

PLASTICE

New technologies to integrate PLASTIC waste in the Circular Economy

Training materials

Module 2: Testing the technologies

Unit 2.4: Hydrothermal liquefaction of plastic waste for olefins recovery: A technoeconomic feasibility study



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement n° 101058540.

Module 2

This module is composed of four units, each showcasing innovative approaches to plastic and textile waste recovery. The units present real-world demonstrations of how emerging technologies can support a circular economy through scalable and sustainable solutions. These include:

- Unit 2.1: Demo-sites for gasification and chemical post-treatment: enabling innovation in circular plastic technologies
- Unit 2.2: Pilot-scale plant for Microwave-Assisted pyrolysis of plastics for oil obtention
- Unit 2.3: Enzymatic hydrolysis: Demonstrating mixed textile-waste recycling at pilot scale
- **Unit 2.4: Hydrothermal liquefaction of plastic waste for olefins recovery: A technoeconomic feasibility study**

These technologies have been developed and validated within the framework of the PLASTICE project, funded by the European Commission, which aims to promote circular solutions for plastic waste valorisation through chemical recycling.



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Unit 2.4

Hydrothermal liquefaction of plastic waste for olefins recovery: A technoeconomic feasibility study

*A comparative techno-economic analysis of hydrothermal liquefaction (HTL) coupled with steam cracking was conducted to evaluate its **potential to produce light olefins** (ethylene and propylene). The results indicate that the process produces 39.4 wt.% ethylene and 19.9 wt.% propylene at the optimal conditions of 450 °C, 230 bar and 30 min. Under these optimized conditions, the olefin yield also contributes to **favorable production costs**: 1.6 €/kg for ethylene and 3.1 €/kg for propylene. Notably, the plant achieved a return on investment (ROI) of 8.2% and a payback period of 3.1 years, highlighting strong economic potential. These findings underline the promise of advanced polyolefin upcycling routes for integrated olefin recovery and **decarbonization within the chemical industry**.*

Key points

- Hydrothermal liquefaction of plastics waste for olefins production.
- Techno-economic feasibility in terms of lower ethylene cost and payback.
- A circular economy approach for polyolefin upcycling route.



Introduction

In the quest for a circular economy, hydrothermal liquefaction (HTL) can be a promising technology within thermochemical recycling methods for **plastic waste valorisation**. HTL operates in the presence of water, typically near its critical point (>400 °C and 180-230 bar), which **eliminates the need for feedstock drying and enhances reaction kinetics** (Boel et al., 2024). The process predominantly converts plastic waste into oil and gas, with minor char production. The products can be further integrated with downstream cracking units (e.g., steam cracking, catalytic cracking, etc.) to maximise the yield of target products such as olefins.

Our lab-scale study on hydrothermal liquefaction (HTL) (Chien et al. 2025) of HDPE-based plastics waste has demonstrated that **it can efficiently convert plastics waste into high yields of oil and gaseous products**. To further demonstrate commercial viability, a detailed techno-economic analysis (TEA) was conducted, and the results are presented in this module.

Hydrothermal liquefaction (HTL) integrated with steam cracking for light olefins and electricity production

To practically assess the potential of hydrothermal liquefaction (HTL) as an advanced recycling technology, this section presents the case study developed by the University of Amsterdam. The model integrates the HTL stage with a **steam cracking unit** and an **energy recovery system**, with the aim of producing light olefins (ethylene and propylene) and electricity from mixed plastic waste. The following sections describe the materials used, the process configuration, and the main techno-economic results.

Materials

Mixed plastics waste, composed of 91.1% polyethylene (PE), 4.1% polypropylene (PP), 0.12% polystyrene (PS), 3.3% paper, and 1.38% metals, was selected as the feedstock for this study on hydrothermal liquefaction (HTL) integrated with steam cracking, targeting the co-production of olefins and electricity. The waste sample was sourced from COGERSA, a partner in the *Plastice* project, based in Asturias, Spain.

Plant process

The entire process plant can be divided into five (5) stages:



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(i) **hydrothermal liquefaction system**, (ii) **steam cracking unit**, (iii) **gas chilling section**, (iv) **distillation and fractionation columns**, and (v) **steam turbine unit**, as shown in Figure 1

