Comparing the carbon footprint of carton packaging against alternative solutions

RISE Bioeconomy

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A comparative analysis of the cradle-to-grave carbon footprint of carton-based solutions against the cradle-to-grave carbon footprint of alternative packaging solutions

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PACKAGING FOR A BETTER WORLD

Contents

Background

Previously, Pro Carton, the European Association of Cartonboard and Carton Manufacturers, calculated the carbon impact of carton packaging using the latest methodologies and data. The calculated carbon footprint covers the cradle-to-grave carbon impact of carton packaging, taking account of fossil and biogenic greenhouse gas (GHG) emissions and removals and emissions from direct land use change (dLUC).

Although the analysis gave interesting results that were well-received by stakeholders, these were stand-alone results for cartons. To provide some context for the results, it is necessary to understand how the carbon footprint of carton packaging compares to alternative solutions available in the market. Subsequently, Pro Carton commissioned RISE (Research Institutes of Sweden) to perform a comparative analysis of the cradle-to-grave carbon footprint of carton-based solutions against the cradle-to-grave carbon footprint of alternative packaging solutions. The study aimed to provide an insight into the relative carbon footprints for each case study and to understand the factors driving the footprint.

This report summarises the results for case studies of the following packaging applications:

- **Frozen food packaging**
- **Ready meal packaging**
- **Fast food packaging**
- **Small electricals packaging**

Approach

Table 1 summarises the cradle-to-gate fossil carbon impact of cartonboard (ready for conversion into cartons) and common packaging polymers (ready for conversion into packaging materials and components). From this table, it is evident that the fossil carbon impact per tonne of material is much lower for cartonboard than polymers. However, this comparison does not take into account the functionality of the different materials. A cartonboard-based packaging solution does not weigh the same as a plastic-based packaging solution. Furthermore, the conversion and end-of-life impacts for each of the solutions will be different. Hence, it is necessary to compare specific packaging solutions on a cradle-to-grave basis.

Table 1 Cradle-to-gate comparison of carbon footprint per tonne of material ready for conversion

Material	Total carbon footprint (kgCO2e per tonne of material ready for conversion)	Fossil carbon footprint (kgCO2e per tonne of material ready for conversion)	Source
Cartonboard	262	1,047	Pro Carton
Amorphous PET granulate	3,093	3,089	Ecoinvent 3.6
PP	2,110	2,122	Ecoinvent 3.6
PVC	2,122	2,108	Ecoinvent 3.6
LDPE granulate	2,305	2,286	Ecoinvent 3.6
HDPE granulate	2,110	2,092	Ecoinvent 3.6

Previously, Pro Carton estimated the cradle-to-grave carbon footprint of carton packaging using the framework developed by CEPI (CEPI, 2017) and the subsequent guidelines for fibre-based packaging from CITPA (CITPA, 2018). The method applied ensures that all emissions and removals associated with forest-based products are taken into account, including aspects that are unique to the forest industry's value chain. This methodology is an important development, as it ensures that some of the unique aspects of the life cycle of fibre-based packaging are taken into account that are otherwise excluded when concentrating on fossil GHG emissions alone. Fossil GHG emissions are those emissions arising from non-renewable sources such as fossil fuels. Biogenic GHG emissions arise from the combustion of biofuels and degradation of bio-based products. Biogenic GHG removals refer to CO2 uptake from the atmosphere through photosynthesis during biomass growth, i.e. associated with forest management as a source of paper fibres, the production of biofuels and of bio-based non-fibre inputs.

There are uncertainties inherent in the calculation of biogenic GHG emissions and removals. Specific factors that could be contributing to uncertainties in the data and results for biogenic GHG emissions and removals include:

- Assumptions in the background data relating to carbon content of wood and wood chips used in cartonboard production (and therefore the carbon removals associated with these)
- Assumptions regarding densities and moisture of different wood species (both during the provision of data by the mills and within the background data sets applied)
- Methods for measuring and/or estimating biogenic GHG emissions arising at the mills producing cartonboard, including assumptions regarding carbon content of biofuels consumed.

Despite the inherent uncertainties, the method highlights the role of biogenic GHG emissions and removals in the life cycle, and the overall low carbon impact of cartons per tonne of packaging, applying the method the following result was achieved:

Cradle-to-grave carbon footprint of cartons, kgCO2e per tonne of cartons	
Fossil GHG emissions	1,025 $kgCO_2e$
Biogenic GHG emissions	1,001 $kgCO_2e$
GHG removals	-1,708 $kgCO_2e$
Direct land-use	9 $kgCO_2e$
Total	**326 $kgCO_2e$**

The same methodology has been used in this study comparing carton packaging solutions against alternative solutions in the market. The alternative materials have been evaluated using the same criteria, i.e. considering fossil GHG emissions, biogenic GHG emissions and removals, and emissions arising from direct land-use change. A total is also presented.

Case study: Frozen food packaging

In this case study, a carton is compared against a multilaminate film bag for packaging frozen fishfingers.

Figure 1

Examples of the frozen fishfinger packaging solutions considered – cartonboard box (left) and multilaminate bag (right)

Table 2 - Packaging specifications considered

Frozen fishfingers	
Solution	**Specification**
Cartonboard box	Carton - 17g Content - 10 fishfingers
Multilaminate bag (50% PE and 50% PP by weight)	Bag - 6g Content - 10 fishfingers

For the cartonboard box, a recycling rate of 84.6% has been considered. This reflects the average European recycling rate for paper and board packaging in 2017 (European Commission, 2017). For the non-recycled portion of the cartonboard boxes, 8.5% is assumed to be sent for energy recovery and 6.9% is assumed to be disposed of to landfill

(European Commission, 2015). The flexible plastic bag is not considered to be recycled. 55% is assumed to be sent for energy recovery and 45% is assumed to be disposed of to landfill (European Commission, 2015).

Results

Overview

The results of the two solutions are summarised in Table 3 and Figure 2. It can be seen that the multilaminate plastic bag has a much higher impact than the cartonboard box when considering the impact per functional unit, i.e. per 1,000 packs.

