BIOECONOMY
Unit

Comparing the environmental profile of innovative FibreForm® food trays against existing plastic packaging solutions

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Executive Summary

Background

FibreForm is a thermoformable paper that offers opportunities for new packaging in a wide variety of applications – including paper cups, stand-up pouches, cartons, formed containers, and trays and blisters. The renewable, bio-based and recyclable nature of FibreForm makes it a strong fit with current environment and sustainability priorities. However, it is important that environmental advantages are demonstrated by sound, independent, transparent and data-driven analysis.

For this reason, BillerudKorsnas has commissioned the research organization RISE (Research Institutes of Sweden) to undertake this life cycle assessment study with the following goal in mind:

"To compare the environmental profile of FibreForm food trays against existing plastic solutions in the market, namely APET/PE trays and EPS trays"

About the approach

In the analysis, three alternative systems have been modelled:

- A shallow FibreForm tray with multilayer lidding film
- A shallow APET/PE tray with multilayer lidding film
- A shallow EPS tray with multilayer lidding film

To facilitate the comparison of the three different solutions, the following functional unit has been applied:

"1,000 trays of product successfully delivered to the final consumer and disposed of after use"

Four impact categories are considered:

- Global Warming Potential (GWP) – the potential to contribute to climate change impacts based on releases of greenhouse gases, considering each chemical's radiative forcing and lifetime
- Acidification Potential (AP) – the potential to cause a wide range of impacts on soil, groundwater, surface water, organisms, ecosystems and materials (buildings) through the release of acidifying substances to the environment
- Eutrophication Potential (EP) – the potential to cause impacts due to excessive levels of macronutrients in the environment caused by emissions of nutrients to air, water and soil
- Photochemical Ozone Creation Potential (POCP) – the potential to cause photo-oxidant formation; photo-oxidants are reactive substances (mainly ozone) which are injurious to human health and ecosystems and which also may damage crops.

These have been chosen as they are representative of the most important environmental interventions associated with paper-based packaging solutions: Energy consumption and climate change (represented by GWP); emissions to air (represented by AP and POCP) and emissions to water (represented by AP and EP). For the global warming potential impact category, in line with the latest methodology recommendations, results are calculated including biogenic GHG emissions and removals.

Results and conclusions

The key takeaways from this analysis are summarised below:

- The results show that the FibreForm tray has a lower environmental impact than the APET/PE tray for all four impact categories considered in this life cycle assessment. This finding is very robust and remains true even allowing for the uncertainties and sensitivities that are inherent in any LCA study. This is borne out in the various aspects of the sensitivity and uncertainty analysis tested in the study.
- For the impact category Global Warming Potential, the results show that the FibreForm tray also performs better than the EPS tray. This finding is also very robust considering the uncertainties and sensitivities identified and tested in the study.
- For the impact categories Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation, the results show that the FibreForm tray performs better than the EPS tray. However, this outcome is dependent on the weight of the EPS tray considered. If a lighter EPS tray was to be considered (3g as opposed to 5g EPS tray considered in the baseline scenario) then there is no significant difference in performance of the FibreForm tray compared to the EPS tray for these three impact categories.

These results show that a brand owner, filler or retailer considering FibreForm trays as a solution can be confident that:

- Choosing FibreForm trays will result in a significantly reduced Global Warming impact compared to using existing plastic packaging solutions available in the market such as APET/PE laminated plastic trays or EPS trays
- Choosing FibreForm trays will also result in a better environmental performance with regards to Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation Potential compared to continued use of existing APET/PE laminated plastic trays
- In most cases, choosing FibreForm trays will result in a better environmental performance with regards to Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation Potential compared to continued use of existing EPS trays. If the alternative is a very light-weight EPS tray then there may be no significant change for these impact categories.

Independent peer review

The study has been performed in compliance with the international standards setting the requirements for LCA studies (ISO14040 and ISO14044). As required by these standards for any comparative LCA, the study has been subject to independent peer review. The independent peer review was undertaken by the global assurance organisation Intertek. The peer review concludes that the study is of high quality, detailed, transparent and appropriate. Intertek considers the results and conclusions to be sound and fair and indicates that the report provides realistic and useful information to specifiers of food trays.

What is FibreForm ?

BillerudKorsnäs focuses on offering the packaging market sustainable, world-leading paper and board materials and solutions that increase customers' profitability while at the same time improving the overall environmental impact. There are numerous unique and innovative solutions in the BillerudKorsnäs range that provide customers with the opportunity to adopt sustainable, renewable and recyclable solutions as an alternative to single-use plastics. FibreForm is one such solution. It is a thermoformable paper that offers opportunities for new packaging in a wide variety of applications – including paper cups, stand-up pouches, cartons, formed containers, and trays and blisters.

What is this report about and who is it for?

The renewable, bio-based and recyclable nature of FibreForm makes it a strong fit with current environment and sustainability policy objectives such as the drive for a bio-based and circular economy and the reduction of single use plastic packaging. However, it is important that environmental claims are supported by sound, independent, transparent and data-driven analysis.

For this reason, BillerudKorsnas has commissioned a life cycle assessment study with the following goal in mind:

"To compare the environmental profile of FibreForm food trays against existing plastic solutions in the market, namely APET/PE trays and EPS trays"

Subsequently, this report details the life cycle assessment study and the results it has generated. In particular, the report details:

- The approach applied
- The systems modelled and data used
- The results achieved and the conclusions that can be drawn from these
- The sensitivities and uncertainties inherent within the analysis

The study is primarily intended to provide an informative resource for packaging specifiers (such as food processors, fillers, co-packers, brand owners and retailers) who produce or market products that are sold in sealed shallow trays (for example, cold meats). However, it may also be of interest to other stakeholders in the value chain for packaged goods, including packaging producers, packaging waste management companies, legislators and, of course, the wider general public.

Who did the work?

The work was undertaken by and the report was prepared by environmental experts from RISE (Research Institutes of Sweden). RISE is a unique, independent research and technology organisation, owned by the Swedish state and working in collaboration with and on behalf of the private and public sectors. RISE's objective is to develop services, products, technologies, processes and materials that contribute to a sustainable future.

Within RISE, sustainability services are primarily focused on the acquisition, processing and interpretation of environmental and sustainability data to facilitate fact-based decision making. Specific activities have included life cycle assessment, carbon footprinting/carbon accounting and sustainability reporting.

The three experts who worked on the project were chosen for this assignment as they are suitably experienced and qualified to perform the study. Between them, they have over sixty years of combined experience in the application of life cycle assessment techniques within the value chains for packaging and packaged goods.

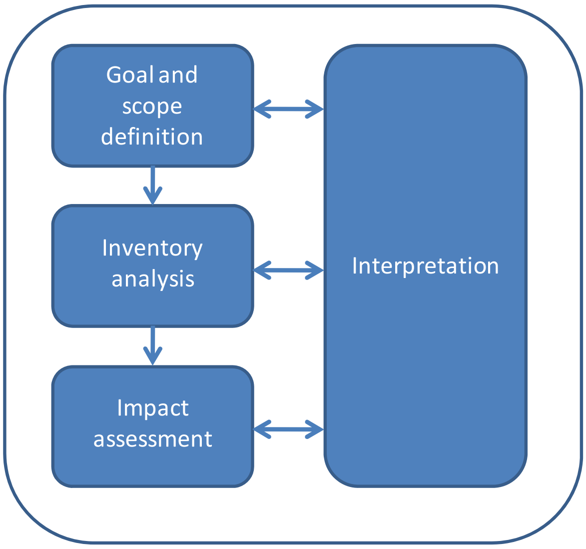
For more information about RISE, please visit: https://www.ri.se/en/about-rise

What methods have been used?

LCA is a technique to quantify the environmental impacts of a product or system, typically from the cradle to the grave i.e. from the winning and conversion of raw materials (including mining and mineral extraction, forestry and agriculture), through manufacturing of products, distribution, use, and finally management of wastes (e.g. disposal to landfill, incineration, recycling, reuse). This study has been compiled in accordance with ISO 14040 and ISO 14044, the International Standards which set out the requirements for life cycle assessment studies. The methodological approach is summarised in Figure 1.

Figure 1

LCA methodology



Source: ISO 14040[1]/ISO14044[2]

ISO international standards define LCA methodology, but by necessity these standards are non-prescriptive. They set out a framework to be followed that ensures that LCA practitioners identify all the parameters and decisions that need to be made in order to complete a justifiable and transparent study.

The work for this study has been performed in line with the requirements of these international standards.

Has the work been independently reviewed?

A key requirement of ISO14040 is that LCA studies which make comparative assertions between competing solutions should be subjected to an independent peer review. For this study, the work has been the subject of a peer review process conducted by Intertek, a leading Total Quality Assurance provider to industries worldwide. A peer review statement describing the scope and findings of the review is provided at the end of this report.

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

[2] ISO 14040:2006 Environmental management -- Life cycle assessment -- Requirements and standard

What systems and boundaries are considered?

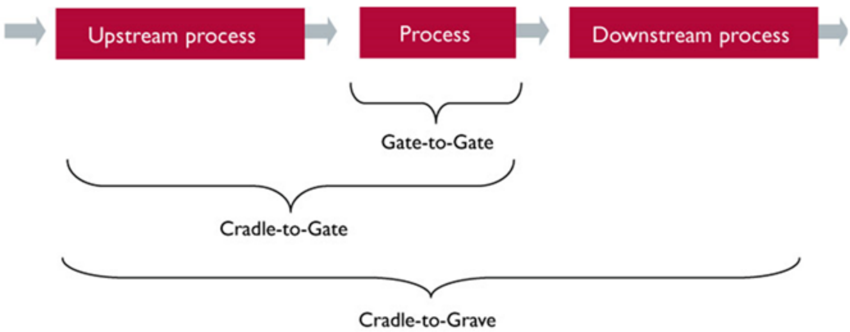
In preparing a life cycle assessment study, several possible system boundary options are available (Figure 2):

- A **gate-to-gate analysis** is limited to what happens in a production facility (from the entry gate to the exit gate)
- A **cradle-to-gate analysis** addresses the environmental interventions of a product or system from raw material acquisition through production; i.e. including the winning and conversion of raw materials (such as mining, forestry and agriculture) and manufacturing of products (e.g. pulping and papermaking), but excluding distribution, use, and management of products at the end of their useful life (e.g. disposal to landfill, incineration, recycling, reuse)
- A **cradle-to-grave analysis** measures the environmental interventions of a product or system right through from material acquisition, through manufacturing, distribution, use and end-of-life management.

This study encompasses all stages of the product life cycle (i.e. cradle-to-grave), as illustrated in Figure 2 below.

Figure 2

Understanding different system boundaries



The FibreForm tray has the advantage at end-of-life that it is potentially recyclable along with other fibre-based packaging waste. In the case of recycling of the FibreForm tray the cut-off method has been applied. The impacts associated with the collection of the used trays is included in the analysis, but the subsequent impacts of reprocessing the material and credits for avoided emissions for production of virgin fibres are not included within the system boundaries.

In LCA, the functional unit is a measure of the function that a system delivers so that comparisons between different scenarios and alternatives can be made on a like-for-like basis. In this report, the functional unit considered for all systems is:

"1,000 trays of product successfully delivered to the final consumer and disposed of after use"

Three alternative systems have been modelled:

- A shallow FibreForm tray with multilayer lidding film
- A shallow APET/PE tray with multilayer lidding film
- A shallow EPS tray with multilayer lidding film

By focusing on the volume of packaged product delivered to the consumer, the functional unit takes into account the fact that the comparative solutions within each case are made of different materials. A weight-based functional unit (e.g. 1,000kg of trays) would not be appropriate, as this would not take into account differences in weights between the comparative solutions.

The material specifications considered for each of the individual solutions are detailed in Table 1 below.

Table 1 Material specifications for each of the solutions investigated

Solution	Tray dimensions	Tray materials and weight	Lidding materials and weight
System 1: FibreForm tray	120mm x 180 mm with a depth of ~15mm	Adhesive laminated structure consisting of 2 layers of 150gsm FibreForm and laminated with multilayer films comprising PE, PA, EVOH and adhesives Total tray weight 7.6g	Printed multilayer film comprising Biaxially oriented PET, PE, PA, EVOH, Polybutylene and adhesives Lid weight 1.5g
System 2: APET/PE tray	120mm x 180 mm with a depth of ~15mm	Laminated multilayer substrate comprising APET, PE, EVOH, Polybutylene, EVA and adhesives Total tray weight 8.7g	Printed multilayer film comprising Biaxially oriented PET, PE, EVOH and adhesives Lid weight 1.4g
System 3: EPS tray	120mm x 180 mm with a depth of ~15mm	Expanded PS Total tray weight 5g	Printed multilayer film (assumed same composition as for System 2) Lid weight 1.4g

It should be noted that the material specifications and weights for the lids for the FibreForm tray and the APET/PE tray are different from one another. In the FibreForm lidding material, Polybutylene and Polyamide (PA) are used, but these are not present in the lidding material for the APET/PE tray:

- The Polybutylene is used as a material to make the lidding peelable. For the FibreForm tray, this is included in the lidding material itself, whilst in the APET/PE tray it is included in the composition of the tray rather than the lidding material.
- Polyamide (PA) is used to provide the lidding for the FibreForm tray (and the tray itself) with greater tear strength. This is included in the lidding and the FibreForm

tray to prevent the lid tearing on opening. The APET/PE tray is inherently more resistant and therefore the addition of the PA is not required.

The systems modelled in the study are summarised in Figures 3-5. In addition to the unit processes shown in these diagrams, the following transport steps have also been considered within the system boundaries:

- Transport of wood to the integrated pulp and papermill for the production of FibreForm (included in the unit process FibreForm production)
- Transport of non-fibre inputs to the mill (included in the unit process FibreForm production)
- Transport of FibreForm reels from mill to lamination plant (included in the unit process Polymers, film and bottom web lamination)
- Transport of films and polymers used for the bottom web to the lamination plant (included in the unit process Polymers, film and bottom web lamination for the FibreForm and APET/PE tray solutions)
- Transport of films and polymers used for the lidding film to the lamination plant (included in the unit process Lidding film production)
- Transport of bottom web from lamination plant to filling (included in the process Form-fill-seal for the FibreForm and APET/PE tray solutions)
- Transport of the EPS trays from tray production to the Fill-seal process (included in the Fill-seal process for the EPS tray solution)
- Transport of lidding film from the lamination plant to filling (included in the process Form-fill-seal for the FibreForm and APET/PE tray solutions; included in the Fill-seal process for the EPS tray solution).

For the analysis, in each case the trays are filled, consumed and disposed of at end-of-life in Belgium. The Belgian market has been chosen existing customers for the FibreForm tray in Belgium have expressed an interest in significantly increasing the volumes they use. However, as the end-of-life recycling rate for paper and board packaging is very high in Belgium the models were structured so as to allow sensitivity analysis of how the trays are managed at end-of-life. This can help stakeholders to better understand the transferability of the results to other markets where different end-of-life treatment options may be the standard.

