INSTITUT FÜR ENERGIE- UND UMWELTFORSCHUNG HEIDELBERG

Meta Study of Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for beverages based on selected studies of the European market.

Meta-Analysis and Overview Matrix on Climate Change of selected studies in European countries

commissioned by Tetra Pak

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1 Background

Tetra Pak has for several decades worked with Life Cycle Assessments (LCAs) as a tool to understand the environmental impact of development decisions and relative to alternative solutions. Over time, the LCA method has become the preferred tool since it is based on scientific principles, including full transparency of sources and assumptions. Tetra Pak will only use LCAs for external purposes that have also undergone a rigorous peer review by independent experts in order to secure credibility of results. In addition, if public claims are to be made, Tetra Pak will publish the full study online for public access of source materials. By conducting a meta study overall findings regarding the climate change impacts of beverage packaging systems shall be identified.

Recently a meta study regarding the environmental performance of beverage cartons commissioned by 'The Alliance for Beverage Cartons and the Environment' (ACE) has been conducted by Circular Analytics [Circular Analytics 2020]. This study includes data from LCA studies commissioned by ACE and its members as well from literature. Included types of packaging systems in this study are beverage cartons, PET bottles and glass bottles (single use and refillable). Included segments in this study are dairy and juice as well as carbonated drinks and wine.

The meta study at hand is based on LCA studies specifically commissioned by Tetra Pak which have been conducted by ifeu between 2018 and 2021. These are ifeu [2018], ifeu [2019a], ifeu [2019b], ifeu [2020a], ifeu [2020b], ifeu [2020c], ifeu [2020d], ifeu [2021a] and ifeu [2021b].

The functional unit used is the packaging of 1000 L beverage and the countries included in this meta LCA are **Austria, Belgium, Croatia, Denmark, Finland, France, Greece, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland** and **United Kingdom**.

In this report the climate impact of **dairy-**, **JNSD-** (juices, nectars and still drinks) and **water packages** will be examined, since out of all the impact categories covered by the LCA studies, climate change is considered by Tetra Pak as the major challenge for society to address in the coming years. For this reason, the impact category climate change is specifically addressed. Also the number of studies presenting climate change results that could be taken into account for this meta study is higher than that of full LCA studies available that also include other environmental impact categories. Being able to be based on more study reports this meta study focusing on climate change therefore delivers more robust results. A second meta study considering further environmental impact categories based on fewer individual studies is conducted separately [ifeu 2021].

The packages included within the product segments are **beverage cartons with plant-based polymers**, **beverage cartons with fossil-based polymers**, **rPET**, **PET** and **HDPE bottles**. The term "plant-based beverage carton" refers to either beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or top/closure. The term "standard beverage carton"

refers to beverage cartons with only fossil-based polymers in sleeve and closure/top. rPET bottles are further classified into 30 % - 100 % recycled content (JNSD Family Pack, Dairy Family Pack), as well as 50 % recycled content and 100 % recycled content (Water Portion Pack).

463 packages were assessed, which includes 264 beverage cartons and 199 alternative types of packages of studies dated from 2018-2021.

1.1 Main Purpose

The main purpose of this report is to transparently present the climate change impact of beverage cartons and alternative beverage packaging systems in relation to packaging types, product segments and regions. By doing this, trends as well as outliers can be identified which is of great importance when producing and marketing products.

1.2 Method

The results presented in this report are based on data that have formally been reviewed by external experts. In case of Croatia at the time this meta study was done, the relating study has not finally been reviewed yet. In this report, mean values regarding climate impact per analysed package are presented in table form and climate impact is defined as kg CO2-e/1000 L.

At the impact assessment level, it must be decided which system allocation approach is applied. Since the authors in the present study consider allocation 50% relevant, only the allocation factor 50% was chosen. In contrast, allocation factors 100% and 50% were considered in all the individual studies. In case of allocation 50%, half of the emissions from recovery are attributed to the examined system and half of the emissions from recovery are attributed to the following system, for example the incineration plants with thermal recovery.

When applying the allocation 50% approach the benefit regarding the LCA results for ‘Climate Change’ of packaging systems containing regenerative materials can promote the increase of use of regenerative materials in packaging system.

The allocation 50% method has been used in numerous LCAs carried out by ifeu and 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].

1.2.1 Method I

Results in detailed segments

The results of the meta study in detailed segments include comparisons of types of packaging systems based on averages per country as well as based on cross-country averages per segment. The included packaging systems cover 14 countries[1] from 6 LCA studies, all of which fulfil the following criteria:

- LCA-based approach (life cycle assessment as basic principle of evaluation)
- Comparative approach
    - comparison of different products, i.e. a beverage carton and at least one other packaging type)
    - comparison of plant-based and standard beverage cartons only is valid and comparable when data for both types of cartons are available in the same study/country (otherwise country specific parameters like the energy mix might affect total averages unilaterally)

In order for the meta study to achieve robust comparative conclusions and to exclude statistical uncertainties, some results (from the analysed LCA studies) were excluded from interpretation:

- Packaging systems of countries that are analysed by less than 2 packaging systems of the same category (plant-based beverage cartons, standard beverage cartons, rPET, PET or HDPE) within a segment.
    - for example: at least 2 HDPE bottles are needed in one and the same product category (e.g. Dairy Family Pack chilled) in one and the same country (e.g. Greece).
- Types of packaging systems for which data from less than 5 packaging systems within a segment is available.
    - for example: at least 5 HDPE bottles are needed in one and the same product category (e.g. Dairy Family Pack chilled) across all the studies in scope.

[1]Austria, Belgium, Croatia, Denmark, Finland, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland and United Kingdom

The following table shows the numbers of the packaging systems considered for the results in detailed segments:

Table 1

Presenting product types and package segments, number of beverage cartons and competing packages used for the results in detailed segments with Method I.