Table 3 Comparative results per 1,000 packs

Total | Fossil GHG emissions | Biogenic GHG emissions | Biogenic GHG removals | dLUC emissions

Cartonboard Box

	Total	Package production	Forming and sealing inc. distribution to filler	Distribution of retail	End - of - life
Total	7.3	4.5	0.4	0.4	2.0
Fossil GHG emissions	18.1	17.8	0.4	0.4	-0.6
Biogenic GHG emissions	18.1	15.5	0.0	0.0	2.6
Biogenic GHG removals	-29.0	-29.0	0.0	0.0	-0.1
dLUC emissions	0.2	0.2	0.0	0.0	0.0

Multilaminate Film Bag

	Total	Package production	Forming and sealing inc. distribution to filler	Distribution of retail	End - of - life
Total	31.0	24.1	0.8	0.2	6.0
Fossil GHG emissions	30.6	23.7	0.8	0.2	6.0
Biogenic GHG emissions	0.4	0.5	0.1	0.0	-0.2
Biogenic GHG removals	-0.9	-1.0	-0.1	0.0	0.2
dLUC emissions	0.9	0.9	0.0	0.0	0.0

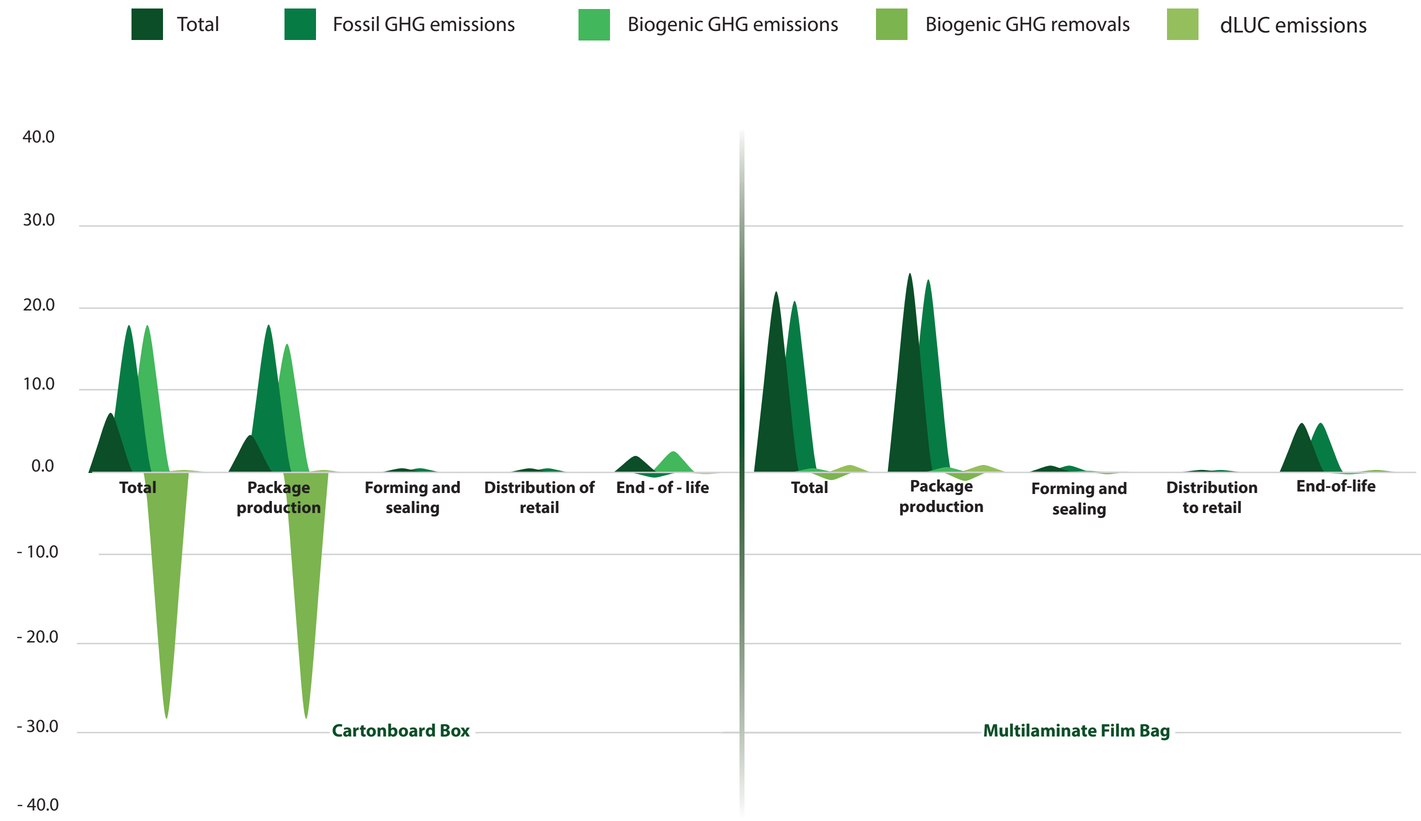
For the cartonboard box, the production of the package dominates the footprint. Production of the cartonboard box accounts for 98% of the total fossil GHG emissions and accounts for virtually all of the biogenic GHG emissions and removals.

For the multilaminate film bag, the production of the package dominates the footprint. Production of the polymers which make up the multilaminate film accounts for 56% of the fossil GHG emissions associated with this life cycle stage and the printing process accounts for a further 38% of the impact. Conversion of the polymers into the film accounts for the remaining 6%.

Impacts associated with end-of-life are significant for both systems. For the cartonboard box, there is a net credit for fossil GHG emissions from end-of-life due to avoided emissions from energy recovery (heat and electricity generation). The biogenic GHG emissions from this life cycle stage are the process emissions from the combustion of the proportion of the cartonboard box sent for energy recovery and from the degradation of the proportion of cartonboard sent to landfill. For the multilaminate film bag, there is a net emission for fossil GHG emissions from end-of-life. This is because process emissions from the combustion of the plastic film are larger than the credit for avoided emissions from energy recovery (heat and electricity generation). GHG emissions from landfilling of the flexible plastic bag are minimal, as the plastic will not degrade and give rise to GHG emissions in the landfill.

