.06		3.29	3.87	3.73
	Credits	-0.27	-0.29	-0.32	-0.32	-0.28	-0.31	-0.31	-0.32		-1.09	-1.28	-1.16
	Net results	1.48	1.65	1.87	1.86	1.67	1.59	1.59	1.74		2.20	2.59	2.57
Non-renewable Primary Energy [GJ]	Burdens	1.08	1.26	1.45	1.10	1.23	1.18	0.83	1.47		3.08	3.57	3.45
	Credits	-0.21	-0.23	-0.25	-0.25	-0.21	-0.24	-0.24	-0.25		-1.02	-1.19	-1.08
	Net results	0.88	1.04	1.20	0.86	1.02	0.94	0.59	1.22		2.06	2.38	2.37
Use of Nature [m²*year]	Burdens	20.68	20.62	21.84	35.04	21.30	24.16	38.67	18.01		0.37	0.63	0.29
	Credits	-0.50	-0.50	-0.55	-0.55	-0.51	-0.54	-0.55	-0.47		-0.03	-0.04	-0.02
	Net results	20.18	20.12	21.30	34.50	20.79	23.62	38.12	17.53		0.33	0.59	0.00
Water use [m³/1000 L]	water cool	0.99	1.13	1.39	1.42	1.24	1.39	1.44	1.38		1.70	2.09	2.04
	water process	2.03	2.05	2.27	2.26	2.18	2.03	2.07	1.97		0.13	0.19	0.18
	water unspecified	0.60	0.64	0.72	0.85	0.69	0.47	0.61	0.29		0.47	0.54	0.50

8.1.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the DAIRY FAMILY PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories 'Aquatic Eutrophication' (21%-64%) and 'Use of Nature' (58%-99%). It is also relevant regarding 'Photo-Oxidant Formation' (28%-49%) 'Acidification' (28%-50%), 'Terrestrial Eutrophication' (27%-50%), 'Particulate Matter' (26%-51%) and also the consumption of 'Total Primary Energy' (35%-48%). Regarding 'Climate Change' the production of LPB is responsible for only 13%-16% of the burdens.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent.

Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (20%-27%) and 'Particulate Matter' (16%-24%). These result from SO2 and NOx emissions from the aluminium production. No shares of burdens are seen for chilled beverage cartons, as these don't have an aluminium layer.

The production of 'plastics for sleeve' of the beverage cartons shows considerable burdens in most impact categories (up to 38%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (9%-14%) and LPB (13%-16%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (9%-38%) and LPB (16%-35%) contribute about the same of the total burdens. If 'plastics for sleeve' contains bio-based plastics, this life cycle step plays a major role (21%-50%) for the overall burdens in all categories apart from 'Climate Change' (11%-12%), 'Acidification' (18%-23%) and 'Total Primary Energy' (15%-18%).

The life cycle step 'top, closure & label' for TBA and TR cartons contributes to a small amount in almost all impact categories (0%-20%). The exception is the TBA Slim with perforation, which shows no burdens in this step. In case of the TT carton this life cycle step contributes to a substantial share in almost all impact categories (1%-45%). In case the plastics used for 'top, closure & label' are bio-based, the results are considerably higher than cartons with fossil based plastics in all categories except 'Climate Change', 'Total Primary Energy Demand' and 'Non-renewable Primary Energy'.

The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'.

The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

The converting process generally plays a minor role (0%-12%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (3%-19%). The exception is 'Ozone Depletion Potential' for the cartons with fossil based plastics. In these cases 'transport packaging' has a higher share of 19%-33% of the burdens due to the low share of the categories 'top, closure & label' and 'plastics for sleeve'. If rollcontainers are used, this lifecycle step shows no impacts, as the production of rollcontainers is neglected due to their high reusability.

The life cycle step 'filling' shows only minor shares of burdens (up to 6%) for all TBA and TR beverage carton systems in all impact categories In case of TT beverage carton systems the shares are higher (up to 10%) due to the additional moulding process of the top.

The life cycle step 'distribution' shows only minor burdens in all impact categories for all beverage carton systems with rollcontainers (max. 9%). In case of beverage cartons with trays this step contributes only up to 2% of the total burdens.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (37%-44%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are very low as in Switzerland only 2.4% of the beverage cartons are recycled. Material credits for 'Climate Change' are especially low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play a minor role on the net results in all categories.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle systems in the DAIRY FAMILY PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories.

The 'converting' process shows for the plastic bottles in this segment a minor share of burdens (1%-11%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (3%-10%) in most categories mainly attributed to the different plastics used for the closures and the aluminium pull tab. In case of bottles with a label made of paper, 'Use of Nature' contributes to 30%-67% to the total burdens.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (4%-10%) in most categories. The exception is 'Use of Nature' for which 75% of the burdens are caused from 'transport packaging' resulting from the used cardboard and wood for pallets. If rollcontainers are used, this lifecycle step shows no impacts, as the production of rollcontainers is neglected due to their high reusability.

The life cycle step 'filling' shows only small shares of burdens (max. 3%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only minor burdens in all impact categories for all bottle systems with rollcontainers (max. 11%). In case of beverage cartons with trays this step contributes only up to 2% of the total burdens.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (40%-42%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is very low in most categories. The exception is 'Climate Change', where the credits reduce the overall burdens by around 10%-30%. The energy credits mainly originate from the incineration plants.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

8.1.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems (with base collection quota) for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 111: Comparison of net results: **TBA Slim Perforation 1500mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (ambient), Switzerland**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Slim Perforation 1500mL** are lower (green)/ higher (orange) than those of					
	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	-19%	-32%	11%	-18%	-69%	-73%
Acidification	-5%	-15%	-36%	-9%	24%	4%
Photo-Oxidant Formation	-6%	-15%	-43%	-8%	18%	-1%
Ozone Depletion Potential	-6%	-14%	-87%	-12%	26%	3%
Terrestrial Eutrophication	-5%	-14%	-47%	-8%	34%	12%
Aquatic Eutrophication	-8%	-15%	-70%	-6%	-11%	-24%
Particulate Matter	-5%	-15%	-44%	-9%	23%	4%

Table 112: Comparison of net results: **TBA Edge WC30 1500mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (ambient), Switzerland**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1500mL** are lower (green)/ higher (orange) than those of					
	TBA Slim Perforation 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	24%	-15%	38%	2%	-62%	-66%
Acidification	5%	-11%	-33%	-4%	31%	10%
Photo-Oxidant Formation	6%	-10%	-39%	-2%	25%	6%
Ozone Depletion Potential	6%	-9%	-86%	-6%	34%	9%
Terrestrial Eutrophication	5%	-9%	-44%	-3%	41%	18%
Aquatic Eutrophication	8%	-8%	-67%	1%	-4%	-18%
Particulate Matter	6%	-10%	-41%	-4%	30%	9%

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

Table 113: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (ambient), Switzerland**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of					
	TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	46%	18%	63%	20%	-55%	-60%
Acidification	18%	12%	-25%	7%	46%	23%
Photo-Oxidant Formation	18%	11%	-32%	9%	39%	17%
Ozone Depletion Potential	17%	10%	-85%	3%	47%	20%
Terrestrial Eutrophication	16%	10%	-38%	7%	55%	30%
Aquatic Eutrophication	17%	8%	-65%	10%	4%	-11%
Particulate Matter	18%	12%	-34%	7%	45%	22%

Table 114: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (ambient), Switzerland**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of					
	TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Mid LC24 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	-10%	-28%	-39%	-26%	-72%	-75%
Acidification	56%	48%	33%	42%	94%	63%
Photo-Oxidant Formation	74%	64%	48%	60%	105%	73%
Ozone Depletion Potential	653%	609%	545%	566%	847%	675%
Terrestrial Eutrophication	88%	78%	62%	72%	151%	110%
Aquatic Eutrophication	232%	206%	183%	211%	195%	151%
Particulate Matter	78%	68%	51%	62%	119%	84%

Table 115: Comparison of net results: **TBA Mid LC24 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Switzerland**, allocation factor 50%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Mid LC24 1000mL** are lower (green)/ higher (orange) than those of					
	TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	22%	-2%	-17%	36%	-63%	-67%
Acidification	10%	5%	-6%	-29%	37%	15%
Photo-Oxidant Formation	9%	2%	-8%	-38%	28%	8%
Ozone Depletion Potential	13%	6%	-3%	-85%	42%	16%
Terrestrial Eutrophication	9%	3%	-6%	-42%	46%	22%
Aquatic Eutrophication	7%	-1%	-9%	-68%	-5%	-19%
Particulate Matter	10%	4%	-7%	-38%	35%	14%

Table 116: Comparison of net results: **TR OSO 34 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Switzerland**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Switzerland	The net results of **TR OSO 34 1000mL** are lower (green)/ higher (orange) than those of		
	TR OSO 34 biobased 1000mL	TT C38 1000mL	HDPE bottle 1 1000mL
Climate Change	247%	-36%	-77%
Acidification	-32%	14%	-6%
Photo-Oxidant Formation	-37%	9%	3%
Ozone Depletion Potential	-84%	35%	24%
Terrestrial Eutrophication	-43%	16%	17%
Aquatic Eutrophication	-65%	11%	-2%
Particulate Matter	-41%	11%	-3%

Table 117: Comparison of net results: **TR OSO 34 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Switzerland**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Switzerland	The net results of **TR OSO 34 biobased 1000mL** are lower (green)/ higher (orange) than those of		
	TR OSO 34 1000mL	TT C38 1000mL	HDPE bottle 1 1000mL
Climate Change	-71%	-82%	-93%
Acidification	47%	68%	38%
Photo-Oxidant Formation	60%	75%	64%
Ozone Depletion Potential	540%	761%	696%
Terrestrial Eutrophication	75%	103%	104%
Aquatic Eutrophication	187%	218%	181%
Particulate Matter	69%	88%	65%

Table 118: Comparison of net results: **TT C38 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Switzerland**, allocation factor 50%

DAIRY FAMILY PACK (chilled), Switzerland	The net results of **TT C38 1000mL** are lower (green)/ higher (orange) than those of		
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	HDPE bottle 1 1000mL
Climate Change	57%	443%	-63%
Acidification	-13%	-40%	-17%
Photo-Oxidant Formation	-9%	-43%	-6%
Ozone Depletion Potential	-26%	-88%	-8%
Terrestrial Eutrophication	-14%	-51%	1%
Aquatic Eutrophication	-10%	-69%	-12%
Particulate Matter	-10%	-47%	-13%

8.1.4 Presentation of results DAIRY FAMILY PACK Switzerland, target collection quota of beverage cartons

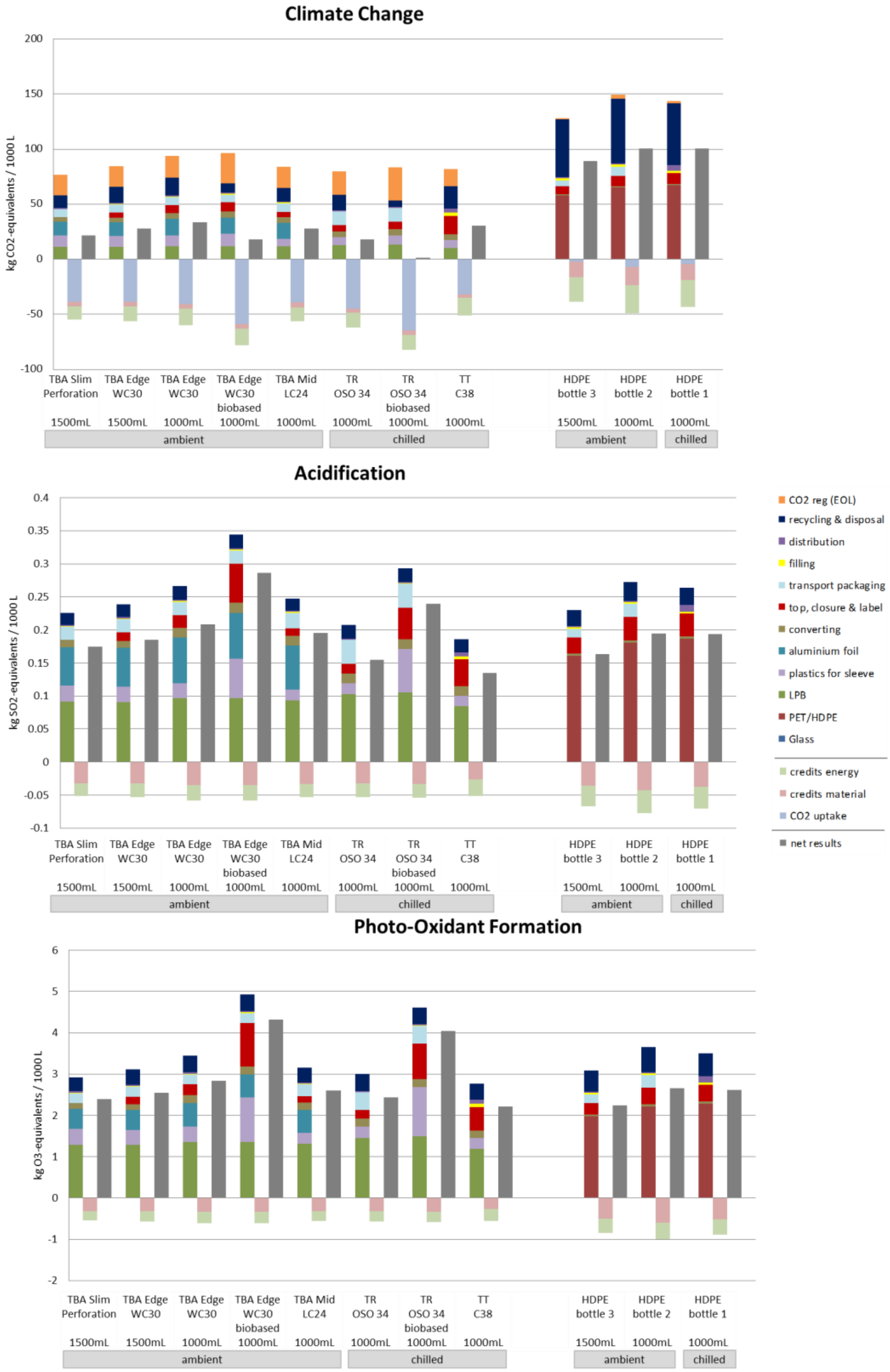


Figure 89: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)

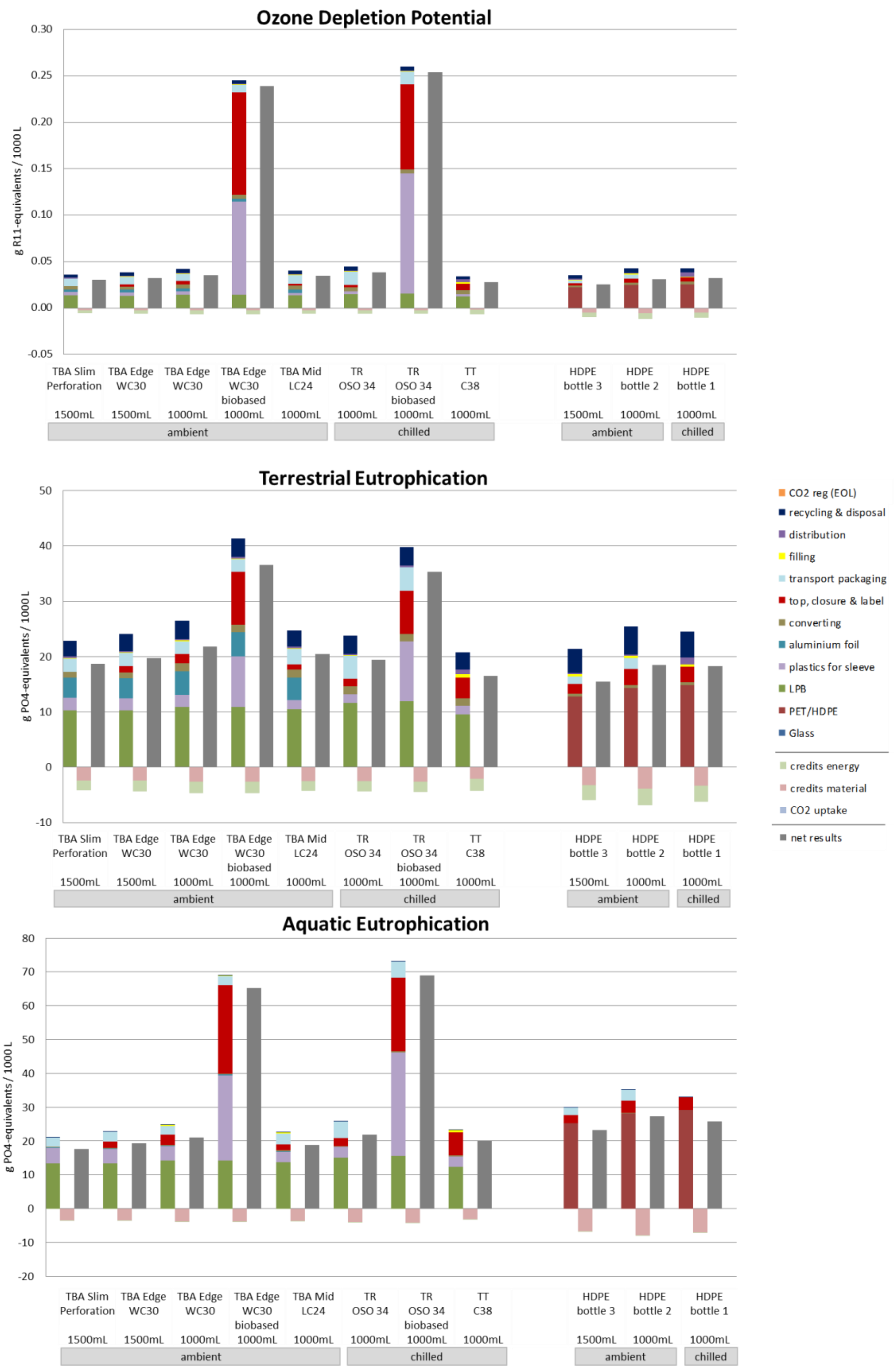


Figure 90 Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 2)

Figure 91: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 3)

Figure 92: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 4)

Table 119: Category indicator results per impact category for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY FAMILY PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 1000mL		HDPE bottle 3 1500mL	HDPE bottle 2 1000mL	HDPE bottle 1 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	58.14	65.79	74.06	69.10	64.85	58.44	53.58	66.32		126.83	145.99	141.38
	CO2 (reg)	18.68	18.60	19.61	27.15	19.04	21.62	30.07	15.38		1.13	3.51	2.15
	Credits	-16.34	-17.85	-19.47	-19.48	-16.88	-17.22	-17.50	-19.12		-36.34	-42.04	-38.87
	CO2 uptake	-38.57	-38.40	-40.48	-58.61	-39.31	-44.60	-64.76	-31.86		-2.27	-7.01	-4.29
	net results	21.91	28.14	33.72	18.16	27.70	18.24	1.40	30.72		89.36	100.44	100.36
Acidification [kg SO2-e/1000 L[	Burdens	0.23	0.24	0.27	0.34	0.25	0.21	0.29	0.19		0.23	0.27	0.26
	Credits	-0.05	-0.05	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05		-0.07	-0.08	-0.07
	Net results	0.17	0.19	0.21	0.29	0.19	0.15	0.24	0.13		0.16	0.19	0.19
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	2.92	3.11	3.45	4.93	3.16	3.00	4.62	2.77		3.09	3.66	3.51
	Credits	-0.54	-0.56	-0.61	-0.61	-0.55	-0.57	-0.58	-0.55		-0.85	-0.99	-0.88
	Net results	2.39	2.55	2.84	4.32	2.61	2.43	4.04	2.22		2.24	2.66	2.62
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.04	0.04	0.25	0.04	0.04	0.26	0.03		0.04	0.04	0.04
	Credits	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01		-0.01	-0.01	-0.01
	Net results	0.03	0.03	0.04	0.24	0.03	0.04	0.25	0.03		0.03	0.03	0.03
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	22.80	24.07	26.48	41.30	24.70	23.75	39.76	20.77		21.36	25.40	24.53
	Credits	-4.12	-4.34	-4.70	-4.70	-4.25	-4.37	-4.45	-4.27		-5.89	-6.90	-6.23
	Net results	18.67	19.74	21.79	36.60	20.45	19.38	35.31	16.50		15.46	18.50	18.29
Aquatic Eutrophication [g PO4/1000 L]	Burdens	21.10	22.81	24.70	69.02	22.49	25.76	73.03	23.16		29.94	35.19	32.88
	Credits	-3.53	-3.52	-3.75	-3.75	-3.60	-3.97	-4.07	-3.20		-6.71	-7.91	-7.03
	Net results	17.57	19.29	20.95	65.26	18.89	21.79	68.96	19.95		23.23	27.28	25.85
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	212.20	224.78	250.20	364.68	231.84	201.05	325.07	183.92		217.09	256.84	248.69
	Credits	-44.84	-46.93	-50.87	-50.89	-46.26	-46.63	-47.57	-45.13		-61.59	-71.99	-65.31
	Net results	167.36	177.85	199.33	313.79	185.59	154.42	277.50	138.79		155.50	184.85	183.38
Total Primary Energy [GJ]	Burdens	1.78	1.98	2.23	2.22	1.98	1.93	1.94	2.09		3.29	3.87	3.73
	Credits	-0.59	-0.61	-0.66	-0.66	-0.60	-0.65	-0.66	-0.60		-1.09	-1.28	-1.16
	Net results	1.20	1.37	1.57	1.56	1.38	1.28	1.28	1.49		2.20	2.59	2.57
Non-renewable Primary Energy [GJ]	Burdens	1.11	1.29	1.47	1.13	1.26	1.21	0.85	1.50		3.08	3.57	3.45
	Credits	-0.28	-0.31	-0.34	-0.34	-0.30	-0.31	-0.31	-0.32		-1.02	-1.19	-1.08
	Net results	0.82	0.98	1.14	0.80	0.96	0.90	0.54	1.17		2.06	2.38	2.37
Use of Nature [m²*year]	Burdens	20.68	20.62	21.85	35.05	21.30	24.16	38.67	18.01		0.37	0.63	0.29
	Credits	-5.02	-4.99	-5.31	-5.31	-5.11	-5.65	-5.79	-4.63		-0.03	-0.04	-0.02
	Net results	15.66	15.63	16.53	29.73	16.20	18.51	32.88	13.38		0.33	0.59	0.00
Water use [m³/1000 L]	water cool	0.97	1.13	1.38	1.42	1.23	1.37	1.41	1.40		1.70	2.09	2.04
	water process	1.84	1.86	2.06	2.05	1.98	1.83	1.86	1.81		0.13	0.19	0.18
	water unspecified	0.57	0.62	0.70	0.82	0.66	0.47	0.61	0.28		0.47	0.54	0.50

8.1.5 Description and interpretation

The increased collection quota of beverage cartons in Switzerland leads to a reduction of net results from 1%-79%. The lowest reductions (1%-7%) are seen in the category ‘Ozone Depletion Potential’. The highest reductions are in the category ‘Climate Change’ (16%-79%), followed by ‘Use of Nature’ (14%-24%) and ‘Total Primary Energy’ (14%-20%).

8.2 Results base scenarios JN FAMILY PACK SWITZERLAND

8.2.1 Presentation of results JN FAMILY PACK Switzerland, base collection quota of beverage cartons

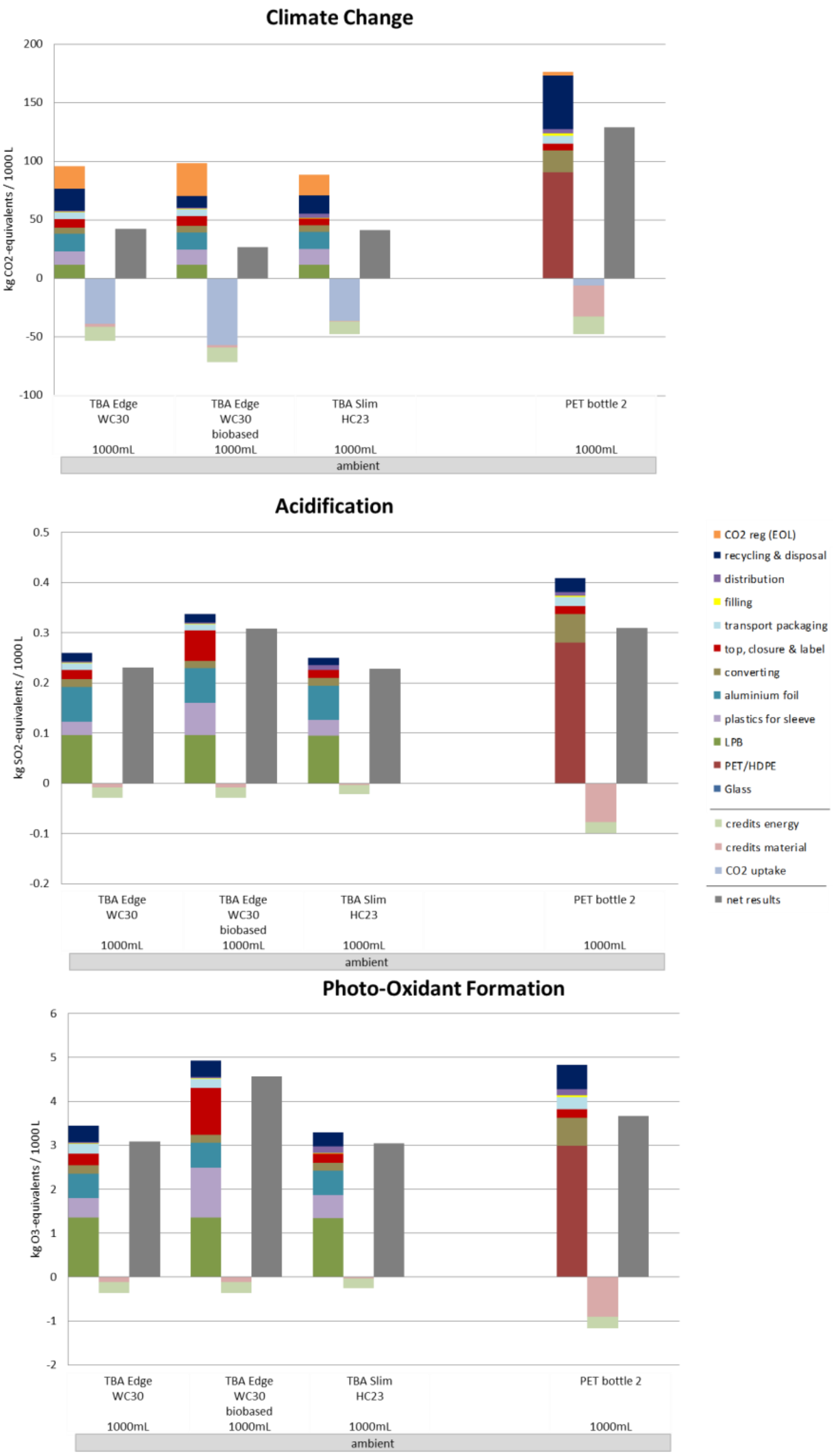


Figure 93: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment JN FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)

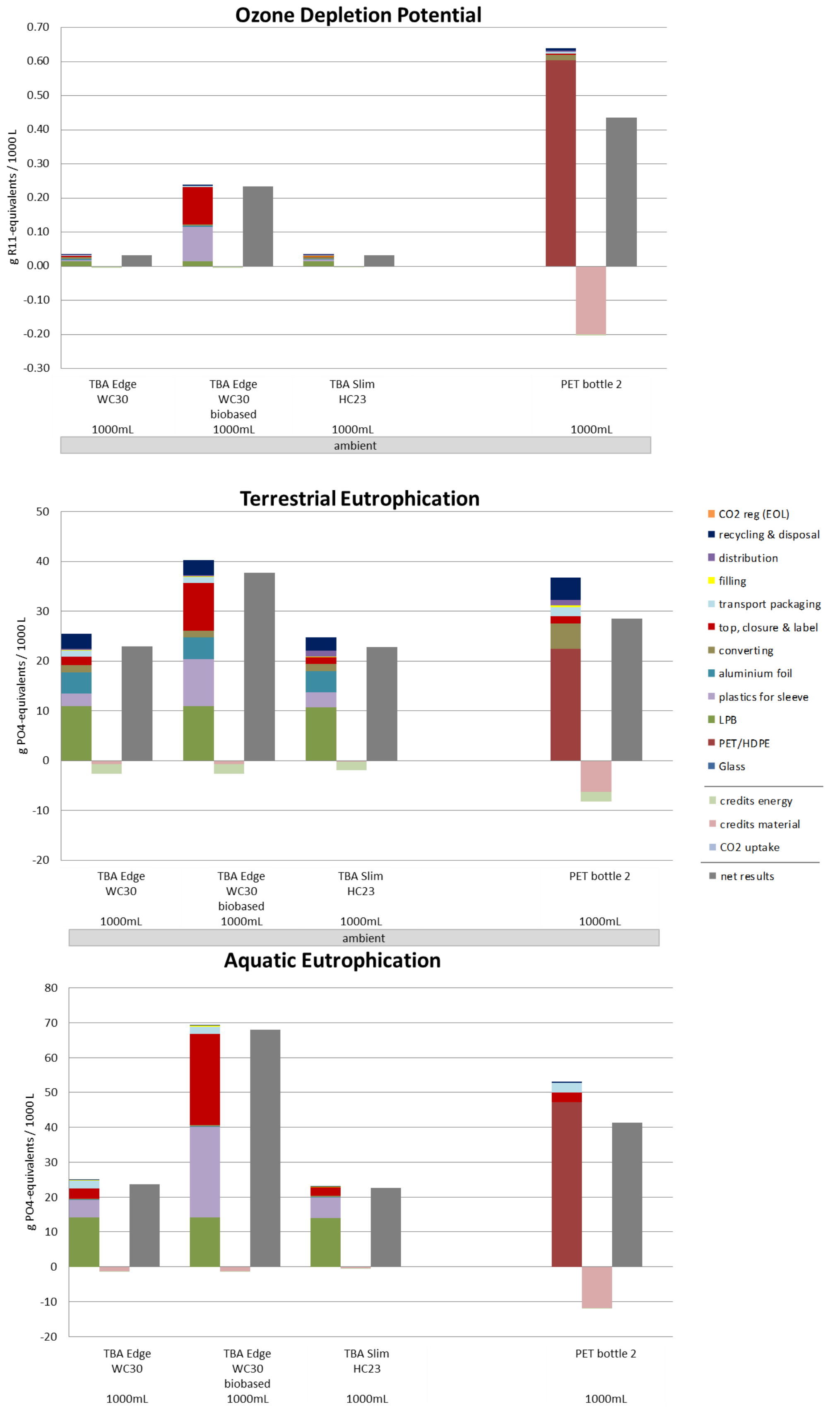


Figure 94: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment JN FAMILY PACK, Switzerland**, allocation factor 50% (Part 2)

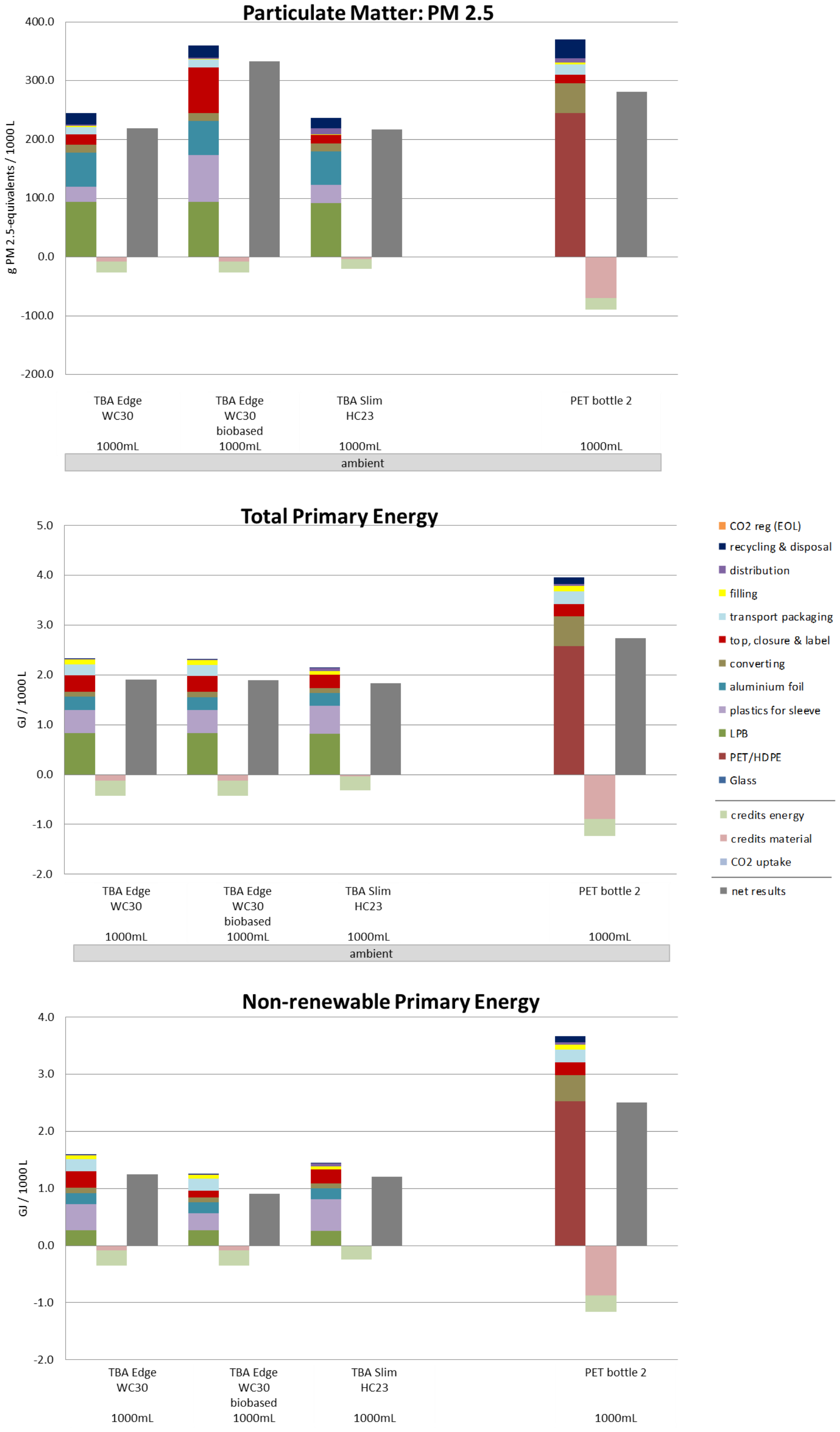
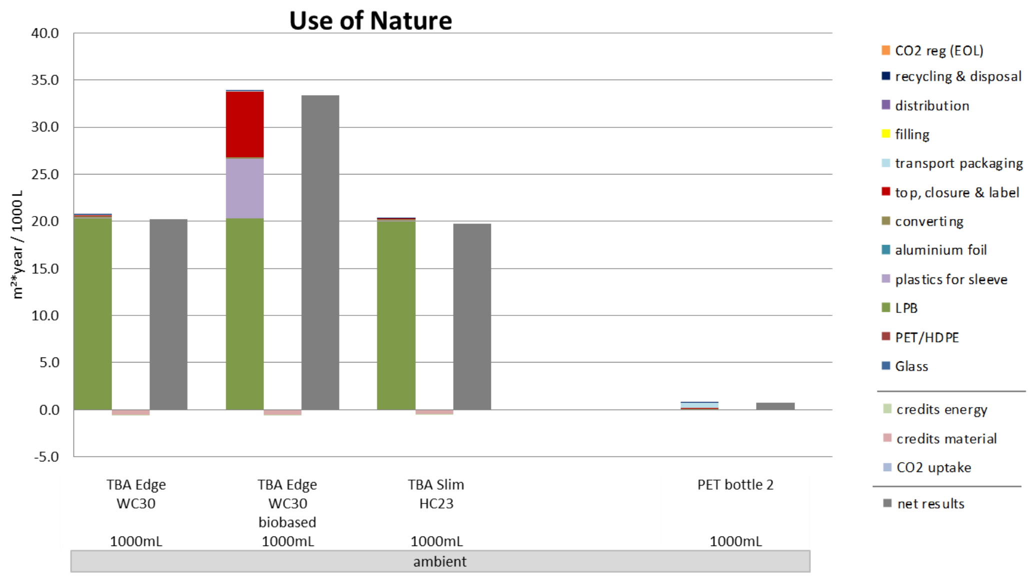


Figure 95: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment JN FAMILY PACK, Switzerland**, allocation factor 50% (Part 3)



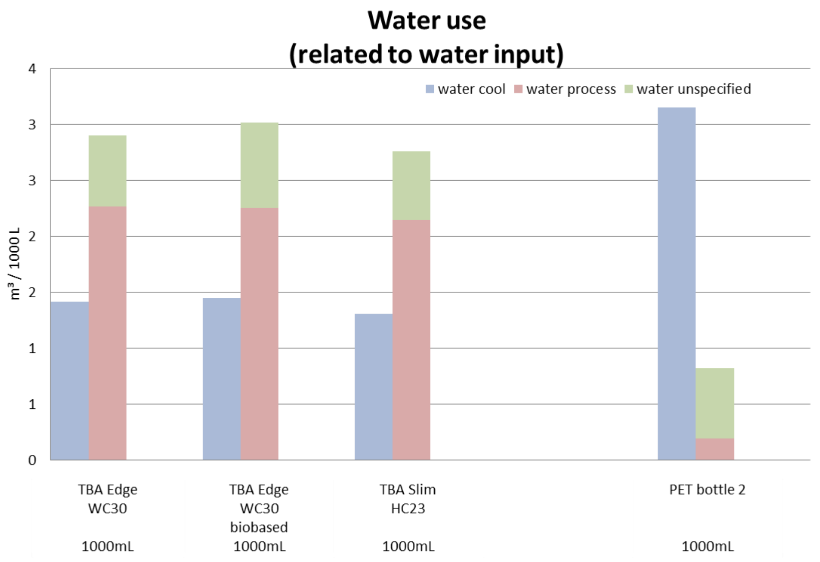


Figure 96: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment JN FAMILY PACK, Switzerland**, allocation factor 50% (Part 4)

Table 120: Category indicator results per impact category for base scenarios with **base collection quota of beverage cartons** of segment JN FAMILY PACK, Switzerland- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places

Allocation 50		TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL		PET bottle 2 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	76.52	70.22	70.94		173.42
	CO2 (reg)	19.19	28.08	17.86		3.05
	Credits	-14.82	-14.84	-11.60		-41.43
	CO2 uptake	-38.52	-56.60	-35.85		-6.09
	net results	42.38	26.86	41.35		128.94
Acidification [kg SO2-e/1000 L[	Burdens	0.26	0.34	0.25		0.41
	Credits	-0.03	-0.03	-0.02		-0.10
	Net results	0.23	0.31	0.23		0.31
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.44	4.93	3.30		4.83
	Credits	-0.36	-0.36	-0.26		-1.16
	Net results	3.08	4.57	3.04		3.67
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.24	0.04		0.64
	Credits	0.00	0.00	0.00		-0.20
	Net results	0.03	0.23	0.03		0.44
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	25.52	40.30	24.74		36.77
	Credits	-2.61	-2.61	-1.96		-8.23
	Net results	22.92	37.69	22.78		28.54
Aquatic Eutrophication [g PO4/1000 L]	Burdens	24.96	69.17	22.96		53.08
	Credits	-1.29	-1.29	-0.39		-11.76
	Net results	23.67	67.88	22.57		41.32
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	245.53	359.73	236.48		370.32
	Credits	-26.42	-26.44	-19.83		-89.12
	Net results	219.11	333.29	216.65		281.20
Total Primary Energy [GJ]	Burdens	2.33	2.32	2.14		3.96
	Credits	-0.43	-0.43	-0.31		-1.23
	Net results	1.90	1.89	1.83		2.73
Non-renewable Primary Energy [GJ]	Burdens	1.60	1.26	1.44		3.66
	Credits	-0.35	-0.35	-0.24		-1.16
	Net results	1.25	0.91	1.20		2.50
Use of Nature [m²*year]	Burdens	20.72	33.89	20.27		0.73
	Credits	-0.54	-0.54	-0.50		-0.03
	Net results	20.18	33.35	19.77		0.70
Water use [m³/1000 L]	water cool	1.42	1.45	1.31		3.15
	water process	2.26	2.25	2.15		0.19
	water unspecified	0.64	0.77	0.61		0.63

8.2.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the JN FAMILY PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories ‘Aquatic Eutrophication’ (20%-61%) and ‘Use of Nature’ (60%-99%). It is also relevant regarding ‘Photo-Oxidant Formation’ (28%-41%) ‘Acidification’ (29%-38%), ‘Terrestrial Eutrophication’ (27%-43%), ‘Particulate Matter’ (26%-39%) and also the consumption of ‘Total Primary Energy’ (36%-38%). Regarding ‘Climate Change’ the production of LPB contributes only to 12%-13%.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both ‘Aquatic Eutrophication’ and ‘Terrestrial Eutrophication’, the latter to a lesser extent. Approximately half of the ‘Aquatic Eutrophication Potential’ is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the ‘Terrestrial Eutrophication Potential’, nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called ‘Kraft process’ is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories ‘Total Primary Energy’ and ‘Non-renewable Primary Energy’.

The production of ‘aluminium foil’ for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories ‘Acidification’ (20%-27%) and ‘Particulate Matter’ (16%-24%). These result from SO2 and NOx emissions from the aluminium production.

The production of ‘plastics for sleeve’ of the beverage cartons with fossil plastics shows considerable burdens in most impact categories (up to 42%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (12%-15%) and LPB (12%-13%) contribute about the same and the inventory category ‘Non-renewable Primary Energy’, where the plastics (24%-38%) contribute more than LPB (17%-21%) to the total burdens. If ‘plastics for sleeve’ contains bio-based plastics, this life cycle step plays a major role (18%-42%) for the overall burdens in all categories apart from ‘Climate Change’ (13%).

The life cycle step ‘top, closure & label’ for the beverage cartons contributes to a small amount in almost all impact categories (0%-18%). In case the plastics used for ‘top, closure & label’ are bio-based, the results are considerably higher than cartons with fossil based plastics in all categories except ‘Climate Change’, ‘Total Primary Energy Demand’ and ‘Non-renewable Primary Energy’.

The reason for the big influence of bio-based plastics on all impact categories apart from ‘Climate Change’ is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category ‘Ozone Depletion Potential’. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories ‘Particulate Matter’, ‘Terrestrial Eutrophication’, ‘Acidification’ and ‘Total Primary Energy’. The burning of bagasse on the field leads to a considerable contribution to ‘Particulate Matter’.

The converting process generally plays a minor role (0%-12%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of ‘transport packaging’ for the beverage carton systems show minor impacts in most categories (0%-16%). If rollcontainers are used, this lifecycle step shows no impacts, as the production of rollcontainers is neglected due to their high reusability.

The life cycle step ‘filling’ shows only minor burdens for all beverage carton systems in all impact categories (max. 5%).

The life cycle step ‘distribution’ shows only minor burdens in all impact categories for all beverage carton systems with rollcontainers (max. 9%). In case of beverage cartons with trays this step contributes only up to 2% of the total burdens.

The life cycle step ‘recycling & disposal’ of the regarded beverage cartons is most relevant in the impact category ‘Climate Change’. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

‘CO2 reg. (recycling & disposal)’ describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category ‘Climate Change’. Together with the fossil-based CO2 emissions of the life cycle step ‘recycling & disposal’, they represent the total CO2 emissions from the packaging’s end-of-life (38%-39%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are very low as in Switzerland only 2.4% of the beverage cartons are recycled. Material credits for ‘Climate Change’ are especially low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play a minor role on the net results in all categories.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the JN FAMILY PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a minor share of burdens (2%-15%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (0%-12%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (1%-6%) in most categories. The exception is 'Use of Nature' for which 71% of the burdens are caused from 'transport packaging' resulting from the used cardboard slip sheets.

The life cycle step 'filling' shows only small shares of burdens (max. 3%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 3%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (28%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 30% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions.

(please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

8.2.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems (with base collection quota) for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 121: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Switzerland**, allocation factor 50%

JN FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of		
	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 2 1000mL
Climate Change	58%	2%	-67%
Acidification	-25%	1%	-26%
Photo-Oxidant Formation	-33%	1%	-16%
Ozone Depletion Potential	-87%	-2%	-93%
Terrestrial Eutrophication	-39%	1%	-20%
Aquatic Eutrophication	-65%	5%	-43%
Particulate Matter	-34%	1%	-22%

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

Table 122: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Switzerland**, allocation factor 50%

JN FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of		
	TBA Edge WC30 1000mL	TBA Slim HC23 1000mL	PET bottle 2 1000mL
Climate Change	-37%	-35%	-79%
Acidification	34%	35%	0%
Photo-Oxidant Formation	48%	50%	24%
Ozone Depletion Potential	644%	633%	-46%
Terrestrial Eutrophication	64%	65%	32%
Aquatic Eutrophication	187%	201%	64%
Particulate Matter	52%	54%	19%

Table 123: Comparison of net results: **TBA Slim HC23 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Switzerland**, allocation factor 50%

JN FAMILY PACK (ambient), Switzerland	The net results of **TBA Slim HC23 1000mL** are lower (green)/ higher (orange) than those of		
	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	PET bottle 2 1000mL
Climate Change	-2%	54%	-68%
Acidification	-1%	-26%	-26%
Photo-Oxidant Formation	-1%	-33%	-17%
Ozone Depletion Potential	2%	-86%	-93%
Terrestrial Eutrophication	-1%	-40%	-20%
Aquatic Eutrophication	-5%	-67%	-45%
Particulate Matter	-1%	-35%	-23%

8.2.4 Presentation of results JN FAMILY PACK Switzerland, target collection quota of beverage cartons

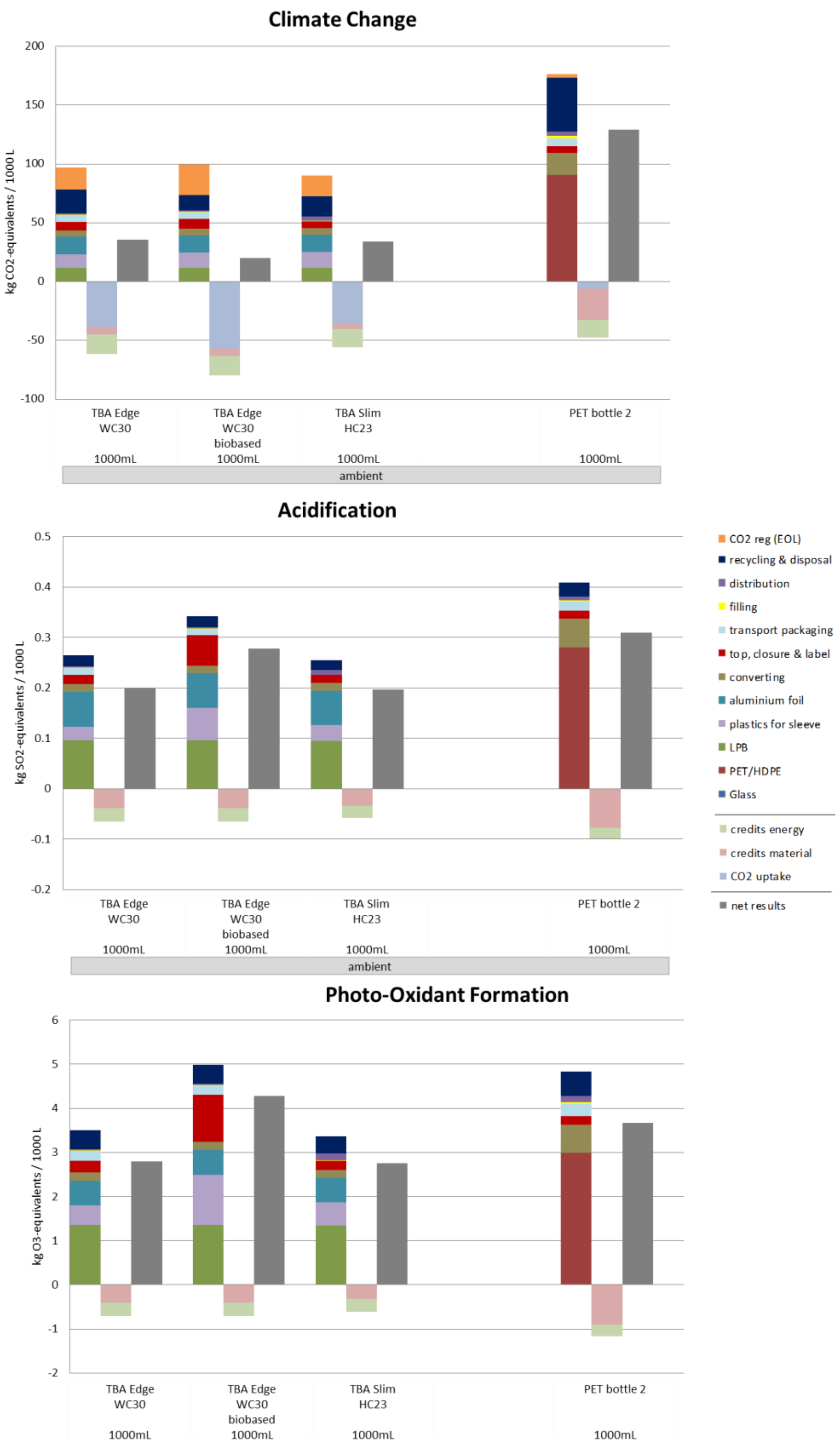


Figure 97: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment JN FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)

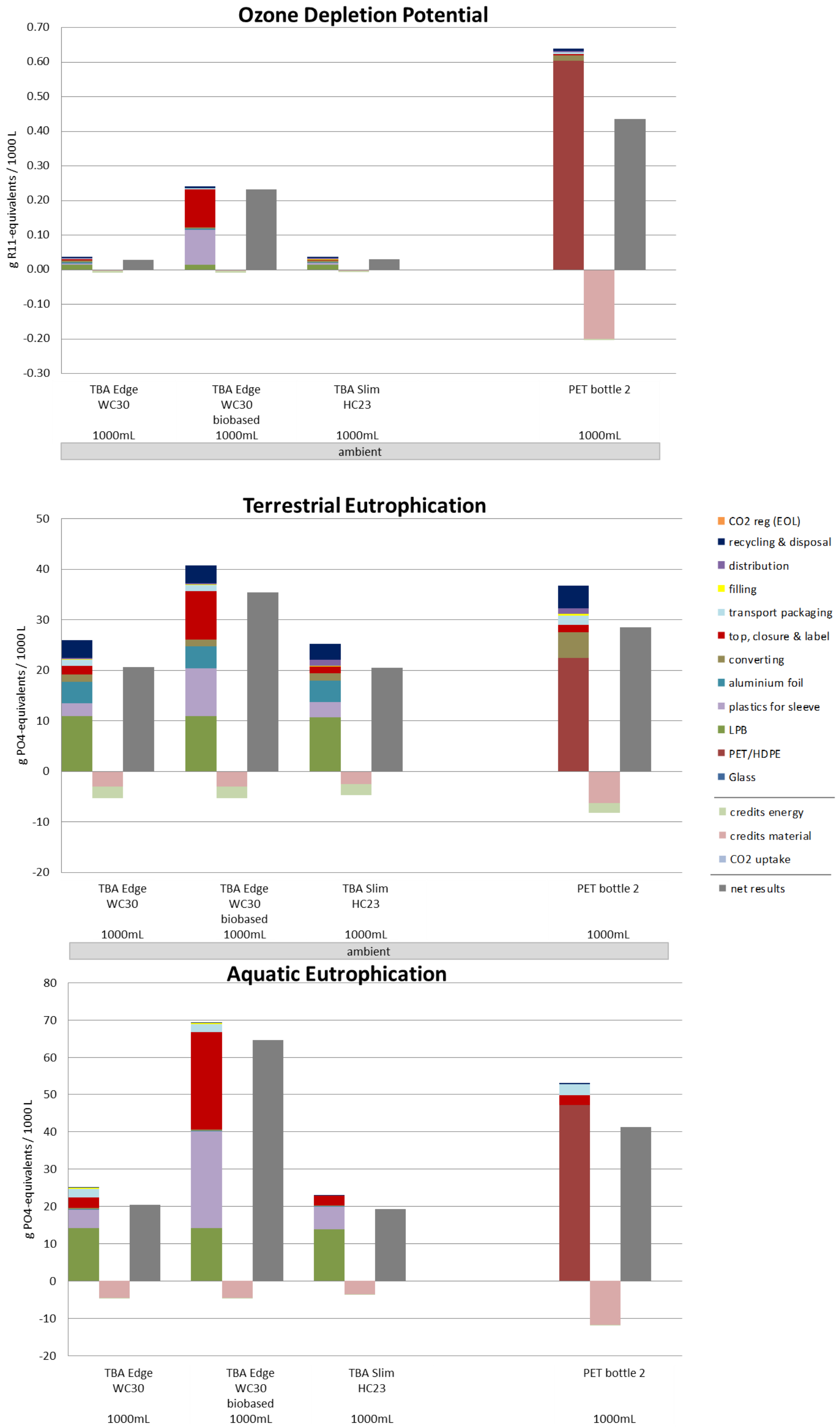


Figure 98: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment JN FAMILY PACK, Switzerland**, allocation factor 50% (Part 2)

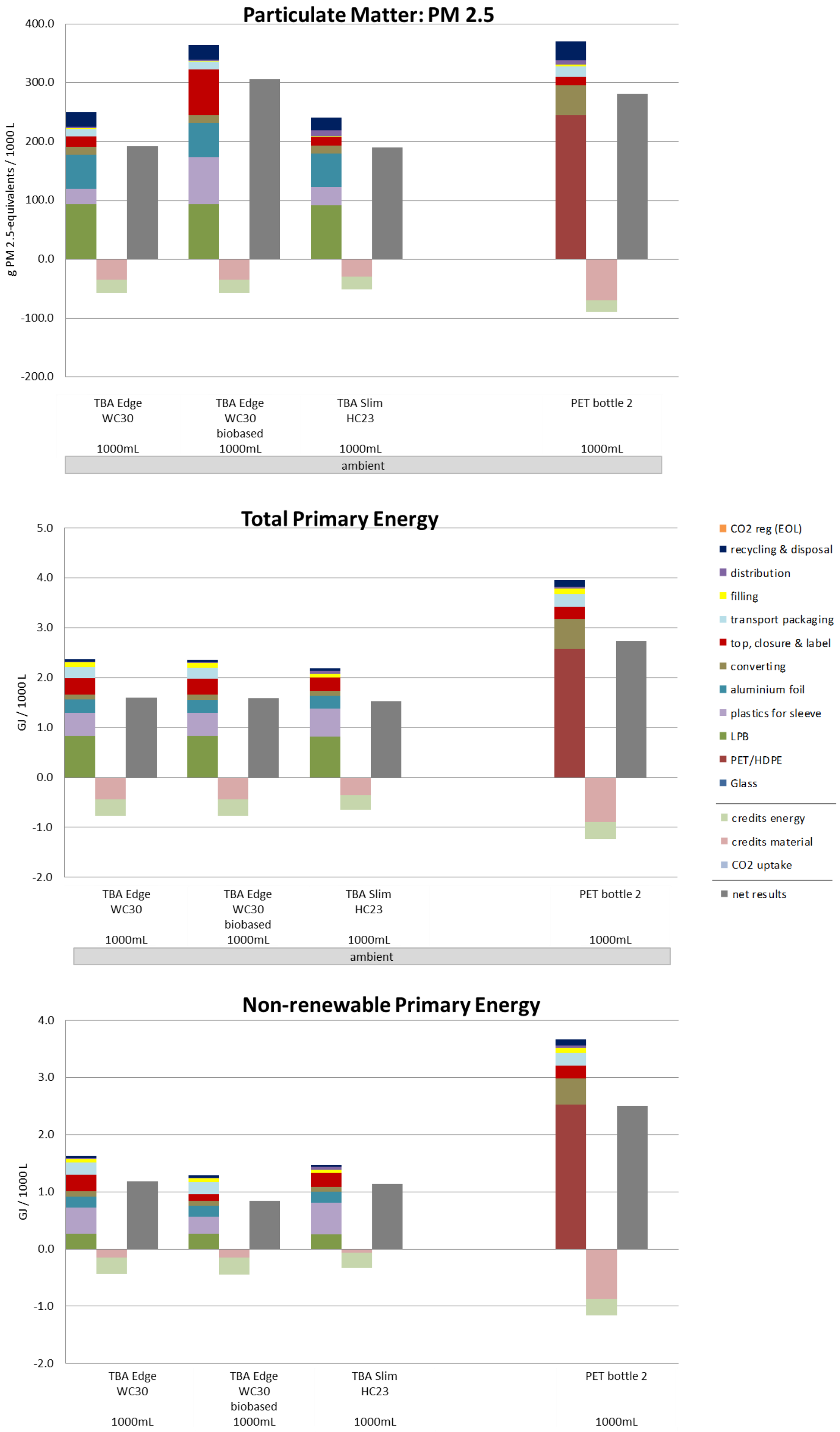


Figure 99: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment JN FAMILY PACK, Switzerland**, allocation factor 50% (Part 3)

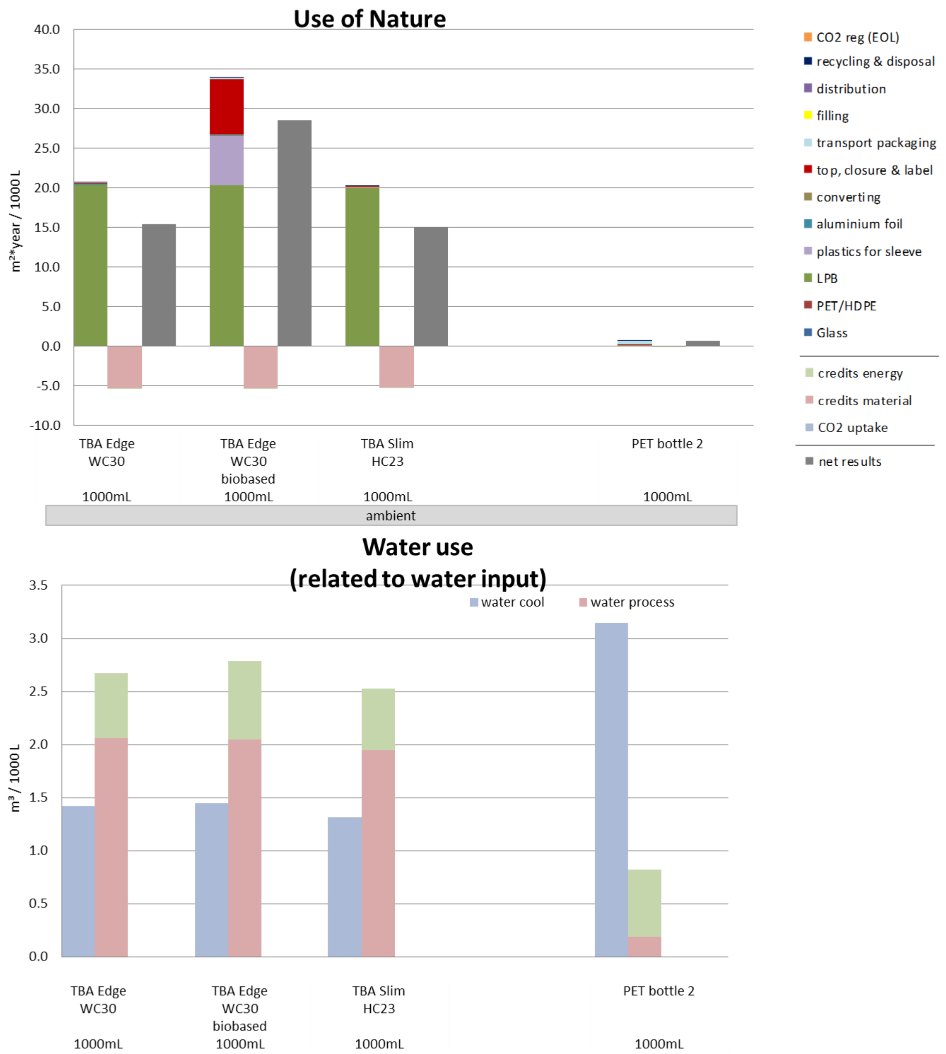


Figure 100: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment JN FAMILY PACK, Switzerland**, allocation factor 50% (Part 4)

Table 124: Category indicator results per impact category for base scenarios with **target collection quota of beverage cartons** of segment JN FAMILY PACK, Switzerland- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places

Allocation 50		TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL		PET bottle 2 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	78.30	73.35	72.77		173.42
	CO2 (reg)	18.63	26.16	17.30		3.05
	Credits	-22.84	-22.86	-19.86		-41.43
	CO2 uptake	-38.52	-56.60	-35.85		-6.09
	net results	35.57	20.05	34.36		128.94
Acidification [kg SO2-e/1000 L[	Burdens	0.26	0.34	0.25		0.41
	Credits	-0.06	-0.06	-0.06		-0.10
	Net results	0.20	0.28	0.20		0.31
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.50	4.99	3.36		4.83
	Credits	-0.71	-0.71	-0.61		-1.16
	Net results	2.79	4.28	2.75		3.67
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.24	0.04		0.64
	Credits	-0.01	-0.01	-0.01		-0.20
	Net results	0.03	0.23	0.03		0.44
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	25.98	40.76	25.20		36.77
	Credits	-5.33	-5.33	-4.69		-8.23
	Net results	20.65	35.42	20.51		28.54
Aquatic Eutrophication [g PO4/1000 L]	Burdens	24.97	69.18	22.98		53.08
	Credits	-4.55	-4.55	-3.61		-11.76
	Net results	20.43	64.63	19.37		41.32
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	249.83	364.03	240.83		370.32
	Credits	-57.34	-57.36	-50.74		-89.12
	Net results	192.49	306.67	190.09		281.20
Total Primary Energy [GJ]	Burdens	2.37	2.35	2.18		3.96
	Credits	-0.77	-0.77	-0.65		-1.23
	Net results	1.60	1.58	1.53		2.73
Non-renewable Primary Energy [GJ]	Burdens	1.63	1.29	1.47		3.66
	Credits	-0.44	-0.44	-0.33		-1.16
	Net results	1.19	0.85	1.14		2.50
Use of Nature [m²*year]	Burdens	20.72	33.89	20.28		0.73
	Credits	-5.31	-5.31	-5.21		-0.03
	Net results	15.42	28.58	15.07		0.70
Water use [m³/1000 L]	water cool	1.42	1.45	1.32		3.15
	water process	2.06	2.05	1.95		0.19
	water unspecified	0.61	0.74	0.59		0.63

8.2.5 Description and interpretation

The increased collection quota of beverage cartons in Switzerland leads to a reduction of net results by 1%-25%. The lowest reductions (1%-7%) are seen in the category 'Ozone Depletion Potential'. The highest reductions are in the category 'Climate Change' (16%-25%), followed by 'Use of Nature' (14%-24%) and 'Total Primary Energy' (16%).

