MURA TECHNOLOGY

WMG Life Cycle Assessment of HydroPRS™

Frequently Asked Questions

The Future of Sustainable Advanced Plastic Recycling

MAY 2023

Overview

Researchers from Warwick Manufacturing Group (WMG) at the University of Warwick have generated a first Life Cycle Assessment (LCA)[1] of the hydrothermal advanced recycling process, **HydroPRS**™. Mura's study is a so-called gate to gate (end of waste) model, assessing the environmental impacts arising from the operation of the first commercial-scale **HydroPRS**™ plant design, under construction at Wilton, Teesside, UK.

Innovate UK have funded WMG under a grant awarded through the Smart Sustainable Plastic Packaging (SSPP) Demonstrator Round 1 funding[2]. This is an independent LCA and the academic paper represents their work alone, independent of funding from Mura Technology.

WMG
THE UNIVERSITY OF WARWICK

UKRI Innovate UK

Purpose of Life Cycle Assessment

The purpose of the LCA is to:

- Understand the environmental impact of the **HydroPRS**™ process
- Support optimisation of all operations to reduce environmental impacts
- Identify potential improvements to energy and resource management
- Set a clear course to meet Mura's ambition for Net Zero

Scope of the LCA – Boundary Conditions

The LCA focuses on the advanced recycling activity at Wilton, Teesside, the first commercial scale **HydroPRS**™ plant, creating a model in which different options for improvements can be made. Whilst the focus of the LCA is Global Warming Potential (GWP) expressed in CO_2 equivalents (CO_2 eq.),[3] other impact categories are also presented. All background data sets relate to the UK grid and plant operations.

The boundary conditions encompass:

- **Transport** - of waste plastic feedstock to the Wilton site from Mura's aggregator, Geminor.
- **Material Preparation Plant** - plastic feedstock preparation stage, to remove materials (metals, glass, paper, cardboard and non-target plastics such as PVC) co-mingled with waste polyethylene and polypropylene plastics. This stage also removes grit and dust and other non-plastic contamination.
- **HydroPRS™ plant** – the hydrothermal liquefaction process which takes the prepared waste plastic feedstock and under supercritical conditions, cracks the plastic polymers into short-chain hydrocarbons. Following the reaction, the depressurisation flash distils the hydrocarbons into discrete products. The LCA also accounts for the recovery of process gas for the heating of the supercritical boiler.

Overview and Context of the Results

- Diverting plastic destined for Energy from Waste (incineration) into **HydroPRS**™ leads to c. 80% carbon emission savings and the production of recycled hydrocarbons for sustainable chemicals.
- Avoided carbon emissions created by Energy from Waste are significantly greater than the carbon intensity of producing recycled or equivalent virgin fossil naphtha.
- Carbon intensity of the **HydroPRS**™ naphtha fraction is equivalent or less than virgin fossil sourced naphtha.
- Use of renewable energy (such as wind) leads to further significant reductions in GWP of over 50%, indicating a clear pathway to further decarbonise the process and the circular plastic and chemicals economy.
- All results from WMG relating to GWP have been reported in kgs. For ease of communication, we have converted to tonnes.

1. Ozoemena, M and Coles S, (2023) Hydrothermal treatment of waste plastics: an environmental impact study. Journal of Polymers and the Environment., https://doi.org/10.1007/s10924-023-02792-3
2. Grant number 49801
3. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Carbon_dioxide_equivalent

1. Diverting Plastic from Waste-to-Energy (Incineration) into HydroPRS™ Leads to Significant Carbon Emission Savings

The paper presents a high-level assessment that expected emissions from burning waste plastic are reduced by approximately 80% by recycling waste plastic into hydrocarbons – with naphtha as a reference product.

In net terms, this is a GWP saving of approximately 1.86 tonnes CO_2 eq., per tonne of plastic waste entering the site at Wilton, a so-called 'counterfactual' credit. For the site as a whole, the expected 21,550 tonnes of waste plastic to be processed per year would lead to GWP savings of c.40,000 tonnes CO_2 eq. annually.