Product type and package segment		Number of beverage cartons	Number of competing packages
	Dairy Family Pack *CHILLED*	41	4
	Dairy Family Pack *AMBIENT*	30	4
	Dairy Portion Pack *CHILLED*	9	12
	Dairy Portion Pack *AMBIENT*	14	11
	JNSD Family Pack *AMBIENT*	56	21
	JNSD Portion Pack *AMBIENT*	18	10
	Water Portion Pack *AMBIENT*	60	88

Result Overview Matrix

Additionally an overview matrix is presented showing the performance regarding the climate change impact of beverage cartons compared to competing packaging systems broken down to countries and segments. As the matrix does not show cross-country averages data from 16 countries[1] from 8 LCA studies is applied, all of which fulfil the following criteria:

- LCA-based approach (life cycle assessment as basic principle of evaluation)
- Comparative approach: Comparison of different products, i.e. a beverage carton and at least one other packaging type)

In order for the meta study to achieve robust comparative conclusions and to exclude statistical uncertainties, some results (from the analysed LCA studies) were excluded from interpretation:

[1]Austria, Belgium, Croatia, Denmark, Finland, France, Greece, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland and United Kingdom

- Packaging systems of (countries) that are analysed by less than 2 packaging systems of the same category (plant-based beverage cartons, standard beverage cartons, rPET, PET or HDPE) within a segment.
    - for example: at least 2 HDPE bottles are needed in one and the same product category (e.g. Dairy Family Pack chilled) in one and the same country (e.g. Greece).

1.2.2 Method II

Results in detailed segments

As the individual packaging specifications (especially weight and volume) have a strong influence on the net results, the above mentioned exclusions were implemented in Method I.

However, alternative packaging systems examined in the individual LCA studies are intended to represent products relevant on the regarded markets or relevant in perspective of Tetra Pak. In the LCA studies beverage carton systems in some segments are often only compared to one alternative packaging system. As this leads to the exclusions of specific segments, which are of substantial importance for Tetra Pak, a further method was used.

In this Method II still excluded from interpretation are:

- Types of packaging systems for which data from less than 5 packaging systems within a segment is available.
    - for example: at least 5 HDPE bottles are needed in one and the same product category (e.g. Dairy Family Pack chilled) across all the studies in scope.

In contrast to Method I, Method II includes also packaging systems of countries with only 1 packaging system of the same category (plant-based beverage cartons, standard beverage cartons, rPET, PET or HDPE) within a segment.

Packaging systems of countries that are analysed by only one packaging system of the same category (standard beverage cartons, rPET, PET or HDPE) within a segment, were considered. It should be noted that this method is more case specific and therefore general conclusions are less robust.

This Method II has been applied additionally to the comparisons with alternative packaging systems in the segments dairy family pack (chilled and ambient), dairy portion pack (chilled and ambient), JNSD Family Pack (ambient), JNSD Portion Pack (ambient) and Water Portion Pack (ambient). These include 16 countries[1] from 8 LCA studies.

[1]Austria, Belgium, Croatia, Denmark, Finland, France, Greece, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland and United Kingdom

The following table shows the numbers of the packaging systems considered for the results in detailed segments:

Table 2

Presenting product types and package segments, number of beverage cartons and competing packages used for the results in detailed segments with Method II.

Product type and package segment		Number of beverage cartons	Number of competing packages
	Dairy Family Pack *CHILLED*	7	15
	Dairy Family Pack *AMBIENT*	2	6
	Dairy Portion Pack *CHILLED*	10	7
	Dairy Portion Pack *AMBIENT*	5	7
	JNSD Family Pack *AMBIENT*	5	7
	JNSD Portion Pack *AMBIENT*	5	2
	Water Portion Pack *AMBIENT*	2	5

Result Overview Matrix

Additionally an overview Matrix is presented showing the performance regarding the climate change impact of beverage cartons compared to competing packaging systems broken down to countries and segments. As the matrix does not show cross-country averages data from 16 countries[1] from 8 LCA studies is applied, all of which fulfil the following criteria:

- LCA-based approach (life cycle assessment as basic principle of evaluation)
- Comparative approach: Comparison of different products, i.e. a beverage carton and at least one other packaging type)

[1]Austria, Belgium, Croatia, Denmark, Finland, France, Greece, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland and United Kingdom

2 Results Method I

In this chapter comparisons of standard beverage cartons and alternative packaging systems are shown. 378 packages were assessed, which includes 228 beverage cartons and 150 alternative types of packages of studies dated from 2018-2021.

2.1 Results in detailed segments

This section of the meta study covers 14 countries[1] from 6 LCA on beverage packaging systems.

256 packages were assessed, which includes 169 beverage cartons and 87 alternative types of packages of studies dated from 2018-2021.

In 23 comparisons out of all 26 in the scope above beverage cartons perform better in climate change than alternative packaging solutions. Thus, local conditions, such as country energy mix, distribution distances, end-of-life phase or other factors do not play a bigger role than initial material choice for the package. The more renewable materials – either carton or plant-based polymers - are used, the lower is the climate impact of a pack assessed. The same effect occurs within various standard beverage cartons: the more fossil-based plastic weight is in a pack, the higher is the climate impact, this can be due to fossil-based plastics layers of packaging material or caps or straws presence and weight. The relatively high share of plant-based material is also the key reason for beverage cartons' lower carbon footprint compared to fossil-based plastics packaging.

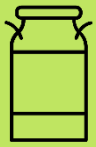
[1]Austria, Belgium, Croatia, Denmark, Finland, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland and United Kingdom

Dairy Family Pack

CHILLED

Table 3

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for chilled dairy in family pack.

Dairy Family Pack ***CHILLED***	**Region (year of study)**	**Plant-based beverage carton[1] [average]**	**Standard beverage carton [average][2]**
	Austria (2019)	4.59	26.54
	Denmark (2019)	2.74	17.84
	Finland (2019)	8.46	22.86
	Ireland (2018)	30.07	41.70
	Italy (2020)	39.26	48.18
	Norway (2019)	3.12	17.14
	Sweden (2019)	-4.61	7.78
Allocation factor 50	**Total [average]**	**11.95**	**26.00**
	Quantity of packaging systems	17	22

[1]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[2]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 17 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. Plant-based beverage cartons' climate impact is on average approximately half as high (54%) compared to the one of standard beverage cartons (min. 19% in Italy, max. 159% in Denmark).

Plant-based beverage cartons in Sweden show negative net results. This is due to the fact that the applied allocation 50% allocates emissions from recycling and recovery processes between the regarded system and following systems. Therefore only half of the regenerative CO2-emissions from incineration with energy recovery are accounted to the beverage carton. Together with the benefit from the CO2 uptake during the plant growth of plant-based materials and the generally low environmental impacts of beverage cartons in Sweden (low landfilling rate and a high use of renewable energy in the Swedish electricity mix), net results can show negative results.

As in this segment was not enough data available to achieve statistically correct results, there is no comparison table for standard beverage cartons vs. alternative packaging systems.

AMBIENT

Table 4

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient dairy in family pack.

