PIONEER PROJECT

Lodestar: A case study for plastics recycling

Designing a model for an 'all plastics' sorting and recycling facility combining mechanical and chemical recycling

The concept of a circular economy is gaining traction all over the world. We need to move away from the linear plastics economy, where we take, make, and dispose of plastic - towards a circular system, where we keep useful plastics in the economy and out of the environment.

To keep plastics in circulation, we will need a combination of practices and methods. In addition to the elimination of problematic and unnecessary plastics, and switching from single-use to reuse models, one important method is recycling. However, today only a very small fraction of plastic packaging is actually recycled. So, if we want to develop a circular economy for plastic packaging, innovation, in terms of suitable collection systems, and recycling facilities, are required.

A conventional Plastics Reprocessing Facility (PRF), relies on mechanical recycling only. In such facilities, a significant share is sent to incineration or landfill. With the aim of increasing the amount of plastics in circulation, away from landfill, incineration, or waste-to-energy, Project Lodestar investigates the potential advantages of combining mechanical and chemical recycling in a single facility. This is done through a desktop modelling exercise of a so-called advanced Plastics Reprocessing Facility (a-PRF). Using the plastic waste composition of Scotland from WRAP[1], material flows, yields, economics, and environmental impacts are modelled.

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Mechanical and Chemical recycling[2]

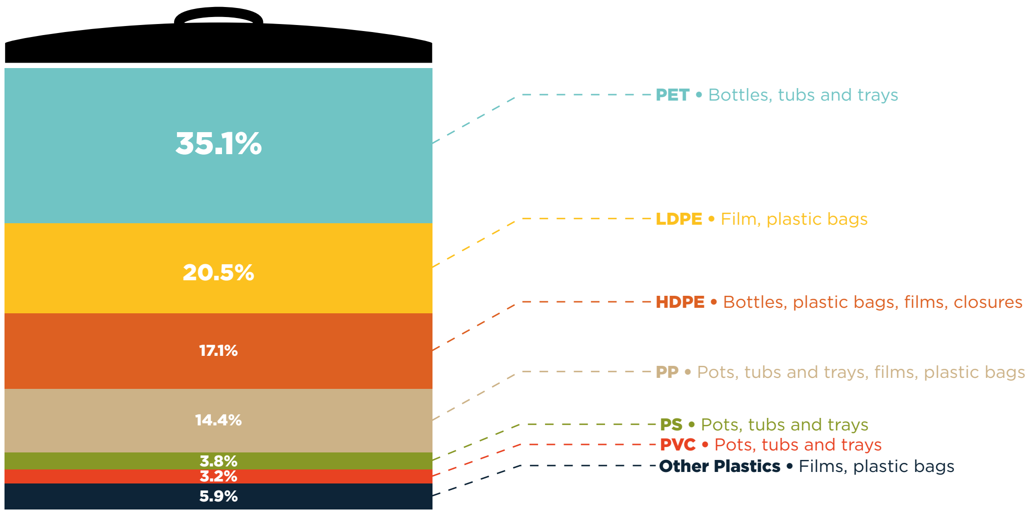
Mechanical Recycling: Operations that restore after-use plastics via mechanical processes (grinding, washing, separating, drying, re-granulating, compounding), without significantly changing the chemical structure of the material.

Chemical recycling: A process to break down polymers into individual monomers or other chemical feedstock that are then reused as building blocks for new polymers (not for waste-to-energy).

Methodology

The PRF and a-PRF model design was based on the assessment of currently available and proven sorting and mechanical recycling technologies. For the a-PRF model, an additional chemical recycling unit (in this case thermal cracking) was incorporated as well. As a result, rejects from mechanical recycling could - in theory - be chemically reprocessed on site into feedstock for new material. The input stream for the models is based on a combination of plastic waste from households and industry in Scotland.[1] In order to optimise the capture of plastic packaging, it was assumed that a separate bin collected all unsorted plastic packaging waste, directly from the consumer and deposited it as the feed for the a-PRF. The project analysis used the current material composition of Scotland to determine the mix of polymer types (e.g. PET, LDPE, PVC, HDPE, PP, PS, etc.) and formats (e.g. pots, tubs, films, etc.). Three a-PRF options were investigated, modelling different material flows and yields by using varied mechanical recycling equipment in different configurations. The a-PRF model with the highest economic return was then examined further for optimisation and sensitivity analysis. The project sought to develop a design for the a-PRF, with the capacity of the facility set to 20,000 tonnes input of plastic packaging waste per annum to achieve a payback on investment of approximately three years. *Further information on methodology (set-up, assumptions, evaluation of the models) is available in the "Technical Appendix - Pioneer Project Lodestar" which can be acquired upon request by writing Recycling Technologies (email: bronwen.jameson@rtech.co.uk)*

