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Summary of Comparative Environmental Impact Study of PE Packaging and Substitutes on the European Market Based on Life Cycle Assessment: Climate Change, Water Scarcity and Fossil Resource Use

Introduction

In recent years, the use and quantity of packaging materials, as well as societal concerns over mismanaged waste have increased. This has led to a focus on the potential environmental impact of packaging. In line with the resource efficiency and decarbonisation goals set in the European Green Deal and the EU's Action Plan for the Circular Economy, the European Union has taken a leading role in developing and adopting measures to mitigate the potential environmental impacts of packaging. As part of this effort, the EU has introduced ambitious recycling targets for packaging materials and bans on certain packaging formats.

In response to these challenges and the evolving legislative landscape, ExxonMobil commissioned a comparative study to Circular Analytics to provide decision-makers with a comprehensive overview of certain potential life cycle environmental impacts of different packaging materials. Specifically, it assesses polyethylene (PE) based and alternative packaging materials in the areas of climate change, water scarcity, and fossil resource use. This comparative study has been conducted in accordance with ISO 14040:2006 and ISO 14044:2006. The study was also critically reviewed by a panel of three independent experts.

Methodology of the study

This study evaluates and compares climate change, water scarcity, and fossil resource use potential impacts for 94 packaging options across 37 packaged products in five end-use applications:

- PE collation shrink films and paper-based alternatives for beverages (4 comparisons, 14 packaging options)
- PE stretch film wraps and paper wrap alternatives for securing pallets (1 comparison, 2 packaging options)
- PE rigid packaging for non-food products and glass, metal, paper, and paper multi-material alternatives (9 comparisons, 20 packaging options)
- PE heavy-duty sacks and paper and paper multi-material alternatives (6 comparisons, 12 packaging options)
- PE flexible food packaging and glass, metal, and paper, and paper multi-material alternatives (17 comparisons, 46 packaging options)

Packaging formats were sampled, and compositions determined by Circular Analytics. Calculations were conducted with a Microsoft Excel tool based on openLCA 1.11 software. Background and secondary datasets were mainly taken from ecoinvent 3.8 database. Transport distances are based on the Product Environmental Footprint (PEF) guidance for the European Union, and end-of-life was modelled according to the circular footprint formula (CFF) of the European Commission. End-of-life (EoL) rates (recycling, landfill and incineration) from Eurostat were used.