Figure 2

Comparative results – frozen fishfingers packaging – cartonboard box versus multilaminate film bag



	Total	Package production	Forming and sealing inc. distribution to filler	Distribution of retail	End - of - life
Total	7.3	4.5	0.4	0.4	2.0
Fossil GHG emissions	18.1	17.8	0.4	0.4	-0.6
Biogenic GHG emissions	18.1	15.5	0.0	0.0	2.6
Biogenic GHG removals	-29.0	-29.0	0.0	0.0	-0.1
dLUC emissions	0.2	0.2	0.0	0.0	0.0

	Total	Package production	Forming and sealing inc. distribution to filler	Distribution of retail	End - of - life
Total	31.0	24.1	0.8	0.2	6.0
Fossil GHG emissions	30.6	23.7	0.8	0.2	6.0
Biogenic GHG emissions	0.4	0.5	0.1	0.0	-0.2
Biogenic GHG removals	-0.9	-1.0	-0.1	0.0	0.2
dLUC emissions	0.9	0.9	0.0	0.0	0.0

Comparative Results

From the perspective of fossil GHG emissions only the cartonboard box (18.1kgCO2e per 1,000 packs) has a lower impact compared to the multilaminate film bag (30.6kgCO2e per 1,000 packs)

When biogenic GHG emissions and removals and dLUC are also considered, the advantage of the cartonboard box (7.3kgCO2e per 1,000 packs) compared to the multilaminate film bag (31.0kgCO2e per 1,000 packs) is significantly increased.

This is due to the uptake of carbon during the growth phase of the forests which supply the virgin fibre used in cartonboard. This biogenic GHG carbon removal is larger than the biogenic GHG emissions that occur (from the combustion of biofuels at the mill) during the manufacture of the board.

However, a high recycling rate is attained for paper and board packaging, including cartons. Thus, a high proportion of the original carbon contained in the product when it is first placed on the market is carried through to the life cycle of subsequent products outside the boundaries of this analysis. A cut off method is used in this analysis, in line with the CITPA methodology (CITPA, 2018). Therefore, the emissions associated with material recycling and the subsequent credits for replacing virgin fibre production are outside the boundaries of the footprint calculation. The carbon contained in the recovered fibres will be passed on to other products until recycling of the fibres is no longer viable, at which stage the fibres will be sent for either incineration with energy recovery or landfill, with associated emissions to consider.

Robustness of the results

The results have been subjected to sensitivity and uncertainty analysis and have been found to be robust.

In particular, the sensitivity of the results to the recycling rate assumed for carton board has been tested. In the comparison, it is assumed that cartons are recycled at a rate of 84.6% (the European average recycling rate) and the laminate pouch is considered to be non-recyclable. However, recycling rates vary between member states. Some countries achieve higher recycling rates than others. If the carton recycling rate is lower, then the total footprint of the cartonboard box increases. However, if the carton recycling rate is changed to 50%, then the difference between the cartonboard box and the flexible plastic film bag is reduced, although it still remains significant.

Case study: Ready meal packaging

Systems studied

In this case study, a cartonboard tray contained in a cartonboard box and PE enclosing film is compared against PP tray with film lid in a cartonboard box for packaging frozen ready meals.

Figure 3

Examples of the ready meal solutions considered – cartonboard tray in a box (left) and PP tray (right)

Table 4 - Packaging specifications considered

Ready meal	
Solution	**Specification**
Carton tray with enclosing film (PE) and cartonboard box	Carton tray - 14g Cartonboard box - 33g Enclosing film - 2g
PP tray with film lid (lidding film 80% PET, 20% PE by weight) and cartonboard box	PP tray – 6g Cartonboard box – 33g Film lid – 1g

For the carton tray and cartonboard box, a recycling rate of 84.6% has been considered. This reflects the average European recycling situation (European Commission, 2017). For the non-recycled portion of the cartonboard tray and boxes, 8.5% is assumed to be sent for energy recovery and 6.9% is assumed to be disposed of to landfill (European Commission, 2015).

For the PP food tray, a recycling rate of 41.8% has been considered. This reflects the average European recycling rate for all plastic packaging (European Commission, 2018). This is probably an overestimate of the recycling rate for this type of packaging, but data at a more detailed level is not available. The lidding film is not considered to be recycled, as collection rates for household packaging films are very low across Europe. For the non-recycled portion of plastics, 55% is assumed to be sent for energy recovery and 45% is assumed to be disposed of to landfill (European Commission, 2015).

Results

Overview

The results of the two solutions are summarised in Table 5 and Figure 4. It can be seen that per tonne of packaging, the PP tray solution has higher impact than the cartonboard tray solutions. This differential is carried through when considering the impact per functional unit, i.e. per 1,000 packs.

Table 5 Comparative results per 1,000 packs

Total | Fossil GHG emissions | Biogenic GHG emissions | Biogenic GHG removals | dLUC emissions

Cartonboard Tray Solutions

	Total	Package production	Distribution to filling	Distribution of retail	End - of - life
	37.2	27.3	1.2	1.2	7.4
	66.5	63.6	1.2	1.2	0.4
	49.4	42.3	0.0	0.0	7.1
	-79.1	-79.0	0.0	0.0	-0.1
	0.4	0.4	0.0	0.0	0.0

PP Tray Solutions

	Total	Package production	Distribution to filling	Distribution of retail	End - of - life
	55.4	46.2	1.2	1.2	6.9
	79.3	71.9	1.2	1.2	5.0
	32.0	30.3	0.0	0.0	1.7
	-56.2	-56.3	0.0	0.0	0.1
	0.3	0.3	0.0	0.0	0.0

For the cartonboard tray with enclosing film in a cartonboard box, the production of the package dominates the footprint. Production of the cartonboard box accounts for 52% of the total fossil GHG emissions. Production of the substrate and forming of the cartonboard tray accounts for a further 36%, and production of the enclosing film accounts for 8%. Production of the cartonboard for the box and tray accounts for virtually all of the biogenic GHG emissions and removals.