Figure 3

System considered for the FibreForm tray

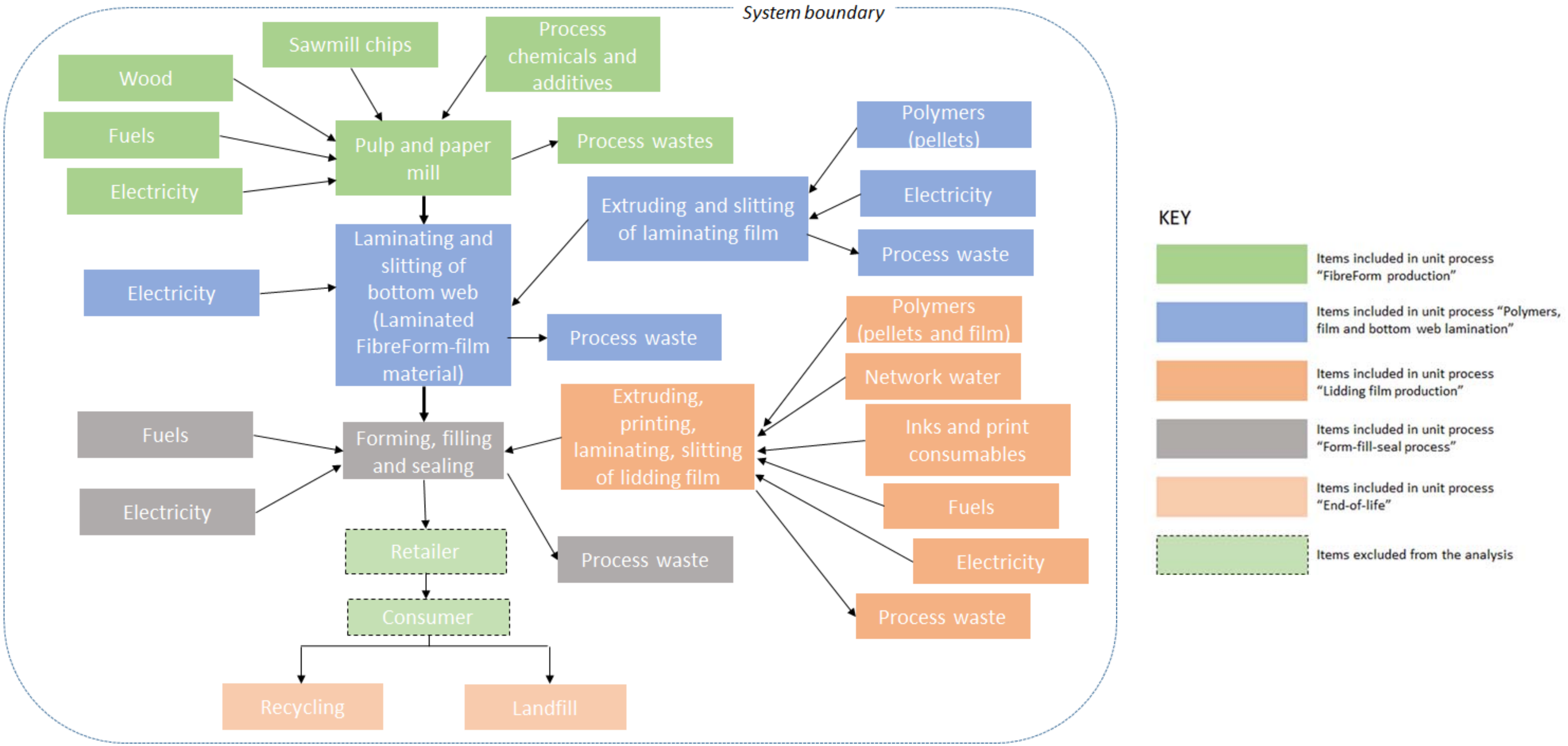


Figure 4

System considered for the APET/PE tray

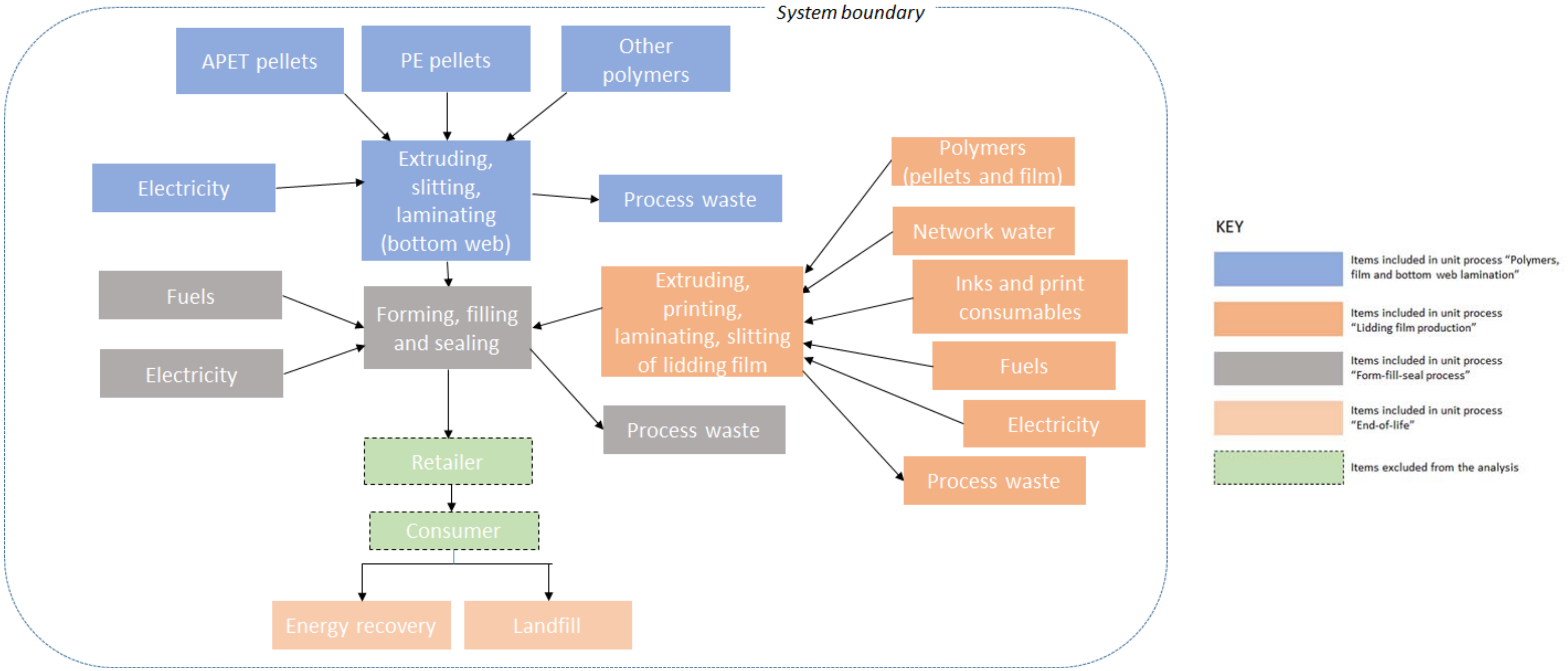
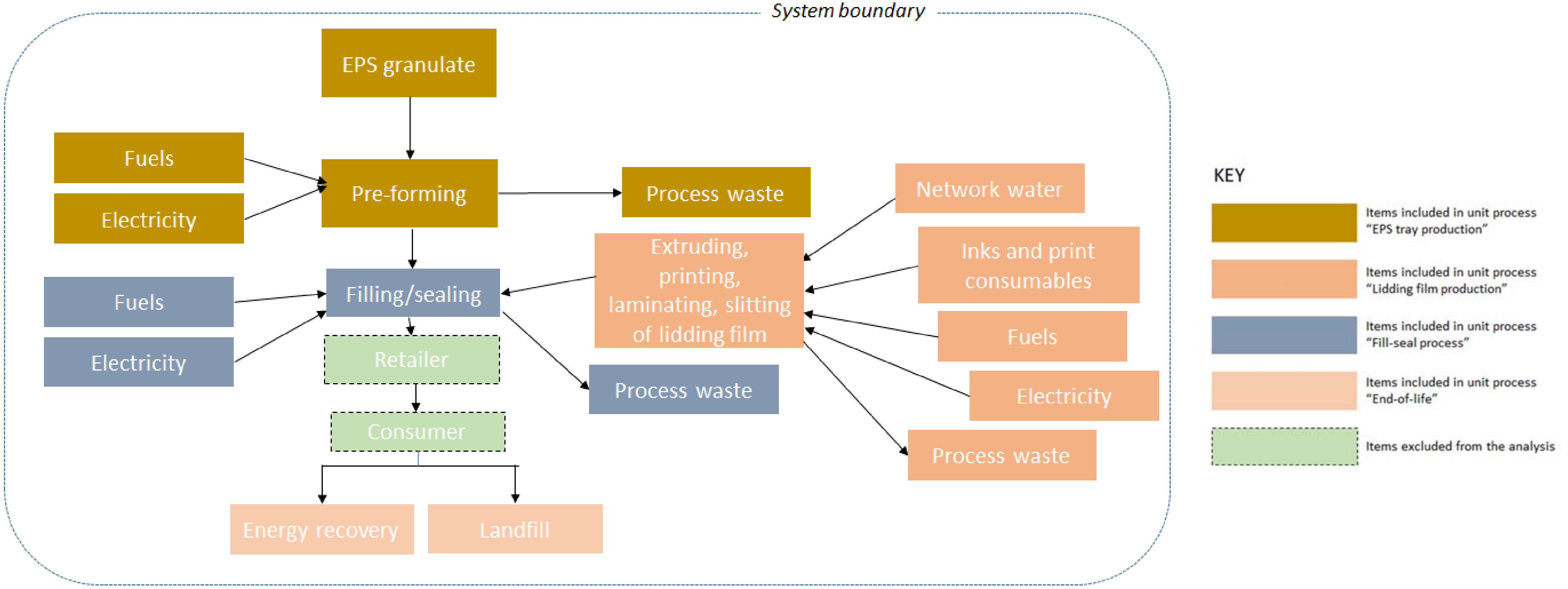


Figure 5

System considered for the EPS tray



For the FibreForm tray, the paper substrate is produced at BillerudKorsnas' integrated pulp and paper mill in Karlsborg, Sweden. Reels of FibreForm substrate are then transported to a convertor in Germany where they are laminated together along with polymers to create the bottom web (i.e. the material that will be formed into the tray). The lidding material is also manufactured and printed at the same facility in Germany. The materials are then transported as reels to the filler in Belgium, where the trays are formed, filled and sealed/lidded in a single integrated filling operation.

The filled products are consumed in Belgium.

The APET/PE tray and its lidding film is also manufactured by the same convertor in Germany and filled and consumed in Belgium.

For the EPS tray, no specific manufacturing chain and suppliers were considered. It has therefore been assumed that the EPS tray is formed in Germany and then transported to the filler in Belgium. It is assumed that the lidding film is also manufactured in Germany and transported as a reel to the filler in Belgium.

As the product is consumed in Belgium, for each system the end-of-life scenario that would be appropriate in Belgium has been considered, as described in Table 2 below. The official data for packaging recovery and recycling in Belgium for 2018 shows that 89.4% of paper and board packaging is recycled, while the remaining material is sent for energy recovery. For non-recyclable plastics packaging such as food trays and lidding films the statistics show that 99% is sent to energy recovery, with the remainder sent to landfill.

Table 2 End-of-life scenarios considered for each solution

Solution	End-of-life scenario considered
System 1: FibreForm tray	Bottom web (tray) – 89.4% material recovery (recycling); residual material to energy recovery Lidding material – 99% to energy recovery, 1% to landfill
System 2: APET/PE tray	Bottom web (tray) – 99% to energy recovery, 1% to landfill Lidding material – 99% to energy recovery, 1% to landfill
System 3: EPS tray	Tray – 99% to energy recovery, 1% to landfill Lidding material – 99% to energy recovery, 1% to landfill

For the sensitivity analysis, alternative end-of-life scenarios were considered for the FibreForm tray. No alternative recycling scenarios were considered for the APET/PE tray or for the EPS tray as no examples of recycling processes capable of handling these solutions were identified.

The models were compiled using the commercially available LCA software tool GaBi4. Further details of the data used for the models are provided in Annex 1 of this report.

What environmental impacts are considered?

For this study, four impact categories are considered:

- Global Warming Potential (GWP) – this refers to the potential to contribute to climate change impacts based on releases of greenhouse gases, considering each chemical's radiative forcing and lifetime
- Acidification Potential (AP) – this refers to the potential to cause a wide range of impacts on soil, groundwater, surface water, organisms, ecosystems and materials (buildings) through the release of acidifying substances to the environment
- Eutrophication Potential (EP) – this refers to the potential to cause impacts due to excessive levels of macronutrients in the environment caused by emissions of nutrients to air, water and soil
- Photochemical Ozone Creation Potential (POCP) – this refers to potential to cause photo-oxidant formation; photo-oxidants are reactive substances (mainly ozone) which are injurious to human health and ecosystems and which also may damage crops.

These four impact categories have been chosen for this study as they are representative of the most important environmental interventions associated with paper-based packaging solutions: Energy consumption and climate change (represented by GWP); emissions to air (represented by AP and POCP) and emissions to water (represented by AP and EP).

For the global warming potential impact category, in line with the latest methodology recommendations, results are calculated including biogenic GHG emissions and removals, but to help with interpretation, results for the fibre-based packaging solution (the FibreForm tray) are presented both including and excluding biogenic GHG emissions.

Characterization factors from CML2001 (Centre of Environmental Science of Leiden University) were applied, as summarised in Table 3.

Table 3 Impact categories considered and units applied

Impact category	Units	Description
Global Warming Potential	kg CO_2-eq	Potential to contribute to climate change based on each chemical's radiative forcing and lifetime. Carbon dioxide is taken as the reference (with a global warming potential of 1kg CO_2-eq per kg of CO_2 released to the atmosphere) as it is the most common greenhouse gas emission. Emissions of other greenhouse gases are weighted according to their potency relative to CO_2
Acidification Potential	kg SO_2-eq	Potential to cause a wide range of impacts on soil, groundwater, surface water, organisms, ecosystems and materials (buildings) through the release of acidifying substances. Sulphur dioxide is taken as the reference emission as this reacts in the environment to from sulphuric acid (e.g. as acid rain). Other emissions that contribute to acidification are weighted according to their potency relative to SO_2
Eutrophication Potential	kg PO_4-eq	Also known as nutrification, potential to cause impacts due to excessive levels of macronutrients in the environment caused by emissions of nutrients to air, water and soil. Phosphate is taken as the reference emission as this as this is an important nutrient in the environment. Other emissions that contribute to eutrophication are weighted according to their impact relative to PO_4
Photochemical Ozone Creation Potential (POCP)	kg ethene-eq	Potential to cause photo-oxidant formation; photo-oxidants are reactive substances (mainly ozone) which are injurious to human health and ecosystems and which also may damage crops. Ethene is taken as the reference emission for this impact category. Other emissions that contribute to eutrophication are weighted according to their impact relative to ethene

What are the results?

In this section, the headline results are presented. The results are presented according to the functional unit, i.e. per 1,000 trays of product successfully delivered to the final consumer.

Figure 6 and Tables 4-7 present the comparative environmental profiles of the FibreForm tray, the APET/PE tray and the EPS tray respectively, for each of the four different impact categories considered for this study.

Figure 6

Results - Comparison of the systems

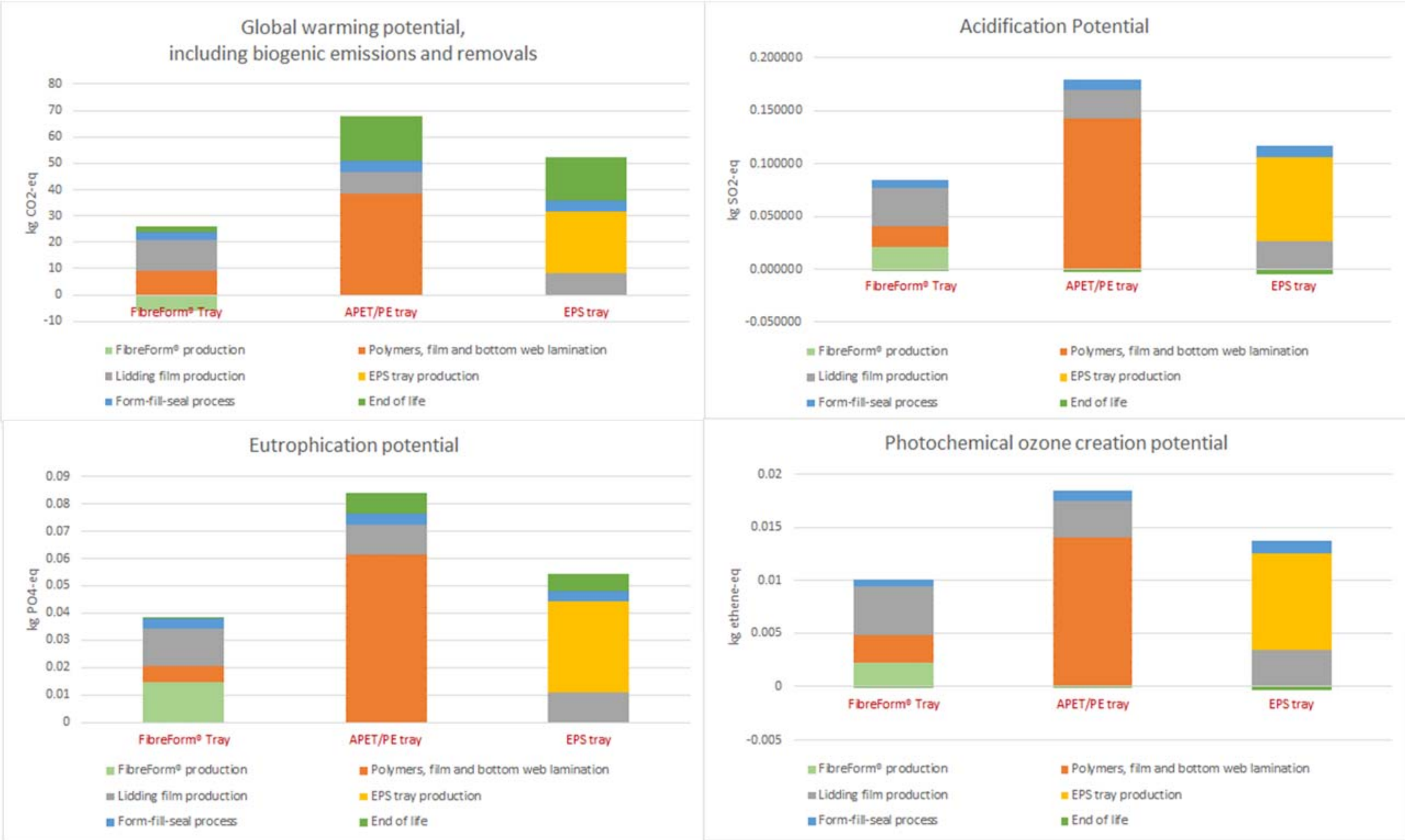


Table 4 Results by life cycle stage – global warming potential, including biogenic GHG emissions and removals (kg CO_2-eq)

	TOTAL	FibreForm production	Polymers, film and bottom web lamination	EPS tray production (EPS production and tray forming)	Lidding film production	Form-fill-seal or Fill-seal process	End-of-life management
FibreForm tray	**20.0**	-5.9	9.2	n/a	11.5	3.5	2.1
APET/PE tray	**67.9**	n/a	38.6	n/a	8.2	4.0	17.0
EPS tray	**52.4**	n/a	n/a	23.5	8.2	4.2	16.6

Table 5 Results by life cycle stage – acidification potential (kg SO_2-eq)

	TOTAL	FibreForm production	Polymers, film and bottom web lamination	EPS tray production (EPS production and tray forming)	Lidding film production	Form-fill-seal or Fill-seal process	End-of-life management
FibreForm tray	**0.0848**	0.0206	0.0194	n/a	0.0376	0.0076	-0.0003
APET/PE tray	**0.1763**	n/a	0.1430	n/a	0.0263	0.0099	-0.0029
EPS tray	**0.1117**	n/a	n/a	0.0802	0.0263	0.0010	-0.0049

Table 6 Results by life cycle stage – Eutrophication potential (kg PO4-eq)

	TOTAL	FibreForm production	Polymers, film and bottom web lamination	EPS tray production (EPS production and tray forming)	Lidding film production	Form-fill-seal or Fill-seal process	End-of-life management
FibreForm tray	**0.0387**	0.0147	0.0057	n/a	0.0140	0.0035	0.0007
APET/PE tray	**0.0898**	n/a	0.0616	n/a	0.0107	0.0043	0.0073
EPS tray	**0.0542**	n/a	n/a	0.0337	0.0107	0.0035	0.0063

Table 7 Results by life cycle stage – photochemical ozone creation potential (kg ethene-eq)

	TOTAL	FibreForm production	Polymers, film and bottom web lamination	EPS tray production (EPS production and tray forming)	Lidding film production	Form-fill-seal or Fill-seal process	End-of-life management
FibreForm tray	**0.01005**	0.0023	0.0025	n/a	0.0047	0.0006	-0.00001
APET/PE tray	**0.0183**	n/a	0.0141	n/a	0.0034	0.0009	-0.0001
EPS tray	**0.0134**	n/a	n/a	0.0091	0.0034	0.0012	-0.0003

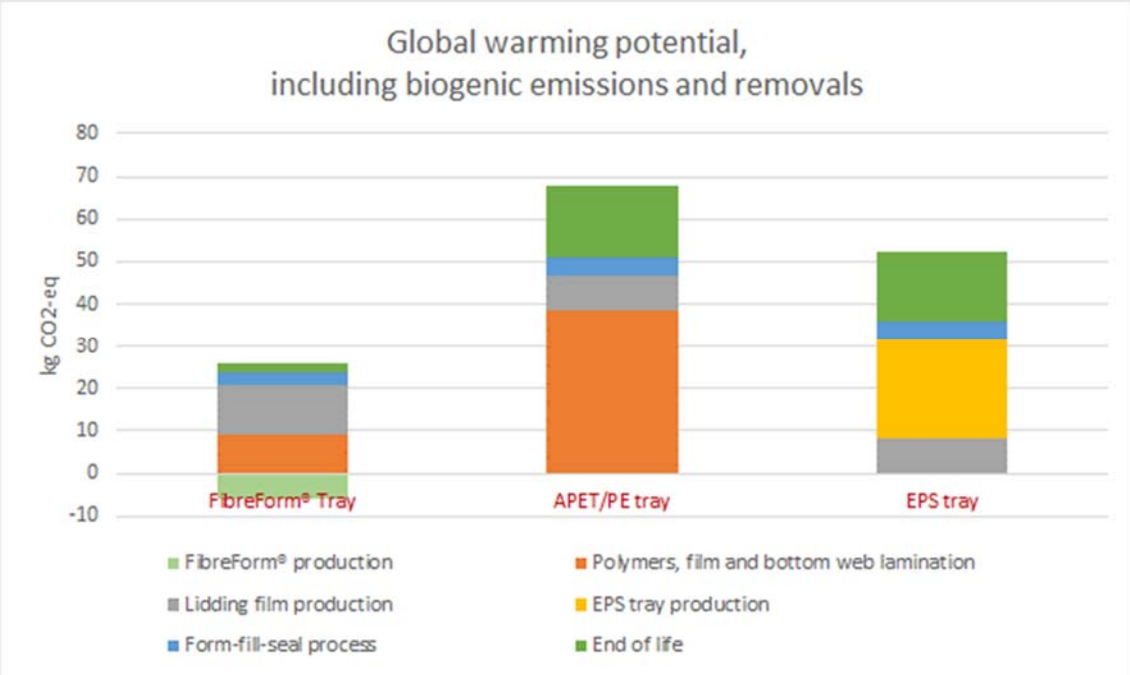
Considering Global Warming Potential

When the global warming results for the three different tray solutions are compared Figure 7 and Table 4), we can draw the following conclusions:

- The FibreForm tray has the lowest impact for Global Warming Potential. At 20.0kg CO2-eq per 1,000 trays consumed and disposed of, the FibreForm tray offers a 62% saving in Global Warming Potential compared to the EPS tray and a 71% saving compared to the APET/PE tray.
- When comparing the FibreForm tray and the APET/PE tray, the advantage is primarily because the production of the FibreForm material has a considerably lower global warming impact than the polymer layers that it replaces compared to the APET/PE tray. The reduced end-of-life impact (due to the high recycling rate for the FibreForm trays) is also significant.
- The trend is similar when comparing the FibreForm tray against the EPS tray. The lower impact of the materials required to produce the tray and the lower end-0f-life impact for the FibreForm tray are important in defining the result when comparing the two systems.
- The impact of the lidding material for the FibreForm tray is noticeably higher than the impact for the lidding material for the APET/PE and EPS trays. This is due to the different specification required for the lidding material for the FibreForm tray to achieve the necessary sealing and physical properties.
- For the form-fill-seal stage (or just form-seal in the case of EPS trays, which are produced and then shipped formed rather than as a reel) the impact for the APET/PE tray and the EPS tray is quantitatively similar. However, the energy used for this life cycle stage for the EPS tray is much lower, as the tray is already formed and only needs to be filled/sealed. However, the formed EPS trays are much less efficient in distribution than the reels of laminated material used for the APET/PE tray and for the FibreForm tray. The subsequent higher transport impact for delivery of EPS trays to the filler accounts for the majority of the impact for the EPS filling/sealing stage.
- The FibreForm solution has the lowest impact when considering the form-fill-seal stage. The forming for the FibreForm trayrequires less heat and therefore less energy than the process used for the APET/PE tray.