Dairy Family Pack *AMBIENT*	**Region (year of study)**	**Plant-based beverage carton[1] [average]**	**Standard beverage carton[2] [average]**
	Croatia (2021)	78.53	93.95
	Italy (2020)	47.00	59.97
	Spain (2020)	61.74	73.82
	Switzerland (2019)	15.75	33.87
Allocation factor 50	**Total [average]**	**50.75**	**65.40**
	Quantity of packaging systems	12	14

[1]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[2]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 12 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. Plant-based beverage cartons have on average a 22% lower climate impact than standard beverage cartons (min. 16% in Spain and Croatia, max. 53% in Switzerland).

As in this segment was not enough data available to achieve statistically correct results, there is no comparison table for standard beverage cartons vs. alternative packaging systems.

Dairy Portion Pack

CHILLED

As in this segment was not enough data available to achieve statistically correct results, there is no comparison table for both plant-based vs. standard beverage cartons and standard beverage cartons vs. alternative packaging systems.

AMBIENT

As in this segment was not enough data available to achieve statistically correct results, there is no comparison table for plant-based- and standard beverage cartons.

Table 5

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient dairy in portion pack.

Dairy Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[1] [average]**	**HDPE bottle [average]**
Allocation factor 50	Ireland (2018)	142.94	405.03
	United Kingdom (2018)	134.83	371.47
	Total [average]	**138.88**	**388.25**
	Quantity of packaging systems	8	7

[1]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 8 assessed beverage cartons perform better in climate change than alternative packaging systems (HDPE bottles).

For ambient dairy in portion packs, standard beverage cartons have on average a 64% lower climate impact, expressed in kg CO2-e/1000 L, compared to HDPE bottles (min. 64% in the UK, max. 65% in Ireland).

JNSD Family Pack

AMBIENT

Table 6

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in family pack.

JNSD Family Pack *AMBIENT*	**Region (year of study)**	**Plant-based beverage carton[1] [average]**	**Standard beverage carton[2] [average]**
	Croatia (2021)	81.00	96.90
	Denmark (2019)	42.05	52.37
	Finland (2019)	46.95	57.01
	Italy (2020)	53.56	68.17
	Norway (2019)	42.02	51.76
	Poland (2020)	73.70	80.56
	Spain (2020)	62.38	78.97
	Sweden (2019)	31.89	41.65
	Total [average]	**54.19**	**65.92**
Allocation factor 50	Quantity of packaging systems	20	17

[1]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[2]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 20 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. Plant-based beverage cartons have on average an 18% lower climate impact than standard beverage cartons (min. 9% in Poland, max. 23% in Italy and Spain).

Table 7

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in family pack.

JNSD Family Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[1] [average]**	**PET bottle [average]**
	Austria (2019)	37.79	98.92
	Croatia (2021)	96.90	161.62
	Italy (2020)	68.17	180.87
	Poland (2020)	80.56	161.62
	Spain (2020)	78.97	101.13
	Switzerland (2019)	40.08	107.08
	Total [average]	**67.08**	**135.21**
Allocation factor 50	Quantity of packaging systems	18	13

[1]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 18 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons for ambient juice in family pack have on average a 50% lower climate impact than PET bottles (min. 22% in Spain, max. 63% in Switzerland).

Table 8

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in family pack.

JNSD Family Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[1] [average]**	**PET bottle ≥ 30 % recycled content [average]**
	Austria (2019)	37.79	98.58
	Italy (2020)	68.17	157.35
	Switzerland (2019)	40.08	94.07
Allocation factor 50	**Total [average]**	**48.68**	**116.67**
	Quantity of packaging systems	11	8

[1]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 11 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles 30 % - 100 % recycled content).

Standard beverage cartons for ambient juice in family pack have on average a 58% lower climate impact than PET bottles with recycled content (min. 57% in Switzerland and Italy, max. 62% in Austria).

JNSD Portion Pack

AMBIENT

As in this segment was not enough data available to achieve statistically correct results, there is no comparison table for plant-based- and standard beverage cartons.

Table 9

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in portion pack

JNSD Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[1] [average]**	**PET bottle [average]**
	Austria (2019)	83.76	142.35
	Belgium (2018)	102.85	303.14
	Netherlands (2018)	137.12	391.06
Allocation factor 50	**Total [average]**	**107.91**	**278.85**
	Quantity of packaging systems	8	8

[1]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 8 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons have on average a 61% lower climate impact than PET bottles (min. 41% in Austria, max. 66% in Belgium).

Water Portion Pack

AMBIENT

Table 10

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient water in portion pack.

Water Portion Pack *AMBIENT*	**Region (year of study)**	**Plant-based beverage carton[1] [average]**	**Standard beverage carton[2] [average]**
	Austria (2019)	53.04	77.48
	Denmark (2019)	69.51	100.95
	Finland (2019)	75.78	107.34
	Norway (2019)	66.00	97.24
	Spain (2020)	93.10	107.94
	Sweden (2019)	50.16	80.91
	Switzerland (2019)	58.82	83.18
	Total [average]	**62.22**	**91.18**
Allocation factor 50	Quantity of packaging systems	28	12

[1]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[2]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 28 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. Plant-based beverage cartons have on average a 32% lower climate impact compared to standard beverage cartons (min. 14% in Spain, max. 38% in Sweden).

Table 11

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient water in portion pack.

Water Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[1] [average]**	**PET bottle [average]**
	Denmark (2019)	100.95	121.74
	Finland (2019)	107.34	151.11
	Norway (2019)	97.24	141.32
	Sweden (2019)	80.91	158.34
	United Kingdom (2018)	112.31	133.21
Allocation factor 50	**Total [average]**	**99.75**	**141.14**
	Quantity of packaging systems	10	20

[1] Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 10 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons have a 39% lower impact than PET bottles (min. 16% in the UK, max. 49% in Sweden).

Table 12

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient water in portion pack.

Water Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[1] [average]**	**PET bottle 50 % recycled content [average]**
	Finland (2019)	107.34	122.27
	Norway (2019)	97.24	112.46
	Sweden (2019)	80.91	122.97
Allocation factor 50	**Total [average]**	**95.16**	**119.23**
	Quantity of packaging systems	6	13

[1]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 6 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottle 50 % recycling).

Standard beverage cartons have on average a 20% lower climate impact than PET bottles containing a recycling content of 50 % (min. 12% in Finland, max. 34% in Sweden).

Table 13

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient water in portion pack.