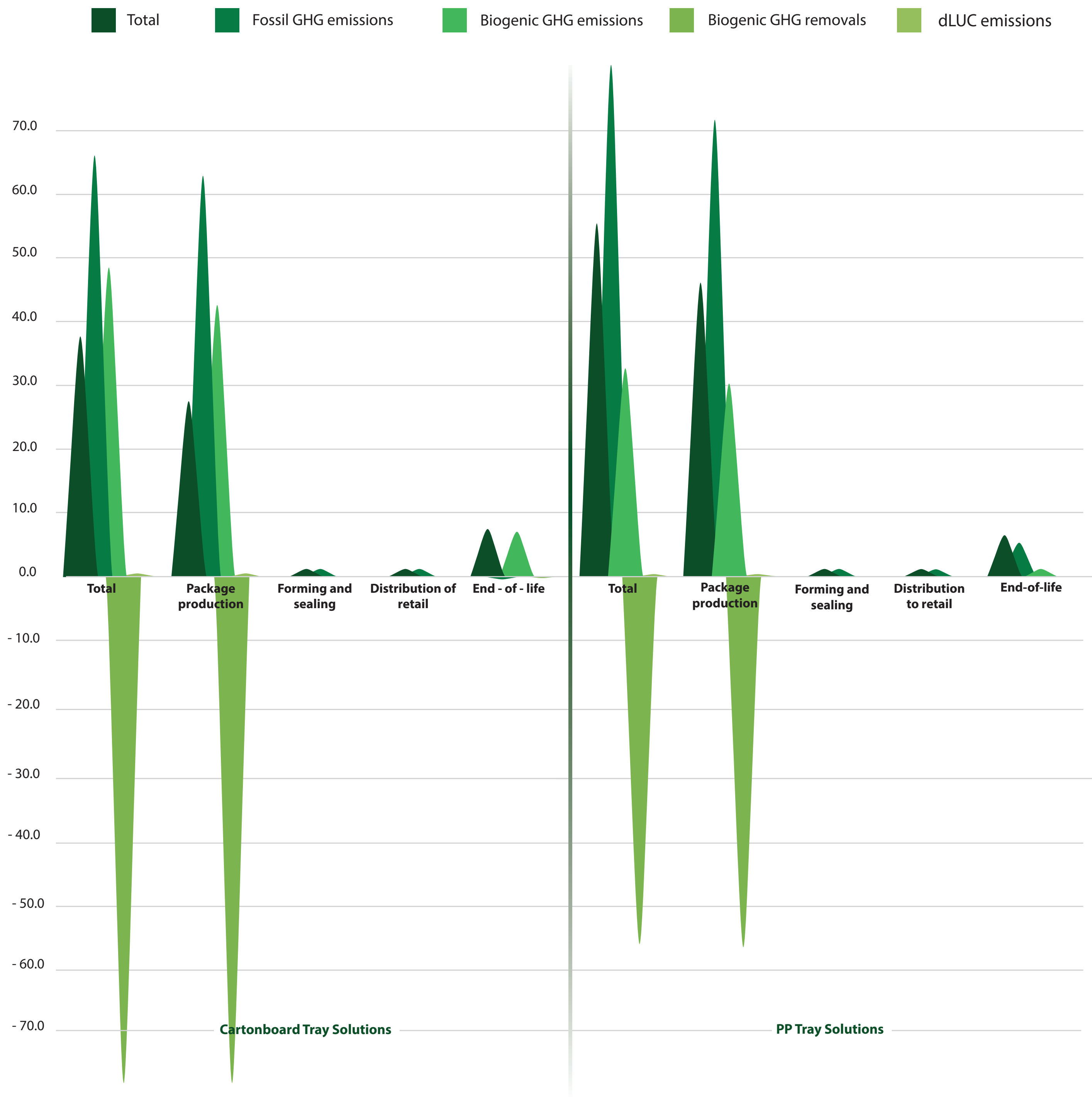
For the PP tray with film lid in a cartonboard box, the production of the package dominates the footprint. Production of the cartonboard box accounts for 43% of the total fossil GHG emissions. Production of the PP polymer and converting into the tray accounts for 40% of the total fossil GHG emissions. Production of the lidding film, including polymer production, accounts for a further 6%.

Impacts associated with end-of-life are significant for both systems. For the cartonboard tray with enclosing film in a cartonboard box, there is net emission for fossil GHG emissions from end-of-life. Although there is a credit for avoided emissions from energy recovery (heat and electricity generation) from the proportion of the cartonboard box and enclosing film that are sent to energy recovery, this is outweighed by fossil GHG emissions from the combustion of the enclosing. The biogenic GHG emissions from this life cycle stage arise from the process emissions from the combustion of the proportion of the carton tray and cartonboard box sent for energy recovery and from the degradation of the proportion of cartonboard sent to landfill.

For the PP tray with film lid in a cartonboard box, there is a net emission for fossil GHG emissions from end-of-life. This is due to the fact that process emissions from the combustion of the plastic film are larger than the credit for avoided emissions from energy recovery (heat and electricity generation). GHG emissions from landfilling of the plastic components are minimal, as the plastic will not degrade and give rise to GHG emissions in the landfill. The biogenic GHG emissions from this life cycle stage arise from the process emissions from the combustion of the proportion of the cartonboard box sent for energy recovery and from the degradation of the proportion of cartonboard sent to landfill.

Figure 4

Comparative results – ready meal packaging – cartonboard tray with enclosing film in a cartonboard box versus PP tray with a film lid in a cartonboard box



	Total	Package production	Distribution to filling	Distribution of retail	End - of - life
	37.2	27.3	1.2	1.2	7.4
	66.5	63.6	1.2	1.2	0.4
	49.4	42.3	0.0	0.0	7.1
	-79.1	-79.0	0.0	0.0	-0.1
	0.4	0.4	0.0	0.0	0.0

	Total	Package production	Distribution to filling	Distribution of retail	End - of - life
	55.4	46.2	1.2	1.2	6.9
	79.3	71.9	1.2	1.2	5.0
	32.0	30.3	0.0	0.0	1.7
	-56.2	-56.3	0.0	0.0	0.1
	0.3	0.3	0.0	0.0	0.0

Comparative Results

From the perspective of fossil GHG emissions only the cartonboard tray solution (66.5kgCO2e per 1,000 packs) has a lower impact compared to the PP tray solution (80.8kgCO2e per 1,000 packs).