8.3 Results base scenarios *SD FAMILY PACK SWITZERLAND*

8.3.1 Presentation of results SD FAMILY PACK Switzerland, base collection quota of beverage cartons

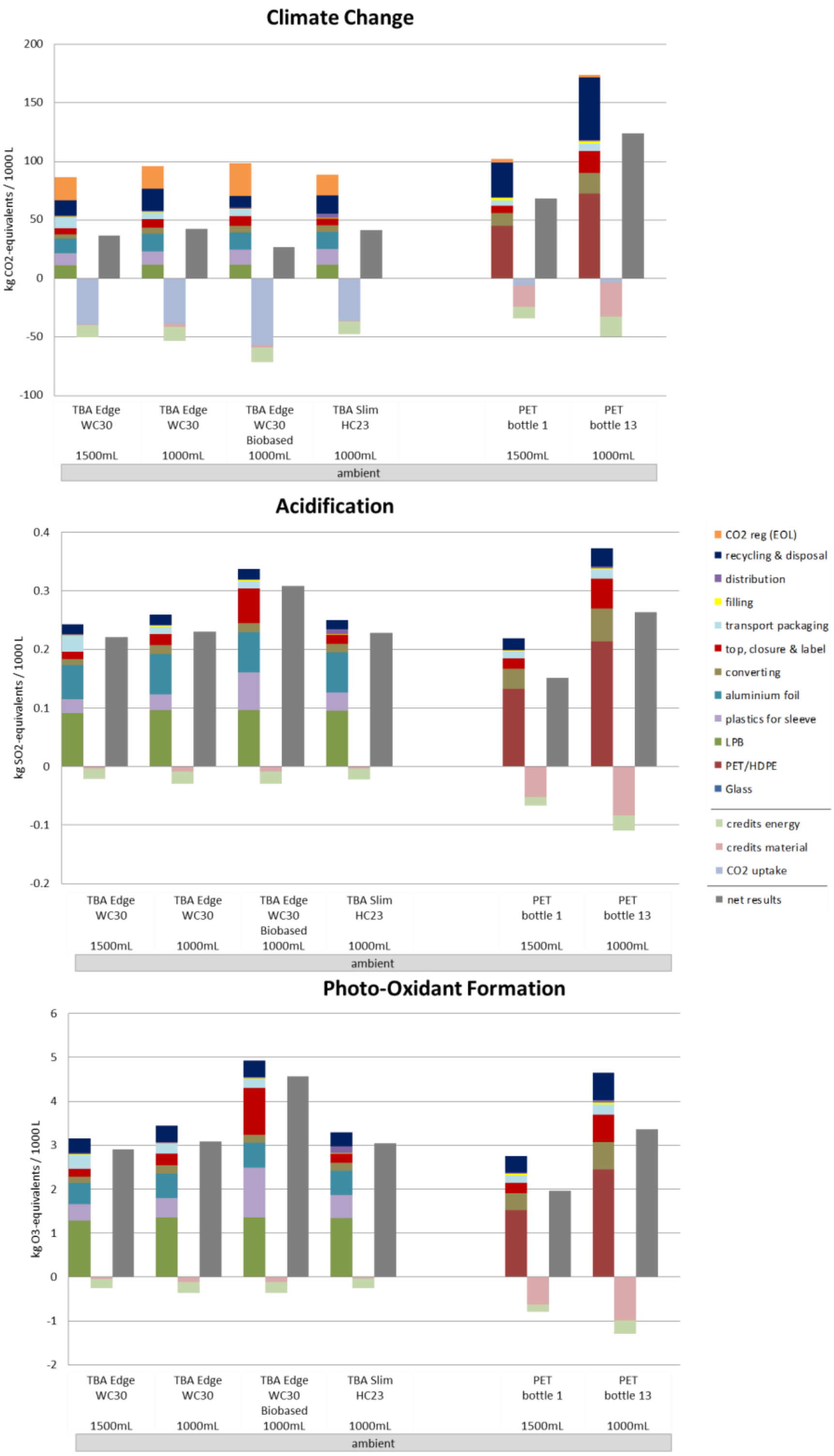


Figure 101: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)

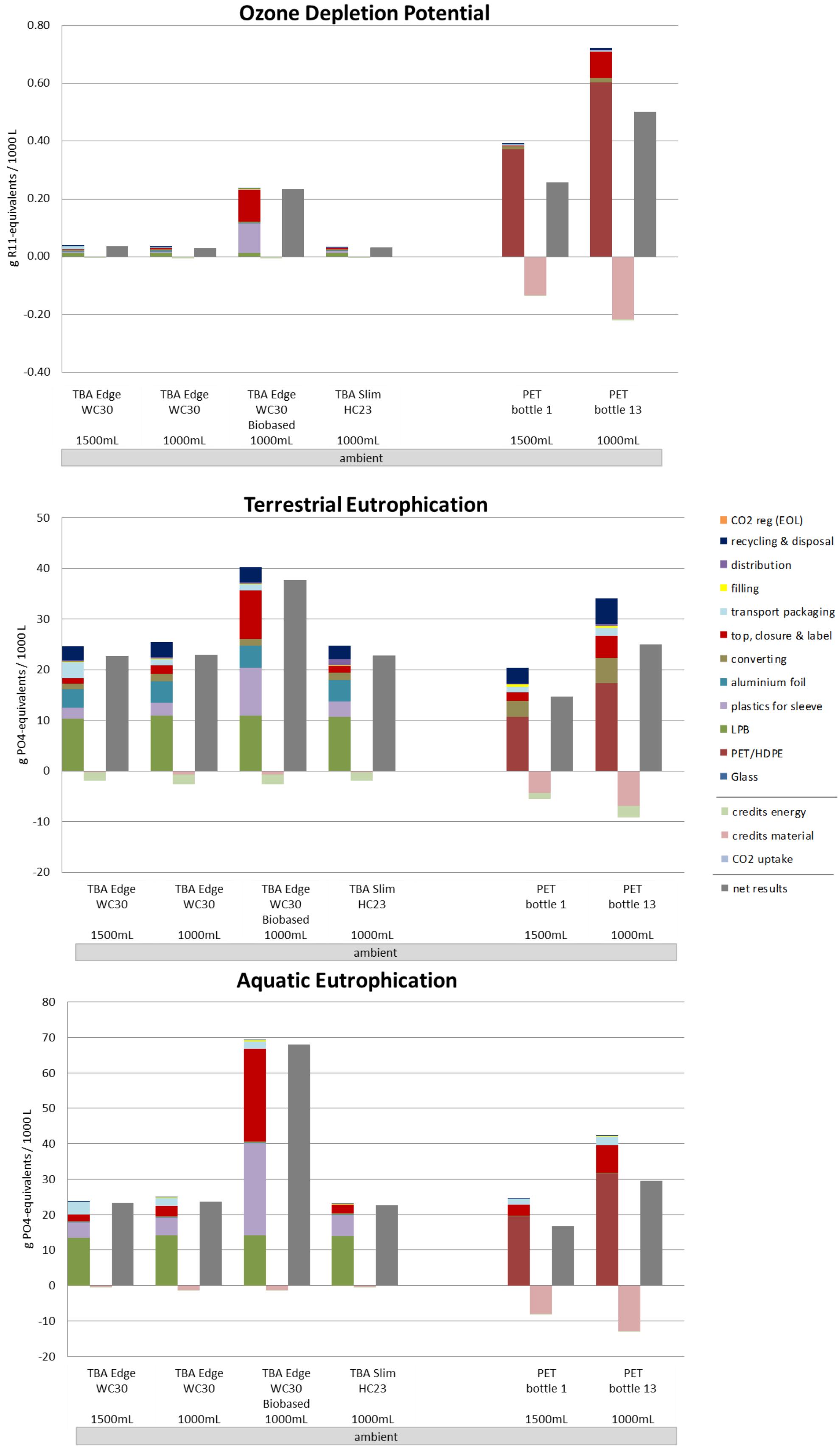


Figure 102: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 2)

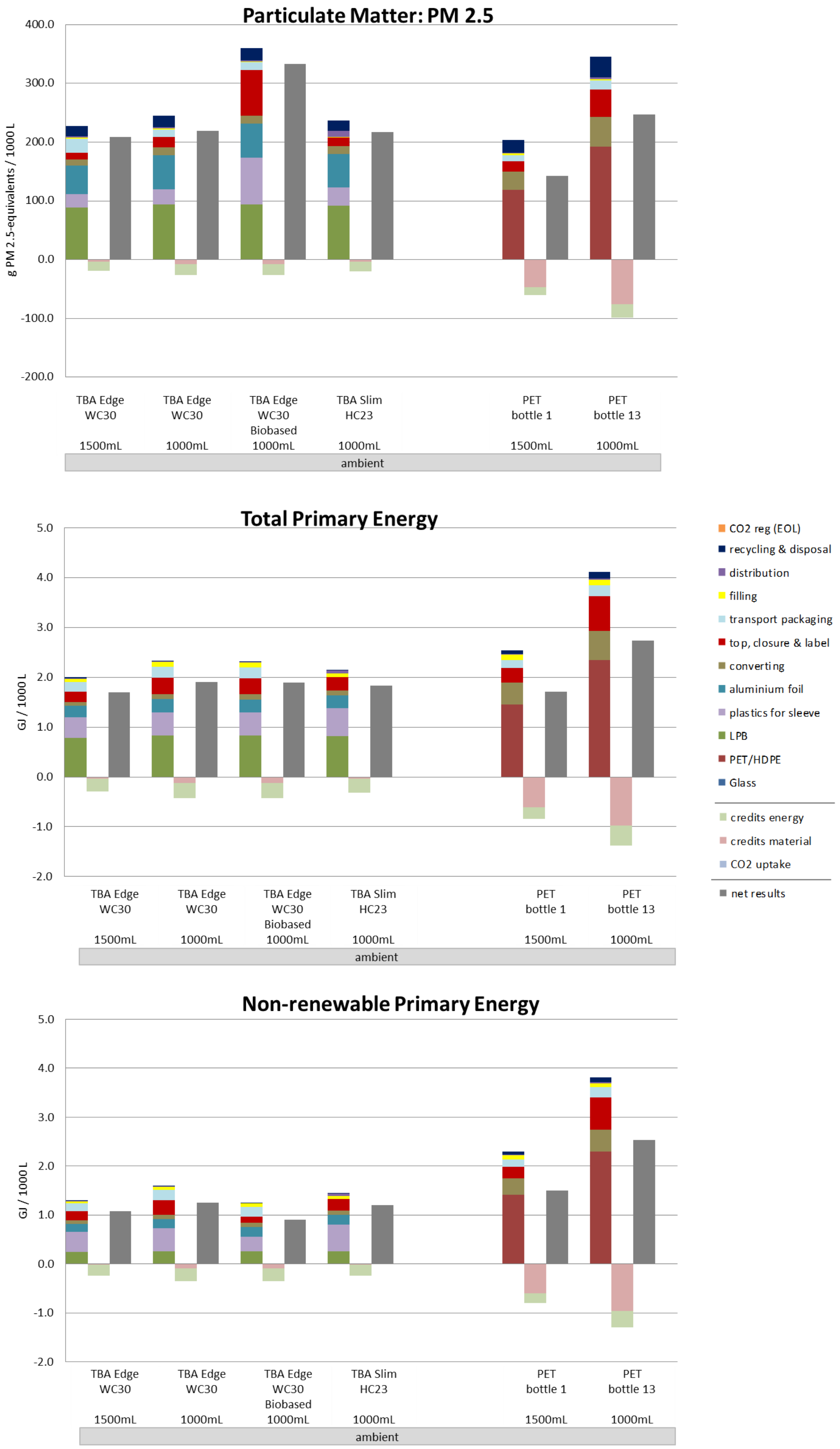
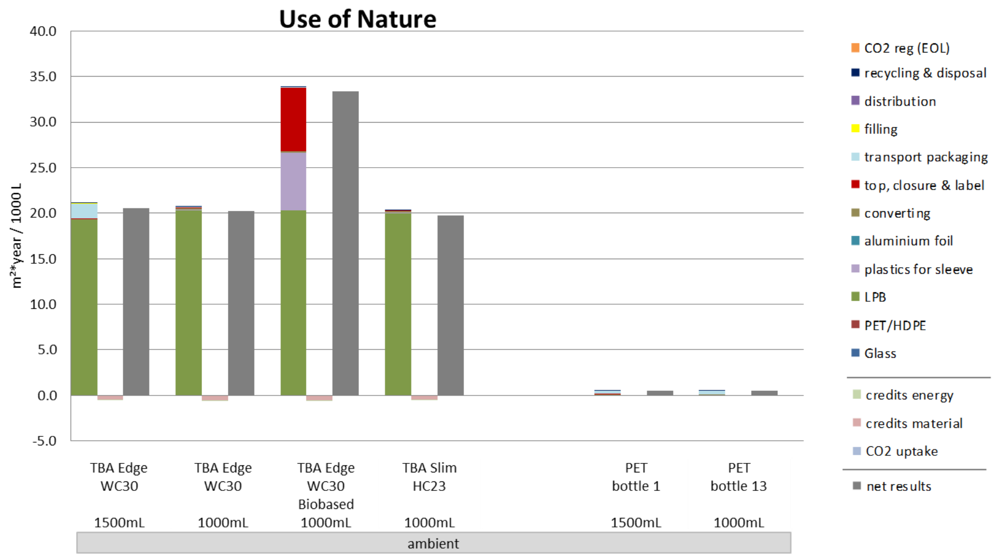


Figure 103: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 3)



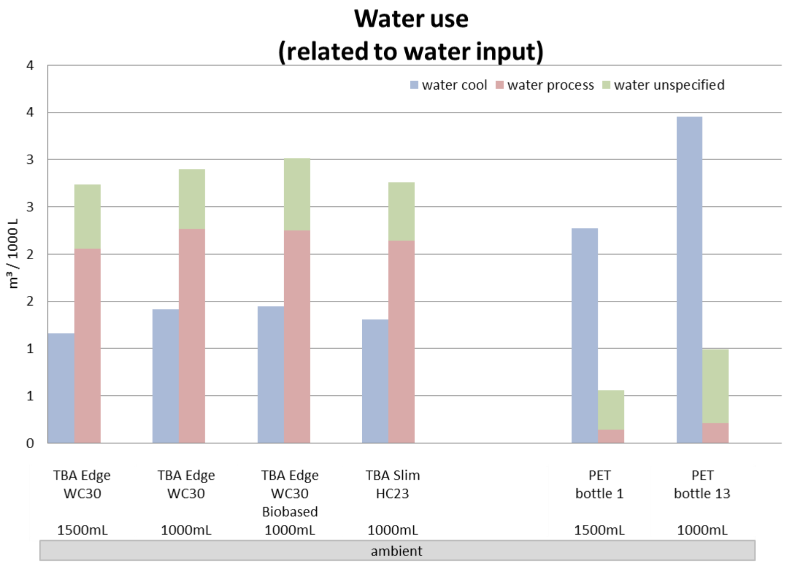


Figure 104: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 4)

Table 125: Category indicator results per impact category for base scenarios with **base collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL		PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	67.06	76.52	70.22	70.94		99.24	171.85
	CO2 (reg)	19.50	19.19	28.08	17.86		2.92	1.72
	Credits	-10.93	-14.82	-14.84	-11.60		-28.07	-46.10
	CO2 uptake	-39.13	-38.52	-56.60	-35.85		-5.84	-3.43
	net results	36.51	42.38	26.86	41.35		68.25	124.04
Acidification [kg SO2-e/1000 L[	Burdens	0.24	0.26	0.34	0.25		0.22	0.37
	Credits	-0.02	-0.03	-0.03	-0.02		-0.07	-0.11
	Net results	0.22	0.23	0.31	0.23		0.15	0.26
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.16	3.44	4.93	3.30		2.76	4.65
	Credits	-0.25	-0.36	-0.36	-0.26		-0.79	-1.29
	Net results	2.91	3.08	4.57	3.04		1.97	3.37
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.04	0.24	0.04		0.39	0.72
	Credits	0.00	0.00	0.00	0.00		-0.14	-0.22
	Net results	0.04	0.03	0.23	0.03		0.26	0.50
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	24.57	25.52	40.30	24.74		20.33	34.11
	Credits	-1.87	-2.61	-2.61	-1.96		-5.60	-9.15
	Net results	22.70	22.92	37.69	22.78		14.73	24.96
Aquatic Eutrophication [g PO4/1000 L]	Burdens	23.74	24.96	69.17	22.96		24.70	42.40
	Credits	-0.44	-1.29	-1.29	-0.39		-8.02	-12.86
	Net results	23.31	23.67	67.88	22.57		16.68	29.55
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	227.88	245.53	359.73	236.48		203.59	345.93
	Credits	-18.86	-26.42	-26.44	-19.83		-60.52	-98.88
	Net results	209.02	219.11	333.29	216.65		143.07	247.05
Total Primary Energy [GJ]	Burdens	2.00	2.33	2.32	2.14		2.54	4.11
	Credits	-0.30	-0.43	-0.43	-0.31		-0.84	-1.37
	Net results	1.70	1.90	1.89	1.83		1.70	2.74
Non-renewable Primary Energy [GJ]	Burdens	1.31	1.60	1.26	1.44		2.30	3.82
	Credits	-0.23	-0.35	-0.35	-0.24		-0.79	-1.29
	Net results	1.08	1.25	0.91	1.20		1.50	2.53
Use of Nature [m²*year]	Burdens	21.07	20.72	33.89	20.27		0.51	0.50
	Credits	-0.49	-0.54	-0.54	-0.50		-0.02	-0.03
	Net results	20.58	20.18	33.35	19.77		0.49	0.47
Water use [m³/1000 L]	water cool	1.16	1.42	1.45	1.31		2.27	3.46
	water process	2.06	2.26	2.25	2.15		0.14	0.21
	water unspecified	0.68	0.64	0.77	0.61		0.41	0.78

8.3.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the SD FAMILY PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories 'Aquatic Eutrophication' (20%-61%) and 'Use of Nature' (60%-99%). It is also relevant regarding 'Photo-Oxidant Formation' (28%-41%) 'Acidification' (29%-38%), 'Terrestrial Eutrophication' (27%-43%), 'Particulate Matter' (26%-39%) and also the consumption of 'Total Primary Energy' (36%-39%). Regarding 'Climate Change' the production of LPB contributes only to 12%-13%.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (20%-27%) and 'Particulate Matter' (16%-24%). These result from SO2 and NOx emissions from the aluminium production.

The production of 'plastics for sleeve' of the beverage cartons with fossil plastics shows considerable burdens in most impact categories (up to 42%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (12%-15%) and LPB (12%-13%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (24%-38%) contribute more than LPB (17%-21%) to the total burdens. If 'plastics for sleeve' contains bio-based plastics, this life cycle step plays a major role (18%-42%) for the overall burdens in all categories apart from 'Climate Change' (13%).

The life cycle step 'top, closure & label' for TBA and TR cartons contributes to a small amount in almost all impact categories (0%-18%). In case the plastics used for 'top, closure & label' are bio-based, the results are considerably higher than cartons with fossil based plastics in all categories except 'Climate Change', 'Total Primary Energy Demand' and 'Non-renewable Primary Energy'.

The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

The converting process generally plays a minor role (0%-12%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (up to 26%). If rollcontainers are used, this lifecycle step shows no impacts, as the production of rollcontainers is neglected due to their high reusability.

The life cycle step 'filling' shows only minor burdens for all beverage carton systems in all impact categories (max. 5%).

The life cycle step 'distribution' shows only minor burdens in all impact categories for all beverage carton systems with rollcontainers (max. 9%). In case of beverage cartons with trays this step contributes only up to 2% of the total burdens.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (38%-39%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are very low as in Switzerland only 2.4% of the beverage cartons are recycled. Material credits for 'Climate Change' are especially low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play a minor role on the net results in all categories.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the SD FAMILY PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of ‘Ozone Depletion Potential’ the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The ‘converting’ process shows for the plastic bottle in this segment a minor share of burdens (2%-20%) in all categories apart from ‘Aquatic Eutrophication’, for which the share of burdens is less than 1%. Emissions from ‘converting’ process almost exclusively derive from electricity production.

The life cycle step ‘top, closure & label’ shows minor impacts shares (1%-19%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of ‘transport packaging’ for the bottle system show minor impact shares (1%-7%) in most categories. The exception is ‘Use of Nature’ for which 73% of the burdens are caused from ‘transport packaging’ resulting from the used cardboard slip sheets.

The life cycle step ‘filling’ shows only small shares of burdens (max. 4%) for all bottle systems in all impact categories.

The life cycle step ‘distribution’ shows only small shares of burdens (max. 1%) for all bottle systems in all impact categories.

The impact of the plastic bottles’ ‘recycling & disposal’ life cycle step is most noticeable regarding ‘Climate Change’ (32%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 30% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Please note that the categories ‘Water Use’ and ‘Use of Nature’ will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

8.3.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems (with base collection quota) for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 126: Comparison of net results: **TBA Edge WC30 1500mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, allocation factor 50%

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1500mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	-14%	36%	-12%	-47%	-71%
Acidification	-4%	-28%	-3%	46%	-16%
Photo-Oxidant Formation	-6%	-36%	-4%	48%	-14%
Ozone Depletion Potential	17%	-84%	15%	-86%	-93%
Terrestrial Eutrophication	-1%	-40%	0%	54%	-9%
Aquatic Eutrophication	-2%	-66%	3%	40%	-21%
Particulate Matter	-5%	-37%	-4%	46%	-15%

Table 127: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, allocation factor 50%

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	16%	58%	2%	-38%	-66%
Acidification	4%	-25%	1%	52%	-12%
Photo-Oxidant Formation	6%	-33%	1%	56%	-8%
Ozone Depletion Potential	-14%	-87%	-2%	-88%	-94%
Terrestrial Eutrophication	1%	-39%	1%	56%	-8%
Aquatic Eutrophication	2%	-65%	5%	42%	-20%
Particulate Matter	5%	-34%	1%	53%	-11%

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

Table 128: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, allocation factor 50%

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	-26%	-37%	-35%	-61%	-78%
Acidification	39%	34%	35%	104%	17%
Photo-Oxidant Formation	57%	48%	50%	132%	36%
Ozone Depletion Potential	538%	644%	633%	-9%	-53%
Terrestrial Eutrophication	66%	64%	65%	156%	51%
Aquatic Eutrophication	191%	187%	201%	307%	130%
Particulate Matter	59%	52%	54%	133%	35%

Table 129: Comparison of net results: **TBA Slim HC30 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, allocation factor 50%

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Slim HC23 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	13%	-2%	54%	-39%	-67%
Acidification	3%	-1%	-26%	51%	-13%
Photo-Oxidant Formation	4%	-1%	-33%	54%	-10%
Ozone Depletion Potential	-13%	2%	-86%	-88%	-94%
Terrestrial Eutrophication	0%	-1%	-40%	55%	-9%
Aquatic Eutrophication	-3%	-5%	-67%	35%	-24%
Particulate Matter	4%	-1%	-35%	51%	-12%

8.3.4 Presentation of results SD FAMILY PACK Switzerland, target collection quota of beverage cartons

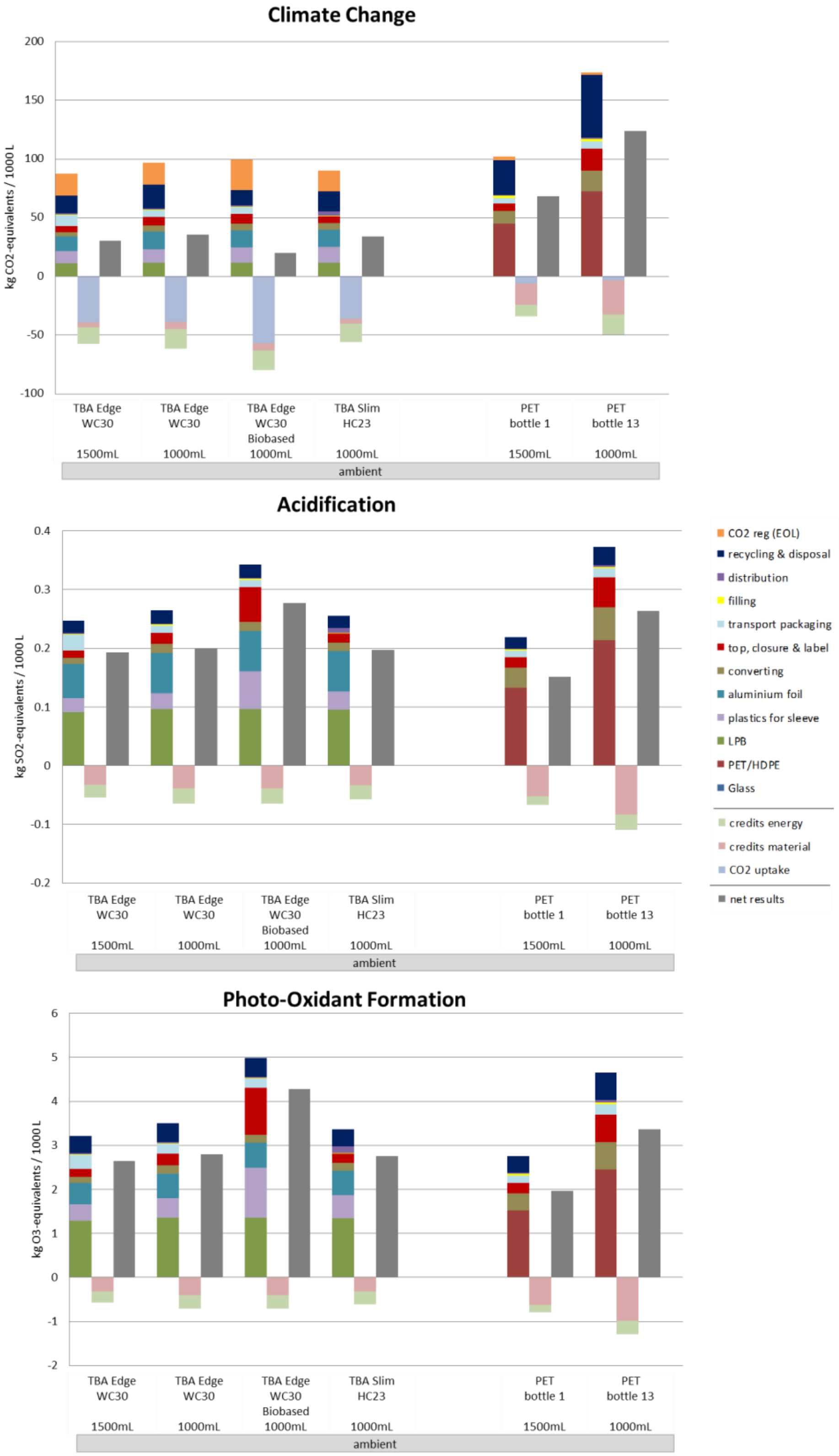
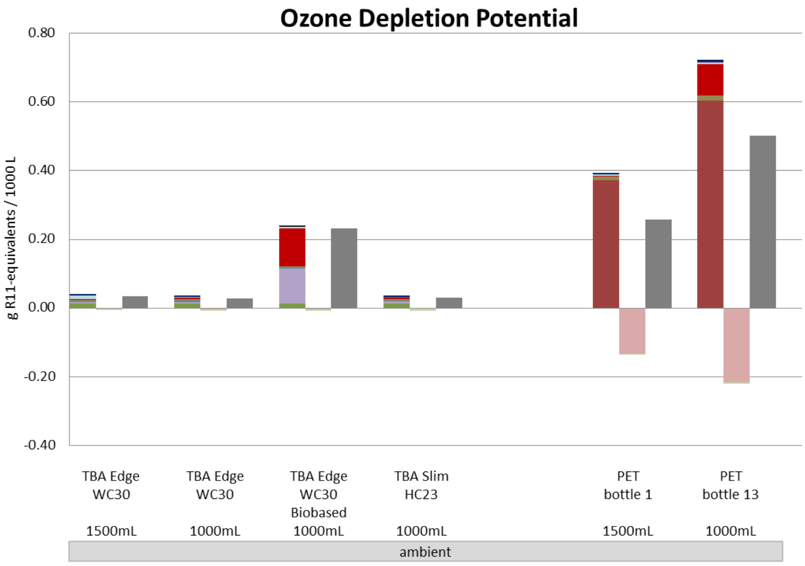
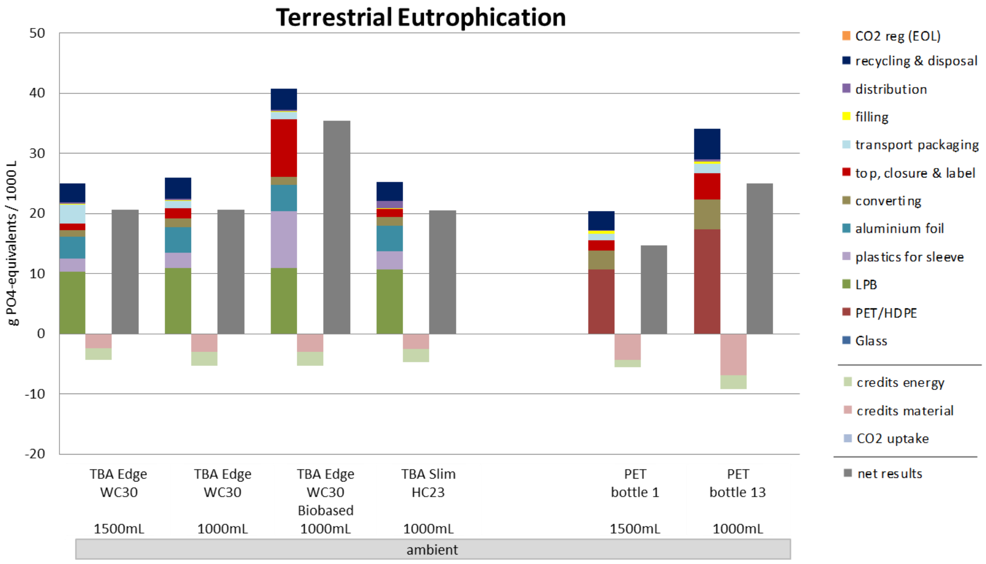


Figure 105: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)





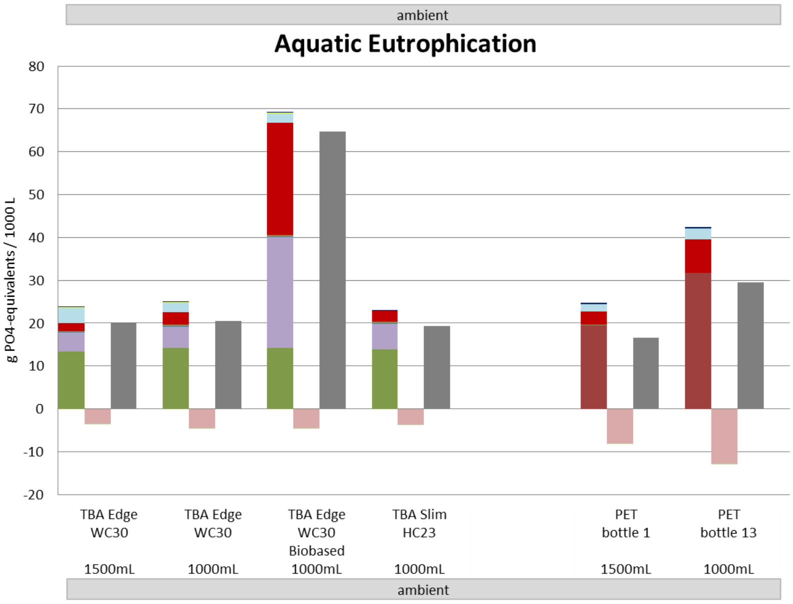


Figure 106: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 2)

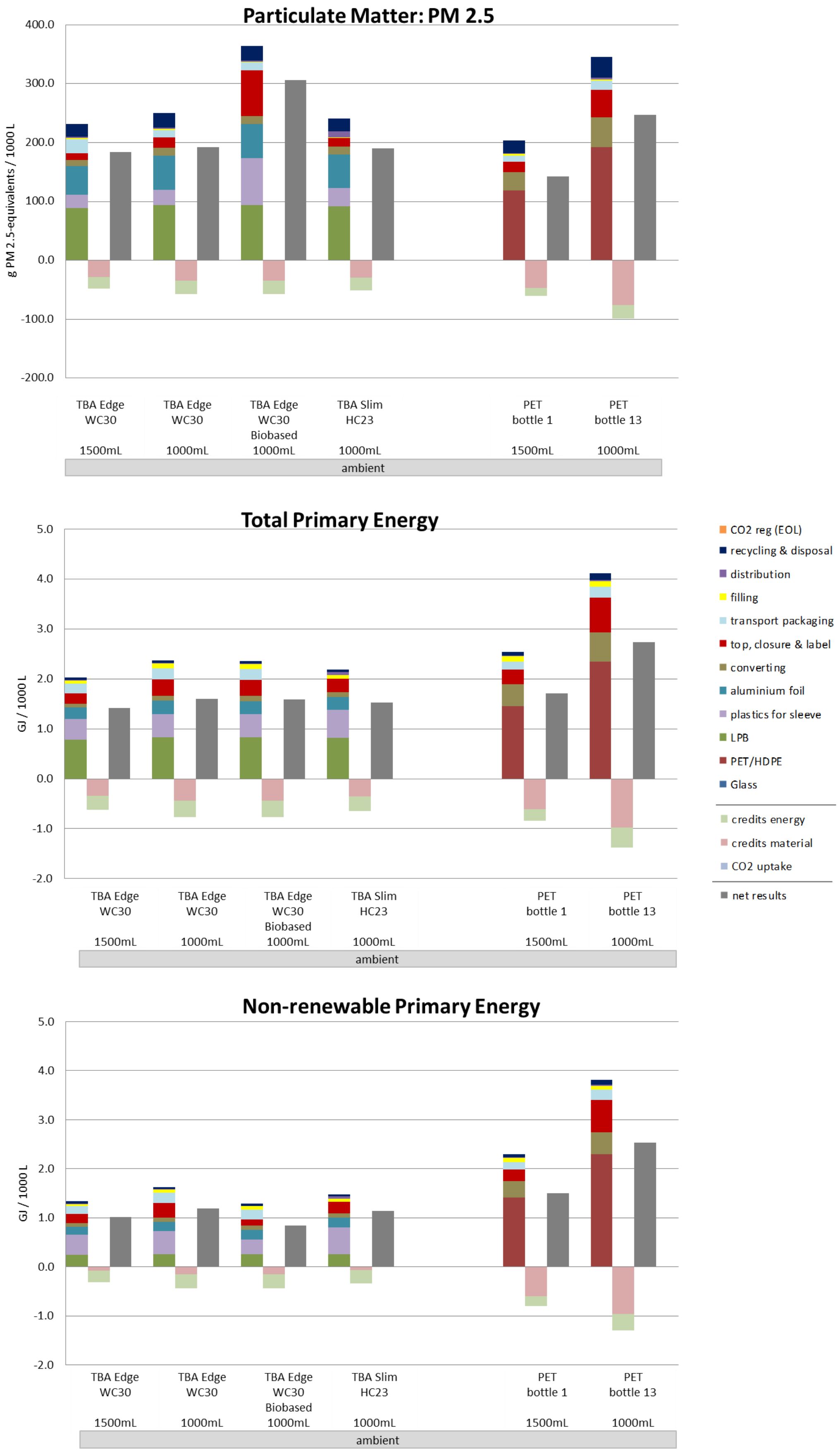
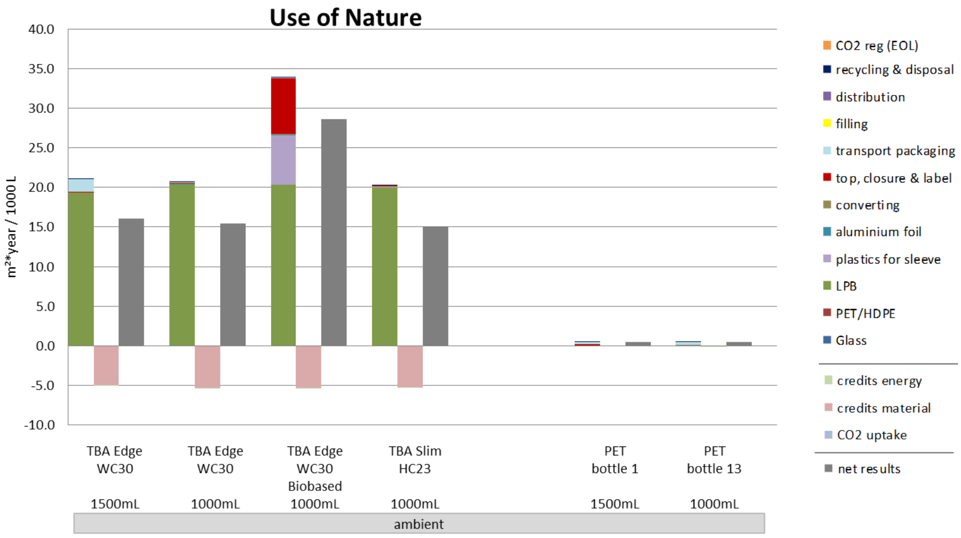


Figure 107: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 3)



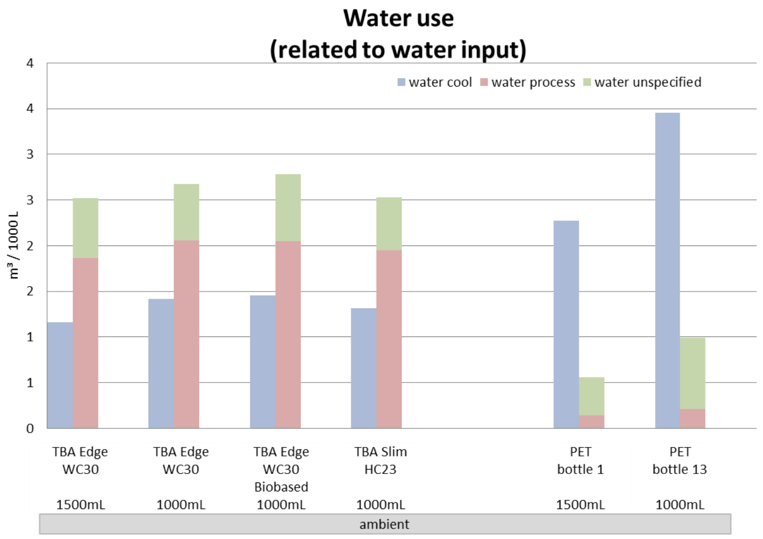


Figure 108: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 4)

Table 130: Category indicator results per impact category for base scenarios with **target collection quota of beverage cartons** of **segment SD FAMILY PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	68.66	78.30	73.35	72.77	99.24	171.85
	CO2 (reg)	18.97	18.63	26.16	17.30	2.92	1.72
	Credits	-18.08	-22.84	-22.86	-19.86	-28.07	-46.10
	CO2 uptake	-39.13	-38.52	-56.60	-35.85	-5.84	-3.43
	net results	30.42	35.57	20.05	34.36	68.25	124.04
Acidification [kg SO2-e/1000 L[	Burdens	0.25	0.26	0.34	0.25	0.22	0.37
	Credits	-0.05	-0.06	-0.06	-0.06	-0.07	-0.11
	Net results	0.19	0.20	0.28	0.20	0.15	0.26
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.21	3.50	4.99	3.36	2.76	4.65
	Credits	-0.57	-0.71	-0.71	-0.61	-0.79	-1.29
	Net results	2.64	2.79	4.28	2.75	1.97	3.37
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.04	0.24	0.04	0.39	0.72
	Credits	-0.01	-0.01	-0.01	-0.01	-0.14	-0.22
	Net results	0.03	0.03	0.23	0.03	0.26	0.50
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	24.99	25.98	40.76	25.20	20.33	34.11
	Credits	-4.38	-5.33	-5.33	-4.69	-5.60	-9.15
	Net results	20.61	20.65	35.42	20.51	14.73	24.96
Aquatic Eutrophication [g PO4/1000 L]	Burdens	23.76	24.97	69.18	22.98	24.70	42.40
	Credits	-3.53	-4.55	-4.55	-3.61	-8.02	-12.86
	Net results	20.23	20.43	64.63	19.37	16.68	29.55
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	231.78	249.83	364.03	240.83	203.59	345.93
	Credits	-47.33	-57.34	-57.36	-50.74	-60.52	-98.88
	Net results	184.45	192.49	306.67	190.09	143.07	247.05
Total Primary Energy [GJ]	Burdens	2.03	2.37	2.35	2.18	2.54	4.11
	Credits	-0.62	-0.77	-0.77	-0.65	-0.84	-1.37
	Net results	1.41	1.60	1.58	1.53	1.70	2.74
Non-renewable Primary Energy [GJ]	Burdens	1.34	1.63	1.29	1.47	2.30	3.82
	Credits	-0.31	-0.44	-0.44	-0.33	-0.79	-1.29
	Net results	1.02	1.19	0.85	1.14	1.50	2.53
Use of Nature [m²*year]	Burdens	21.07	20.72	33.89	20.28	0.51	0.50
	Credits	-5.01	-5.31	-5.31	-5.21	-0.02	-0.03
	Net results	16.06	15.42	28.58	15.07	0.49	0.47
Water use [m³/1000 L]	water cool	1.16	1.42	1.45	1.32	2.27	3.46
	water process	1.87	2.06	2.05	1.95	0.14	0.21
	water unspecified	0.66	0.61	0.74	0.59	0.41	0.78

8.3.5 Description and interpretation

The increased collection quota of beverage cartons in Switzerland leads to a reduction of net results by 1%-35%. The lowest reductions (1%-7%) are seen in the category 'Ozone Depletion Potential'. The highest reductions are in the category 'Climate Change' (16%-25%), followed by 'Use of Nature' (14%-24%) and 'Total Primary Energy' (16%-17%).

8.4 Results base scenarios DAIRY PORTION PACK SWITZERLAND

8.4.1 Presentation of results DAIRY PORTION PACK Switzerland, base collection quota of beverage cartons

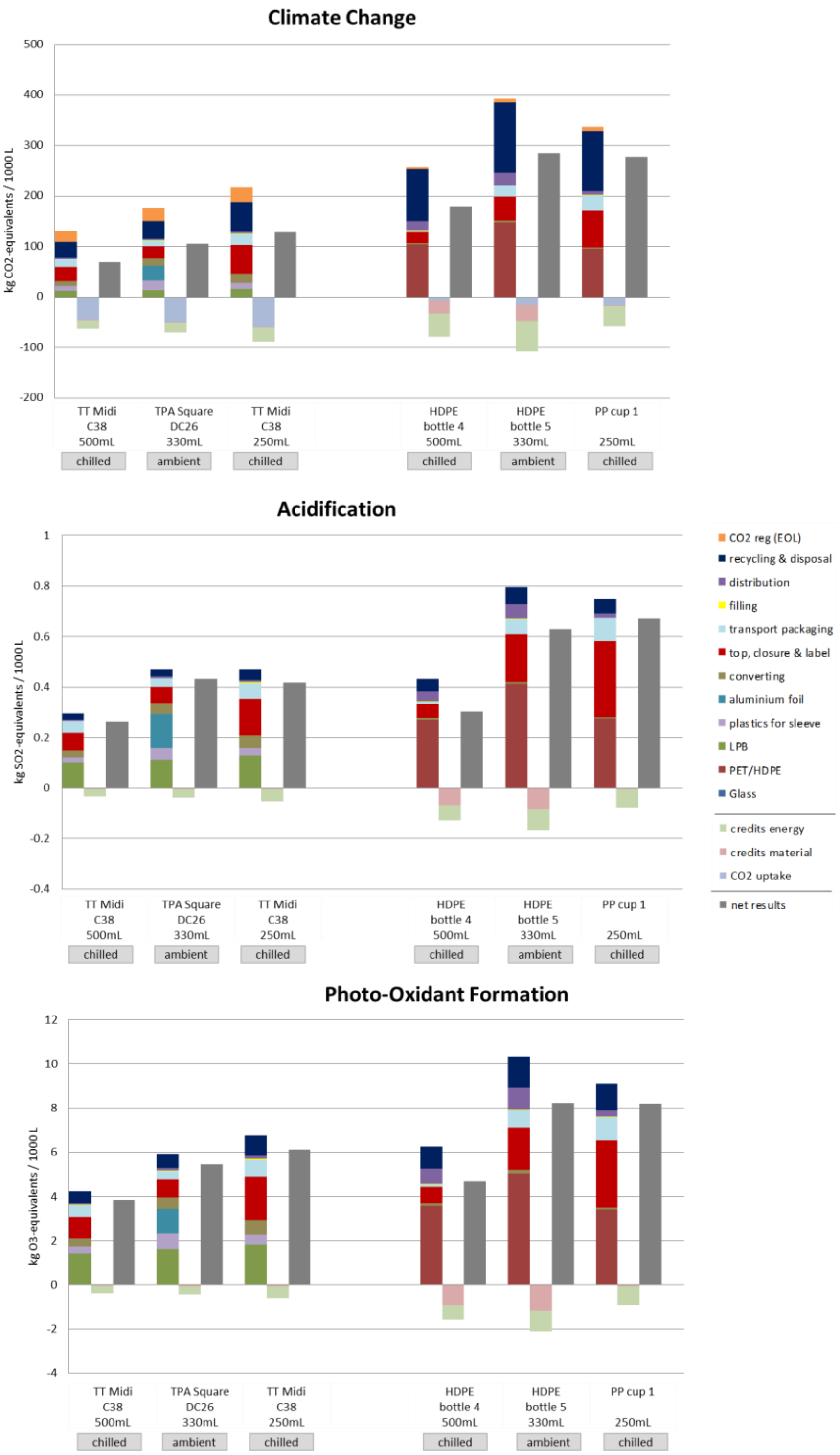


Figure 109: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 1)

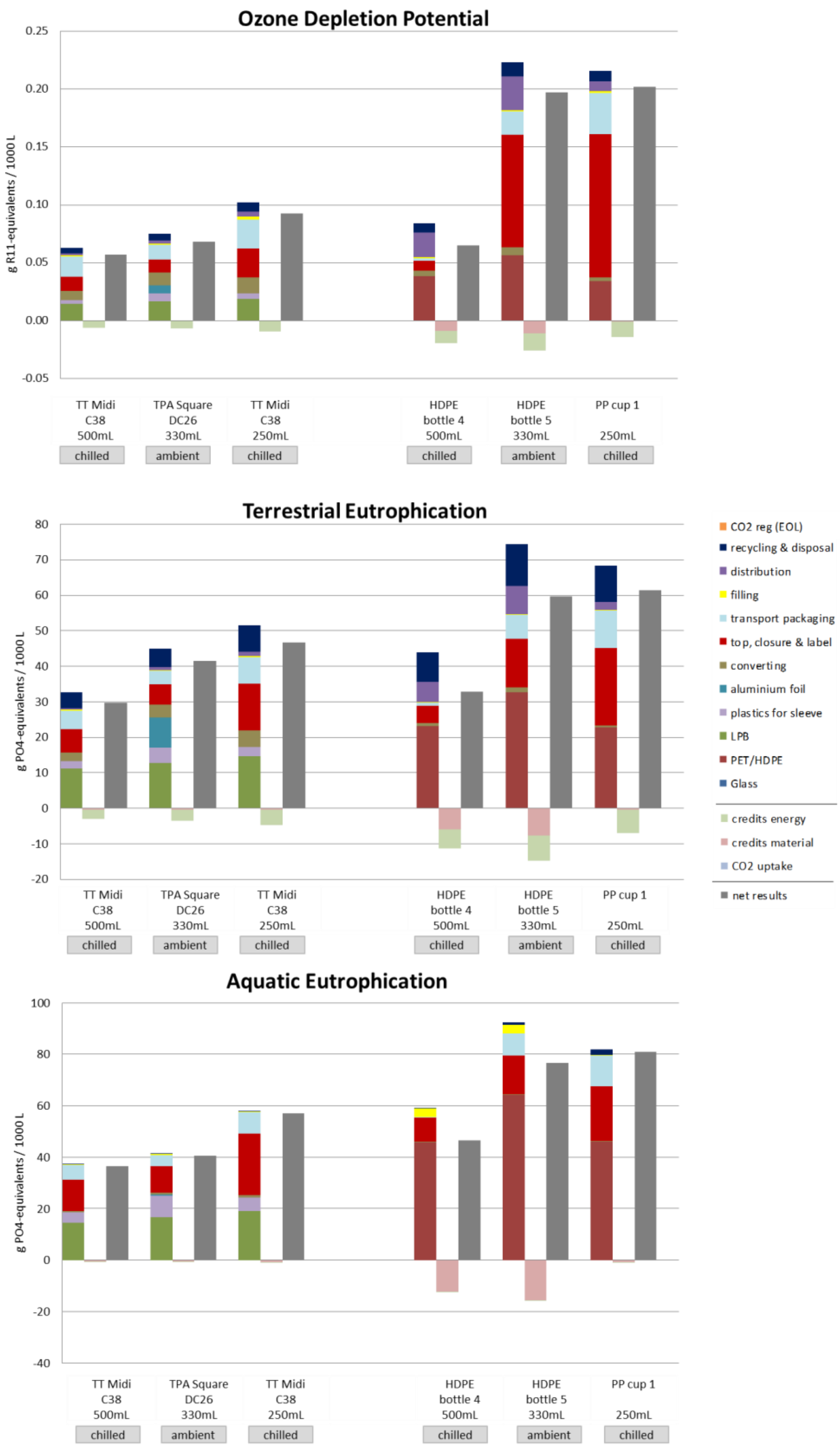


Figure 110 Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 2)

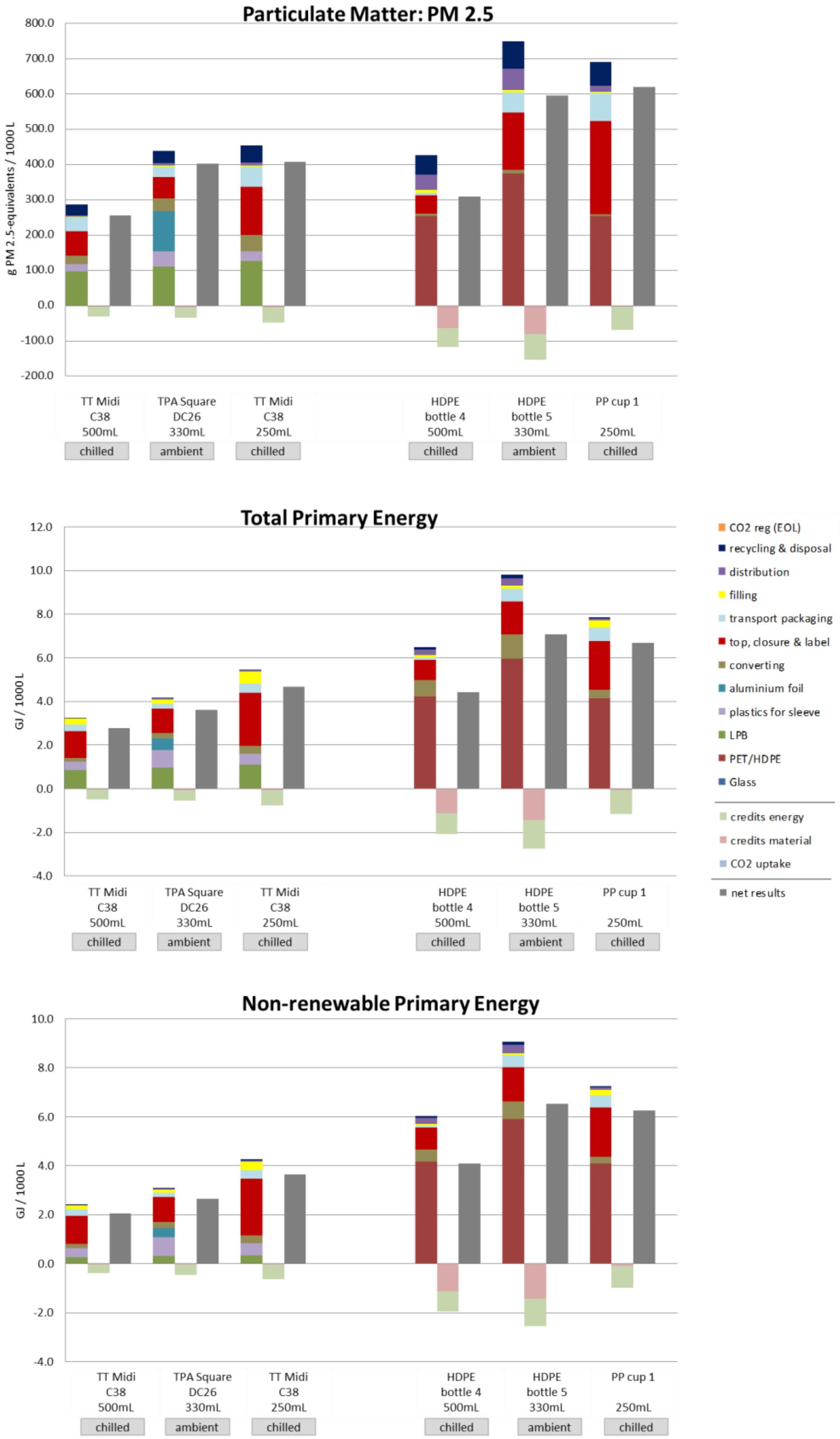
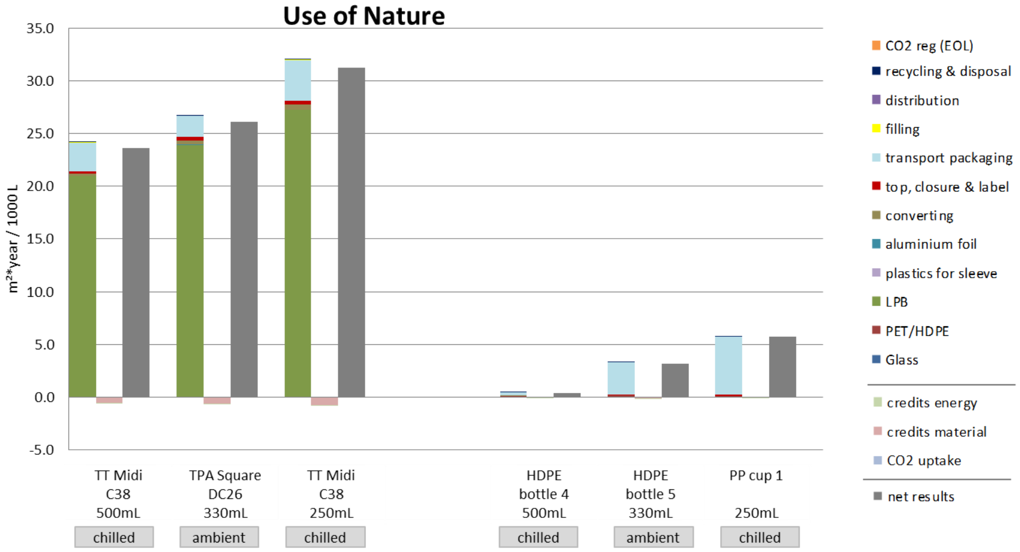


Figure 111: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 3)



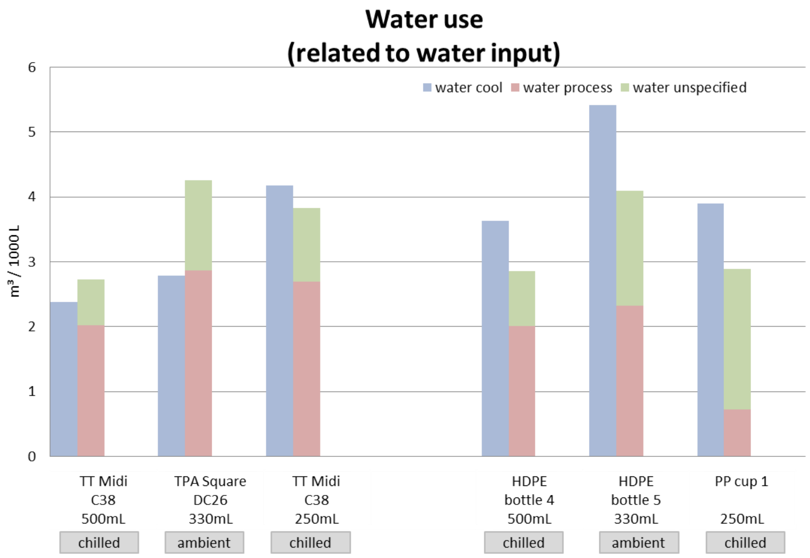


Figure 112: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 4)

Table 131: Category indicator results per impact category for base scenarios with **base collection quota of beverage cartons** of segment DAIRY PORTION PACK, Switzerland- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TT Midi C38 500mL	TPA Square DC26 330mL	TT Midi C38 250mL		HDPE bottle 4 500mL	HDPE bottle 5 330mL	PP cup 1 250mL
Climate Change [kg CO2-e/1000 L[	Burdens	109.43	151.02	187.78		254.04	385.65	328.39
	CO2 (reg)	22.30	24.64	29.29		3.60	7.57	8.33
	Credits	-18.21	-20.62	-29.21		-70.78	-92.56	-41.78
	CO2 uptake	-44.73	-49.43	-58.76		-7.20	-15.14	-16.66
	net results	68.78	105.61	129.10		179.66	285.52	278.29
Acidification [kg SO2-e/1000 L[	Burdens	0.30	0.47	0.47		0.43	0.79	0.75
	Credits	-0.03	-0.04	-0.05		-0.13	-0.17	-0.08
	Net results	0.26	0.43	0.42		0.30	0.63	0.67
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	4.24	5.92	6.74		6.27	10.32	9.12
	Credits	-0.40	-0.45	-0.63		-1.59	-2.10	-0.91
	Net results	3.84	5.46	6.12		4.67	8.23	8.21
Ozone Depletion [g R11/1000 L]	Burdens	0.06	0.07	0.10		0.08	0.22	0.22
	Credits	-0.01	-0.01	-0.01		-0.02	-0.03	-0.01
	Net results	0.06	0.07	0.09		0.06	0.20	0.20
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	32.75	44.92	51.53		44.00	74.34	68.39
	Credits	-3.00	-3.44	-4.75		-11.23	-14.75	-6.91
	Net results	29.75	41.48	46.77		32.77	59.60	61.48
Aquatic Eutrophication [g PO4/1000 L]	Burdens	37.16	41.16	57.79		58.84	92.38	81.80
	Credits	-0.56	-0.64	-0.78		-12.40	-15.77	-0.84
	Net results	36.59	40.51	57.01		46.43	76.61	80.97
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	285.73	437.46	454.57		426.29	749.34	689.55
	Credits	-30.13	-34.73	-47.73		-117.38	-154.07	-69.36
	Net results	255.60	402.73	406.85		308.92	595.27	620.19
Total Primary Energy [GJ]	Burdens	3.26	4.16	5.45		6.50	9.80	7.85
	Credits	-0.49	-0.55	-0.77		-2.09	-2.74	-1.16
	Net results	2.77	3.61	4.68		4.41	7.06	6.69
Non-renewable Primary Energy [GJ]	Burdens	2.44	3.10	4.26		6.04	9.06	7.24
	Credits	-0.39	-0.44	-0.63		-1.94	-2.53	-0.98
	Net results	2.05	2.66	3.64		4.10	6.53	6.26
Use of Nature [m²*year]	Burdens	24.16	26.70	32.02		0.50	3.30	5.76
	Credits	-0.57	-0.60	-0.75		-0.08	-0.10	-0.05
	Net results	23.59	26.10	31.27		0.42	3.20	5.72
Water use [m³/1000 L]	water cool	2.38	2.78	4.18		3.64	5.42	3.90
	water process	2.02	2.86	2.69		2.00	2.32	0.72
	water unspecified	0.71	1.39	1.13		0.85	1.78	2.17

8.4.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the DAIRY PORTION PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories ‘Aquatic Eutrophication’ (33%-40%) and ‘Use of Nature’ (85%-89%). It is also relevant regarding ‘Photo-Oxidant Formation’ (27%-33%) ‘Acidification’ (24%-34%), ‘Terrestrial Eutrophication’ (28%-34%), ‘Particulate Matter’ (25%-34%) and also the consumption of ‘Total Primary Energy’ (20%-26%). Regarding ‘Climate Change’ the production of LPB is responsible for only 7%-9% of the burdens.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of the ambient beverage carton shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (29%) and 'Particulate Matter' (26%). These result from SO2 and NOx emissions from the aluminium production. No shares of burdens are seen for chilled beverage cartons, as these don't have an aluminium layer.