Water Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[1] [average]**	**PET bottle 100 % recycled content [average]**
	Denmark (2019)	100.95	93.86
	Finland (2019)	107.34	97.11
	Norway (2019)	97.24	84.71
	Sweden (2019)	80.91	90.77
Allocation factor 50	**Total [average]**	**96.61**	**91.61**
	Quantity of packaging systems	8	18

[1]Beverage cartons with only fossil-based polymers in sleeve and closure/top

Regarding the water segment, which is usually the most challenging segment for beverage cartons, the worst case was investigated to compare standard beverage cartons and 100% rPET.

Based on 18 bottles analysed, mostly in sensitivity scenarios sections, which model PET bottles within the scope of the study to become theoretically 100% rPET, that 100% rPET gives significant progress for PET in climate change, which becomes on average 36% better than PET bottles without recycled content. 6 of 8 assessed beverage cartons show higher or similar impacts in climate change than alternative packaging systems (PET bottle 100% recycled content). Higher averages for beverage cartons are shown in the studies of Denmark (8%), Finland (11%) and Norway (15%). On average 100% rPET shows 5% lower climate change impact than standard beverage cartons.

2.2 Results Overview Matrix

This section of the meta study covers 16 countries[1] from 8 LCA on beverage packaging systems.

The overview matrix below shows the performance regarding the climate change impact of beverage cartons compared to competing packaging systems broken down to countries and the segments dairy family pack (chilled and ambient), dairy portion pack (chilled and ambient), JNSD family pack (ambient), JNSD portion pack (ambient) and water portion pack (ambient). The matrix shows lower-, higher- and similar impacts, which are identified to give an

Table 14

Description for Matrix of beverage cartons in comparison with selected packaging systems regarding climate impact.

S	Similar impact: Difference less than 10.0 kg CO2-e/1000 L
H	Higher impact: Difference more than 10.0 kg CO2-e/1000 L
L	Lower impact: Difference more than 10.0 kg CO2-e/1000 L
	Sufficient data not available
	Plant-based beverage carton[1]
	Standard beverage carton[2]
	HDPE bottle
	Bottle containing recycled content (30 % - 100 %[3], 50 %[4], 100 %[4])
	PET bottle
[A]	Ambient
[C]	Chilled

[1]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[2]Beverage cartons with only fossil-based polymers in sleeve and closure/top

[3]Only considered in dairy and JNSD segments

[4]Only considered in water segment

[1] Austria, Belgium, Croatia, Denmark, Finland, France, Greece, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland and United Kingdom

Table 15

Matrix of beverage cartons in comparison with selected packaging systems regarding climate impact.

	Segment	vs.	vs.	vs.	vs. 30%-100%	vs. 30%-100%	vs. 50%	vs. 50%	vs. 100%	vs. 100%	vs.	vs.
Austria (2019)	Dairy FP [C]	L			L	L						
	JNSD FP [A]					L						L
	JNSD PP [A]					L						L
	Water PP [A]	L										
Belgium (2018)	JNSD PP [A]											L
Croatia (2021)	Dairy FP [A]	L										
	Dairy PP [C]											L
	JNSD FP [A]	L									L	L
Denmark (2019)	Dairy FP [C]	L										
	JNSD FP [A]	L										
	Water PP [A]	L							L	S	L	L
Finland (2019)	Dairy FP [C]	L										
	JNSD FP [A]	L										
	Water PP [A]	L					L	L	L	H	L	L
France (2020)	Water PP [A]						L		L		L	
Greece (2021)	Dairy FP [C]										L	
	Water PP [A]										S	
Ireland (2018)	Dairy FP [C]	L	L	L								
	Dairy PP [A]			L								L
Italy (2020)	Dairy FP [C]	L									L	L
	Dairy FP [A]	L										
	JNSD FP [A]	L			L	L					L	L
	Water PP [A]						L		L		L	
Netherlands (2018)	JNSD PP [A]											L
Norway (2019)	Dairy FP [C]	L										
	JNSD FP [A]	L										
	Water PP [A]	L					L	L	L	H	L	L
Poland (2020)	JNSD FP [A]	L									L	L
	Water PP [A]										L	
Spain (2020)	Dairy FP [A]	L	L	L								
	JNSD FP [A]	L									L	L
	Water PP [A]	L										
Sweden (2019)	Dairy FP [C]	L										
	Dairy PP [C]			L								
	JNSD FP [A]	L									L	L
	Water PP [A]	L					L	L	L	S	L	L
Switzerland (2019)	Dairy FP [A]	L	L	L								
	JNSD FP [A]					L						L
	Water PP [A]	L										
United Kingdom (2018)	Dairy PP [A]			L								L
	Water PP [A]											L

3 Combined results of Method I and Method II

In this chapter comparisons of standard beverage cartons and alternative packaging systems are shown, while combining method I and method II. 463 packages were assessed, which includes 264 beverage cartons and 199 alternative types of packages of studies dated from 2018-2021. As described in chapter 1.2.2, packaging systems of countries that are analysed by only one packaging system of the same category (standard beverage cartons, rPET, PET or HDPE) within a segment, were also considered. It should be noted that method II is more case specific and therefore general conclusions are less robust. For method II 85 packages were assessed, which includes 36 beverage cartons and 49 alternative types of packages.

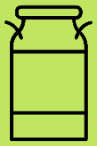
3.1 Results in detailed segments

Dairy Family Pack

CHILLED

Table 16

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for chilled dairy in family pack.

Dairy Family Pack *CHILLED*	**Region (year of study)**	**Plant-based beverage carton[3] [average]**	**Standard beverage carton[4] [average]**
	Austria (2019)	4.59[1]	26.54[1]
	Denmark (2019)	2.74[1]	17.84[1]
	Finland (2019)	8.46[1]	22.86[1]
	Ireland (2018)	30.07[1]	41.70[1]
	Italy (2020)	39.26[1]	48.18[1]
	Netherlands (2018)	22.99[2]	35.88[2]
	Norway (2019)	3.12[1]	17.14[1]
	Poland (2020)	63.10[2]	63.83[2]
	Sweden (2019)	-4.61[1]	7.78[1]
	United Kingdom (2018)	19.16[2]	32.24[2]
	Total [average]	**18.89**	**31.40**
Allocation factor 50	Quantity of packaging systems	20	25

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[4]Beverage cartons with only fossil-based polymers in sleeve and closure/top

19 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. In Poland the plant-based beverage carton performs similar as the standard beverage carton as the packaging systems vary. Plant-based beverage cartons' climate impact is on average 40% lower compared to the one of standard beverage cartons (min. 19% in Italy, max. 159% in Sweden).

