The Consumer Goods FORUM

Plastic Waste

Assessing the Life Cycle Environmental Impacts of Post-consumer Plastic Film Made from Plastic Waste Through Pyrolysis-based Chemical Recycling Technologies

A NON TECHNICAL EXECUTIVE SUMMARY

A paper commissioned by members of The Consumer Goods Forum's Coalition of Action on Plastic Waste

www.tcgfplasticwaste.com

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About The Consumer Goods Forum's Coalition of Action on Plastic Waste

The Consumer Goods Forum ("CGF") Coalition of Action on Plastic Waste was founded in 2020 with the aim of developing a more circular approach to the development and processing of plastic packaging in the consumer goods industry. The development of the Coalition builds of the CGF's 2018 endorsement of the Ellen MacArthur Foundation's New Plastics Economy. As a CEO-led group of 40 committed and innovative retailers and manufacturers, the Coalition's vision of accelerating progress towards the New Plastics Economy is embodied by its central aims for members to work towards implementing impactful measures through multi-stakeholder collaborations that will help make circularity the norm in the industry.

Assessing the Life Cycle Environmental Impacts of Post-consumer Plastic Film Made from Plastic Waste Through Pyrolysis-based Chemical Recycling Technologies

This document is a Non-Technical Summary of an ISO-conformant Life Cycle Assessment (LCA) study commissioned by the Consumer Goods Forum (CGF) on behalf of the CGF member companies in the CGF Plastic Waste Coalition of Action (PWCoA).

The study was carried out by Sphera – a leading provider of LCA services, software and data - and critically reviewed by an independent expert panel composed of Jennifer B. Dunn (Associate Professor at Northwestern University), Llorenç Milà i Canals (Head of Secretariat of the Life Cycle Initiative at the United Nation Environment Program), and Simon Hann (Principal Consultant at Eunomia).

Primary data on pyrolysis-based or related chemical recycling (Py-CR) was provided by three companies. Associated chemical processes to convert the pyrolysis oil into food-grade PE and PP films were modelled using literature data;

The charter of the PWCoA follows the Global Commitment to a New Plastics Economy and is clear that elimination of unnecessary single-use packaging should be the first priority for member companies (including shifting from single-use to reuse models where possible) and recycling is a secondary option for single-use materials that cannot be eliminated.

This document is a non-technical summary written by the CGF Plastic Waste Coalition of Action to communicate the results of the LCA with stakeholders in industry, government, civil society and the wider public. This document has not been critically reviewed by the Expert Panel. Please refer to the full LCA report available on CGF website for more details.

About the CGF Plastic Waste Coalition of Action

The main objective of the PWCoA is to accelerate progress towards the New Plastics Economy Global Commitment. The coalition is currently focused on three priorities:

- Achieving the **broad adoption of plastic packaging design changes** that ensure packaging is designed for a circular end of life, as codified in our 9 'Golden Design Rules'
- **Providing critical and effective support to recycling in priority mature and developing markets through** Extended Producer Responsibility (EPR) programmes for packaging, in line with our principles for Optimal EPR
- **Increasing recycling rates safely,** by providing a complementary recycling "loop" for plastics that are not recycled in practice and at scale in today's system.

As part of this third workstream, we have developed a set of 6 shared principles for the safe scaling of chemical recycling, which are:

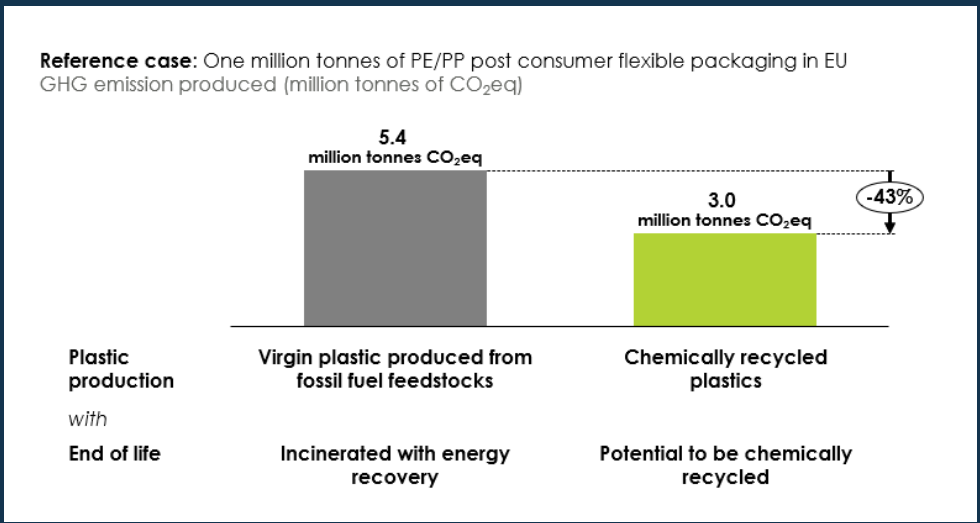
1. **Source of input material** for chemical recycling does not include material that can be economically recycled by mechanical recycling in practice and at scale.
2. **Traceability:** Recycled content is accurately traced using a credible mass balance protocol.
3. **Process yields:** Plastic production from chemical recycling is maximised, with production of other materials (e.g. wax) and fuels de-prioritised
4. **Environmental impact:** The life cycle climate impact of chemically recycled plastics is credibly demonstrated as lower than fossil fuel-based virgin plastics in a comparable system.
5. **Claims** made by companies regarding chemical recycled plastic should be credibly and transparently communicated
6. **Health & Safety:** Emissions and pollution from chemical recycling processes must safely managed

This LCA seeks to assess the environmental impact of pyrolysis based chemical recycling, in line with principle 4.

Summary of LCA Results

Where residual waste is disposed only through waste-to-energy incineration, the LCA shows that expanding pyrolysis-based chemical recycling (Py-CR) for hard-to-recycle[1] plastic packaging waste would reduce overall greenhouse gas (GHG) emissions (see exhibit 1).

Exhibit 1: Climate change assessment results from the LCA analysis[2]



1. Hard-to-recycle plastic packaging waste refers to materials that are not suitable for mechanical recycling
2. Emissions include avoided emissions from incinerations which are described in the technical report

What is Pyrolysis-Based Chemical Recycling (Py-CR)?

Py-CR is a technology which allows the conversion of mixed hydrocarbon-based plastic (i.e. mixed polyethylene, polypropylene and potentially polystyrene) into pyrolysis oil using a thermal process. Pyrolysis oil can be used as input into existing chemical processes such as steam crackers to produce the building monomers of plastic (in this case ethylene and propylene).

Py-CR is the most commercially advanced pathway to recycle hard-to-recycle[1] flexible plastics packaging and other mixed polyethylene polypropylene (PE/PP) waste into food grade PE/PP recycled plastic under current European regulations. Flexible plastic packaging makes up almost 40% of all post-consumer packaging in Europe (by weight)[3] and is mostly made of PE or PP plastics. Scaling up Py-CR would increase packaging recycling rates and enable companies to increase their usage of recycled plastics in products and packaging in line with European policy targets.[4]

Scale-up of Py-CR as a recycling solution for PE/PP post-consumer flexible packaging does not remove the need for packaging elimination, reduction, and reuse following circular economy hierarchy and principles. In the "Vision and Principles" paper published alongside this LCA study, the co-authoring companies from the PWCoA state that Py-CR should contribute to increase overall recycling rates and that input material for Py-CR should not include material that can be economically recycled by mechanical recycling in practice and at scale.

Why Was This Life Cycle Assessment Commissioned by the PWCoA?

In recent years, several reports and position papers have been published on chemical recycling (including Py-CR), highlighting the need for independently assessed LCA analysis of the different technologies to better understand their potential environmental impacts compared to alternative options for plastic manufacturing and end-of-life disposal.