Figure 7

Global Warming Potential – comparative results for the three systems



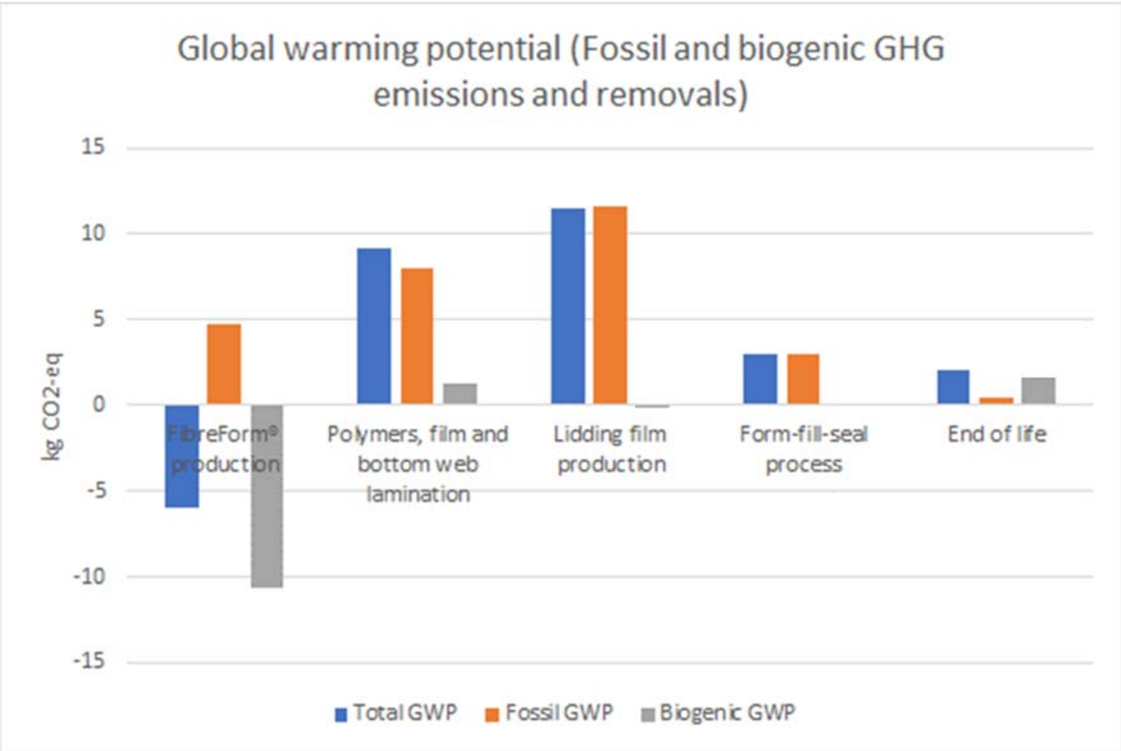
These results and conclusions are very specific to the supply chain considered in this analysis. However, as the differences between the FibreForm system and the existing APET/PE and EPS trays considered in the analysis are so large, the conclusion that the FibreForm tray is the best option from a Global warming potential perspective does not appear to be sensitive to the data and assumptions used. This is supported in the sensitivity analysis in Annex 2 of this report. The detailed results for baseline scenario for each solution are considered in the sections below.

FibreForm tray

Figure 8 summarises the global warming potential across the life cycle of the FibreForm tray. Fossil and biogenic emissions and removals are shown separately and as a combined total.

Figure 8

Global Warming Potential for the FibreForm tray, by life cycle stage (separate presentation of fossil and biogenic GHG emissions and removals)



FibreForm Production

It can be observed that production of the FibreForm material has a net negative global warming potential. This is because the emissions of fossil GHGs and biogenic GHGs arising from the transport, fuels, energy and non-fibre inputs associated with the pulp and paper life cycle stage are outweighed by the biogenic GHG removals occurring during forestry.

Emissions from the transport of wood and non-fibre inputs to the mill account for the largest share (more than 50%) of the fossil GHG emissions global warming potential arising from FibreForm production. After this, emissions arising from the production of non-fibre inputs are most significant (accounting for 26%). Onsite emissions from the combustion of fossil fuels plus emission associated with purchased electricity account for a further 5% of the fossil global warming potential for FibreForm production. Forest management activities and off-site management of process wastes account for the remaining emissions that contribute to the total for FibreForm production.

Polymers, film and bottom web lamination

For the production of the bottom web (excluding the production of the FibreForm material itself, which is presented separately in the graph), fossil emissions associated with the production of the polymers used in the lamination dominate the impact, accounting for 71% of the fossil GHG impact. Transport of the materials to the laminating site (including transport of the FibreForm and transport of the polymers) accounts for a further 21% of the fossil GHG impact, with electricity consumed during the various extruding, laminating and slitting processes accounting for the remaining 21% of the fossil footprint. There is a small net credit of fossil emissions due to the management of process wastes arising from the process (the process wastes are sent for energy recovery). There is also a biogenic GHG impact for the process which is due partly to emissions from bio-based fuels within the purchased grid electricity mix but mostly due to biogenic emissions arising from the management of the process wastes (i.e. from energy recovery of the FibreForm portion of the process wastes).

Lidding film

The impact of the lidding film makes the most significant contribution to the overall global warming potential impact across the life cycle. The production of the polymers and films used in the lidding material production process accounts for the largest share (64%) of the fossil global warming potential for this life cycle stage. Transport of these materials to the production site accounts for a further 21% of the impact. The remaining fossil Global Warming Impact is accounted for by emissions from purchased grid electricity, purchased steam, emissions arising from the onsite combustion of gas and the production of other fuels and materials used in the process (such as production of natural gas and production of steam), plus a small credit for the net emissions arising from the waste management of process wastes (sent for energy recovery). There is also a very small biogenic GHG credit which relates to avoided emissions from bio-based fuels due to the waste management of the process wastes).

Form-Fill-Seal process

For the Form-Fill-Seal process, emissions arising from the purchased grid electricity used in the process account for 36% of the impact, with the remaining 64% of the impact attributable to the transport of the laminated bottom web and lidding material substrates from the production site in Germany to the converting and filling site in Belgium.

End-of-life

The FibreForm trays are recyclable and could be recycled in existing paper and board packaging recycling systems. In Belgium, the current recycling rate for paper and board packaging is 89.4%. It has therefore been assumed for modelling purposes that 89.4% of the trays will be sent for material recycling, with the remaining 10.6% sent for energy recovery. The impacts associated with the collection of the used materials are included in the system boundaries of the analysis, up to the delivery of the material to recycling mills gate. However, as is common in LCA studies, a cut-off approach has been applied for the recycling of the material, so impacts associated with the reprocessing of the fibre have not been included and nor has any credit been included for offset production of virgin pulp. Therefore, the end-of-life emissions for the FibreForm tray are primarily due to the net emissions arising from the incineration with energy recovery of the non-recycled fraction of the waste stream (although a credit is considered for the energy recovered from the incineration of the waste paper packaging, emissions arising from the process exceed the avoided emissions).

The cut-off approach assumes that the burdens associated with reprocessing and the credit for avoided virgin materials are applied to the product that uses the recovered fibre, rather than the system that generates the material for recycling. This is a commonly used approach in life cycle assessment and has been adopted for this study due to the difficulties of defining an appropriate credit for recycling. In effect, in this study a conservative approach has been applied and the net benefit of recycling of used paper sacks has been considered as zero from the point of view of the primary system using the fibre. However, this approach does create a challenge when accounting for biogenic GHGs. A proportion of the biogenic GHG removals occurring as part of the FibreForm production is effectively being carried through to subsequent products in the form of carbon contained in the fibres. However, this carbon will eventually be released back into the environment when the subsequent products are finally disposed of to landfill, composting or energy recovery. This must be considered when interpreting the results.

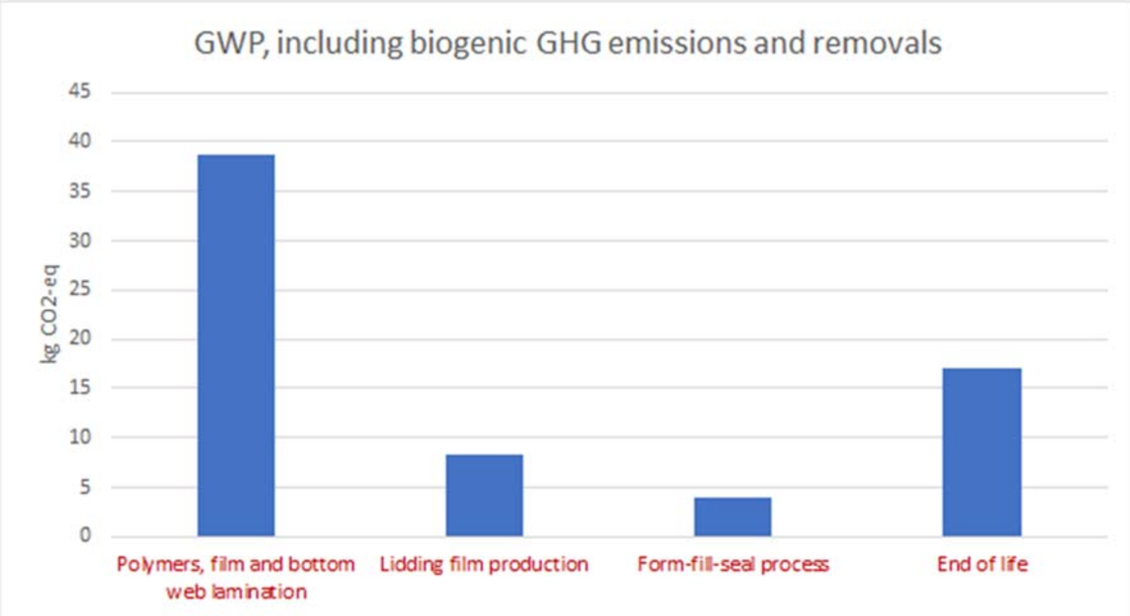
The influence of the selected recycling rate and the choice of the cut-off approach for recycling of the trays is investigated further in the sensitivity analysis presented in Annex 2 of this report.

APET/PE tray

Figure 9 summarises the global warming potential across the life cycle of the APET/PE tray. The total global warming potential (combined fossil and biogenic emissions) have been presented without separating them, as the share of biogenic emissions and removals is insignificant for this system.

Figure 9

Global Warming Potential for the APET/PE tray, by life cycle stage (combined fossil and biogenic GHG emissions and removals)



Polymers, film and bottom web lamination

For the APET/PE tray, the production of the bottom web (including the production of the polymers and films used and the lamination process) is the most important life cycle stage in terms of the solution's Global Warming Potential impact. Production of polymers and films used in the construction of the lamination makes the largest contribution to this life cycle stage (accounting for around 75% of the impact). Transport of these materials to the production site is also important (accounting for a further 18% of the life cycle stage's impact). The remaining impact is due to emissions associated with the purchased electricity consumed by the process and the net emissions due to the management of process wastes (which are disposed of through energy recovery).

Lidding film

For production of the lidding film for the APET/PE tray, the production of the polymers and films used accounts for the largest share (56%) of the global warming potential for this life cycle stage. Transport of these materials to the production site accounts for a further 26% of the impact. The remaining Global Warming Impact is accounted for by emissions from purchased grid electricity, purchased steam, emissions arising from the onsite combustion of gas and the production of other fuels and materials used in the process (such as production of natural gas and production of steam), plus a small credit for the net emissions arising from the waste management of process wastes (sent for energy recovery).

Form-Fill-Seal process

For the Form-Fill-Seal process for the APET/PE tray, emissions arising from the purchased grid electricity used in the process account for 56% of the impact, with the remaining 44% of the impact attributable to the transport of the laminated bottom web and lidding material substrates from the production site in Germany to the converting and filling site in Belgium.

End-of-life

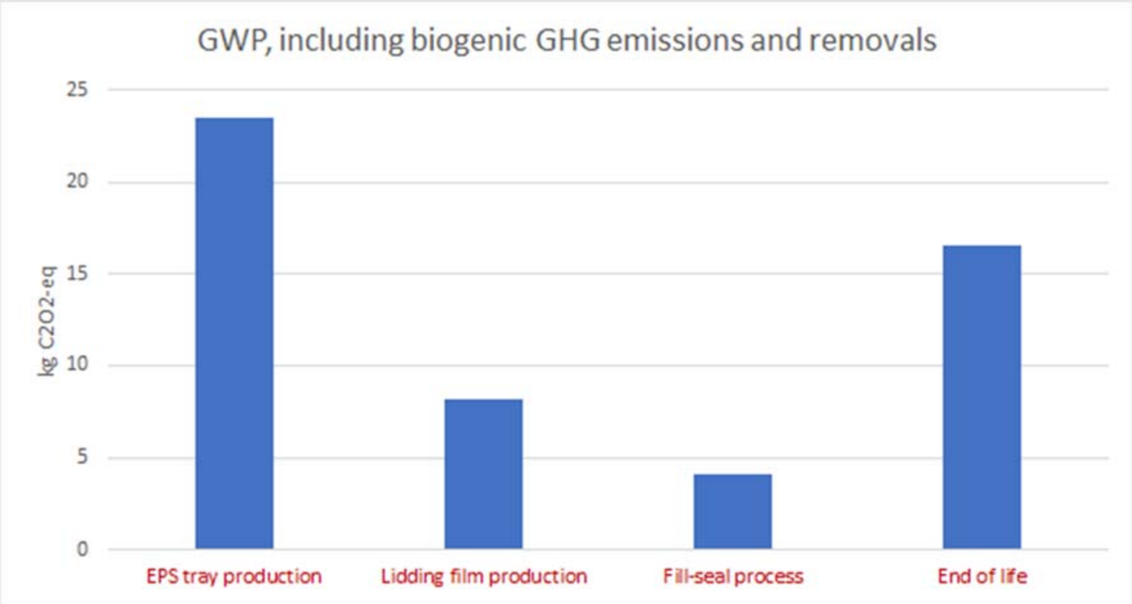
In the models, 99% of used APET/PE trays are assumed to be sent for energy recovery, with the remaining 1% sent to landfill. This is in line with the current situation in Belgium. Therefore, the end-of-life Global Warming Impact is due almost exclusively to the net emissions from the process (i.e. the emissions arising from incineration of the trays minus the credit provided for energy recovery).

EPS tray

Figure 10 summarises the global warming potential across the life cycle of the EPS tray. The total global warming potential (combined fossil and biogenic emissions) have been presented without separating them, as the share of biogenic emissions and removals is insignificant for this system.

Figure 10

Global Warming Potential for the EPS tray, by life cycle stage (combined fossil and biogenic GHG emissions and removals)



EPS tray production

For the EPS tray, the production of the tray itself is the most important life cycle stage in terms of the solution's Global Warming Potential impact. Production of the EPS granules used in the process accounts for 75% of the impact for this life cycle stage, whilst the emissions from purchased electricity for the tray forming account for a further 20%. The remaining emissions are due to other energy and material inputs to the process.

Lidding film

For the lidding film for the EPS tray, due to a lack of any product specific information, the same construction has been assumed as for the lidding film used for the APET/PE tray. The trends are therefore the same. i.e. the production of the polymers and films used accounts for the largest share (56%) of the global warming potential for this life cycle stage. Transport of these materials to the production site accounts for a further 26% of the impact. The remaining Global Warming Impact is accounted for by emissions from purchased grid electricity, purchased steam, emissions arising from the onsite combustion of gas and the production of other fuels and materials used in the process (such as production of natural gas and production of steam), plus a small credit for the net emissions arising from the waste management of process wastes (sent for energy recovery).

Filling and sealing

For the Filling and sealing process for the EPS tray, emissions arising from the transport of the trays from the tray producer in Germany to the filler in Belgium account for 95% of the impact, whilst emissions from the electricity required for the filling/sealing process itself accounts for just 5% of the impact.

End-of-life

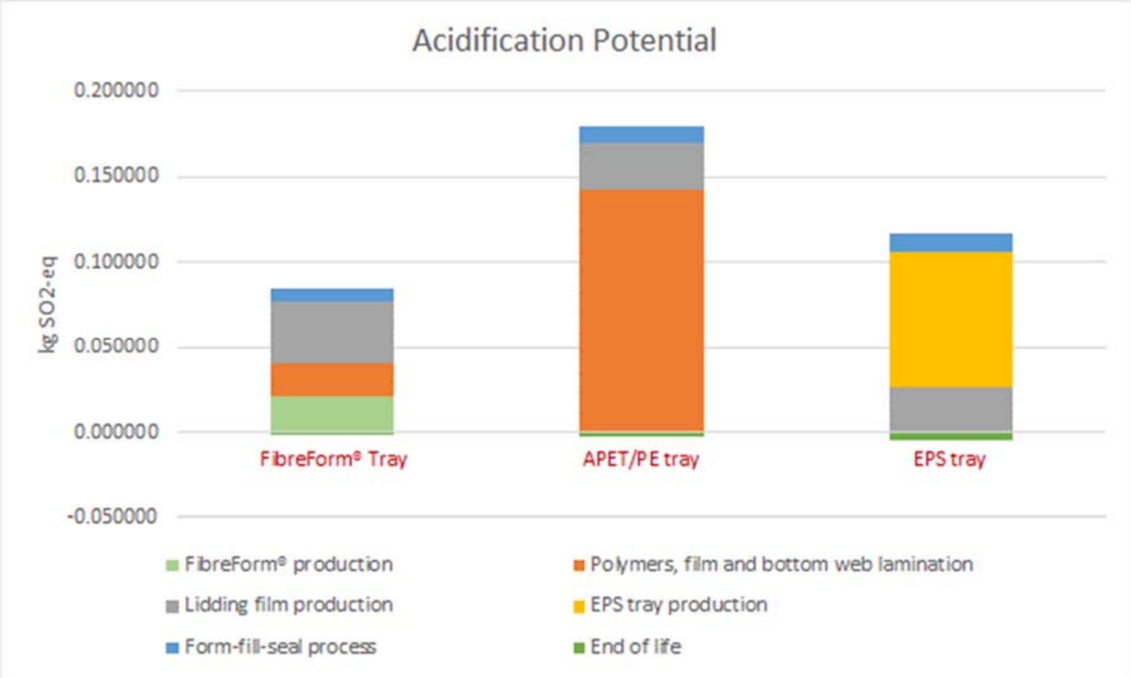
As for the APET/PE trays, it is assumed that 99% of the used EPS trays are sent for energy recovery, with the remaining 1% sent to landfill. Therefore, the end-of-life Global Warming Impact is due almost exclusively to the net emissions from the process (i.e. the emissions arising from incineration of the trays minus the credit provided for energy recovery).

Considering Acidification Potential

When the Acidification Potential results for the three different tray solutions are compared Figure 11 and Table 5), we can draw the following conclusions:

- The FibreForm tray has the lowest impact, providing a 24% saving in Acidification Potential compared to the EPS tray and a 52% saving compared to the APET/PE tray.
- When comparing the FibreForm tray and the APET/PE tray, the advantage is primarily because the production of the FibreForm material has a considerably lower Acidification Potential impact than the polymer layers that it replaces compared to the APET/PE tray.
- The trend is similar when comparing the FibreForm tray against the EPS tray. The lower impact of the materials required to produce the tray is important in defining the result when comparing the two systems.
- The impact of the lidding material for the FibreForm tray is noticeably higher than the impact for the lidding material for the APET/PE and EPS trays. This is due to the different specification required for the lidding material for the FibreForm tray to achieve the necessary sealing and physical properties.
- For the form-fill-seal stage (or just form-seal in the case of EPS trays, which are produced and then shipped formed rather than as a reel) the impact for the APET/PE tray and the EPS tray is quantitatively similar. However, the energy used for this life cycle stage for the EPS tray is much lower (as the tray is already formed and only needs to be filled/sealed) but the formed EPS trays are much less efficient in distribution than the reels of laminated material used for the APET/PE tray and for the FibreForm tray. The subsequent higher transport impact for delivery of EPS trays to the filler accounts for the majority of the impact for the EPS filling/sealing stage.
- The FibreForm solution has the lowest impact when considering the form-fill-seal stage. The forming for the FibreForm tray requires less heat and therefore less energy than the process used for the APET/PE tray.

Figure 11
Acidification Potential – comparative results for the three systems



These results and conclusions are very specific to the supply chain considered in this analysis. Nonetheless, the sensitivity analysis presented in Annex 2 of this report suggests that, whilst specific values may change, the relative standing of three systems when compared is generally consistent when different data, assumptions and conditions are considered. However, there is one assumption that can influence the relative standing of the FibreForm tray in comparison to the EPS tray. If a lighter weight EPS tray is considered (3g instead of 5g) then there is no longer a significant difference between the FibreForm tray and the EPS tray for the impact category Acidification Potential. The detailed results for baseline scenario for each solution are considered in the sections below.

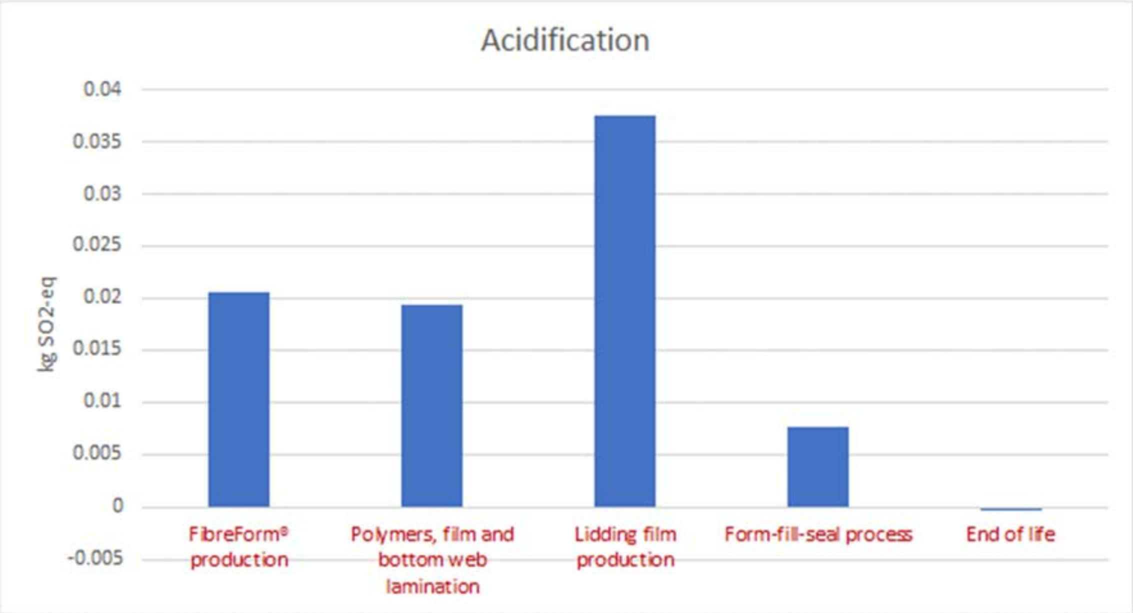
FibreForm tray

Figure 12 summarises the acidification potential across the life cycle of the FibreForm tray. Emissions of SOx, NOx and ammonia to air are the most important contributors to acidification potential for this system. Together these account for over 97% of the impact.

