A circular multilayer plastic approach for value retention of end-of life multilayers films

D6.2 Life Cycle Assessment - Screening

WP6 - Circular economy – Impact assessment

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Abbreviations

CIMPA.. Circular multilayer plastic approach

EoL.. End of life

GWP.. Global warming potential

LCA.. Life cycle assessment

LDPE... Low density polyethylene

LLDPE.. Linear low density polyethylene

PE .... Polyethylene

PET.. Polyethylene terephthalate

Executive summary

The recycling of multilayer packaging has been a challenge as conventional mechanical recycling will result in a polymer mix with undesired properties. CIMPA intends to tackle this issue by two different scenarios: mechanical recycling and dissolution based physical recycling. Each scenario consists of multiple steps to ensure that a high quality film can be obtained after recycling of a model multilayer film PET/LDPE. In this report, a screening life cycle assessment (LCA) methodology is used to analyse the environmental impact of these two scenarios in comparison to the state-of-the-art (a combination of landfill and incineration with energy recovery) within the European geography. For simplicity, it is assumed that for the dissolution based physical recycling case only the recovered PE is recycled while the PET fraction is incinerated and that the quality of the recycled products in the two scenarios is equivalent, which is very likely to change when more experimental data is gathered.

The result of the LCA screening showed the potential improvement by a 24% decrease in global warming potential (GWP) by using CIMPA technology for mechanical recycling (inclusion of METEOR technology-scenario 2), while using the dissolution based technology (scenario 1) less improvement is observed. The latter originates from lower material efficiency of the dissolution technology as only the PE fraction is assumed to be recycled which needs to be improved. Recycling the PET fraction can provide additional improvements in the material efficiency and the environmental impact. Similarly, the equivalent quality of the recycled product can be a parameter that can impact the results and needs to be confirmed experimentally.

The major difference between the two alternative CIMPA solutions is the use of either dissolution or extensional mixing technology developed by IPC (METEOR) in the recycling steps. METEOR is used to control the morphology of immiscible polymers. During the process, shear rate, extensional flow, ratios of additives and polymers will be adjusted in order to develop best controlled morphologies between lamella and fibril.

The electricity consumption is another factor which leads to higher environmental burdens for both scenarios using six impact assessment categories (particulate matter formation, terrestrial acidification, freshwater eutrophication, terrestrial ecotoxicity, human carcinogenic toxicity and mineral resource scarcity). Using a future (2050) model for electricity grid mix and recycling rate, the environmental performance is improved whereby a 25 and 36% decrease in GWP was achieved in scenario 1 and 2, respectively. An increase in the total recycled material efficiency is recommended to achieve better results. Moreover, the quality of the products need to be taken into account for the future full LCA study using actual properties to allocate realistic credit to the produced films.

Deliverable report

Introduction

Environmental life cycle assessment (LCA) has developed over the last decades and today, is widely used as a tool for supporting technical developments and policies and performance-based regulation. Over the past decades, LCA has broadened to also include life cycle costing (LCC) and social LCA (SLCA). With these developments, LCA expended from merely environmental assessment to a more comprehensive life cycle sustainability assessment (LCSA). Life cycle sustainability assessment (LCSA) refers to the evaluation of all environmental, social and economic negative impacts and benefits in decision-making processes towards more sustainable products throughout their life cycle.

The screening LCA performed shows how the environmental impact of multilayer films can be reduced in the future by using CIMPA technology. This study, for the first time, includes the detailed material flow of multilayer films from cradle to grave and uses future electricity grids to report a fair estimate of recycling potentials. In the next steps, the quality of recycled films is included in the assessment so that the recycled product receives a fair credit for replacing virgin material.

The assessment addresses the full life cycle of multilayer films, for the first time material and energy flow of the films from cradle-to-grave are used. Realistic estimates of recycling technologies are made using future electricity and recycling rate.

Description

The screening LCA is carried out to assess the impact of CIMPA technologies for the waste treatment of multilayer packaging. Two alternative scenarios for PET/LDPE are compared with the SoA EoL treatment which is a combination of landfill and incineration. Both scenarios include washing, sorting and upgrading steps. The major difference between the two alternative CIMPA solutions are the use of either dissolution or extensional mixing technology developed by IPC (METEOR) in the recycling steps. METEOR is used to control the morphology of immiscible polymers. During the process, shear rate, extensional flow, ratios of additives and polymers will be adjusted in order to develop best controlled morphologies between lamella and fibril. Both scenarios include washing, sorting and upgrading steps. The LCA is carried out for European geography. The temporal scope is considered to be in 1) 2021 and 2) 2050. (see Appendix for details)

The use of future electricity grid (International Energy Agency 2021) is only considered for the EoL treatment (and not for the material production) to highlight the advances that CIMPA technologies bring. Table 1 summarizes the scenarios studied in this LCA.