The production of 'plastics for sleeve' of the beverage cartons shows considerable burdens in most impact categories (up to 25%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (6%-11%) and LPB (7%-9%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (11%-25%) contribute more than LPB (8%-11%) to the total burdens.

The life cycle step 'top, closure & label' for TPA carton contributes to a considerable amount in almost all impact categories (1%-33%). In case of the TT cartons this life cycle step contributes to a substantial share in almost all impact categories (1%-54%).

The converting process generally plays a minor role (1%-15%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (8%-28%).

The life cycle step ‘filling’ shows only minor shares of burdens (up to 5%) for the TPA beverage carton system in all impact categories In case of TT beverage carton systems the shares are higher (up to 10%) due to the additional moulding process of the top.

The life cycle step ‘distribution’ shows only very minor burdens in all impact categories for all beverage carton systems (4%).

The life cycle step ‘recycling & disposal’ of the regarded beverage cartons is most relevant in the impact category ‘Climate Change’. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

‘CO2 reg. (recycling & disposal)’ describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of paper. They play an important role for the results of all beverage carton systems in the impact category ‘Climate Change’. Together with the fossil-based CO2 emissions of the life cycle step ‘recycling & disposal’, they represent the total CO2 emissions from the packaging’s end-of-life (34%-41%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are very low as in Switzerland only 2.4% of the beverage cartons are recycled. Material credits for ‘Climate Change’ are especially low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play a minor role on the net results in all categories.

The uptake of CO2 by trees harvested for the production of paperboard 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. 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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle systems in the DAIRY FAMILY PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories.

The ‘converting’ process shows for the plastic bottles in this segment a minor share of burdens (1%-11%) in all categories apart from ‘Aquatic Eutrophication’, for which the share of burdens is less than 1%. Emissions from ‘converting’ process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' for the HDPE bottle 4 shows minor impacts shares (6%-16%) in most categories mainly attributed to the different plastics used for the closures. The share of burden in this step for the HDPE bottle 5 are substantial (2%-44%) resulting from the aluminium pull tab.

The production and provision of 'transport packaging' for the HDPE 5 system show minor impact shares (6%-9%) in most categories. The exception is 'Use of Nature' for which 91% of the burdens are caused from 'transport packaging' resulting from the used cardboard and wood for pallets. Due to the reusable secondary packaging of the HDPE bottle 4 its share of burden for this step is very low (0%-3%). The exception is 'Use of Nature' for which 62% of the burdens are caused from 'transport packaging' resulting from the used wood for pallets.

The life cycle step 'filling' shows only small shares of burdens (max. 6%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows considerable burdens in most impact categories (3%-25%) resulting from the secondary packaging configuration leading to a relatively small amount of bottles on a pallet.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (37%-41%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is very low in most categories. The exception is 'Climate Change', where the credits reduce the overall burdens by around 10%-30%. The energy credits mainly originate from the incineration plants and cement kilns.

PP cup (specifications see section 2.2.2)

In the regarded PP cup system in the DAIRY PORTION PACK segment, the major shares of the environmental burdens are caused by the production of the base materials of the cups (2%-56%), the life cycle step 'top, closure & label' (2%-57%) and 'Transport Packaging' (7%-96%).

The 'converting' process of the regarded PP Cup shows a small share of impacts (max 5%) in all categories apart from 'Aquatic Eutrophication' with less than 1% share of burdens. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows high impacts (2%-57%) in most categories attributed to the used plastics in cap and label as well as to the aluminium used for the pull taps.

The production and provision of 'transport packaging' for the PP cups shows high shares of impacts (7%-96%) in all categories. The relevant emissions derive from the production of paper for trays and slip sheets.

The life cycle step 'filling' shows only minor shares of burdens (max. 4%) for the PP cup in all categories.

The life cycle step ‘distribution’ shows minor shares of burdens (max. 4%) in all impact categories.

The impact of the PP Cup’s ‘recycling & disposal’ life cycle step is most noticeable regarding ‘Climate Change’ (38%). The incineration of cups in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is minor in most categories. Energy credits reduce the overall burdens by 0%-14% in most categories. The energy credits mainly originate from the incineration plants. As PP cups are not materially recycled in Switzerland, material credits are very low, resulting only from the recycling of secondary and tertiary packaging.

Please note that the categories ‘Water Use’ and ‘Use of Nature’ will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

8.4.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems (with base collection quota) for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 132: Comparison of net results: **TT Midi C38 500mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (chilled), Switzerland**, allocation factor 50%

DAIRY PORTION PACK (chilled), Switzerland	The net results of **TT Midi C38 500mL** are lower (green)/ higher (orange) than those of		
	TT Midi C38 250mL	HDPE bottle 4 500mL	PP cup 1 250mL
Climate Change	-47%	-62%	-75%
Acidification	-37%	-14%	-61%
Photo-Oxidant Formation	-37%	-18%	-53%
Ozone Depletion Potential	-38%	-12%	-72%
Terrestrial Eutrophication	-36%	-9%	-52%
Aquatic Eutrophication	-36%	-21%	-55%
Particulate Matter	-37%	-17%	-59%

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

Table 133: Comparison of net results: **TT Midi C38 250mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (chilled), Switzerland**, allocation factor 50%

DAIRY PORTION PACK (chilled), Switzerland	The net results of **TT Midi C38 250mL** are lower (green)/ higher (orange) than those of		
	TT Midi C38 500mL	HDPE bottle 4 500mL	PP cup 1 250mL
Climate Change	88%	-28%	-54%
Acidification	59%	37%	-38%
Photo-Oxidant Formation	59%	31%	-25%
Ozone Depletion Potential	62%	43%	-54%
Terrestrial Eutrophication	57%	43%	-24%
Aquatic Eutrophication	56%	23%	-30%
Particulate Matter	59%	32%	-34%

Table 134: Comparison of net results: **TPA Square DC26 330mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (ambient), Switzerland**, allocation factor 50%

DAIRY PORTION PACK (ambient), Switzerland	The net results of **TPA Square DC26 330mL** are lower (green)/ higher (orange) than those of
	HDPE bottle 5 330mL
Climate Change	-63%
Acidification	-31%
Photo-Oxidant Formation	-34%
Ozone Depletion Potential	-65%
Terrestrial Eutrophication	-30%
Aquatic Eutrophication	-47%
Particulate Matter	-32%

8.4.4 Presentation of results DAIRY PORTION PACK Switzerland, target collection quota of beverage cartons

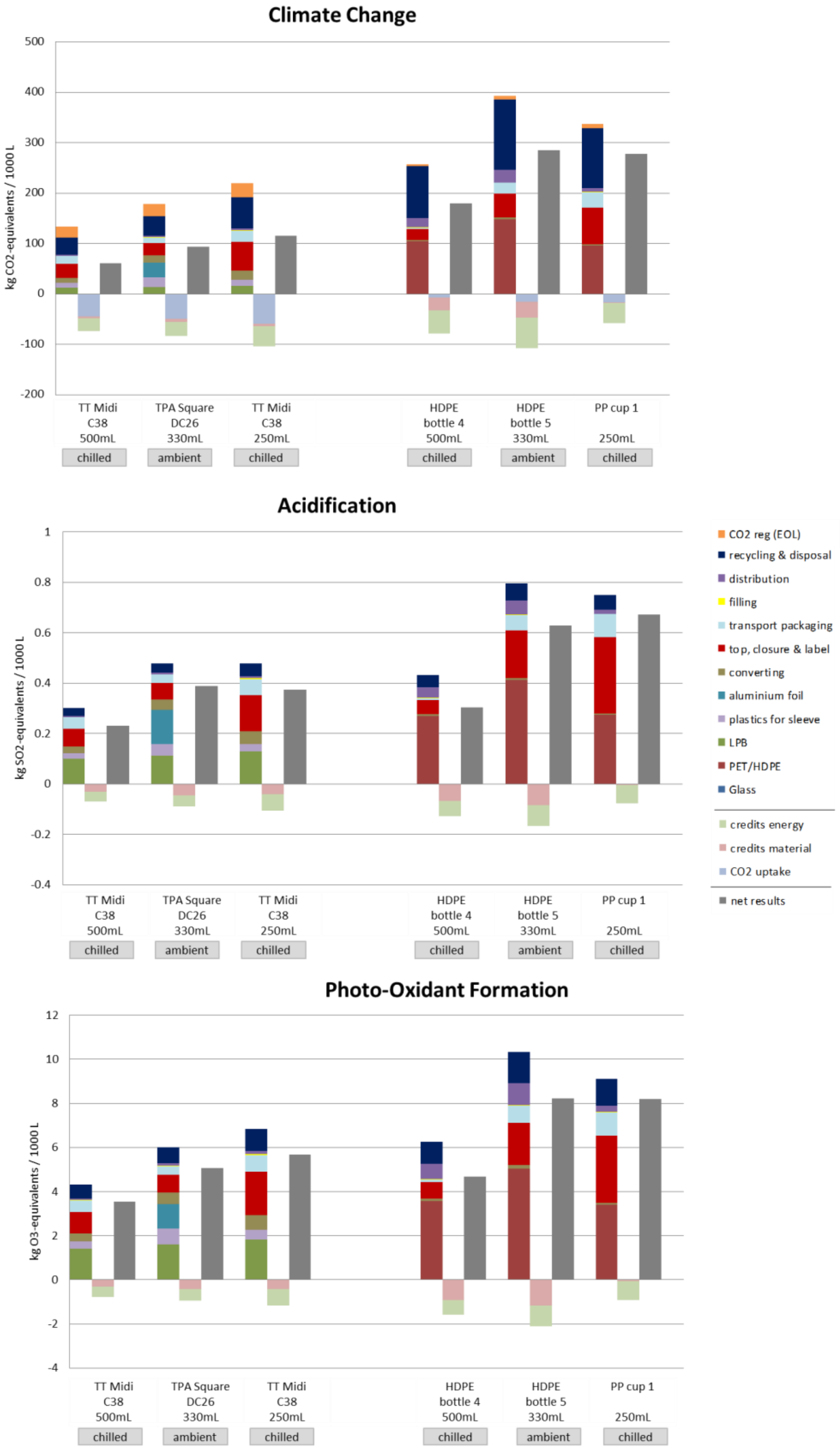


Figure 113: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 1)

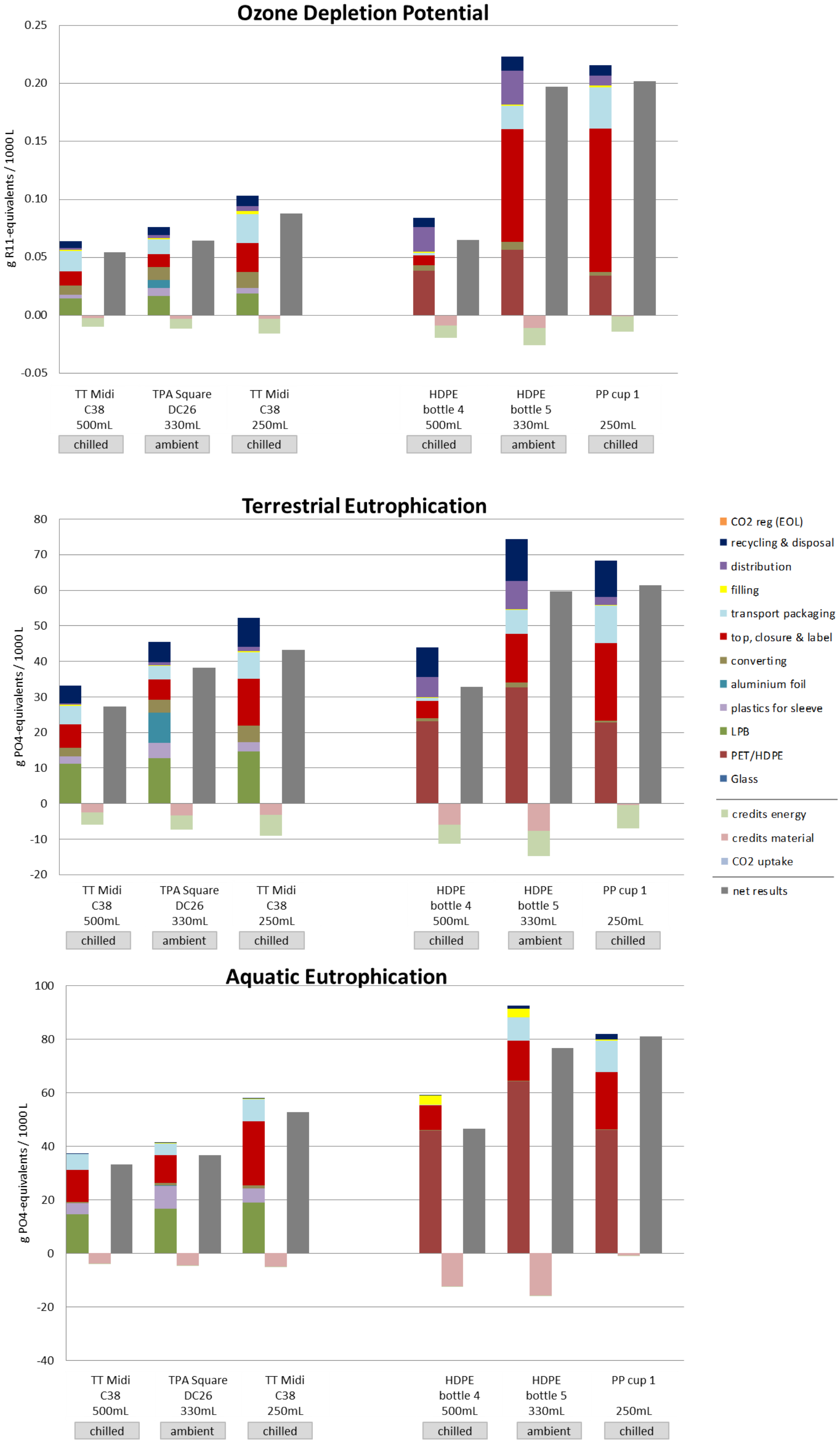
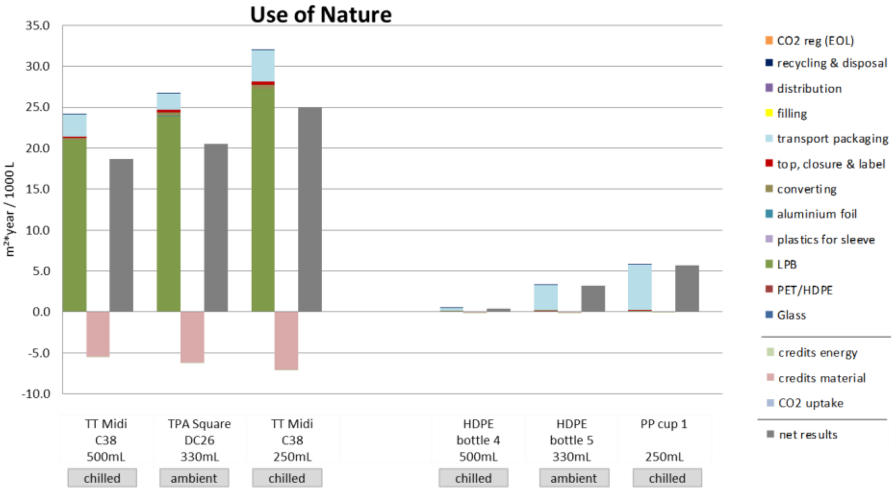


Figure 114 Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 2)

Figure 115: Indicator results for base scenarios of segment DAIRY PORTION PACK, Switzerland, allocation factor 50% (Part 3)



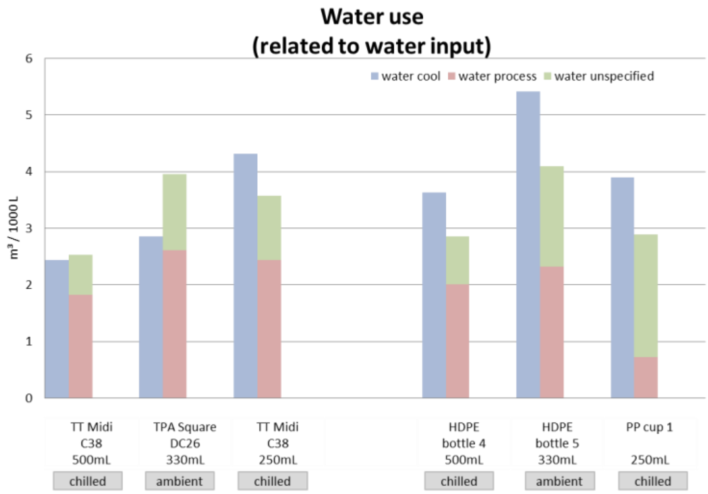


Figure 116: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 4)

Table 135: Category indicator results per impact category for base scenarios with **target collection quota of beverage cartons** of **segment DAIRY PORTION PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TT Midi C38 500mL	TPA Square DC26 330mL	TT Midi C38 250mL		HDPE bottle 4 500mL	HDPE bottle 5 330mL	PP cup 1 250mL
Climate Change [kg CO2-e/1000 L[	Burdens	111.68	153.96	191.34		254.04	385.65	328.39
	CO2 (reg)	21.72	23.99	28.56		3.60	7.57	8.33
	Credits	-28.36	-34.46	-45.63		-70.78	-92.56	-41.78
	CO2 uptake	-44.73	-49.43	-58.76		-7.20	-15.14	-16.66
	net results	60.31	94.06	115.50		179.66	285.52	278.29
Acidification [kg SO2-e/1000 L[	Burdens	0.30	0.48	0.48		0.43	0.79	0.75
	Credits	-0.07	-0.09	-0.11		-0.13	-0.17	-0.08
	Net results	0.23	0.39	0.37		0.30	0.63	0.67
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	4.30	6.01	6.84		6.27	10.32	9.12
	Credits	-0.77	-0.95	-1.17		-1.59	-2.10	-0.91
	Net results	3.53	5.05	5.67		4.67	8.23	8.21
Ozone Depletion [g R11/1000 L]	Burdens	0.06	0.08	0.10		0.08	0.22	0.22
	Credits	-0.01	-0.01	-0.02		-0.02	-0.03	-0.01
	Net results	0.05	0.06	0.09		0.06	0.20	0.20
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	33.22	45.56	52.19		44.00	74.34	68.39
	Credits	-5.92	-7.31	-8.97		-11.23	-14.75	-6.91
	Net results	27.30	38.25	43.22		32.77	59.60	61.48
Aquatic Eutrophication [g PO4/1000 L]	Burdens	37.17	41.18	57.81		58.84	92.38	81.80
	Credits	-3.90	-4.49	-5.12		-12.40	-15.77	-0.84
	Net results	33.27	36.68	52.69		46.43	76.61	80.97
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	290.68	444.00	462.06		426.29	749.34	689.55
	Credits	-62.03	-78.50	-93.31		-117.38	-154.07	-69.36
	Net results	228.65	365.50	368.75		308.92	595.27	620.19
Total Primary Energy [GJ]	Burdens	3.30	4.22	5.52		6.50	9.80	7.85
	Credits	-0.83	-0.99	-1.24		-2.09	-2.74	-1.16
	Net results	2.47	3.23	4.28		4.41	7.06	6.69
Non-renewable Primary Energy [GJ]	Burdens	2.47	3.15	4.32		6.04	9.06	7.24
	Credits	-0.49	-0.59	-0.78		-1.94	-2.53	-0.98
	Net results	1.98	2.56	3.53		4.10	6.53	6.26
Use of Nature [m²*year]	Burdens	24.16	26.70	32.02		0.50	3.30	5.76
	Credits	-5.48	-6.23	-7.13		-0.08	-0.10	-0.05
	Net results	18.68	20.48	24.90		0.42	3.20	5.72
Water use [m³/1000 L]	water cool	2.44	2.85	4.32		3.64	5.42	3.90
	water process	1.82	2.61	2.44		2.00	2.32	0.72
	water unspecified	0.71	1.34	1.13		0.85	1.78	2.17

8.4.5 Description and interpretation

The increased collection quota of beverage cartons in Switzerland leads to a reduction of net results by 3%-22%. The lowest reductions (3%-4%) are seen in the category 'Non-renewable Primary Energy'. The highest reductions are in the category 'Use of Nature' (20%-22%), followed by 'Climate Change' (11%-12%), and 'Acidification' (10%-12%).

8.5 Results base scenarios SD PORTION PACK SWITZERLAND

8.5.1 Presentation of results SD PORTION PACK Switzerland, base collection quota of beverage cartons

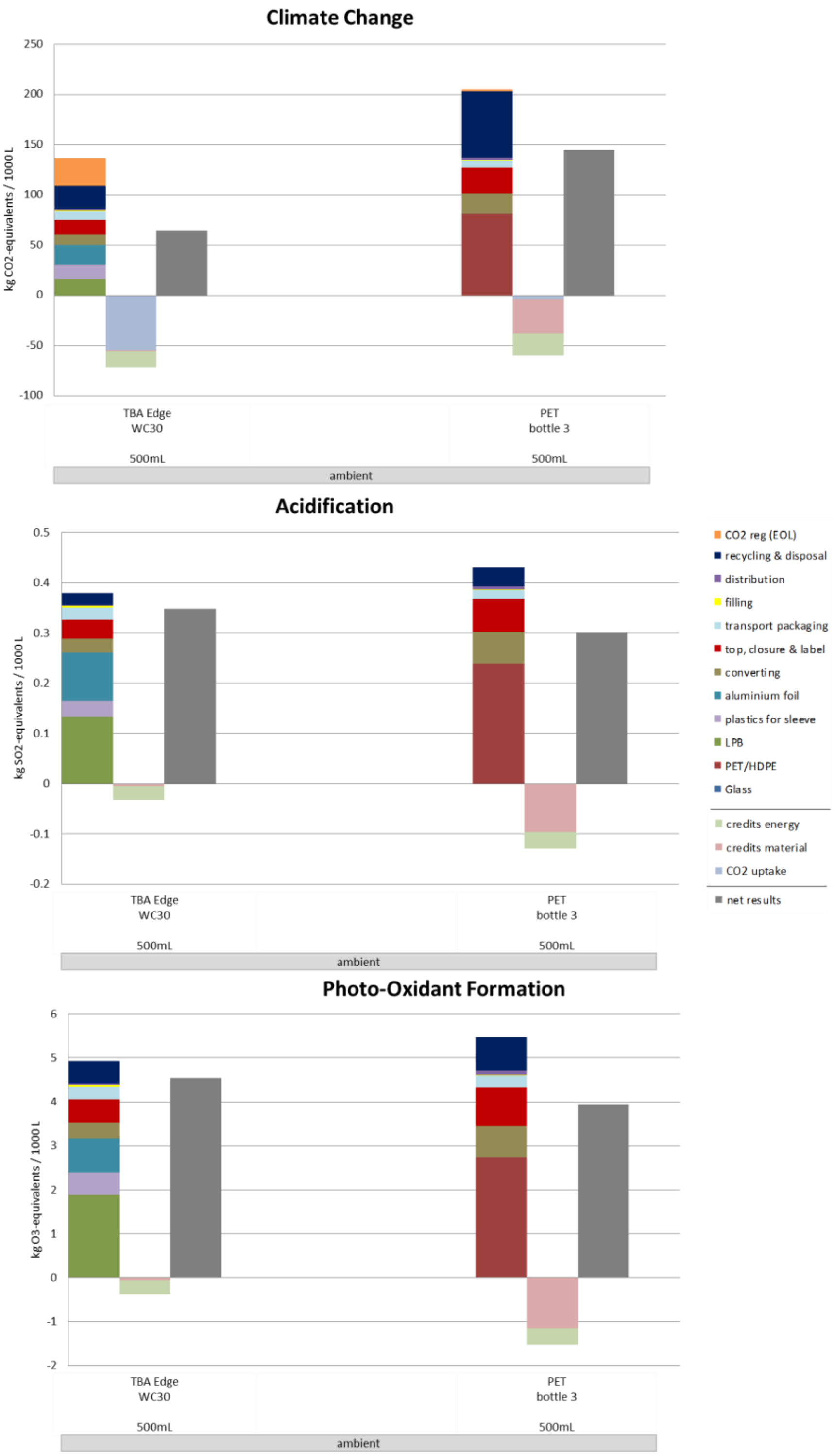


Figure 117: Indicator results for base scenarios with **base collection quota of beverage cartons** of segment SD PORTION PACK, Switzerland, allocation factor 50% (Part 1)

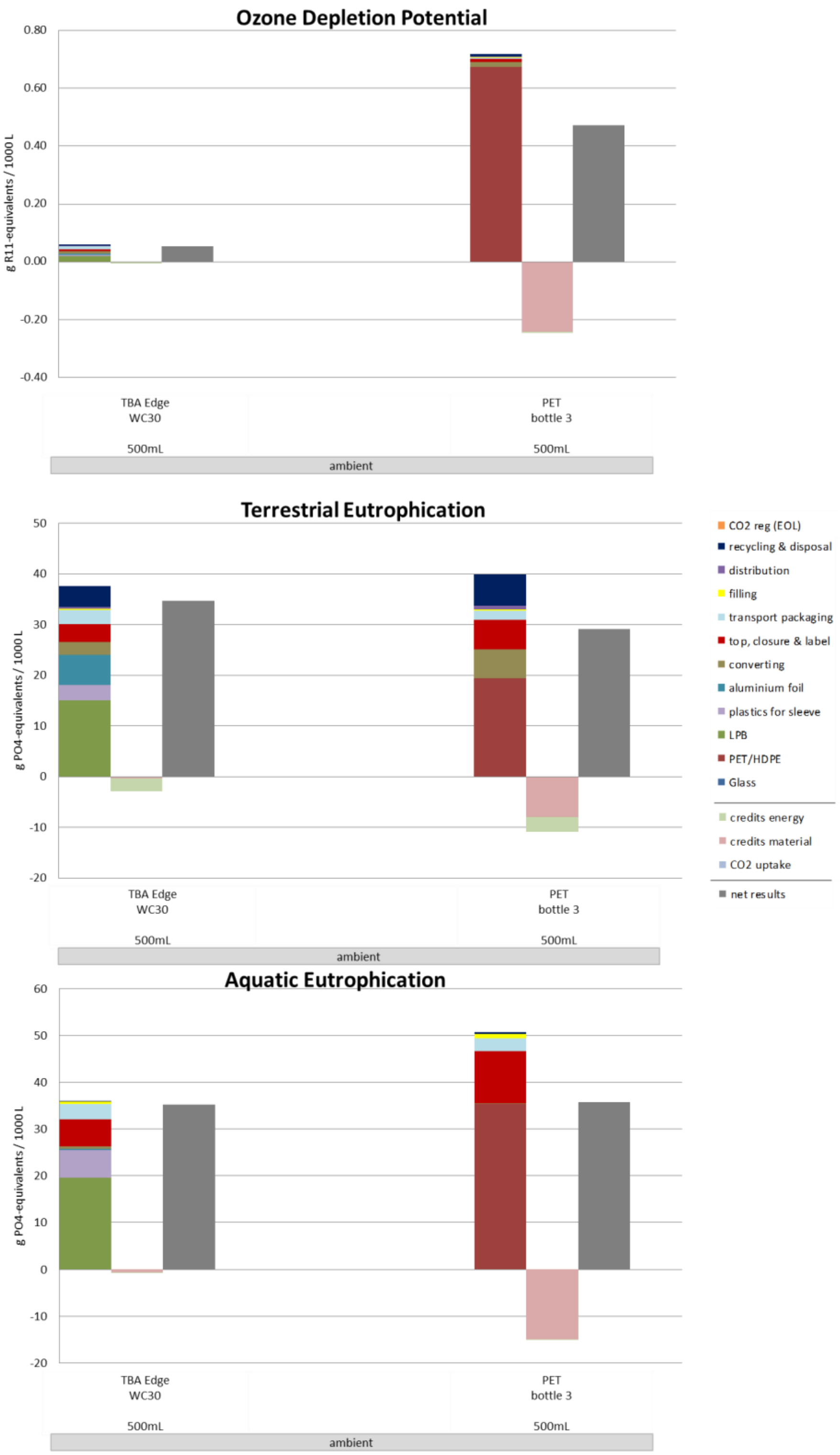


Figure 118 Indicator results for base scenarios with **base collection quota of beverage cartons** of segment SD PORTION PACK, Switzerland, allocation factor 50% (Part 2)

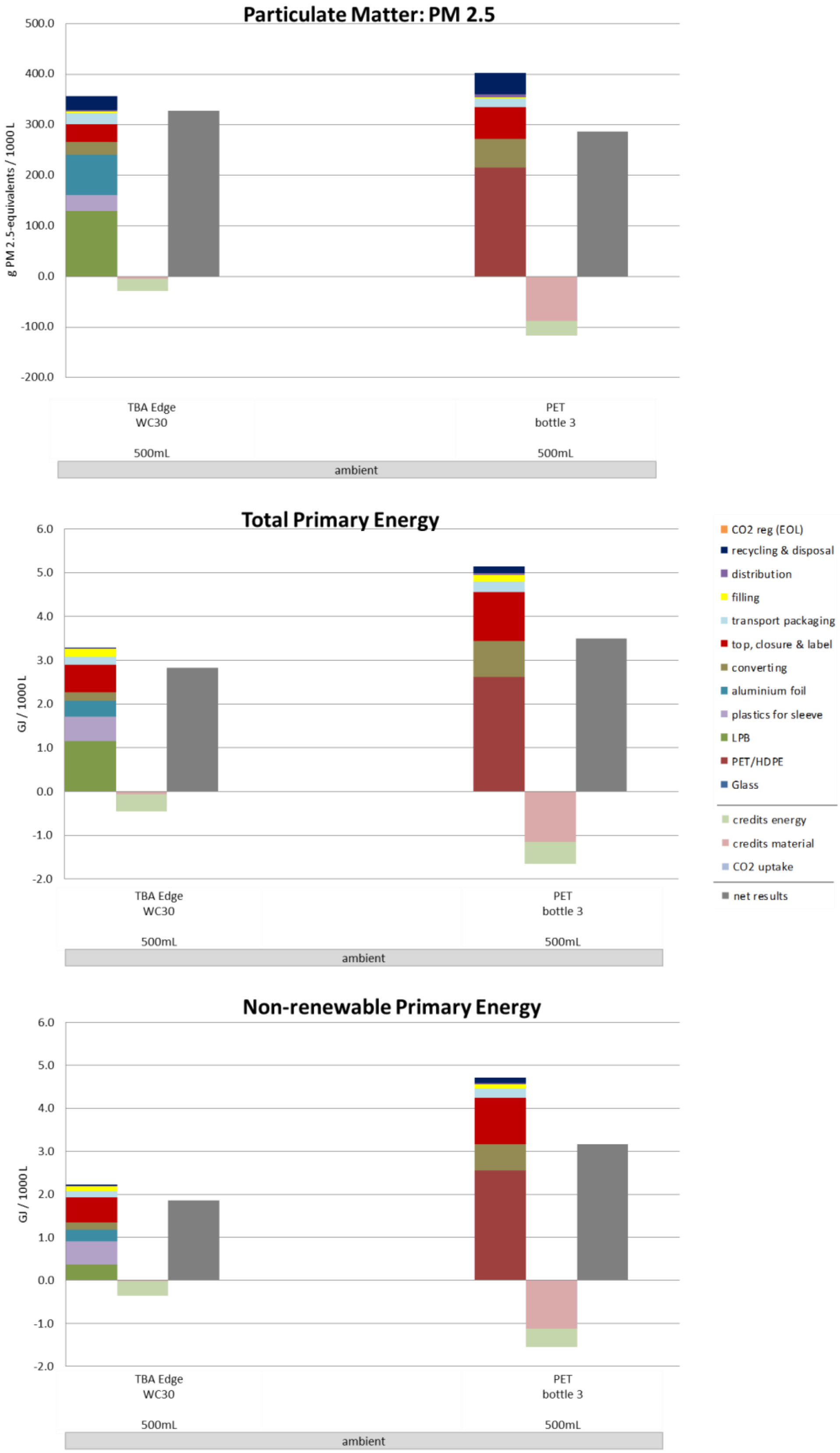
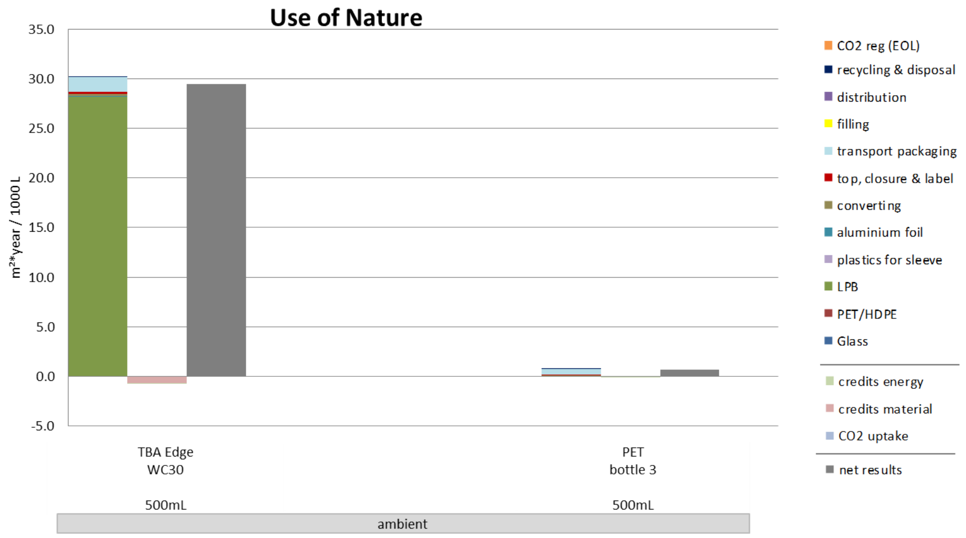


Figure 119: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment SD PORTION PACK, Switzerland**, allocation factor 50% (Part 3)



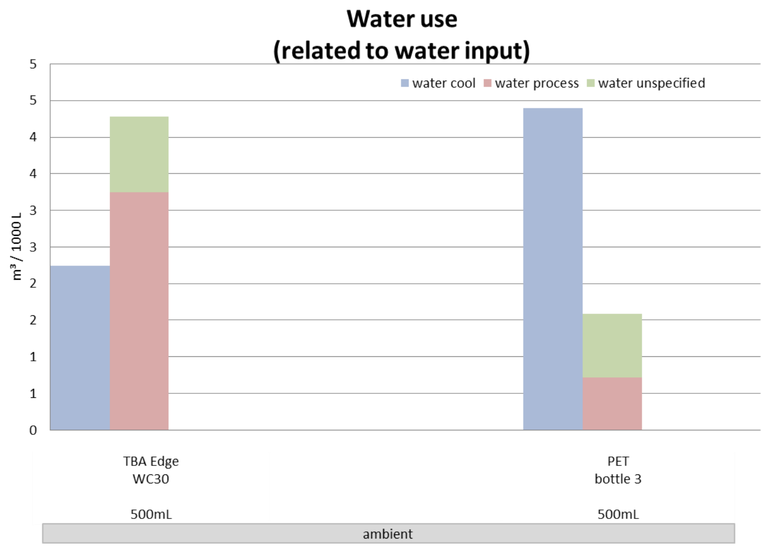


Figure 120: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment SD PORTION PACK, Switzerland**, allocation factor 50% (Part 4)

Table 136: Category indicator results per impact category for base scenarios with **base collection quota of beverage cartons** of **segment SD PORTION PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge WC30 500mL		PET bottle 3 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	108.96		202.86
	CO2 (reg)	27.26		2.07
	Credits	-16.88		-55.96
	CO2 uptake	-54.69		-4.15
	net results	64.65		144.83
Acidification [kg SO2-e/1000 L[	Burdens	0.38		0.43
	Credits	-0.03		-0.13
	Net results	0.35		0.30
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	4.92		5.47
	Credits	-0.38		-1.52
	Net results	4.54		3.95
Ozone Depletion [g R11/1000 L]	Burdens	0.06		0.72
	Credits	-0.01		-0.25
	Net results	0.05		0.47
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	37.58		39.90
	Credits	-2.87		-10.82
	Net results	34.71		29.08
Aquatic Eutrophication [g PO4/1000 L]	Burdens	35.84		50.65
	Credits	-0.62		-14.96
	Net results	35.21		35.68
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	356.81		403.04
	Credits	-28.97		-116.65
	Net results	327.84		286.39
Total Primary Energy [GJ]	Burdens	3.29		5.14
	Credits	-0.46		-1.65
	Net results	2.83		3.49
Non-renewable Primary Energy [GJ]	Burdens	2.22		4.71
	Credits	-0.36		-1.55
	Net results	1.87		3.17
Use of Nature [m²*year]	Burdens	30.17		0.74
	Credits	-0.70		-0.03
	Net results	29.47		0.70
Water use [m³/1000 L]	water cool	2.25		4.40
	water process	3.24		0.72
	water unspecified	1.04		0.87

8.5.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton system regarded in the SD PORTION PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories ‘Aquatic Eutrophication’ (55%) and ‘Use of Nature’ (93%). It is also relevant regarding ‘Photo-Oxidant Formation’ (38%) ‘Acidification’ (35%), ‘Terrestrial Eutrophication’ (40%), ‘Particulate Matter’ (36%) and also the consumption of ‘Total Primary Energy’ (35%). Regarding ‘Climate Change’ the production of LPB contributes only to 12%.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both ‘Aquatic Eutrophication’ and ‘Terrestrial Eutrophication’, the latter to a lesser extent. Approximately half of the ‘Aquatic Eutrophication Potential’ is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the ‘Terrestrial Eutrophication Potential’, nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called ‘Kraft process’ is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories ‘Total Primary Energy’ and ‘Non-renewable Primary Energy’.

The production of ‘aluminium foil’ for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories ‘Acidification’ (25%) and ‘Particulate Matter’ (22%). These result from SO2 and NOx emissions from the aluminium production.

The production of ‘plastics for sleeve’ of the beverage cartons with fossil plastics shows considerable burdens in most impact categories (up to 25%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (10%) and LPB (12%) contribute about the same and the inventory category ‘Non-renewable Primary Energy’, where the plastics (25%) contribute more than LPB (16%) to the total burdens.

The life cycle step ‘top, closure & label’ for TBA and TR cartons contributes to a considerable amount in almost all impact categories (1%-26%).

The converting process generally plays a minor role (1%-13%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (5%-16%).

The life cycle step 'filling' shows only minor burdens for all beverage carton systems in all impact categories (max. 5%).

The life cycle step 'distribution' shows only very minor burdens (max. 2%). in all impact categories for all beverage carton systems.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (37%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are very low as in Switzerland only 2.4% of the beverage cartons are recycled. Material credits for 'Climate Change' are especially low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play a minor role on the net results in all categories.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the SD PORTION PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The ‘converting’ process shows for the plastic bottle in this segment a minor share of burdens (3%-17%) in all categories apart from ‘Aquatic Eutrophication’, for which the share of burdens is less than 1%. Emissions from ‘converting’ process almost exclusively derive from electricity production.

The life cycle step ‘top, closure & label’ shows considerable impacts shares (1%-23%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of ‘transport packaging’ for the bottle system show minor impact shares (1%-5%) in most categories. The exception is ‘Use of Nature’ for which 75% of the burdens are caused from ‘transport packaging’ resulting from the used cardboard slip sheets.

The life cycle step ‘filling’ shows only small shares of burdens (max. 3%) for all bottle systems in all impact categories.

The life cycle step ‘distribution’ shows only small shares of burdens (max. 2%) for all bottle systems in all impact categories.

The impact of the plastic bottles’ ‘recycling & disposal’ life cycle step is most noticeable regarding ‘Climate Change’ (33%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 30% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Please note that the categories ‘Water Use’ and ‘Use of Nature’ will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

8.5.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems (with base collection quota) for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 137: Comparison of net results: **TBA Edge WC30 500mL** versus competing carton based and alternative packaging systems in **segment SD PORTION PACK (ambient), Switzerland**, allocation factor 50%

SD PORTION PACK (ambient), Switzerland	The net results of **TBA Edge WC30 500mL** are lower (green)/ higher (orange) than those of
	PET bottle 3 500mL
Climate Change	-55%
Acidification	16%
Photo-Oxidant Formation	15%
Ozone Depletion Potential	-88%
Terrestrial Eutrophication	19%
Aquatic Eutrophication	-1%
Particulate Matter	14%

8.5.4 Presentation of results SD PORTION PACK Switzerland, target collection quota of beverage cartons

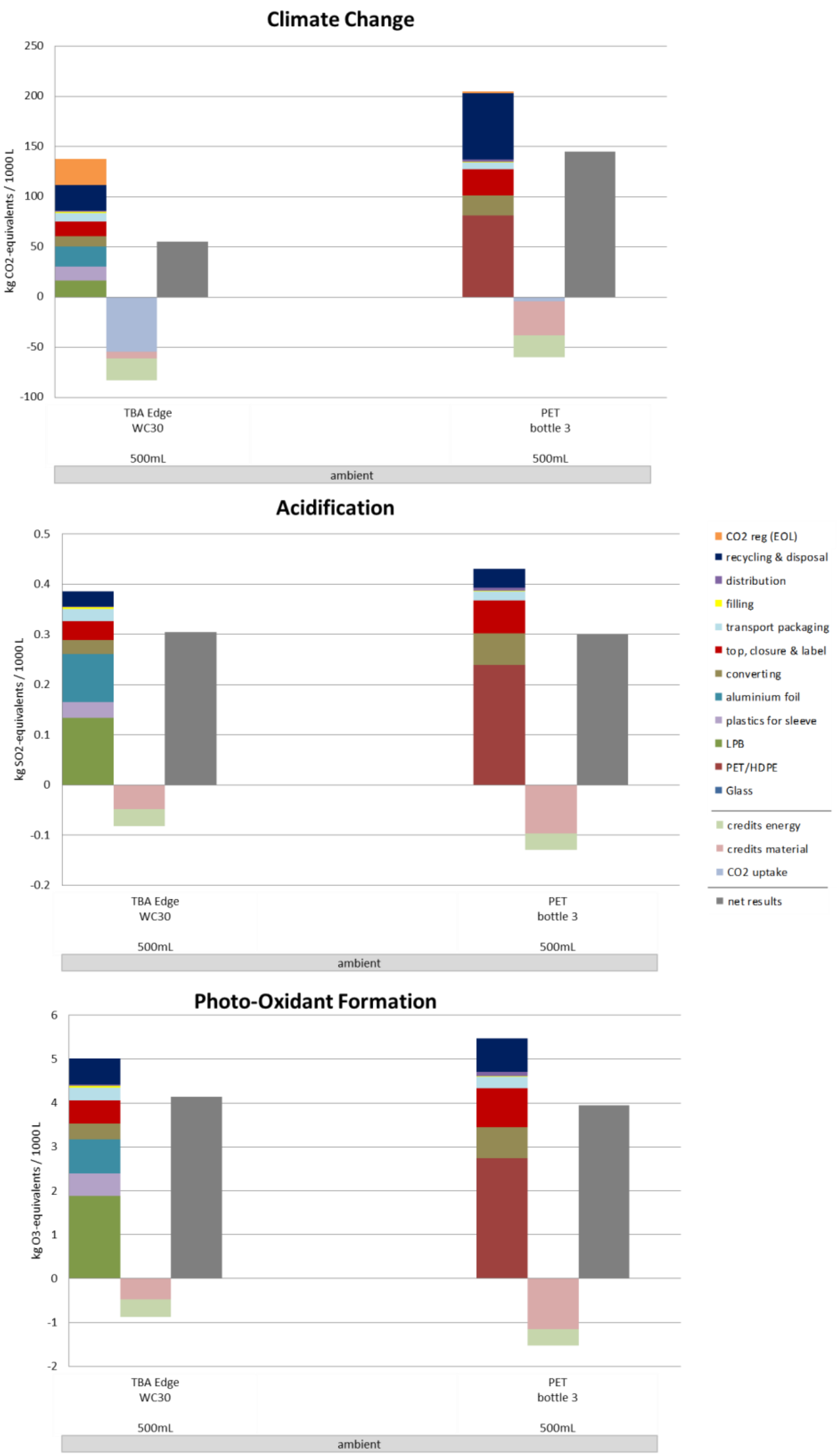


Figure 121: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment SD PORTION PACK, Switzerland**, allocation factor 50% (Part 1)

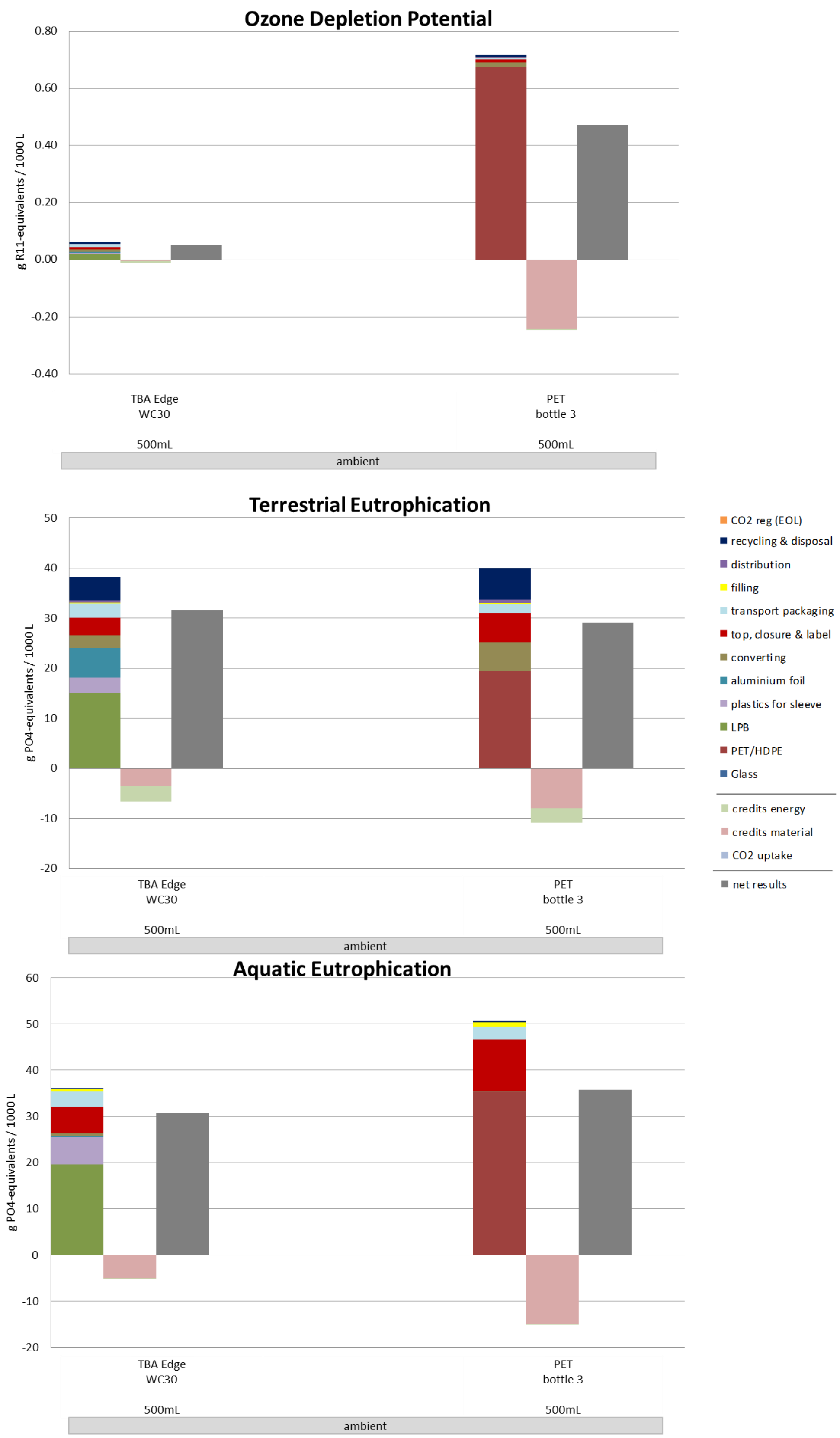


Figure 122 Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment SD PORTION PACK, Switzerland**, allocation factor 50% (Part 2)

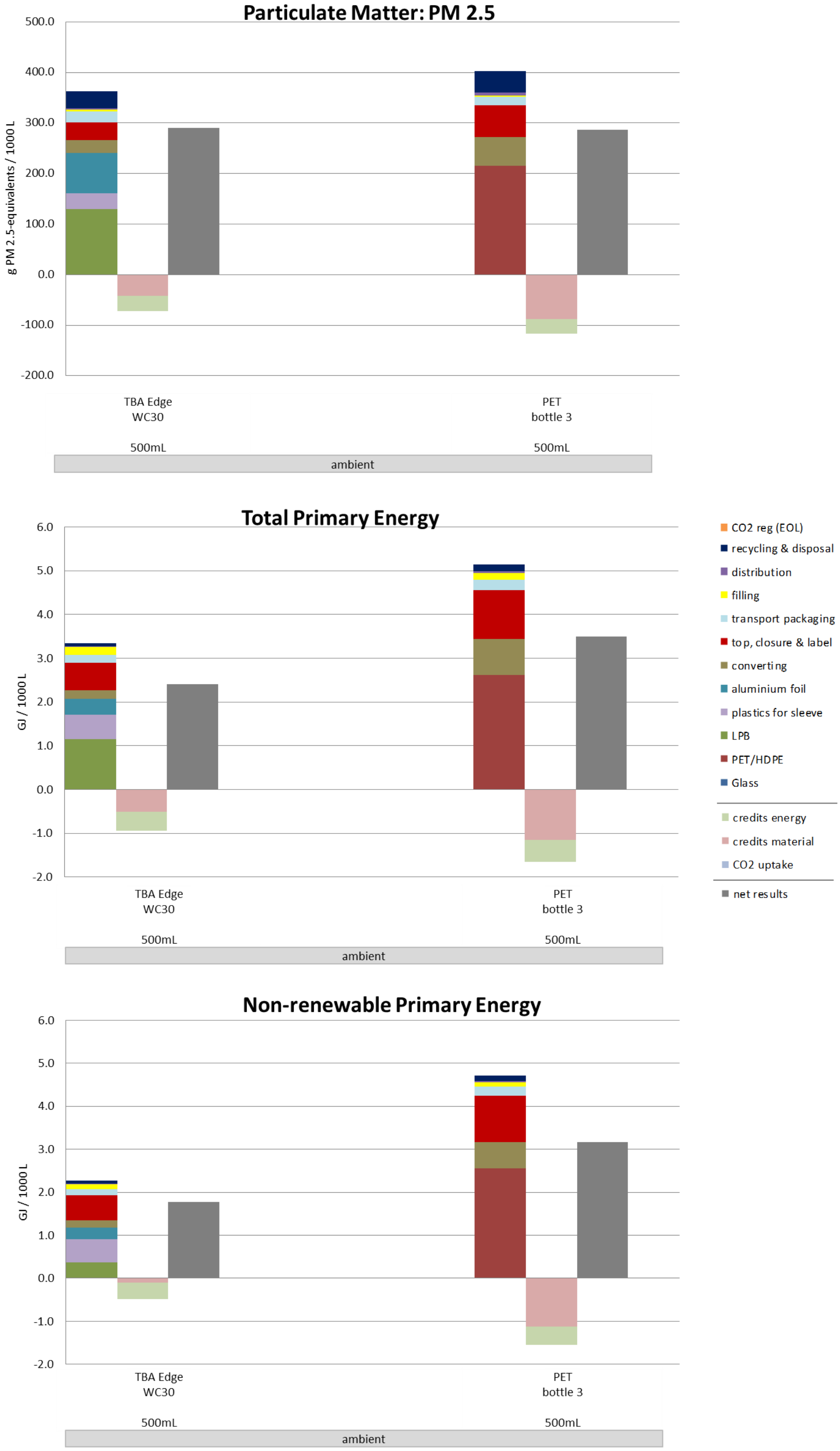


Figure 123: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment SD PORTION PACK, Switzerland**, allocation factor 50% (Part 3)

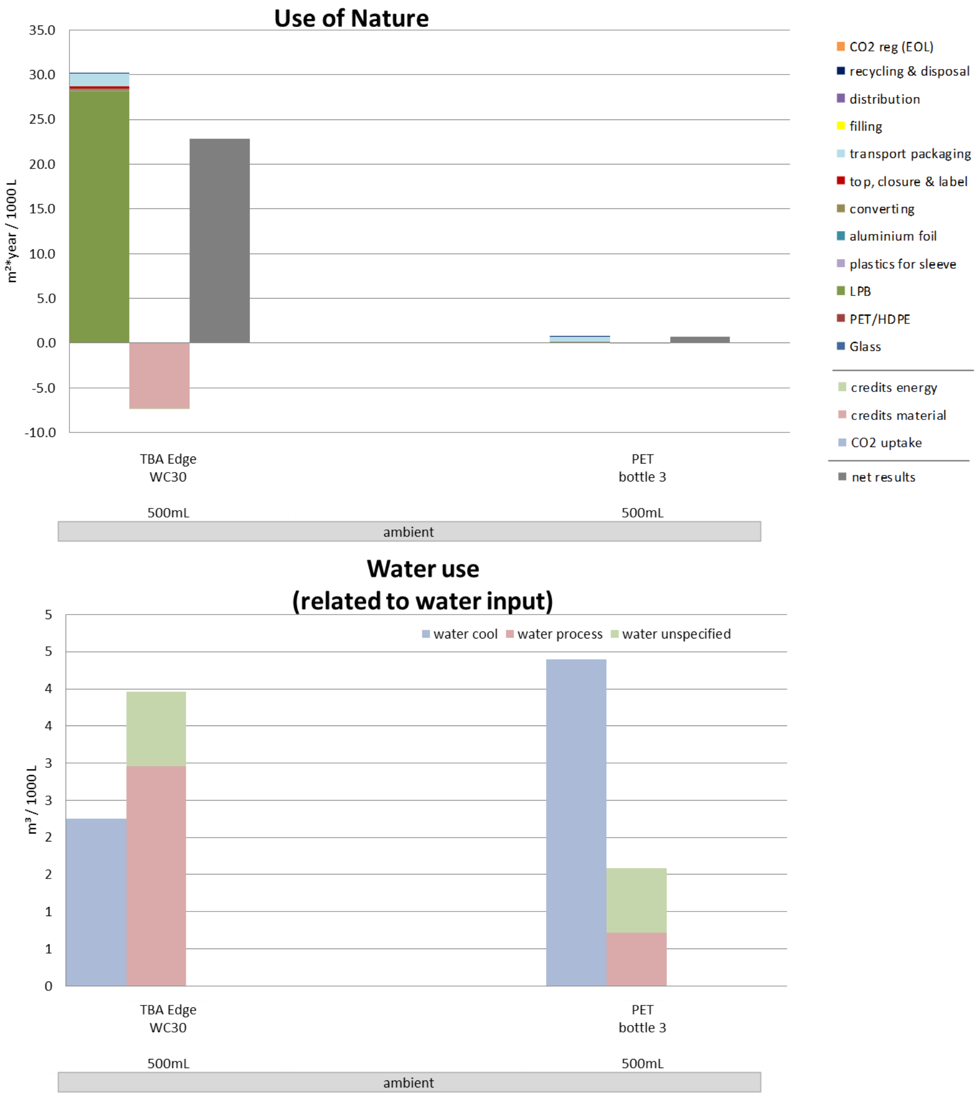


Figure 124: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment SD PORTION PACK, Switzerland**, allocation factor 50% (Part 4)

Table 138: Category indicator results per impact category for base scenarios with **target collection quota of beverage cartons** of **segment SD PORTION PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge WC30 500mL		PET bottle 3 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	111.47		202.86
	CO2 (reg)	26.47		2.07
	Credits	-28.24		-55.96
	CO2 uptake	-54.69		-4.15
	net results	55.01		144.83
Acidification [kg SO2-e/1000 L[	Burdens	0.39		0.43
	Credits	-0.08		-0.13
	Net results	0.30		0.30
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.01		5.47
	Credits	-0.87		-1.52
	Net results	4.14		3.95
Ozone Depletion [g R11/1000 L]	Burdens	0.06		0.72
	Credits	-0.01		-0.25
	Net results	0.05		0.47
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	38.21		39.90
	Credits	-6.67		-10.82
	Net results	31.54		29.08
Aquatic Eutrophication [g PO4/1000 L]	Burdens	35.86		50.65
	Credits	-5.16		-14.96
	Net results	30.70		35.68
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	362.81		403.04
	Credits	-72.12		-116.65
	Net results	290.69		286.39
Total Primary Energy [GJ]	Burdens	3.34		5.14
	Credits	-0.93		-1.65
	Net results	2.41		3.49
Non-renewable Primary Energy [GJ]	Burdens	2.27		4.71
	Credits	-0.49		-1.55
	Net results	1.78		3.17
Use of Nature [m²*year]	Burdens	30.18		0.74
	Credits	-7.33		-0.03
	Net results	22.85		0.70
Water use [m³/1000 L]	water cool	2.25		4.40
	water process	2.96		0.72
	water unspecified	1.00		0.87

8.5.5 Description and interpretation

The increased collection quota of beverage cartons in Switzerland leads to a reduction of net results by 5%-22%. The lowest reduction (5%) is seen in the categories 'Ozone Depletion Potential' and 'Non-renewable Primary Energy. The highest reductions are in the category 'Use of Nature' (22%) , followed by 'Climate Change' (15%) and 'Total Primary Energy' (15%).