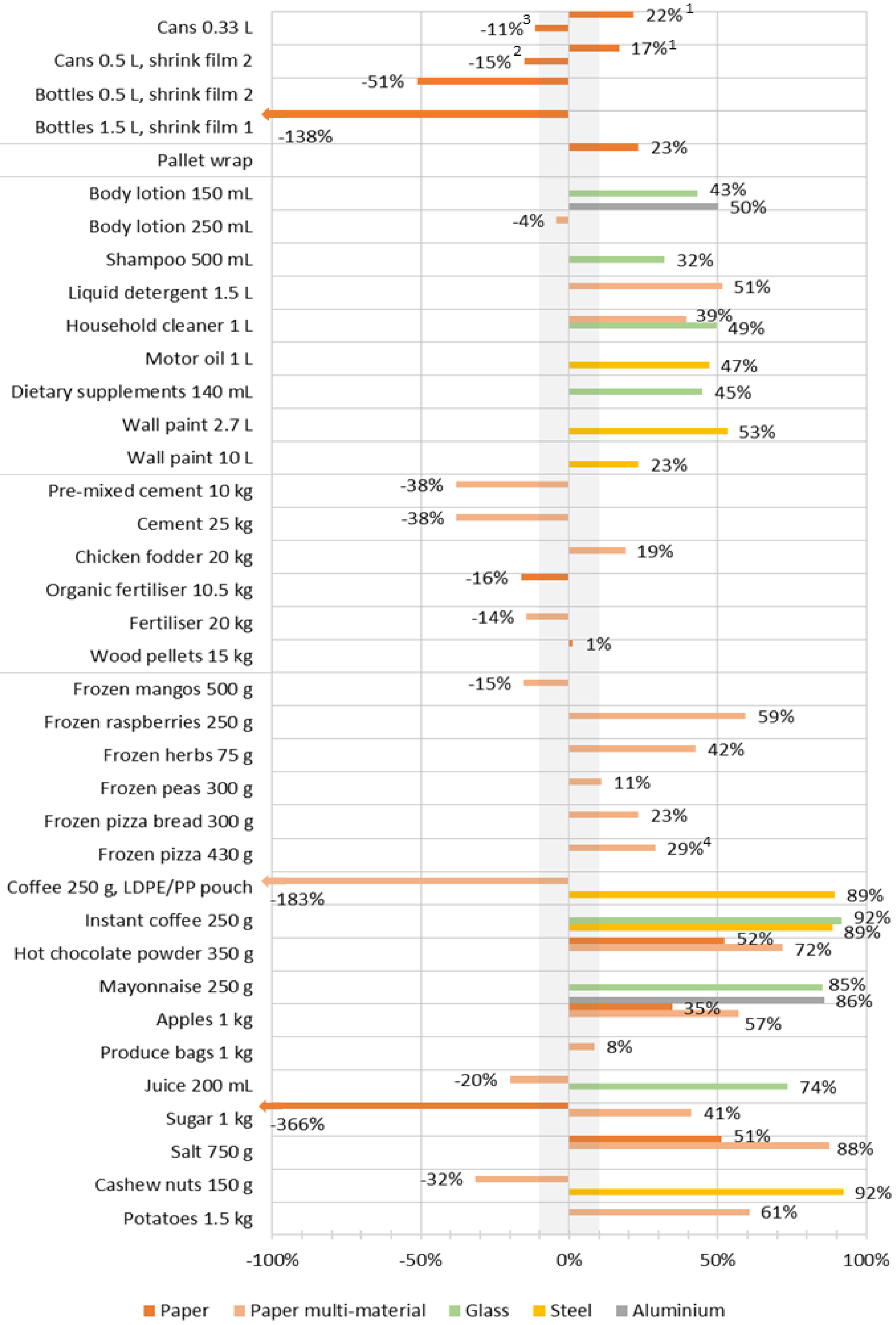
For the 37 PE packaged products studied, where a PE format was compared with one or more alternatives (paper, metals and glass) for a packaged product, fifty (50) comparisons could be made. However, the study only considered comparisons of PE-based packaging and the alternative with the lowest potential environmental impact. For each packaged product, this resulted in a total of 37 product comparisons. Though other types of comparisons could be made, this approach is chosen to show conservative results for PE-based packaging. The analysis focuses on the European average market, covering cradle-to-end-of-life, but excludes the use phase (e.g., breakage rates, product loss, shelf-life extension), with regional sensitivity analyses performed using Germany and United Kingdom scenarios.

Plastics provide important performance characteristics for many packaging applications. Therefore, identifying non-plastic market alternatives was difficult for some products. In this context, it is important to note that the study only considered comparisons where the functions of packaging are similar based on functional units defined as the packaging required to contain and protect a specified quantity of product. For example, PE stretch films and collation shrink films and their paper alternatives are assumed in this study to be used to fulfil similar packaging functions under dry and indoor environments. It is important to note that the study excluded wet and outdoor environments for these applications, which are conditions where paper may not provide the similar packaging integrity of PE-based packaging. Thus, a reasonable basis for comparison was to consider only dry storage conditions for these applications.

Key Findings

Overall, PE-based packaging had potentially lower climate change impact than the studied alternatives in 21 of 37 (57%) packaging comparisons across the five packaging applications assessed. For water scarcity and fossil resource use, PE-based packaging had potentially lower impact than all alternatives in 12 of 37 (32%) comparisons across the five packaging applications assessed. In the rest of the comparisons, PE-based packaging was found to have potentially similar or higher impacts than at least one alternative in the assessed environmental impact category. PE tended to have lower impacts than glass and metals (steel and aluminium), with four exceptions (in the rigid non-food application) where PE-based packaging was found to have similar or higher water scarcity and fossil resource use than glass and steel-based alternatives. Notably, sensitivity analyses to increasing recycled material content and recyclability of packaging formats showed a general trend of reductions in the considered impact categories for packaging materials. The study recommends increasing the recycled material content and recyclability of packaging formats to reduce the impact of packaging in the considered impact categories.