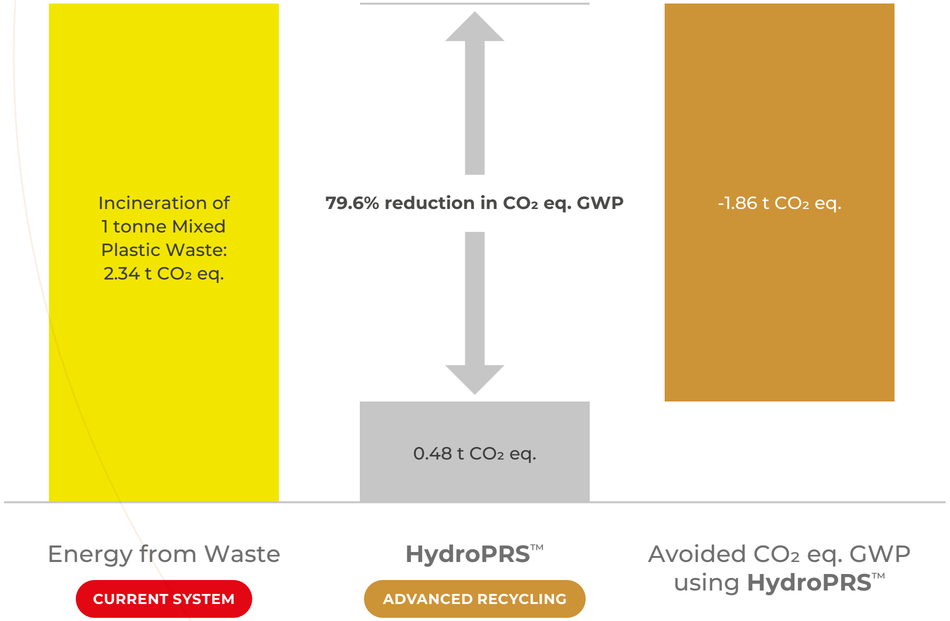
These results are consistent with two further LCA reports. These are:

- EU Commission's Joint Research Centre, which shows a reduction of c. 60% emissions of **HydroPRS™** compared to Energy from Waste (February 2023).
- Consumer Goods Forum , which shows a reduction in GWP of 2 tonnes CO_2 eq. but over the full life cycle of polyethylene. Put simply, the study demonstrates clear carbon savings by recycling the so-called unrecyclable plastic waste into hydrocarbons (April 2022).

Calculation

- GWP from incineration, per tonne of mixed plastic waste: **2340 kg CO_2 eq**
- GWP per tonne of waste plastic processed by **HydroPRS™**: **478 kg CO_2 eq**
- Carbon emissions avoided: 2340-478 = **1862 kg CO_2 eq**
- **% Carbon emissions avoided: 1862/2340 x 100 = 79.6%**

Figure 1: GWP (Global Warming Potential) Impact from Processing 1 Tonne Mixed Plastic Waste (Tonnes CO_2 eq. GWP).



Ozoemena, M.C and Coles, S.R, WMG at the University of Warwick, February 2023, Hydrothermal Treatment of Waste Plastics: An Environmental Impact Study, Journal of Polymers and the Environment.

Further consequential LCA work is underway to quantify the energy replacement equivalent for the removal of plastic from incineration and the carbon benefits of producing the full range of hydrocarbons generated by **HydroPRS™**.

2. Outperforming Virgin Fossil Production - Comparison between Fossil Naphtha and Naphtha Produced from HydroPRS™

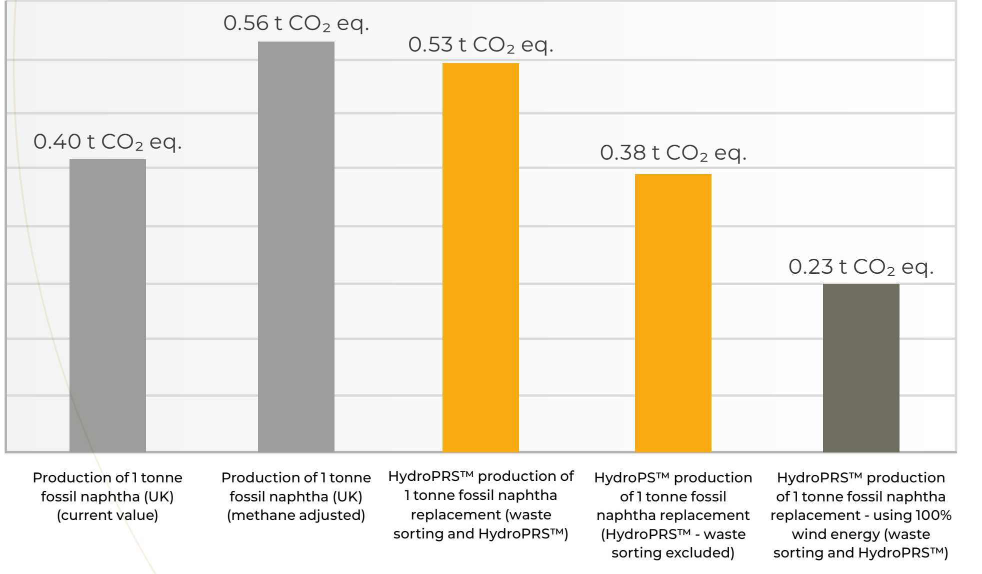
When comparing the production of 1 tonne of naphtha fraction from the **HydroPRS™** process (excluding the MPP, Material Preparation Plant to sort the waste plastic) with fossil naphtha, the value for **HydroPRS™** is **0.38 tonnes CO_2 eq.**, with the comparator fossil naphtha at **0.4 tonnes CO_2 eq.**, indicating a lower carbon footprint for Mura's hydrocarbon naphtha product.