It can be seen that for the FibreForm tray, production of the lidding film accounts for the greatest share of the Acidification Potential result, followed by production of the FibreForm substrate and the production of the polymers and films and the lamination process to manufacture the bottom web. The form-fill-seal process makes a less significant contribution to the overall impact. End-of-life management of the trays after use generates a very small net credit due to avoided emissions considered for these processes.

Figure 12

Acidificati0n Potential for the FibreForm tray, by life cycle stage



FibreForm Production

Looking in more depth at the FibreForm life cycle stage, emissions arising from the production and supply of chemicals and additives used in the production of the material account for 37% of the impact. Emissions from the transport of wood to the production site account for a further 30% of the impact, whilst emissions from the production site itself (from the onsite combustion of fuels) accounts for 24% of the Acidification impact for this life cycle stage. The remaining impact arises from the production of the wood itself (e.g. from combustion of fuels during forestry operations), production of the fuels used and from offsite treatment of process wastes.

Polymers, film and bottom web lamination

The production of the polymers used in the construction of the bottom web account for approximately two thirds of the Acidification impact for this life cycle stage. Transport of the polymers to the production site accounts for a further 19% of the impact and emissions from purchased grid electricity account for a further 12%. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Lidding material

For the production of the lidding material, the polymers used in the construction account for 70% of the Acidification impact, with transport of these materials to the production site adding a further 15% of the impact. Emissions from purchased grid electricity account for a further 9%, with the remaining impact from this life cycle stage arising from other raw materials (inks, etc), fuels consumed and onsite emissions.

Form-fill-seal process

For the Form-Fill-Seal process, emissions arising from the purchased grid electricity used in the process account for 37% of the Acidification Impact, with the remaining 63% of the impact attributable to the transport of the laminated bottom web and lidding material substrates from the production site in Germany to the converting and filling site in Belgium.

End-of-life

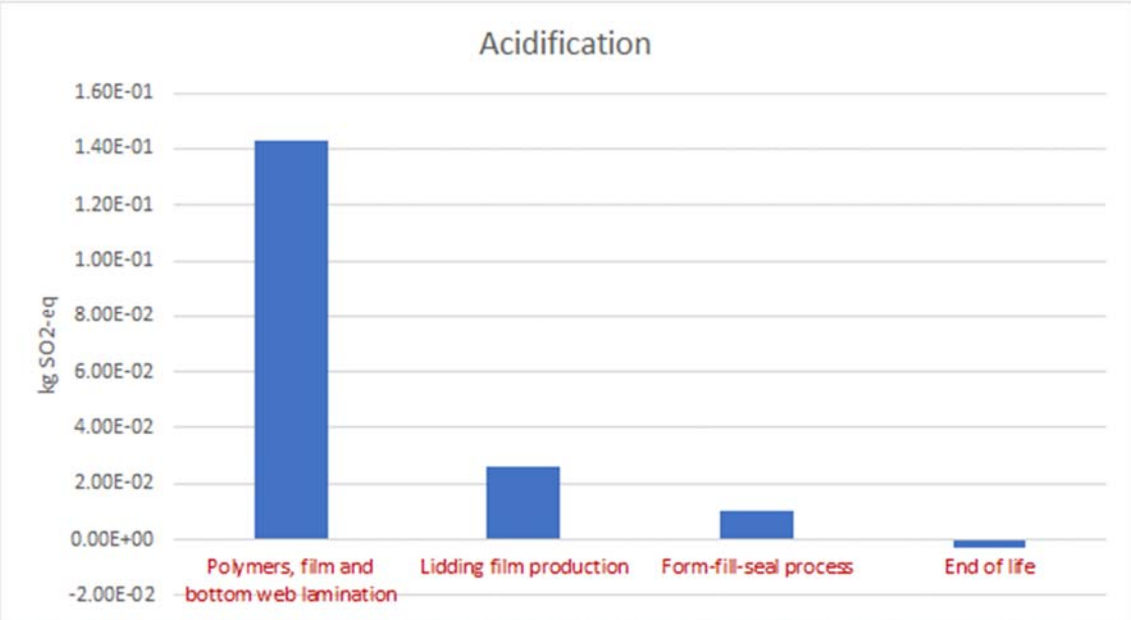
For end-of-life, there is a small net credit as the avoided emissions associated with the energy recovery are higher than the process emissions from the incineration process.

APET/PE tray

Figure 13 summarises the acidification potential across the life cycle of the APET/PE tray. Again, emissions of SOx, NOx and ammonia to air are the most important contributors to the Acidification Potential for this system. Together these account for over 98% of the impact.

Figure 13

Acidification Potential for the APET/PE tray, by life cycle stage



Polymers, film and bottom web lamination & lidding film production

For the bottom web and the lidding material, the sub-processes the contribute to the total for each unit process are similar. The production of the polymers used in the construction of the bottom web account for the majority (77%) of the Acidification impact for this life cycle stage. Transport of the polymers to the production site accounts for a further 15% of the impact and emissions from purchased grid electricity account for a further 11%. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

For the production of the lidding material, the polymers used in the construction account for 60% of the Acidification impact, with transport of these materials to the production site adding a further 19% of the impact. Emissions from purchased grid electricity account for a further 13%, with the remaining impact from this life cycle stage arising from other raw materials (inks, etc), fuels consumed and onsite emissions.

Form-fill-seal process

For the Form-Fill-Seal process, emissions arising from the purchased grid electricity used in the process account for 57% of the Acidification Impact, with the remaining 43% of the impact attributable to the transport of the laminated bottom web and lidding material substrates from the production site in Germany to the converting and filling site in Belgium.

End-of-life

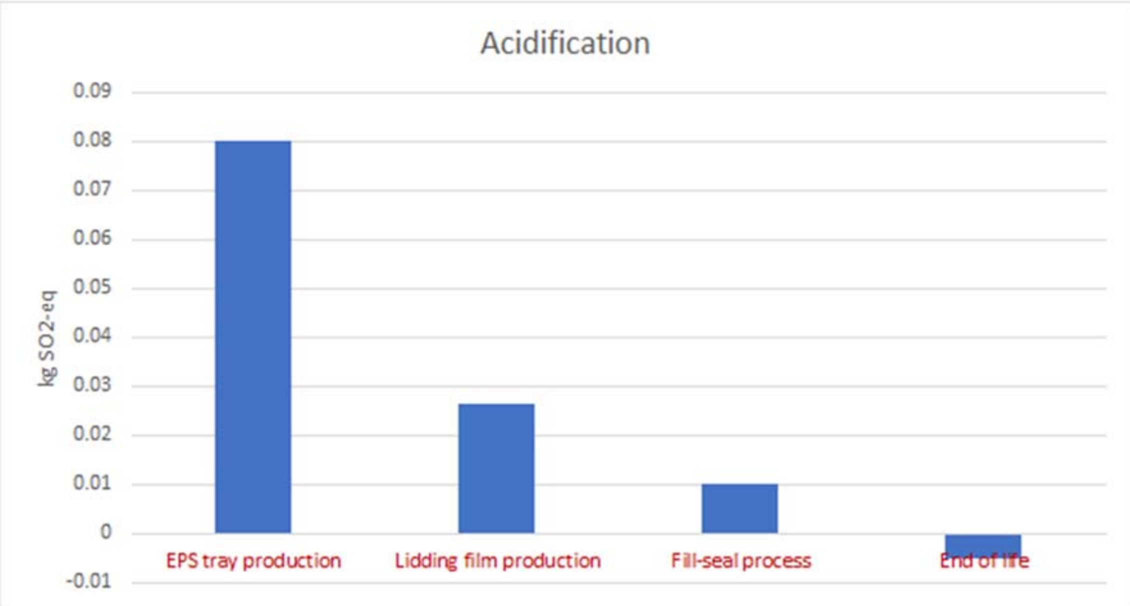
For end-of-life, there is a small net credit as the avoided emissions associated with the energy recovery are higher than the process emissions from the incineration process.

EPS tray

Figure 14 summarises the acidification potential across the life cycle of the EPS tray. Again, emissions of SOx, NOx and ammonia to air are the most important contributors to the Acidification Potential for this system. Together these account for over 98% of the impact.

Figure 14

Acidificati0n Potential for the EPS tray, by life cycle stage



EPS tray production

For the EPS tray, the production of the tray itself is the most important life cycle stage in terms of the solution's Acidication impact. Production of the EPS granules used in the process accounts for 69% of the impact for this life cycle stage, whilst the emissions from purchased electricity for the tray forming account for a further 26%. The remaining emissions are due to other energy and material inputs to the process.

Lidding film

The same lidding material is assumed as for the APET/PE tray, so the Acidification results for this life cycle stage mirror those of the lidding materials for the APET/PE tray, i.e., the polymers used in the construction account for 60% of the Acidification impact, with transport of these materials to the production site adding a further 19% of the impact. Emissions from purchased grid electricity account for a further 13%, with the remaining impact from this life cycle stage arising from other raw materials (inks, etc), fuels consumed and onsite emissions.

Fill-seal process

For the Fill-seal process, emissions arising from the purchased grid electricity used in the process account for 6% of the Acidification Impact, with the remaining 94% of the impact attributable to the transport of the formed trays from the production site in Germany to the filling site in Belgium. The high share of the impact for transport reflects the fact that the formed EPS trays are less space efficient in transit compared to the reeled materials used for the FibreForm and EPS trays.

End-of-life

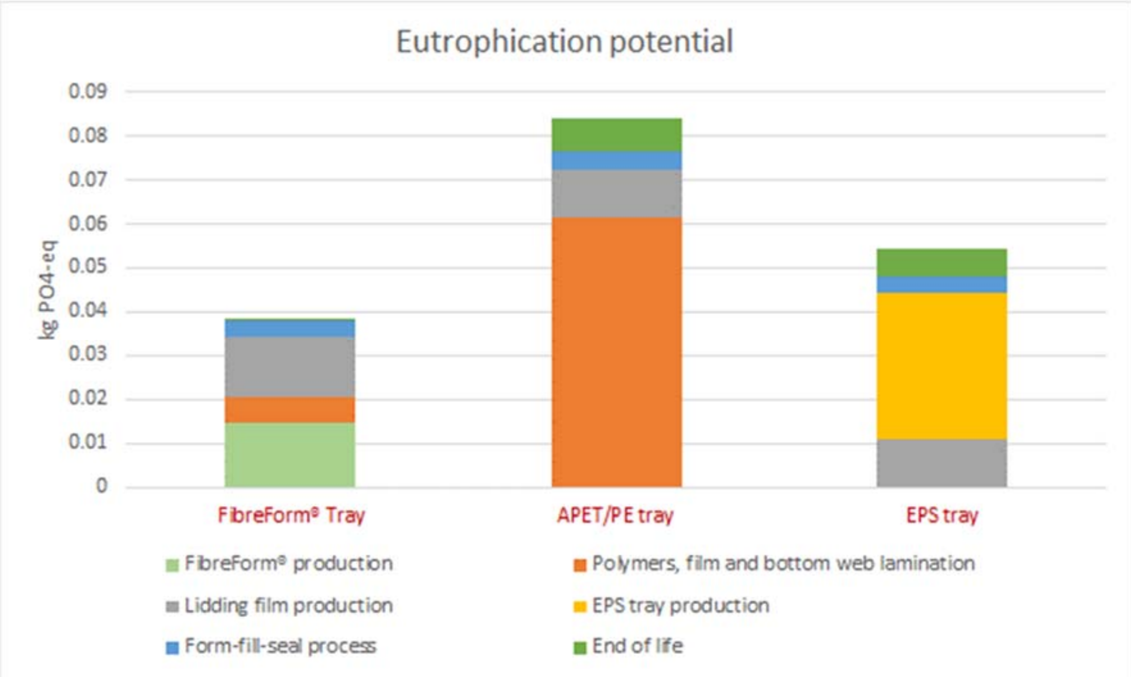
For end-of-life, there is a small net credit as the avoided emissions associated with the energy recovery are higher than the process emissions from the incineration process.

Considering Eutrophication Potential

When the Eutrophication Potential results for the three different tray solutions are compared (Figure 15 and Table 6), we can draw the following conclusions:

- The FibreForm tray has the lowest impact, providing a 29% saving in Eutrophication Potential compared to the EPS tray and a 54% saving compared to the APET/PE tray.
- When comparing the FibreForm tray and the APET/PE tray, the advantage is primarily because the production of the FibreForm material has a considerably lower Eutrophication Potential impact than the polymer layers that it replaces compared to the APET/PE tray.
- The trend is similar when comparing the FibreForm tray against the EPS tray. The lower impact of the materials required to produce the tray is important in defining the result when comparing the two systems.
- The impact of the lidding material for the FibreForm tray is noticeably higher than the impact for the lidding material for the APET/PE and EPS trays. This is due to the different specification required for the lidding material for the FibreForm tray to achieve the necessary sealing and physical properties.
- For the form-fill-seal stage (or just form-seal in the case of EPS trays, which are produced and then shipped formed rather than as a reel) the impact for the APET/PE tray and the EPS tray is quantitatively similar. However, the energy used for this life cycle stage for the EPS tray is much lower (as the tray is already formed and only needs to be filled/sealed) but the formed EPS trays are much less efficient in distribution than the reels of laminated material used for the APET/PE tray and for the FibreForm tray. The subsequent higher transport impact for delivery of EPS trays to the filler accounts for the majority of the impact for the EPS filling/sealing stage.
- The FibreForm solution has the lowest impact when considering the form-fill-seal stage. The forming for the FibreForm trayrequires less heat and therefore less energy than the process used for the APET/PE tray.
- For end-of-life, the FibreForm solution also has a very low Eutrophication impact compared to the APET/PE tray and the EPS tray, due to the high recycling rate considered for the FibreForm tray.

Figure 15
Eutrophication Potential – comparative results for the three systems



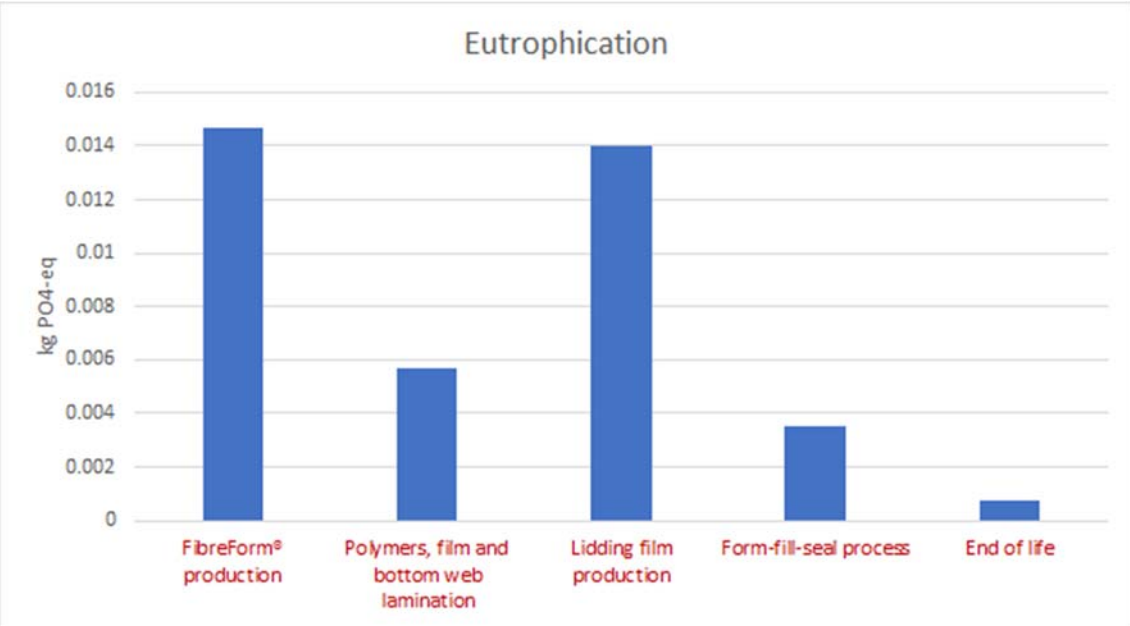
These results and conclusions are very specific to the supply chain considered in this analysis. Nonetheless, the sensitivity analysis presented in Annex 2 of this report suggests that, whilst specific values may change, the relative standing of three systems when compared is generally consistent when different data, assumptions and conditions are considered. However, there is one assumption that can influence the relative standing of the FibreForm tray in comparison to the EPS tray. If a lighter weight EPS tray is considered (3g instead of 5g) then there is no longer a significant difference between the FibreForm tray and the EPS tray for the impact category Eutrophication Potential. The detailed results for baseline scenario for each solution are considered in the sections below.

FibreForm tray

Figure 16 summarises the Eutrophication Potential across the life cycle of the FibreForm tray. Emissions of Total Organic Carbon (TOC), Phosphate, Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) to freshwater are the most important contributors to this impact category for this system. Together these account for around 70% of the total Eutrophication Potential for the systems. Emissions to air of nitrogen-based compounds such as NOx also make a contribution to the total.

Figure 16

Eutrophication Potential for the FibreForm tray, by life cycle stage



Production of the FibreForm material and production of the lidding film for the tray make the most significant contribution to the Eutrophication Potential for this system.

FibreForm Production

Emissions from the mill (to freshwater and to air) account for around 41% of the Eutrophication impact of the FibreForm life cycle stage. Production of the chemicals and other non-fibre raw materials used accounts for a further 25% of the impact, and management of process wastes including disposal of sludges from the mill accounts for a further 15%. Emissions from transport of raw materials to the mill accounts for a further 14% of this unit processes impact.

Lidding film

For the production of the lidding material, the polymers used in the construction account for 52% of the Eutrophication impact, with transport of these materials to the production site adding a further 13% of the impact. Emissions from purchased grid electricity account for 27%, with the remaining impact from this life cycle stage arising from other raw materials (inks, etc), fuels consumed and onsite emissions. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Polymers, film and bottom web lamination

Emissions from the production of the electricity consumed during the bottom web production stage account for 42% of the Eutrophication impact for this life cycle stage. The production of the polymers used in the construction of the bottom web account for a further 39% of the impact, with transport of the materials to the production accounting for a further 19%. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Form-fill-seal process

For the form-fill-seal process, emissions arising from the purchased grid electricity used in the process account for 47% of the Eutrophication Impact, with the remaining 53% of the impact attributable to the transport of the laminated bottom web and lidding material substrates from the production site in Germany to the converting and filling site in Belgium.

End-of-life

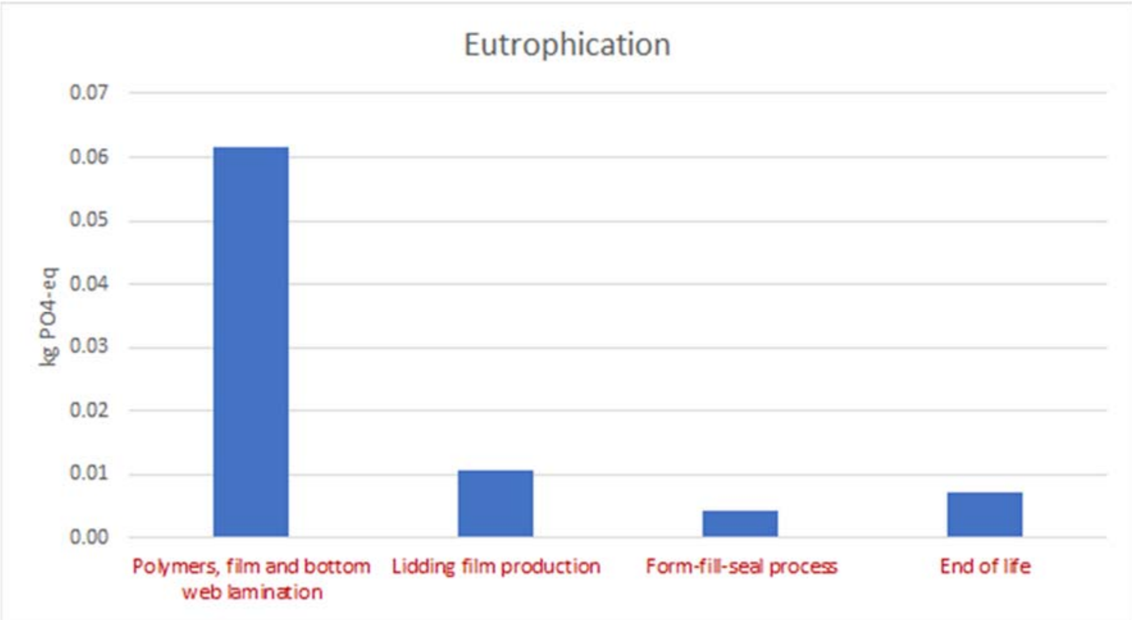
For end-of-life, there is a net Eutrophication impact as the emissions to water associated with this impact category from the incineration process are greater than the benefits of the avoided energy production.