Plant-based beverage cartons in Sweden show negative net results. This is due to the fact that the applied allocation 50% allocates emissions from recycling and recovery processes between the regarded system and following systems. Therefore only half of the regenerative CO2-emissions from incineration with energy recovery are accounted to the beverage carton. Together with the benefit from the CO2 uptake during the plant growth of plant-based materials and the generally low environmental impacts of beverage cartons

in Sweden (low landfilling rate and a high use of renewable energy in the Swedish electricity mix), net results can show negative results.

Table 17

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for chilled dairy in family pack.

Dairy Family Pack *CHILLED*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**HDPE bottle [average]**
	Denmark (2019)	17.84[1]	169.97[2]
	Finland (2019)	22.86[1]	190.06[2]
	Ireland (2018)	41.70[1]	92.17[1]
	Netherlands (2018)	35.88[2]	140.19[2]
	Norway (2019)	17.14[1]	183.26[2]
	Poland (2020)	63.83[2]	77.65[2]
	Sweden (2019)	7.78[1]	163.80[2]
	Switzerland (2019)	30.16[1]	100.36[2]
	United Kingdom (2018)	32.24[2]	88.61[2]
	Total [average]	**29.94**	**134.01**
Allocation factor 50	Quantity of packaging systems	22	10

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 22 assessed beverage cartons perform better in climate change than alternative packaging systems (HDPE bottles).

For chilled dairy in family packs, standard beverage cartons have on average a 78% lower climate impact, expressed in kg CO2-e/1000 L, compared to HDPE bottles (min. 18% in Poland, max. 95% in Sweden).

Table 18

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for chilled dairy in family pack.

Dairy Family Pack *CHILLED*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**PET bottle [average]**
	Austria (2019)	26.54[1]	99.49[2]
	Denmark (2019)	17.84[1]	117.58[2]
	Finland (2019)	22.86[1]	128.30[2]
	Italy (2020)	48.18[1]	89.50[1]
	Netherlands (2018)	35.88[2]	141.66[2]
	Norway (2019)	17.14[1]	117.69[2]
	Poland (2020)	63.83[2]	118.09[2]
	Sweden (2019)	7.78[1]	111.34[2]
Allocation factor 50	**Total [average]**	**30.00**	**115.46**
	Quantity of packaging systems	22	9

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 22 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons for chilled dairy in family pack have on average a 74% lower climate impact than PET bottles (min. 46% in Italy and Poland, max. 93% in Sweden).

AMBIENT

Table 19

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient dairy in family pack.

Dairy Family Pack *AMBIENT*	**Region (year of study)**	**Plant-based beverage carton[3] [average]**	**Standard beverage carton[4] [average]**
	Austria (2019)	16.66[2]	30.68[1]
	Belgium (2018)	30.47[2]	43.07[1]
	Croatia (2021)	78.53[1]	93.95[1]
	Italy (2020)	47.00[1]	59.97[1]
	Netherlands (2018)	42.66[2]	54.77[1]
	Spain (2020)	61.74[1]	73.82[1]
	Switzerland (2019)	15.75[1]	33.87[1]
Allocation factor 50	**Total [average]**	**41.83**	**55.73**
	Quantity of packaging systems	15	20

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[4]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 15 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. Plant-based beverage cartons have on average a 25% lower climate impact than standard beverage cartons (min. 16% in Spain and Croatia, max. 53% in Switzerland).

Table 20

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient dairy in family pack.

Dairy Family Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**HDPE bottle [average]**
Allocation factor 50	Italy (2020)	59.97[1]	98.92[2]
	Netherlands (2018)	54.77[1]	152.66[2]
	Spain (2020)	73.82[1]	88.49[1]
	Switzerland (2019)	33.87[1]	94.90[1]
	Total [average]	**55.61**	**108.74**
	Quantity of packaging systems	12	6

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 12 assessed beverage cartons perform better in climate change than alternative packaging systems (HDPE bottles).

For ambient dairy in family packs, standard beverage cartons have on average a 49% lower climate impact, expressed in kg CO2-e/1000 L, compared to HDPE bottles (min. 17% in Spain, max. 64% in the Netherlands and Sweden).

Dairy Portion Pack

CHILLED

As in this segment was not enough data available to achieve statistically correct results, there is no comparison table for both plant-based vs. standard beverage cartons and standard beverage cartons vs. alternative packaging systems.

Table 21

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for chilled dairy in portion pack.

Dairy Portion Pack *CHILLED*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**HDPE bottle [average]**
	Denmark (2019)	91.78[2]	314.82[1]
	Finland (2019)	97.63[2]	342.41[1]
	Poland (2020)	188.45[2]	157.79[2]
	Sweden (2019)	74.28[1]	297.33[1]
	Switzerland (2019)	98.94[1]	179.66[2]
	United Kingdom (2018)	71.16[2]	316.92[2]
Allocation factor 50	**Total [average]**	**103.71**	**268.15**
	Quantity of packaging systems	9	9

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 9 assessed beverage cartons perform better in climate change than alternative packaging systems (HDPE bottles).

For chilled dairy in family packs, standard beverage cartons have on average a 61% lower climate impact, expressed in kg CO2-e/1000 L, compared to HDPE bottles (min. 19% in Poland, max. 78% in the UK).

Table 22

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for chilled dairy in portion pack.

Dairy Portion Pack *CHILLED*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**PET bottle [average]**
	Austria (2019)	86.44[1]	162.52[2]
	Belgium (2018)	90.38[2]	240.78[2]
	Croatia (2021)	235.08[1]	250.61[1]
	Netherlands (2018)	135.57[2]	325.13[2]
	Poland (2020)	188.45[2]	264.54[2]
Allocation factor 50	**Total [average]**	**147.18**	**248.72**
	Quantity of packaging systems	7	7

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 7 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons for chilled dairy in family pack have on average a 41% lower climate impact than PET bottles (min. 6% in Croatia, max. 62% in Belgium).

AMBIENT

As in this segment was not enough data available to achieve statistically correct results, there is no comparison table for both plant-based vs. standard beverage cartons and standard beverage cartons vs. alternative packaging systems.

Table 23

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient dairy in portion pack.

Dairy Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**HDPE bottle [average]**
	Belgium (2018)	105.47[1]	232.41[2]
	Ireland (2018)	142.94[1]	405.03[1]
	Netherlands (2018)	146.06[1]	328.21[2]
	Switzerland (2019)	105.61[2]	285.52[2]
	United Kingdom (2018)	134.83[1]	371.47[1]
Allocation factor 50	**Total [average]**	**126.98**	**324.53**
	Quantity of packaging systems	14	9

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 14 assessed beverage cartons perform better in climate change than alternative packaging systems (HDPE bottles).