When biogenic GHG emissions and removals and dLUC are also considered, the advantage of the cartonboard tray solution (37.2kgCO2e per 1,000 packs) compared to the PP tray solution (57.6kgCO2e per 1,000 packs) is significantly increased.

This is due to the uptake of carbon during the growth phase of the forests which supply the virgin fibre used in cartonboard. This biogenic GHG carbon removal is larger than the biogenic GHG emissions that occur (from the combustion of biofuels at the mill) during the manufacture of the board.

However, a high recycling rate is attained for paper and board packaging, including cartons. A high proportion of the original carbon contained in the product when it is first placed on the market is carried through to the life cycle of subsequent products outside the boundaries of this analysis. A cut off method is used in this analysis, in line with the CITPA methodology (CITPA, 2018). Therefore, the emissions associated with material recycling and the subsequent credits for replacing virgin fibre production are outside the boundaries of the footprint calculation. The carbon contained in the recovered fibres will be passed on to other products until recycling of the fibres is no longer viable, at which stage the fibres will be sent for either incineration with energy recovery or landfill, with associated emissions to consider.

Robustness of the results

The results have been subjected to sensitivity and uncertainty analysis. This revealed that the results for both solutions are sensitive to the end-of-life scenarios considered for the trays. With a 0% tray recycling rate, the impact for both solutions is increased, although the increase is more marked for the cartonboard tray solution due to the release of additional biogenic greenhouse gases from the energy recovery process or from degradation in landfill. Subsequently, if the cartonboard trays are not recycled then whether it is recycled or not the PP tray solution has a lower total carbon impact.

These results highlight the importance of recycling paper and board products wherever technically and economically viable, as recycling delays releasing carbon contained within fibre-based packaging back into the atmosphere.

Case study: Fast food packaging

Systems studied

In this case study, a folding carton is compared against a PET tray with PET lid for packaging takeout salad.

Figure 5

Examples of the takeout salad solutions considered – folding cartonboard box (left) and PET tray and lid (right)

Table 6 - Packaging specifications considered

Takeout Salad	
Solution	**Specification**
Folding cartonboard box	Carton – 19.5g
PET tray and lid	PET tray – 12g PET lid – 3g

For the cartonboard box, a recycling rate of 84.6% has been considered. This reflects the average European recycling situation (European Commission, 2017). For the non-recycled portion of the cartonboard boxes, 8.5% is assumed to be sent for energy recovery and 6.9% is assumed to be disposed of to landfill (European Commission, 2015).

For the PET tray and lid, a recycling rate of 41.8% has been considered. This reflects the average European recycling rate for all plastic packaging (European Commission, 2018). In reality, this is probably an overestimate of the recycling rate for this type of packaging, but data at a more detailed level is not available. For the non-recycled portion of plastics, 55% is assumed to be sent for energy recovery and 45% is assumed to be disposed of to landfill (European Commission, 2015).

Results

Overview

The results of the two solutions are summarised in Table 7 and Figure 6. It can be seen that the PET tray and lid has a much higher impact than the cartonboard box when considering the impact per functional unit, i.e. per 1,000 packs.

Table 7 Comparative results per 1,000 packs

Total | Fossil GHG emissions | Biogenic GHG emissions | Biogenic GHG removals | dLUC emissions

Cartonboard Box

	Total	Package production	Distribution of retail	End - of - life
	7.9	5.1	0.5	2.3
	20.3	20.4	0.5	-0.6
	20.8	17.7	0.0	3.0
	-33.3	-33.2	0.0	0.1
	0.2	0.2	0.0	0.0

PET tray and lid

	Total	Package production	Distribution of retail	End - of - life
	62.5	55.5	0.4	6.5
	62.4	55.5	0.4	6.5
	0.9	1.1	0.0	-0.1
	-0.9	-1.0	0.0	0.1
	0.2	0.0	0.0	0.0

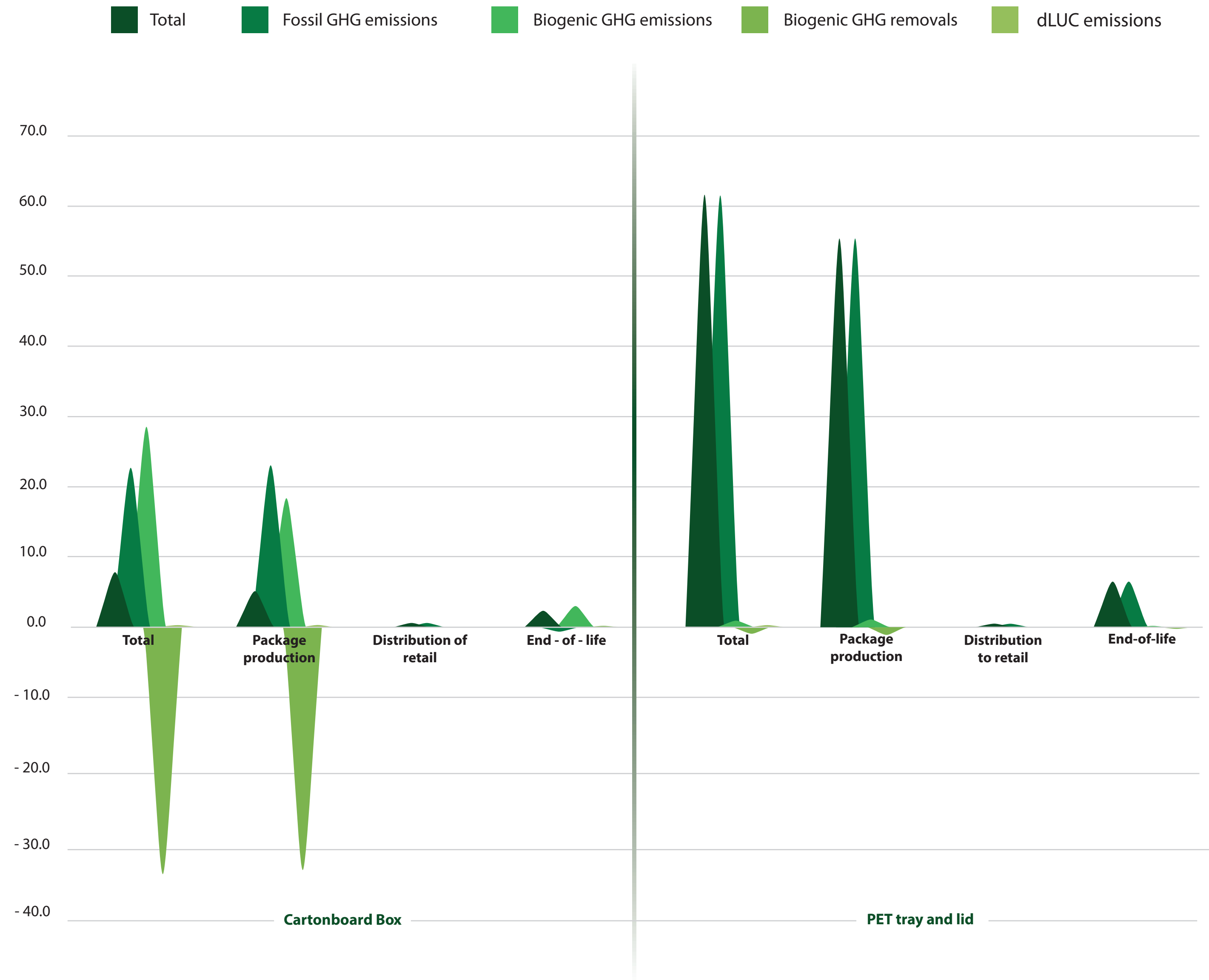
For the cartonboard box, the production of the package dominates the footprint. Production of the cartonboard box accounts for virtually all of the fossil GHG emissions and of the biogenic GHG emissions and removals across the life cycle.

