

PLASTICE

New technologies to integrate PLASTIC waste in the Circular Economy

Training materials

Module 2: Testing the technologies

Unit 2.2: Pilot-scale plant for Microwave-Assisted pyrolysis of plastics for oil obtention



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

MODULE 2 Overview

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: Demo-sites as innovation hubs for startups and academic entrepreneurs

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 2.2

Pilot-scale plant for Microwave-Assisted pyrolysis of plastics for oil obtention

The MW-assisted pyrolysis procedure described in module 1 is physically represented in CIRCE's use case within the PLASTICE project for valorising plastics. This model offers an alternative for reintroducing such waste into the value chain. Given the centre's accumulated experience in microwave-assisted pyrolysis (Fresneda-Cruz et al., 2025), an intermediate-scale model is proposed to test the efficiency and scalability of a continuous feeding process.

Key points of Unit 2.2

- **Optimisation** of the MW heating process
- Continuous **feedstock supply**
- **Pyrolysis** oil obtention
- **Scalability**



Introduction

Pyrolysis involves breaking down complex chemical structures into smaller pieces in the absence of oxygen. **Temperature and residence time** became critical parameters that directly influenced the type and structure of the chemicals obtained, typically syngas, bio-oil, and char.

This pilot is intended and designed for continuous pyrolysis of plastics streams, to obtain **pyrolysis oil** (which contains linear paraffins and olefins in the range C6–C25) that can serve as a chemical precursor of high-value-added compounds, such as fuels or the second generation of olefin compounds.

As has been shown in module 1, this pilot aims to test and demonstrate scalability and feasibility for microwave heating for plastics valorisation, acting as a bridge between lab-scale and an industrial plant.

Process operation at the Spanish pilot plant

Application of microwave technology in pyrolysis and other thermal processes offers **significant advantages** over conventional heating methods, particularly in terms of **energy efficiency, process control, and temperature control**. Microwaves enable direct energy transfer to the material's interior, resulting in faster and uniform heating. Enhancing, directly in the selectivity of the products obtained.

When talking about plastics, the potential of these waste streams to produce oil and fuels instead of energetic valorisation has only increased in recent years of study. Because of the possibility of decreasing the dependence on fossil fuels and the real possibility of reintroducing these compounds into the value chain. (Liu et al., 2024)

This document aims to present the real case tackled within the framework of PLASTICE, in which a unique continuous microwave-assisted pilot for plastics pyrolysis has been designed, developed, and installed at Circe's facilities.





Figure 1 Microwave-assisted unsorted plastic waste pyrolysis pilot plant¹

To achieve the efficient microwave-assisted pyrolysis operation, the pilot installed at Circe's facilities can operate at **400-500°C** with a MW power of up to **9 kW** while being fed with a flow rate of 10-22 kg/h.

At lab scale, pyrolysis yields of up to 70% have been obtained, demonstrating the high efficiency of the process under optimised conditions. The feedstock for the pilot consists of a plastic mixture predominantly composed of low-density **polyethene (LDPE)** at **90%**, **polypropylene (PP)**, with **polyethene terephthalate (PET)** also included. The pyrolysis oils obtained show an olefins-to-

¹ The service offered is classified as a trade secret following the provisions of Spanish Law 1/2019 of February 20, 2019 (Directive (EU) 2016/943 of the European Parliament and of the Council of 8 June 2016), on the protection of trade secrets, and enjoys full legal protection



paraffins ratio of approximately 70:30 and are free of aromatics, making them suitable as clean chemical precursors.

The pilot's objective within the PLASTICE project is to obtain pyrolysis oil by microwave-assisted pyrolysis of plastic waste streams. The **tests** aim to **optimise the plant's operating conditions**, ensuring the yield and quality of the oil obtained per quantity of plastic fed.



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Conclusion:

Pilot developed and operated by CIRCE, aims to bridge the gap between laboratory studies and industrial applications of continuous microwave-assisted plastic pyrolysis processes, which represent a significant step into circular recycling models in the polymers industry and reducing dependency on fossil fuels.

- **Support for Innovation and Scale-Up:** Bring significant long-term environmental and economic benefits by promoting emerging technologies and supporting investment in electrified pyrolysis techniques
- **Renewable energy integration:** Promote synergies between microwave-assisted systems and renewable energy infrastructures
- **Standardization of processes and safety protocols:** formulate new norms and standards to enhance the robustness and reproducibility of microwave-assisted processes in industry. These measures should unify methods of quality control, maintenance routines and safety protocols
- **Recognition of plastic-derived pyrolysis oil as a sustainable feedstock:** by establishing a regulatory mechanism that should be accompanied by reward schemes and cost-reduction measures for companies that adopt and integrate such oils into their production processes.



Bibliography

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NEXT

UNIT 2.3

Enzymatic hydrolysis: demonstrating mixed textile-waste recycling at pilot scale



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