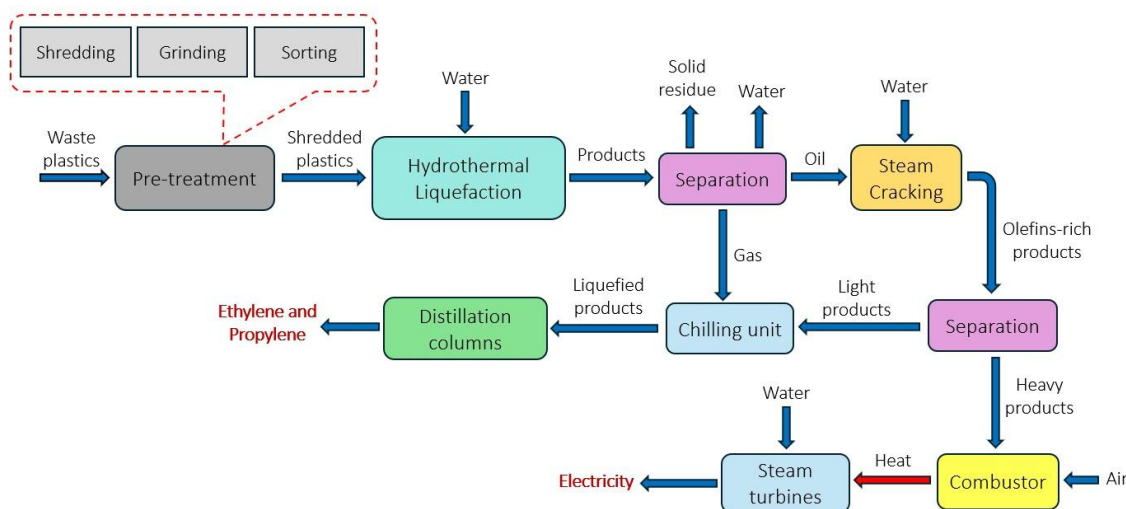


Figure 1: Simplified layout of a plant producing olefins and electricity from plastic waste using the hydrothermal liquefaction process.

The pre-treated plastics feed, along with a stoichiometrically adjusted amount of water, is introduced into the hydrothermal liquefaction (HTL) reactor, and heated up to the temperature of 450 °C and pressure of 230 bar for 30 minutes. This process results in the production of a high fraction of oil and gas, with a minor portion forming solid residue (char).

Following the removal of char, the resulting oil fraction is directed to the steam cracking unit (SCU) for further upgrading. The SCU functions at elevated conditions of 850 °C and 1 bar, facilitating the thermal cracking of heavier hydrocarbons (C_4 – C_6) and high-boiling oil compounds (C_6 – C_{20}) into lighter gas mixtures, predominantly C_1 – C_4 . The steam cracker is heated with the combustible gases obtained from burning the other undesired gases (C_1 – C_4) and heavy oil (C_6 – C_{20}) from the process.

Three distillation columns are employed to separate gases based on carbon number (C_1 , C_2 , C_3 , and C_4), while two fractionation columns separate gases within the same carbon number, specifically C_2H_4/C_2H_6 and C_3H_6/C_3H_8 . All final products achieve a purity exceeding 99%.

After the recovery of the targeted olefins (ethylene and propylene), the residual gaseous fractions, including H_2 , CH_4 , C_2H_6 , C_3H_8 , and C_4 hydrocarbons, are combusted in a high-temperature combustor at 1650 °C. The heat generated drives steam production, which powers a two-pressure-level steam turbine unit (STU), facilitating electricity generation (Mallick et al. 2025).



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Techno-economic results

The hydrothermal liquefaction reactor exhibited the highest energy demand at 47%, followed by the steam cracker (25%) and distillation columns (15%) towards the plant's total energy consumption. It is to be noted that the steam cracker and reboilers are heated by burning unconverted gases and heavy oil and therefore, are not considered in the energy consumption calculation. The elevated power demand in these separation units arises from high-temperature chemical reactions, high reflux ratios and distillate flow rates needed for the effective recovery of light hydrocarbon gases (C_1 – C_4).

CAPEX: Direct costs account for approximately 80% of the fixed capital investment (FCI), with equipment costs constituting the largest portion (42.5%), followed by instrumentation and control (12%). Indirect costs represent the remaining 20% of FCI and are evenly distributed among engineering, construction, contractor fees, and contingency.

OPEX: Direct production cost contributes 57.63%, while general expenses, including administrative overheads, distribution and marketing, and research and development, constitute 20.94% of the OPEX.

The production cost of ethylene and propylene is found to be 1.55 €/kg and 3.07 €/kg, respectively, with a return on investment (ROI) of 8.2% and a payback period of 3.05 years. The higher CAPEX involved with the HTL process impacted the payback despite higher olefins production. However, selling the products at the market price will drop the ROI and increase the payback drastically.

Conclusion

In conclusion, the integration of HTL with steam cracking offers a promising route for converting plastic waste into high-value olefins and electricity at a commercial scale. From the technical point of view, the feeding of wet plastic mix into the HTL reactor has proven to yield more ethylene in the gas phase and lighter oil fractions.

The economic assessment pushes the HTL process slightly on the higher side, primarily due to the involvement of high equipment cost (~40% of CAPEX).

Policy recommendations



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Before claiming feasibility credits, the study requires more engagement with certification bodies and policymakers. However, with continued technological development, increased market acceptance, and heightened investor awareness, both CAPEX and OPEX are expected to decrease, enhancing overall economic viability. These can be done via:

- (a) **Social benefit** - promoting emerging HTL technology as a potential for the circular economy.
- (b) **Economic and environmental benefit** - integration of electrified systems in the process at lower renewable energy prices for long-term sustainable operation.

Bibliography

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NEXT

MODULE 3

**Policy Alignment – Towards a Coherent and Supportive
Framework for Plastic Recycling**



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