For the PET tray and lid, the production of the package dominates the footprint. Production of the polymers which make up the tray and lid accounts for 74% of the fossil GHG emissions. Thermoforming of the polymers into the containers accounts for a further 14%.

Impacts associated with end-of-life are significant for both systems. For the cartonboard box, there is net credit for fossil GHG emissions from end-of-life due to avoided emissions from energy recovery (heat and electricity generation). The biogenic GHG emissions from this life cycle stage arise from the process emissions from the combustion of the proportion of the cartonboard box sent for energy recovery and from the degradation of the proportion of cartonboard sent to landfill. For the PET tray and lid, there is a net emission of fossil GHGs from end-of-life. This is due to the fact that process emissions from the combustion of the plastic are larger than the credit for avoided emissions from energy recovery (heat and electricity generation). GHG emissions from landfilling of the PET tray and lid are minimal, as the plastic will not degrade and give rise to GHG emissions in the landfill.

Figure 6

Comparative results – takeout salad packaging – cartonboard box versus PET tray and lid.



	Total	Package production	Distribution of retail	End - of - life
	7.9	5.1	0.5	2.3
	20.3	20.4	0.5	-0.6
	20.8	17.7	0.0	3.0
	-33.3	-33.2	0.0	0.1
	0.2	0.2	0.0	0.0

	Total	Package production	Distribution of retail	End - of - life
	62.5	55.5	0.4	6.5
	62.4	55.5	0.4	6.5
	0.9	1.1	0.0	-0.1
	-0.9	-1.0	0.0	0.1
	0.2	0.0	0.0	0.0

Comparative Results

Considering fossil GHG emissions only the cartonboard box (20.3kgCO2e per 1,000 packs) has a lower impact compared to the PET tray and lid (62.4kgCO2e per 1,000 packs).

When biogenic GHG emissions and removals and dLUC are also considered, the advantage of the cartonboard box (7.9kgCO2e per 1,000 packs) compared to the PET tray and lid (62.5kgCO2e per 1,000 packs) is significantly increased. This is due to the uptake of carbon during the growth phase of the forests which supply the virgin fibre used in cartonboard. This biogenic GHG carbon removal is larger than the biogenic GHG emissions that occur (from the combustion of biofuels at the mill) during the manufacture of the board.

However, a high recycling rate is attained for paper and board packaging, including cartons. A high proportion of the original carbon contained in the product when it is first placed on the market is carried through to the life cycle of subsequent products outside the boundaries of this analysis. A cut off method is used in this analysis, in line with the CITPA methodology. Therefore, the emissions associated with material recycling and the subsequent credits for replacing virgin fibre production are outside the boundaries of the footprint calculation. The carbon contained in the recovered fibres will be passed on to other products until recycling of the fibres is no longer viable, at which stage the fibres will be sent for either incineration with energy recovery or landfill, with associated emissions to consider.

Robustness of the results

The results have been subjected to sensitivity and uncertainty analysis and have been found to be robust.

In particular, the recycling rate for both the cartonboard box and the PET tray and lid is tested. It is possible that separate collection of the takeout containers may not be available, or they will be rejected at sorting sites or at the reprocessors due to food contamination.

Sensitivity analysis shows that the results for the cartonboard box solution are sensitive to the end-of-life scenario considered. With a 0% cartonboard recycling rate, the impact for the cartonboard box solution is significantly increased. However, the comparative standing of the two systems is unchanged no matter what combination of end-of-life scenarios is considered.

Case study: Small electricals packaging

Systems studied

In this case study, a carton is compared against a PVC blister pack with cartonboard fitments for packaging a 5m HDMI cable.

Figure 7

Examples of the cable packaging solutions considered – cartonboard box (left image) and PVC blister pack with cartonboard fitments (right image).

Table 8 - Packaging specifications considered

5m HDMI cable	
Solution	**Specification**
Cartonboard box	Carton – 35g PET hanger tag – 2g
PVC blister pack with cartonboard fitments	PVC Blister pack – 58g Cartonboard fitments – 20g

For the cartonboard box and the cartonboard fitments, a recycling rate of 84.6% has been considered. This reflects the average European recycling situation (European Commission, 2017). For the non-recycled portion of the cartonboard boxes, 8.5% is assumed to be sent for energy recovery and 6.9% is assumed to be disposed of to landfill (European Commission, 2015).