For ambient dairy in portion packs, standard beverage cartons have on average a 61% lower climate impact, expressed in kg CO2-e/1000 L, compared to HDPE bottles (min. 55% in Belgium and the Netherlands, max. 65% in Ireland).

Table 24

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient dairy in portion pack.

Dairy Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**PET bottle [average]**
	Belgium (2018)	105.47[1]	222.55[2]
	Ireland (2018)	142.94[1]	411.51[1]
	Netherlands (2018)	146.06[1]	302.33[2]
	Spain (2020)	181.29[2]	296.16[2]
	United Kingdom (2018)	134.83[1]	419.54[1]
Allocation factor 50	**Total [average]**	**142.12**	**330.42**
	Quantity of packaging systems	15	7

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 15 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons for ambient dairy in family pack have on average a 57% lower climate impact than PET bottles (min. 39% in Spain, max. 68% in the UK).

JNSD Family Pack

AMBIENT

Table 25

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in family pack.

JNSD Family Pack *AMBIENT*	**Region (year of study)**	**Plant-based beverage carton[3] [average]**	**Standard beverage carton[4] [average]**
	Austria (2019)	21.29[2]	37.79[1]
	Belgium (2018)	31.22[2]	50.89[1]
	Croatia (2021)	81.00[1]	96.90[1]
	Denmark (2019)	42.05[1]	52.37[1]
	Finland (2019)	46.95[1]	57.01[1]
	Ireland (2018)	56.32[2]	78.03[1]
	Italy (2020)	53.56[1]	68.17[1]
	Netherlands (2018)	43.74[2]	64.38[1]
	Norway (2019)	42.02[1]	51.76[1]
	Poland (2020)	73.70[1]	80.56[1]
	Spain (2020)	62.38[1]	78.97[1]
	Sweden (2019)	31.89[1]	41.65[1]
	Switzerland (2019)	26.86[2]	40.08[1]
	United Kingdom (2018)	50.03[2]	71.60[1]
	Total [average]	**47.36**	**62.15**
Allocation factor 50	Quantity of packaging systems	26	34

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[4]Beverage cartons with only fossil-based polymers in sleeve and closure/top

15 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. 9 assessed plant-based beverage cartons in Norway, Poland and Sweden perform similar. Plant-based beverage cartons have on average an 24% lower climate impact than standard beverage cartons (min. 9% in Poland, max. 44% in Austria).

Table 26

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in family pack.

JNSD Family Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**PET bottle [average]**
	Austria (2019)	37.79[1]	98.92[1]
	Belgium (2018)	50.89[1]	123.71[2]
	Croatia (2021)	96.90[1]	161.62[1]
	Denmark (2019)	52.37[1]	137.02[2]
	Finland (2019)	57.01[1]	143.96[2]
	Ireland (2018)	78.03[1]	133.53[2]
	Italy (2020)	68.17[1]	180.87[1]
	Netherlands (2018)	64.38[1]	154.15[2]
	Poland (2020)	80.56[1]	161.62[1]
	Spain (2020)	78.97[1]	101.13[1]
	Sweden (2019)	41.65[1]	111.86[2]
	Switzerland (2019)	40.08[1]	107.08[1]
	United Kingdom (2018)	71.60[1]	127.59[2]
Allocation factor 50	**Total [average]**	**62.95**	**134.08**
	Quantity of packaging systems	32	20

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 32 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons for ambient juice in family pack have on average a 53% lower climate impact than PET bottles (min. 22% in Spain, max. 63% in Switzerland and Sweden).

Table 27

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in family pack.

JNSD Family Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[2] [average]**	**PET bottle ≥ 30 % recycled content [average]**
Allocation factor 50	Austria (2019)	37.79[1]	98.58[1]
	Italy (2020)	68.17[1]	157.35[1]
	Switzerland (2019)	40.08[1]	94.07[1]
	Total [average]	**48.68**	**116.67**
	Quantity of packaging systems	11	8

[1]Averages calculated with method I

[2]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 11 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles 30 % - 100 % recycled content).

Standard beverage cartons for ambient juice in family pack have on average a 58% lower climate impact than PET bottles with recycled content (min. 57% in Switzerland and Italy, max. 62% in Austria).

JNSD Portion Pack

AMBIENT

Table 28

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in portion pack.

JNSD Portion Pack ***AMBIENT***	**Region (year of study)**	**Plant-based beverage carton[3] [average]**	**Standard beverage carton[4] [average]**
	Austria (2019)	66.60[2]	83.76[1]
	Ireland (2018)	136.11[2]	148.03[1]
	Netherlands (2018)	126.57[2]	137.12[1]
	Spain (2020)	143.27[2]	155.29[2]
	United Kingdom (2018)	128.63[2]	138.96[1]
	Total [average]	**120.24**	**132.63**
Allocation factor 50	Quantity of packaging systems	5	14

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[4]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 5 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. Plant-based beverage cartons have on average an 9% lower climate impact than standard beverage cartons (min. 7% in the UK, max. 20% in Austria).

Table 29

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient JNSD in portion pack

JNSD Portion Pack *AMBIENT*	Region (year of study)	Standard beverage carton[3] [average]	PET bottle [average]
	Austria (2019)	83.76[1]	142.35[1]
	Belgium (2018)	102.85[1]	303.14[1]
	Ireland (2018)	148.03[1]	457.31[2]
	Netherlands (2018)	137.12[1]	391.06[1]
	Switzerland (2019)	64.65[2]	144.83[2]
	United Kingdom (2018)	138.96[1]	458.76[2]
	Total [average]	**112.56**	**316.24**
Allocation factor 50	Quantity of packaging systems	17	11

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 17 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons have on average a 64% lower climate impact than PET bottles (min. 41% in Austria, max. 70% in the UK).

Water Portion Pack

AMBIENT

Table 30

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient water in portion pack.