The academic paper also notes that the value for fossil naphtha is set to be revised upwards, reflecting more accurate fugitive methane emissions from oil extraction and refining processes. Estimates are an increase of 25-40%[4] of the current fossil naphtha GWP, taking the value of currently expressed GWP from **0.4 to 0.5-0.56 tonnes CO_2 eq.**, making the margin for savings from **HydroPRS™** greater. When combining the MPP sorting stage with the **HydroPRS™** process, the impact is **0.53 tonnes CO_2 eq**. GWP, which brings the fossil and recycled naphtha fraction within the same range for the full process.

The paper notes that improvements to the overall waste sorting for residual plastics to improve bale quality can reduce burdens on the MPP, therefore improving efficiency for the overall **HydroPRS™** operation (noting no credit was given in the LCA to the MPP process from other recyclates, such as metals, removed from the waste plastic feedstock).

Note: results expressed in the paper in relation to production of naphtha are based on 895kg waste plastic input to the **HydroPRS™** process (105 kg is estimated to be removed from the 1 tonne entering the Material Preparation Plant). In Figure 2, the bar chart is normalised for 1 tonne output of products for ease of comparability.

Figure 2: GWP Impact from Production of 1 Tonne of Naphtha Replacement (Tonnes CO_2 eq. GWP, per Tonne of Product)



4. https://www.nature.com/articles/s41586-020-1991-8

3. How Does the Life Cycle Assessment Help with the Transition to Low Carbon Production of Chemical Feedstocks?

Reducing a carbon footprint starts with reducing consumption of energy. Mura is working now to examine Scope 1 emissions on site and how they can be reduced through energy efficiency measures such as heat recovery and the recycling of process gas that is currently recovered on site to provide energy to generate supercritical steam.

Figure 2 (previous page) also shows the impact of reducing Scope 2 emissions – energy generation – using wind sourced renewable energy. The GWP of sorting the plastic waste, plus the **HydroPRS™** plant falls by more than 50% over the current UK grid, heralding the potential for decarbonising waste plastic recycling and chemical and plastic production over using virgin fossil sourced material.

Calculation

GWP for production of 1 tonne naphtha if renewable (100% wind) energy was deployed:

Material Preparation Plant + HydroPRS™ output (0.895 tonnes output) = 0.204 t CO_2 eq.

Convert value to 1 tonne for comparative purposes: (0.204 /0.895) = 0.23 t CO_2 eq.

4. LCA Underpins Mura's Net Zero Ambitions for all Sectors in the Circular Economy

The results presented in the paper indicate a pathway to Net Zero for the **HydroPRS™** technology, supported by a transition from the current electricity grid mix to a renewable energy source, as well as reducing Scope 1 emissions on site through energy efficiency measures such as heat recovery. Mura is developing further projects in the United States and Germany where electricity is in scope to be supplied from renewable energy sources – hydroelectric (United States) and wind (Germany).

In addition, the substantial remaining component of carbon emissions relates to the consumption of process gas generated through the recycling of the waste plastic. Mura is now working with partners to be able to take this gas for onward processing into products, as opposed to recovering this gas for energy generation.

Recycling the gas and instead replacing the use of gas through the electrification of the heating process will have the potential to reduce the GWP of the overall process. Following this transition, residual carbon emissions would largely be from the transport of materials and minor deposits of grit and dust to landfill.

Put simply, this initial LCA of the first commercial scale **HydroPRS™** plant sets out a clear pathway for advanced recycling to produce low carbon recycled hydrocarbons and to reduce the carbon emissions for the Energy from Waste, recycling, chemical production and downstream user sectors such as packaging or automotive.