8.6 Results base scenarios *WATER PORTION PACK SWITZERLAND*

8.6.1 Presentation of results WATER PORTION PACK Switzerland, base collection quota of beverage cartons

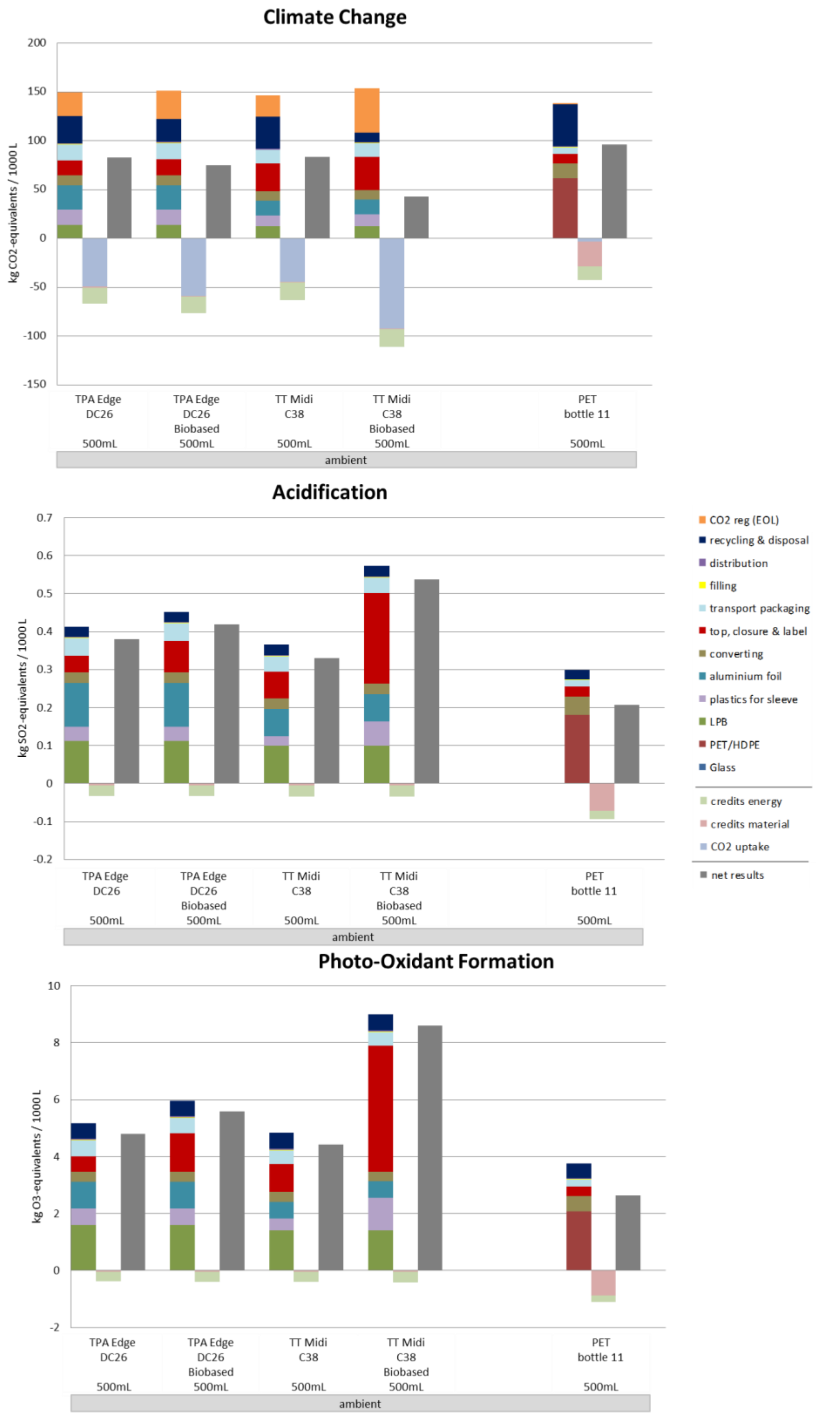


Figure 125: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland**, allocation factor 50% (Part 1)

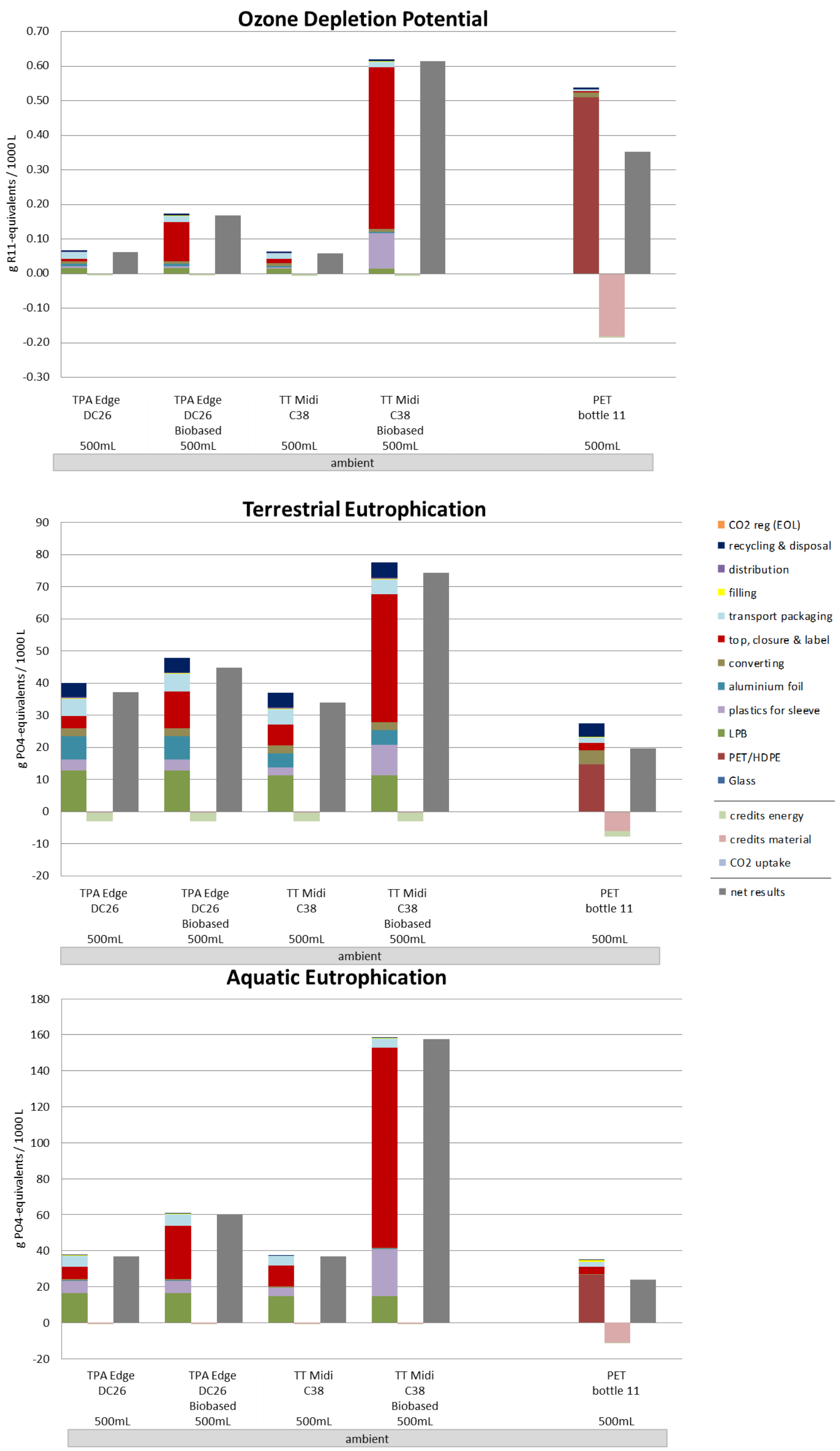


Figure 126: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland**, allocation factor 50% (Part 2)

Figure 127: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland**, allocation factor 50% (Part 3)

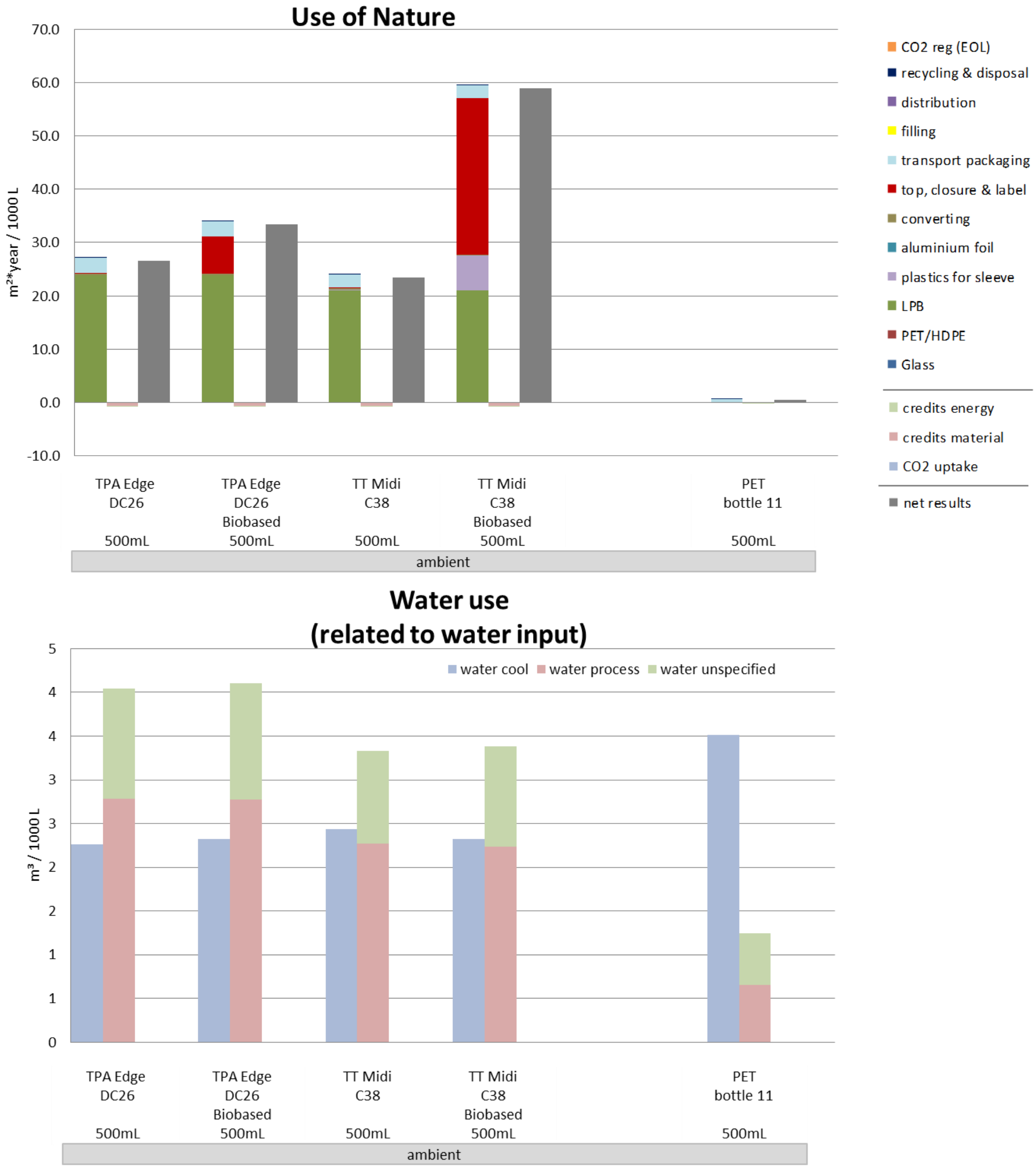


Figure 128: Indicator results for base scenarios with **base collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland**, allocation factor 50% (Part 4)

Table 139: Category indicator results per impact category for base scenarios with **base collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland** - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL		PET bottle 11 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	125.09	121.94	124.35	108.01		137.12
	CO2 (reg)	24.67	29.31	22.04	45.57		1.64
	Credits	-17.38	-17.42	-18.68	-18.76		-39.34
	CO2 uptake	-49.48	-58.87	-44.23	-92.13		-3.28
	net results	82.89	74.96	83.48	42.68		96.14
Acidification [kg SO2-e/1000 L[	Burdens	0.41	0.45	0.37	0.57		0.30
	Credits	-0.03	-0.03	-0.03	-0.03		-0.09
	Net results	0.38	0.42	0.33	0.54		0.21
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.17	5.97	4.84	9.00		3.75
	Credits	-0.38	-0.39	-0.40	-0.41		-1.10
	Net results	4.79	5.58	4.43	8.59		2.65
Ozone Depletion [g R11/1000 L]	Burdens	0.07	0.17	0.06	0.62		0.54
	Credits	-0.01	-0.01	-0.01	-0.01		-0.19
	Net results	0.06	0.17	0.06	0.61		0.35
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	40.12	47.80	36.99	77.48		27.47
	Credits	-2.92	-2.93	-3.08	-3.09		-7.80
	Net results	37.19	44.88	33.92	74.39		19.67
Aquatic Eutrophication [g PO4/1000 L]	Burdens	37.55	60.52	37.37	158.08		35.01
	Credits	-0.57	-0.57	-0.57	-0.57		-11.21
	Net results	36.98	59.95	36.80	157.51		23.81
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	383.41	442.00	344.58	654.25		279.92
	Credits	-29.53	-29.58	-31.06	-31.19		-84.33
	Net results	353.88	412.42	313.52	623.06		195.59
Total Primary Energy [GJ]	Burdens	3.50	3.50	3.53	3.52		3.64
	Credits	-0.47	-0.47	-0.50	-0.50		-1.18
	Net results	3.04	3.04	3.03	3.02		2.47
Non-renewable Primary Energy [GJ]	Burdens	2.51	2.34	2.64	1.75		3.29
	Credits	-0.37	-0.37	-0.40	-0.40		-1.11
	Net results	2.14	1.97	2.24	1.35		2.17
Use of Nature [m²*year]	Burdens	27.21	34.04	24.05	59.55		0.58
	Credits	-0.60	-0.60	-0.60	-0.60		-0.02
	Net results	26.61	33.44	23.45	58.95		0.55
Water use [m³/1000 L]	water cool	2.26	2.32	2.43	2.32		3.51
	water process	2.78	2.77	2.27	2.24		0.65
	water unspecified	1.27	1.33	1.06	1.15		0.59

8.6.2 Description and interpretation

Beverage carton systems (specifications see section 2.2.1)

For the beverage carton systems regarded in the WATER PORTION PACK segment, in most impact categories a considerable part of the environmental burdens is caused by the production of the material components of the beverage carton.

The production of LPB is responsible for a substantial share of the burdens of the impact categories ‘Aquatic Eutrophication’ (9%-44%) and ‘Use of Nature’ (35%-88%). It is also relevant regarding ‘Photo-Oxidant Formation’ (16%-31%) ‘Acidification’ (17%-27%), 'Terrestrial Eutrophication' (15%-32%), 'Particulate Matter' (15%-29%) and also the consumption of 'Total Primary Energy' (24%-28%). Regarding 'Climate Change' the production of LPB is responsible for only 8%-9% of the burdens.

The key source of primary fibres for the production of LPB are trees, therefore an adequate land area is required to provide this raw material. The demand of LPB is covered by forest areas and the production sites in Northern Europe and reflected in the corresponding category.

The production of paperboard generates emissions that cause contributions to both 'Aquatic Eutrophication' and 'Terrestrial Eutrophication', the latter to a lesser extent. Approximately half of the 'Aquatic Eutrophication Potential' is caused by the Chemical Oxygen Demand (COD). As the production of paper causes contributions of organic compounds into the surface water an overabundance of oxygen-consuming reactions takes place which therefore may lead to oxygen shortage in the water. In the 'Terrestrial Eutrophication Potential', nitrogen oxides are determined as main contributor.

For the separation of the cellulose needed for paper production from the ligneous wood fibres, the so called 'Kraft process' is applied, in which sodium hydroxide and sodium sulphide are used. This leads to additional emissions of SO2, thus contributing considerably to the acidifying potential.

The required energy for paper production mainly originates from recovered process residues (for example hemicellulose and lignin dissolved in black liquor). Therefore, the required process energy is mainly generated from renewable sources. This and the additional electricity reflect the results for the categories 'Total Primary Energy' and 'Non-renewable Primary Energy'.

The production of 'aluminium foil' for the sleeves of ambient beverage cartons shows burdens in most impact categories. Considerable shares of burdens can be seen for the categories 'Acidification' (13%-28%) and 'Particulate Matter' (9%-25%). These result from SO2 and NOx emissions from the aluminium production. No shares of burdens are seen for chilled beverage cartons, as these don't have an aluminium layer.

The production of 'plastics for sleeve' of the beverage cartons shows considerable burdens in most impact categories (up to 27%). These are considerably lower than those of the LPB production, which is easily explained by its lower material share than that of LPB. The two exceptions are climate change, where plastics (7%-10%) and LPB (8%-9%) contribute about the same and the inventory category 'Non-renewable Primary Energy', where the plastics (16%-27%) and LPB (10%-16%) contribute about the same of the total burdens.

The life cycle step 'top, closure & label' for the TPA carton with fossil based plastics contributes to a small amount in almost all impact categories (1%-27%). In case of the TT carton with fossil based plastics this life cycle step contributes to a substantial share in almost all impact categories (1%-43%). In case the plastics used for 'top, closure & label' are bio-based, the results are considerably higher than cartons with fossil based plastics in all categories except 'Climate Change', 'Total Primary Energy Demand' and 'Non-renewable Primary Energy'.

The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

The converting process generally plays a minor role (0%-12%). Main source of the emissions from this process is the electricity demand of the converting process.

The production and provision of 'transport packaging' for the beverage carton systems show minor impacts in most categories (3%-16%). The exception is 'Ozone Depletion Potential' for the cartons with fossil based plastics. In these cases 'transport packaging' has a higher share of 8%-27% of the burdens due to the low share of the categories 'top, closure & label' and 'plastics for sleeve'.

The life cycle step 'filling' shows only minor shares of burdens (up to 5%) for all TPA beverage carton systems in all impact categories In case of TT beverage carton systems the shares are higher (up to 9%) due to the additional moulding process of the top.

The life cycle step 'distribution' shows only very minor burdens (max. 1%). in all impact categories for all beverage carton systems.

The life cycle step 'recycling & disposal' of the regarded beverage cartons is most relevant in the impact category 'Climate Change'. Greenhouse gases are generated by the energy production required in the respective recycling and disposal processes as well as by incineration of packaging materials in MSWI or cement kilns.

'CO2 reg. (recycling & disposal)' describes separately all regenerative CO2 emissions from recycling and disposal processes. In case of beverage cartons these derive mainly from the incineration of bio-based plastics and paper. They play an important role for the results of all beverage carton systems in the impact category 'Climate Change'. Together with the fossil-based CO2 emissions of the life cycle step 'recycling & disposal', they represent the total CO2 emissions from the packaging's end-of-life (35%-37%).

Energy credits result from the recovery of energy in incineration plants and cement kilns. Material credits from material recycling are very low as in Switzerland only 2.4% of the beverage cartons are recycled. Material credits for 'Climate Change' are especially low because the production of substituted primary paper fibres has low greenhouse gas emissions. Together, energy and material credits play a minor role on the net results in all categories.

The uptake of CO2 by trees harvested for the production of paperboard and by sugarcane for bio-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. It should be noted that to the energy recovery at incineration plants the allocation factor 50 % is applied. This explains the difference between the uptake and the impact from emissions of regenerative CO2.

Plastic bottles (specifications see section 2.2.2)

In the regarded plastic bottle system in the JN FAMILY PACK segment, the biggest part of the environmental burdens is also caused by the production of the base materials of the bottles in most impact and inventory categories. In case of 'Ozone Depletion Potential' the high burdens of this life cycle step are caused by the production of terephthalic acid (PTA) for PET, which leads to high emissions of methyl bromide.

The 'converting' process shows for the plastic bottle in this segment a minor share of burdens (3%-20%) in all categories apart from 'Aquatic Eutrophication', for which the share of burdens is less than 1%. Emissions from 'converting' process almost exclusively derive from electricity production.

The life cycle step 'top, closure & label' shows minor impacts shares (1%-12%) in most categories mainly attributed to the different plastics used for the closures.

The production and provision of 'transport packaging' for the bottle system show minor impact shares (1%-8%) in most categories. The exception is 'Use of Nature' for which 76% of the burdens are caused from 'transport packaging' resulting from the used cardboard slip sheets.

The life cycle step 'filling' shows only small shares of burdens (max. 4%) for all bottle systems in all impact categories.

The life cycle step 'distribution' shows only small shares of burdens (max. 1%) for all bottle systems in all impact categories.

The impact of the plastic bottles' 'recycling & disposal' life cycle step is most noticeable regarding 'Climate Change' (32%). The incineration of plastic bottles in MSWIs causes high greenhouse gas emissions.

The influence of credits on the net result is relevant in most categories. The credits reduce the overall burdens by around 30% in most categories. The energy credits mainly originate from the incineration plants. Material credits originate mainly from the substitution of virgin PET with recycled PET from the bottle.

Please note that the categories 'Water Use' and 'Use of Nature' will not feature in the comparison and sensitivity sections, nor will they be considered for the final conclusions. (please see details in section 1.8). The graphs of the base results are included anyhow to give an indication about the importance of these categories.

8.6.3 Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems (with base collection quota) for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 140: Comparison of net results: **TBA Edge DC26 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Switzerland**, allocation factor 50%

WATER PORTION PACK (ambient), Switzerland	The net results of **TPA Edge DC26 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL	PET bottle 11 500mL
Climate Change	11%	-1%	94%	-14%
Acidification	-9%	15%	-29%	84%
Photo-Oxidant Formation	-14%	8%	-44%	81%
Ozone Depletion Potential	-63%	6%	-90%	-82%
Terrestrial Eutrophication	-17%	10%	-50%	89%
Aquatic Eutrophication	-38%	0%	-77%	55%
Particulate Matter	-14%	13%	-43%	81%

Table 141: Comparison of net results: **TBA Edge DC26 biobased 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Switzerland**, allocation factor 50%

WATER PORTION PACK (ambient), Switzerland	The net results of **TPA Edge DC26 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL	PET bottle 11 500mL
Climate Change	-10%	-10%	76%	-22%
Acidification	10%	27%	-22%	103%
Photo-Oxidant Formation	17%	26%	-35%	111%
Ozone Depletion Potential	168%	185%	-73%	-52%
Terrestrial Eutrophication	21%	32%	-40%	128%
Aquatic Eutrophication	62%	63%	-62%	152%
Particulate Matter	17%	32%	-34%	111%

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

Table 142: Comparison of net results: **TT Midi C38 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Switzerland**, allocation factor 50%

WATER PORTION PACK (ambient), Switzerland	The net results of **TT Midi C38 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 biobased 500mL	PET bottle 11 500mL
Climate Change	1%	11%	96%	-13%
Acidification	-13%	-21%	-38%	60%
Photo-Oxidant Formation	-7%	-21%	-48%	67%
Ozone Depletion Potential	-6%	-65%	-90%	-83%
Terrestrial Eutrophication	-9%	-24%	-54%	72%
Aquatic Eutrophication	0%	-39%	-77%	55%
Particulate Matter	-11%	-24%	-50%	60%

Table 143: Comparison of net results: **TT Midi C38 biobased 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Switzerland**, allocation factor 50%

WATER PORTION PACK (ambient), Switzerland	The net results of **TT Midi C38 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	PET bottle 11 500mL
Climate Change	-49%	-43%	-49%	-56%
Acidification	42%	28%	63%	161%
Photo-Oxidant Formation	79%	54%	94%	225%
Ozone Depletion Potential	879%	265%	940%	74%
Terrestrial Eutrophication	100%	66%	119%	278%
Aquatic Eutrophication	326%	163%	328%	562%
Particulate Matter	76%	51%	99%	219%

8.6.4 Presentation of results WATER PORTION PACK Switzerland, target collection quota of beverage cartons

Figure 129: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland**, allocation factor 50% (Part 1)

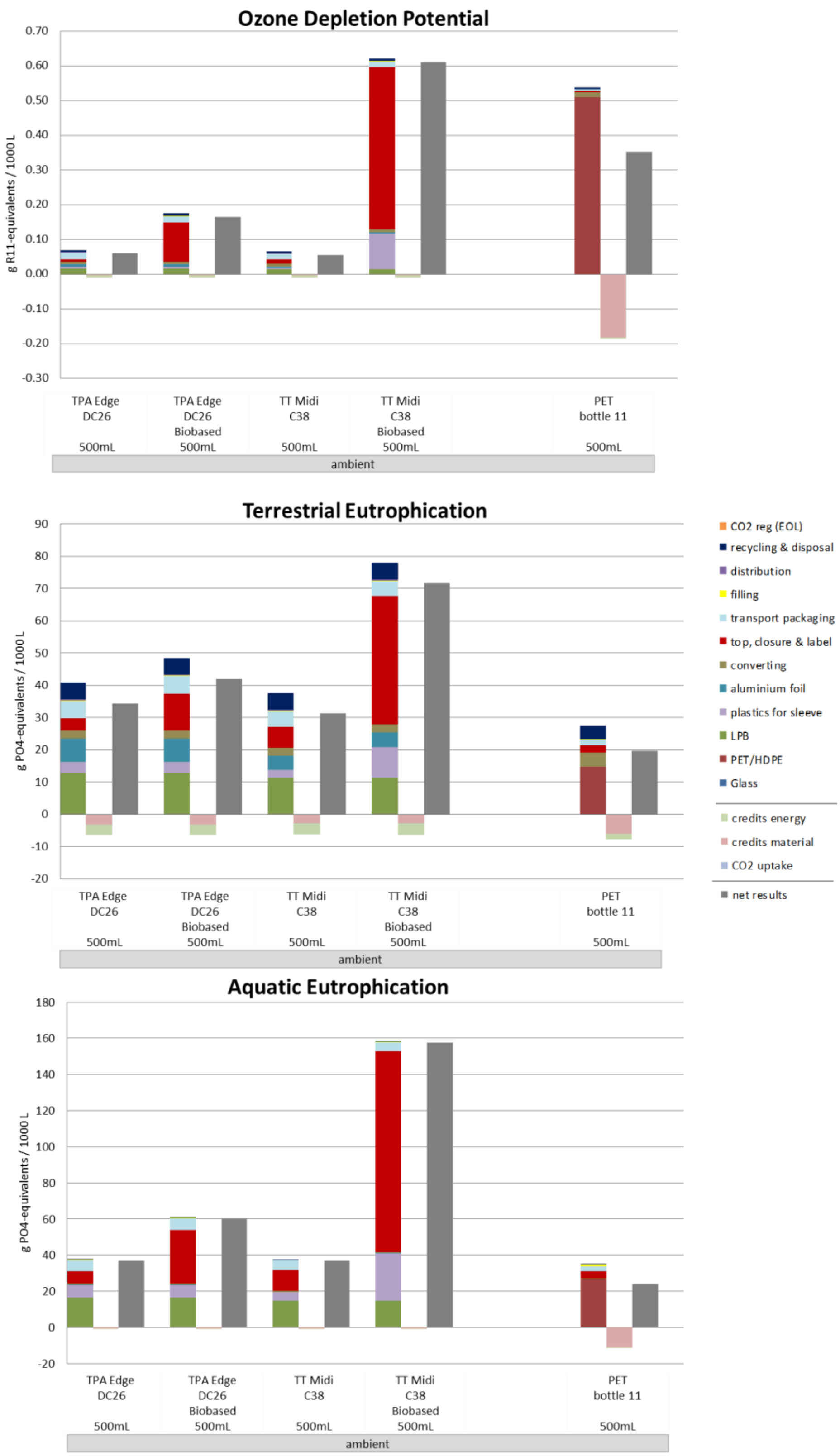


Figure 130: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland**, allocation factor 50% (Part 2)

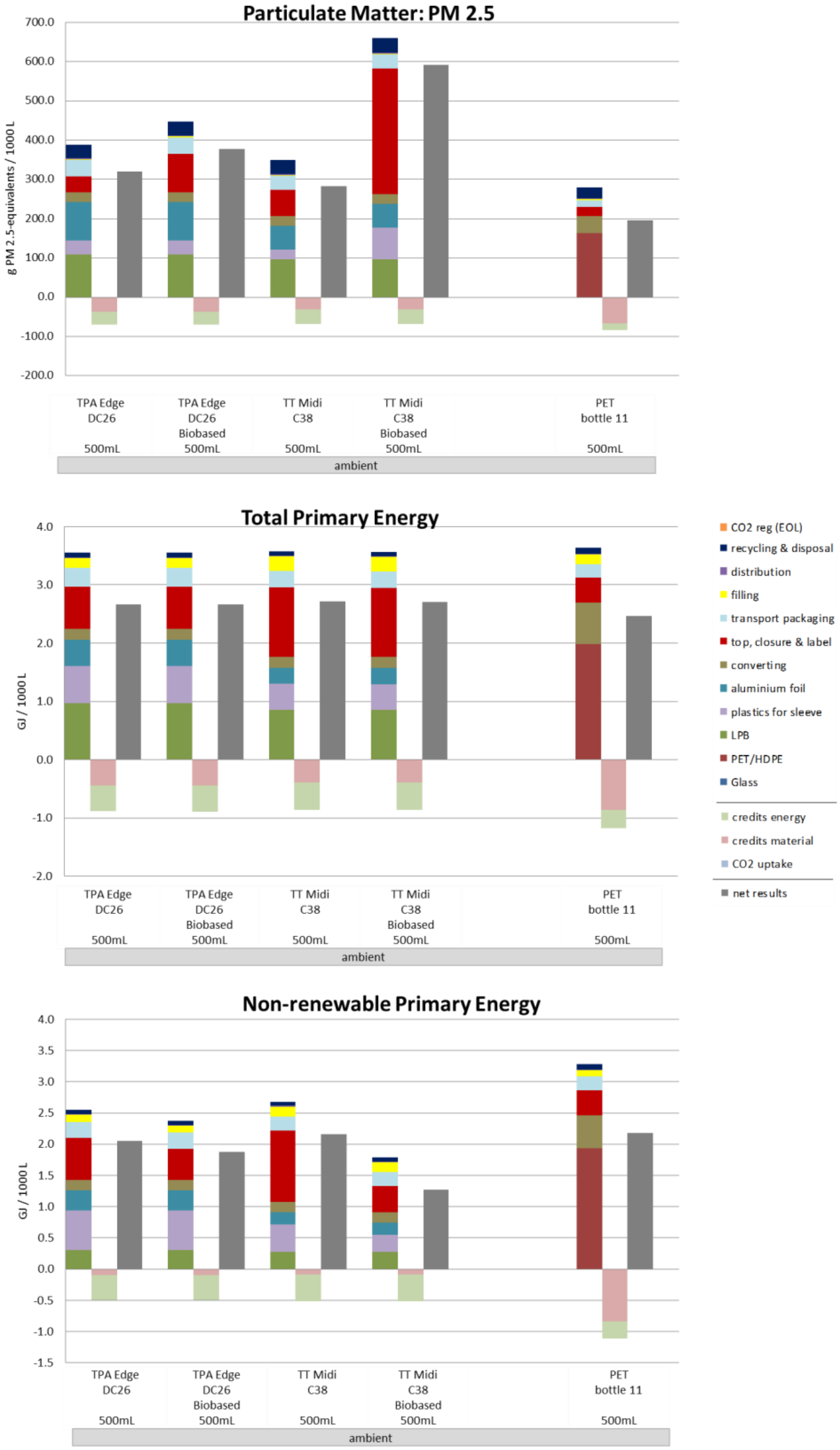


Figure 131: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland**, allocation factor 50% (Part 3)

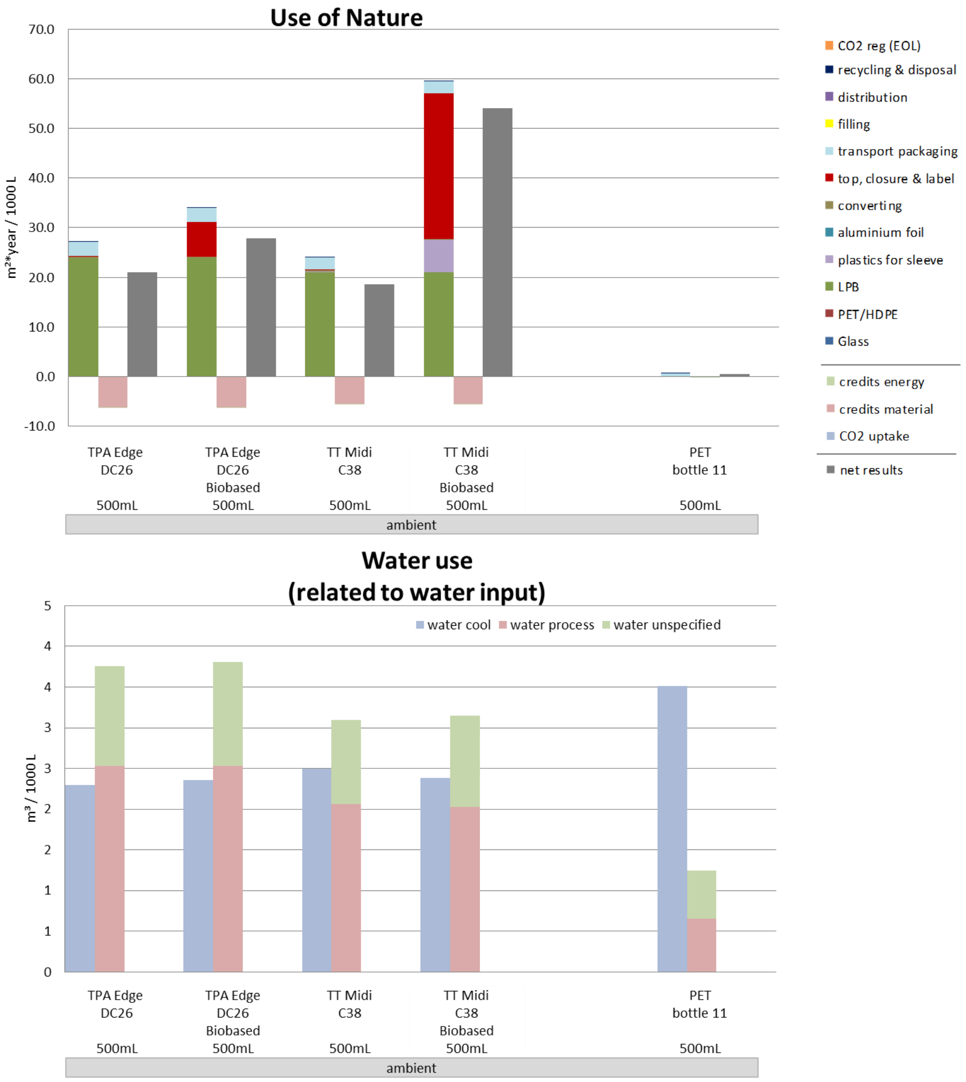


Figure 132: Indicator results for base scenarios with **target collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland**, allocation factor 50% (Part 4)

Table 144: Category indicator results per impact category for base scenarios with **target collection quota of beverage cartons** of **segment WATER PORTION PACK, Switzerland** - burdens, credits and net results per functional unit of 1000 L, allocation factor 50% (All figures are rounded to two decimal places.)

Allocation 50		TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL		PET bottle 1l 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	127.60	125.07	126.85	114.21		137.12
	CO2 (reg)	24.01	28.02	21.47	41.27		1.64
	Credits	-29.01	-29.06	-30.23	-30.33		-39.34
	CO2 uptake	-49.48	-58.87	-44.23	-92.13		-3.28
	net results	73.12	65.17	73.85	33.02		96.14
Acidification [kg SO2-e/1000 L[	Burdens	0.42	0.46	0.37	0.58		0.30
	Credits	-0.08	-0.08	-0.08	-0.08		-0.09
	Net results	0.34	0.38	0.30	0.50		0.21
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.25	6.05	4.91	9.07		3.75
	Credits	-0.84	-0.84	-0.82	-0.83		-1.10
	Net results	4.41	5.21	4.09	8.25		2.65
Ozone Depletion [g R11/1000 L]	Burdens	0.07	0.17	0.07	0.62		0.54
	Credits	-0.01	-0.01	-0.01	-0.01		-0.19
	Net results	0.06	0.17	0.06	0.61		0.35
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	40.71	48.39	37.53	78.01		27.47
	Credits	-6.46	-6.47	-6.33	-6.34		-7.80
	Net results	34.25	41.93	31.20	71.67		19.67
Aquatic Eutrophication [g PO4/1000 L]	Burdens	37.57	60.54	37.39	158.10		35.01
	Credits	-4.41	-4.41	-3.94	-3.94		-11.21
	Net results	33.16	56.13	33.45	154.16		23.81
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	389.20	447.79	350.16	659.81		279.92
	Credits	-69.74	-69.79	-67.28	-67.42		-84.33
	Net results	319.47	378.00	282.88	592.39		195.59
Total Primary Energy [GJ]	Burdens	3.55	3.55	3.58	3.57		3.64
	Credits	-0.89	-0.89	-0.86	-0.87		-1.18
	Net results	2.67	2.67	2.71	2.70		2.47
Non-renewable Primary Energy [GJ]	Burdens	2.55	2.38	2.68	1.78		3.29
	Credits	-0.50	-0.50	-0.51	-0.52		-1.11
	Net results	2.05	1.88	2.16	1.27		2.17
Use of Nature [m²*year]	Burdens	27.21	34.05	24.05	59.55		0.58
	Credits	-6.20	-6.20	-5.52	-5.52		-0.02
	Net results	21.01	27.85	18.53	54.03		0.55
Water use [m³/1000 L]	water cool	2.30	2.36	2.50	2.38		3.51
	water process	2.53	2.53	2.06	2.03		0.65
	water unspecified	1.22	1.28	1.03	1.12		0.59

8.6.5 Description and interpretation

The increased collection quota of beverage cartons in Switzerland leads to a reduction of net results by less than 1%-23%. The lowest reductions (less than 1%-5%) are seen in the category 'Ozone Depletion Potential'. The highest reductions are in the category 'Climate Change' (12%-23%), followed by 'Use of Nature' (8%-21%) and 'Total Primary Energy' (11%-12%).

9 Sensitivity Analyses Switzerland

9.1 DAIRY FAMILY PACK SWITZERLAND

9.1.1 Sensitivity analysis on system allocation DAIRY FAMILY PACK Switzerland

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

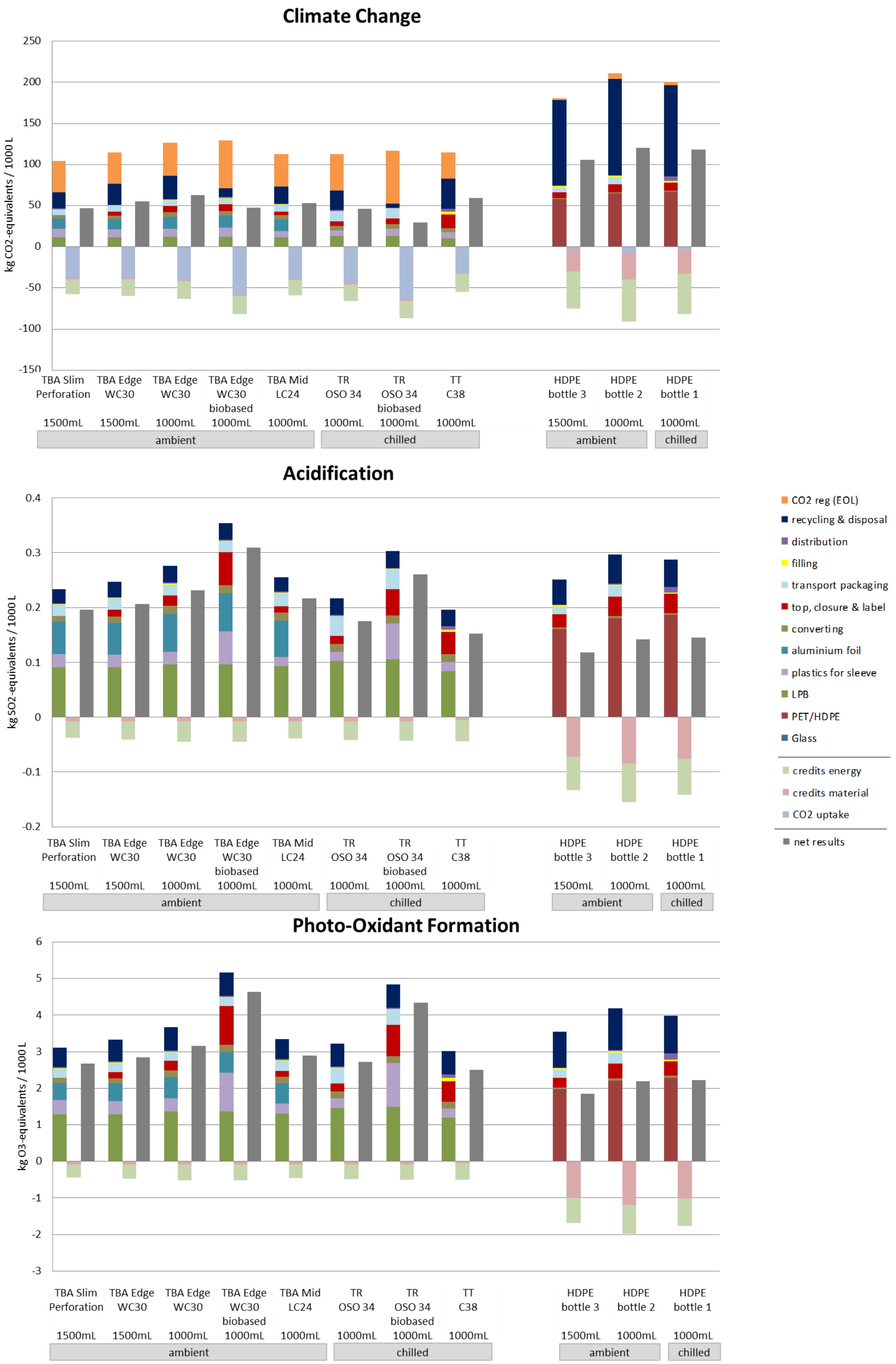


Figure 133: Indicator results for sensitivity analysis on system allocation of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 100% (Part 1)

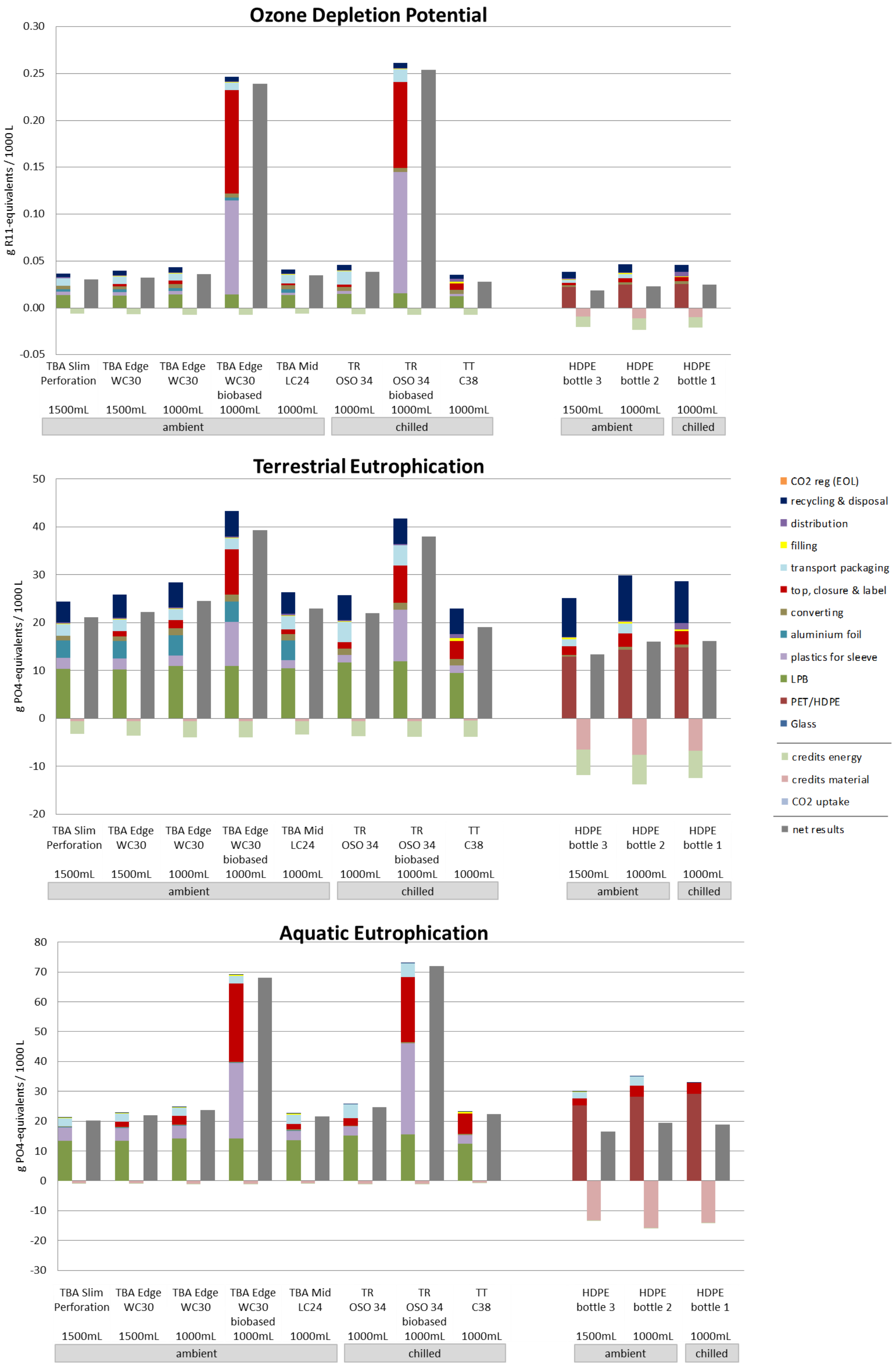


Figure 134: Indicator results for sensitivity analysis on system allocation of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 100% (Part 2)

Figure 135: Indicator results for sensitivity analysis on system allocation of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 100% (Part 3)

Table 145: Category indicator results per impact category for sensitivity analysis on system allocation scenarios of **segment DAIRY FAMILY PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	TT C38 1000mL		HDPE bottle 3 1500mL	HDPE bottle 2 1000mL	HDPE bottle 1 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	65.89	76.37	86.01	70.85	73.20	67.99	52.23	82.87		178.42	204.06	196.16
	CO2 (reg)	38.45	38.28	40.34	58.13	39.18	44.47	64.35	31.74		2.27	7.01	4.29
	Credits	-19.10	-21.11	-23.04	-23.07	-19.73	-21.65	-21.99	-23.35		-72.75	-84.12	-77.74
	CO2 uptake	-38.57	-38.40	-40.48	-58.61	-39.31	-44.60	-64.76	-31.86		-2.27	-7.01	-4.29
	net results	46.66	55.14	62.83	47.30	53.35	46.21	29.83	59.40		105.68	119.94	118.42
Acidification [kg SO2-e/1000 L[	Burdens	0.23	0.25	0.28	0.35	0.26	0.22	0.30	0.20		0.25	0.30	0.29
	Credits	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04		-0.13	-0.16	-0.14
	Net results	0.20	0.21	0.23	0.31	0.22	0.18	0.26	0.15		0.12	0.14	0.15
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.11	3.32	3.67	5.16	3.35	3.22	4.84	3.02		3.54	4.18	3.99
	Credits	-0.43	-0.48	-0.52	-0.52	-0.45	-0.49	-0.50	-0.51		-1.69	-1.99	-1.77
	Net results	2.67	2.85	3.15	4.64	2.90	2.73	4.34	2.51		1.85	2.19	2.22
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.04	0.04	0.25	0.04	0.05	0.26	0.04		0.04	0.05	0.05
	Credits	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01		-0.02	-0.02	-0.02
	Net results	0.03	0.03	0.04	0.24	0.03	0.04	0.25	0.03		0.02	0.02	0.02
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	24.37	25.87	28.43	43.25	26.34	25.66	41.70	22.88		25.16	29.80	28.58
	Credits	-3.30	-3.62	-3.94	-3.94	-3.41	-3.73	-3.80	-3.88		-11.80	-13.80	-12.47
	Net results	21.07	22.25	24.49	39.30	22.93	21.92	37.90	19.00		13.36	16.01	16.11
Aquatic Eutrophication [g PO4/1000 L]	Burdens	21.09	22.80	24.69	69.00	22.48	25.75	73.02	23.15		29.94	35.19	32.88
	Credits	-0.87	-0.89	-0.98	-0.98	-0.89	-0.97	-0.99	-0.74		-13.41	-15.82	-14.06
	Net results	20.22	21.91	23.71	68.02	21.59	24.78	72.03	22.41		16.53	19.37	18.83
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	221.48	235.43	261.74	376.25	241.53	212.59	336.76	196.41		241.81	285.44	275.05
	Credits	-33.62	-36.77	-40.14	-40.18	-34.78	-37.75	-38.36	-39.18		-123.30	-144.06	-130.63
	Net results	187.86	198.66	221.60	336.06	206.76	174.84	298.40	157.23		118.51	141.38	144.42
Total Primary Energy [GJ]	Burdens	1.75	1.95	2.20	2.18	1.95	1.90	1.91	2.06		3.32	3.91	3.77
	Credits	-0.53	-0.58	-0.63	-0.63	-0.55	-0.61	-0.62	-0.63		-2.19	-2.56	-2.32
	Net results	1.22	1.37	1.56	1.55	1.40	1.29	1.29	1.43		1.14	1.35	1.45
Non-renewable Primary Energy [GJ]	Burdens	1.09	1.27	1.45	1.11	1.23	1.18	0.83	1.47		3.11	3.60	3.47
	Credits	-0.41	-0.45	-0.49	-0.49	-0.42	-0.47	-0.47	-0.49		-2.04	-2.38	-2.16
	Net results	0.68	0.82	0.96	0.62	0.81	0.71	0.35	0.98		1.07	1.22	1.31
Use of Nature [m²*year]	Burdens	20.68	20.62	21.84	35.04	21.30	24.16	38.67	18.01		0.37	0.63	0.29
	Credits	-1.00	-0.99	-1.10	-1.10	-1.01	-1.08	-1.11	-0.95		-0.06	-0.08	-0.05
	Net results	19.69	19.63	20.75	33.95	20.29	23.08	37.56	17.06		0.30	0.55	0.00
Water use [m³/1000 L]	water cool	0.76	0.87	1.10	1.13	1.00	1.11	1.16	1.09		1.06	1.34	1.38
	water process	2.01	2.03	2.25	2.23	2.16	2.01	2.05	1.96		0.12	0.17	0.17
	water unspecified	0.59	0.63	0.72	0.85	0.68	0.47	0.61	0.29		0.37	0.42	0.39

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 regarded system.