Basket of Plastics (BoP)



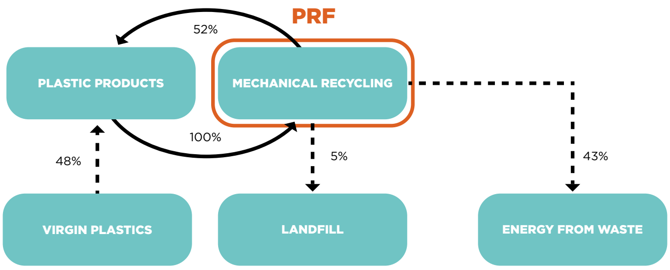
Basket of plastics showing the composition of the input stream for the PRF and the a-PRF models. The input is based on a combination of household and industrial waste composition of Scotland 2016.[1]

The modelling of the PRF and the a-PRF showed that combining mechanical and chemical recycling processes could increase the fraction of plastics kept in circulation - instead of being lost to landfill or incineration - with both economic and environmental benefits. While both the PRF and the a-PRF are able to mechanically recycle 52% of the input into recycled polymer flakes and send 5% (mainly PVC) to landfill, the PRF sends the remaining 43% to incineration, while the a-PRF sends this fraction through chemical recycling and reprocessing. Here, according to the model, 14% could be converted back to plastics, 18 % into other materials, with the remaining 11% being used for internal fuelling. All these figures could be improved with better product design and material choices (e.g. eliminating PVC from packaging).

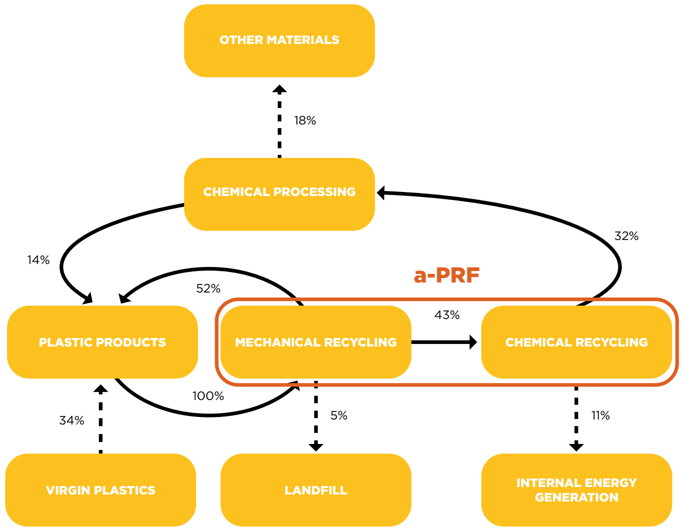
Further research and pilot tests are needed to confirm the benefits found in this modelling project, in particular to ensure that the output from chemical recycling can actually be converted back into new plastics in a viable way.

1. *Plastics Spatial Flow, Valpak & WRAP (June 2016)*
2. *Adapted from World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company,* **The New Plastics Economy — Rethinking the future of plastics** *(2016).*

MATERIAL FLOWS - POLYMER REPROCESSING FACILITY (PRF)



MATERIAL FLOWS - ADVANCED POLYMER REPROCESSING FACILITY (PRF)



Amount of plastic circulated for the PRF and the a-PRF model.

The modelling suggests that keeping non-mechanically-recycled plastic materials in the economy, with chemical reprocessing technologies, could bring an economic advantage over incineration and landfilling in regions with landfill taxes and gate fees for incineration. For the a-PRF facility modelled at 20,000 tonnes per annum, the potential revenue generated from the sale of the products from chemical recycling could enable the a-PRF overall revenue to increase by 25%, decreasing the payback of the facility by 11% in comparison with a traditional PRF set-up[3].