The PVC blister pack is not considered to be recyclable. 55% is assumed to be sent for energy recovery and 45% is assumed to be disposed of to landfill (European Commission, 2015).

Results

Overview

The results of the two solutions are summarised in Table 9 and Figure 8. It can be seen that the blister pack with carton fitments has a much higher impact than the cartonboard box.

Table 9 Comparative results per 1,000 packs

Total | Fossil GHG emissions | Biogenic GHG emissions | Biogenic GHG removals | dLUC emissions

Cartonboard Box

	Total	Package production	Distribution of filler	Distribution of retail	End - of - life
	23.3	15.8	0.9	0.9	5.6
	45.5	43.3	0.9	0.9	0.3
	37.4	32.0	0.0	0.0	5.4
	-59.9	-59.8	0.0	0.0	-0.1
	0.3	0.3	0.0	0.0	0.0

PVC blister with cartonboard fitments

	Total	Package production	Distribution of filler	Distribution of retail	End - of - life
	223.6	165.1	2.0	2.0	54.5
	235.4	180.0	2.0	2.0	51.4
	20.2	19.0	0.0	0.0	1.2
	-32.2	-34.1	0.0	0.0	1.9
	0.2	0.2	0.0	0.0	0.0

For the cartonboard box, the production of the package dominates the footprint. Production of the cartonboard box accounts for 85% of the fossil GHG emissions for this stage of the life cycle. Production of the PET hanger accounts for the remaining fossil GHG emissions associated with the packaging production. The production of the cartonboard box accounts for virtually all of the biogenic GHG emissions and removals.

For the PVC blister pack with cartonboard fitments, the production of the package dominates the footprint. Production of the PVC polymer which makes up the blister pack accounts for 68% of the fossil GHG emissions associated with this life cycle stage. Conversion of the PVC into the blister (thermoforming) accounts for a further 20% pf the package production impact, with the production of the cartonboard fitments accounting for the remaining 12%. The production of the cartonboard fitments accounts for virtually all of the biogenic GHG emissions and removals.

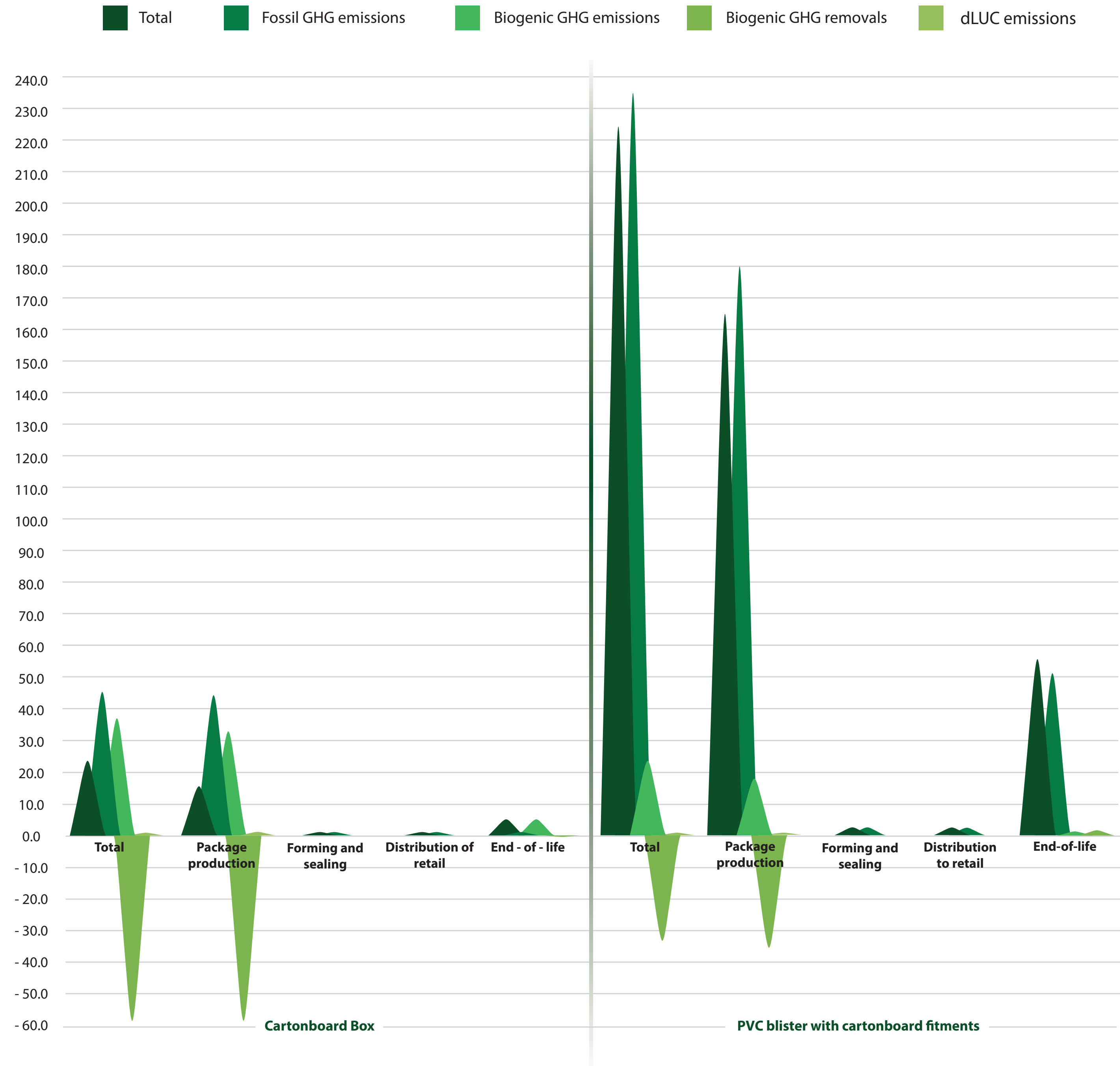
Impacts associated with end-of-life are significant for both systems. For the cartonboard box, there is net emission for fossil GHG emissions from end-of-life.