PWCoA member companies believe that Py-CR technologies can only play a role in a circular economy for packaging if it is developed and operated under credible, ethical, safe, and environmentally sound conditions meeting the six principles outlined in our Vision & Principles paper. This LCA study was commissioned to address one of those principles by assessing the potential life cycle environmental impacts of chemically recycled plastics compared to fossil fuel-based virgin plastics that are disposed through waste-to-energy incineration.

3. Breaking the Plastic Wave Europe – forthcoming publication in 2022 – in peer review process
4. For example, the Single Use Plastics Directive requires 30% recycled content in all plastic bottles by 2030

What Are the Main Findings of This LCA Study?

The LCA study is focused on the European Union where demand for food-grade recycled plastic is highest[4] and policy instruments are phasing out landfilling of residual waste[5] in favour of waste-to-energy incineration.[6]

Where residual plastic waste is disposed only through waste-to-energy incineration, the LCA shows that expanding pyrolysis-based chemical recycling (Py-CR) for hard-to-recycle2 plastic packaging waste would reduce overall greenhouse gas (GHG) emissions.

Specifically, the life cycle GHG emissions of PE/PP post-consumer flexible packaging made from plastic waste through Py-CR and potentially recycled through Py-CR at end of life is 43% lower than plastic films manufactured from fossil fuels and disposed through waste-to-energy incineration at end of life.

The study investigates several scenarios to understand the role of key factors such as (1) the role of energy grid mix decarbonization (2) the end-of-life pathway (incineration vs landfill) and (3) the yield of the pyrolysis process.

1. Electricity decarbonization in Europe could further improve the relative benefits of Py-CR to 48% lower than the alternative. This is because waste-to-energy incineration becomes less attractive when the recovered energy substitutes a less carbon-intensive grid mix.
2. Where residual waste is disposed through landfilling instead, the LCA shows that expanding Py-CR for hard-to-recycle plastic packaging waste could increase life-cycle GHG emissions by 20%. This is because plastics in landfills take a long time to degrade and release their feedstock carbon back to the atmosphere. This result should not be misunderstood as an argument for more landfilling of residual waste in Europe, particularly given GHG emissions from non-plastic fractions in residual waste and other environmental impacts from landfills such as fossil resource depletion.
3. Increased yields of pyrolysis process (+5%) have a marginal impact on the results. Higher yields result in a lower amount of plastic waste needed to produce that same tonne of plastic film and higher amount of pyrolysis oil produced at the end of life resulting in 1% lower GHG emissions. However, in the comparative benchmark scenario it results in a lower amount of waste being incinerated initially which also reduces

5. Residual waste refers to waste that will end up being disposed and not recycled
6. The European landfill directive has set to 10% the maximum amount of municipal waste that should go to landfill by 2030

GHG emissions. The net gain is therefore marginal when taking the full system into consideration.

The reality in Europe today is that most member states have a mix of waste-to-energy incineration and landfilling of residual waste. Assuming an average end-of-life pathway based on EU members data (55% landfill and 45% incineration), the life cycle GHG emissions of plastic films made from plastic waste through Py-CR and potentially recycled through Py-CR at end of life is 25% lower than plastic films manufactured from fossil fuels and disposed through an average European end-of-life pathway.

Has CGF commissioned Results for Other Environmental Categories Beyond GHG Emissions?

This report does not study environmental metrics beyond GHG emissions including eutrophication, ocean acidification, ozone layer depletion – all of which are mostly driven by NOx emissions. The methodology used to assess NOx for incineration while being internationally recognized and used across many industries, is based on an allocation model using mix waste of which plastic is just a fraction, creating a virtually low NOx fraction allocated to plastic. The work underlining this report highlighted the need to discuss further the applicability of that methodology when compared to pyrolysis.

What Methodology Was Used to Carry out This Study?