APET/PE tray

Figure 17 summarises the Eutrophication Potential across the life cycle of the APET/PE tray. Emissions of Total Organic Carbon (TOC), Phosphate, Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) to freshwater are the most important contributors to this impact category for this system.

Figure 17

Eutrophication Potential for the APET/PE tray, by life cycle stage



Polymers, film and bottom web lamination

Production of the bottom web (including the production of the polymers and films used and the lamination process) is the dominant life cycle stage contributing to this impact category.

Emissions from the production of the electricity consumed during the bottom web production stage account for 28% of the Eutrophication impact for this life cycle stage. The production of the polymers used in the construction of the bottom web account for a further 63% of the impact, with transport of the materials to the production site accounting for a further 9%. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Lidding film

For the production of the lidding material, the polymers used in the construction account for 40% of the Eutrophication impact, with transport of these materials to the production site adding a further 15% of the impact. Emissions from purchased grid electricity account for 35%, with the remaining impact from this life cycle stage arising from other raw materials (inks, etc), fuels consumed and onsite emissions. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Form-fill-seal process

For the form-fill-seal process, emissions arising from the purchased grid electricity used in the process account for 67% of the Eutrophication Impact, with the remaining 33% of the impact attributable to the transport of the laminated bottom web and lidding material substrates from the production site in Germany to the converting and filling site in Belgium.

End-of-life

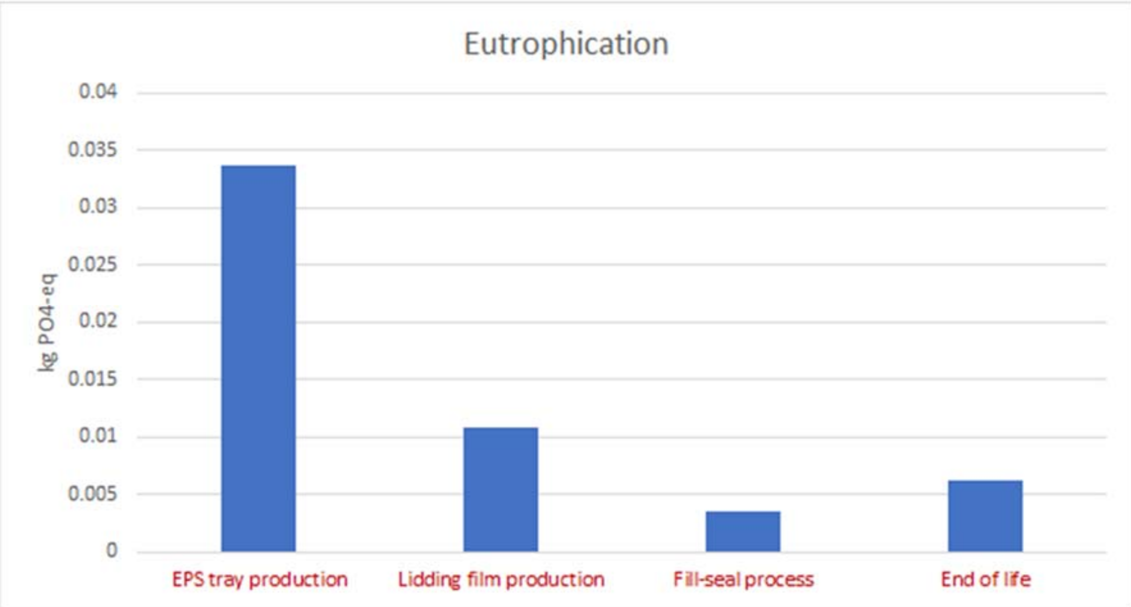
For end-of-life, there is a net Eutrophication impact as the emissions to water associated with this impact category from the incineration process are greater than the benefits of the avoided energy production.

EPS tray

Figure 18 summarises the Eutrophication Potential across the life cycle of the EPS tray. Emissions of Total Organic Carbon (TOC), Phosphate, Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) to freshwater are the most important contributors to this impact category for this system.

Figure 18

Eutrophication Potential for the EPS tray, by life cycle stage



EPS tray production

For the EPS tray, the production of the tray itself is the most important life cycle stage in terms of the solution's Eutrophication impact. Production of the EPS granules used in the process accounts for 21% of the impact for this life cycle stage, whilst the emissions from purchased electricity for the tray forming account for 71%. The remaining emissions are due to other energy and material inputs to the process.

Lidding film

For the production of the lidding material, the polymers used in the construction account for 40% of the Eutrophication impact, with transport of these materials to the production site adding a further 15% of the impact. Emissions from purchased grid electricity account for 35%, with the remaining impact from this life cycle stage arising from other raw materials (inks, etc), fuels consumed and onsite emissions. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Fill-seal process

For the Fill-seal process, emissions arising from the purchased grid electricity used in the process account for 8% of the Acidification Impact, with the remaining 92% of the impact attributable to the transport of the formed trays from the production site in Germany to the filling site in Belgium. The high share of the impact for transport reflects the fact that the formed EPS trays are less space efficient in transit compared to the reeled materials used for the FibreForm and EPS trays.

End-of-life

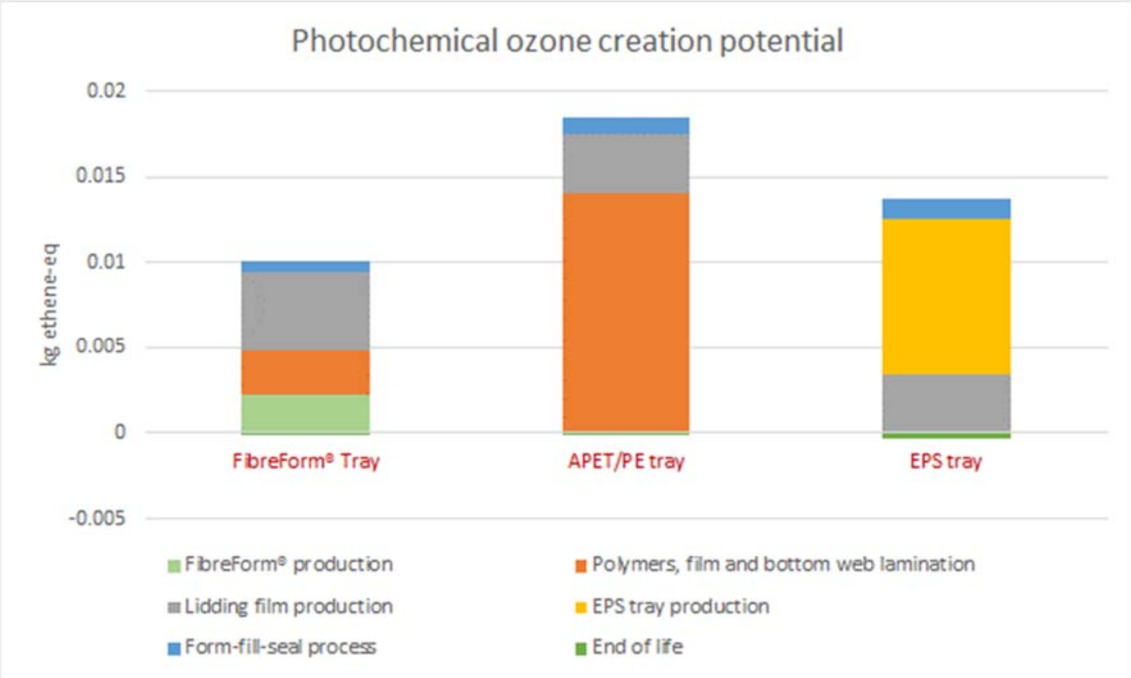
For end-of-life, there is a net Eutrophication impact as the emissions to water associated with this impact category from the incineration process are greater than the benefits of the avoided energy production.

Considering Photochemical Ozone Creation Potential (POCP)

When the POCP results for the three different tray solutions are compared (Figure 19 and Table 7), we can draw the following conclusions:

- The FibreForm tray has the lowest impact, providing a 25% saving in Photochemical Ozone Creation Potential compared to the EPS tray and a 45% saving compared to the APET/PE tray.
- When comparing the FibreForm tray and the APET/PE tray, the advantage is primarily because the production of the FibreForm material has a considerably lower POCP impact than the polymer layers that it replaces compared to the APET/PE tray.
- The trend is similar when comparing the FibreForm tray against the EPS tray. The lower impact of the materials required to produce the tray is important in defining the result when comparing the two systems.
- The impact of the lidding material for the FibreForm tray is noticeably higher than the impact for the lidding material for the APET/PE and EPS trays. This is due to the different specification required for the lidding material for the FibreForm tray to achieve the necessary sealing and physical properties.
- For the form-fill-seal stage (or just form-seal in the case of EPS trays, which are produced and then shipped formed rather than as a reel) the impact for the APET/PE tray and the EPS tray is quantitatively similar. However, the energy used for this life cycle stage for the EPS tray is much lower (as the tray is already formed and only needs to be filled/sealed) but the formed EPS trays are much less efficient in distribution than the reels of laminated material used for the APET/PE tray and for the FibreForm tray. The subsequent higher transport impact for delivery of EPS trays to the filler accounts for the majority of the impact for the EPS filling/sealing stage.
- The FibreForm solution has the lowest impact when considering the form-fill-seal stage. The forming for the FibreForm trayrequires less heat and therefore less energy than the process used for the APET/PE tray.

Figure 19
Photochemical Ozone Creation Potential – comparative results for the three systems



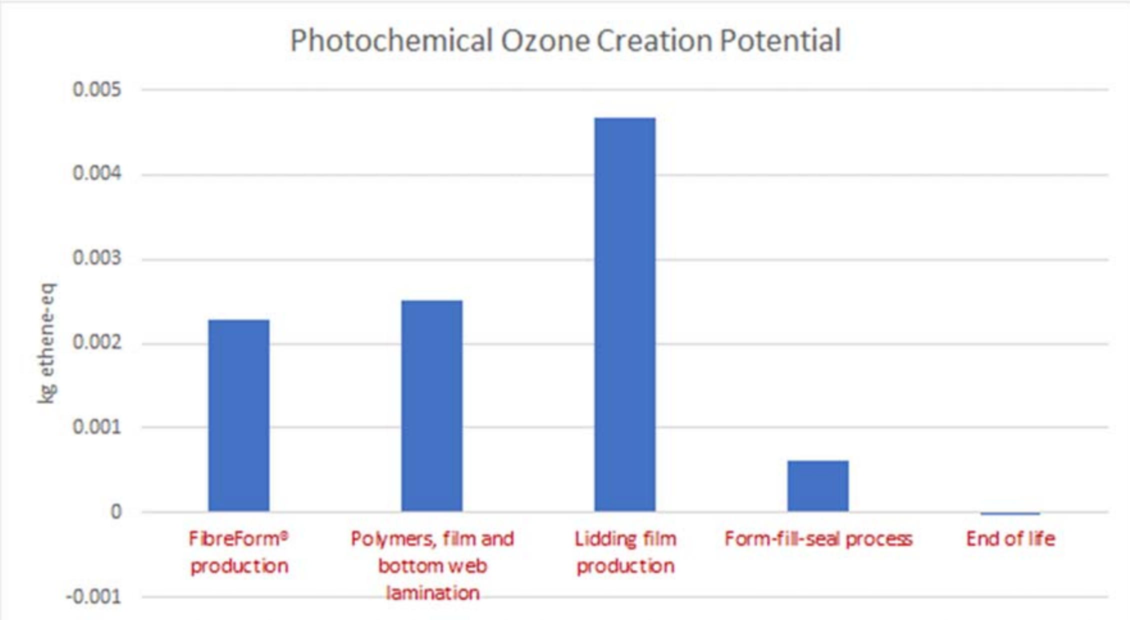
These results and conclusions are very specific to the supply chain considered in this analysis. Nonetheless, the sensitivity analysis presented in Annex 2 of this report suggests that, whilst specific values may change, the relative standing of three systems when compared is generally consistent when different data, assumptions and conditions are considered. However, there is one assumption that can influence the relative standing of the FibreForm tray in comparison to the EPS tray. If a lighter weight EPS tray is considered (3g instead of 5g) then there is no longer a significant difference between the FibreForm tray and the EPS tray for the impact category Eutrophication Potential. The detailed results for baseline scenario for each solution are considered in the sections below.

FibreForm tray

Figure 20 summarises the POCP across the life cycle of the FibreForm tray. Emissions to air of non-methane VOCs, SOx, NOx, Carbon Monoxide and Methane are the most important contributors to this impact category for this system. Together these account for around 80% of the total POCP impact for the systems.

Figure 20

Photochemical Ozone Creation Potential for the FibreForm tray, by life cycle stage



FibreForm Production

The FibreForm production stage, transport of raw materials to the mill accounts for the largest share of the POCP impact (57%). Production of the non-fibre inputs (chemicals and additives) is the next most important contribution, accounting for 26% of the impact. Emissions from the forestry operations (e.g. from vehicle movements for planting, thinning, felling, etc) account for a further 7%. Emissions from all other activities included in this life cycle stage (e.g. emissions from combustion of fuels at the mill, management of process wastes, purchased grid electricity and production of fuels) account for the remaining share of the impact.

Polymers, film and bottom web lamination

Emissions from the production of the polymers used in the construction of the bottom web account for 77% of the POCP impact for this life cycle stage. Transport of materials to the production site accounts for a further 20% of the impact. Electricity and other inputs make only a small contribution. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Lidding film

For the production of the lidding material, the polymers used in the construction account for 75% of the POCP impact, with transport of these materials to the production site adding a further 15% of the impact. The remaining impact from this life cycle stage arises from emissions from purchased grid electricity, production of other raw materials (inks, etc), fuels consumed and onsite emissions. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Form-fill-seal process

For the form-fill-seal process, emissions arising from the purchased grid electricity used in the process account for 23% of the POCP Impact, with the remaining 77% of the impact attributable to the transport of the laminated bottom web and lidding material substrates from the production site in Germany to the converting and filling site in Belgium.

End-of-life

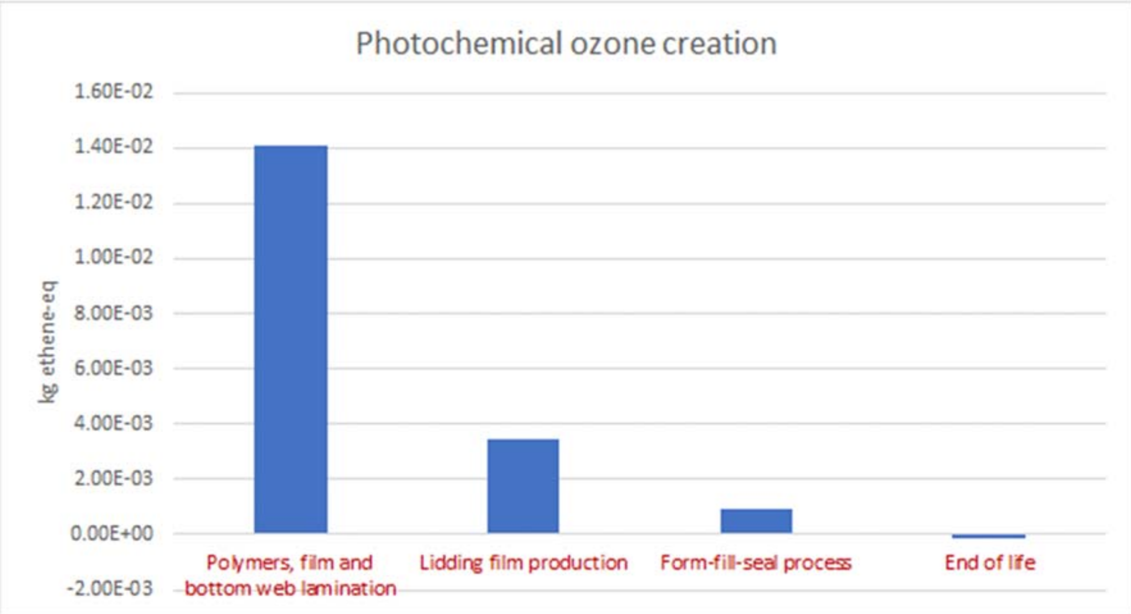
For end-of-life, there is a small net credit as the avoided emissions associated with the energy recovery are higher than the process emissions from the incineration process.

APET/PE tray

Figure 21 summarises the POCP across the life cycle of the APET/PE tray. Emissions to air of non-methane VOCs, SOx, NOx, Carbon Monoxide and Methane are the most important contributors to this impact category for this system. Together these account for around 80% of the total POCP impact for the systems.

Figure 21

Photochemical Ozone Creation Potential for the APET/PE tray, by life cycle stage



Polymers, film and bottom web lamination

Emissions from the production of the polymers used in the construction of the bottom web account for 82% of the POCP impact for this life cycle stage. Transport of materials to the production site accounts for a further 15% of the impact. Electricity and other inputs make only a small contribution. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Lidding film

For the production of the lidding material for the PET/PE tray, the polymers used in the construction account for 68% of the POCP impact, with transport of these materials to the production site adding a further 18% of the impact. The remaining impact from this life cycle stage arises from emissions from purchased grid electricity, production of other raw materials (inks, etc), fuels consumed and onsite emissions. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Form-fill-seal process

For the form-fill-seal process, emissions arising from the purchased grid electricity used in the process account for 41% of the POCP Impact, with the remaining 59% of the impact attributable to the transport of the laminated bottom web and lidding material substrates from the production site in Germany to the converting and filling site in Belgium.

End-of-life

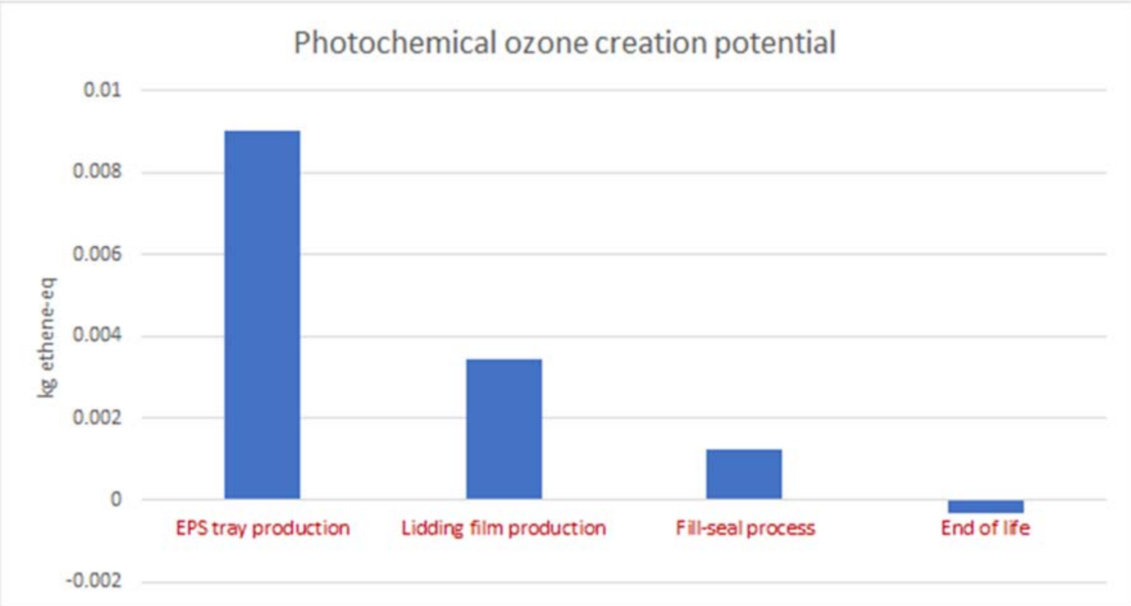
For end-of-life, there is a small net credit as the avoided emissions associated with the energy recovery are higher than the process emissions from the incineration process.