Although there is a credit for avoided emissions from energy recovery (heat and electricity generation) from the proportion of the cartonboard box and PET hanger that are sent to energy recovery, this is outweighed by fossil GHG emissions from the combustion of the PET hanger. The biogenic GHG emissions from this life cycle stage arise from the process emissions from the combustion of the proportion of the cartonboard box sent for energy recovery and from the degradation of the proportion of cartonboard sent to landfill.

For the PVC, there is a net emission for fossil GHG emissions from end-of-life. This is due to the fact that process emissions from the combustion of the PVC blister are larger than the credit for avoided emissions from energy recovery (heat and electricity generation). GHG emissions from landfilling of the PVC are minimal, as the polymer will not degrade and give rise to GHG emissions in the landfill. The biogenic GHG emissions from this life cycle stage of the PVC blister arise from the process emissions from the combustion of the proportion of the cartonboard fitments sent for energy recovery and from the degradation of the proportion of cartonboard fitments sent to landfill.

Figure 8

Comparative results – HDMI cable packaging – cartonboard box versus PVC blister



	Total	Package production	Distribution of filler	Distribution of retail	End - of - life
	23.3	15.8	0.9	0.9	5.6
	45.5	43.3	0.9	0.9	0.3
	37.4	32.0	0.0	0.0	5.4
	-59.9	-59.8	0.0	0.0	-0.1
	0.3	0.3	0.0	0.0	0.0

	Total	Package production	Distribution of filler	Distribution of retail	End - of - life
	223.6	165.1	2.0	2.0	54.5
	235.4	180.0	2.0	2.0	51.4
	20.2	19.0	0.0	0.0	1.2
	-32.2	-34.1	0.0	0.0	1.9
	0.2	0.2	0.0	0.0	0.0

Comparative Results

Considering fossil GHG emissions only the cartonboard box has a considerably lower impact (45.3kgCO2e per 1,000 packs) compared to the PVC blister pack with cartonboard fitments (235.4kgCO2e per 1,000 packs)

When biogenic GHG emissions and removals and dLUC are also considered, the footprint of the cartonboard box (23.4kgCO2e per 1,000 packs) is further reduced relative to the footprint of the PVC blister with cartonboard fitments (223.6kgCO2e per 1,000 packs).

This is due to the uptake of carbon during the growth phase of the forests which supply the virgin fibre used in cartonboard. This biogenic GHG carbon removal is larger than the biogenic GHG emissions that occur (from the combustion of biofuels at the mill) during the manufacture of the board.

However, it should be noted that a high recycling rate is attained for paper and board packaging, including cartons. Thus, a high proportion of the original carbon contained in the product when it is first placed on the market is carried through to the life cycle of subsequent products outside the boundaries of this analysis. In line with the CITPA methodology (CITPA, 2018) applied in this analysis, a cut-off method is applied, and therefore the emissions associated with material recycling and the subsequent credits for replacing virgin fibre production are outside the boundaries of the footprint calculation. It should be remembered that the carbon contained in the recovered fibres will be passed on to other products until recycling of the fibres is no longer viable, at which stage the fibres will be sent for either incineration with energy recovery or landfill, with associated emissions to consider.

Robustness of the results

The results have been subjected to sensitivity and uncertainty analysis and have been found to be robust.

In particular, the sensitivity of the results to the recycling rate assumed for carton board has been tested. If the carton recycling rate is lower, then the total footprint of the cartonboard box increases. However, if the carton recycling rate is changed to 50%, then the difference between the cartonboard box and the PVC blister with cartonboard fitments is reduced, although it still remains significant and the comparative results for the two systems are not sensitive to the recycling rate assumed.

Conclusions

The table below summarises the results from the case studies. As in any modelling exercise, there are uncertainties and assumptions in the systems modelled and data used. It is also stressed that calculating and communicating the carbon footprint of fibre-based packaging materials is complex. Stakeholders should not take the results presented at face value but are encouraged to read this report to fully understand the factors and methodology decisions that contribute to the results.

Nonetheless, the results achieved for these case studies are generally robust and suggest that cartonboard packaging solutions are a low carbon solution when compared to alternative plastics-based packaging solutions in the market.

Table 10 Summary of case study results

	Results considering total GHG emissions and removals	Results considering fossil GHG emissions only
Case study: Frozen fishfingers	The cartonboard box has a lower total GHG impact compared to the multilaminate bag. This result is not dependent on the data and methodology applied for biogenic GHG emissions and removals.	The cartonboard box has a lower fossil GHG impact compared to the multilaminate bag. This result is not sensitive to any of the parameters investigated.
Case study: Ready meals	The cartonboard tray solution has a lower total GHG impact compared to the PP tray solution. This result is dependent on the end-of-life scenario considered for the cartonboard trays. In the event that the cartonboard trays were not recycled, then the PP tray solution has a lower total GHG impact compared to the cartonboard tray solution.	The cartonboard tray solution has a lower fossil GHG impact compared to the PP tray solution. This result is not sensitive to any of the parameters investigated.
Case study: Takeout salads	The cartonboard box has a lower total GHG impact compared to the PET tray and lid. This result is not dependent on the data and methodology applied for biogenic GHG emissions and removals.	The cartonboard box has a lower fossil GHG impact compared to the PET tray and lid. This result is not sensitive to any of the parameters investigated.
Case study: HDMI cable	The cartonboard box has a lower total GHG impact compared to the PVC blister pack with cartonboard fitments. This result is not dependent on the data and methodology applied for biogenic GHG emissions and removals.	The cartonboard box has a lower fossil GHG impact compared to the PVC blister pack with cartonboard fitments. This result is not sensitive to any of the parameters investigated.

Peer review

Studies which make comparative assertions between competing solutions should be subjected to an independent peer review. For this study, the work was the subject of a peer review process conducted by Intertek, a leading Total Quality Assurance provider to industries worldwide.

The peer review considered the results and conclusions to be sound and fair based on the data and methodologies used. Intertek found that the analysis underpinning the case studies was of high quality with appropriate use of data and carbon methodology. Intertek concluded that the results are believed to be reliable and useful for specifiers of packaging and other stakeholders.

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