

PLASTICE

New technologies to integrate PLASTIC waste in the Circular Economy

Training materials

Module 1: Innovative technologies to enable circular plastic value chains

Unit 2.2: Gasification and catalytic post-treatment for circular plastic valorisation: syngas to olefins conversion



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

MODULE 1 Overview

This module is divided into three units, each of which addresses specific challenges in plastic waste management and demonstrates how advanced methods can transform **waste into valuable resources** through sustainable and scalable processes. These technologies are:

- Microwave-assisted thermochemical processing: prospects and scalability (Unit 1.1)
- **Gasification and catalytic post-treatment for circular plastic valorisation: syngas to olefins conversion (Unit 1.2)**
- Enzymatic hydrolysis: a green approach to separate waste streams for recycling (Unit 1.3)

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 1.2

Gasification and catalytic post-treatment for circular plastic valorisation: syngas to olefins conversion

***Solid Recovered Fuel (SRF)** characterisation confirmed its suitability to produce syngas that can be **converted to Dimethyl Ether (DME)** by a catalytic process in a **Zeolitic Entrained Bed (ZEB)** reactor that works at high temperature and pressure. Gasification modelling permitted the analysis of the influence of process parameters and plastic residue composition on the syngas characteristics.*

*In order to **improve the syngas to DME conversion**, the ZEB uses a multifunctional catalyst to **speed up the reactions** and a selective membrane to **remove water** from the reaction zone. The conversion process from syngas to DME occurs at 50 bar with a yield of 35%. The DME-to-olefins (DTO) process achieves 35% olefin yield.*

Key points of Unit 1.2

- **SRF gasification produces syngas**, which can be converted into DME and olefins, enabling circular plastic value chains.
- Gasification modelling shows that temperature, moisture, and oxygen affect **syngas quality**.
- **Multifunctional catalysts and selective membranes** enhance syngas-to-DME and DME-to-olefins conversion efficiency.



Introduction

The increasing demand for sustainable plastic waste management has driven the development of **advanced thermochemical conversion** technologies. **Gasification** is a key process that transforms Solid Recovered Fuel (SRF) into **syngas**, a valuable intermediate for chemical production. Hydrogen and carbon monoxide content in the syngas composition can be maximised by varying temperature, moisture, and oxygen levels.

The utilisation of a **multifunctional catalyst** increases the conversion yield for both syngas to DME and DME to olefins. The integration of **catalyst regeneration** ensures continuous production.

Description of the gasification technological process

The SRF characterisation confirmed its classification as SRF fuel. A thermodynamic gasification model highlighted that increasing temperature (800-900°C) raises nitrogen and reduces H₂ and CO. Oxygen enrichment increases CO (24.7-28.3 vol.%) and H₂ (23.54-26.85 vol.%). Air-steam gasification enhances syngas, reaching 40.5 vol.% H₂ and 26.1 vol.% CO.

A small **rotary kiln reactor** (CSM-RKR), as depicted in the figure below, was built at RINA-CSM (a partner of the PLASTICE consortium) facilities to perform SRF gasification experimental trials and tune the model parameters. The gasification of HDPE and LDPE in an air atmosphere produces **higher levels of hydrogen** (H₂), 19.3 vol.% and 18.4 vol.% respectively, and carbon monoxide (CO), 19.0% and 18.0 vol.% respectively. However, the highest CO value is measured in **rubber gasification**, with a value of 24.7 vol.% due to the higher C content. The rubber, which has the highest content of **ashes**, also produces the highest level of hydrogen sulphide (H₂S), with a value of 0.2 vol.%; for these reasons, it is necessary to minimise the presence of this material in the feedstock to prevent catalyst poisoning.





Figure 1 Rotary kiln reactor

A demo site gasifier (CE-RKR) with a maximum capacity of 1,5 tonne/h is going to be assembled. After the assembling process, hot and cold tests will be performed.