Climate Change

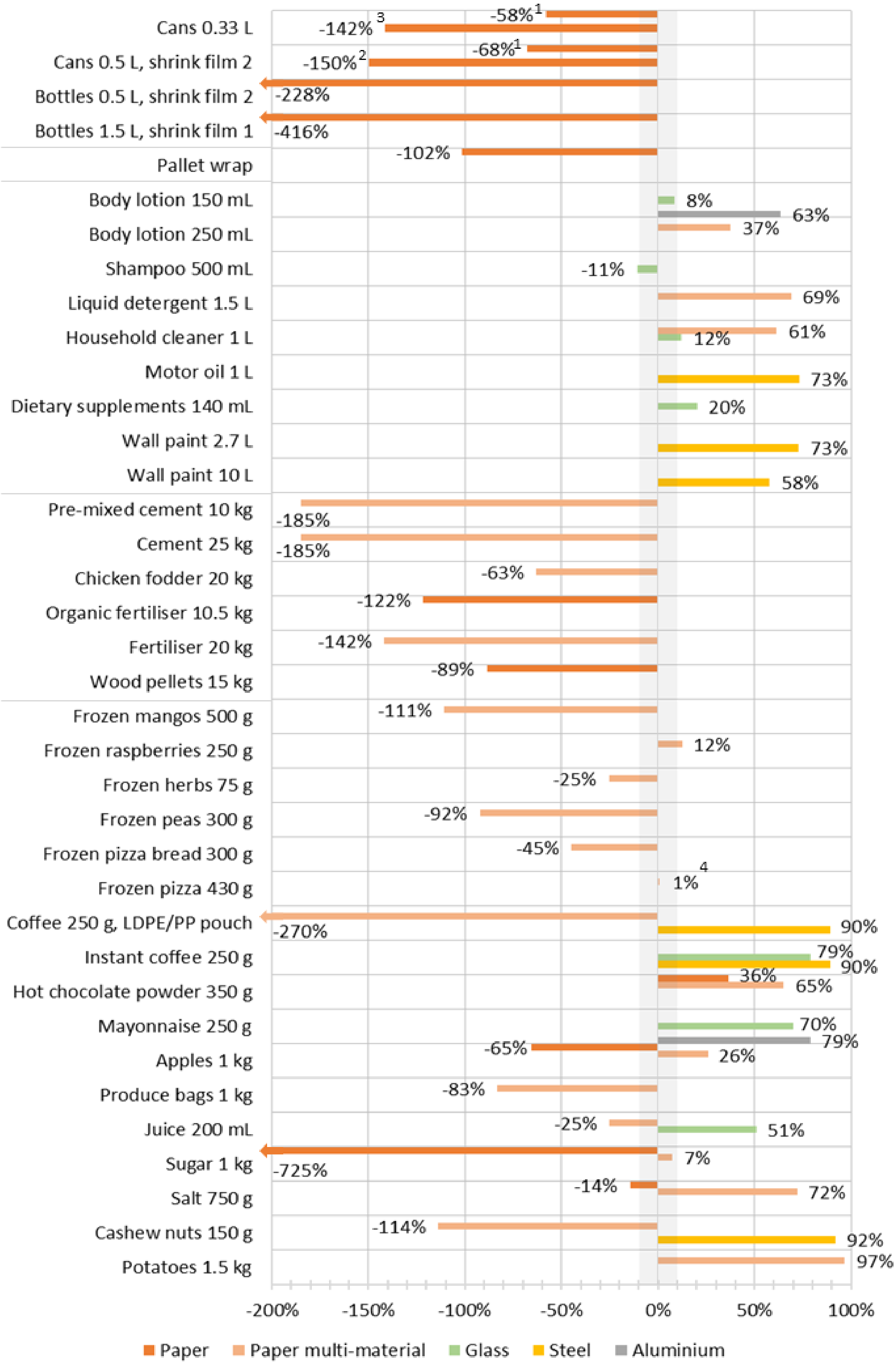


1: paperboard wrap, 2: cardboard carrier, 3: cardboard carrier 2, 4: laminated paper pouch

Figure 1: Substitution potential of PE – climate change. $Substitution\ potential\,\% = (Impact[best\ alternative] - Impact[PE]) / Impact[best\ alternative] * 100$. *"best alternative" is defined as the studied alternative with the lowest potential impact and is shown for all thirty-seven (37) product comparisons. Thirteen (13) additional market alternatives are shown for completeness.*

The study found that PE-based packaging had the potential to lower climate change impact among assessed packaging alternatives examples in 57% of the 37 comparisons. PE-based packaging was found to have lower climate change impact than at least one alternative in all 5 packaging applications studied. Comparative results varied across applications and regions. For collation shrink films, paper-based carrier alternatives were found to generally have lower climate change impacts than PE in the 4 studied comparisons, whereas paper-based wraps were found to generally have higher climate change impacts than PE. PE stretch film for pallet wrapping was found to have lower climate change impact than a paper wrap alternative. For rigid non-food applications, PE-based packaging was found to have the lowest climate change impact in 8 of 9 (89%) comparisons. In heavy-duty sacks, PE had lower impacts than paper and paper multi-material sacks in 1 of 6 (17%) comparisons. PE-based packaging showed significantly lower climate change impact in 11 of 17 (65%) comparisons in the flexible food applications. The study also found that PE-based packaging has more favorable results compared to alternative packaging in a European average market scenario than in Germany or United Kingdom scenarios. This is due to differences in end-of-life dispositions (recycling, incineration and landfilling) and varying transport distances that significantly affect the potential climate change impact of transporting heavier alternative materials.