In the cases of beverage cartons in the Swiss segment DAIRY FAMILY PACK applying the allocation factor 100% instead of 50% leads to similar net results in almost all impact categories. This is because the absolute value of the credits similar than that of the burdens from recycling and disposal regardless of the allocation factor. In case of 'Climate Change' applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of plastic bottles in this segment applying the allocation factor 100% instead of 50% leads to lower or similar net results in almost all impact categories as the additionally allocated credits and burdens show lower or similar absolute values. The exception is 'Climate Change'. For 'Climate Change' net results increase when applying the 100% allocation factor as burdens from incineration are higher than energy and material credits.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 146: Comparison of net results: **TBA Slim Perforation 1500mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (ambient), Switzerland**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Slim Perforation 1500mL** are lower (green)/ higher (orange) than those of					
	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	-15%	-26%	-1%	-13%	-56%	-61%
Acidification	-5%	-15%	-37%	-10%	65%	38%
Photo-Oxidant Formation	-6%	-15%	-42%	-8%	44%	22%
Ozone Depletion Potential	-6%	-14%	-87%	-12%	67%	35%
Terrestrial Eutrophication	-5%	-14%	-46%	-8%	58%	32%
Aquatic Eutrophication	-8%	-15%	-70%	-6%	22%	4%
Particulate Matter	-5%	-15%	-44%	-9%	59%	33%

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

Table 147: Comparison of net results: **TBA Edge WC30 1500mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (ambient), Switzerland**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1500mL** are lower (green)/ higher (orange) than those of					
	TBA Slim Perforation 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	18%	-12%	17%	3%	-48%	-54%
Acidification	5%	-11%	-33%	-5%	74%	46%
Photo-Oxidant Formation	7%	-10%	-39%	-2%	54%	30%
Ozone Depletion Potential	6%	-9%	-86%	-6%	77%	43%
Terrestrial Eutrophication	6%	-9%	-43%	-3%	67%	39%
Aquatic Eutrophication	8%	-8%	-68%	1%	33%	13%
Particulate Matter	6%	-10%	-41%	-4%	68%	41%

Table 148: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (ambient), Switzerland**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of					
	TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 biobased 1000mL	TBA Mid LC24 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	35%	14%	33%	18%	-41%	-48%
Acidification	18%	12%	-25%	7%	95%	63%
Photo-Oxidant Formation	18%	11%	-32%	9%	71%	44%
Ozone Depletion Potential	17%	10%	-85%	3%	94%	57%
Terrestrial Eutrophication	16%	10%	-38%	7%	83%	53%
Aquatic Eutrophication	17%	8%	-65%	10%	43%	22%
Particulate Matter	18%	12%	-34%	7%	87%	57%

Table 149: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (ambient), Switzerland**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of					
	TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Mid LC24 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	1%	-14%	-25%	-11%	-55%	-61%
Acidification	58%	50%	34%	43%	161%	118%
Photo-Oxidant Formation	74%	63%	47%	60%	151%	112%
Ozone Depletion Potential	681%	636%	570%	588%	1201%	951%
Terrestrial Eutrophication	87%	77%	60%	71%	194%	146%
Aquatic Eutrophication	236%	210%	187%	215%	312%	251%
Particulate Matter	79%	69%	52%	63%	184%	138%

Table 150: Comparison of net results: **TBA Mid LC24 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Switzerland**, allocation factor 100%

DAIRY FAMILY PACK (ambient), Switzerland	The net results of **TBA Mid LC24 1000mL** are lower (green)/ higher (orange) than those of					
	TBA Slim Perforation 1500mL	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	HDPE bottle 3 1500mL	HDPE bottle 2 1000mL
Climate Change	14%	-3%	-15%	13%	-50%	-56%
Acidification	11%	5%	-6%	-30%	83%	53%
Photo-Oxidant Formation	9%	2%	-8%	-38%	57%	32%
Ozone Depletion Potential	13%	7%	-3%	-85%	89%	53%
Terrestrial Eutrophication	9%	3%	-6%	-42%	72%	43%
Aquatic Eutrophication	7%	-1%	-9%	-68%	31%	11%
Particulate Matter	10%	4%	-7%	-38%	74%	46%

Table 151: Comparison of net results: **TR OSO 34 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Switzerland**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Switzerland	The net results of **TR OSO 34 1000mL** are lower (green)/ higher (orange) than those of		
	TR OSO 34 biobased 1000mL	TT C38 1000mL	HDPE bottle 1 1000mL
Climate Change	55%	-22%	-61%
Acidification	-33%	15%	20%
Photo-Oxidant Formation	-37%	9%	23%
Ozone Depletion Potential	-85%	37%	55%
Terrestrial Eutrophication	-42%	15%	36%
Aquatic Eutrophication	-66%	11%	32%
Particulate Matter	-41%	11%	21%

Table 152: Comparison of net results: **TR OSO 34 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Switzerland**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Switzerland	The net results of **TR OSO 34 biobased 1000mL** are lower (green)/ higher (orange) than those of		
	TR OSO 34 1000mL	TT C38 1000mL	HDPE bottle 1 1000mL
Climate Change	-35%	-50%	-75%
Acidification	49%	71%	79%
Photo-Oxidant Formation	59%	73%	96%
Ozone Depletion Potential	561%	804%	924%
Terrestrial Eutrophication	73%	99%	135%
Aquatic Eutrophication	191%	221%	283%
Particulate Matter	71%	90%	107%

Table 153: Comparison of net results: **TT C38 1000mL** versus competing carton based and alternative packaging systems in **segment Dairy Family Pack (chilled), Switzerland**, allocation factor 100%

DAIRY FAMILY PACK (chilled), Switzerland	The net results of **TT C38 1000mL** are lower (green)/ higher (orange) than those of		
	TR OSO 34 1000mL	TR OSO 34 biobased 1000mL	HDPE bottle 1 1000mL
Climate Change	29%	99%	-50%
Acidification	-13%	-42%	4%
Photo-Oxidant Formation	-8%	-42%	13%
Ozone Depletion Potential	-27%	-89%	13%
Terrestrial Eutrophication	-13%	-50%	18%
Aquatic Eutrophication	-10%	-69%	19%

9.2 JN FAMILY PACK SWITZERLAND

9.2.1 Sensitivity analysis on system allocation JN FAMILY PACK Switzerland

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%. Results are shown in the following figures.

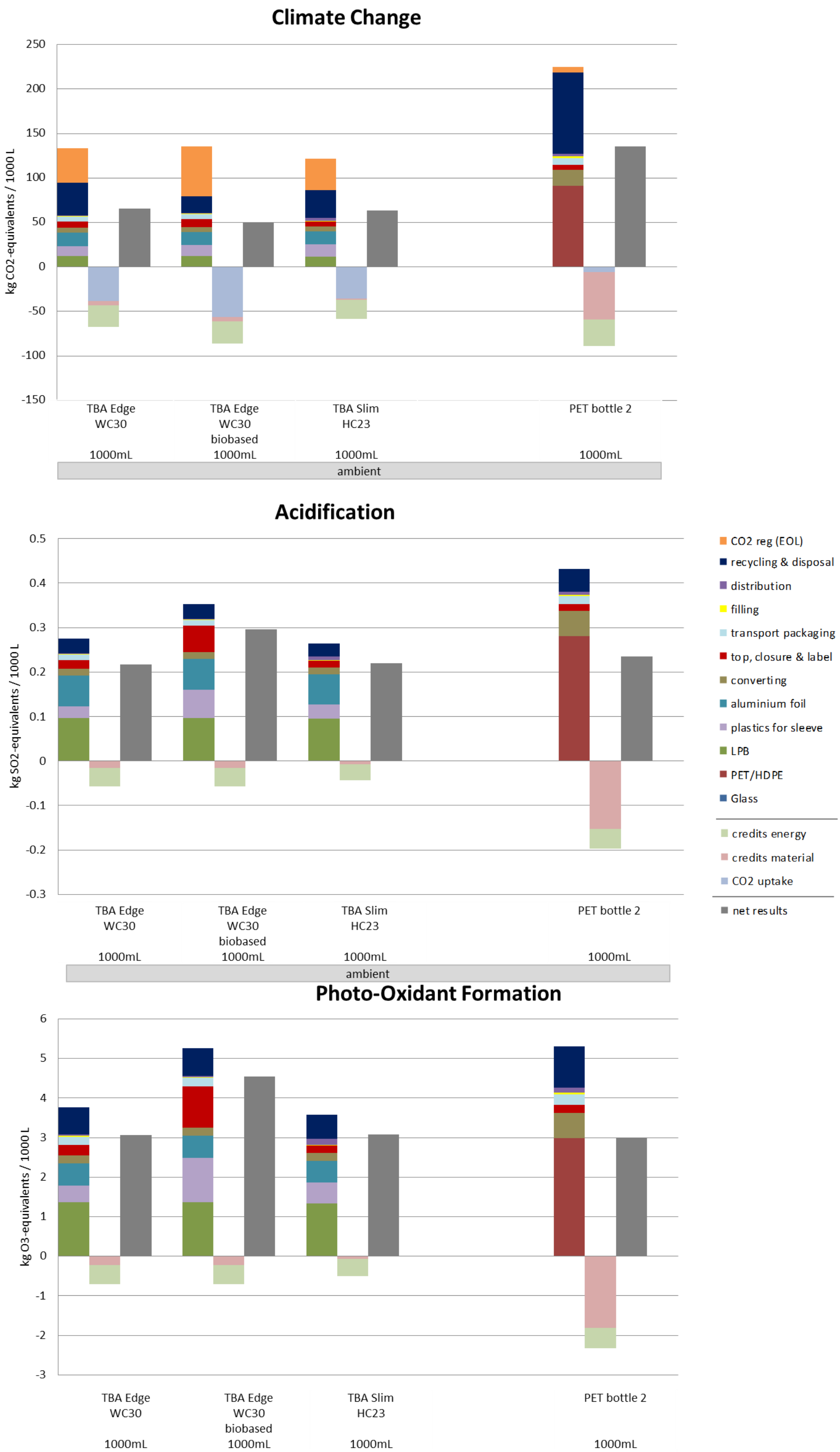


Figure 136: Indicator results for sensitivity analysis on system allocation of segment JN FAMILY PACK, Switzerland, allocation factor 100% (Part 1)

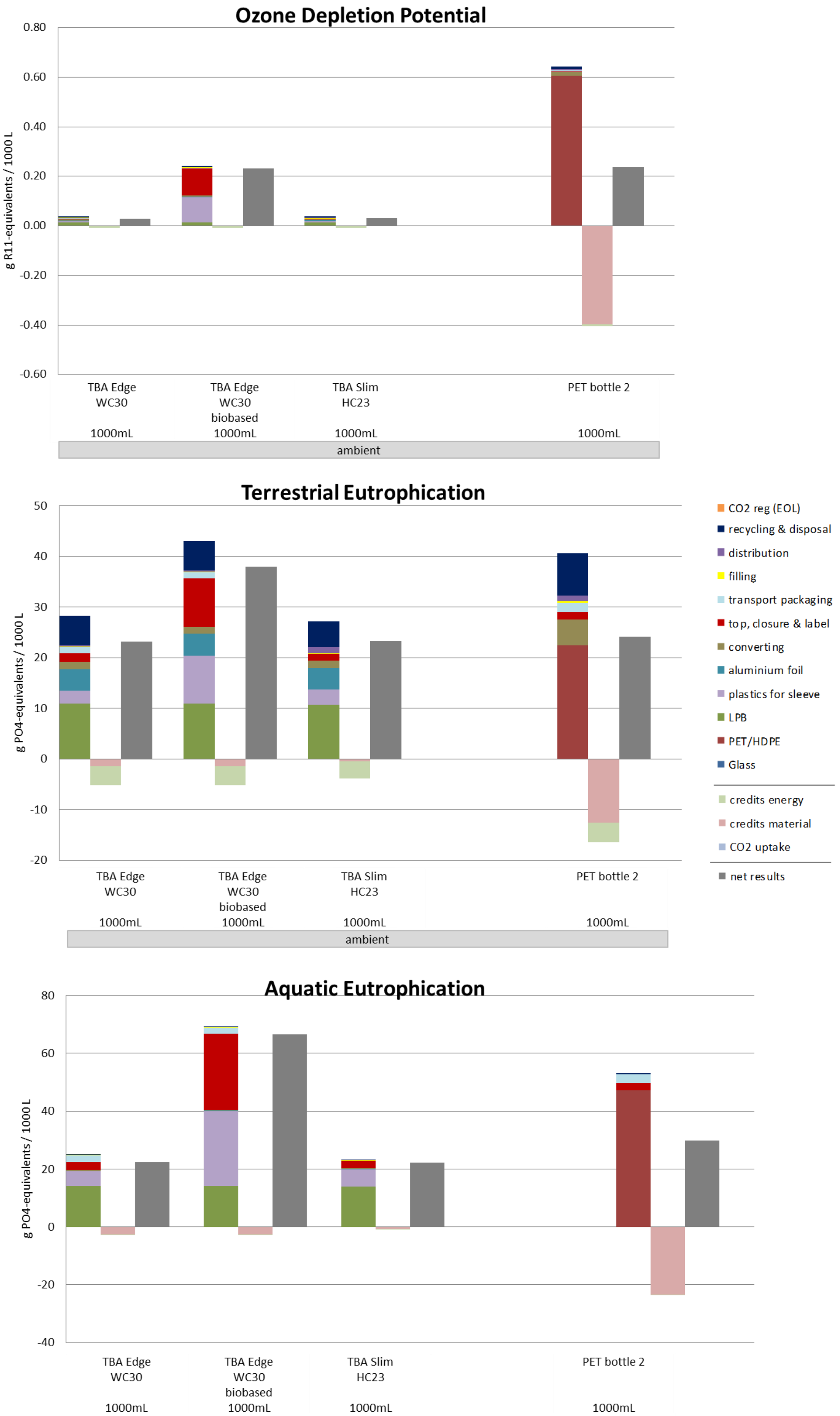


Figure 137: Indicator results for sensitivity analysis on system allocation of segment JN FAMILY PACK, Switzerland, allocation factor 100% (Part 2)

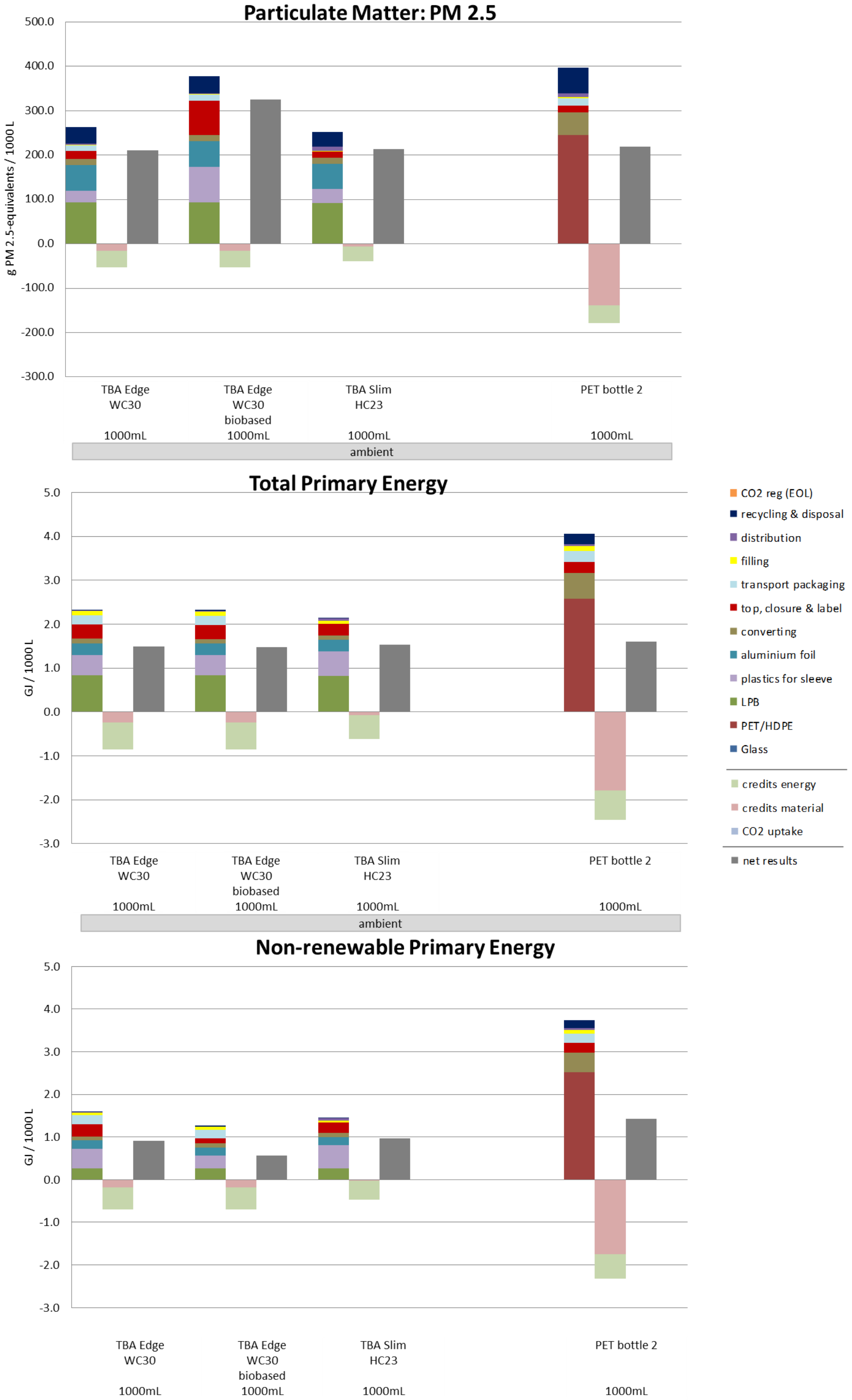


Figure 138: Indicator results for sensitivity analysis on system allocation of **segment JN FAMILY PACK, Switzerland**, allocation factor 100% (Part 3)

Table 63: Category indicator results per impact category for sensitivity analysis on system allocation of **segment JN FAMILY PACK, Switzerland** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL		PET bottle 2 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	94.70	79.55	86.21		218.44
	CO2 (reg)	38.38	56.15	35.72		6.09
	Credits	-29.19	-29.22	-22.73		-82.89
	CO2 uptake	-38.52	-56.60	-35.85		-6.09
	net results	65.37	49.88	63.35		135.55
Acidification [kg SO2-e/1000 L[	Burdens	0.28	0.35	0.26		0.43
	Credits	-0.06	-0.06	-0.04		-0.20
	Net results	0.22	0.30	0.22		0.23
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.77	5.25	3.58		5.30
	Credits	-0.71	-0.71	-0.50		-2.32
	Net results	3.06	4.54	3.08		2.98
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.24	0.04		0.64
	Credits	-0.01	-0.01	-0.01		-0.41
	Net results	0.03	0.23	0.03		0.24
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	28.26	43.04	27.13		40.62
	Credits	-5.14	-5.15	-3.85		-16.47
	Net results	23.12	37.89	23.28		24.15
Aquatic Eutrophication [g PO4/1000 L]	Burdens	24.96	69.17	22.96		53.28
	Credits	-2.57	-2.57	-0.78		-23.52
	Net results	22.39	66.60	22.18		29.76
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	263.41	377.63	252.11		397.05
	Credits	-52.36	-52.41	-39.14		-178.29
	Net results	211.05	325.23	212.97		218.76
Total Primary Energy [GJ]	Burdens	2.33	2.32	2.14		4.06
	Credits	-0.85	-0.85	-0.61		-2.46
	Net results	1.48	1.47	1.53		1.60
Non-renewable Primary Energy [GJ]	Burdens	1.60	1.26	1.45		3.74
	Credits	-0.69	-0.69	-0.48		-2.32
	Net results	0.91	0.57	0.97		1.42
Use of Nature [m²*year]	Burdens	20.72	33.89	20.27		0.74
	Credits	-1.08	-1.08	-1.01		-0.06
	Net results	19.64	32.81	19.27		0.68
Water use [m³/1000 L]	water cool	1.05	1.08	1.03		2.23
	water process	2.24	2.23	2.13		0.16
	water unspecified	0.62	0.75	0.61		0.34

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 regarded system.

In the cases of beverage cartons in the Swiss segment JN FAMILY PACK applying the allocation factor 100% instead of 50% leads to similar net results in almost all impact categories. This is because the absolute value of the credits is similar than that of the burdens from recycling and disposal regardless of the allocation factor. In case of 'Climate Change' applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of plastic bottles in this segment, applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories as the additionally allocated credits and burdens show lower or similar absolute values. The exception is 'Climate Change'. For 'Climate Change' net results increase when applying the 100% allocation factor as burdens from incineration are higher than energy and material credits.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 154: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Switzerland**, allocation factor 100%

JN FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of		
	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 2 1000mL
Climate Change	31%	3%	-52%
Acidification	-26%	-1%	-7%
Photo-Oxidant Formation	-33%	-1%	3%
Ozone Depletion Potential	-87%	-4%	-88%
Terrestrial Eutrophication	-39%	-1%	-4%
Aquatic Eutrophication	-66%	1%	-25%
Particulate Matter	-35%	-1%	-4%

Table 155: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Switzerland**, allocation factor 100%

JN FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of		
	TBA Edge WC30 1000mL	TBA Slim HC23 1000mL	PET bottle 2 1000mL
Climate Change	-24%	-21%	-63%
Acidification	36%	34%	26%
Photo-Oxidant Formation	49%	47%	52%
Ozone Depletion Potential	698%	663%	-2%
Terrestrial Eutrophication	64%	63%	57%
Aquatic Eutrophication	197%	200%	124%
Particulate Matter	54%	53%	49%

Table 156: Comparison of net results: **TBA Slim HC23 1000mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Switzerland**, allocation factor 100%

JN FAMILY PACK (ambient), Switzerland	The net results of **TBA Slim HC23 1000mL** are lower (green)/ higher (orange) than those of		
	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	PET bottle 2 1000mL
Climate Change	-3%	27%	-53%
Acidification	1%	-25%	-6%
Photo-Oxidant Formation	1%	-32%	3%
Ozone Depletion Potential	5%	-87%	-87%
Terrestrial Eutrophication	1%	-39%	-4%
Aquatic Eutrophication	-1%	-67%	-25%
Particulate Matter	1%	-35%	-3%

9.2.2 Sensitivity analysis regarding recycled PET in PET bottles

To consider potential future developments in terms of the share of recyclate of the plastic bottles, two additional scenarios for plastic bottles with a recycled content of PET of 30% and 100% are analysed and illustrated in this sensitivity analysis (for details please see section 2.4.4). Results are shown in the following break even graphs.

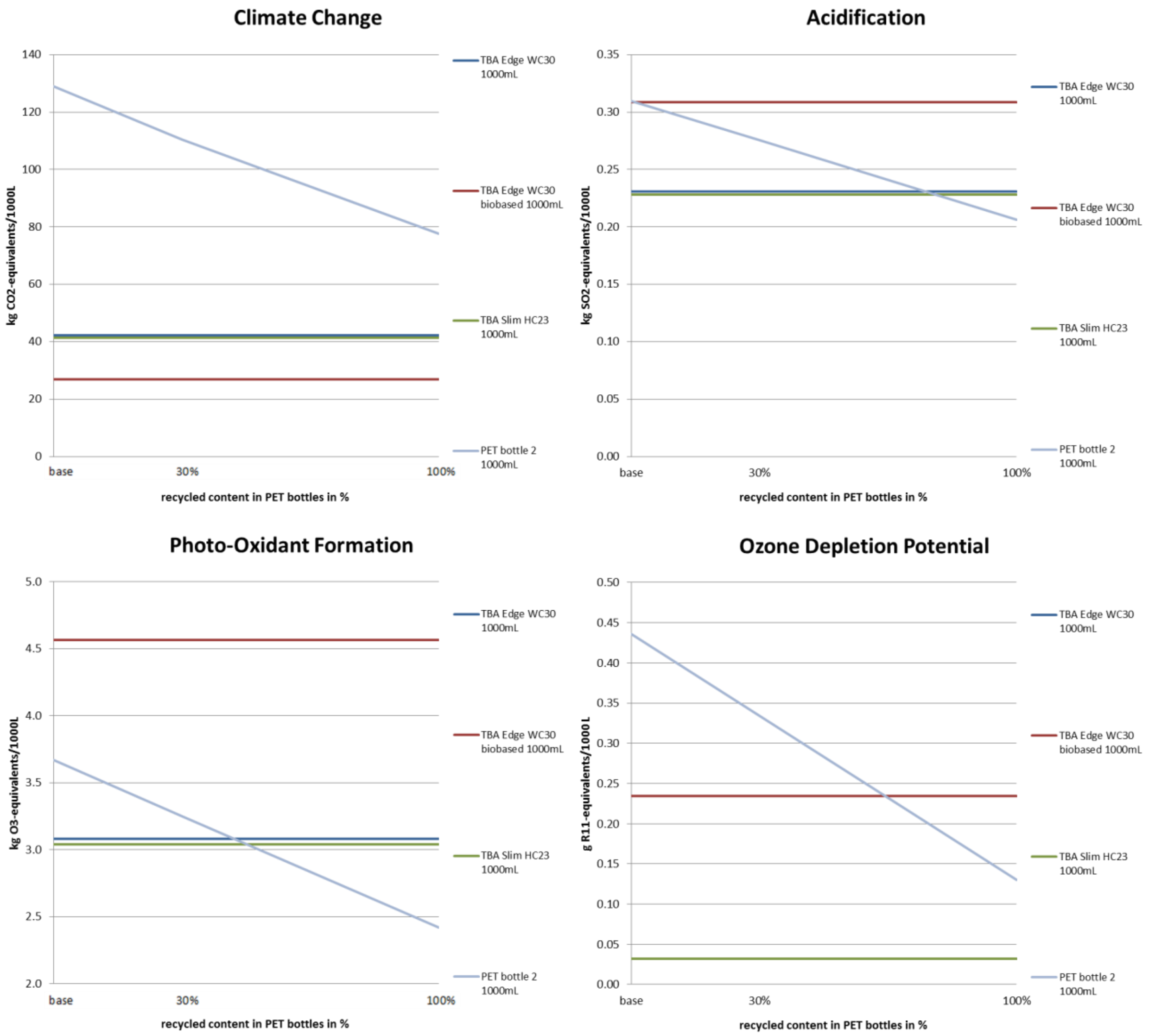


Figure 139: Indicator results for sensitivity analysis recycled PET of **segment JN Family Pack, Switzerland**, allocation factor 50% (Part 1)

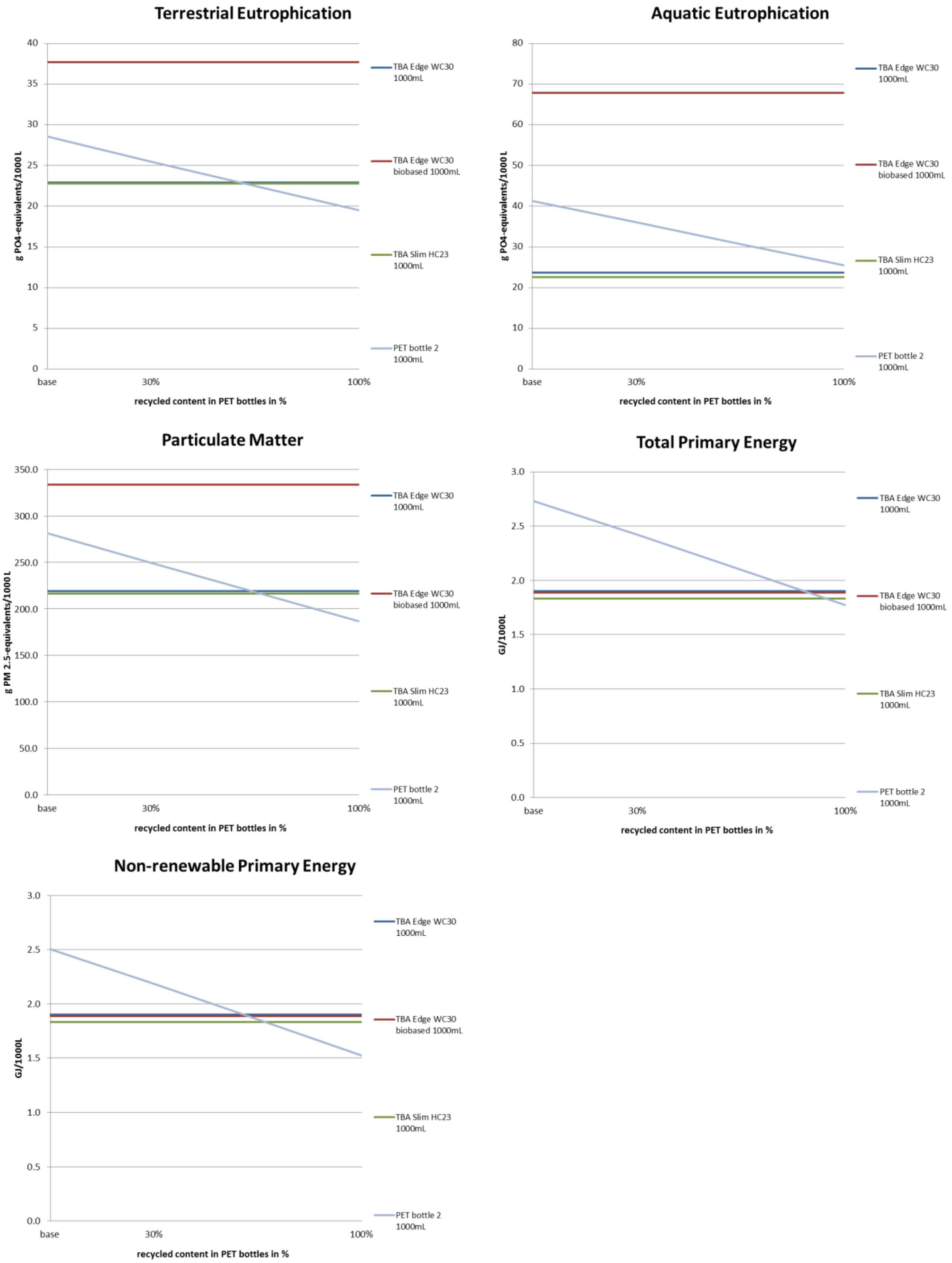


Figure 140: Indicator results for sensitivity analysis recycled PET of **segment JN Family Pack, Switzerland**, allocation factor 50% (Part 2)

Description and Interpretation

In most categories, the PET bottle with an increasing recycled content will break even with at least some beverage cartons. The exceptions is 'Climate Change', for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

9.3 SD FAMILY PACK SWITZERLAND

9.3.1 Sensitivity analysis on system allocation SD FAMILY PACK Switzerland

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

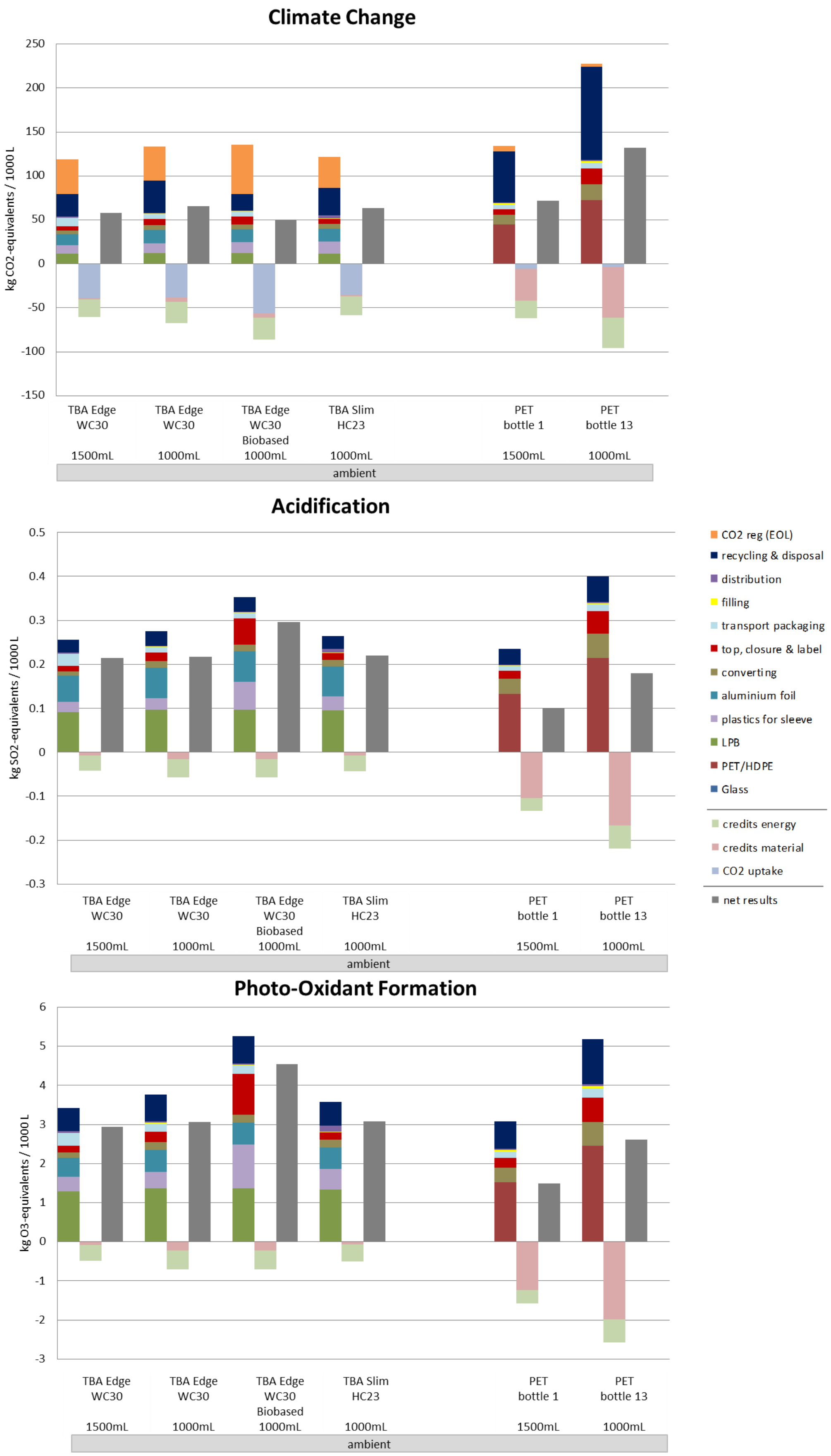


Figure 141: Indicator results on system allocation of **segment SD FAMILY PACK, Switzerland**, allocation factor 100% (Part 1)

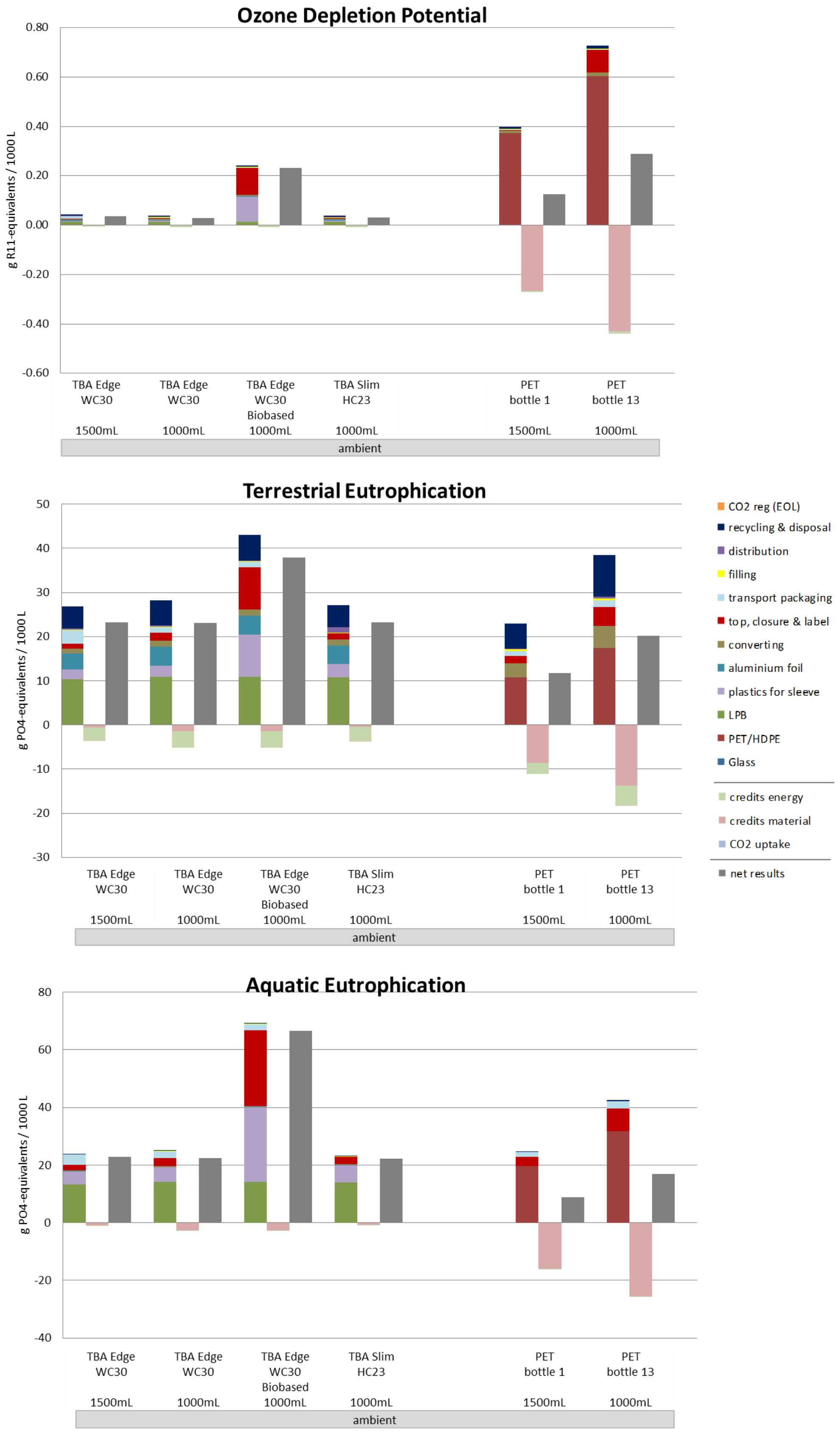


Figure 142: Indicator results on system allocation of **segment SD FAMILY PACK, Switzerland**, allocation factor 100% (Part 2)

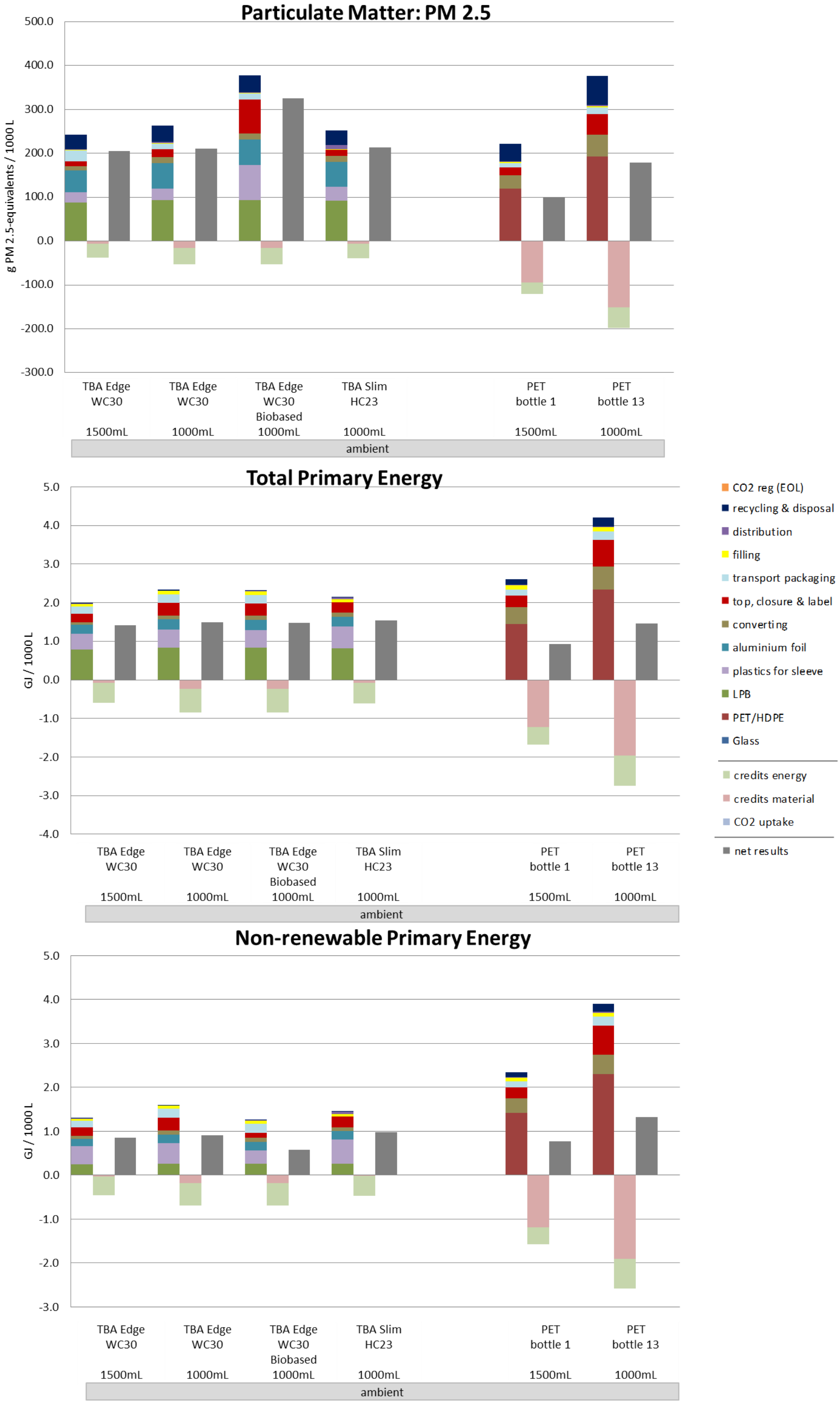


Figure 143: Indicator results on system allocation of segment SD FAMILY PACK, Switzerland, allocation factor 100% (Part 3)

Table 157: Category indicator results per impact category on system allocation of **segment SD FAMILY PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL		PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	79.52	94.70	79.55	86.21		128.10	224.27
	CO2 (reg)	39.01	38.38	56.15	35.72		5.84	3.43
	Credits	-21.40	-29.19	-29.22	-22.73		-56.16	-92.23
	CO2 uptake	-39.13	-38.52	-56.60	-35.85		-5.84	-3.43
	net results	58.00	65.37	49.88	63.35		71.94	132.04
Acidification [kg SO2-e/1000 L[	Burdens	0.26	0.28	0.35	0.26		0.23	0.40
	Credits	-0.04	-0.06	-0.06	-0.04		-0.13	-0.22
	Net results	0.21	0.22	0.30	0.22		0.10	0.18
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	3.43	3.77	5.25	3.58		3.08	5.19
	Credits	-0.48	-0.71	-0.71	-0.50		-1.58	-2.58
	Net results	2.94	3.06	4.54	3.08		1.49	2.61
Ozone Depletion [g R11/1000 L]	Burdens	0.04	0.04	0.24	0.04		0.40	0.73
	Credits	-0.01	-0.01	-0.01	-0.01		-0.27	-0.44
	Net results	0.04	0.03	0.23	0.03		0.13	0.29
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	26.83	28.26	43.04	27.13		22.92	38.51
	Credits	-3.66	-5.14	-5.15	-3.85		-11.20	-18.31
	Net results	23.17	23.12	37.89	23.28		11.73	20.19
Aquatic Eutrophication [g PO4/1000 L]	Burdens	23.75	24.96	69.17	22.96		24.82	42.60
	Credits	-0.88	-2.57	-2.57	-0.78		-16.05	-25.71
	Net results	22.87	22.39	66.60	22.18		8.77	16.89
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	242.72	263.41	377.63	252.11		221.59	376.15
	Credits	-37.23	-52.36	-52.41	-39.14		-121.07	-197.82
	Net results	205.49	211.05	325.23	212.97		100.51	178.33
Total Primary Energy [GJ]	Burdens	2.00	2.33	2.32	2.14		2.60	4.21
	Credits	-0.59	-0.85	-0.85	-0.61		-1.68	-2.75
	Net results	1.41	1.48	1.47	1.53		0.92	1.46
Non-renewable Primary Energy [GJ]	Burdens	1.31	1.60	1.26	1.45		2.34	3.90
	Credits	-0.46	-0.69	-0.69	-0.48		-1.58	-2.58
	Net results	0.85	0.91	0.57	0.97		0.76	1.31
Use of Nature [m²*year]	Burdens	21.07	20.72	33.89	20.27		0.51	0.51
	Credits	-0.97	-1.08	-1.08	-1.01		-0.04	-0.06
	Net results	20.09	19.64	32.81	19.27		0.47	0.45
Water use [m³/1000 L]	water cool	0.90	1.05	1.08	1.03		1.64	2.41
	water process	2.04	2.24	2.23	2.13		0.12	0.17
	water unspecified	0.68	0.62	0.75	0.61		0.21	0.46

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 regarded system.

In the cases of beverage cartons in the Swiss segment SD FAMILY PACK applying the allocation factor 100% instead of 50% leads to similar net results in almost all impact categories. This is because the absolute value of the credits is similar than that of the burdens from recycling and disposal regardless of the allocation factor. In case of 'Climate Change' applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of plastic bottles in this segment, applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories as the additionally allocated credits and burdens show lower or similar absolute values. The exception is 'Climate Change'. For 'Climate Change' net results increase slightly when applying the 100% allocation factor as burdens from incineration are higher than energy and material credits.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging

systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 158: Comparison of net results: **TBA Edge WC30 1500mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, allocation factor 100%

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1500mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	-11%	16%	-8%	-19%	-56%
Acidification	-2%	-28%	-3%	113%	19%
Photo-Oxidant Formation	-4%	-35%	-4%	97%	13%
Ozone Depletion Potential	21%	-85%	16%	-72%	-88%
Terrestrial Eutrophication	0%	-39%	0%	98%	15%
Aquatic Eutrophication	2%	-66%	3%	161%	35%
Particulate Matter	-3%	-37%	-4%	104%	15%

Table 159: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, allocation factor 100%

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	13%	31%	3%	-9%	-50%
Acidification	2%	-26%	-1%	117%	21%
Photo-Oxidant Formation	4%	-33%	-1%	105%	17%
Ozone Depletion Potential	-18%	-87%	-4%	-77%	-90%
Terrestrial Eutrophication	0%	-39%	-1%	97%	14%
Aquatic Eutrophication	-2%	-66%	1%	155%	33%
Particulate Matter	3%	-35%	-1%	110%	18%

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

Table 160: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, allocation factor 100%

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	-14%	-24%	-21%	-31%	-62%
Acidification	38%	36%	34%	194%	64%
Photo-Oxidant Formation	54%	49%	47%	204%	74%
Ozone Depletion Potential	558%	698%	663%	84%	-19%
Terrestrial Eutrophication	64%	64%	63%	223%	88%
Aquatic Eutrophication	191%	197%	200%	659%	294%
Particulate Matter	58%	54%	53%	224%	82%

Table 161: Comparison of net results: **TBA Slim HC30 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, allocation factor 100%

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Slim HC23 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	9%	-3%	27%	-12%	-52%
Acidification	3%	1%	-25%	119%	22%
Photo-Oxidant Formation	5%	1%	-32%	106%	18%
Ozone Depletion Potential	-14%	5%	-87%	-76%	-89%
Terrestrial Eutrophication	0%	1%	-39%	99%	15%
Aquatic Eutrophication	-3%	-1%	-67%	153%	31%
Particulate Matter	4%	1%	-35%	112%	19%

9.3.2 Sensitivity analysis regarding the consideration of regenerative carbon

To illustrate the effect of the choice the consideration of regenerative carbon has on the results of the environmental impact category 'Climate Change' while allocation factor of 50% is applied, a sensitivity analysis in which neither uptake nor emissions of regenerative carbon is considered, is conducted. In the following graphs the results of this sensitivity analysis is presented.

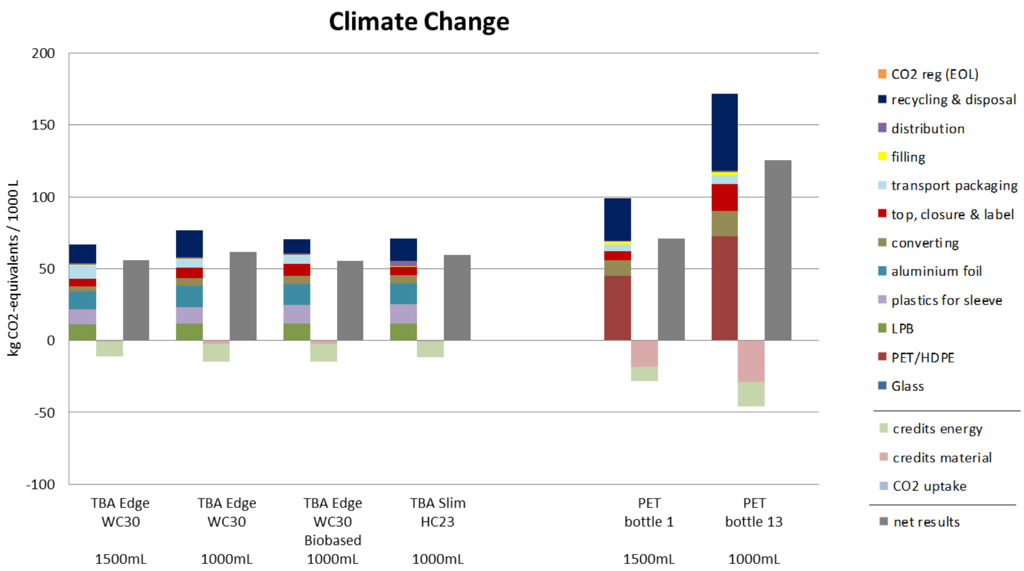


Figure 144: Indicator results 'Climate Change' of **segment SD FAMILY PACK, Switzerland**, regenerative carbon (Part 1)

Table 162: Category indicator results for 'Climate Change' for sensitivity on regenerative carbon of **segment SD FAMILY PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L. (All figures are rounded to two decimal places.)

Allocation 50		TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL		PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change [kg CO2-e/1000 L[	Burdens	67.06	76.52	70.22	70.94		99.24	171.85
	CO2 (reg)	0.00	0.00	0.00	0.00		0.00	0.00
	Credits	-10.93	-14.82	-14.84	-11.60		-28.07	-46.10
	CO2 uptake	0.00	0.00	0.00	0.00		0.00	0.00
	net results	56.13	61.70	55.39	59.34		71.17	125.76

Description and interpretation

The non-consideration of regenerative carbon leads to lower burdens as the regenerative CO2 emissions, which are allocated in the base scenario (50%) are no longer considered. As the uptake which is not allocated in the base scenario is also not considered anymore, the net results increase for all packaging systems. The effect is significantly higher for the beverage cartons as they contain much more bio-based material than the plastic bottle (only in label and secondary/tertiary packaging). Nevertheless Climate Change results of all beverage cartons are still significantly lower than the PET bottles, as shown in the tables of the following section.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for 'Climate Change' compared to those of the other regarded packaging system 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 163: Comparison of net results: **TBA Edge WC30 1500mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, regenerative carbon

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1500mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	-9%	1%	-5%	-21%	-55%

Table 164: Comparison of net results: **TBA Edge WC30 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, regenerative carbon

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 biobased 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	10%	11%	4%	-13%	-51%

Table 165: Comparison of net results: **TBA Edge WC30 biobased 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, regenerative carbon

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Edge WC30 biobased 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Slim HC23 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	-1%	-10%	-7%	-22%	-56%

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

Table 166: Comparison of net results: **TBA Slim HC30 1000mL** versus competing carton based and alternative packaging systems in **segment SD Family Pack (ambient), Switzerland**, regenerative carbon

SD FAMILY PACK (ambient), Switzerland	The net results of **TBA Slim HC23 1000mL** are lower (green)/ higher (orange) than those of				
	TBA Edge WC30 1500mL	TBA Edge WC30 1000mL	TBA Edge WC30 biobased 1000mL	PET bottle 1 1500mL	PET bottle 13 1000mL
Climate Change	6%	-4%	7%	-17%	-53%

9.3.3 Sensitivity analysis regarding recycled PET in PET bottles

To consider potential future developments in terms of the share of recyclate of the plastic bottles, two additional scenarios for plastic bottles with a recycled content of PET of 30% and 100% are analysed and illustrated in this sensitivity analysis (for details please see section 2.4.4). Results are shown in the following break even graphs.