For syngas-to-DME conversion, a **multifunctional hybrid catalyst** was developed by CNR. A 2.0 kg of catalyst was synthesized using a customized apparatus. Quality checks confirmed the new catalyst maintaining stable performance over 100 hours, with a DME yield of 35% for more than four days at 250°C and 50 bar.

The Zeolite Entrained Bed reactor and the cavitator are systems dedicated to the dehydration and purification of the reaction gases. The design of the CE ZEB (see the representation in the figure below) prioritized modularity and flexibility, enabling operation with gasifiers of varying sizes beyond the PLASTICE demonstrator.



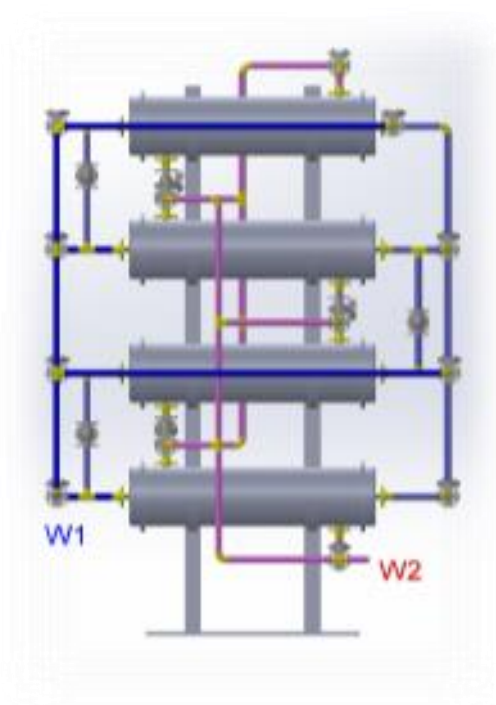


Figure 2 Demo site gasifier (CE-RKR)

Each ZEB reactor can process up to **300 m³ of syngas**. The system consists of 12 main ZEB reactors for DME synthesis and 2 secondary reactors to convert residual methanol into DME. The reactors operate independently or in unison, treating up to **3,600 m³ of syngas simultaneously**. Finally, for DME-to-olefins (DTO) conversion, the system was optimised for maximum olefin yield. The DME to olefins process operates at 300°C and atmospheric pressure, maintaining a DME conversion of 100% and producing light olefins with a yield of 35%. Catalysts were carefully tested for longevity, with regeneration methods using calcination at high temperatures successfully restoring catalyst activity. This process, integrated with downstream fractionation and catalyst regeneration units, **ensures continuous production without plant shutdowns**, maintaining efficient olefin production and contributing to a circular plastics economy.



Conclusions

1. Enhancing plastic waste valorisation

Gasification and catalytic post-treatment offer a viable route to transform plastic waste into valuable chemicals, reducing dependency on fossil resources. Syngas composition is influenced by operational parameters, highlighting the need for optimized conditions to maximize efficiency.

2. Scaling up demonstration and industrial adoption

Pilot and demo-scale studies confirm the feasibility of converting syngas into DME and olefins, but industrial adoption requires further scale-up and process integration. Modular reactor designs enable flexibility in different industrial settings.

3. Ensuring process sustainability and circularity

The integration of catalyst regeneration and continuous processing prevents resource waste and enhances economic viability. Maintaining stable catalyst performance over long operation cycles is essential for sustainable production.

4. Regulatory and market frameworks

The development of a regulatory framework is crucial to support the commercialization of advanced plastic waste conversion technologies. Clear policies on waste classification, emissions control, and syngas valorisation will facilitate market entry.

5. Education and workforce development

The transition to a circular plastic economy requires trained professionals and increased awareness of innovative waste conversion technologies. Educational initiatives and industry training programs can bridge the knowledge gap.



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NEXT

UNIT 1.3

Enzymatic hydrolysis: a green approach to separate waste streams for recycling



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