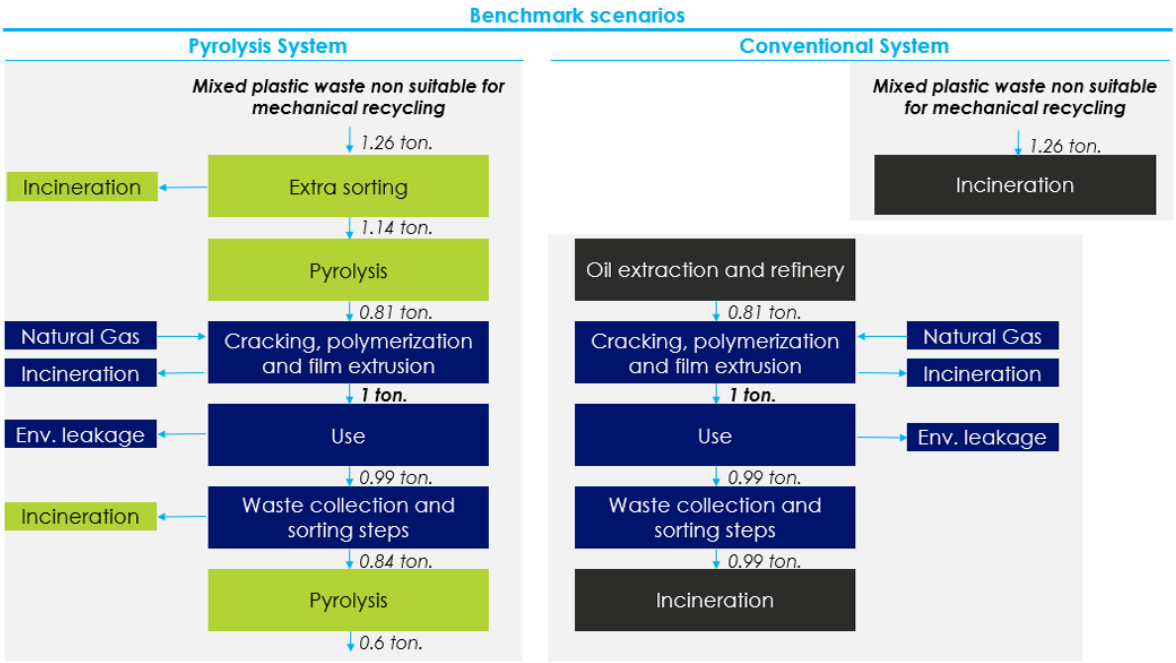
For the purpose of this study, data was collected from three different technology providers each operating pyrolysis or related chemical recycling technologies. Data obtained is based on real-life conditions of processes at different scales.

The study compares the life cycle GHG emissions of PE/PP post-consumer flexible packaging made from plastic waste through Py-CR and potentially recycled through Py-CR at end of life, compared to PE/PP post-consumer flexible packaging manufactured from fossil fuels and disposed with residual waste at end of life (Exhibit 2). It is based on 1 ton of in-use PE/PP flexible packaging.

Different scenarios were explored to understand the impact of (1) improved yields (2) decarbonized electricity grid (3) landfilling as opposed to incineration as an end-of-life disposal pathway.

Whilst this is not presented as a scenario in the LCA study, the results table allows us to assess an alternative “system boundary” where the PE/PP post-consumer flexible packaging is made from plastic waste through Py-CR and disposed through waste-to-energy incineration at end of life with no assumption that any of that material will go on to be chemically recycled after use. In this case, the life cycle GHG emissions would be 23% lower than plastic films manufactured from fossil fuels and disposed through waste-to-energy incineration at end of life.[7]

Exhibit 2: Simplified production to end-of-life mass flow of benchmark scenarios and key sensitivity analyses



Why Is This LCA Analysis Different from Other Studies?

This study has been commissioned by the CGF on behalf of the CGF member companies in the PWCoA which makes it the first study commissioned by a pre-competitive group of plastic users instead of being commissioned or performed by plastic producers. It has been critically reviewed according to ISO 14044 (clause 6.3) by an independent expert panel comprised of an academic, an expert consultant, and an UNEP representative.

The primary data used for the pyrolysis stage of this study is unique empirical data from three different technology providers. Whilst industry average data was used for the conversion of pyrolysis oil to plastics, this data was also validated through comparison against primary data provided by one petrochemical company.