Water Scarcity

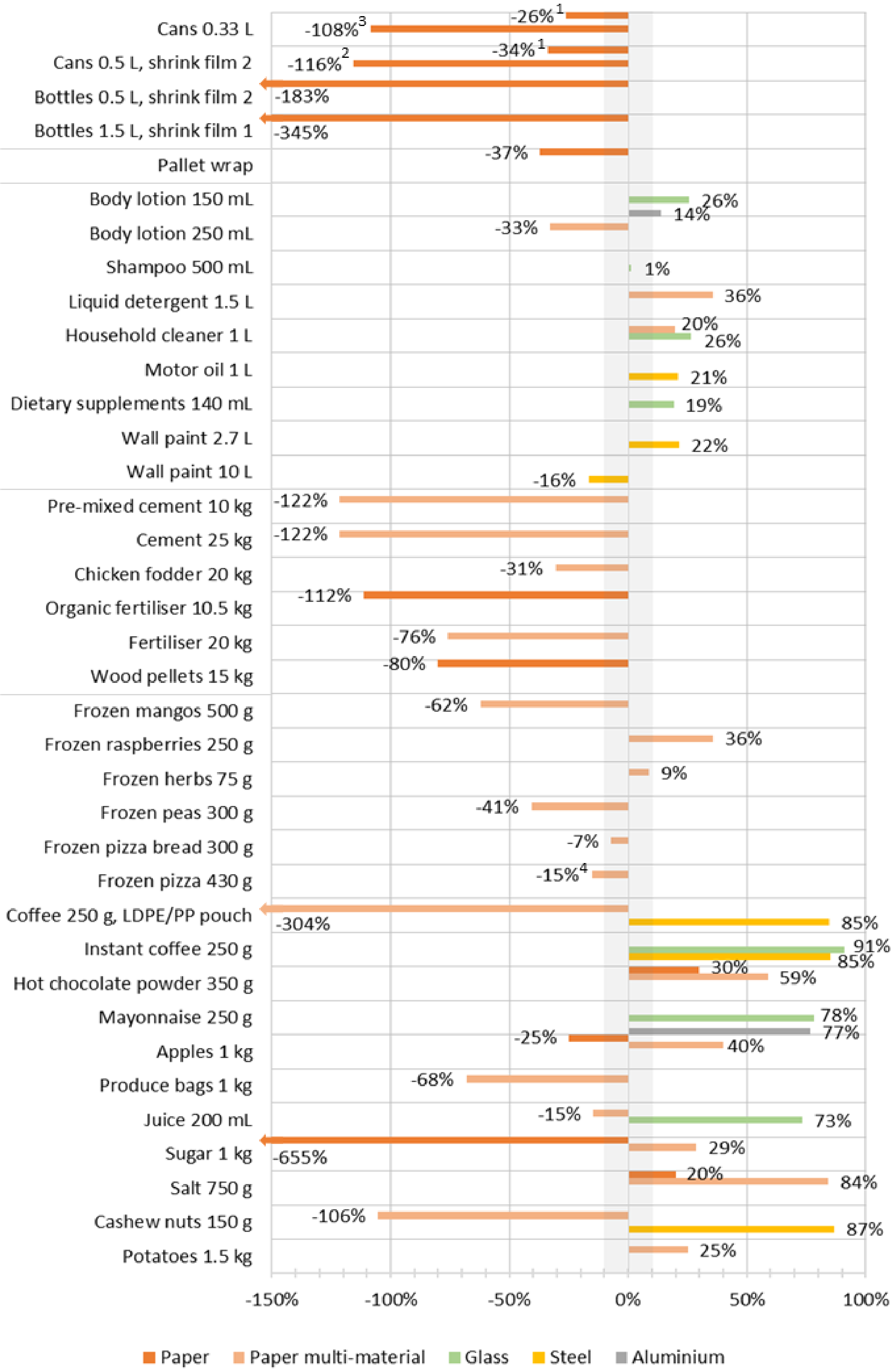


1: paperboard wrap, 2: cardboard carrier, 3: cardboard carrier 2, 4: laminated paper pouch

*Figure 2: Substitution potential of PE – water scarcity. Substitution potential % = (Impact [best alternative] – Impact [PE]) / Impact [best alternative] * 100. "best alternative" is defined as the studied alternative with the lowest potential impact and is shown for all thirty-seven (37) product comparisons. Thirteen (13) additional market alternatives are shown for completeness.*