EPS tray

Figure 22 summarises the POCP across the life cycle of the EPS tray. Emissions to air of non-methane VOCs, SOx, NOx, Carbon Monoxide and Methane are the most important contributors to this impact category for this system. Together these account for around 80% of the total POCP impact for the systems.

Figure 22

Photochemical Ozone Creation Potential for the EPS tray, by life cycle stage



EPS tray production

For the EPS tray system, the production of the tray itself is the most important life cycle stage in terms of the solution's POCP impact. Production of the EPS granules used in the process accounts for 88% of the impact for this life cycle stage, whilst the emissions from purchased electricity for the tray forming account for 7%. The remaining emissions are due to other energy and material inputs to the process.

Lidding films

As the same lidding material is considered for the EPS tray as for the APET/PE tray, the trends are the same for this life cycle stage for both systems, i.e., the polymers used in the construction account for 68% of the POCP impact, with transport of these materials to the production site adding a further 18% of the impact. The remaining impact from this life cycle stage arises from emissions from purchased grid electricity, production of other raw materials (inks, etc), fuels consumed and onsite emissions. There is a small credit arising from the management of process wastes (sent for energy recovery) but this does not have a significant influence on the overall results.

Fill-seal process

For the Fill-seal process, emissions arising from the transport of the formed trays from the production site in Germany to the filling site in Belgium according for 97% of the impact for this life cycle stage. The high share of the impact for transport reflects the fact that the formed EPS trays are less space efficient in transit compared to the reeled materials used for the FibreForm and EPS trays.

End-of-life

For end-of-life, there is a small net credit as the avoided emissions associated with the energy recovery are higher than the process emissions from the incineration process.

Are the results sensitive to data or assumptions?

Detailed results from the sensitivity and uncertainty analysis are presented in Annex 2 of this report. Generally, the results presented and the subsequent conclusions that can be drawn from the analysis are robust. The key takeaways from this analysis are summarised below:

- The results show that the FibreForm tray has a lower environmental impact than the APET/PE tray for all four impact categories considered in this life cycle assessment. This finding is very robust and remains true even allowing for the uncertainties and sensitivities that are inherent in any LCA study. This is borne out in the various aspects of the sensitivity and uncertainty analysis presented in Annex 2.
- For the impact category Global Warming Potential, the results show that the FibreForm tray also performs better than the EPS tray. This finding is also very robust considering the uncertainties and sensitivities identified and tested in the study.
- For the impact categories Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation, the results show that the FibreForm tray performs better than the EPS tray. However, this outcome is dependent on the weight of the EPS tray considered. If a lighter EPS tray was to be considered (3g as opposed to 5g) then there is no significant difference in performance of the FibreForm tray compared to the EPS tray.

What do the results mean?

A brand owner/filler or retailer considering innovative FibreForm trays as a solution to pack products such as cooked meats can be confident that:

- Choosing FibreForm trays will result in a significantly reduced Global Warming impact compared to using existing plastic packaging solutions available in the market such as APET/PE laminated plastic trays or EPS trays
- Choosing FibreForm trays will also result in a better environmental performance with regards to Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation Potential compared to continued use of existing APET/PE laminated plastic trays
- In most cases, choosing FibreForm trays will result in a better environmental performance with regards to Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation Potential compared to continued use of existing EPS trays. If the alternative is a very light-weight EPS tray then there may be no significant change for these impact categories.

What does the peer reviewer say?

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PEER REVIEW STATEMENT: "Comparing the environmental profile of innovative FibreForm® food trays against existing plastic packaging solutions."

Intertek has completed an independent peer review of the life cycle assessment project "Comparing the environmental profile of innovative FibreForm® food trays against existing plastic packaging solutions." Intertek was involved as the study progressed. The authors offered full transparency, with a commendable openness to receiving feedback and acting on it. Intertek found that the study was being carried out with attention to detail, experience and expertise.

The data on which the study is based are believed by Intertek to be extensive, accurate and up to date. Where specific (primary) data have been used, they are considered to be accurate. Where secondary data have been used, they are considered to be valid and as accurate as possible. The data used and their quality and applicability are accurately described in the document. Intertek believes the quality of data supports robust findings. As far as Intertek can determine, environmental impact calculations have been carried out accurately and appropriately. Therefore, Intertek has faith in the accuracy of the results.

Arguably the most important environmental metric calculated in this study is the global warming potential. The global warming potential of the FibreForm® food trays has been calculated including both fossil and biogenic emissions and removals. This approach is in line with the recommended industry best practice for LCA studies of forest based products, for example the CEPI Ten Toes methodology and the Product Environmental Footprint (PEF). Other approaches also exist. Accounting for carbon emissions and removals in the paper supply chain is complex, and methods may vary in terms of final results. This study reports the results from the main analysis in the main body of the report. This study also has an annex reporting results achieved under other scenarios. Some stakeholders will prefer the method and results incorporating the biogenic emissions and removals, others may prefer results achieved by other methods (which tend to result in a higher carbon impact for paper products). These varying views are recognised and catered for. It is worth noting that even considering only the fossil GHG emissions, the FibreForm® trays still perform well. This highlights the robustness of the results.

Perhaps the second most important consideration affecting the results after the approach for GHG emissions is recycling assumptions. In the main body of the report, the FibreForm® trays are assumed to be highly recycled. Intertek considers it reasonable to assume a high recycling rate considering that these products are potentially recyclable alongside other paper and board packaging materials. However, high levels of recycling have yet to be proved in the real world. Therefore, the study considers other end of life options (in particular, energy recovery) in an annex. The FibreForm® trays perform well even without recycling, which again underlines the robustness of the results.

Continued...

The study uses the "cut off" method to account for recycling. Intertek considers this the best and fairest method to use, since it aligns with the financial reality of the waste processing market. The cut off method is conservative: it grants less credit for recycling to the FibreForm® trays than other methods would. Other accounting methods are possible, such as the "50:50" method, and these would slightly improve the total environmental results achieved by the FibreForm® trays. This again highlights the robustness of the results.

Other environmental impact results are presented in addition to global warming potential. Intertek finds the choice of environmental impact measures to be suitable, useful and relevant to the main environmental impacts anticipated for the products studied. The study presents all results transparently and appropriately.

In conclusion, Intertek considers the results and conclusions to be sound and fair based on the data and methodologies used. Intertek finds this study to be high quality, detailed, transparent and appropriate. The results are considered to be trustworthy. The report is likely to provide realistic and useful information to specifiers of food trays.

Gary Parker
Sustainability Group Head
Health, Environmental & Regulatory Services
Intertek
2 September 2019

Annex 1: Data and assumptions

Whilst no quantitative data quality goals were set for this study, the data quality principles outlined in Table 8 below were applied. The subsequent data sourced and described in Table 9 to Table 11 are evaluated against these principles to highlight any data points of lower quality which have then been prioritised in the sensitivity and uncertainty analysis.

Table 8 Data quality principles applied in this study

Data quality principle	Description	Comments on approach
Relevance	Data should be representative of the current (2018) technology and market situation. Data should cover the main sources of inventory inputs/outputs across the life cycle	To achieve these objectives primary data was collected wherever possible for foreground unit processes and the aim was to use secondary data from widely used publicly available databases, dating from 2010 onwards, for background unit processes.
Completeness	Data should cover all major unit processes in the life cycle for each system considered Inventory data should include all major inventory burdens relevant to the impact categories for each stage of the life cycle	
Consistency	Data provided should be consistent in order to enable aggregation of data from different suppliers Data should enable meaningful comparison with previous results	For primary data, efforts were made to ensure that all sites providing data did so considering consistent system boundaries, allocation principles, etc. The RISE team provided support to primary data providers and undertook consistency/sense checks of the data provided. Any data points identified as weak or uncertain weree revisited and/or subject to sensitivity analysis in order to identify the level of influence these have over the results achieved and conclusions drawn. For secondary data, wherever possible data was sourced from the Ecoinvent3 database only. This ensures consistency of boundaries, allocations, etc for secondary datasets. Where alternative datasets are required for selected inputs this is highlighted and any potential limitations are discussed
Accuracy	Uncertainties in the data should be minimised	
Transparency	Within bounds of confidentiality, data used should be transparent and/or referenced	All secondary data used in the analysis is clearly referenced. For commercial confidentiality reasons, primary data from individual unit processes has not be made available unless otherwise agreed with the data providers

Table 9 Data and assumptions for FibreForm system

Life cycle stage	Data points	Data sources and assumptions	View on LCI Data quality
FibreForm production	Quantities of resources and energy consumed; wastes produced; emissions to air of fossil and biogenic CO2, NOx, SOx and dust; and substances to water	Primary data provided by the mill	Complies with data quality principles
	Emissions of methane and nitrous oxide from combustion of fuels at the mill	Calculated based on standard emissions factors for the fuels consumed	Complies with data quality principles
	LCI data for wood consumed at the pulp mill	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for non-fibre inputs to pulp and papermaking: calcium oxide, oxygen, magnesium sulphate, alum	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for non-fibre inputs to pulp and papermaking: hydrogen peroxide, sodium chlorate, sodium hydroxide/lye	Primary data from supplier of chemicals to the mill	Complies with data quality principles
	LCI data for non-fibre inputs to pulp and papermaking: sulphuric acid, starch	Secondary data from Ecoinvent, but with the supplier specific CO2 emissions factor substituted for accurate calculation of GWP	Complies with data quality principles
	LCI data for non-fibre inputs to pulp and papermaking: release agents, internal size	No data for the specific chemicals was identified, and therefore generic data for “Chemicals, organics” from Ecoinvent 3 was used	Relevance is compromised, but together inputs of all these chemicals represent less than 2% of the total non-fibre inputs and data is therefore considered acceptable for the study
	LCI data for production fuels consumed	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for management of waste streams	Secondary data from Ecoinvent 3	Complies with data quality principles

	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for Swedish grid electricity, but with the supplier specific CO2e emissions factor substituted for accurate calculation of GWP	Complies with data quality principles
Polymers, film and bottom web lamination	Quantities of resources and energy consumed and wastes produced	Primary data provided by a representative producer of laminated webs	Complies with data quality principles
	LCI data for polymers and adhesives/sealants consumed	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for management of waste streams	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for German grid electricity, but with the supplier specific CO2e emissions factor substituted for accurate calculation of GWP	Complies with data quality principles
Production and printing of the lidding film	Quantities of resources and energy consumed and wastes produced	Primary data provided by a representative producer of laminated webs	Complies with data quality principles
	LCI data for polymers, adhesives/sealants, inks and solvents consumed	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for production of biaxially oriented APET film	Secondary data from Ecoinvent 3 for biaxially oriented APET For converting to film, data for electricity consumption and waste quantities for film extrusion sourced from “Eco-profiles of the European Plastics	Complies with data quality principles Data not compliant with relevance principle, but previous experience and current results show that the film extrusion step has a minor impact

		Industry, LDPE film extrusion", Plastics Europe, March 2005	compared to the production of the polymer
	LCI data for management of waste streams	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for German grid electricity, but with the supplier specific CO2e emissions factor substituted for accurate calculation of GWP	Complies with data quality principles
	GHG emissions from onsite fuel combustion	Calculated based on standard emissions factors for the fuels consumed	Complies with data quality principles
	Process GHG emissions from printing	Estimated based on emission factors from Danish print carbon tool, assuming 0.92kgCO2e per kg ink consumed; 2.2kgCO2e per kg IPA	Complies with data quality principles
Forming, filling and sealing	Quantity of energy consumed	BillerudKorsnas has published FibreForm Converting Guidelines which specifies thermoforming temperatures ranging between 90 and 120°C. This is approximately half the temperature required for thermoforming an APET/PE laminated web, and therefore for modelling purposes it is assumed that process would consume 50% of the energy required for the thermoforming process modelled for the APET/PE tray	Complies with data quality principles
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for Belgian grid electricity	Complies with data quality principles
	Data on waste arising from the process	No data available	Data not compliant with completeness principle. This is a data gap that could not be resolved.

End-of-life	LCI data for recycling	The following have been considered: Emissions for the collection of waste paper packaging have been allocated to the FibreForm tray system No emissions or credits have been considered for the actual recycling process, as these would be allocated to the subsequent system making use of the recycled fibres	This approach has been tested in the sensitivity analysis
	LCI data for energy recovery	Secondary data from Ecoinvent 3 for emissions from incineration and avoided emissions for heat and energy recovery	Complies with data quality principles
Transport data	Transport distances for wood and chemical inputs to the mill	Transport distances determined based on distances from supplier sites (identified by the mill) to the mill	Complies with data quality principles
	Transport of FibreForm from mill to convertor	Estimated based on proposed delivery route	Complies with data quality principles
	Transport of films and polymers to the laminating plant (bottom web production and lidding film production)	Primary data on transport distances from supplier to plant provided by a representative produced of laminated webs	Complies with data quality principles
	Transport of laminated materials bottom web and lidding film) from lamination plant to filler	Estimated based on propose delivery route	Complies with data quality principles
	LCI emissions from modes of transport	Secondary data from Ecoinvent 3 for emissions per tonne.km	Complies with data quality principles

Table 10 Data and assumptions for APET/PE system

Life cycle stage	Data points	Data sources and assumptions	View on LCI Data quality
Production of the bottom web	Quantities of resources and energy consumed and wastes produced	Primary data provided by a representative produced of laminated webs	Complies with data quality principles
	LCI data for polymers and adhesives/sealants consumed	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for management of waste streams	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for German grid electricity, but with the supplier specific CO2e emissions factor substituted for accurate calculation of GWP	Complies with data quality principles
Production and printing of the lidding film	Quantities of resources and energy consumed and wastes produced	Primary data provided by a representative producer of laminated webs	Complies with data quality principles
	LCI data for polymers, adhesives/sealants, inks and solvents consumed	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for production of biaxially oriented APET film	Secondary data from Ecoinvent 3 for biaxially oriented APET For converting to film, data for electricity consumption and waste quantities for film extrusion sourced from "Eco-profiles of the European Plastics Industry, LDPE film extrusion", Plastics Europe, March 2005	Complies with data quality principles Data not compliant with relevance principle, but previous experience and current results show that the film extrusion step has a minor impact compared to the production of the polymer

	LCI data for management of waste streams	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for German grid electricity, but with the supplier specific CO2e emissions factor substituted for accurate calculation of GWP	Complies with data quality principles
	GHG emissions from onsite fuel combustion	Calculated based on standard emissions factors for the fuels consumed	Complies with data quality principles
	Process GHG emissions from printing	Estimated based on emission factors from Danish print carbon tool, assuming 0.92kgCO2e per kg ink consumed; 2.2kgCO2e per kg IPA	Complies with data quality principles
Thermo-Forming, filling and sealing	Quantity of energy consumed	Estimated based on the specified running power consumption for an appropriate thermoforming machine, assuming a power factor of 0.75, producing 45 trays per minute	Power consumption for thermoforming could vary, so this data point is subjected to dominance and sensitivity analysis
	Quantity of compressed air consumed	Estimated based on specification for an appropriate thermoforming machine	Compressed air consumption for thermoforming could vary, so this data point is subjected to dominance and sensitivity analysis
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for Belgian grid electricity	Complies with data quality principles
	LCI data for compressed air	Secondary data from Ecoinvent 3	Complies with data quality principles
	Data on waste arising from the process	No data available	Data not compliant with completeness principle. This is a data gap that could not be resolved.

End-of-life	LCI data for energy recovery	Secondary data from Ecoinvent 3 for emissions from incineration and avoided emissions for heat and energy recovery	Complies with data quality principles
	LCI data for landfill	Secondary data from Ecoinvent 3	Complies with data quality principles
Transport data	Transport of films and polymers to the laminating plant (bottom web production and lidding film production)	Primary data on transport distances from supplier to plant provided by a representative producer of laminated webs	Complies with data quality principles
	Transport of laminated materials bottom web and lidding film) from lamination plant to filler	Estimated based on propose delivery route	Complies with data quality principles
	LCI emissions from modes of transport	Secondary data from Ecoinvent 3 for emissions per tonne.km	Complies with data quality principles

Table 11 Data and assumptions for EPS system

Life cycle stage	Data points	Data sources and assumptions	View on LCI Data quality
Production of the EPS tray	Quantities of resources and energy consumed	Secondary data derived from research article "Foamy polystyrene trays for fresh meat packaging: Life cycle inventory data collection and environmental impact assessment", Ingrao et al, Food Research International, 76 (2015) 418-426[3]	Complies with data quality principles
	LCI data for expandable polystyrene	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for Butane 1,4-diol	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for German grid electricity	Complies with data quality principles
	LCI data for heat from natural gas	Secondary data from Ecoinvent 3	Data used may not be entirely consistent with the type of boiler used in the process
Production and printing of the lidding film	Quantities of resources and energy consumed and wastes produced	Primary data provided by the Wipack (producer of the web)	Complies with data quality principles
	LCI data for polymers, adhesives/sealants, inks and solvents consumed	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for production of biaxially oriented APET film	Secondary data from Ecoinvent 3 for biaxially oriented APET For converting to film, data for electricity consumption and waste quantities for film extrusion sourced from "Eco-profiles of the European Plastics	Complies with data quality principles Data not compliant with relevance principle, but previous experience and current results show that the film extrusion step has a minor impact

[3] Extracted April 2019 from https://www.sciencedirect.com/science/article/pii/S0963996915301204?via%3Dihub

		Industry, LDPE film extrusion", Plastics Europe, March 2005	compared to the production of the polymer
	LCI data for management of waste streams	Secondary data from Ecoinvent 3	Complies with data quality principles
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for German grid electricity, but with the supplier specific CO2e emissions factor substituted for accurate calculation of GWP	Complies with data quality principles
	GHG emissions from onsite fuel combustion	Calculated based on standard emissions factors for the fuels consumed	Complies with data quality principles
	Process GHG emissions from printing	Estimated based on emission factors from Danish print carbon tool, assuming 0.92kgCO2e per kg ink consumed; 2.2kgCO2e per kg IPA	Complies with data quality principles
Filling and sealing	Quantity of energy consumed	Estimated based on consultant experience	This is a weak data point, but is subjected to dominance and sensitivity analysis that shows that it is not influential over the overall results achieved and conclusions drawn
	LCI data for purchased electricity	Secondary data from Ecoinvent 3 for Belgian grid electricity	Complies with data quality principles
	LCI data for compressed air	Secondary data from Ecoinvent 3	Complies with data quality principles
	Data on waste arising from the process	No data available	Data not compliant with completeness principle. This is a data gap that could not be resolved.

End-of-life	LCI data for energy recovery	Secondary data from Ecoinvent 3 for emissions from incineration and avoided emissions for heat and energy recovery	Complies with data quality principles
	LCI data for landfill	Secondary data from Ecoinvent 3	Complies with data quality principles
Transport data	Transport of EPS granules and other inputs to the tray a tray producer for standalone rigid trays	No data available, so estimated at 500km	This is a weak data point, but is subjected to dominance and sensitivity analysis that shows that it is not influential over the overall results achieved and conclusions drawn
	Transport of films and polymers to the laminating plant (lidding film production)	Primary data on transport distances from supplier to plant provided by a representative producer of laminated webs	Complies with data quality principles
	Transport of laminated material (lidding film) from lamination plant to filler	Estimated based on proposed delivery route	Complies with data quality principles
	Transport of EPS tray from tray producer to filler	Distance estimated based on proposed delivery route. Number of trays per pallet and number of pallets per truck determined using palletisation/loading tool	Complies with data quality principles
	LCI emissions from modes of transport	Secondary data from Ecoinvent 3 for emissions per tonne.km	Complies with data quality principles

Annex 2: Uncertainty and sensitivity analysis

In this Annex the results achieved and conclusions drawn are subjected to sensitivity and uncertainty analysis. Key methodological choices, assumptions and weak data points have been investigated. In particular, the results have been tested to check their robustness with regards to the following parameters:

- Consideration of biogenic CO2 emissions and removals
- Alternative data sources for the FibreForm tray (secondary data for material inputs for pulp and papermaking)
- Different material specifications:
    - Considering trays made of printed FibreForm laminate
    - Considering a PE laminated FibreForm tray
    - Alternative materials for APET/PE tray
    - Weight of EPS tray
- End-of-life assumptions and approaches

The outcomes from the various scenarios investigated are summarised in Table 2 below. Figures 23-26 also show the results for each baseline scenario against the results for the various sensitivity analysis scenarios investigated. It can be clearly seen that overall the analysis shows that only the weight of the EPS tray has a significant bearing on the results. If a lighter EPS tray was to be considered (a 3g tray as opposed to the 5g EPS tray considered in the baseline scenario) then there is no longer a significant difference in performance of the FibreForm tray compared to the EPS tray for the impact categories Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation Potential. However, even considering the lighter-weight EPS tray, the FibreForm tray still performs better from a Global Warming Potential perspective. For all other parameters investigated, the findings are robust and the order of ranking for the three systems remains the same. Further explanation of the sensitivity scenarios considered and the findings from these are provided in the following sections of this Annex.