The study also suggests that there could be an environmental benefit in reprocessing plastics into feedstock for new materials rather than incinerating it for energy recovery. Unlike plastic waste going to waste-to-energy, chemically recycled plastics could reenter the economy, whilst benefiting from a lower carbon footprint of chemical recycling in comparison to incineration. This could result in a 21% decrease in the carbon footprint calculated between a PRF and an a-PRF[4].

Compared to mechanical recycling alone, modelling suggests that an a-PRF could increase revenue by 25% and decrease the payback time of the facility by 11%

3. That is assuming a cost of 100 £/t of waste-to-energy and landfilling + tax (source: https://www.letsrecycle.com/prices/efw-landfill-rdf-2/).

4. The Global Warming Potential was calculated comparing a traditional PRF with flows from the mass balance analysis: 100% into PRF, 52% mechanically recycled into r-pellets, 43% sent to incineration, and 5% sent to landfill. The a-PRF flows were: 100% into a-PRF, of which 52% was mechanically recycled into polymer flakes (r-polymer flakes), 43% was sent to chemical recycling (via thermal cracking), and 5% was sent to landfill. The hydrocarbon fraction out of chemical recycling (32% of total material) is sent to downstream processing into r-polymer flakes, via a steam cracker and other downstream processes. The analysis assumes a constant mass, so that material lost through incineration is replenished by virgin material.

As the project unfolded, it was re-confirmed that in order to build a plastics system that works, better recycling facilities need to go hand in hand with better packaging design and comprehensive collection systems. For Lodestar, the group assumed a collection system for households in which all plastic packaging is collected in one single bin, regardless of format. In Scotland, where only some types of plastic packaging are collected for recycling, a collection system for households in which all plastic packaging is collected has the potential of capturing more. Residual household plastic packaging that is not collected for recycling today represents a share of 69%[1] of the total household plastic waste in Scotland.

Additional design changes with respect to material combinations and formats would further enable a larger share of plastic packaging material to be reprocessed back to plastics. For example, post-consumer PVC contained in packaging waste is currently not mechanically recycled, contaminates mechanical recycling streams of other plastics, and is only processed to a limited extent through chemical recycling methods. If PVC were designed out of plastic packaging, this would increase overall recycling rates.

In addition, the regional context plays a substantial role in indentifying end markets for recycled plastics.

Project Lodestar, which brought together experts from the whole plastics value chain, demonstrated the importance of transparency and cross-industry dialogue. In order to investigate other ideas, technologies, designs, etc. that can contribute to creating a circular economy for plastics, more multi-stakeholder initiatives are needed. For example, while there is theoretical evidence for the potential of converting oils from the chemical recycling of plastics back into feedstock for plastics, further research and investments (as well as initiatives between recyclers, academia, and downstream processing industries) are needed in order to ensure that maximum output from chemical recycling is actually used to create new materials in a viable way. In the same vein, collaboration between policymakers, cities, municipal authorities, and industry is needed in order to innovate and design better packaging and comprehensive collection and reprocessing systems.

CONTRIBUTORS TO PIONEER PROJECT LODESTAR

Pioneer Project Lodestar was lead by Recycling Technologies and facilitated by the Ellen MacArthur Foundation. The participant group consisted of representatives from Borealis, Coca-Cola, EcoldeaM, ExcelRise, Danone, Impact Solutions, Mars, NexTek, Recycle BC, NatureWorks, Re-Poly, Swire Beverages, Unilever and Zero Waste Scotland.

PIONEER PROJECT

WHAT ARE PIONEER PROJECTS?

Today's plastics system face challenges that no organisation can address alone.

Pioneer Projects are pre-competitive collaborations that are led and run by participants of the New Plastics Economy initiative and invite stakeholders from across the plastics value chain to design and test innovations that could change the way we make, use and reuse plastics.

The **New Plastics Economy** Initiative is an initiative led by the Ellen MacArthur Foundation. A foundation that works with business, government and academia to build a framework for an economy that is restorative and regenerative by design.

The **Ellen MacArthur Foundation** is not to be held responsible for any output from the Pioneer Projects. It solely focuses on facilitating the setup, engaging in the process and encouraging circular thinking and a systems perspective.