The study found that PE-based packaging had the potential to lower water scarcity impact among the packaging materials studied in 12 of 37 comparisons. For collation shrink films, PE-based packaging was found to have higher water scarcity impact potential in 4 considered comparisons with paper-based carriers and wraps. The comparative study showed that a paper-based pallet wrap had a lower water scarcity impact than a PE-based stretch film for pallet wrap. In the rigid non-food application, PE-based packaging was found to have lower water scarcity impacts in 7 of 9 (78%) comparisons. In the heavy-duty sacks application, paper and paper multi-material sacks showed lower water scarcity impacts than PE-based packaging in all 6 considered comparisons. PE-based packaging showed a significantly lower water scarcity impact in 5 of 17 (29%) comparisons in the flexible food applications. The study also found that for water scarcity, PE-based packaging formats have higher water scarcity impacts in a European average market scenario compared to Germany and United Kingdom country scenarios. The results were sensitive to geographical location, as the lowest water scarcity impact fluctuates between Germany and the United Kingdom. Assessments of water scarcity need further research because some errors were found. Different methodological and regional characterization approaches for paper and plastics were identified in ecoinvent and openLCA software. For example, in ecoinvent unpolluted water (e.g., cooling water) for LDPE- and HDPE datasets were treated as wastewater whereas for paper datasets (e.g., kraft paper), unpolluted water was treated as elementary flow (and not treated as wastewater). A mismatch of regional characterization of water flows was also identified. Some of these errors were corrected, however, additional validation of water inventories and characterization methods is needed.

Fossil Resource Use



1: paperboard wrap, 2: cardboard carrier, 3: cardboard carrier 2, 4: laminated paper pouch

Figure 3: Substitution potential of PE – fossil resource use. $Substitution\ potential\ \% = (Impact[best\ alternative] - Impact[PE]) / Impact[best\ alternative] * 100$. "best alternative" is defined as the studied alternative with the lowest potential impact and is shown for all thirty-seven (37) product comparisons. Thirteen (13) additional market alternatives are shown for completeness.

The study found that PE-based packaging had the potential to lower fossil resource use impact among the packaging materials studied in 12 of 37 (32%) comparisons. The comparative study showed that paper-based products generally had a lower fossil resource use impact than PE-based packaging for the collation shrink film and stretch film for pallet wrap applications. In the rigid non-food application, PE-based packaging was found to have lower fossil resource use impacts in 6 of 9 (67%) comparisons. In heavy-duty sacks, paper and paper multi-material sacks showed lower fossil resource use impacts than PE-based packaging in all 6 considered comparisons. PE-based packaging showed significantly lower fossil resource use in 6 of 17 (35%) comparisons in the flexible food applications. The study also found that PE-based packaging had more favorable results compared to alternative packaging in a Germany scenario than in a European average market scenario.

Conclusion

This study seeks to offer valuable insights that can support stakeholders and decision-makers in making science-based decisions regarding the potential environmental impacts of PE-based packaging compared to alternative packaging materials such as paper, glass, steel, and aluminium. The study draws the following conclusions:

- Plastics generally have lower potential environmental impacts than glass and metals, except in four cases (in the rigid non-food application) where PE-based packaging has higher or similar water scarcity and fossil resource use than glass and tin-plated steel packaging formats.
- For 57% of the analysed packaging comparisons, PE-based packaging shows a lower potential climate change impact among the packaging material studies, but only in 32% of the cases for fossil resources use, where paper alternatives often have a lower potential impact. However, it should be noted that the potential environmental impact assessment of packaging is a complex process and must be considered case by case.
- Plastics and other materials can enable paper to fulfil packaging functions which may not be met by paper alone. For example, many of the paper-based packaging examples studied were multi-material formulations with plastic layers or components to provide the required performance attributes.
- Sensitivity analysis showed that the weight of the packaging material, end-of-life dispositions, geographical location effects, transport distances, and electric grid mixes are key parameters that influenced the results.
- The study found no distinct trend in which material has the lowest potential environmental impacts. Factors such as packaging material composition and packaging format designs and weights were found to be important parameters in the analyses.
- Increasing recycled material content and recyclability of PE-based packaging, and metal and glass alternative formats show a general trend of reductions in the considered potential environmental impact categories for packaging materials.

Note that use-phase packaging performance differences, such as product shelf-life, breakage rates, and product losses, are excluded from the study and may affect the results.

For more details, refer to: Life cycle assessment of polyethylene packaging and alternatives on the European market - ScienceDirect