Table 12 Summary of sensitivity analysis results

		Scenarios considered								
Solution	Impact Category	Baseline	Sensitivity 1: only fossil GHG	Sensitivity 2: Apportioning biogenic GHGs to subsequent life cycles	Sensitivity 3: Secondary data sources for FibreForm chemicals and ingredients	Sensitivity 4: Printed FibreForm laminate	Sensitivity 5: PE laminated FibreForm (instead of adhesive laminated)	Sensitivity 6: No recycling of FibreForm	Sensitivity 7: No recycling of FibreForm, fossil GHGs only	Sensitivity 8: Lower EPS tray weight
FibreForm tray	Global warming potential									
	Acidification potential		n/a	n/a					n/a	
	Eutrophication potential		n/a	n/a					n/a	
	POCP		n/a	n/a					n/a	
APET/PE tray	Global warming potential									
	Acidification potential		n/a	n/a					n/a	
	Eutrophication potential		n/a	n/a					n/a	
	POCP		n/a	n/a					n/a	
EPS tray	Global warming potential									
	Acidification potential		n/a	n/a					n/a	
	Eutrophication potential		n/a	n/a					n/a	
	POCP		n/a	n/a					n/a	

Key:

	Lowest impact solution
	Medium impact solution
	Highest impact solution

Figure 23

Comparison of baseline scenarios against all sensitivity analysis scenarios, Global warming potential results

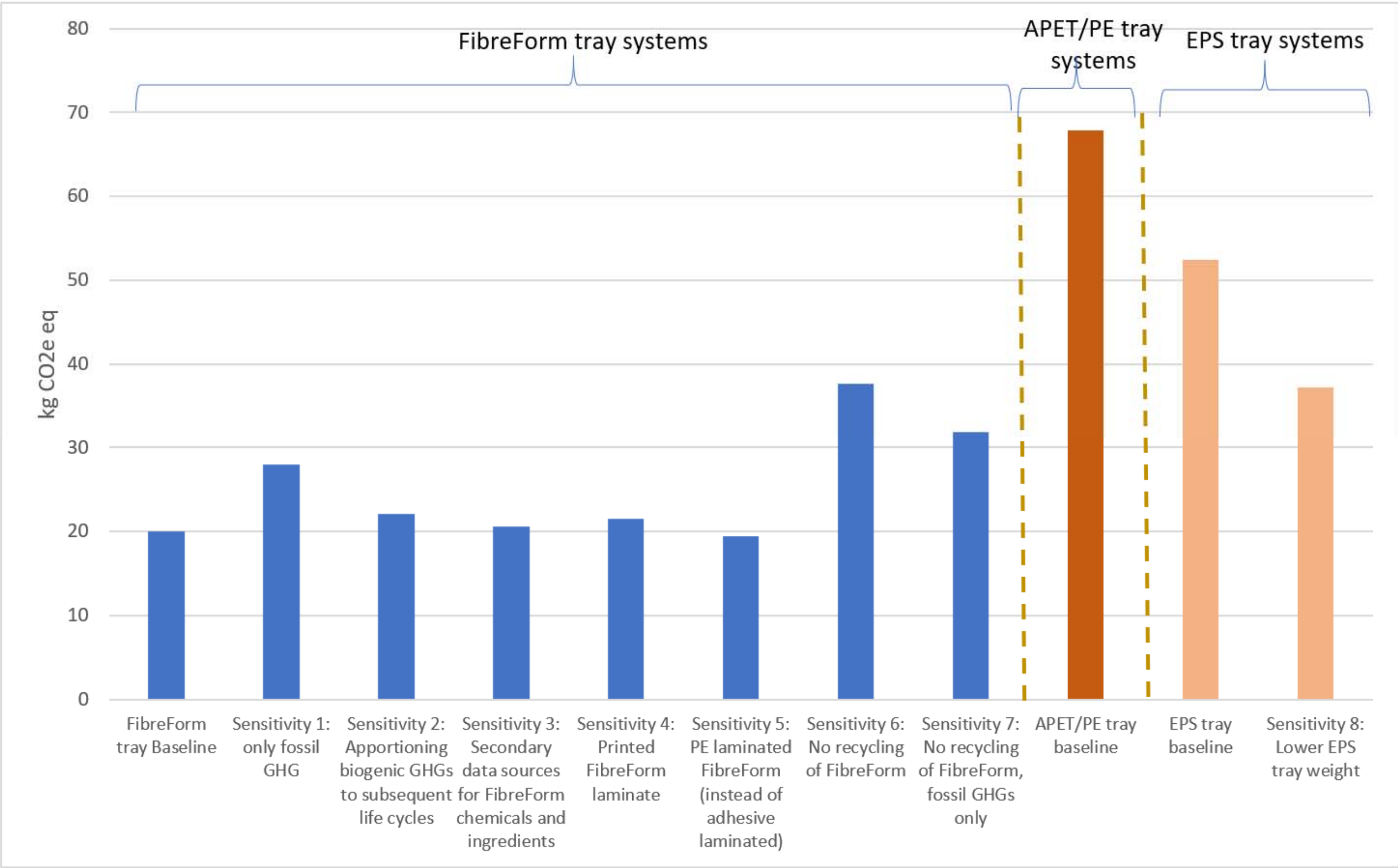


Figure 24

Comparison of baseline scenarios against all sensitivity analysis scenarios, Acidification potential results

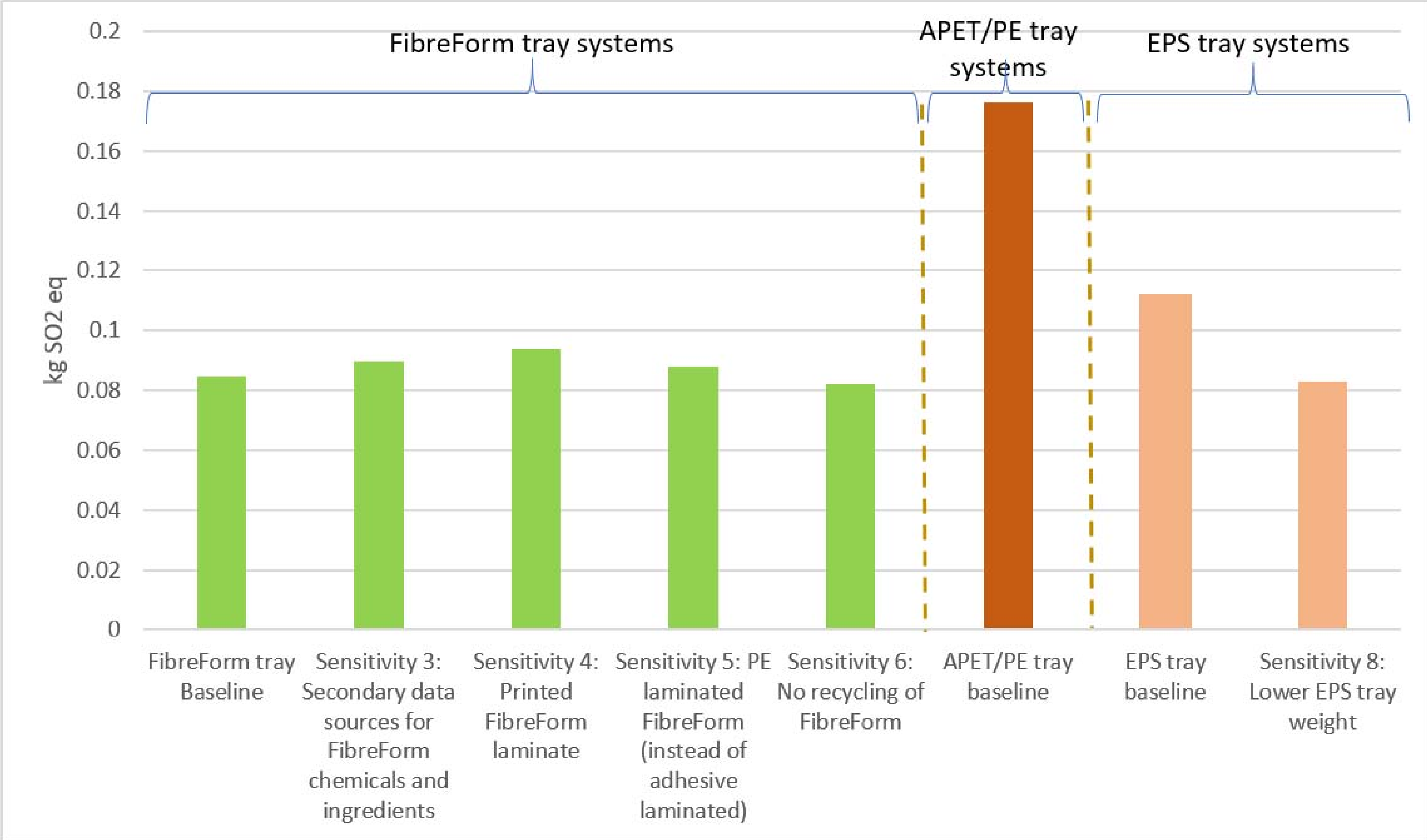


Figure 25

Comparison of baseline scenarios against all sensitivity analysis scenarios, Eutrophication potential results

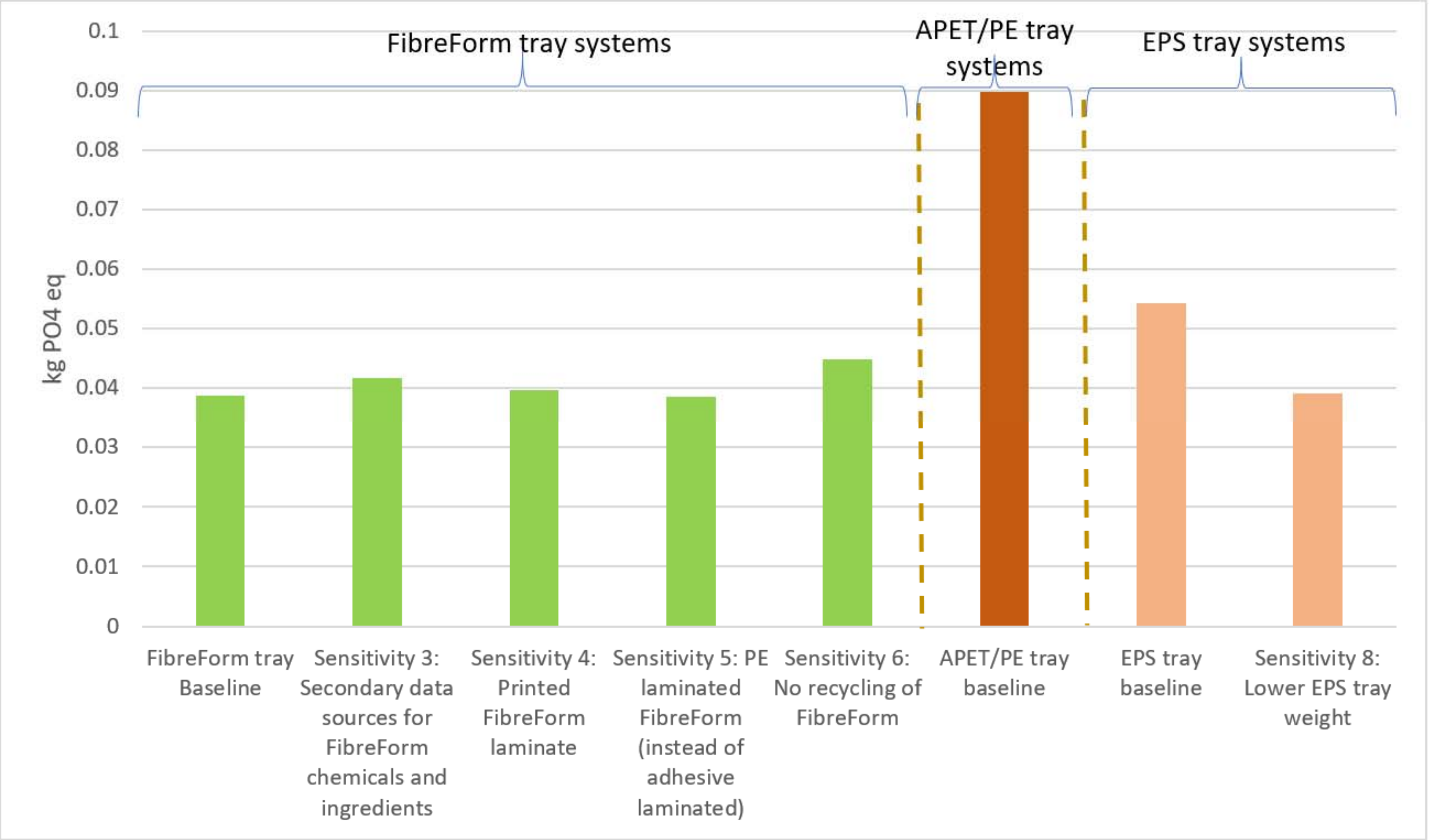
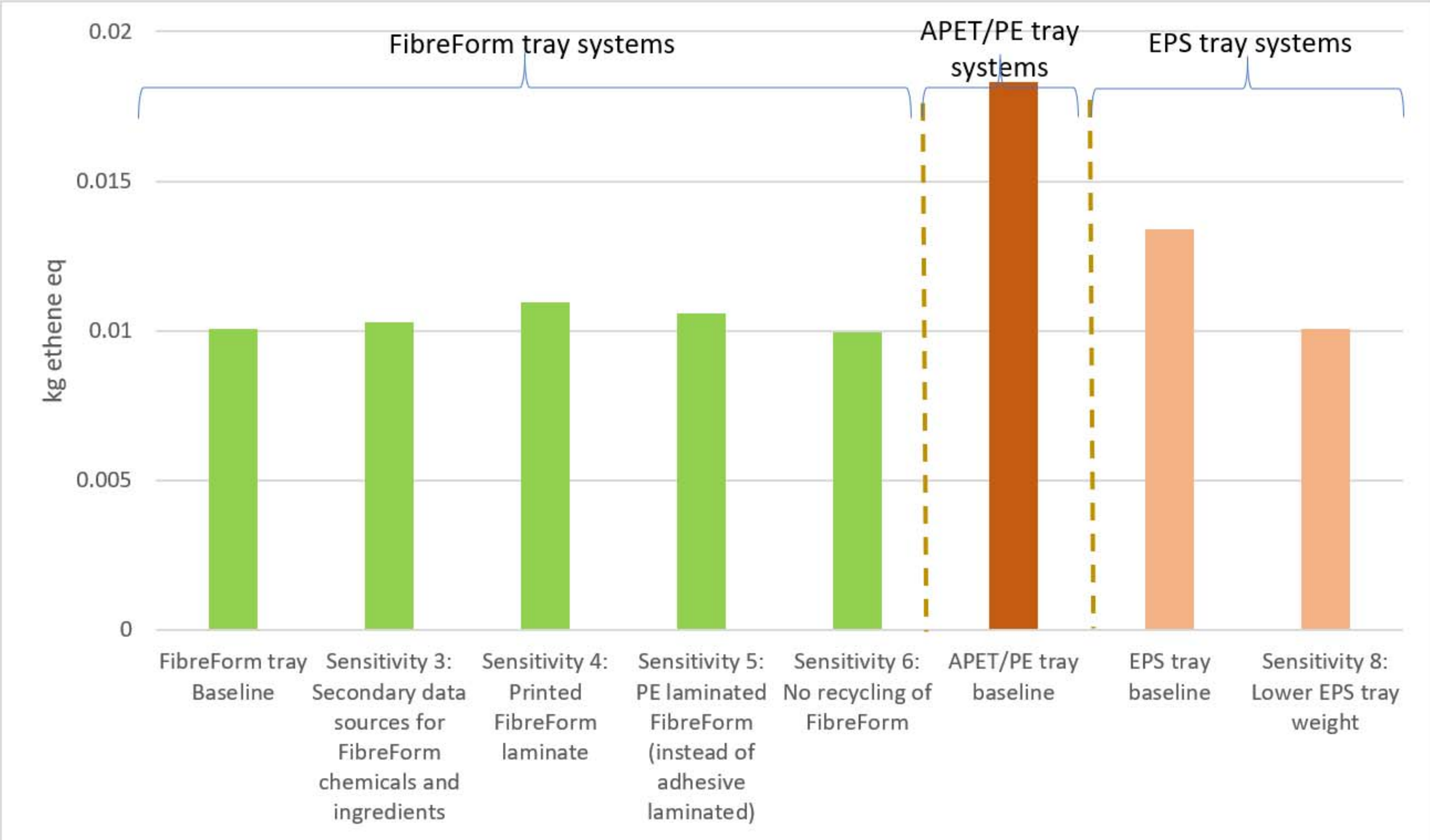


Figure 26

Comparison of baseline scenarios against all sensitivity analysis scenarios, POCP results



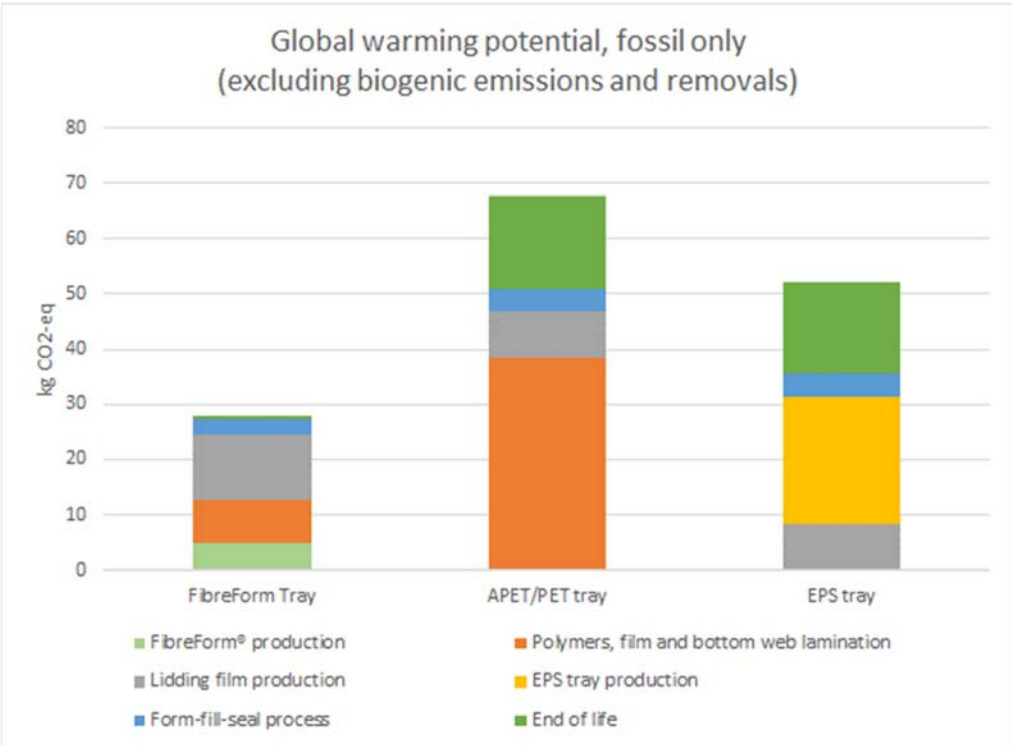
Consideration of biogenic GHG emissions and removals

In the baseline analysis presented in this document both fossil and biogenic GHG emissions and removals have been considered. The fossil and biogenic results have been presented separately but also presented as a combined total value for the fibre-based solution. This approach is in line with current recommendations for estimating the climate change impact of fibre-based packaging[4].

However, in order to determine the sensitivity of the results to this methodological approach Figure 27 presents the results excluding biogenic GHG emissions and removals.