Water Portion Pack ***AMBIENT***	**Region (year of study)**	**Plant-based beverage carton[3] [average]**	**Standard beverage carton[4] [average]**
	Austria (2019)	53.04[1]	77.48[1]
	Denmark (2019)	69.51[1]	100.95[1]
	Finland (2019)	75.78[1]	107.34[1]
	Netherlands (2018)	127.80[2]	136.75[1]
	Norway (2019)	66.00[1]	97.24[1]
	Spain (2020)	93.10[1]	107.94[1]
	Sweden (2019)	50.16[1]	80.91[1]
	Switzerland (2019)	58.82[1]	83.18[1]
	United Kingdom (2018)	84.03[2]	112.31[1]
Allocation factor 50	**Total [average]**	**75.36**	**100.46**
	Quantity of packaging systems	30	16

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3]Beverage cartons with only plant-based polymers in sleeve and closure/top, or beverage cartons with shares of plant-based polymers in sleeve and or closure/top

[4]Beverage cartons with only fossil-based polymers in sleeve and closure/top

29 assessed plant-based beverage cartons perform better in climate change than standard beverage cartons. 1 assessed plant-based beverage cartons in the Netherlands performs similar. Plant-based beverage cartons have on average a 25% lower climate impact compared to standard beverage cartons (min. 7% in the Netherlands, max. 38% in Sweden).

Table 31

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient water in portion pack.

Water Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**PET bottle [average]**
	Austria (2019)	77.48[1]	108.43[2]
	Denmark (2019)	100.95[1]	121.74[1]
	Finland (2019)	107.34[1]	151.11[1]
	Netherlands (2018)	136.75[1]	238.49[2]
	Norway (2019)	97.24[1]	141.32[1]
	Sweden (2019)	80.91[1]	158.34[1]
	Switzerland (2019)	83.18[1]	96.14[2]
	United Kingdom (2018)	112.31[1]	133.21[1]
	Total [average]	**99.52**	**143.60**
Allocation factor 50	Quantity of packaging systems	16	23

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3] Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 16 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottles).

Standard beverage cartons have a 31% lower impact than PET bottles (min. 13% in Switzerland, max. 49% in Sweden).

Table 32

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient water in portion pack.

Water Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[2] [average]**	**PET bottle 50 % recycled content [average]**
Allocation factor 50	Finland (2019)	107.34[1]	122.27[1]
	Norway (2019)	97.24[1]	112.46[1]
	Sweden (2019)	80.91[1]	122.97[1]
	Total [average]	**95.16**	**119.23**
	Quantity of packaging systems	6	13

[1]Averages calculated with method I

[2]Beverage cartons with only fossil-based polymers in sleeve and closure/top

All 6 assessed beverage cartons perform better in climate change than alternative packaging systems (PET bottle 50 % recycling).

Standard beverage cartons have on average a 20% lower climate impact than PET bottles containing a recycling content of 50 % (min. 12% in Finland, max. 34% in Sweden).

Table 33

Presenting mean values regarding climate impact expressed as kg CO2-e/1000 L for ambient water in portion pack.

Water Portion Pack *AMBIENT*	**Region (year of study)**	**Standard beverage carton[3] [average]**	**PET bottle 100 % recycled content [average]**
	Austria (2019)	77.48[1]	83.88[2]
	Denmark (2019)	100.95[1]	93.86[1]
	Finland (2019)	107.34[1]	97.11[1]
	Norway (2019)	97.24[1]	84.71[1]
	Sweden (2019)	80.91[1]	90.77[1]
	Switzerland (2019)	83.18[1]	55.57[2]
Allocation factor 50	**Total [average]**	**91.18**	**84.32**
	Quantity of packaging systems	12	20

[1]Averages calculated with method I

[2]Averages calculated with method II (average based on only one packaging system per study)

[3] Beverage cartons with only fossil-based polymers in sleeve and closure/top

Regarding the water segment, which is usually the most challenging segment for beverage cartons, the worst case was investigated to compare standard beverage cartons and 100% rPET.

Based on 20 bottles analysed, mostly in sensitivity scenarios sections, which model PET bottles within the scope of the study to become theoretically 100% rPET, that 100% rPET gives significant progress for PET in climate change, which becomes on average 36% better than PET bottles without recycled content. 9 of 12 assessed beverage cartons show higher or similar impacts in climate change than alternative packaging systems (PET bottle 100% recycled content). Higher averages for beverage cartons are shown in the studies of Denmark (8%), Finland (11%), Norway (15%) and Switzerland (50%). On average 100% rPET shows 8% lower climate change impact than standard beverage cartons.

3.2 Results Overview Matrix

This section of the meta study covers comparisons of standard beverage cartons and competing packaging systems for all regarded segments from 16 countries[1] from 8 LCA on beverage packaging systems.

The overview Matrix below shows the performance regarding the climate change impact of beverage cartons compared to competing packaging systems broken down to countries and the segments dairy family pack (chilled and ambient), dairy portion pack (chilled and ambient), JNSD family pack (ambient), JNSD portion pack (ambient) and water portion pack (ambient). The matrix shows lower-, higher- and similar impacts, which are identified to give an overall view.

Table 34

Description for matrix of beverage cartons in comparison with selected packaging systems regarding climate impact.

S	Similar impact: Difference less than 10.0 kg CO2-e/1000 L
H	Higher impact: Difference more than 10.0 kg CO2-e/1000 L
L	Lower impact: Difference more than 10.0 kg CO2-e/1000 L
	Sufficient data not available
	Standard beverage carton[1]
	HDPE bottle
	Bottle containing recycled content (30 % - 100 %[2])
	PET bottle
[A]	Ambient
[C]	Chilled

[1] Beverage cartons with only fossil-based polymers in sleeve and closure/top

[2] Only considered in dairy segments

[1] Austria, Belgium, Croatia, Denmark, Finland, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland and United Kingdom

Table 35

Matrix of beverage cartons in the segments dairy family pack (chilled and ambient) and dairy portion pack (chilled) in comparison with selected packaging systems regarding climate impact.