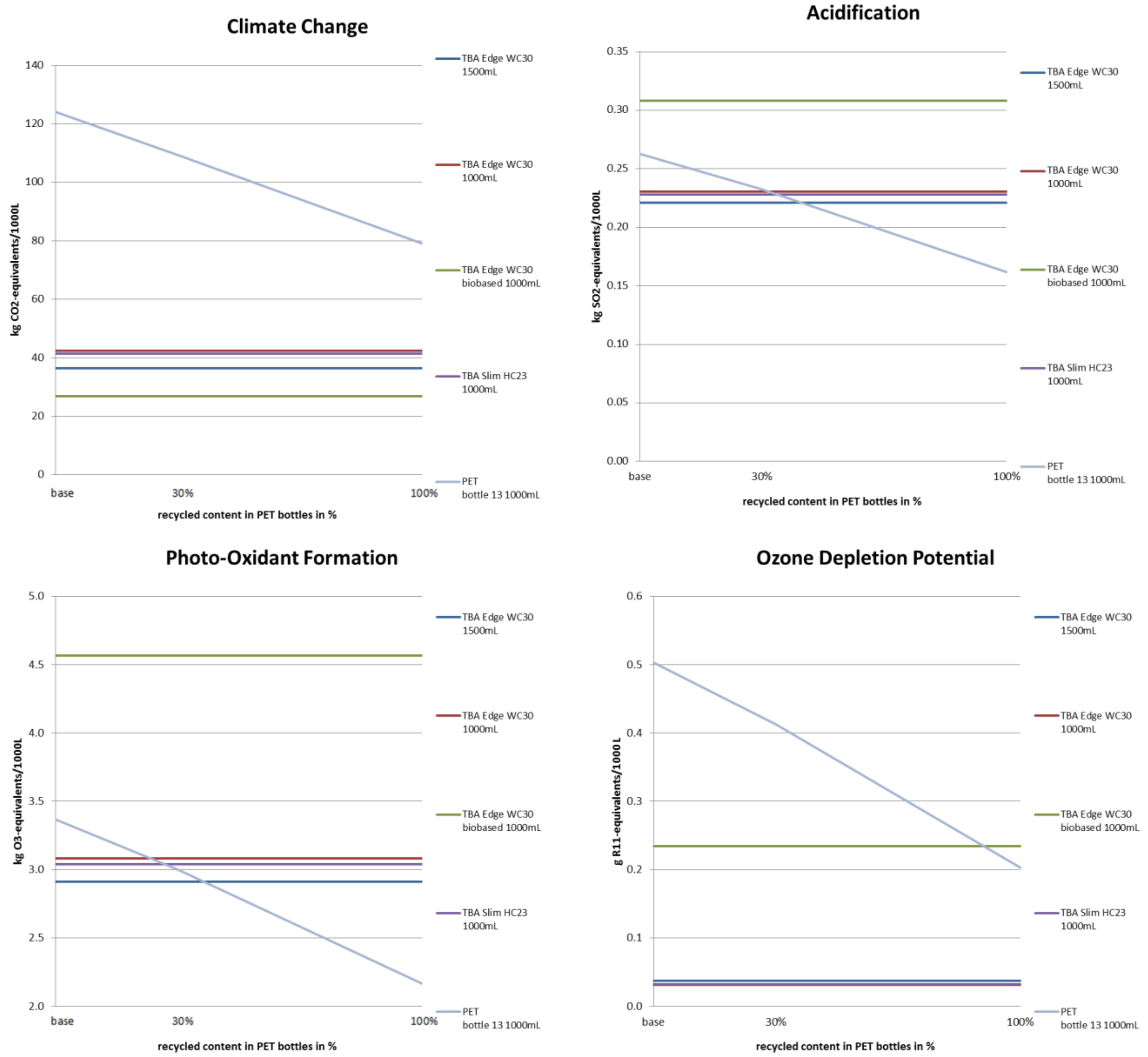


Figure 145: Indicator results for sensitivity analysis recycled PET of **segment SD Family Pack, Switzerland**, allocation factor 50% (Part 1)

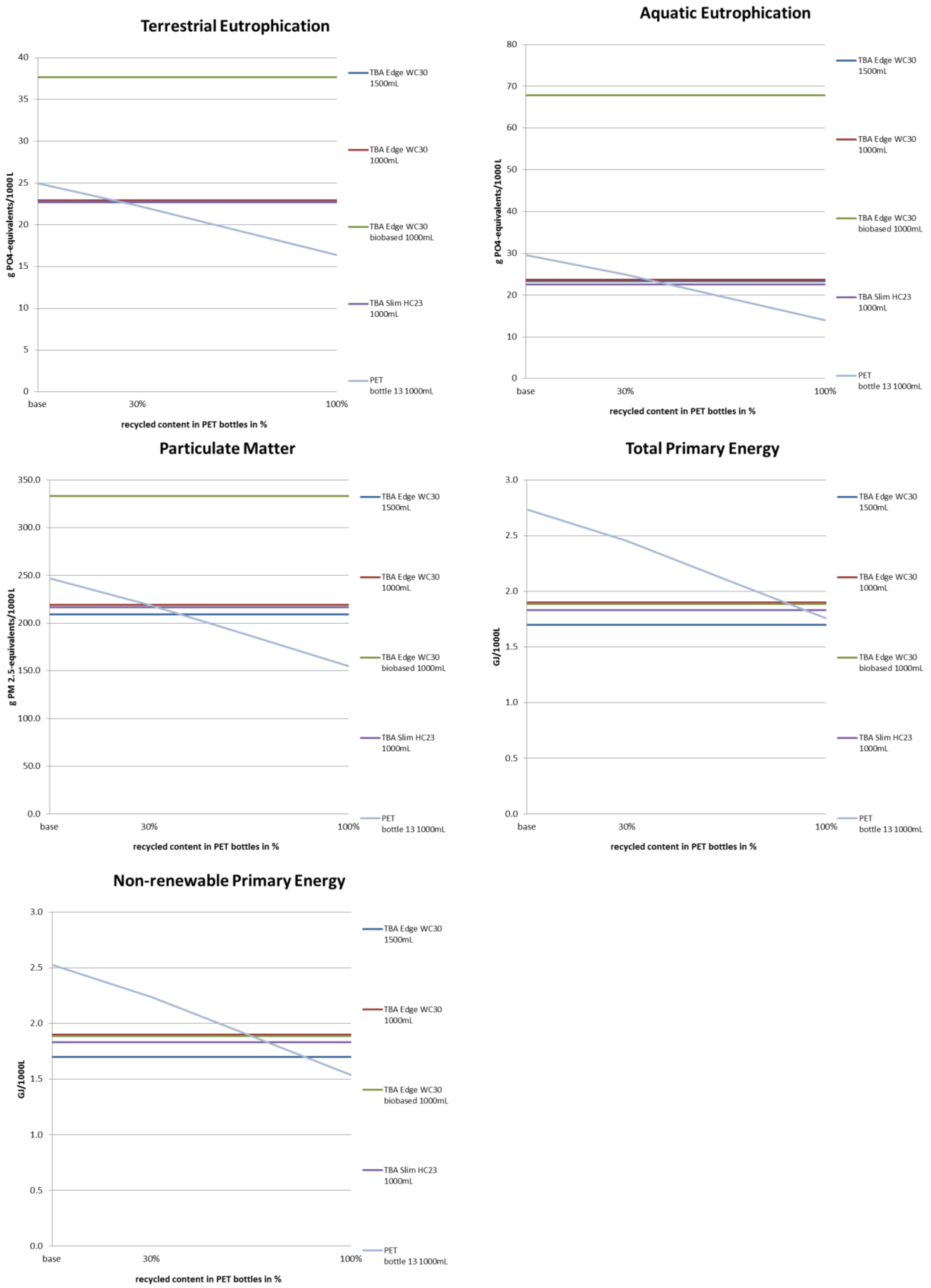


Figure 146: Indicator results for sensitivity analysis recycled PET of **segment SD Family Pack, Switzerland**, allocation factor 50% (Part 2)

Description and Interpretation

In most categories, the PET bottle with an increasing recycled content will break even with at least some beverage cartons. The exceptions is 'Climate Change', for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

9.4 DAIRY PORTION PACK SWITZERLAND

9.4.1 Sensitivity analysis on system allocation DAIRY PORTION PACK Switzerland

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

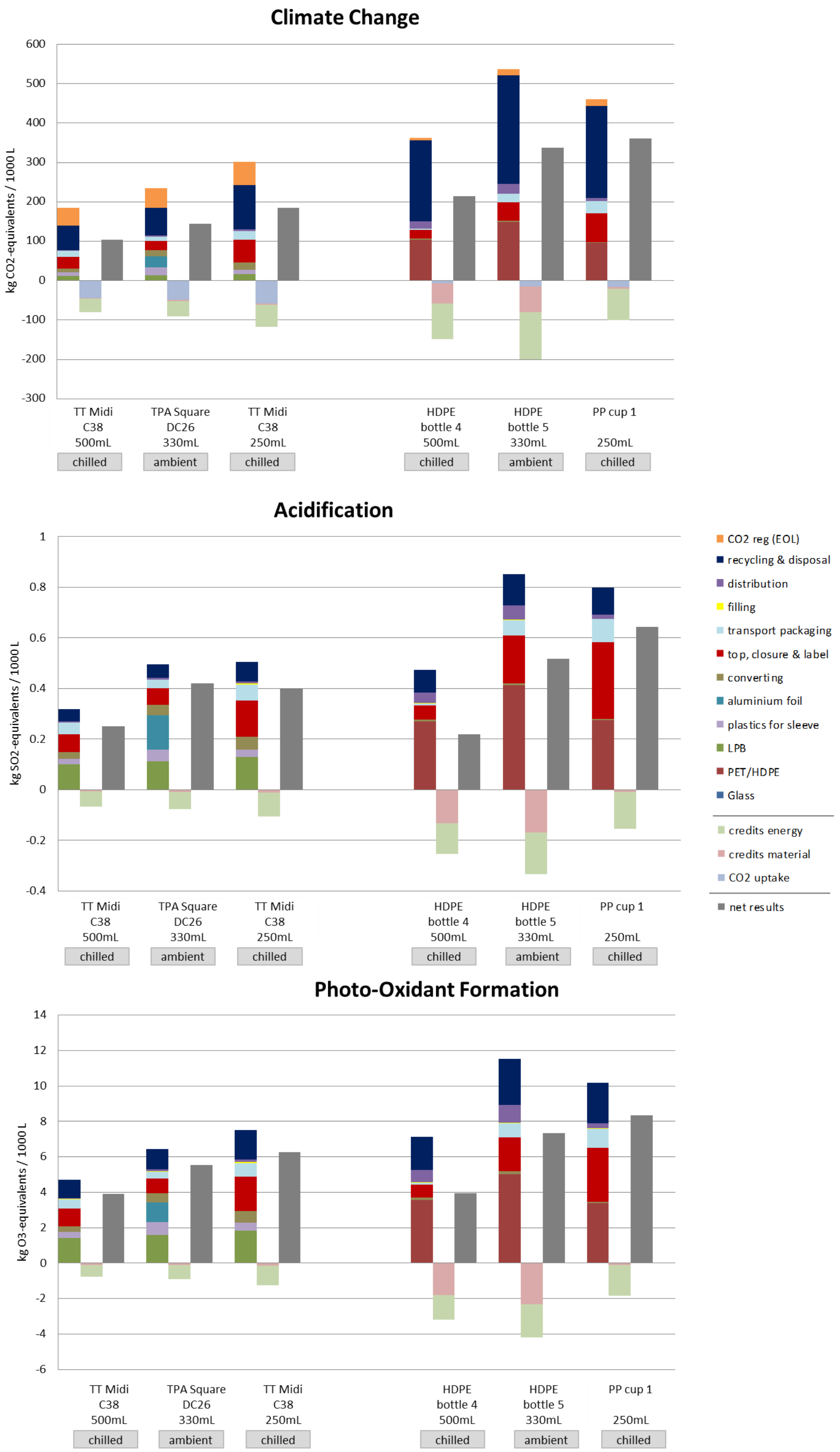


Figure 147: Indicator results on system allocation of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 100% (Part 1)

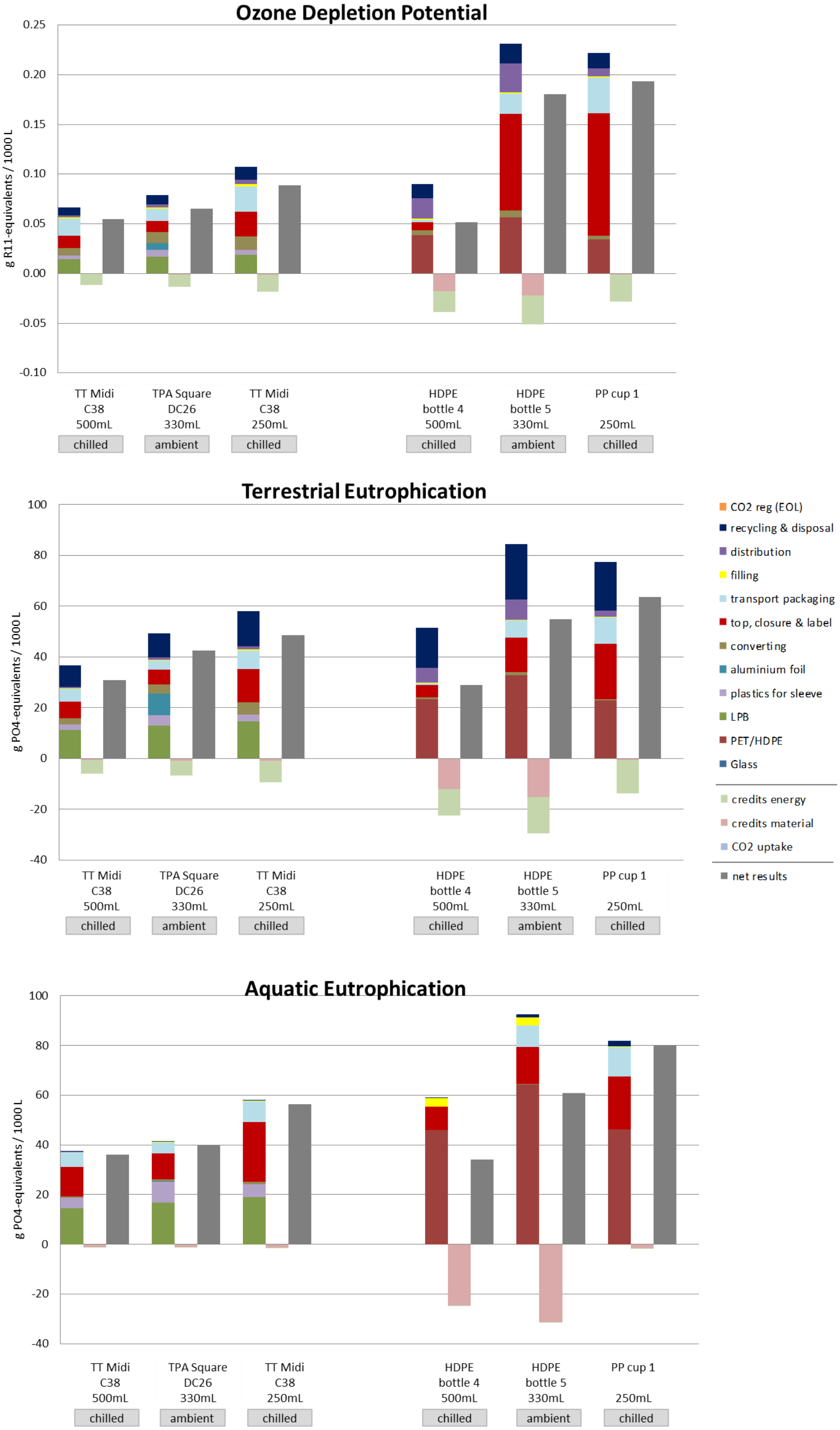


Figure 148 Indicator results for on system allocation of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 100% (Part 2)

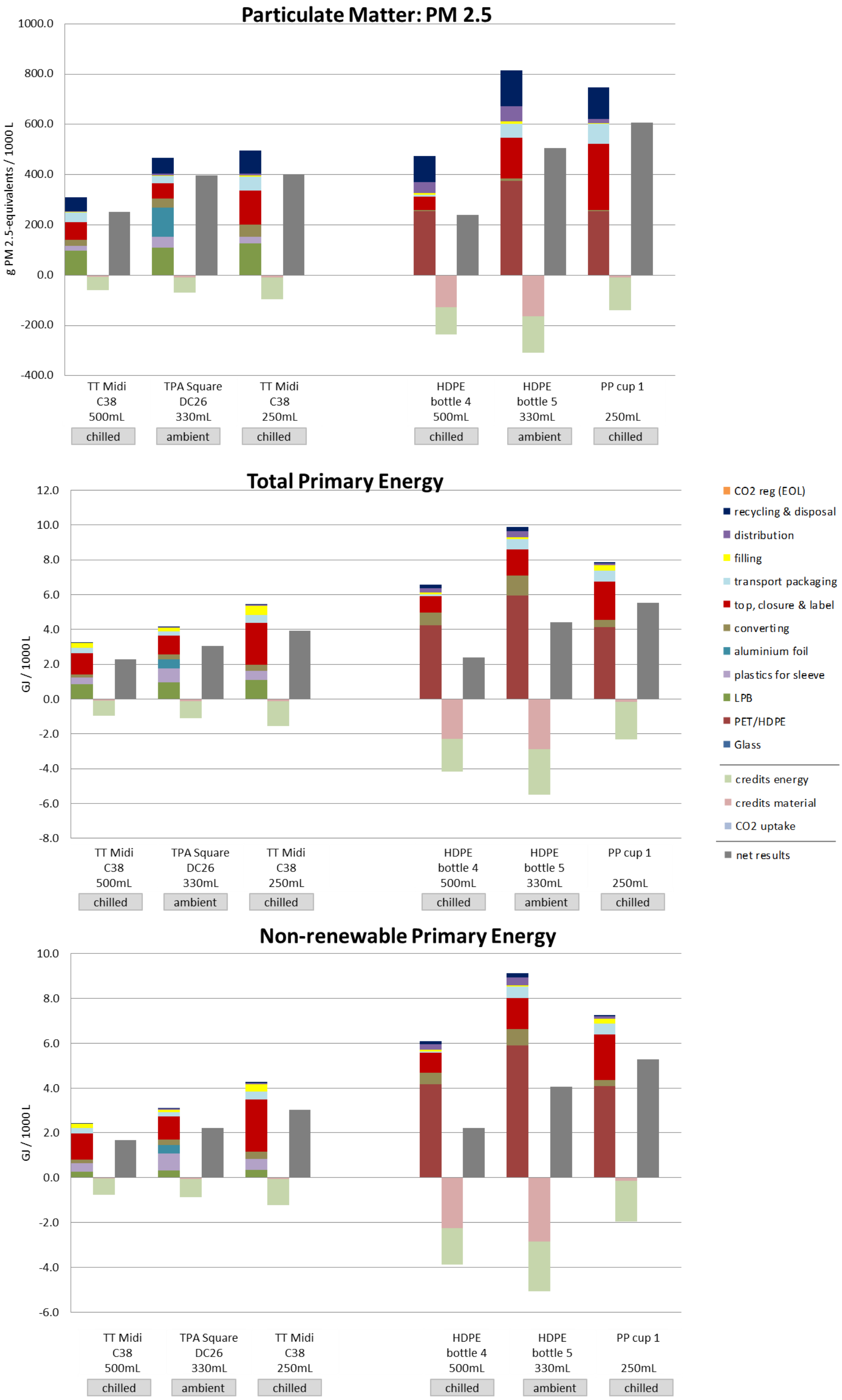


Figure 149: Indicator results on system allocation of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 100% (Part 3)

Table 167: Category indicator results per impact category for sensitivity analysis on system allocation scenarios of **segment DAIRY PORTION PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TT Midi C38 500mL	TPA Square DC26 330mL	TT Midi C38 250mL		HDPE bottle 4 500mL	HDPE bottle 5 330mL	PP cup 1 250mL
Climate Change [kg CO2-e/1000 L[	Burdens	140.00	185.46	242.75		355.85	522.02	443.98
	CO2 (reg)	44.59	49.29	58.58		7.21	15.14	16.66
	Credits	-35.93	-40.68	-57.78		-141.57	-185.18	-83.59
	CO2 uptake	-44.73	-49.43	-58.76		-7.21	-15.14	-16.66
	net results	103.93	144.63	184.79		214.28	336.84	360.39
Acidification [kg SO2-e/1000 L[	Burdens	0.32	0.50	0.51		0.47	0.85	0.80
	Credits	-0.07	-0.08	-0.11		-0.25	-0.33	-0.15
	Net results	0.25	0.42	0.40		0.22	0.52	0.64
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	4.71	6.44	7.50		7.14	11.52	10.16
	Credits	-0.78	-0.90	-1.24		-3.19	-4.19	-1.83
	Net results	3.93	5.55	6.26		3.95	7.32	8.34
Ozone Depletion [g R11/1000 L]	Burdens	0.07	0.08	0.11		0.09	0.23	0.22
	Credits	-0.01	-0.01	-0.02		-0.04	-0.05	-0.03
	Net results	0.05	0.07	0.09		0.05	0.18	0.19
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	36.66	49.31	57.87		51.35	84.40	77.26
	Credits	-5.92	-6.79	-9.41		-22.46	-29.51	-13.83
	Net results	30.74	42.53	48.46		28.89	54.90	63.43
Aquatic Eutrophication [g PO4/1000 L]	Burdens	37.16	41.16	57.79		58.85	92.39	81.80
	Credits	-1.13	-1.28	-1.56		-24.81	-31.53	-1.68
	Net results	36.03	39.87	56.23		34.04	60.85	80.13
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	311.20	466.12	495.81		473.78	814.31	746.08
	Credits	-59.72	-68.85	-94.75		-234.77	-308.24	-138.77
	Net results	251.48	397.27	401.06		239.02	506.07	607.31
Total Primary Energy [GJ]	Burdens	3.26	4.16	5.46		6.56	9.88	7.85
	Credits	-0.97	-1.09	-1.54		-4.18	-5.48	-2.32
	Net results	2.30	3.07	3.92		2.38	4.41	5.53
Non-renewable Primary Energy [GJ]	Burdens	2.44	3.10	4.27		6.09	9.12	7.24
	Credits	-0.77	-0.88	-1.24		-3.88	-5.06	-1.95
	Net results	1.67	2.23	3.03		2.21	4.06	5.29
Use of Nature [m²*year]	Burdens	24.16	26.70	32.02		0.50	3.31	5.76
	Credits	-1.15	-1.20	-1.49		-0.16	-0.21	-0.10
	Net results	23.01	25.50	30.52		0.34	3.10	5.67
Water use [m³/1000 L]	water cool	1.92	2.27	3.45		2.43	3.80	2.70
	water process	2.00	2.84	2.67		1.99	2.29	0.73
	water unspecified	0.71	1.38	1.13		0.66	1.54	2.15

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 regarded system.

In the cases of beverage cartons in the Swiss segment DAIRY PORTION PACK applying the allocation factor 100% instead of 50% leads to similar net results in almost all impact categories. This is because the absolute value of the credits is similar than that of the burdens from recycling and disposal regardless of the allocation factor. In case of 'Climate Change' applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of plastic bottles in this segment applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories as the additionally allocated credits and burdens show lower absolute values. The exception is 'Climate Change'. For 'Climate Change' net results increase when applying the 100% allocation factor as burdens from incineration are higher than energy and material credits.

In the cases of the PP cup in this segment applying the allocation factor 100% instead of 50% leads to similar net results in almost all impact categories as the additionally allocated credits and burdens show similar absolute values. The exception is 'Climate Change'. For 'Climate Change' net results increase when applying the 100% allocation factor as burdens from incineration are higher than energy and material credits.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons, plastic bottles and the PP cup in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

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

Table 168: Comparison of net results: **TT Midi C38 500mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (chilled), Switzerland**, allocation factor 100%

DAIRY PORTION PACK (chilled), Switzerland	The net results of **TT Midi C38 500mL** are lower (green)/ higher (orange) than those of		
	TT Midi C38 250mL	HDPE bottle 4 500mL	PP cup 1 250mL
Climate Change	-44%	-51%	-71%
Acidification	-37%	15%	-61%
Photo-Oxidant Formation	-37%	-1%	-53%
Ozone Depletion Potential	-38%	7%	-72%
Terrestrial Eutrophication	-37%	6%	-52%
Aquatic Eutrophication	-36%	6%	-55%
Particulate Matter	-37%	5%	-59%

Table 169: Comparison of net results: **TT Midi C38 250mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (chilled), Switzerland**, allocation factor 100%

DAIRY PORTION PACK (chilled), Switzerland	The net results of **TT Midi C38 250mL** are lower (green)/ higher (orange) than those of		
	TT Midi C38 500mL	HDPE bottle 4 500mL	PP cup 1 250mL
Climate Change	78%	-14%	-49%
Acidification	59%	83%	-38%
Photo-Oxidant Formation	59%	58%	-25%
Ozone Depletion Potential	62%	72%	-54%
Terrestrial Eutrophication	58%	68%	-24%
Aquatic Eutrophication	56%	65%	-30%
Particulate Matter	59%	68%	-34%

Table 170: Comparison of net results: **TPA Square DC26 330mL** versus competing carton based and alternative packaging systems in **segment DAIRY Portion Pack (ambient), Switzerland**, allocation factor 100%

DAIRY PORTION PACK (ambient), Switzerland	The net results of **TPA Square DC26 330mL** are lower (green)/ higher (orange) than those of
	HDPE bottle 5 330mL
Climate Change	-57%
Acidification	-19%
Photo-Oxidant Formation	-24%
Ozone Depletion Potential	-64%
Terrestrial Eutrophication	-23%
Aquatic Eutrophication	-34%
Particulate Matter	-21%

9.5 SD PORTION PACK SWITZERLAND

9.5.1 Sensitivity analysis on system allocation SD PORTION PACK Switzerland

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard’s recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

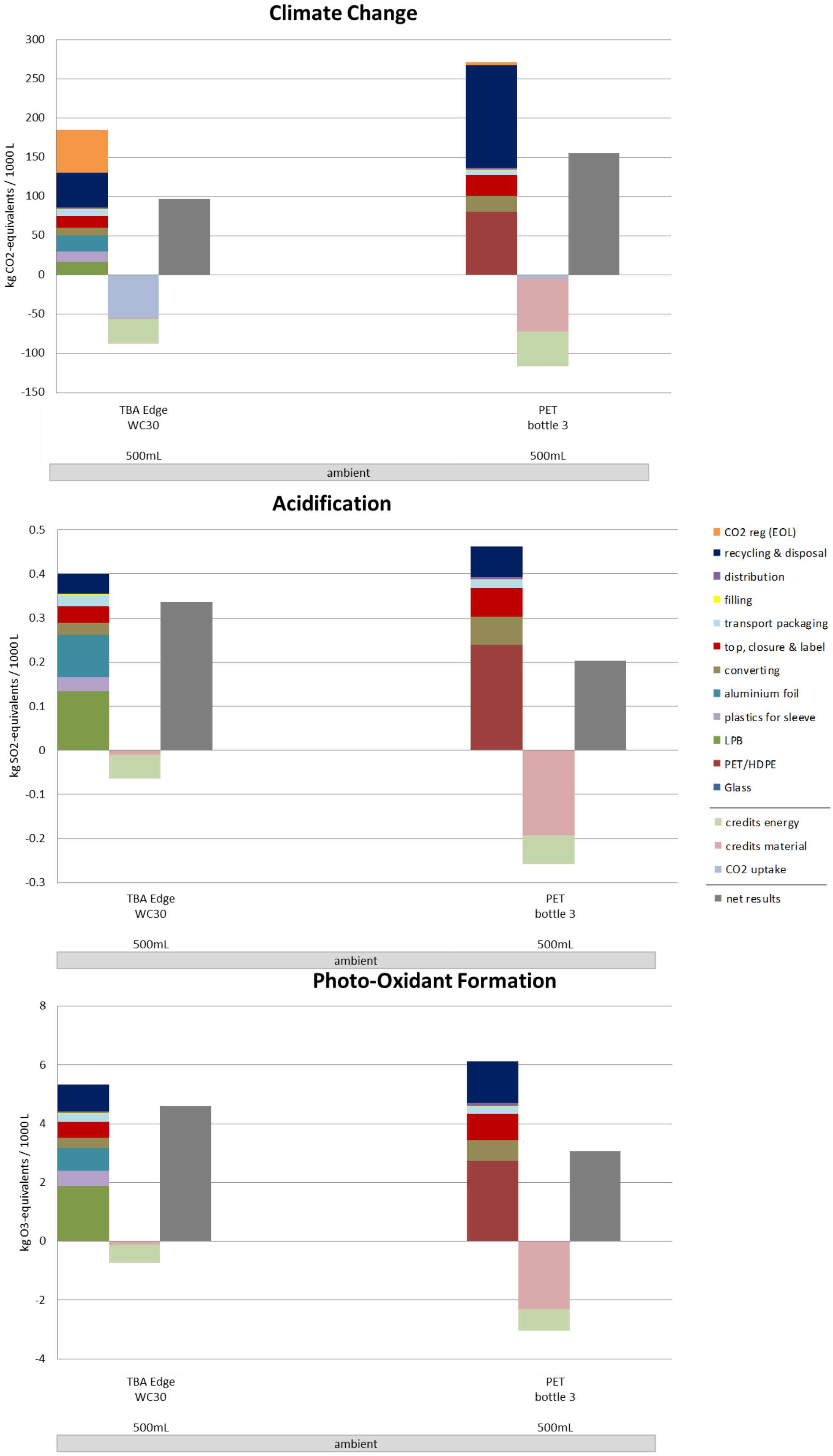
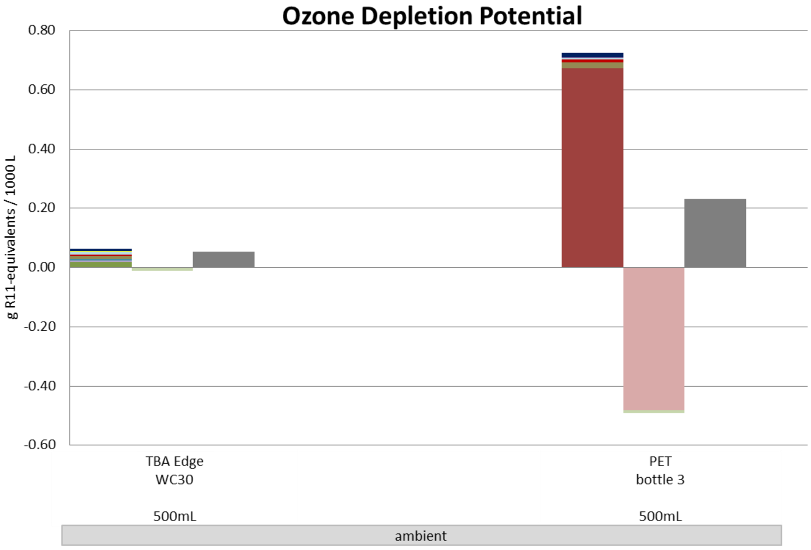
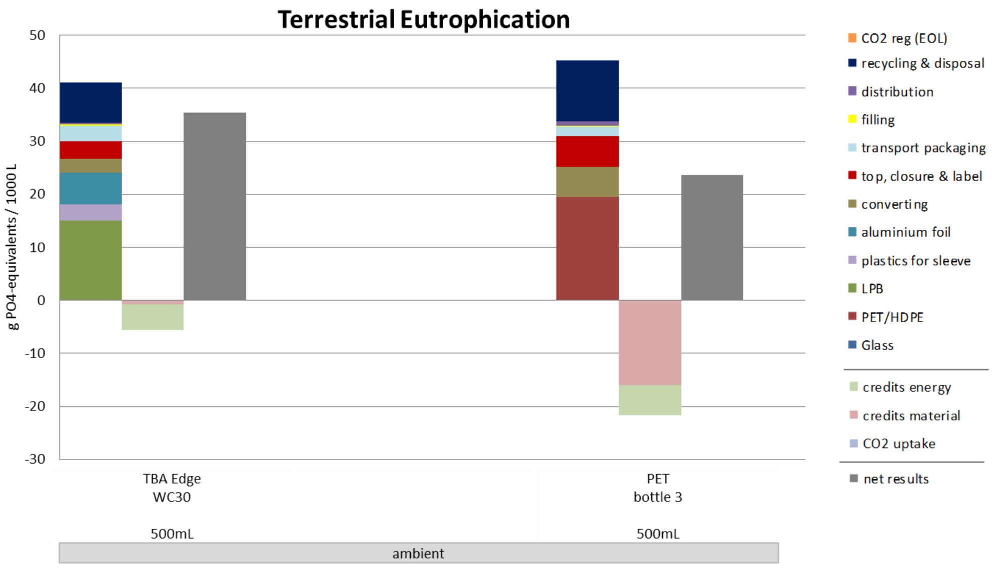


Figure 150: Indicator results on system allocation of segment SD PORTION PACK, Switzerland, allocation factor 100% (Part 1)





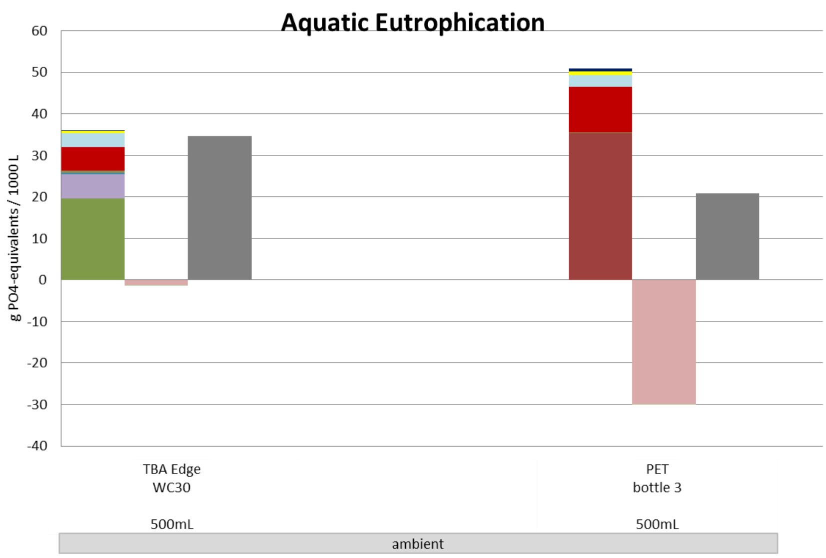


Figure 151 Indicator results on system allocation of **segment SD PORTION PACK, Switzerland**, allocation factor 100% (Part 2)

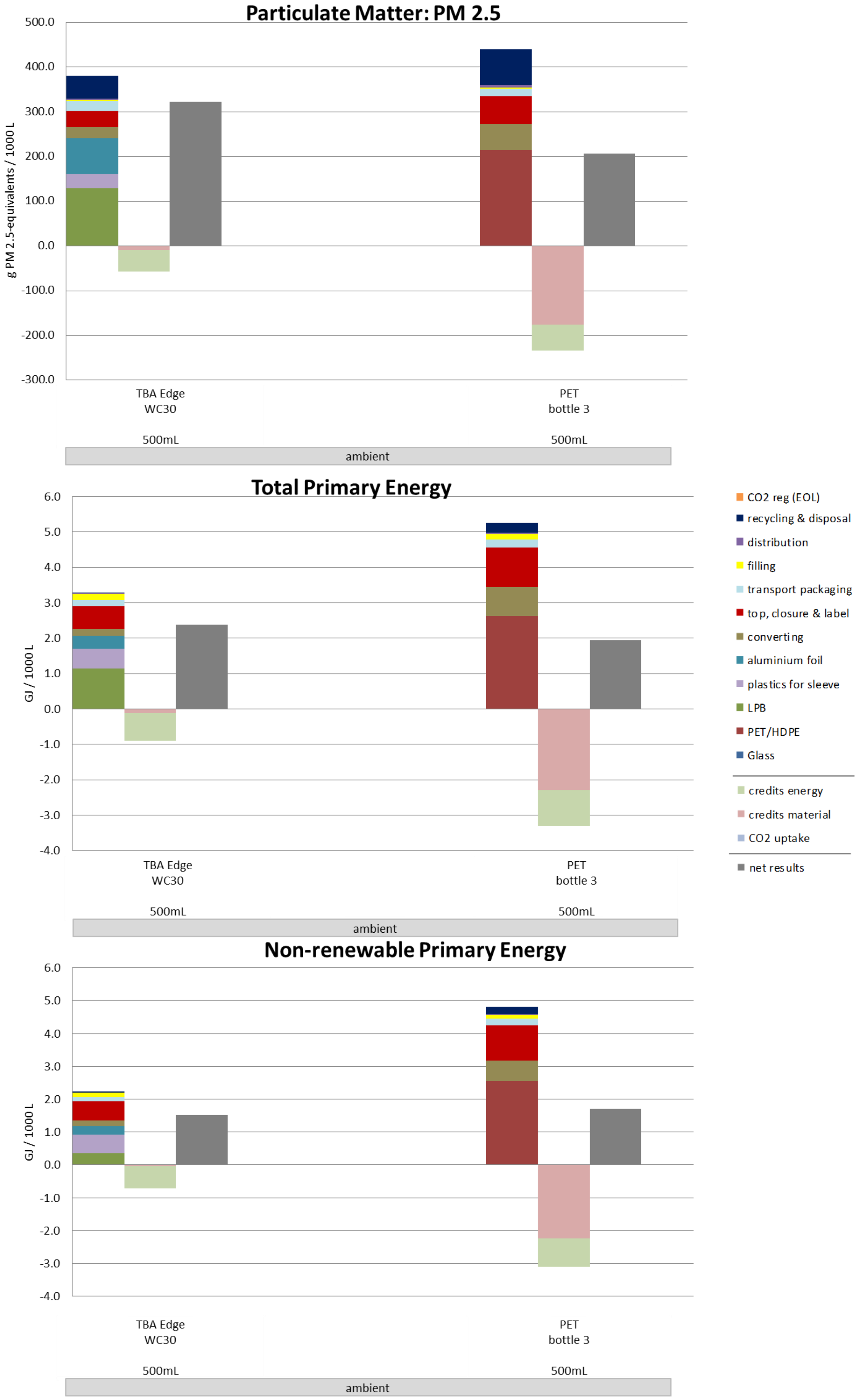


Figure 152: Indicator results on system allocation of **segment SD PORTION PACK, Switzerland**, allocation factor 100% (Part 3)

Table 171: Category indicator results per impact category on system allocation of **segment SD PORTION PACK, Switzerland**- burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TBA Edge WC30 500mL		PET bottle 3 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	130.67		267.54
	CO2 (reg)	54.51		4.15
	Credits	-33.09		-111.95
	CO2 uptake	-54.69		-4.15
	net results	97.41		155.59
Acidification [kg SO2-e/1000 L[	Burdens	0.40		0.46
	Credits	-0.06		-0.26
	Net results	0.34		0.20
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.34		6.12
	Credits	-0.74		-3.05
	Net results	4.60		3.07
Ozone Depletion [g R11/1000 L]	Burdens	0.06		0.72
	Credits	-0.01		-0.49
	Net results	0.05		0.23
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	41.10		45.21
	Credits	-5.63		-21.64
	Net results	35.46		23.57
Aquatic Eutrophication [g PO4/1000 L]	Burdens	35.84		50.87
	Credits	-1.24		-29.93
	Net results	34.60		20.94
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	379.83		439.40
	Credits	-57.21		-233.36
	Net results	322.62		206.04
Total Primary Energy [GJ]	Burdens	3.29		5.25
	Credits	-0.90		-3.30
	Net results	2.38		1.95
Non-renewable Primary Energy [GJ]	Burdens	2.23		4.81
	Credits	-0.71		-3.10
	Net results	1.52		1.71
Use of Nature [m²*year]	Burdens	30.17		0.74
	Credits	-1.40		-0.07
	Net results	28.77		0.68
Water use [m³/1000 L]	water cool	1.83		3.16
	water process	3.22		0.67
	water unspecified	1.03		0.50

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 regarded system.

In the cases of the beverage carton in the Swiss segment SD FAMILY PACK applying the allocation factor 100% instead of 50% leads to similar net results in almost all impact categories. This is because the absolute value of the credits is lower or similar than that of the burdens from recycling and disposal regardless of the allocation factor. The exception is ‘Climate Change’. In case of ‘Climate Change’ applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don’t increase when applying the 100% allocation factor.

In the cases of the plastic bottle in this segment, applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories as the additionally allocated credits and burdens show lower or similar absolute values. The exception is ‘Climate Change’. For ‘Climate Change’ net results increase slightly when applying the 100% allocation factor as burdens from incineration are higher than energy and material credits.

For the inventory categories ‘Total Primary Energy’ and ‘Non-renewable Energy’ net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging

systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 172: Comparison of net results: **TBA Edge WC30 500mL** versus competing carton based and alternative packaging systems in **segment JN Family Pack (ambient), Switzerland**, allocation factor 100%

SD PORTION PACK (ambient), Switzerland	The net results of **TBA Edge WC30 500mL** are lower (green)/ higher (orange) than those of
	PET bottle 3 500mL
Climate Change	-37%
Acidification	65%
Photo-Oxidant Formation	50%
Ozone Depletion Potential	-77%
Terrestrial Eutrophication	50%
Aquatic Eutrophication	65%
Particulate Matter	57%

9.6 WATER PORTION PACK SWITZERLAND

9.6.1 Sensitivity analysis on system allocation WATER PORTION PACK Switzerland

In the base scenarios of this study open-loop allocation is performed with an allocation factor of 50%. Following the ISO standard's recommendation on subjective choices, this sensitivity analysis is conducted to verify the influence of the allocation method on the final results. For that purpose, an allocation factor of 100% is applied. The following graphs show the results of the sensitivity analysis on system allocation with an allocation factor of 100%.

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

Figure 153: Indicator results on system allocation of **segment WATER PORTION PACK, Switzerland**, allocation factor 100% (Part 1)

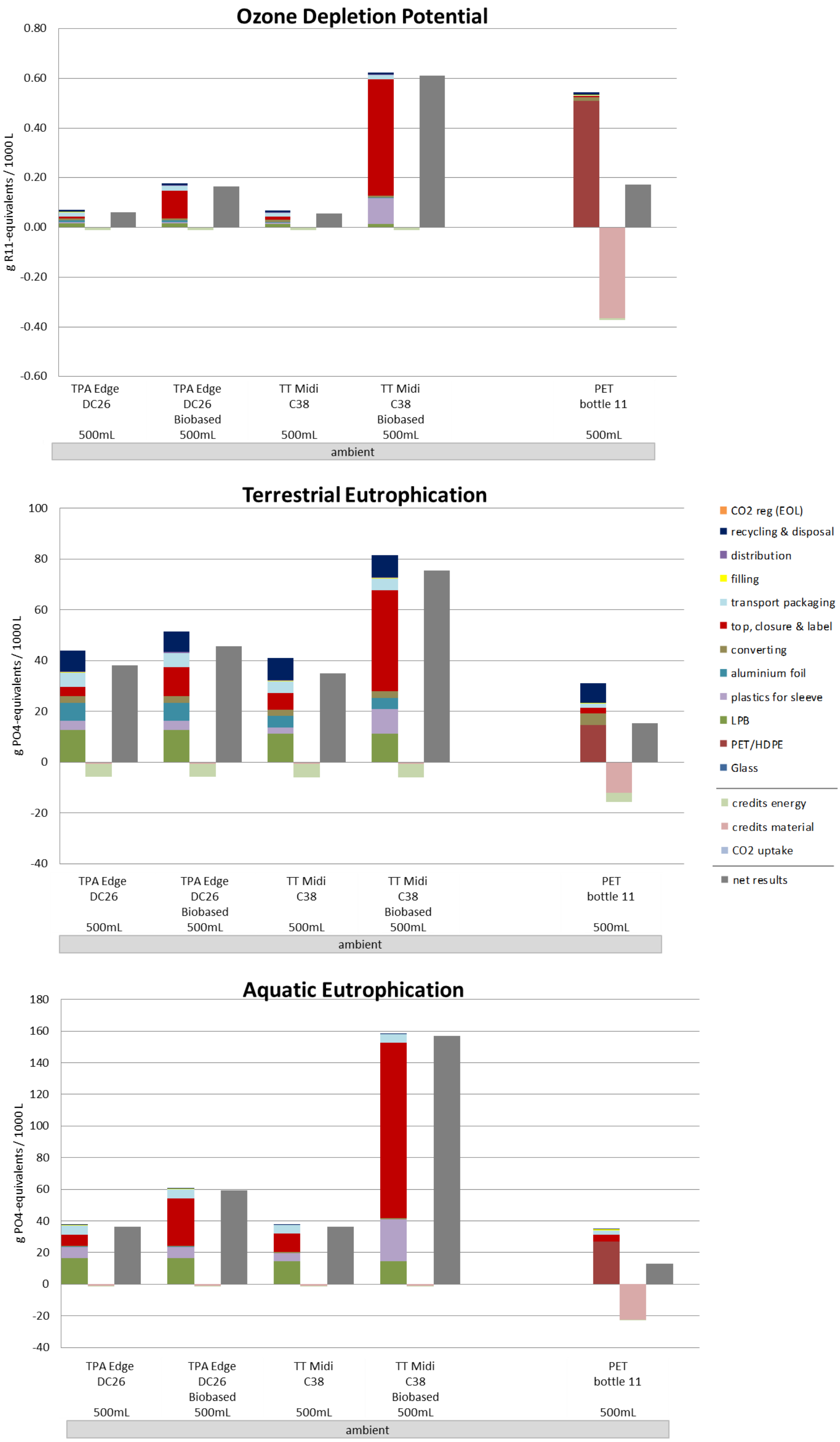


Figure 154: Indicator results on system allocation of segment WATER PORTION PACK, Switzerland, allocation factor 100% (Part 2)

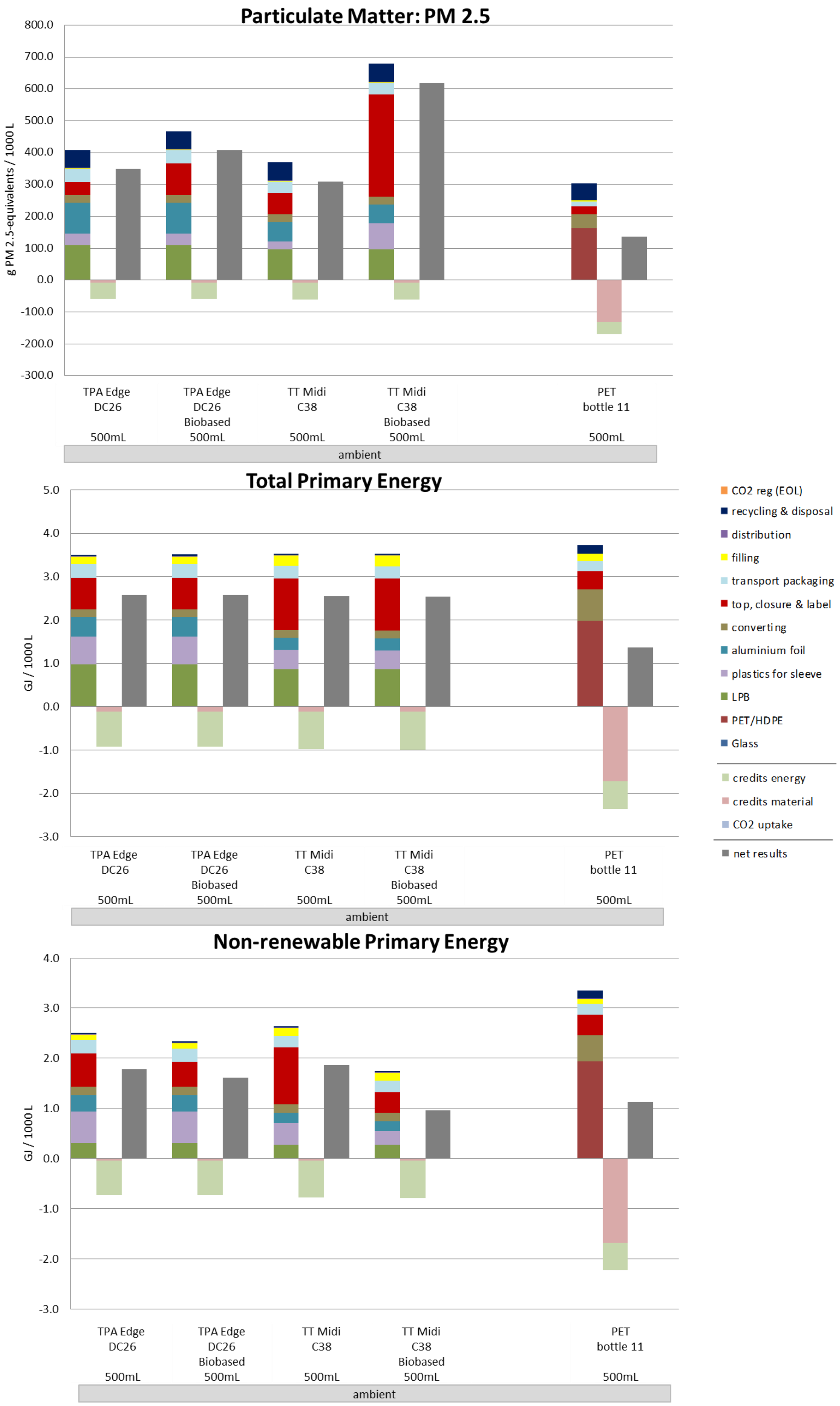


Figure 155: Indicator results on system allocation of **segment WATER PORTION PACK, Switzerland**, allocation factor 100% (Part 3)

Table 173: Category indicator results per impact category on system allocation of **segment WATER PORTION PACK, Switzerland** - burdens, credits and net results per functional unit of 1000 L, allocation factor 100% (All figures are rounded to two decimal places.)

Allocation 100		TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL		PET bottle 11 500mL
Climate Change [kg CO2-e/1000 L[	Burdens	150.82	143.13	155.52	115.87		179.24
	CO2 (reg)	49.33	58.61	44.09	91.14		3.28
	Credits	-34.20	-34.27	-36.87	-37.03		-78.72
	CO2 uptake	-49.48	-58.87	-44.23	-92.13		-3.28
	net results	116.47	108.61	118.51	77.85		100.53
Acidification [kg SO2-e/1000 L[	Burdens	0.43	0.47	0.39	0.59		0.32
	Credits	-0.07	-0.07	-0.07	-0.07		-0.19
	Net results	0.37	0.41	0.32	0.53		0.13
Photo-Oxidant Formation [kg O3 e/1000 L]	Burdens	5.61	6.41	5.31	9.47		4.18
	Credits	-0.76	-0.76	-0.80	-0.80		-2.21
	Net results	4.86	5.65	4.51	8.67		1.97
Ozone Depletion [g R11/1000 L]	Burdens	0.07	0.18	0.07	0.62		0.54
	Credits	-0.01	-0.01	-0.01	-0.01		-0.37
	Net results	0.06	0.17	0.06	0.61		0.17
Terrestrial Eutrophication [g PO4/1000 L]	Burdens	43.80	51.49	40.93	81.44		31.00
	Credits	-5.75	-5.76	-6.07	-6.10		-15.61
	Net results	38.05	45.73	34.86	75.34		15.39
Aquatic Eutrophication [g PO4/1000 L]	Burdens	37.55	60.52	37.37	158.08		35.18
	Credits	-1.15	-1.15	-1.15	-1.15		-22.41
	Net results	36.40	59.37	36.22	156.93		12.77
Particulate Matter [g PM 2.5-e/1000 L]	Burdens	407.46	466.11	370.28	680.07		304.24
	Credits	-58.44	-58.55	-61.59	-61.84		-168.71
	Net results	349.02	407.56	308.70	618.24		135.53
Total Primary Energy [GJ]	Burdens	3.51	3.51	3.53	3.52		3.73
	Credits	-0.92	-0.93	-0.98	-0.99		-2.35
	Net results	2.58	2.58	2.55	2.54		1.37
Non-renewable Primary Energy [GJ]	Burdens	2.51	2.34	2.64	1.75		3.35
	Credits	-0.73	-0.73	-0.78	-0.79		-2.22
	Net results	1.78	1.61	1.86	0.96		1.13
Use of Nature [m²*year]	Burdens	27.21	34.04	24.05	59.55		0.58
	Credits	-1.20	-1.20	-1.20	-1.20		-0.05
	Net results	26.01	32.84	22.85	58.35		0.53
Water use [m³/1000 L]	water cool	1.83	1.89	1.98	1.86		2.63
	water process	2.76	2.75	2.25	2.21		0.62
	water unspecified	1.26	1.32	1.06	1.14		0.32

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 regarded system.

In the cases of the beverage cartons in the Swiss segment WATER PORTION PACK applying the allocation factor 100% instead of 50% leads to similar net results in almost all impact categories. This is because the absolute value of the credits is lower or similar than that of the burdens from recycling and disposal regardless of the allocation factor. The exception is 'Climate Change'. In case of 'Climate Change' applying the allocation factor 100% instead of 50% leads to higher net results. This is because in this case the absolute value of the credits is lower than that of the burdens from recycling and disposal regardless of the allocation factor. Also the allocation factor is not applied for the CO2 uptake, therefore the values for the CO2 uptake don't increase when applying the 100% allocation factor.

In the cases of the plastic bottle in this segment, applying the allocation factor 100% instead of 50% leads to lower net results in almost all impact categories as the additionally allocated credits and burdens show lower or similar absolute values. The exception is 'Climate Change'. For 'Climate Change' net results increase slightly when applying the 100% allocation factor as burdens from incineration are higher than energy and material credits.

For the inventory categories 'Total Primary Energy' and 'Non-renewable Energy' net results decrease for beverage cartons and plastic bottles in this segment when rising the allocation factor to 100% for both, beverage carton systems and plastic bottles due to the lower energy demand in the recycling and disposal processes compared to the processes of avoided energy and material production.

Comparison between packaging systems

The following tables show the net results of the regarded beverage cartons systems for all impact categories compared to those of the other regarded 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 system named in the heading and net results of the compared packaging

systems listed in the separate columns. The percentage is based on the net result of each compared packaging system[1].

Table 174: Comparison of net results: **TBA Edge DC26 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Switzerland**, allocation factor 100%

WATER PORTION PACK (ambient), Switzerland	The net results of **TPA Edge DC26 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL	PET bottle 11 500mL
Climate Change	7%	-2%	50%	16%
Acidification	-10%	16%	-30%	174%
Photo-Oxidant Formation	-14%	8%	-44%	146%
Ozone Depletion Potential	-64%	7%	-90%	-65%
Terrestrial Eutrophication	-17%	9%	-50%	147%
Aquatic Eutrophication	-39%	0%	-77%	185%
Particulate Matter	-14%	13%	-44%	158%

Table 175: Comparison of net results: **TBA Edge DC26 biobased 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Switzerland**, allocation factor 100%

WATER PORTION PACK (ambient), Switzerland	The net results of **TPA Edge DC26 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TT Midi C38 500mL	TT Midi C38 biobased 500mL	PET bottle 11 500mL
Climate Change	-7%	-8%	40%	8%
Acidification	11%	28%	-23%	203%
Photo-Oxidant Formation	16%	25%	-35%	187%
Ozone Depletion Potential	175%	193%	-73%	-3%
Terrestrial Eutrophication	20%	31%	-39%	197%
Aquatic Eutrophication	63%	64%	-62%	365%
Particulate Matter	17%	32%	-34%	201%

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

Table 176: Comparison of net results: **TT Midi C38 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Switzerland**, allocation factor 100%

WATER PORTION PACK (ambient), Switzerland	The net results of **TT Midi C38 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 biobased 500mL	PET bottle 11 500mL
Climate Change	2%	9%	52%	18%
Acidification	-13%	-22%	-39%	137%
Photo-Oxidant Formation	-7%	-20%	-48%	129%
Ozone Depletion Potential	-6%	-66%	-91%	-67%
Terrestrial Eutrophication	-8%	-24%	-54%	127%
Aquatic Eutrophication	0%	-39%	-77%	184%
Particulate Matter	-12%	-24%	-50%	128%

Table 177: Comparison of net results: **TT Midi C38 biobased 500mL** versus competing carton based and alternative packaging systems in **segment WATER PORTION PACK (ambient), Switzerland**, allocation factor 100%

WATER PORTION PACK (ambient), Switzerland	The net results of **TT Midi C38 biobased 500mL** are lower (green)/ higher (orange) than those of			
	TPA Edge DC26 500mL	TPA Edge DC26 biobased 500mL	TT Midi C38 500mL	PET bottle 11 500mL
Climate Change	-33%	-28%	-34%	-23%
Acidification	43%	29%	65%	291%
Photo-Oxidant Formation	79%	53%	92%	340%
Ozone Depletion Potential	913%	269%	982%	257%
Terrestrial Eutrophication	98%	65%	116%	390%
Aquatic Eutrophication	331%	164%	333%	1129%
Particulate Matter	77%	52%	100%	356%

9.6.2 Sensitivity analysis regarding recycled PET in PET bottles

To consider potential future developments in terms of the share of recyclate of the plastic bottles, two additional scenarios for plastic bottles with a recycled content of PET of 30% and 100% are analysed and illustrated in this sensitivity analysis (for details please see section 2.4.4). Results are shown in the following break even graphs.

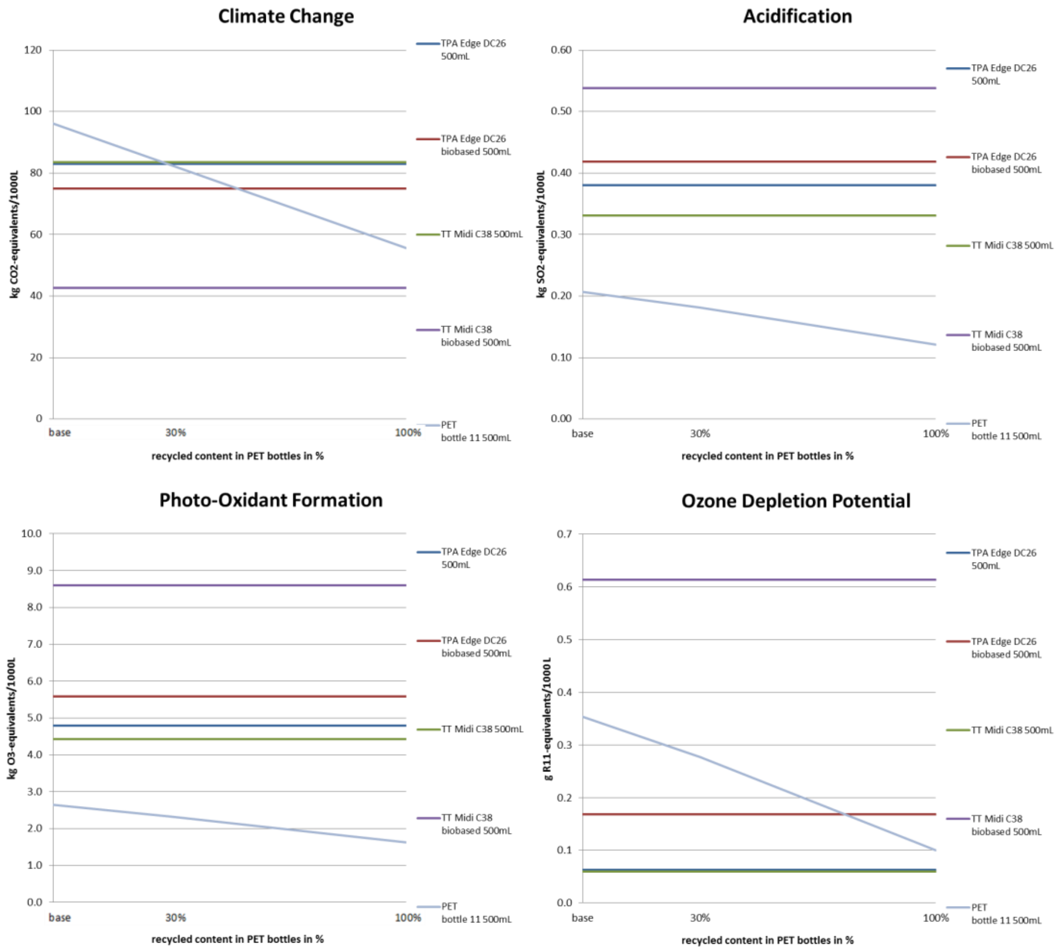


Figure 156: Indicator results for sensitivity analysis recycled PET of **segment WATER Portion Pack, Switzerland**, allocation factor 50% (Part 1)

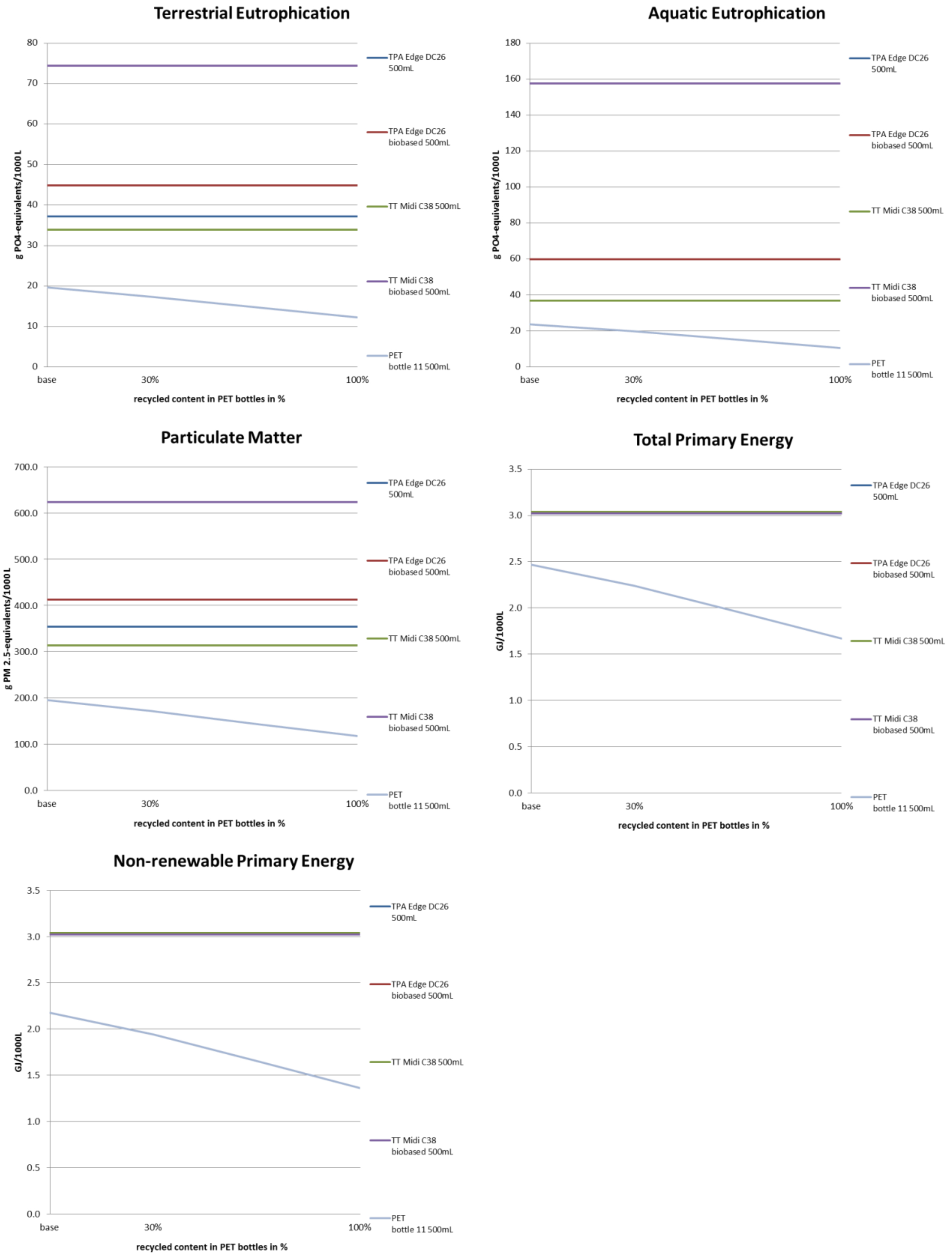


Figure 157: Indicator results for sensitivity analysis recycled PET of **segment WATER Portion Pack, Switzerland**, allocation factor 50% (Part 2)

Description and Interpretation

The ranking between the PET bottle with increased recycled content and the compared beverage cartons stays mostly the same with the regarded decrease of weight. One exception is 'Climate Change' for which the recycled content of more than around 50% leads to lower net results than all compared beverage cartons except the 'TT Midi C38 biobased 500mL'. The other exception is 'Ozone Depletion Potential' for which the recycled content of more than around 75% leads to lower net results than the 'TPA Edge DC26 biobased 500mL'.

10 Scenario Variants Switzerland

10.1 DAIRY FAMILY PACK SWITZERLAND

10.1.1 Scenario variant regarding bio-based PE in beverage cartons

The base scenarios already include beverage cartons containing bio-based plastic materials. For some cartons the use of bio-based plastics is still in development. In order to take into account the further use of bio-based plastics in beverage cartons, a scenario variant with bio-based plastics is performed for the additional beverage cartons listed in Table 35. In these analyses, the allocation factor applied for open-loop-recycling is 50%. Results are shown in the following figures.