Figure 27

Global warming potential results, recalculated considering fossil GHGs only



It can be seen that, when biogenic GHG emissions and removals are excluded, the impact of the APET/PE tray and the EPS tray is still more than twice the impact of the FibreForm tray. Thus, the relative standing of the FibreForm tray when compared against the

[4] See for example, CEPI. (April 2017). *Framework For Carbon Footprints For paper and board products.* Brussels, CEPI

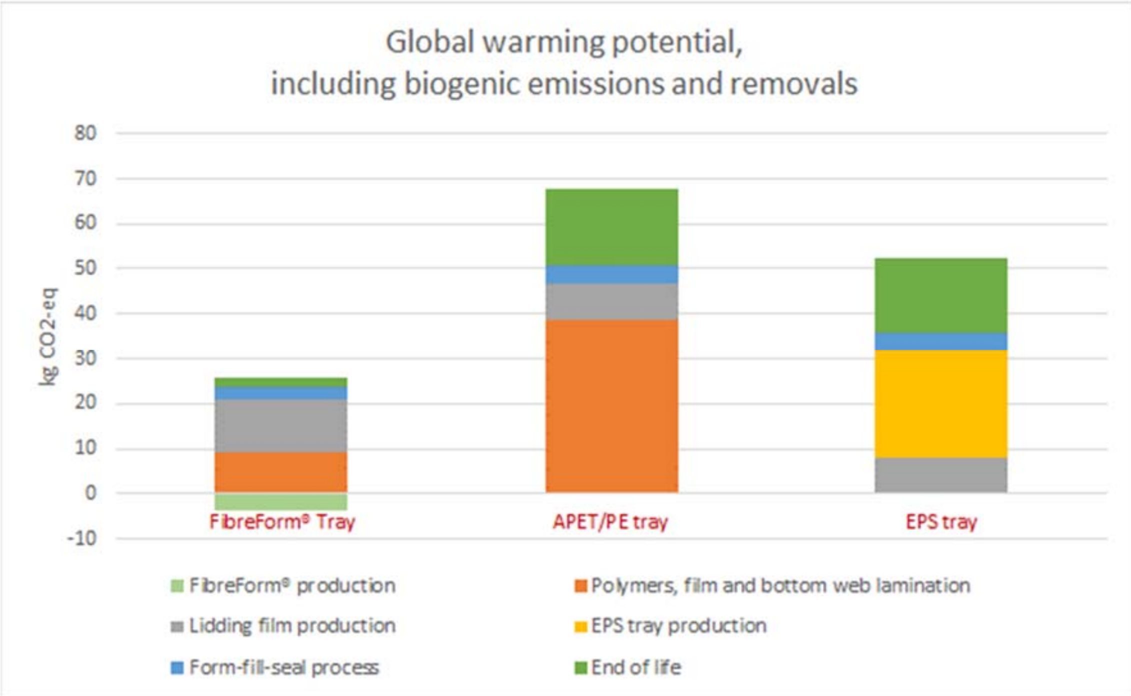
APET/PE and EPS is not sensitive to whether biogenic GHG emissions and removals are included in the analysis.

A further aspect regarding the consideration of biogenic GHGs and removals is the fact that a high proportion of the FibreForm trays are assumed to be recycled at end-of-life. The impacts associated with the collection of the used materials are included in the system boundaries of the analysis, up to the delivery of the material to recycling mills gate. However, a cut-off approach has been applied for the recycling of the material, so impacts associated with the reprocessing of the fibre have not been included and nor has any credit been included for offset production of virgin pulp. This approach assumes that the credit is applied to the product that uses the recovered fibre, rather than the system that generates the material for recycling. Whilst this approach has been adopted due to the difficulties of defining an appropriate credit for recycling, it creates a challenge when accounting for biogenic GHGs. A proportion of the biogenic GHG removals occurring as part of the FibreForm production is effectively being carried through to subsequent products in the form of carbon contained in the fibres. However, this carbon will eventually be released back into the environment when the subsequent products are finally disposed of to landfill, composting or energy recovery, and this release does not register in the current system boundaries. It may be considered unfair to apportion all of the biogenic GHG removals from the growing of forests for fibre to the current system, whilst the subsequent emissions of biogenic GHG emissions from landfill, composting or energy recovery will be quantified in the life cycle of the product that uses the fibres in the final cycle of their life. Whilst one approach would be to consider only the fossil GHG emissions (as shown in Figure 23) another approach could be to allocate on a proportion of the biogenic GHG removals to our system. It is often quoted that paper fibres can be recycled seven times. If we consider this, then we could potentially apportion one seventh of the biogenic GHG removals that are incorporated into the product as carbon to the FibreForm system. The effect of this on the results is shown in Figure 28 below.

It can be seen that the Global Warming Potential results for the FibreForm product, although increased compared to the baseline, are still significantly lower the than those for the APET/PE tray and for the EPS tray.

Figure 28

Global warming potential results, apportioning the biogenic GHG removals incorporated into the fibres across the life cycles of the FibreForm trays and subsequent products incorporating the recovered fibres



Comment on the application of primary versus secondary data

As is typical in life cycle assessment studies, it has been necessary to utilise a mix of primary and secondary data to model the systems. The results for each system in this study are dominated by the production and conversion of the raw materials.

For the FibreForm system it has been possible to secure a higher degree of primary data. For example, primary data has been used for the production of the FibreForm substrate and for many of the upstream inputs to the pulp and papermaking process (transport of materials, production of selected chemicals, etc). Primary data has also been utilised for the laminating process (for the production of the bottom web) and the printing and laminating of the lidding film.

In contrast, for the APET/PE tray, whilst primary data has also been applied for the laminating process and for the production of the lidding film, there has been much greater reliance on secondary data for upstream processes such as the production of polymers used in the construction of the bottom web. For the EPS tray, only secondary data has been available.

As is usually the case in LCA studies, the extent of primary data available reflects the fact that participation in the data collection is usually limited to the sponsoring organisation and their direct supply chain partners (i.e. in this case BillerudKorsnas and some of their suppliers plus a convertor of laminated webs). Whilst a greater degree of primary data for all solutions studied would aways be preferable, it is rarely practical or possible.

To demonstrate why the choice of primary or secondary data can be important, in Figure 29 the results for the FibreForm tray are reworked using secondary data only for all upstream non-fibre inputs (chemicals, fillers, etc consumed at the pulp and paper mill).

The results show that considering only secondary data slightly increases the impacts of the FibreForm tray when compared to the other solutions. However, the overall trends in the results remain consistent whichever data is applied.

Figure 29

Results comparison, applying secondary data to upstream processes for the FibreForm trays

Different material specifications

Considering trays made of printed FibreForm laminate

In the baseline comparison in this analysis, it has been assumed that only the lidding film is printed. Currently, this is the case for APET/PE trays and EPS trays in the market and therefore it is logical in the comparison to consider that the FibreForm laminate that is used to make the tray for the FibreForm solution is also unprinted. However, printability of the laminate for the tray is a significant advantage for the FibreForm solution compared to the other solutions in the market. It is likely that many brand owners and fillers will take advantage of this printability to add value and shelf-impact to their products when using FibreForm trays.

Therefore, in this section we have investigated the potential additional impact if the FibreForm laminate materials were also printed. The results are shown in Figure 30. In this analysis, the additional impact from the printing process has been included in the unit process. A flexographic printing process has been considered, which is commonly used for printing packaging materials.

It can be observed that whilst this increases the environmental impact of the FibreForm solution, the increase is not significant when considered across the entire life cycle, and the additional impact does not change the relative standing of the alternative solusions.

Figure 30

Results comparison, including printing of the FibreForm laminate

Considering a PE laminated FibreForm tray

In the baseline analysis, an adhesive laminated structure is considered. However, an alternative approach would use a PE laminated base layer instead of adhesive, with an overall structure of FibreForm/PE/FibreForm/barrier layer.

In this section, the potential impact of this alternative structure is considered. To facilitate the sensitivity analysis, a 20gsm PE layer is considered as a replacement for the adhesive layer. This results in changes in the life cycle impact of the FibreForm solution in each impact category. For acidification and POCP the impact is increased by ~4% and 5% respectively. For global warming potential there is a small reduction in the impact of ~3%. For eutrophication potential, the result is virtually unchanged at less than 1% lower than the baseline scenario.

Subsequently, as shown in Figure 31, the relative standing of the different solutions remains unchanged. The FibreForm solution still has a lower impact for all four impact categories considered.

Figure 31

Results comparison, considering a PE-laminated FibreForm tray rather than adhesive laminated

Alternative specification for the APET/PE tray

Whilst the APET/PE tray is the dominant laminated plastic tray available in the market, and the solution against which the FibreForm tray will most directly compete, other configurations are also available. One potential solution also investigated was a tray manufactured entirely of APET (excluding PE) and with a different lidding film construction. However, as the APET/PE tray has a considerably higher result for each of the impact categories considered compared to the FibreForm and EPS trays, the results achieved and conclusions drawn were not found to be sensitive to the configuration of the laminated plastic tray considered.

Weight of EPS tray

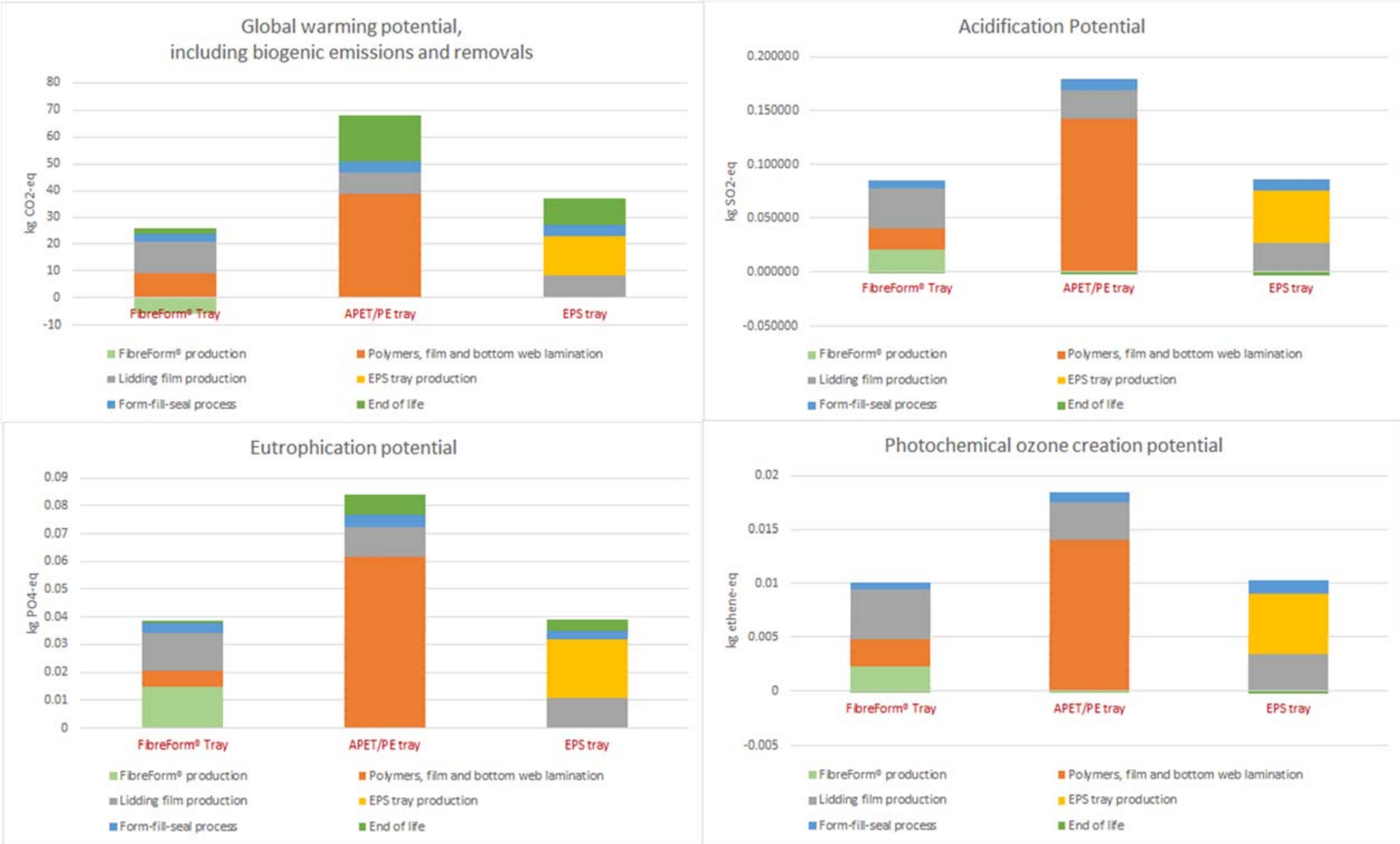
In this analysis, primary data on the tray weights for the FibreForm solution and for the APET/PE solution were applied. However, as none of the stakeholders involved in the provision of primary data for the study have experience in the production and marketing of EPS trays, it was necessary to make an assumption regarding the likely weight of the EPS tray for the comparison. The chosen weight for the tray was 5g. This assumption was based on a combination of estimations (considering the anticipated dimensions of the tray, the assumed thickness of the walls and the assumed density of the material) and the weighing of a limited number of samples of trays from the UK market, sense-checked based on the experience of BillerudKorsnas staff working in markets across Europe. It was also necessary to make an assumption regarding the weight and construction of the lidding film.

However, the weight of EPS trays can vary considerably based on design and material specifications, especially density the material once formed. Therefore, it was felt important to test the sensitivity of the results for the EPS tray to see if a lower weight tray could change the relative standing of the solution compared to the FibreForm tray.

The potential influence of these assumptions is shown in the example presented in Figure 32. In this example, we consider a lower weight tray of 3.0g. In this case, whilst the FibreForm tray is still significantly better than the EPS tray for global warming (representing a 46% saving), the differences between the FibreForm tray and the EPS tray are no longer significant for the other impact categories of Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation Potential

Figure 32

Results comparison, considering lower weight for the EPS tray



End-of-life assumptions and approaches

For the FibreForm tray, it has been assumed that the trays (which are 85% fibre) are recyclable, and that the majority of the post-consumer trays are sent for material recycling. A recycling rate of 89.4% has been applied, in line with the average paper and board packaging recycling rate achieved in Belgium, where the trays are assumed to be consumed.

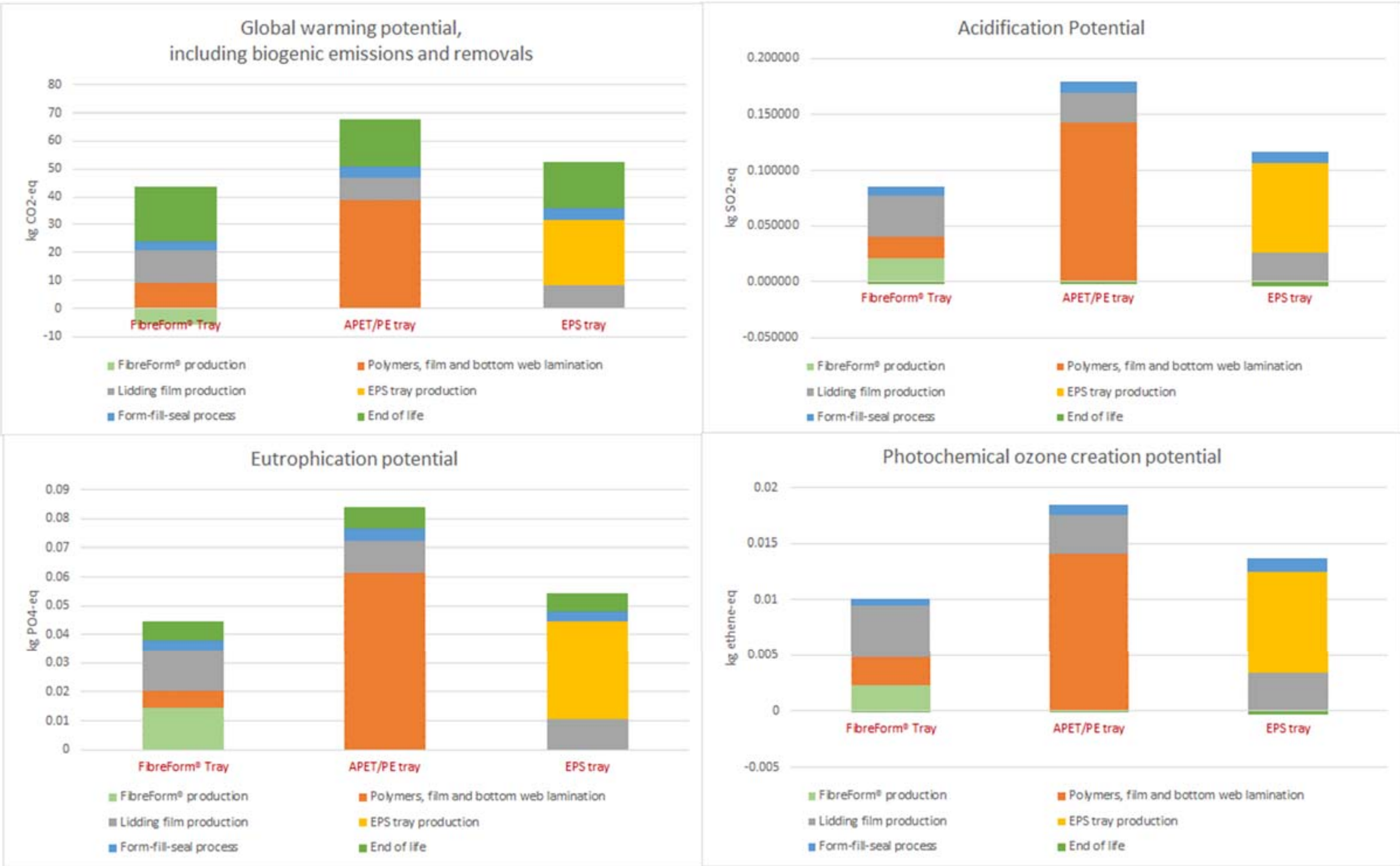
Whilst all paper and board packaging materials are recyclable, laminated materials may need to be recycled in specialised mills or dedicated repulping processes, as the repulping regimes applied at many standard recycling mills may be unable to remove the fibres from the plastic[5]. In this case, it is possible that the trays that are collected and sent for material recycling will be rejected and removed in the repulping process. In such an instance, the rejected trays are likely to be sent for incineration with energy recovery. Thus, Figure 33 below, shows the comparative results if all the FibreForm materials are disposed of via energy recovery with 0% material recycling.

This significantly increases the global warming potential impact of the Fibre Form system, almost doubling it from 20.0 kg CO2-eq per 1,000 trays to 37.6 kg CO2-eq per 1,000 trays. Nonetheless, the FibreForm solution still has a significantly lower impact than the alternatives, representing a 28% saving compared to the EPS tray and a 46% saving compared to the APET/PE tray. Similarly, considering the other impact categories, the FibreForm tray is still significantly favourable compared to the EPS tray and the APET/PE tray. Therefore, the relative standing of the systems is not sensitive to the assumed end-of-life for the FibreForm tray.

[5] See for example, Paper and Board Packaging Recyclability Guidelines, CPI, 2019, which advocates that "*Designers should restrict plastic content to 5% of pack weight as a maximum, although the industry would prefer no more than 3% by weight*"

Figure 33

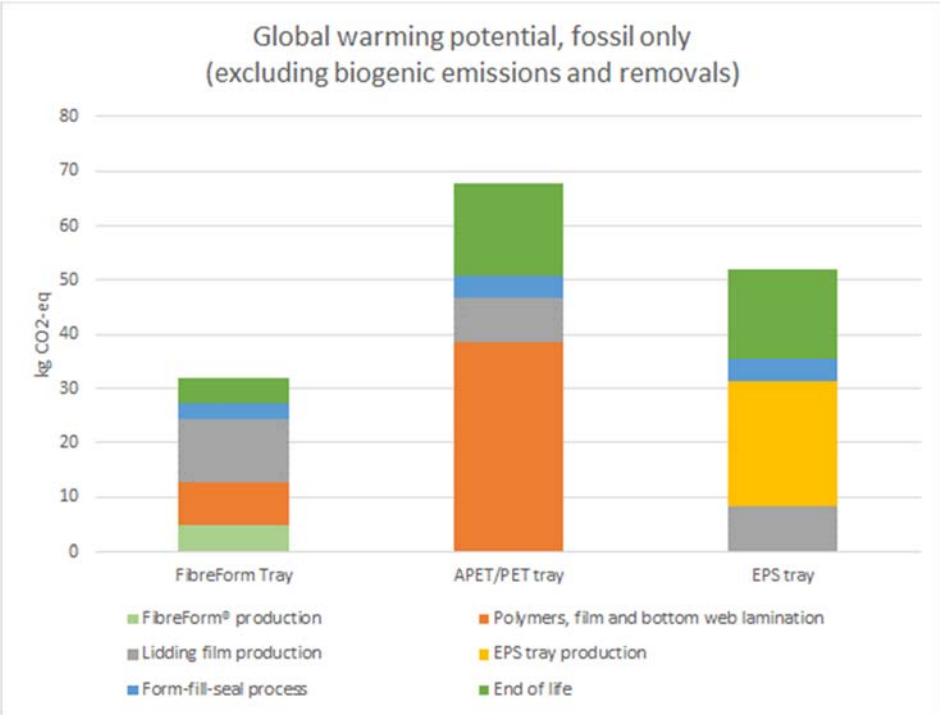
Results comparison, assuming the FibreForm trays are not recycled



If only fossil GHG emissions were considered in the analysis (see Figure 34), then the differences between the FibreForm tray and the alternatives still remains significant.

Figure 34

Global warming potential results considering 0% recycling for FibreForm trays, recalculated considering fossil GHGs only



A further consideration when modelling the recycling of the FibreForm trays is the issue of whether to include a credit for recycling. For this analysis, no credit has been applied for recycling of the trays, although it could be argued that the recovery of the fibres would offset primary production of virgin fibres. However, in this study we have applied a cut-off approach, thereby assigning any credit for recycling to the product which incorporates the recycled fibres rather than the system that generates the fibres. If a credit were to be included, this would obviously reduce the impact of the FibreForm tray.

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