	Segment	vs.	vs.	vs.	vs. 30%-100%	vs. 30%-100%	vs. 50%	vs. 50%	vs. 100%	vs. 100%	vs.	vs.
Austria (2019)	Dairy FP [C]	L1			L1	L1					L1,2	L1,2
	Dairy PP [C]											L1,2
	JNSD FP [A]	L2,1			L2,1	L1					L2,1	L1
	JNSD PP [A]	L2,1			L2,1	L1					L2,1	L1
	Water PP [A]	L1								S1,2	L1,2	L1,2
Belgium (2018)	Dairy FP [A]	L2,1							L2	L1,2		
	Dairy PP [C]											L2
	Dairy PP [A]			L1,2								L1,2
	JNSD FP [A]	L2,1									L2	L1,2
	JNSD PP [A]											L1
Croatia (2021)	Dairy FP [A]	L1										
	Dairy PP [C]											L1
	JNSD FP [A]	L1									L1	L1
Denmark (2019)	Dairy FP [C]	L1	L1,2	L1,2							L1,2	L1,2
	Dairy PP [C]	L2	L2,1	L2,1								
	JNSD FP [A]	L1									L1,2	L1,2
	Water PP [A]	L1							L1	S1	L1	L1
Finland (2019)	Dairy FP [C]	L1	L1,2	L1,2							L1,2	L1,2
	Dairy PP [C]	L2	L2,1	L2,1								
	JNSD FP [A]	L1									L1,2	L1,2
	Water PP [A]	L1					L1	L1	L1	H1	L1	L1
France (2020)	Water PP [A]						L1		L1		L1	
Greece (2021)	Dairy FP [C]										L2,1	
	Dairy PP [C]										L2,1	
	JNSD FP [A]										L1,2	
	Water PP [A]										S1	
Ireland (2018)	Dairy FP [C]	L1	L1	L1								
	Dairy PP [A]	L2,1	L2,1	L1							L2,1	L1
	JNSD FP [A]	L2,1									L2	L1,2
	JNSD PP [A]	L2,1									L2	L1,2
Italy (2020)	Dairy FP [C]	L1									L1	L1
	Dairy FP [A]	L1	L1,2	L1,2								
	JNSD FP [A]	L1			L1	L1					L1	L1
	Water PP [A]						L1		L1		L1	
Netherlands (2018)	Dairy FP [C]	L2	L2	L2							L2	L2
	Dairy FP [A]	L2,1	L2	L1,2							L2	L1,2
	Dairy PP [C]											L2
	Dairy PP [A]			L1,2								L1,2
	JNSD FP [A]	L2,1									L2	L1,2
	JNSD PP [A]	L2,1									L2,1	L1
	Water PP [A]	S2,1									L2	L1,2
Norway (2019)	Dairy FP [C]	L1	L1,2	L1,2							L1,2	L1,2
	JNSD FP [A]	S1										
	Water PP [A]	L1					L1	L1	L1	H1	L1	L1
Poland (2020)	Dairy FP [C]	S2		L2								L2

	Dairy PP [C]			L^{2}								L^{2}
	JNSD FP [A]	S^{1}									L^{1}	L^{1}
	JNSD PP [A]										$L^{1,2}$	
	Water PP [A]										L^{1}	
Spain (2020)	Dairy FP [A]	L^{1}	L^{1}	L^{1}							$L^{1,2}$	$L^{1,2}$
	Dairy PP [A]											L^{2}
	JNSD FP [A]	L^{1}									L^{1}	L^{1}
	JNSD PP [A]	L^{2}										
	Water PP [A]	L^{1}										
Sweden (2019)	Dairy FP [C]	L^{1}	$L^{1,2}$	$L^{1,2}$							$L^{1,2}$	$L^{1,2}$
	Dairy PP [C]	$L^{2,1}$	$L^{2,1}$	L^{1}								
	JNSD FP [A]	S^{1}									$L^{1,2}$	$L^{1,2}$
	Water PP [A]	L^{1}					L^{1}	L^{1}	L^{1}	S^{1}	L^{1}	L^{1}
Switzerland (2019)	Dairy FP [C]			$L^{1,2}$								
	Dairy FP [A]	L^{1}	L^{1}	L^{1}								
	Dairy PP [C]			$L^{1,2}$								
	Dairy PP [A]			L^{2}								
	JNSD FP [A]	$L^{2,1}$			$L^{2,1}$	L^{1}					$L^{2,1}$	L^{1}
	JNSD PP [A]											L^{2}
	Water PP [A]	L^{1}								$H^{1,2}$	$L^{1,2}$	$L^{1,2}$
United Kingdom (2018)	Dairy FP [C]	L^{2}	L^{2}	L^{2}								
	Dairy PP [C]			L^{2}								
	Dairy PP [A]	$S^{2,1}$	$L^{2,1}$	L^{1}							$L^{2,1}$	L^{1}
	JNSD FP [A]	$L^{2,1}$									L^{2}	$L^{1,2}$
	JNSD PP [A]	$L^{2,1}$									L^{2}	$L^{1,2}$
	Water PP [A]	$L^{2,1}$									$L^{2,1}$	L^{1}

[1]Comparisons of averages calculated only with method I

[2]Comparisons of averages calculated only with method II (average based on only one packaging system per study)

[1,2] Comparison where for the first mentioned packaging type an average calculated with method I was used and for the second packaging type an average calculated with method II (average based on only one packaging system per study)

[2,1]Comparison where for the first mentioned packaging type an average calculated with method II was used (average based on only one packaging system per study) and for the second packaging type an average calculated with method I

4 Limitations and overall Conclusions

Limitations

- The results of this meta study include LCA studies covering 16 European countries. Nevertheless not all countries in Europe are included in this study.
- The conclusions of this meta study are based on the results of the considered countries. The impact of background settings of non-regarded countries cannot be addressed in this study.
- As different beverage carton types are assessed, comparisons can lead to deviations (e.g. comparisons of plant-based cartons and standard beverage cartons can lead to deviations that are independent of the material).

Overall Conclusions

- This meta study shows that beverage cartons show lower climate change impacts compared to most competing packaging systems.
    - Compared to 100% rPET bottles in the segment water portion pack the standard beverage cartons' performance regarding climate change impacts is similar or worse.
- This meta study shows that plant-based beverage cartons show lower climate change impacts than standard beverage cartons (in 6 out of 49 comparisons they show similar climate change impacts due to different specifications of compared beverage carton types).
- This meta study shows that plant-based beverage cartons show lower climate change impacts than competing packaging systems in most cases except one for Greece where the results are similar for the comparison of plant-based beverage cartons vs. PET bottles.
    - Compared with 100% rPET bottles the plant-based beverage cartons show lower climate change impacts than those. This is true for all segments including water portion pack.
- Although the climate change impacts of packaging systems differ between the regarded countries, this meta study shows that the overall comparative result is not impacted by the local settings in the considered countries.
- With an increased share of plant-based polymers 'Climate Change' results of beverage cartons in all regarded segments (Dairy Family Pack chilled, Dairy Family

Pack ambient, JNSD Family Pack ambient, JNSD Portion Pack ambient, Water Portion Pack ambient) improve (18%-64% lower impacts).

- As the share of plastics in a small volume beverage carton is higher than in beverage cartons of bigger volumes, the choice of plastic material type, e.g. fossil-based or plant-based, plays a decisive role for the environmental performance. As a result, plant-based beverage cartons show higher reductions regarding climate change compared to standard beverage cartons in the same segments.

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