This study aims to understand what the best pathway is to treat hard-to-recycle PP/PE post-consumer flexible packaging. Therefore, the study is constructed around the material use rather than the technology process and includes the entire value chain from production to end-of-life.

This study explores different scenarios to offer full visibility into the impact of different key conditions on Py-CR.

7. These alternative boundaries were not in the scope of work commissioned to Sphera and the analysis is based from the data provided in the technical report (Figure ES-1 p 17)

What Are the Limitations of This LCA Study?

Life Cycle Assessments (LCAs) are an environmental management tool standardized under ISO to evaluate the potential environment impacts of goods and services. This methodology has limitations yet is commonly accepted as a useful tool for decision-making. This LCA study was performed by Sphera, a leading provider of LCA services, software and data, according to ISO 14040/14044 and independently reviewed by third parties.

The geographic coverage of the project is the EU, meaning that underlying assumptions used in this study are based on current European conditions and projections for 2030. It includes among other assumptions made for (1) collection and associated recycling rates, (2) electricity mix and (3) virgin plastic production processes.

This study assumes that pyrolysis oil (the output of Py-CR) and naphtha (the output of the chemical industry used as raw material for virgin plastic) are interchangeable chemical products and results in similar outputs when processed in a typical European steam cracker. To enable a comparison to be made, the study models a "segregated system" where pyrolysis oil is not mixed with virgin naphtha in the cracking process.

There is currently no internationally accepted methodology to include the impact of plastic waste litter and microplastic released in the environment as part of an LCA analysis to date. Therefore, the scenarios and the conclusions of this study exclude any impact of littering and the associated microplastic release in the environment.

Why Is Py-CR Not Compared to Mechanical Recycling in This Study?

It is well-studied that mechanical recycling is less energy intensive and therefore more environmentally beneficial compared to Py-CR. Academic literature reviews have concluded that further comparison of mechanical and chemical recycling is not valuable.[8]

As per the Vision and Principles Paper, it is the view of the PWCoA that Py-CR should contribute to increase overall recycling rates and that input material for Py-CR should not include material that can be economically recycled by mechanical recycling in practice and at scale. [9] Therefore, the study focuses only on assessing the options for mixed plastic waste that are not suitable for mechanical recycling.

This study was conducted as if pyrolysis based chemical recycling is implemented when it is the only viable solution to produce food grade post-consumer packaging films as an alternative to disposal through waste-to-energy incineration.

8. https://www.sciencedirect.com/science/article/abs/pii/S0959652621003838

Conclusion

As Py-CR has grown in prominence as a potential solution for hard-to-recycle plastic waste, the question of life cycle GHG emissions has been a key focus for debate. Like many LCA topics, the question of "would scaling up pyrolysis-based chemical recycling be positive or negative for climate change mitigation?" is more complex than it seems. The answer depends on factors specific to the Py-CR process and the counter-factual production and waste disposal system that would predominate if Py-CR was not scaled up.

The study does not conclude that Py-CR is a silver bullet solution for the plastic waste challenge. It does indicate that in countries that are moving towards high rates of waste-to-energy incineration (which is the policy direction for all of the European Union by 2030) there are likely to be clear GHG emissions benefit from scaling up chemical recycling as a solution for hard-to-recycle plastic waste. The CGF would welcome feedback and engagement on this study and our broader work in the Plastic Waste Coalition of Action.

9. Additional work is needed to define how to safeguard complementarity of mechanical and chemical recycling

About The Consumer Goods Forum

The Consumer Goods Forum ("CGF") is a global, parity-based industry network that is driven by its members to encouage the global adoption of practices and standards that serves the consumer goods industry worldwide. It brings together the CEOs and senior management of some 400 retailers, manufacturers, service providers, and other stakeholders across 70 countries, and it reflects the diversity of the industry in geography, size, product category and format. Its member companies have combined sales of EUR 4.6 trillion and directly employ nearly 10 million people, with a further 90 million related jobs estimated along the value chain. It is governed by its Board of Directors, which comprises more than 55 manufacturer and retailer CEOs. For more information, please visit: www.theconsumergoodsforum.com.

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