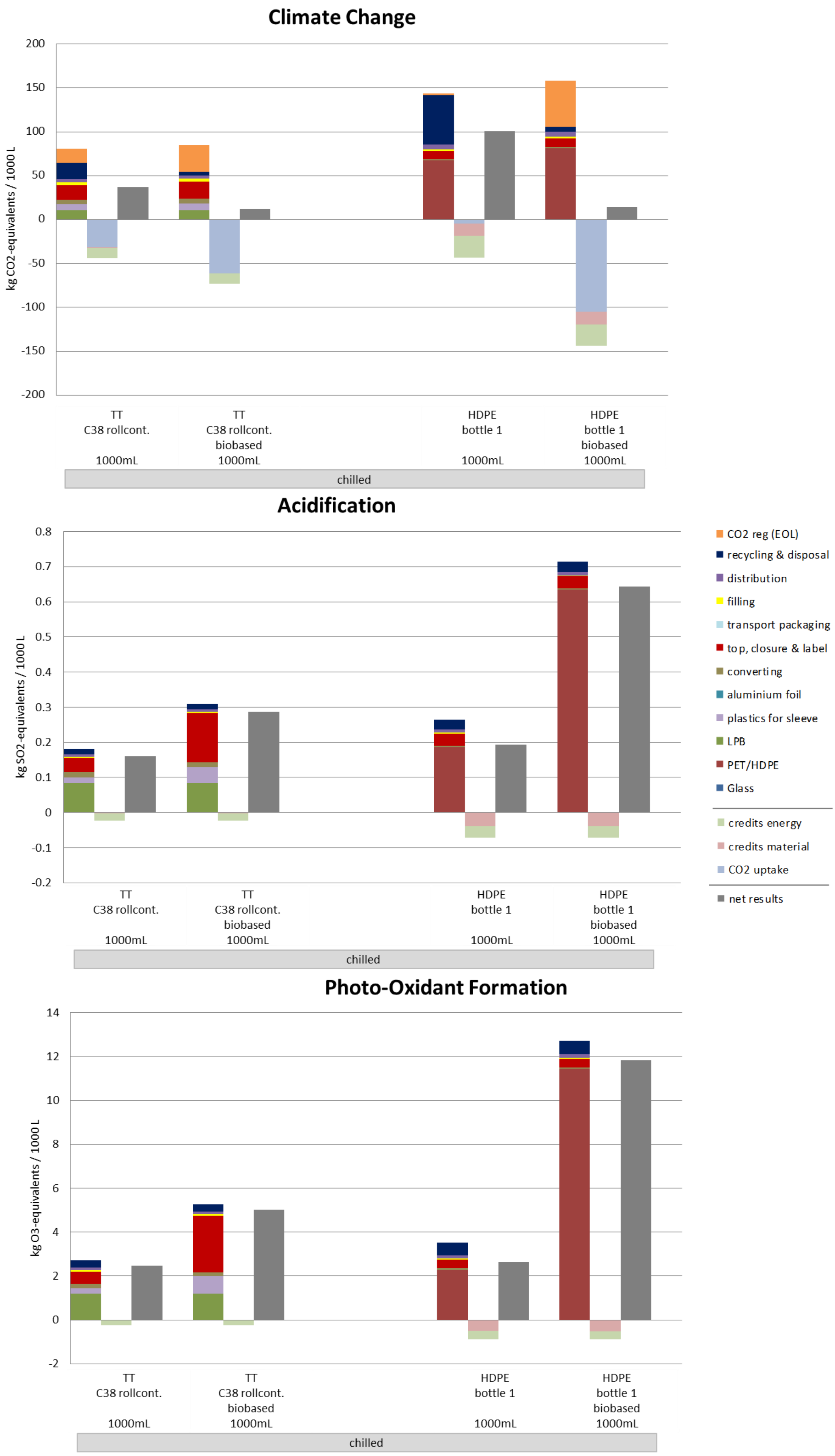


Figure 158: Indicator results for scenario variants regarding bio-based PE in beverage cartons of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)

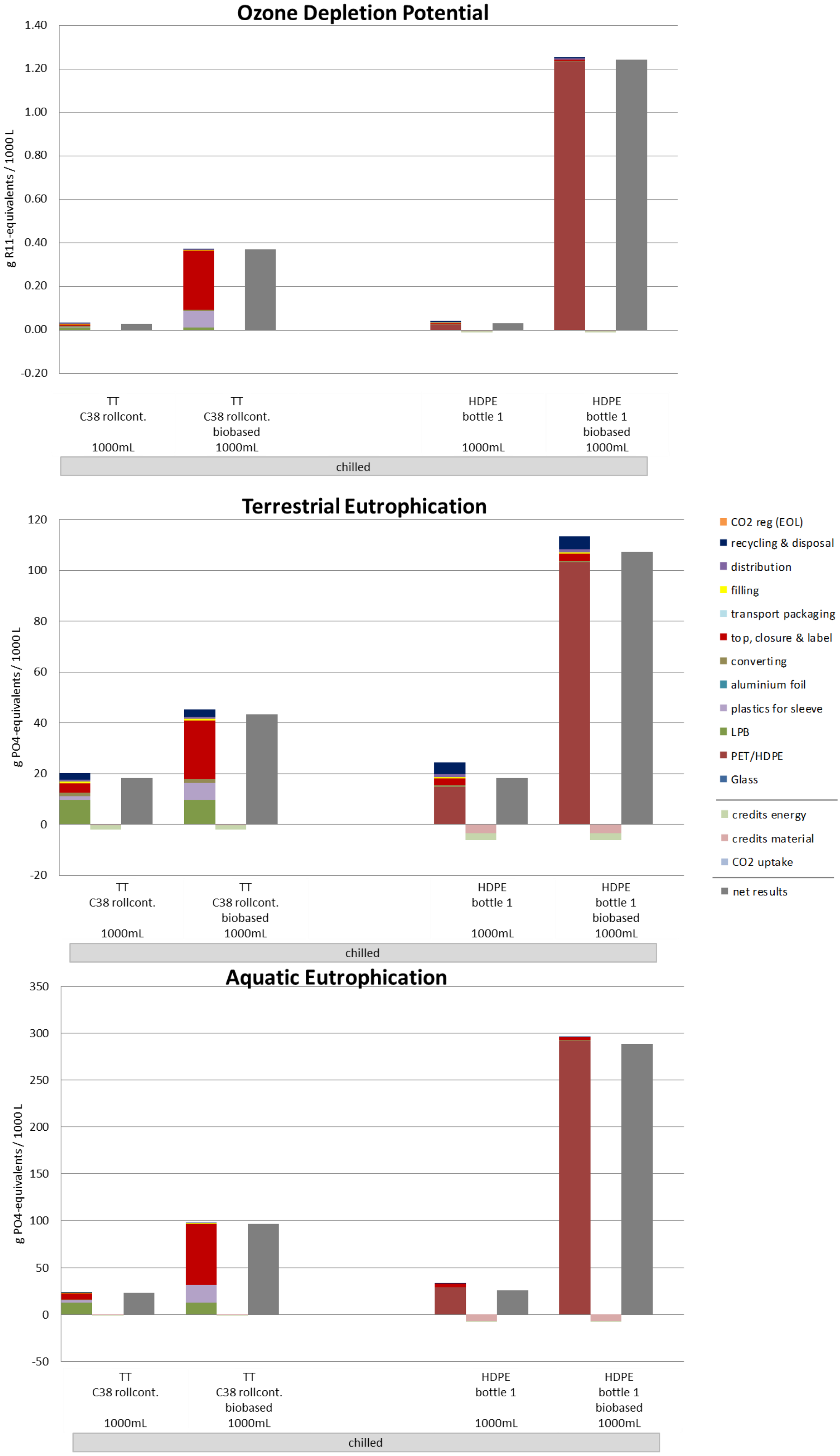


Figure 159 Indicator results for scenario variants regarding bio-based PE in beverage cartons of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 2)

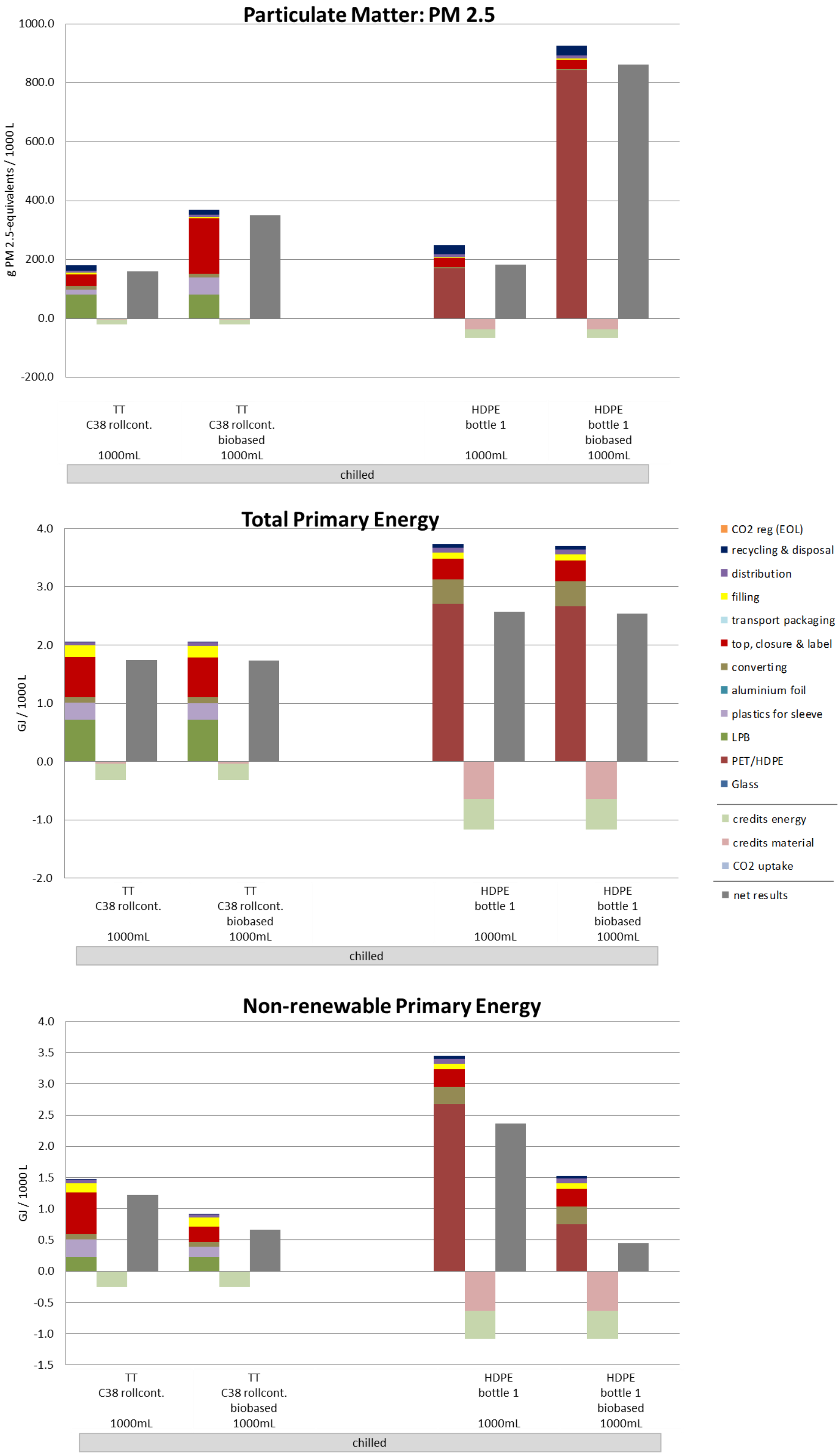


Figure 160: Indicator results for scenario variants regarding bio-based PE in beverage cartons of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 3)

Description and Interpretation

The replacement of fossil based plastics with bio-based plastics in the regarded beverage carton system leads to 68% lower net results for 'Climate Change' and 45% lower 'Non-renewable Primary Energy'. In most of the other categories the use of bio-based plastics leads to 80%-1146% higher net results. The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' and 'Non-renewable Primary Energy' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

10.1.2 Scenario variants regarding bio-based plastics in HDPE bottles

The study includes beverage cartons containing bio-based plastic materials. In order to take also bio-based material in plastic bottles into account scenario variants is performed for the packaging systems listed in Table 35. In these analyses, the allocation factor applied for open-loop-recycling is 50%.

Figure 161: Indicator results for scenario variants regarding bio-based plastics in HDPE bottles of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)

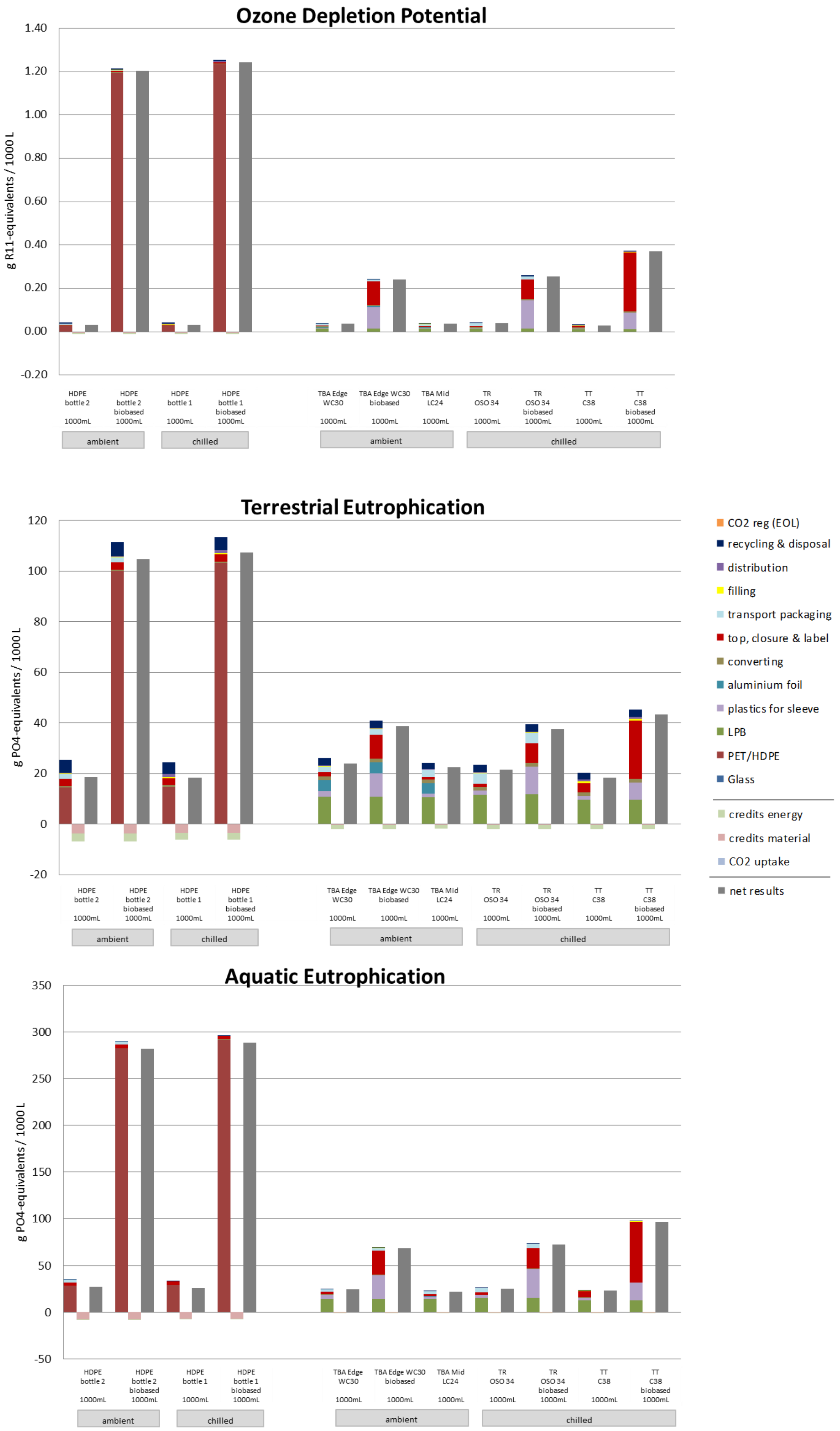


Figure 162 Indicator results for scenario variants regarding bio-based plastics in HDPE bottles of segment DAIRY FAMILY PACK, Switzerland, allocation factor 50% (Part 2)

Figure 163: Indicator results for scenario variants regarding bio-based plastics in HDPE bottles of **segment DAIRY FAMILY PACK, Switzerland**, allocation factor 50% (Part 3)

Description and Interpretation

The replacement of fossil based HDPE with bio-based HDPE in the regarded HDPE bottles leads to 83%-86% lower net results for 'Climate Change' and 78%-81% lower net results for 'Non-renewable Primary Energy'. In all other categories the use of bio-based plastics leads to 224%-3769% higher net results. The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' and 'Non-renewable Primary Energy' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

10.2 SD FAMILY PACK SWITZERLAND

10.2.1 Scenario variants regarding plastic bottle weights

To consider potential future developments in terms of weight of the plastic bottles, two additional weights of plastic bottles are analysed and illustrated in these scenario variants (for details please see section 2.4.8). Results are shown in the following break even graphs.

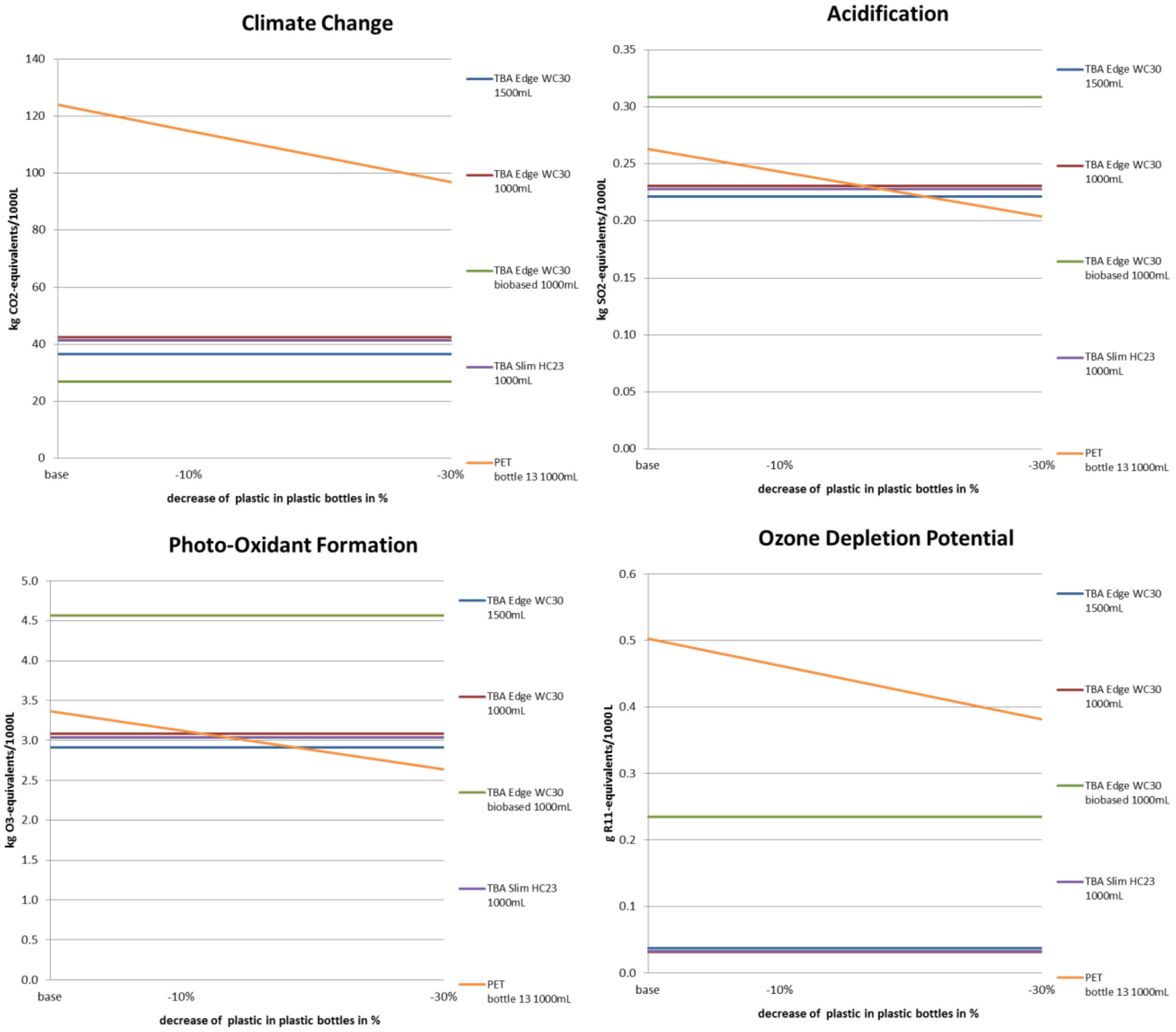


Figure 164: Indicator results for scenario variants on plastic bottle weight of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 1)

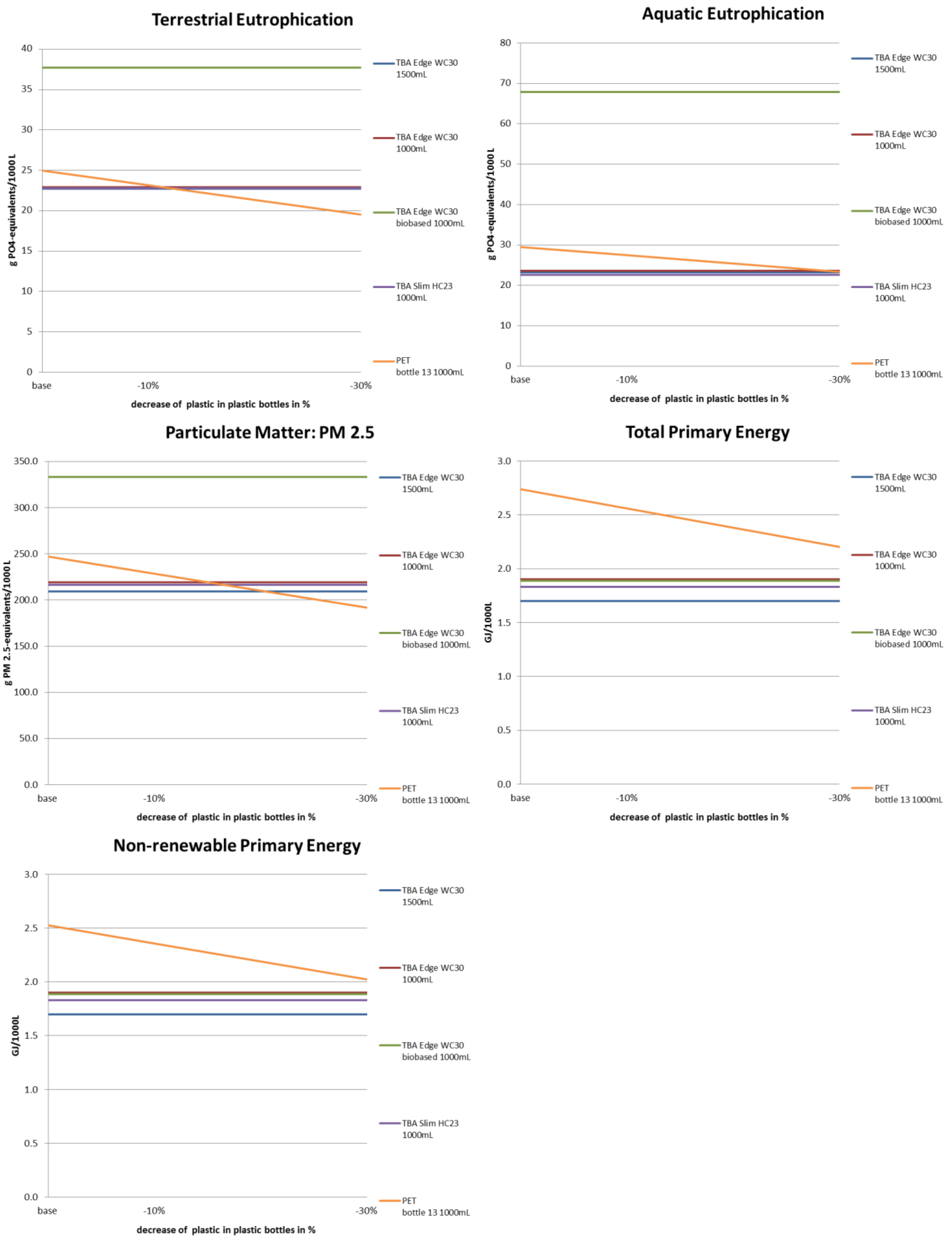


Figure 165: Indicator results for scenario variants on plastic bottle weight of **segment SD FAMILY PACK, Switzerland**, allocation factor 50% (Part 2)

Description and Interpretation

The recalculation of the PET bottle with reduced weights shows that the impacts in all categories are lower if less material is used. Nevertheless in the categories 'Climate Change', 'Ozone Depletion Potential', 'Total Primary Energy' and 'Non-renewable Primary Energy' the PET bottle shows higher results than all compared beverage cartons systems, regardless of the reduced bottle weight. In all other impact categories break even points are reached with various beverage cartons.

10.3 DAIRY PORTION PACK SWITZERLAND

10.3.1 Scenario variant regarding bio-based PE in beverage cartons

The base scenarios already include beverage cartons containing bio-based plastic materials. For some cartons the use of bio-based plastics is still in development. In order to take into account the further use of bio-based plastics in beverage cartons, a scenario variant with bio-based plastics is performed for the additional beverage cartons listed in Table 35. In these analyses, the allocation factor applied for open-loop-recycling is 50%. Results are shown in the following figures.

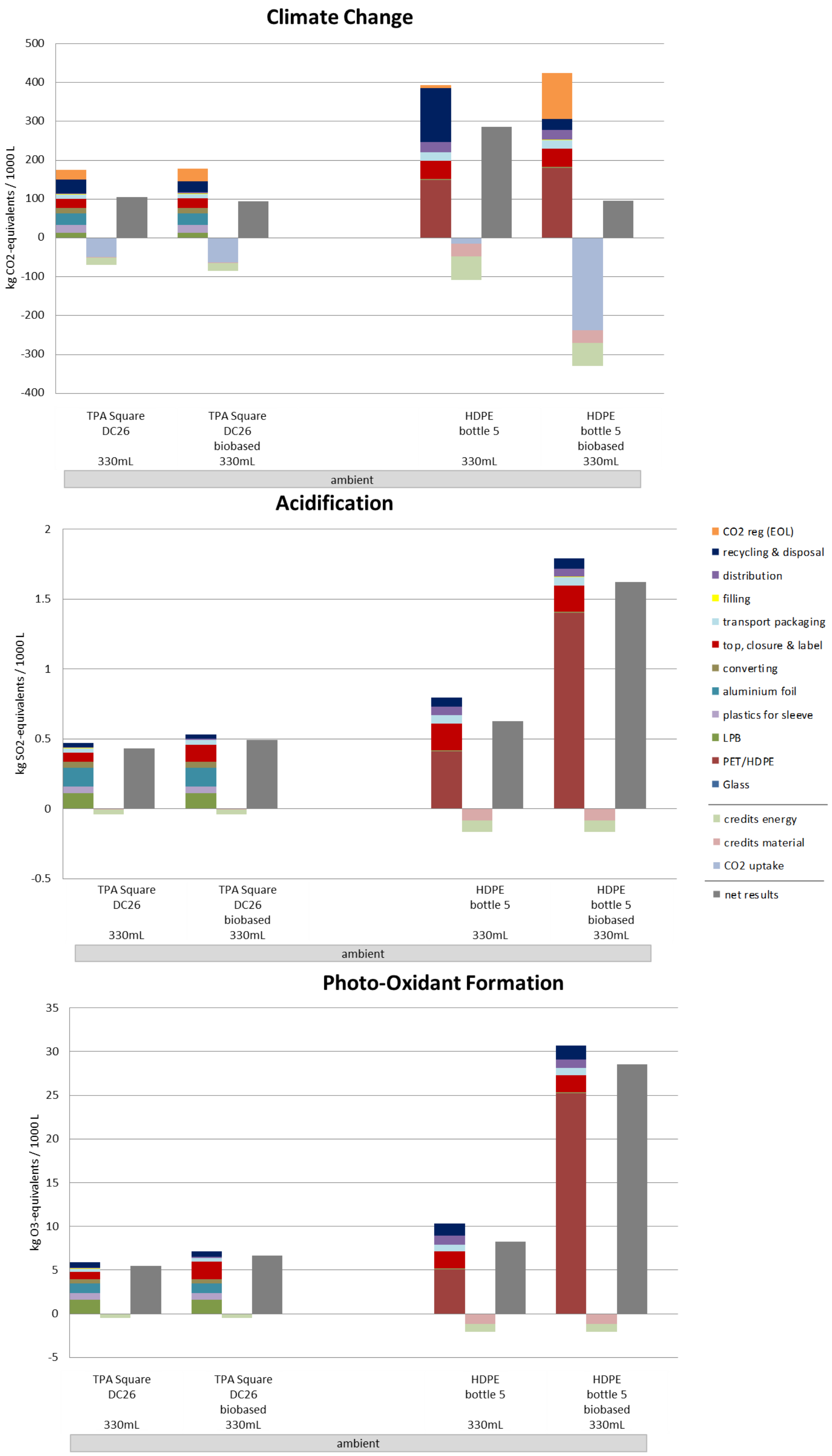


Figure 166: Indicator results for scenario variants regarding bio-based PE in beverage cartons of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 1)

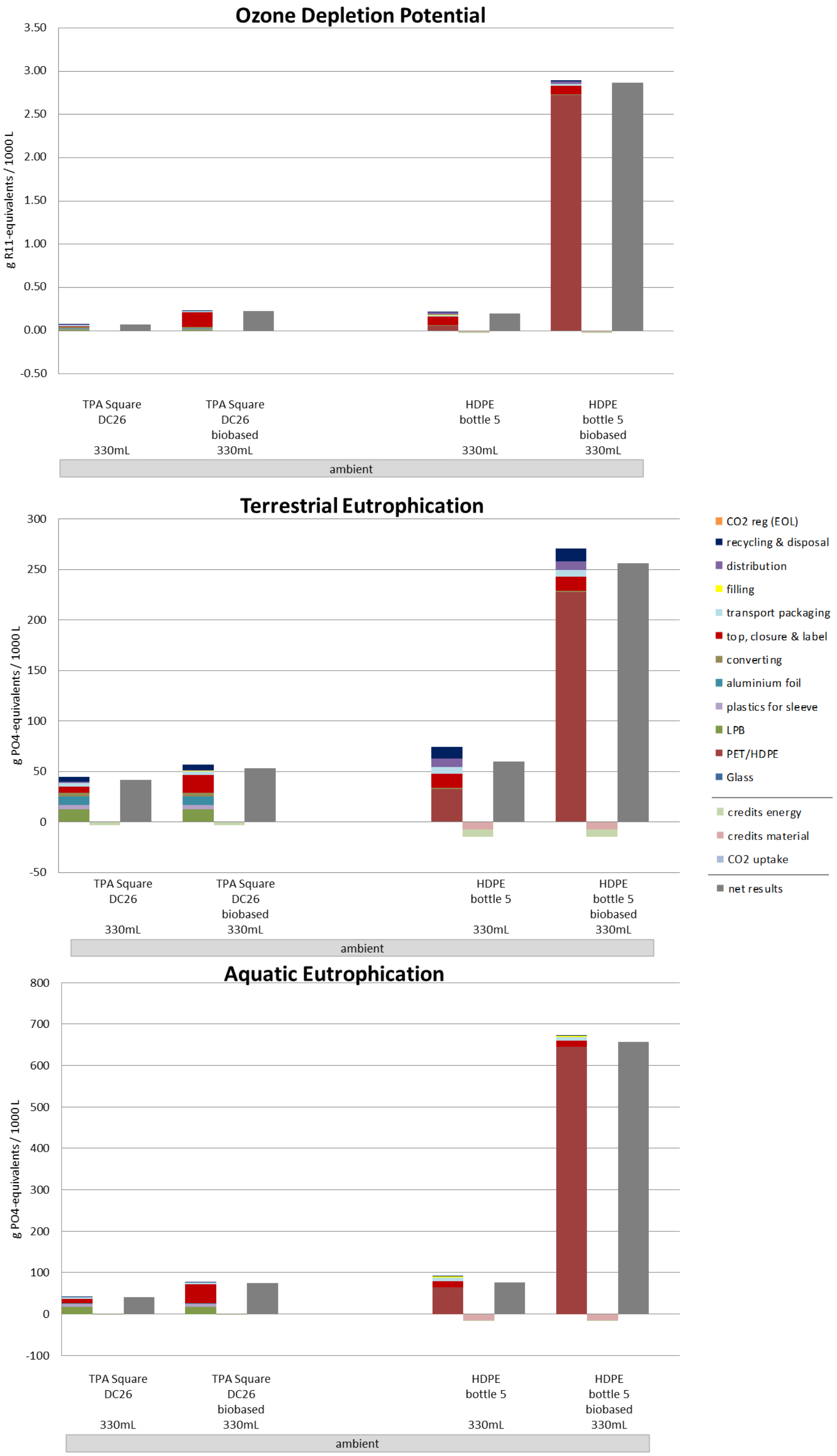


Figure 167 Indicator results for scenario variants regarding bio-based PE in beverage cartons of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 2)

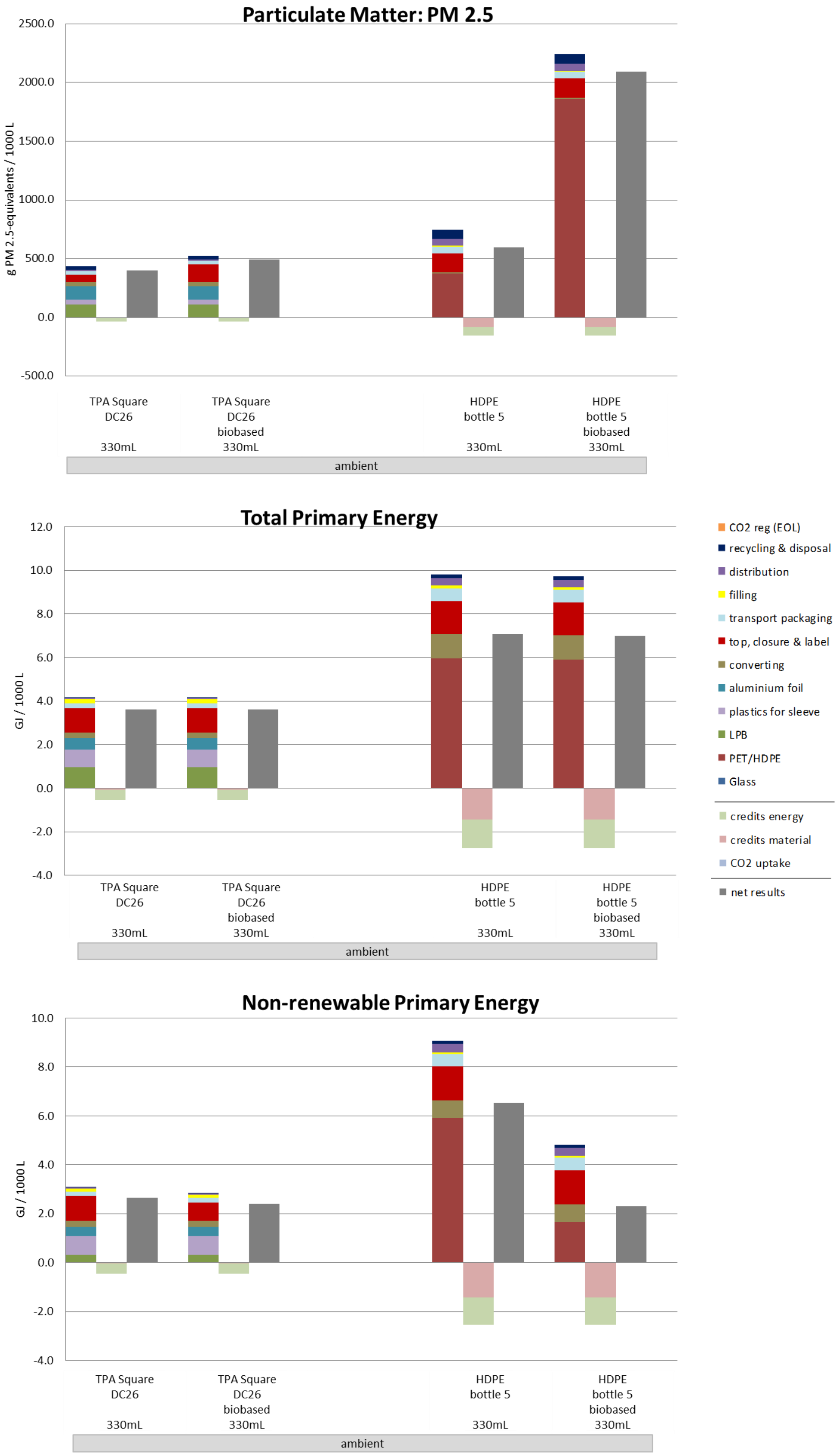


Figure 168: Indicator results for scenario variants regarding bio-based PE in beverage cartons of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 3)

Description and Interpretation

The replacement of fossil based plastics with bio-based plastics in the regarded beverage carton system leads to about 11% lower net results for 'Climate Change' and 10% lower net results for 'Non-renewable Primary Energy'. In most of the other categories the use of bio-based plastics leads to 14%-233% higher net results. The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' and 'Non-renewable Primary Energy' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

10.3.2 Scenario variant regarding bio-based plastics in HDPE bottles

The study includes beverage cartons containing bio-based plastic materials. In order to take also bio-based material in plastic bottles into account a scenario variant is performed for the packaging systems listed in Table 35. In these analyses, the allocation factor applied for open-loop-recycling is 50%.

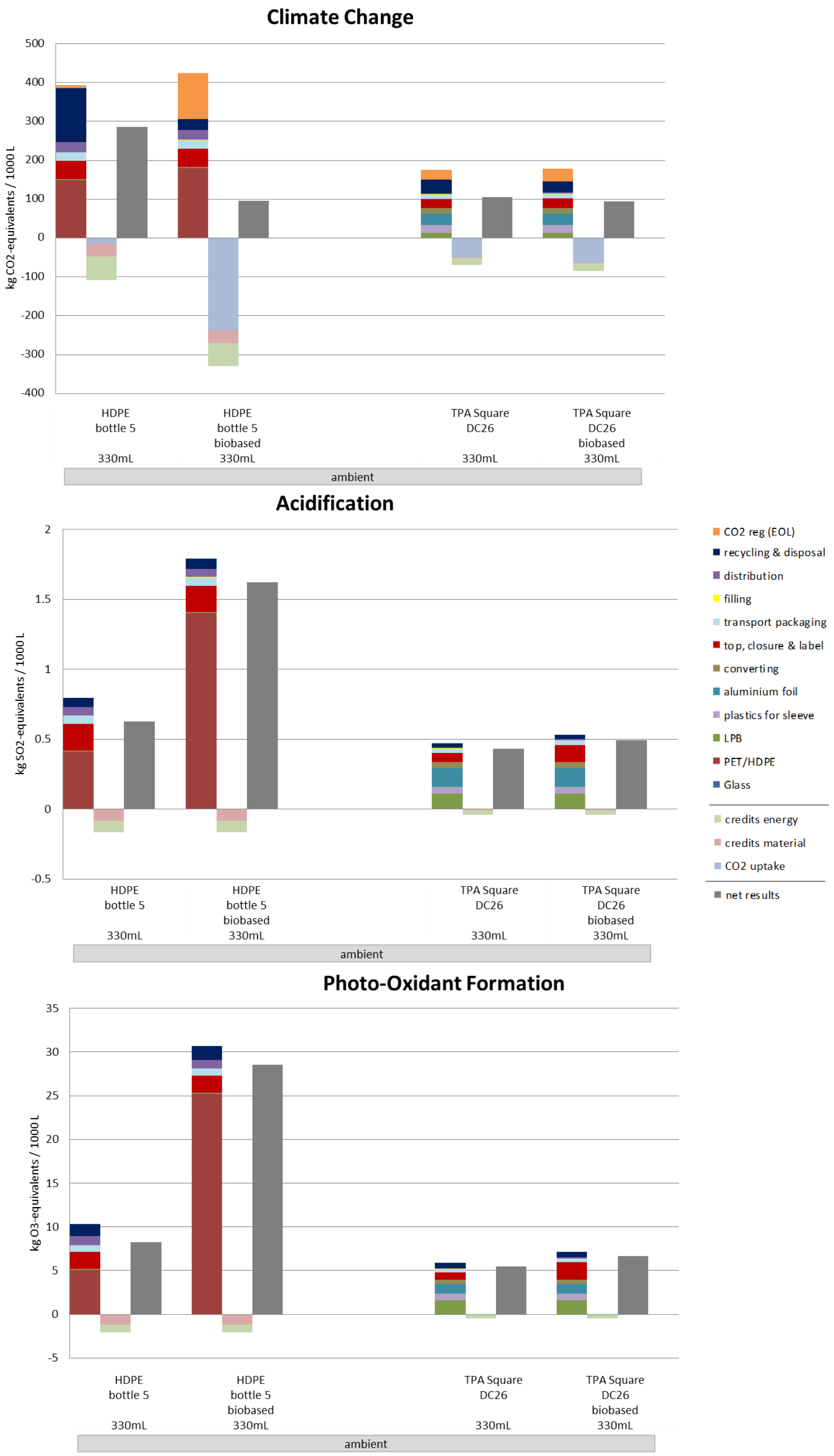


Figure 169: Indicator results for scenario variants regarding bio-based plastics in HDPE bottles of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 1)

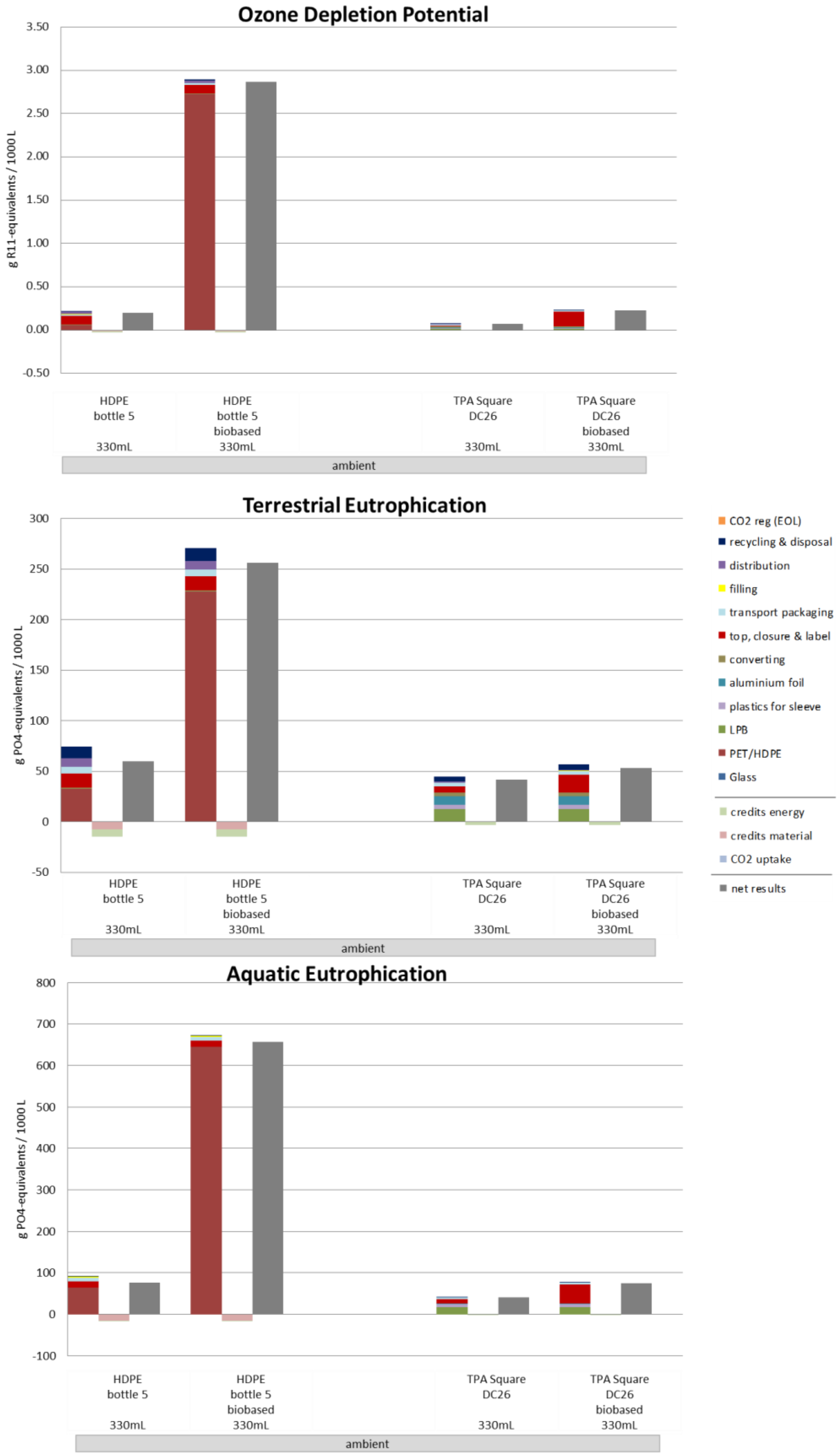
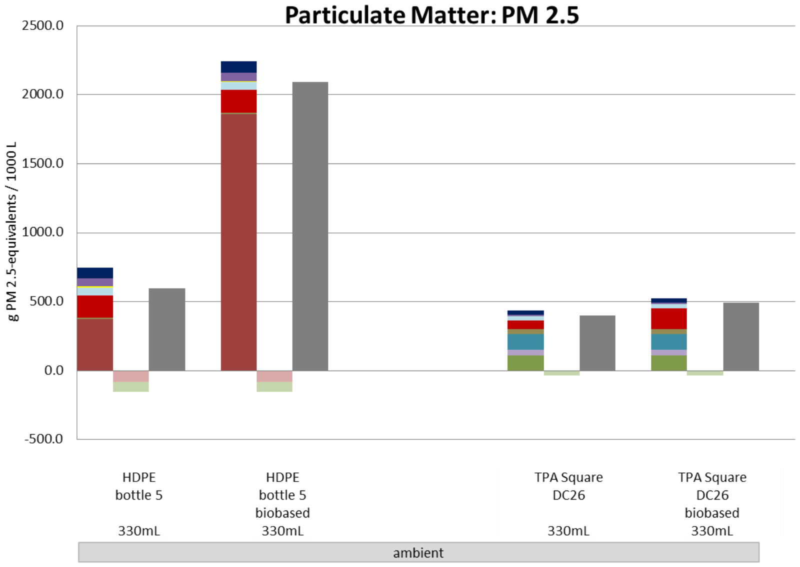
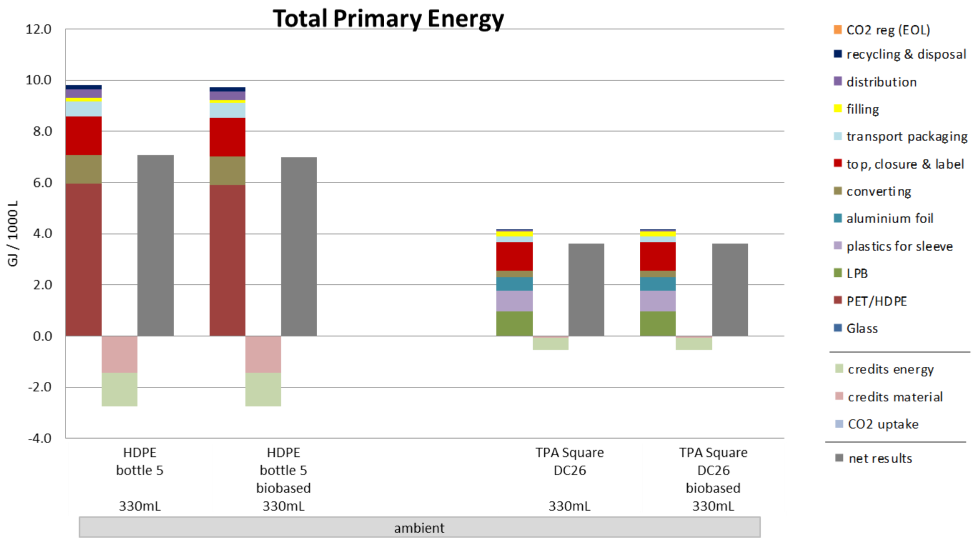


Figure 170 Indicator results for scenario variants regarding bio-based plastics in HDPE bottles of segment DAIRY PORTION PACK, Switzerland, allocation factor 50% (Part 2)





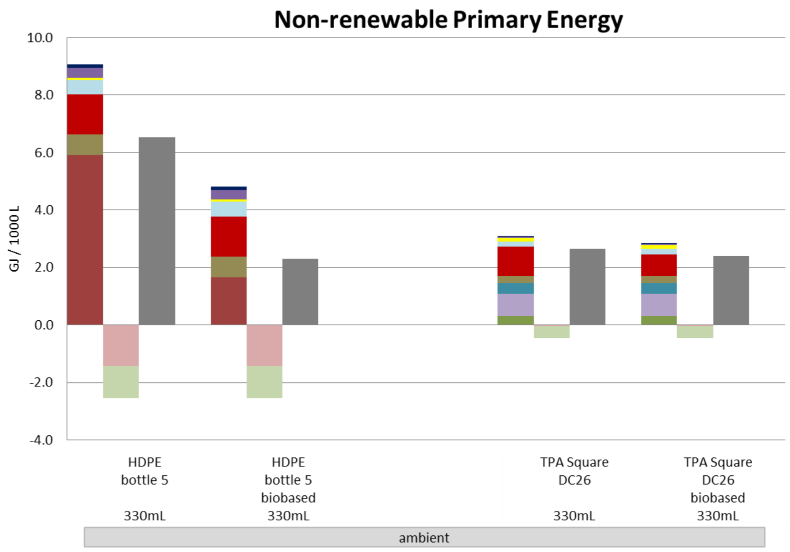


Figure 171: Indicator results for scenario variants regarding bio-based plastics in HDPE bottles of **segment DAIRY PORTION PACK, Switzerland**, allocation factor 50% (Part 3)

Description and Interpretation

The replacement of fossil based HDPE with bio-based HDPE in the regarded HDPE bottle leads to 67% lower net results for 'Climate Change' and 65% lower net results for 'Non-renewable Primary Energy'. In most other categories the use of bio-based plastics leads to 158%-1353% higher net results. The reason for the big influence of bio-based plastics on all impact categories apart from 'Climate Change' and 'Non-renewable Primary Energy' is the high energy demand, and the cultivation of sugar cane. The latter is reflected especially in the impact category 'Ozone Depletion Potential'. This is due to the field emissions of N2O from the use of nitrogen fertilisers on sugarcane fields. The high energy demand of the production of thick juice for Bio PE is reflected in the categories 'Particulate Matter', 'Terrestrial Eutrophication', 'Acidification' and 'Total Primary Energy'. The burning of bagasse on the field leads to a considerable contribution to 'Particulate Matter'.

10.4 WATER PORTION PACK SWITZERLAND

10.4.1 Scenario variants regarding plastic bottle weights

To consider potential future developments in terms of weight of the plastic bottles, two additional weights of plastic bottles are analysed and illustrated in these scenario variants (for details please see section 2.4.8). Results are shown in the following break even graphs.

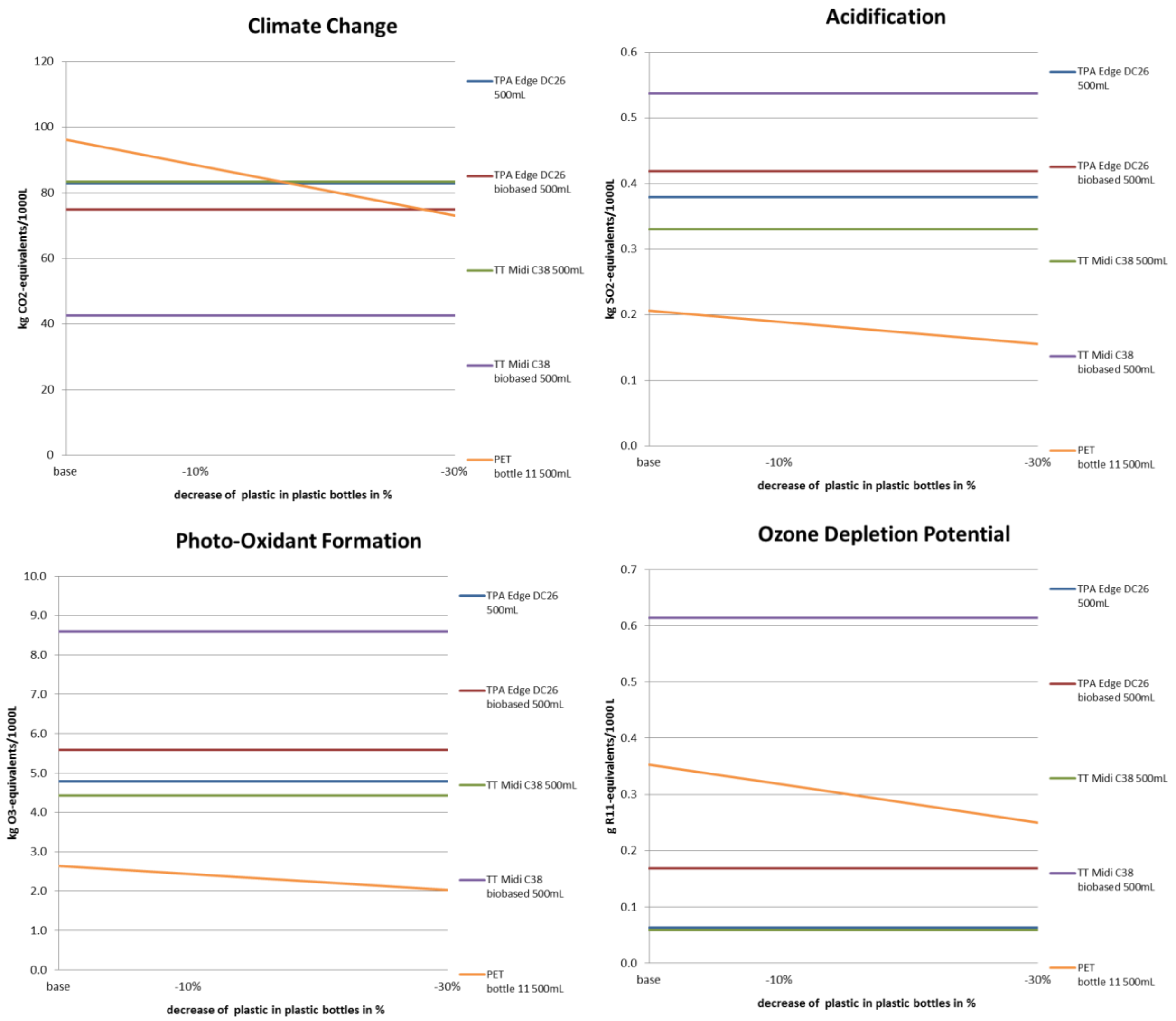


Figure 172: Indicator results for scenario variants on plastic bottle weight of **segment WATER Portion Pack, Switzerland**, allocation factor 50% (Part 1)

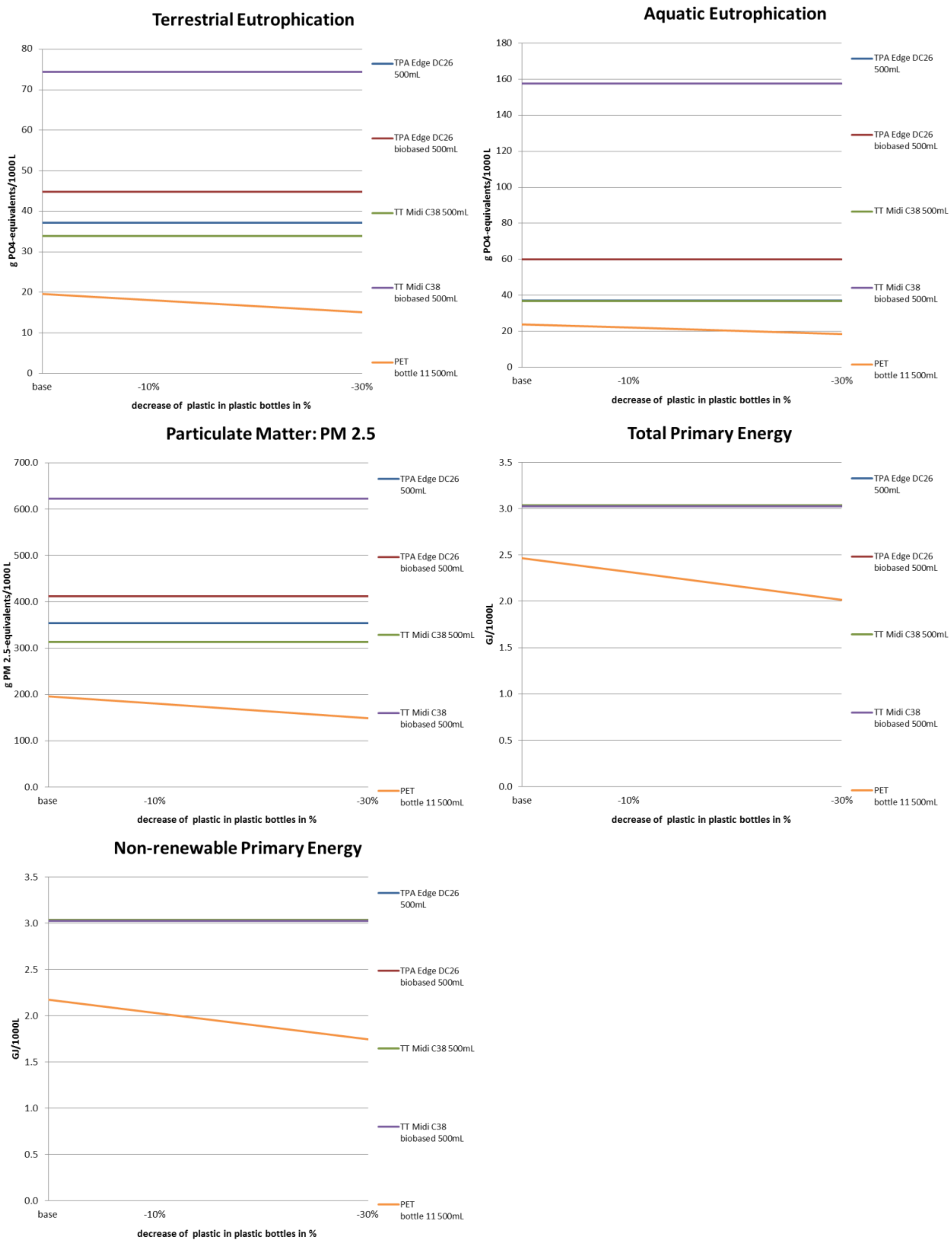


Figure 173: Indicator results for scenario variants on plastic bottle weight of **segment WATER Portion Pack, Switzerland**, allocation factor 50% (Part 2)

Description and interpretation

The recalculation of the PET bottle with reduced weights shows that the impacts in all categories are lower if less material is used. Nevertheless the ranking between the PET bottle and the compared beverage cartons stays the same with the regarded decrease of weight. The exception is 'Climate Change' for which the weight reduction of 30% leads to lower net results than all compared beverage cartons except the 'TT Midi C38 biobased 500mL'.