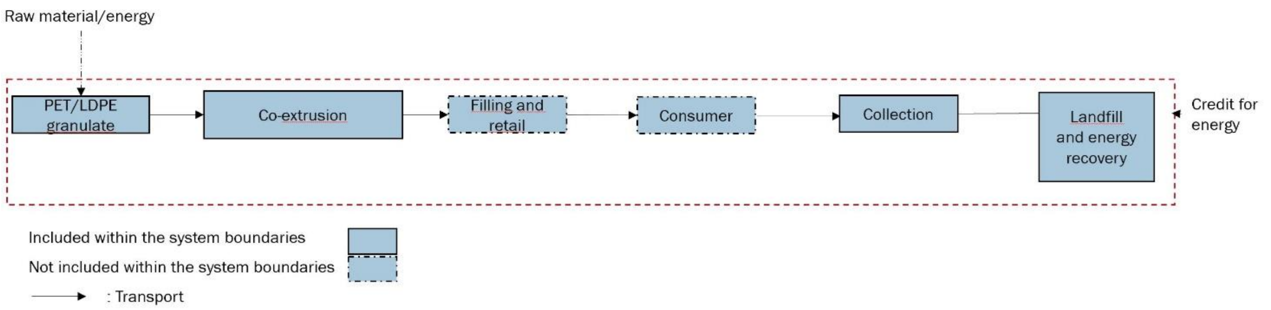

Figure 1. System boundary for the state-of-the-art (SoA) scenario. The end of life (EoL) includes the disposal of the multilayer films (incineration and landfill).

The functional unit for the LCA is **1 m² of a PET-LDPE multilayer film**. The thickness of the PET is 12 micron and LDPE 70 micron. For the screening LCA, two impact assessment methods are considered, namely, **ReCiPe 2016 Midpoint (H)** for calculating environmental impacts and **IPCC 2013 GWP 100a version 1.03 for calculating carbon footprint**.

Conclusion and next steps

CIMPA plans to reduce the impact of multilayers by designing a suitable end-of-life treatment for the packaging and agricultural films. CIMPA proposes two different routes for the waste treatment via a series of treatment steps. These two scenarios are compared to the state-of-the-art using life cycle assessment (LCA). Furthermore, each scenario is studied within two time frames, namely current (2021) and future scenarios (2050).

The result of LCA screening showed the potential improvement by using CIMPA technology for mechanical recycling (inclusion of METEOR technology-scenario 2) by 24% decrease in GWP, while using dissolution technology (scenario 1) did not improve the GWP. These numbers will change in the full LCA, as the effect of PET recycling will improve the dissolution process significantly, making it ideal for high quality and quantity recycling of multilayers.

Using the future (2050) electricity grid and recycling rate, the performance is improved whereby a 25 and 36% decrease in GWP was achieved in scenario 1 and 2, respectively. The 2050 electricity grid contributes to less emissions during the EoL treatment (recycling) steps, while the recycling rate increases the amount of films collected for the recycling and thus the material efficiency.

An increase in the material efficiency is recommended to achieve better results. In the next stages of CIMPA, the quality of the products will to be taken into account to allocate realistic credit to the produced films.

The results although compare two recycling routes for one type of ML film, in the full LCA, each film will be aimed for either mechanical recycling or dissolution. In practice, depending on the composition of the films, the appropriate recycling route can be chosen and then, the LCA will compare the result with the state-of-the art (landfill and incineration) to follow realistic scenarios.

Table 1. Summary of the studied scenarios in LCA for PET/LDPE films (Antonopoulos et al. 2021).

Entry	Scenario ID	Year	Electricity grid mix	Incineration	Landfill	Recycling
1	SoA 2021	2021	2021	56%	47%	0
2	SoA 2050	2050	2050	90%	10%	0
3	CIMPA 2021 scenario1	2021	2021	35%	30%	35%
4	CIMPA 2050 scenario 1	2050	2050	28%	3%	69%
5	CIMPA 2021 scenario 2	2021	2021	35%	30%	35%
6	CIMPA 2050 scenario 2	2050	2050	28%	3%	69%

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Appendix

Table 2. Sources of electricity grid mix for the future scenario (2050) (International Energy Agency (2021)).

Source	Percentage
Natural gas	0.81%
Coal	0.39%
Oil	0.00%
Nuclear	12.40%
Hydro	8.92%
Wind	53.69%
Solar	14.45%
Biomass	8.40%
Other fuels	0.94%
Total	100%