11 Conclusions SWITZERLAND

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 Swiss market. This section addresses all sensitivity analyses. In doing so, results of the 50% allocation (base) scenarios and the 100% allocation sensitivity analysis are taken into account to the same degree.

11.1 DAIRY FAMILY PACK SWITZERLAND

In case of 'Climate Change' all beverage cartons in this segment show lower impacts than the compared HDPE bottles regardless of the allocation factor.

For the other categories the comparison of the examined beverage carton systems with fossil based plastics to the HDPE bottles in this segment, no unambiguous result can be observed.

In case of the beverage carton containing bio-based plastics, environmental impacts in the category 'Climate Change' are lower than those of cartons with fossil based plastics. However, the use of bio-based plastics also leads to higher environmental impacts in all other impact categories examined. This leads to the beverage carton showing higher impacts in most categories than the compared bottles.

In case of the beverage carton TBA Slim without opening 1500mL, the beverage carton shows lower or similar impacts in almost all categories.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has only a small influence on the assessment of the environmental impacts in this segment.

The scenario variants regarding bio-based PE in beverage cartons and HDPE bottles show that a substitution of fossil plastics by bio-based plastics leads to lower environmental impacts in the categories 'Climate Change' and 'Non-renewable Primary Energy' but to substantial higher impacts in almost all other categories.

11.2 JN FAMILY PACK SWITZERLAND

In case of 'Climate Change' all beverage cartons in this segment show lower impacts than the compared PET bottle regardless of the allocation factor.

For the other categories, the comparisons of the examined beverage carton systems with fossil based plastics to the PET bottle in this segment show lower or similar impacts for the beverage cartons depending on the allocation factor.

In case of the beverage carton containing bio-based plastics, environmental impacts in the category ‘Climate Change’ are lower than those of cartons with fossil based plastics. However, the use of bio-based plastics also leads to higher environmental impacts in all other impact categories examined. This leads to the beverage carton showing higher impacts in most categories than the compared bottles.

In case of the comparisons between the beverage cartons with fossil based plastics and the PET bottle 2 1000mL the choice of allocation factor 100% leads in several categories to similar impacts from the beverage cartons and the PET bottle.

The sensitivity analysis regarding recycled content of the PET bottle shows, that the PET bottle with an increasing recycled content will break even with at least some beverage cartons. The exceptions is ‘Climate Change’, for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

11.3 SD FAMILY PACK SWITZERLAND

In case of ‘Climate Change’ almost all beverage cartons in this segment show lower impacts than the compared PET bottles regardless on the allocation factor. The exception is the comparison of the TBA Edge WC30 1000mL with the PET bottle 1 1500mL. For this comparison lower or similar impacts are shown for the beverage carton depending on the allocation factor.

For the other categories, the comparisons of the examined beverage carton systems with fossil based plastics to the 1500mL PET bottle in this segment shows mostly higher impacts for the beverage cartons. When comparing the beverage carton systems with fossil based plastics to the 1000mL PET bottle mostly lower or mostly higher impacts are shown for the beverage cartons, depending on the allocation factor.

In case of the beverage carton containing bio-based plastics, environmental impacts in the category ‘Climate Change’ are lower than those of cartons with fossil based plastics. However, the use of bio-based plastics also leads to higher environmental impacts in all other impact categories examined. This leads to the beverage carton showing higher impacts in most categories than the compared bottles.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has in the comparisons between the beverage cartons and the PET bottle 1 1500mL only a small influence on the assessment of the environmental impacts. The exception is the comparison of the TBA Edge WC30 1000mL, where the impacts become similar to the PET bottle 1 1500mL when applying the 100% allocation factor.

As the sensitivity on regenerative carbon still shows lower net results for the beverage cartons than the compared bottles it confirms that the choice of methodology for consideration of regenerative carbon does not affect the comparisons.

In case of the comparisons between the beverage cartons with fossil based plastics and the PET bottle 13 1000mL the choice of allocation factor 100 leads in several categories to higher impacts from the beverage cartons than from the PET bottle.

The sensitivity analysis regarding recycled content of the PET bottle shows, that the PET bottle with an increasing recycled content will break even with at least some beverage cartons. The exceptions is 'Climate Change', for which the PET bottle shows higher results than all compared beverage cartons systems, regardless of the PET bottles share of recycled PET.

The scenario variants regarding reduced weights of PET bottles show that the impacts in all categories are lower if less material is used. Nevertheless in the impact categories 'Climate Change' and 'Ozone Depletion Potential' the PET bottle shows higher results than all compared beverage cartons systems, regardless of the reduced bottle weight. In all other impact categories break even points are reached with various beverage cartons.

11.4 DAIRY PORTION PACK SWITZERLAND

In case of 'Climate Change' all beverage cartons in this segment show lower impacts than the compared HDPE bottle and PP cup regardless of the allocation factor.

The comparisons of the TT Midi C38 500mL and the PP cup 1 250mL shows in most of the other categories lower impacts for the beverage cartons. The comparisons of the TT Midi C38 500mL and the HDPE bottle 4 500mL shows in most of the other categories lower or similar impacts for the beverage cartons depending on the allocation factor. The comparisons of the TT Midi C38 250mL and the HDPE bottle 4 500mL shows in most of the other categories higher impacts for the beverage cartons. The comparisons of the TT Midi C38 250mL and the PP cup 1 250mL shows in most of the other categories lower impacts for the beverage cartons. The comparisons of the TPA Square DC26 330mL and the HDPE bottle 5 330mL shows in all of the other categories lower impacts for the beverage cartons.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has an influence on the assessment of the environmental impacts in this segment. Applying the 50% allocation factor the TT Midi C38 500mL shows in most categories except 'Climate Change' lower impacts than the HDPE bottle 4 500mL. When applying the 100% allocation factor the impacts in most categories except 'Climate Change' are similar for the TT Midi C38 500mL and the HDPE bottle 4 500mL.

The scenario variants regarding bio-based PE in beverage cartons and HDPE bottles show that a substitution of fossil plastics by bio-based plastics leads to lower environmental impacts in the categories 'Climate Change' and 'Non-renewable Primary Energy' but to substantial higher impacts in almost all other categories.

11.5 SD PORTION PACK SWITZERLAND

In case of 'Climate Change' the beverage carton in this segment shows lower impacts than the compared PET regardless of the allocation factor.

For the other categories the comparison of the examined beverage carton systems with fossil based plastics to the PET bottles in this segment, no unambiguous result can be observed.

The sensitivity analysis on system allocation shows, that the choice of allocation factor has only a minor influence on the assessment of the environmental impacts in this segment.

11.6 WATER PORTION PACK SWITZERLAND

In case of 'Climate Change' almost all of the beverage cartons in this segment show lower or higher impacts than the compared PET bottle respective of the allocation factor. When applying allocation factor 50% all beverage cartons show lower impacts then the PET bottle. When applying the allocation factor 100% only the TT Midi C38 biobased 500mL beverage carton shows lower impacts than the PET bottle, all other beverage cartons show higher or similar impacts.

Regarding the comparison of the examined beverage carton systems and the PET bottles for the other categories in this segment, the beverage cartons show mostly higher impacts than the PET bottle regardless of the allocation factor.

In case of the beverage carton containing bio-based plastics, environmental impacts in the category 'Climate Change' are lower than those of cartons with fossil based plastics. However, the use of bio-based plastics also leads to higher environmental impacts in all other impact categories examined. This leads to the beverage carton showing even higher impacts in most categories than the compared bottles.

Regarding the sensitivity analysis on recycled content of the PET bottle, the ranking between the PET bottle with increased recycled content and the compared beverage cartons stays mostly the same with the regarded increase of recycled content. One exception is 'Climate Change' for which the recycled content of more than around 50% leads to lower net results than all compared beverage cartons except the 'TT Midi C38 biobased 500mL'. The other exception is 'Ozone Depletion Potential' for which the recycled content of more than around 75% leads to lower net results than the 'TPA Edge DC26 biobased 500mL'.

Regarding the scenario variants on reduced bottle weight of the PET bottle the ranking between the PET bottle and the compared beverage cartons stays the same with the regarded decrease of weight. The exception is 'Climate Change' for which the weight reduction of 30% leads to lower net results than all compared beverage cartons except the 'TT Midi C38 biobased 500mL'.

12 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, Cream, JN, SD and Water. Even though carton packaging systems, plastic bottles, plastic cups and glass bottles 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 markets of Austria and Switzerland.

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 method**:
The selection of the environmental categories applied in this study covers impact categories and 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 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 **categories**:
The conclusions are valid only for the environmental impact categories, which were examined and are considered to deliver robust results, thus excluding the category 'Use of Nature'. They are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

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 Austria and Switzerland, 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, most recent versions of published ecoprofile datasets, various sources along the value chain of beverage packaging systems, literature, and data from ifeu's internal database.

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

13 Overall conclusion and recommendations

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

The beverage carton systems analysed in this study show different environmental performances depending on different segments and markets as well as their packaging specifications.

Alternative packaging systems examined in this study show high burdens from the production of their base materials, like plastics, glass or aluminium. For beverage 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.

Beverage cartons show lower environmental impacts than their compared plastic bottles or cups in almost all segments within the two studied markets regarding 'Climate Change'.

The results of the comparisons with plastic bottles and cups for the other categories are more diverse between the different markets, segments and packaging systems. Therefore for conclusions regarding the comparative performances of beverage cartons beyond climate change, the detailed conclusion section of each segment and market should be consulted.

The utilisation of bio-based polyethylene instead of fossil-based polyethylene does not deliver unambiguous results. While it leads to lower results in 'Climate Change', the emissions from the production of this bio-polyethylene, including its agricultural background system, increase the environmental impacts in all the other impact categories considered.

Compared to the regarded glass bottles on the Austrian market there is a big difference between the comparison with one-way and refillable glass bottles. Compared with one-way glass bottles beverage cartons show lower impacts in almost all categories apart from 'Aquatic Eutrophication' resulting from paper production. Compared with refillable bottles only a few beverage cartons show lower impacts in only a few categories. In most cases the refillable bottles show lower impacts.

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

- From an environmental viewpoint no general recommendation for one type of packaging can be given that is valid for all segments.
- If there is a strong focus on climate change mitigation in Tetra Pak's environmental policy, the utilisation of bio-based polyethylene can be an applicable path to follow as the 'Climate Change' impacts of bio-based plastics are lower than those of fossil based plastics. Because of the additional impacts in all categories except 'Climate Change' resulting from the production of bio-based plastics, the use of bio-based plastics, though, can not be endorsed unreservedly. In any case the consequences for the environmental performance in other impact categories should never be disregarded completely.
- It is shown in this study that the closures play a crucial role in the life cycle of the 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.
- It is recommended to the industries and related associations in general to provide more comprehensive process inventory data, especially for production processes to reduce the level of data asymmetries that could lead to misinterpreted results (f.e. regarding water use: regionalised data and water output flows). This is required to allow recently developed methods such as assessment methods for water consumption and UseTox to be successfully applicable.

14 References

[ARA 2018]: Persönliche Kommunikation zu Altstoff Recycling Austria AG (ARA)

[BAFU 2016]: Bericht Module 3 + 4 Verwertung Kunststoffabfälle Schweiz im Auftrag des Runden Tisches Kunststoff unter der Leitung des BAFU mit Stellungsnahmen der Mitglieder des Projektausschusses Runder Tisch Kunststoff. Bundesamt für Umwelt BAFU. Dezember 2016

[BAFU 2017]: Recycling von Getränkeverpackungen 2016. Bundesamt für Umwelt BAFU. Dezember 2017

[Berglandmilch 2019]: Presse Berglandmilch - Berglandmilch/Greenpeace: Gemeinsam für Comeback der Mehrweg-Milchflasche. https://www.berglandmilch.at/presse/?id=241#top (Access July 4th, 2019)

[bmnt 2017]: Bundes-Abfallwirtschaftsplan 2017. Bundesministerium für Nachhaltigkeit und Tourismus. Wien. Dezember 2017.

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

[Berger/Finkbeiner 2010]: Berger, Markus; Finkbeiner, Matthias: Water Footprinting: How to Address Water Use in Life Cycle Assessment? Sustainability 2010, 2, 919-944.

[Bettens & Bagard 2016]: Bettens, Frédéric; Bagard, Rémi. Life Cycle Assessment of Container Glass in Europe – Methodological report for European Container Glass Federation (FEVE). RDC Environment SA. Brussels. 2016

[Boulay et al. 2017]: Boulay, AM., Bare, J., Benini, L. et al. Int J Life Cycle Assess (2017). https://doi.org/10.1007/s11367-017-1333-8

[Brandao & Mila i Canals 2013]: Miguel Brandao, Llorenc Mila i Canals. 2013. Global characterisation factors to assess land use impacts on biotic production. Int J Life Cycle Assess 18: 1243-1252

[Carter 2010] Carter, W. P. L.: Development of the SARC-07 Chemical Mechanism and Updated Ozone Reactivity Scales. Updated Chemical Mechanisms for Airshed Model Applications. Supplementary Material. California Air Resources Board, , May 2012

[Carter 2008] Carter, W. P. L.: Estimation of the Maximum Ozone Impacts of Oxides of Nitrogen. College of Engineering Center for Environmental Research and Technology (CE-CERT) University of California, Riverside, CA, January 2008

[Chalmers 2009]: Liptow, C; Tillman, A.-M.: Comparative life cycle assessment of polyethylene based on sugarcane and crude oil, Göteborg 2009

[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.

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

[Dannenberg & Paquin 2000]: Dannenberg, E. M., Paquin, L. and Gwinnell, H. 2000. Carbon Black. Kirk-Othmer Encyclopedia of Chemical Technology. .

[De Leeuw 2002]: De Leeuw. F.: A set of emission categories for long-range transboundary air pollution. Bilthoven 2002

[Dinkel & Kägi 2014]: Dinkel, F., Kägi, T.. Ökobilanz Getränkeverpackungen. Carbotech AG. Basel. July 2014

[Dinkel et al. 2017]: Dinkel, F., Kägi, T. Bunge R., Pohl, T., Stäubli A.. (Kunststoff Recycling und Verwertung) Ökonomisch-ökologische Analyse von Sammel- und Verwertungssystemen von Kunststoffen aus Haushalten in der Schweiz. Carbotech, Basel & UMTEC, Rapperswil

[Dinkel & Kägi 2017]: Dinkel, F., Kägi, T.. Die Zukunft des Getränkekarton-Recycling. Carbotech AG. Basel. November 2017

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

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

[EcoTransIT World 2016]: Ecological Transport Information Tool for Worldwide Transports-Methodology and Data Update. EcoTransIT World Initiative (EWI) .Berne, Hannover, Heidelberg. June 2016[EPA 1996]: AP 42 Compilation of Air Pollutant Emission Factors, Washington, D.C. 1996

[epa 2016]: Waste Packaging Statistics for Ireland. Environmental Protection Agency. Ireland. 2016

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

[ERM 2010]: Life cycle assessment of example packaging systems for milk. On behalf of Waste & Resources Action Programme (wrap). Oxford. 2010 http://www.wrap.org.uk/sites/files/wrap/Final%20Report%20Retail%202010.pdf (Last access July 25th, 2016).

[Eurostat 2017]: Eurostat Municipal Waste Luxembourg, 2016. http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics#Municipal_waste_treated_in_Europe (Access August 10th, 2017)

[FEFCO 2015]: Fédération Européenne des Fabricantes de Papiers pour Ondulé (FEFCO) and Cepi Container Board: European Database for Corrugated Board Life Cycle Studies. Brussels, 2015.

[Fehrenbach et al. 2015]: Fehrenbach H., Grahl B., Giegrich J., Busch M.: Hemeroby as an impact category indicator for the integration of land use into life cycle (impact) assessment. Inernational Journal of Life Cycle Assessment, September 2015

[Fehrenbach et al. 2016]: Fehrenbach H, Köppen S, Markwardt S, Vogt R (2016): Aktualisierung der Eingangsdaten und Emissionsbilanzen wesentlicher biogener Energienutzungspfade (BioEm); UBA Texte 09/2016, Dessau-Roßlau, Germany

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

[Frischknecht & Büsser Knöpfel 2013] Frischknecht R., Büsser Knöpfel S. 2013: Ökofaktoren Schweiz 2013 gemäß der Methode der ökologischen Knappheit. Methodische Grundlagen und Anwendung auf die Schweiz. Bundesamt für Umwelt. Bern. Umwelt-Wissen Nr. 1330:256 S.

[Giegrich et al. 2012]: Giegrich J., Liebich A., Lauwigi C., Reinhardt J.: Indikatoren / Kennzahlen für den Rohstoffverbrauch im Rahmen der Nachhaltigkeitsdiskussion, ifeu im Auftrag Umweltbundesamt, Dessau-Roßlau, Januar 2012

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

[IFEU 2013]: Lauwigi, C.; Fehrenbach, H.: Documentation for the UMBERTO based electricity grid model created by IFEU. 2013. http://www.ifeu.de/industrieundemissionen/pdf/Documentation Electricity Mix IFEU_version_2013.pdf

[ifeu 2017]: Markwardt, S.; Wellenreuther, F.; Drescher, A.; Harth, J.; Busch, M.: Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for liquid food on the Nordic market.

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

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

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

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

[IVL 2009]: Jelse, K.; Eriksson, E; Einarson, E.: Life cycle assessment of consumer packaging for liquid food. LCA of Tetra Pak and alternative packaging on the Nordic market. IVL Swedish Environmental Research Institute. 2009

[JRC 2011]: European Commission-Joint Research Centre – Institute for Environment and Sustainability (2011): International Life Cycle Data System (ILCD) Handbook – Recommendations for Life Cycle Impact Assessment in the European context. First Edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union.

[JRC 2016]: Environmental footprint – Update of Life Cycle Impact methods; Draft for TAB. Resources, water, land. May 2016.

[Kauertz et al 2011]: Kauertz, B., Döhner A., Detzel, A.. Ökobilanz von Getränkeverpackungen in Österreich – Sachstand 2010. Ifeu- Institut für Energie- und Umweltforschung Heidelberg GmbH. Heidelberg. 2011

[Klöpffer 1996]: Allocation rule for open-loop recycling in LCA; Klöpffer. in Int. J. LCA 1 (1) 27-32 (1996)

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

[Koellner et al. 2013]: Thomas Koellner, Laura de Baan, Tabea Beck, Miguel Brandão, Barbara Civit, Manuele Margni, Llorenc Milà i Canals, Rosie Saad, Danielle Maia de Souza, Ruedi Müller-Wenk. 2013. Method for assessing impacts on life support functions (LSF) related to the use of “fertile land” in Life Cycle Assessment (LCA). UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA. Int J Life Cycle Assess 18: 1188–1202.

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

[Macedo 2008]: Macedo, I.C.; Seabra, J.E.A.; Silva, J.E.A.R.: Greenhouse gases emissions in the production and use of ethanol from sugarcane in Brazil: The 2005/2006 averages and a prediction for 2020 in Biomass and Bioenergy 32 (2008) p. 582-595. Elsevier, 2008

[Micales and Skog 1997]: The Decomposition of Forest Products in Landfills. Micales. Skog. in International Biodeterioation and Biodegradation Vol. 39. No. 2, p. 145-158

[Mila i Canals et al. 2007]: Llorenc Mila i Canals, Joan Romanya, Sarah J. Cowell. 2007. Method for assessing impacts on life support functions (LSF) related to the use of “fertile land” in Life Cycle Assessment (LCA). Journal of Cleaner Production 15: 1426-1440.

[pet2pet 2019]:pet2pet. http://www.pet2pet.at/en/node/52. (Access October 15th, 2019)

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

[PlasticsEurope 2012a]: General-Purpose Polystyrene (GPPS) and High-Impact Polystyrene (HIPS). Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers, November 2012, PlasticsEurope.

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

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

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

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

[Posch et al. 2008]: Posch, M., Seppälä, J., Hettelingh, J.P., Johansson, M., Margni M., Jolliet, O. (2008): The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. International Journal of Life Cycle Assessment (13) pp.477–486.

[ReCiPe 2008]: Goedekoop, Mark; Heijungs, Reinout; Huijbregts, Mark; De Schryver, An; Struijs, Jaap; van Zelm, Rosalie (2009). ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at midpoint and endpoint level. First edition. Report I: Characterisation.

[Rosenbaum et al. 2008]: Rosenbaum, R. K.; Bachmann, T. M.; Gold, L. S.; Huijbregts, M. A. J.; Jolliet, O.; Juraske, R.; Koehler, A.; Larsen,H.F.; MacLeod,M.; Margni,M.; McKone,T.E.; Payet,J.; Schuhmacher,M.; van der Meent,D.; Hauschlid,M.Z. (2008). USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. The International Journal of Life Cycle.

[Robertson 2016]: Robertson, Gordon L. Food packaging: principles and practice. CRC press, 2016.

[Skog 2000]: Carbon Sequestration in Wood and Paper Products, Skog, Nicholson, in USDA Forest Service Gen. Tech. Rep. RMRS-GTR-59, p. 79-88

[Tetra Pak 2013]: Tetra Pak® - development in brief. Tetra Pak®, 2011, http://www.tetrapak.com/documentbank/9704en.pdf (download May 2015).

[Tetra Pak 2016]: Internal Tetra Pak Recycling Mapping

[Tetra Pak 2017]: Information provided by Tetra Pak

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

[UBA 2016] Umweltbundesamt. Berlin (Hrsg.): Prüfung und Aktualisierung der Ökobilanzen für Getränkeverpackungen. UBA-Texte 19/2016. Berlin. 2016.

[Ullmann 1986]: Ullmann's Encyclopedia of Industrial Chemistry', 1986, volume A5, pp140-157.

[Umweltbundesamt 2007]: Böhmer, S.; Kügler, I.; Stoiber, H.; Walter, B. Abfallverbrennung in Österreich – Statusbericht 2006. Umweltbundesamt GmbH. Wien 2007

[VBSA 2018]: Abfallverwertung. Verband der Betreiber Schweizerischer Abfallverwertungsanlagen (VBSA). http://vbsa.ch/fakten/abfallverwertung/ (accessed March 21th 2018)

[VDI 1997]: VDI 4600: Kumulierter Energieaufwand (Cumulative Energy Demand), German and English, VDI-Gesellschaft Energietechnik Richtlinienausschuß Kumulierter Energieaufwand, Düsseldorf 1999

[Voll & Kleinschmitt 2010]: Voll, M. and Kleinschmit, P. 2010. Carbon, 6. Carbon Black. Ullmann's Encyclopedia of Industrial Chemistry. .

[WKÖ 2017]: Nachhaltige Entwicklungen – Nachhaltigkeitsagenda der österreichischen Getränkewirtschaft – Umsetzungsbericht. Wirtschaftskammer Österreich WKÖ, Abteilung für Umwelt- und Energiepolitik. Juni 20017

[WMO 2011]: WMO (World Meteorological Organization), Scientific Assessment of Ozone Depletion: 2010, Global Ozone Research and Monitoring Project–Report No. 52, 516 pp., Geneva, Switzerland, 2011.

[World Steel 2010] Methodology report – Life cycle inventory study for steel products. World, World Steel Association, Brussels, 2011.

List of figures

List of tables

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 Photo-oxidant formation

Due to the complex reactions during the formation of near-ground ozone (photo smog or summer smog), the modelling of the relationships between the emissions of unsaturated hydrocarbons and nitrogen oxides is extremely difficult.

The method to be applied for the impact category Photo-oxidant formation, should be the „Maximum Incremental Reactivity“ of VOC und Nitrogen-MIR (Nitrogen-MIR) based on the publication of [Carter 2010]. The MIR concept is the most appropriate characterisation model for LCIA based on generic spatial independent global inventory data and combines a consistent modelling of potential impacts for VOC and NOx and the precautionary principle. The MIR and NMIR are calculated based on scenarios where ozone formation has maximum sensitivities either to VOC or NOx inputs. The unit for the category indicator MIR is kg O_3-e.
The related characterisation factors applied in this study are based on [Carter 2010]. Examples of the factors for more than 1100 substances are listed in Table A-2.

Harmful gas (examples)	Characterisation factors (MIR/NMIRs$_i$) [Carter 2010] [g O_3-e/g-emission]
1-Butene	9.73
1-Propanol	2.50
2-Propanol	0.61
Acetaldehyde	6.54
Acetic acid	0.68
Acetone	0.36
Benzene	0.72
Carbon monoxide, fossil	0.056
Ethane	0.28
Ethanol	1.53
Ethene	9.00
Formaldehyde	9.46
Methane, fossil	0.014
Methanol	0.67
NMVOC, unspecified	3.60
Styrene	1.73
Nitrogen dioxide	16.85
Nitrogen monoxide	24.79
Toluene	4,00

Source: [Carter 2010]

Table A-2: Maximum Incremental Reactivity (MIR) of substances considered in this project (excerpt)

The contribution to the Maximum Incremental Reactivity is calculated by summing the products of the amounts of the individual harmful substances and the respective MIR values using the following equation:

$$MIR = \sum_i (m_i \times MIR_i)$$

A.3 Stratospheric ozone depletion

Stratospheric ozone depletion refers to the thinning of the stratospheric ozone layer as a result of anthropogenic emissions. This causes a greater fraction of solar UV-B radiation to reach the earth's surface, with potentially harmful impacts on human health, animal health, terrestrial and aquatic ecosystems, biochemical cycles and materials [UNEP 1998].
The ozone depletion potential category indicator that was selected and described in [CML 1992, CML 2002] uses a list of 'best estimates' for ODPs that has been compiled by the World Meteorological Organisation (WMO). These ODPs are steady-state ODPs based on a model. They describe the integrated impact of an emission or of a substance on the ozone layer compared with CFC-11 [CML 2002]. The following table shows the list of harmful substances considered in this study, along with their respective ozone depletion potential (ODP) expressed as CFC-11 equivalents based on the latest publication of the WMO [WMO 2011].

Harmful substance	CFC-11 equivalent (ODP_i)
CFC-11	1
CFC-12	0.82
CFC-113	0.85
CFC-114	0.58
CFC-115	0.57
Halon-1301	15.9
Halon-1211	7.9
Halon-2402	13
CCl_4	0.82
CH3CCl3	0.16
HCFC-22	0.04
HCFC-123	0.01
HCFC-141b	0.12
HCFC-142b	0.06
CH_3Br	0.66
N_20	0.017
• Source: [WMO 2011]	

Table A-4: Ozone depletion potential of substances considered in this study

The contribution to the ozone depletion potential is calculated by summing the products of the amounts of the individual harmful substances and the respective ODP values using the following equation:

$$ODP = \sum_i (m_i \times ODP_i)$$

A.4 Eutrophication and oxygen-depletion

Eutrophication means the excessive supply of nutrients and can apply to both surface waters and soils. With respect to the different environmental mechanisms and the different safeguard subjects, the impact category eutrophication is split up into the terrestrial eutrophication and aquatic eutrophication.

The safeguard subject for freshwater aquatic ecosystems is defined as preservation of aerobic conditions and the conservation of site-specific biodiversity, whereas the safeguard subject for terrestrial ecosystems addresses the preservation of the natural balance of the specific ecosystem, the preservation of nutrient-poor ecosystems as high moors and the conservation of site-specific biodiversity.

It is assumed here for simplification that all nutrients emitted via the air cause enrichment of the terrestrial ecosystems and that all nutrients emitted via water cause enrichment of the aquatic ecosystems. Oligotrophy freshwater systems in pristine areas of alpine or boreal regions are often not affected by effluent releases, but due to their nitrogen limitation sensitive regarding atmospheric nitrogen deposition. Therefore, the potential impacts of atmospheric nitrogen deposition on oligotrophic waters are included in the impact category terrestrial eutrophication.

The eutrophication of surface waters also causes oxygen-depletion as secondary effect. If there is an over-abundance of oxygen-consuming reactions taking place, this can lead to oxygen shortage in the water. The possible perturbation of the oxygen levels could be measured by the Bio-chemical Oxygen Demand (BOD) or the Chemical Oxygen Demand (COD). As the BOD is often not available in the inventory data and the COD essentially represents all the available potential for oxygen-depletion, the COD is used as a conservative estimate[1].

In order to quantify the magnitude of this undesired supply of nutrients and oxygen depletion substances, the eutrophication potential category was chosen. This category is expressed as phosphate equivalents [Heijungs et al. 1992]. The table below shows the harmful substances and nutrients that were considered in this study, along with their respective characterisation factors:

[1] The COD is (depending on the degree of degradation) higher than the BOD, which is why the equivalence factor is deemed relatively unreliable and too high.

Harmful substance	PO_4^{3-} equivalents (EP_i) in kg PO_4^{3-} equiv./kg
Eutrophication potential (terrestrial)	
Nitrogen oxides (NO_X as NO_2)	• 0.13
Ammonia (NH_3)	• 0.35
Dinitrogen oxide (N_2O)	• 0.27
Eutrophication potential (aquatic) (+ oxygen depletion)	
Phosphate ($PO4^{3-}$)	• 1
Total phosphorus	• 3.06
Chemical Oxygen Demand (COD)	• 0.022
Ammonium (NH_4^+)	• 0.33
Nitrate (NO_3^{2-})	• 0.1
N-compounds. unspec.	• 0.42
P as P_2O_5	• 1.34
P-compounds unspec.	• 3.06
• Source: [Heijungs et al 1992]	

Table A-3: Eutrophication potential of substances considered in this study

The eutrophication potential (EP) is calculated separately for terrestrial and aquatic systems. In a rough simplification the oligotrophic aquatic systems are covered by the terrestrial eutrophication potential. In each case, that contribution is obtained by summing the products of the amounts of harmful substances that are emitted and the respective EP values.

The following equations are used for terrestrial or aquatic eutrophication:

$$EP(aquatic) = \sum_i (m_i \times EP(aquatic)_i)$$

$$EP(terrestrial) = \sum_i (m_i \times EP(terrestrial)_i)$$

A.4 Acidification

Acidification can occur in both terrestrial and aquatic systems. The emission of acid-forming substances is responsible for this.

The acidification potential impact category that was selected and described in [CML 1992, CML 2002, Klöpffer 1995] is deemed adequate for this purpose. No specific characteristics of the affected soil or water systems are hence necessary. The acidification potential is usually expressed as SO_2 equivalents. The table below shows the harmful substances considered in this study, along with their respective acidification potential (AP) expressed as SO_2 equivalents.

Harmful substance	SO_2 equivalents (AP_i)
Sulphur dioxide (SO_2)	• 1
Nitrogen oxides (NO_X)	• 0.7
Hydrochloric acid (HCl)	• 0.88
Hydrogen sulphide (H_2S)	• 1.88
Hydrogen fluoride (HF)	• 1.6
Hydrogen cyanide (HCN)	• 1.6
Ammonia (NH_3)	• 1.88
Nitric acid (HNO_3)	• 0.51
Nitrogen oxide (NO)	• 1.07
Phosphoric acid (H_3PO_4)	• 0.98
Sulphur trioxide (SO_3)	• 0.8
Sulphuric acid (H_2SO_4)	• 0.65
• Source: [Hauschild und Wenzel 1998] taken from [CML 2010]	

Table A-4: Acidification potential of substances considered in this study

The contribution to the acidification potential is calculated by summing the products of the amounts of the individual harmful substances and the respective AP values using the following equation:

$$AP = \sum_i (m_i \times AP_i)$$

A.5 Particulate matter

The category chosen for this assessment examines the potential threat to human health and natural environment due to the emission of fine particulates (primary particulates as well as precursors). Epidemiological studies have shown a correlation between the exposure to particulate matter and the mortality from respiratory diseases as well as a weakening of the immune system. Relevant are small particles with a diameter of less than 10 and especially less than 2.5 µm (in short referred to as PM10 and PM2.5).These particles cannot be absorbed by protection mechanisms and thus deeply penetrate into the lung and cause damage.

Particulate matter is subsuming primary particulates and precursors of secondary particulates. Fine particulate matter can be formed from emissions by different mechanisms: On the one hand particulate matter is emitted directly during the combustion process (primary particles), on the other hand particles are formed by chemical processes from nitrogen oxide and sulphur-dioxide (secondary particles).

They are characterised according to an approach by [De Leeuw 2002].

In accordance with the guidelines of [WHO 2005], PM2.5 is mostly relevant for the toxic effect on human health. Thus, the category indicator aerosol formation potential (AFP) referring to PM2.5-equivalents is applied. The substances assigned to this category are primary particles and secondary particles formed by SO_2, NOx, NH_3 and NMVOCs ([WHO 2005]). The non-organic substances are characterised according to an approach by [De Leeuw 2002]. This characterisation factors were used for reporting by the European Environmental Agency until 2011 and are based on dispersion model results by [Van Jaarsveld 1995]. [ReCiPe 2008] and [JRC 2011] are also using the same base dispersion model results for the calculation of particulate formation. The model by [De Leeuw 2002] covers European emissions and conditions, but is the best available approach for quantifying population density independent factors and is therefore applied for all emissions.

Regarding NMVOC emissions, only the knowledge of exact organic compounds would allow quantification as secondary particles. Therefore, an average value for unspecified NMVOCs calculated by [Heldstab et al. 2003] is applied.

Harmful substance	PM2.5 equivalents (PFP_i) (Air) [kg PM2.5 equivalents/kg]
PM2.5	1
PM10	0.5
NH_3	0.64
SO_2	0.54
SO_x	0.54
NO	0.88
NO_x	0.88
NO_2	0.88
NMVOC[1)]	0.012
Source: [De Leeuw 2002]; [1)] [Heldstab et al. 2003]	

Table A-5: PM2.5 equivalents of substances considered in this study

The contribution to the Aerosol Formation Potential (AFP) is calculated by summing the products of the amounts of the individual harmful substances and the respective AFP equivalent values using the following equation:

$$PFP = \sum_i (m_i \times AFP_i)$$

A.6 Use of Nature

Traditionally, LCAs carried out by the German Federal Enviroment Agency (UBA) include the impact category land use based on the metric 'Degree of naturalness of areas'. Despite the recent developments on land use in LCAs, the fundamental idea to characterise 'naturalness' as an overarching conservation goal (desired state) forming the basic concept to address selected conservation assets is still appropriate. The idea central to the concept follows the logic that intact ecosystems are not prone to higher levels of disturbance and negative impacts.

Recently the so called hemeroby concept in order to provide an applicable and meaningful impact category indicator for the integration of land use and biodiversity into the Life Cycle (Impact) Assessment has been developed by [Fehrenbach et al. 2015]. This approach is operationalized by a multi-criteria assessment linking the use of land to different subjects of protection: Structure and functionality of ecosystems, biological diversity and different ecosystem services contributing to human wellbeing. In this sense hemeroby is understood as a mid-point indicator giving explicit information on naturalness and providing implicit information, at least partly, on biodiversity (number of species, number of rare or threatened species, diversity of structures), and soil quality (low impact.)

The system of hemeroby is subdivided in to seven classes (see Table 1). This system is appropriate to be applied on any type of land-use type accountable in LCA. Particularly production systems for biomass (wood from forests, all kinds of biomass from agriculture) are assessed in a differentiated way:

> To describe forest systems three criteria are defined: (1) natural character of the soil, (2) natural character of the forest vegetation, (3) natural character of the development conditions. The degree of performance is figured out by applying by 7 metrics for each criterion.
>
> Agricultural systems are assessed by four criteria: (1) diversity of weeds, (2) Diversity of structures, (3) Soil conservation, (4) Material input. Three metrics are used for each criterion to calculate the grade of hemeroby.

The approach includes the derivation of inventory results (x m^2 of area classified as class y) as well as the aggregation to the category indicator 'Distance-to-Nature-Potential' (DNP) (m^2-e * 1a) by characterization factors.

Class	Class name	Land-use type
1	• Natural	undisturbed ecosystem, pristine forest
2	• close-to-nature	close-to-nature forest management
3	• partially close to nature	intermedium forest management, Highly diversified structured agroforestry systems
4	• semi-natural	half-natural forest management, Extensive grassland, mixed orchards
5	• partially distant to nature	mono-cultural forest, Intensified grassland (pastures); Agriculture with medium large cuts
6	• distant-to-nature	Highly intensified agricultural land, large areas cleared landscape
7	• non-natural, artificial	long-term sealed, degraded or devastated area
Source: Fehrenbach et al. 2015		

Table A-6.1: The classification system of hemeroby classes

Class VII as the category most distant from nature is characterized by factor 1. Each class ascending towards naturalness will be characterized by a factor half from the precedent. Therefore the maximum span from class VII to class II is 1 : 32, an span which corresponds with share of class VII area of entire area.[1] Table A-6.2 lists the characterisation factors for each class.

Class	Characterisation factor (DNP_i)
1	0
2	0.0313
3	0.0625
4	0.125
5	0.25
6	0.5
7	1

Table A-6.2: The characterisation factors of hemeroby classes

The 'Distance-to-Nature-Potential' (DNP) is calculated by summing the products of the square meters of area classified as land use class 2 to 7 and the respective characterization factor using the following equation:

$$DNP = \sum_i ((m^2 * a)_i \times DNP_i)$$

[1] The global share of area classified as class VII amounts to approximately 3 % of total land area. In consequence, the ratio between class VII land and the sum of other areas is 1:33. (see [Fehrenbach et al. 2015])

A.8 References (for Appendix A)

[Carter 2010] Carter, W. P. L.: Development of the SARC-07 Chemical Mechanism and Updated Ozone Reactivity Scales. Updated Chemical Mechanisms for Airshed Model Applications. Supplementary Material. California Air Resources Board, 11. Mai 2012

[CML 1992]: Environmental life cycle assessment of products. Guide and backgrounds, Center of Environmental Science (CML), Netherlands Organisation for Applied Scientific Research (TNO), Fuels and Raw Materials Bureau (B&G). Leiden. 1992

[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.

[CML 2010]: CML-IA database that contains characterisation factors for life cycle impact assessment (LCIA) for all baseline characterisation methods mentioned in [CML 2002]. Database CML-IA v3.7, Institute of Environmental Sciences, Leiden University, Leiden, November 2010; http://www.cml.leiden.edu/software/data-cmlia.html

[Derwent et al. 1999]: Derwent, R., R. Friedl, I.L., Karol, V.W.J.H., Kirchhoff. T. Ogawa. M.J. Rossi. P. Wennberg. 1999: Impacts of aircraft emissions on atmospheric ozone. – In: J.E.Penner. D.H. Lister. D.J. Griggs, D.J. Dokken. M.McFarlandD (Eds.): Aviation and the Global Atmosphere. A Special Report of IPCC Working Groups I and III. Cambridge University Press. Cambridge. UK. pp.27–64

[Fehrenbach et al. 2015]: Fehrenbach H., Grahl B., Giegrich J., Busch M.: Hemeroby as an impact category indicator for the integration of land use into life cycle (impact) assessment. Inernational Journal of Life Cycle Assessment, September 2015

[Giegrich, J., Sturm, K.] (1996) Methodenpapier zur Naturraumbeanspruchung für Waldökosysteme; Materialband „Methodische Grundlagen B in: Tiedemann A (2000) Ökobilanzen für graphische Papieren; Texte 22/00, Berlin

[Guineé & Heijungs 1995]: Guinée, J.B. & Heijungs, R. A proposal for the definition of resource equivalency factors for use in product life-cycle assessment. Environmental Toxicology and Chemistry, 14 (5), pp. 917-925. (Article),1995

[Guinee 2008]: Personal communication between Jeroen Guinée and Martina Krüger. January 2008.

[Hauschild & Wenzel 1998]: Michael Hauschild & Henrik Wenzel. 1998: Environmental Assessment of Products. Volume 2: Scientific Background London. Chapman & Hall

[Heijungs et al 1992]: Heijungs. R.. J. Guinée. G. Huppes. R.M. Lankreijer. H.A. Udo de Haes. A. Wegener Sleeswijk. A.M.M. Ansems. P.G. Eggels. R. van Duin. H.P. de Goede. 1992: Environmental Life Cycle Assessment of products. Guide and Backgrounds, Centre of Environmental Science (CML). Leiden University. Leiden.

[Heldstab 2003] Heldstab, J. et al.: Modelling of PM10 and PM2.5 ambient oncentrations in Switzerland 2000 and 2010. Environmental Documentation No.169. Swiss Agency for the Environment, Forests and Landscape SAEFL. Bern, Switzerland, 2003.

[IFEU 2008]: Characterisation factors for group emissions VOC. NMVOC for the impact category Summer Smog (POCP). Heidelberg. 2008. (unpublished)

[Impact 2002]: Olivier Jolliet. Manuele Margni. Raphaël Charles. Sébastien Humbert. Jérôme Payet. Gerald Rebitzer and Ralph Rosenbaum: IMPACT 2002+: A New Life Cycle Impact Assessment Methodology. Int J LCA 8 (6) pp. 324 – 330 (2003)

[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.

[JRC 2011]: European Commission-Joint Research Centre – Institute for Environment and Sustainability (2011): International Life Cycle Data System (ILCD) Handbook – Recommendations for Life Cycle Impact Assessment in the European context. First Edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union.

[Kim et al. 1997] Kim et al.: Allocation for cascade recycling system; In: Int. J. LCA 2 (4) pp. 27-32 (1997)

[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.

[Leeuw 2002]: Leeuw. F.D.: A set of emission categories for long-range transboundary air pollution. Bilthoven 2002

[ReCiPe 2008]: Goedekoop, Mark; Heijungs, Reinout; Huijbregts, Mark; De Schryver, An; Struijs, Jaap; van Zelm, Rosalie (2009). ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category categories at midpoint and endpoint level. First edition. Report I: Characterisation.

[ReCiPe108]: ReCiPe Mid/Endpoint method, version 1.07 February 2013. http://www.lcia-recipe.net/ (download March 2013)

[UBA 1995]: Umweltbundesamt (Publisher): Ökobilanz für Getränkeverpackungen. Datengrundlagen. Berlin. 1995. (UBA-Texte 52/95)

[UBA 1998]: Umweltbundesamt Berlin (Publisher): Ökobilanz Graphischer Papiere. Berlin. 1998.

[UBA 1999]: Umweltbundesamt: Bewertung in Ökobilanzen. UBA-Texte 92/99. Berlin. 1999.

[UBA 2016]: Umweltbundesamt. Berlin (Hrsg.): Prüfung und Aktualisierung der Ökobilanzen für Getränkeverpackungen. UBA-Texte 19/2016. Berlin. 2016.

[Van Zelm et al. 2007]: van Zelm, R.,Huijbregtsa, M.A.J., den Hollanderc, H.A,. van Jaarsveldd, H.A., Sautere, F.J., Struijsb, J., van Wijnenc, H.J., van de Meenta, D. European characterization factors for human health damage of PM10 and ozone in life cycle impact assessment. Atmospheric Environment Volume 42, Issue 3, January 2008, Pages 441–453

[WHO 2005]: World Health Organization and United Nations Economic Commission for Europe: Air Quality Guidelines, Global Update 2005, Particulate matter, ozone, nitrogen dioxide and sulphur dioxide. 2006, Copenhagen

[WMO 2011]: WMO (World Meteorological Organization), Scientific Assessment of Ozone Depletion: 2010, Global Ozone Research and Monitoring Project–Report No. 52, 516 pp., Geneva, Switzerland, 2011.

Appendix B: Critical Review Report

Critical Review of the report and study
"Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages and liquid dairy products on the Swiss and Austrian market"

Review report

based on "LCA TPATCH FinalReport_15.10.19.pdf" provided on Oct. 15th, 2019

November 12th, 2019

Authors of the study:

Samuel Schlecht
Frank Wellenreuther
Mirjam Busch
Stefanie Markwardt
IFEU – Institut für Energie- und Umweltforschung Heidelberg

Review Panel:

Jürgen Heinisch, Jürgen Heinisch Consulting
Harald Pilz, to4to – together for tomorrow (chair of review panel)
Andy Spörri, EBP Schweiz AG

1 Introduction

1.1 Background and motivation for the LCA study

Tetra Pak systematically works 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.

Tetra Pak has recently finalized LCA studies for several packaging formats in several European markets. The results are only valid for the indicated geographic scope. Therefore, Tetra Pak commissioned the Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research, ifeu) to conduct a comparative LCA study for key carton packages as well as key competing packages in different beverage segments covering the markets of Austria and Switzerland.

1.2 Goal and scope of the study

The goal of the study is to conduct an LCA for the Swiss and Austrian market, analysing the environmental performance of beverage carton systems (partly with bio-based material) compared to alternative beverage packaging systems (filling volumes range from 200 to 2000 ml). Competing packaging systems include: PET and HDPE bottles and PP/PS cups. Additionally one-way and refillable glass bottles are analysed for the Austrian market.

The analysed packaging systems contain the following chilled and ambient beverage segments: Juice and Nectars (JN), Still Drinks (SD), DAIRY products like milk or coffee drinks, CREAM (whipping cream and coffee cream), and still unflavoured WATER.

2 Critical Review Tasks, Process and Panel

The comparative results of this study are intended to be disclosed by Tetra Pak. According to the ISO standards on LCA [ISO 14040 and 14044 (2006)], this requires a critical review process undertaken by a critical review panel. The members of the critical review panel responsible for reviewing this LCA study are

- Harald Pilz (chair), to4to – together for tomorrow
- Jürgen Heinisch, Jürgen Heinisch consulting
- Andy Spörri, EBP Schweiz AG

Harald Pilz is working in the field of LCA since 1994, with a focus on packaging systems. His experiences include LCA studies for various European countries, detailed knowledge of Austrian waste management conditions, as well as participation in several critical review processes.

Jürgen Heinisch has been working in the field of packaging market research and LCA for beverage packaging since 1990. In this review process his focus was market analysis, in particular the selection and specification of packaging systems, approaches to model distribution, as well as trip rates of refillable systems.

Andy Spörri is working in the field of LCA since 2007, conducting and reviewing several LCA studies, amongst others in the field of waste collection and recycling, and acting as lecturer at ETH Zurich in the field of prospective environmental assessments. Beside the critical reflection of the conducted study from a generic methodological perspective, in the review process he focused on the adequate representation of the Swiss waste management practices.

According to ISO 14044 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.

The critical review was organised as an accompanying process. The critical reviewers were able to comment on the project from the time the goal and scope description was available. Feedback of the reviewers on the goal and scope description was discussed in a meeting in April 2018. Harald Pilz and Andy Spörri also supported the data collection, where specific inputs for Austrian or Swiss conditions were needed. IFEU delivered a draft report in August 2019. The reviewers checked the report and sent a detailed list of comments and questions to IFEU, which were discussed in a meeting in September 2019. On Oct. 15th 2019 IFEU delivered the final report titled "LCA TPATCH FinalReport_15.10.19.pdf", which was the basis of this review report. In addition IFEU provided a list with comments to the reviewers, how each of the earlier inputs of the reviewers was considered during the final revision of the report.

3 Topics discussed and improved during the review process

This chapter lists the most relevant topics discussed and improved during the review process. In almost all cases questions of the review panel were answered satisfactorily. Numerous modifications were implemented in the documentation, calculation, and presentation of results. Two interesting remaining aspects related to transport impacts and to regenerative carbon are discussed below.

3.1 Investigated beverage packaging systems; packaging specifications

- The selection of packaging systems was based on the concept of typical packaging. TetraPak cartons were selected using internal sales data and Nielsen data. The choice of alternative packaging systems was based on Nielsen data. Where insufficient market data was available, the selection was justified qualitatively. Details on the selected packaging products were available for / discussed with the review panel.
- Packaging specification data is presented transparently and was checked by the review panel based on the given market knowledge.
- Trip rates for refillable glass bottles were agreed with the review panel. Based on this proposal, a scenario with lower trip rates for reusable packaging for juices and nectars was carried out. As the low trip rate for refillable dairy glass bottles referred to one source only, a scenario with a higher trip rate was performed. In an established reusable system, such higher trip rate could be reached.
- Other aspects discussed were the share of recycled content in PET bottles, mass shares of barrier materials in PET bottles, and the change in PET milk bottle design in Austria while this study was elaborated.

3.2 Production processes

- Aspects discussed include sources of LCI data for various materials, comparison of different sources for processing energy, and electricity mixes used (production mix versus market mix).

3.3 Transport processes, Distribution model

- Assumptions for the distribution model were provided together with model calculations, and were discussed in detail between IFEU and the review panel. IFEU implemented decisions on changes. Since modelled transport distances only consider bottlers using TetraPak, the data don't necessarily reflect average transport distances of all bottlers.
- Earlier LCA studies on beverage packaging systems have shown that input data on "actual litres fitting on one truck, depending on the specific packaging system" are an important influence for the results. The number of packaging units per pallet or rollcontainer is presented in the tables of chapter 2.2, but the final gross weight loaded on a truck, together with the respective total packaging units per truck (sometimes limited by volume, sometimes limited by weight) are not described in the report. In addition, the number of layers on pallets in practice can deviate from the theoretical maximum.
- In this study the fuel consumption and emissions of transports are determined as a function of the actual truck load and distance. In addition, the impacts of transporting beverages from fillers to retailers are allocated to packaging and packed product. Only the share allocated to packaging is considered in this study. The review panel checked the influence of this allocation approach, compared to an alternative approach, where the full impact of transporting beverages from fillers to retailers is considered. (Main argument for the alternative approach: The actual litres fitting on one truck are directly influenced by the respective packaging system; therefore packaging systems also influence the impacts of transporting the beverage itself.) The outcome of this comparison is interesting:
    - If all trucks are loaded with the same gross load, then the share of impacts allocated to the packed content is always the same, and the share allocated to packaging shows the full delta between packaging systems.
    - Trucks which are loaded with a higher gross load reduce the share allocated to packaging, and vice versa.
    - This means that the net differences of results of the two approaches will differ, if the gross loads on trucks are different.

3.4 Discussed and improved aspects of waste management

- Specification of recycling and recovery routes for Austria and Switzerland
- Substitution factors due to barrier materials
- Substitution of primary materials due to re-processing of recyclates
- Treatment of residues from sorting and recycling
- Energy efficiency of municipal solid waste incineration plants

3.5 Presentation and interpretation of results

- Pros and cons of detailed graphs for results
- Agreement on sensitivity analyses to show effects of different input data and different methodical approaches
- Exclusion of land use and water consumption when interpreting results

3.6 Consideration of regenerative CO_2 cycles / emissions, in combination with end-of-life allocation options

Many previous LCA studies, also published by IFEU, have ignored both, uptake of CO_2 by plants, and renewable CO_2 emissions at end-of life. The argument for this approach was that impacts and credits are mostly balancing each other. Only carbon sequestration in landfills, and methane emissions from landfills were considered as relevant net effects.

In the current LCA study for Tetra Pak both, uptake of CO_2 by plants, and renewable CO_2 emissions at end-of life are considered. In addition, this approach is combined with the "50 % allocation for waste treatment", which allocates 50 % of impacts and credits of open loop recycling and recovery to the investigated beverage packaging system, and the remaining 50 % to the system utilising the secondary resources.

As a result, the full CO_2 uptake, but only 50 % of the regenerative CO_2 emissions are included in the standard version of the results, **which causes very low absolute GWP results for all beverage carton systems**. While this methodical approach seems to be consistent with the "minimum requirements for life cycle assessments of beverage packaging of the German Environment Agency", several questions are arising:

- When wood is transformed to packaging materials, which are finally incinerated (sometimes after a few recycling loops; no landfilling in Austria and Switzerland), there is no net carbon sequestration realised by the packaging systems. Nevertheless the combination of full CO_2 uptake, but only 50 % of the regenerative CO_2 emissions more or less represents a situation, where 50 % of the carbon uptake would be sequestered.
- IFEU presents all results also based on the "100 % allocation for waste treatment", which means that 100 % of the recovery and recycling impacts and credits are allocated to the investigated beverage packaging systems. In this allocation version, the full CO_2 uptake is actually balanced out with the full regenerative CO_2 emissions. On the other hand, open-loop recycling processes show the same net benefits as closed loop recycling processes in this allocation approach. This means that PET bottles with recycled content (closed loop recycling) are put at a disadvantage compared to packaging solutions without shares of closed loop recycling.
- Finally, carbon in plastic bottles and carbon in beverage cartons show the *same* GWP impacts in the system where the respective waste is incinerated: In the "50 % allocation for waste treatment" half of the carbon in both materials contributes to GWP impacts, and in the "100 % allocation for waste treatment" none of the carbon in both materials contributes to GWP impacts. In the same way as this does not seem to be appropriate for incineration processes (disadvantage for bio-based materials, compared to fossil materials), the chosen approaches cause the equivalent "mirror effects" in the investigated beverage packaging systems (advantage for bio-based materials, compared to fossil materials).
- For future studies it could be worth considering
  - either not to consider regenerative carbon uptakes and emissions for *short-lived* packaging products
  - or to use a 50 % allocation also for the CO_2 uptake, in the same way as a 50 % allocation is applied to recycled content.

Both approaches would solve the questions listed above.

IFEU therefore also produced two sensitivity analyses, where neither CO_2 uptake nor regenerative CO_2 emissions are considered. Respective results are shown for Still Drinks ("Family Pack" sizes) in both markets. The interested reader can derive adapted results for the same approach also for all beverages and versions where the results are presented in tables (CO_2 uptake and regenerative CO_2 emissions are listed in separate lines).

For Still Drinks family packs the sensitivity analyses show that GWP results are still lower for the beverage cartons, compared to alternative PET bottle. In this specific case the choice of methodology for consideration of regenerative carbon does not affect the ranking regarding GWP. A different situation can be derived for portion packs for still water in Austria. Leaving out regenerative carbon gives comparable GWP results for the TPA Edge beverage cartons and PET bottles (500 ml filling volume). In addition the PET bottle would show a GWP benefit of more than 10 % for recycled contents of 60 % or higher. Portion packs for still drinks in Austria start to show equal GWP results with 85 % recycled content. Due to higher PET recycling rates in Switzerland, the respective break even points are already reached for lower shares of recycled content.

3.7 Summary: Aspects to consider regarding comparability of the results of this LCA studies with other LCA studies

Chapter 12 on limitations in the study already highlights many aspects which can be different in other LCA studies on similar types of packaging

- Packaging weight, masses of packaging components, including barrier requirements of specific packaging products for a given filing volume
- Considered environmental impacts and applied assessment methods
- Waste management conditions (recycling, recovery, disposal)

In addition, the review panel wants to highlight the following aspects, which need to be considered when comparing the results of this study with other LCA studies:

- Inclusion or exclusion of regenerative carbon, in combination with applied allocation method for waste treatment (see chapter 3.6)
- Choice of allocation method for impacts of transport (total impact or allocation to packaging only) in combination with gross loads of trucks (see chapter 3.3)
- Data inputs on total litres transported by one truck (see chapter 3.3), and transport distances
- Electricity mixes: This study uses production mix data, while other studies might use market mix data (production + imports)
- Specific modelling of recycling (losses in sorting and recycling; substitution factors; substituted materials)
- Credits from industrial energy recovery: In this study, 100 % substitution of coal is assumed; other studies might assume other mixes of substituted fossil fuels
- "Final disposal" of volumes recycled into different product systems may be included or not; final disposal is modelled with 100 % MSWI in this study and could as well be a mix of MSWI and industrial energy recovery.

4 Results of the critical review

4.1 Are the methods used scientifically and technically valid and consistent with ISO 14044?

Yes they are. Chapter 1 of the report reflects a very high level of knowledge and technical application of up-to-date LCA methodology. Also on the level of transport calculations and on the level of waste management the applied methodologies are very advanced. As discussed above, the chosen approaches for considering and allocating regenerative carbon lead to several questions and challenges, where no perfect answer seems to be available today. Ideally, in the view of the review panel, GWP results would always be displayed for all four variations discussed in this report: with and without considering regenerative carbon, and in both cases using the 50 % or the 100 % allocation for waste treatment. For *short-lived* packaging products, many LCA specialists will still prefer not to consider regenerative carbon, and to use the 50 % allocation for waste treatment, which is mostly in line with the new "circular footprint formula" developed within the Product Environmental Footprint Program of the European Commission.

4.2 Are the data used appropriate and reasonable in relation to the goal of the study?

Yes they are. Data sources of high quality are precisely described for every process of the total value chain. Assumptions are discussed and described in detail, and are reasonable in the view of the reviewers. For future studies the reviewers recommend documenting the actual number of litres fitting on one truck (or put on one truck in reality), to enable detailed comparisons of the transport impacts with other LCA studies.

4.3 Do the interpretations reflect the goal of the study and the limitations identified?

Yes they do. The selection of considered environmental impacts is well described and justified in chapter 1 of the report. While beverage cartons tend to consume more water and more land in their total life cycle, the reviewers accept that these parameters are not considered for the conclusions, because either the weighting methods (water scarcity, quality of land) or the data availability are insufficient today. Sensitivity analyses are performed to vary the most relevant variations in input data and methodical approaches. Limitations for the validity of results are well described in the respective chapter of the report.

4.4 Is the study report transparent and consistent?

Yes it is. With 480 pages the report is extensive, but the good and detailed structure of the report supports the reader to look up details needed for understanding. Bookmarks in the PDF version help to find respective chapters of the report quickly. For future reports, the review panel recommends to include pictures of the investigated packaging systems. Especially for the beverage carton systems many abbreviations are used. Pictures would help to relate these abbreviations to packaging products available on the Austrian and Swiss market.

5 Review statement

As the four relevant questions for the review process could be answered positively, the review panel recommends the utilisation and disclosure of this study. Future summary documents should keep the differentiation made in the respective conclusion chapters. Also, the specific effects of the approaches chosen for regenerative carbon, and for transporting beverages from fillers to retailers, should be mentioned in such summary documents.

The study is a valuable contribution for an improved, differentiated and factual discussion on advantages and disadvantages of beverage packaging systems, and on the potentials for improvement in terms of environmental sustainability.

November 12th, 2019

Harald Pilz | Jürgen Heinisch | Andy Spörri