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**Liquid Pyrolysis of Mixed Plastic Waste for the Co-production of Lubricants and Hydrogen: the Plasbreaker™ Process**

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## Introduction

Plastic waste has become a major environmental issue in recent times. Thermo-mechanical recycling processes are suitable for less than a third of the total plastic waste production, and they work properly only with rather chemically homogeneous plastic waste, which is only a fraction of the total [1]. Mixed plastic waste is generally treated with environmentally impacting processes such as incineration and landfill disposal, which may generate harmful compounds such as pollutants, greenhouse gases, and microplastics [2-3]. The Plasbreaker™ is a possible solution for this problem: this process treats mixed plastic waste (according to COREPLA mass composition: PE 50%, PP 25%, PS 15%, PET 7%, PVC 3%) through a mild liquid pyrolysis process to turn them into high-performance lubricants while using a small amount of energy. The light ends of the process are then reformed and converted into blue hydrogen, leading to a significant reduction of the CO2 emissions thanks to a final Carbon Capture, Utilization, and Storage (CCUS) step.

## Methods

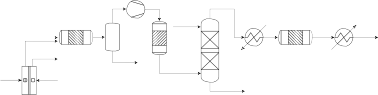
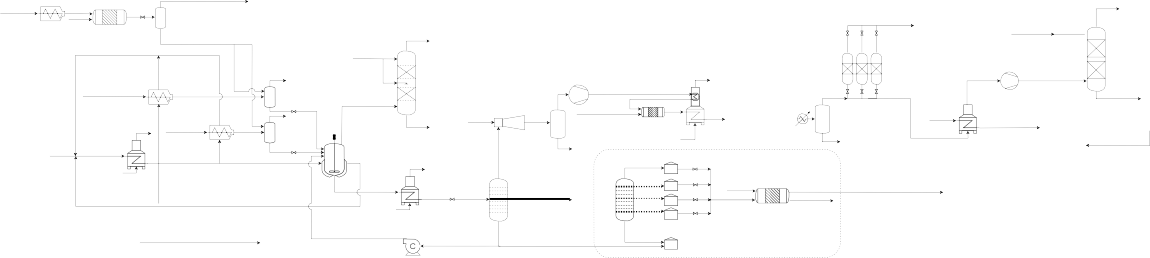
The Plasbreaker™ process was modeled in the commercial simulation software Aspen HYSYS® V11. A Process Flow Diagram of the process is reported in Figure 1. The scheme refers to the revamping of an existing refinery treating exhaust lubricant oils (Itelyum Regeneration). In the first section of the process a plastic waste stream of 15 kt/y is melted through oil-heated twin-screw extruders, exiting at 250°C and 5 bar. Two alternating production lines are present, so that continuous operations are guaranteed even during ordinary maintenance. An auxiliary line for treating vulcanized rubber is also present, where the sulfur is removed through a H2-fed reactor. The molten plastic is fed to a buffer where off-gas is disengaged, and the liquid is sent to the de- halogenation section. Here, a 15.1 kt/y stream of non-regenerable mineral waste oil is co-fed with molten plastic to an oil-heated mixer working at 300-350°C. The mixture is de-halogenated, generating HCl that is sent to a packed washing column using a NaOH solution, leading to a removal efficiency higher than 99.9%. The de-halogenated liquid mixture enters the Plasbreaker furnace, which heats the mixture at 350-550°C for several minutes, leading to the depolymerization of the plastic feedstock. The waste oil acts as a heat carrier, facilitating the heat transfer in the mixture and enhancing the conversion of the plastic. The effluent from the tubular reactor is then separated in a full-reflux distillation column working at 350°C, 50 torr at the bottom and 50°C, 10 torr at the top. The heavy fraction exiting from the bottom of the column is recirculated to the de-halogenation mixer, while the main product is withdrawn from the bottom-half of the column. The light ends are removed from the top of the column and then pre-reformed at 500°C to transform them into methane, which is then converted into syngas in a steam reforming unit that produces an effluent at 850°C, 24 bar. The syngas is then cooled to 350°C and it is sent to a WGS reactor to generate hydrogen from CO. The WGS effluent is processed in a PSA unit, producing 99.999% pure hydrogen with an 86% recovery [4]. The PSA tail gas is sent to a thermo-oxidizer to generate high-pressure steam, which is used in the previous reforming section as well as a heating utility in the plant. The flue gas from this unit are treated in a DEA-based chemical washing step with CO2 removal efficiency higher than 70%. The majority of the pure CO2 captured by the amine loop is compressed and stored as product, while another fraction is sent to an AG2S unit [5] where it produces syngas by reacting both with O2 produced from a renewable-based water electrolyzer and H2S

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produced in the refinery and in the rubber de-vulcanization step. After the reaction, the gas is sweetened before entering the PSA unit.

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## Results and discussion



**Figure 1.** Process Flow Diagram of the Plasbreaker™ Process.

The Plasbreaker™ process produces 22.5 kt/y of base oil for lubricants and 1.1 kt/y of blue hydrogen starting from 15 kt/y of mixed plastic waste and/or vulcanized rubber and 15.1 kt/y of non-regenerable mineral waste oil and/or oil from emulsions, reaching an overall product yield approaching 80%. Moreover, it has many environmental benefits compared with other processes: it produces no solid waste and it shows CO2 emissions lower than 65%, 61%, and 57% compared with incineration, gasification, and pyrolysis, respectively [6].

**GHG Emissions [kgCO2/kgPLASTIC]**

4

3

2

1

0

Plasbreaker Pyrolysis Gasification Incineration

**Figure 2.** Comparison of CO2 emissions between the Plasbreaker™ and other waste disposal processes.

## Conclusions

The Plasbreaker™ process offers a feasible, low-impact solution for the conversion of plastic waste into high- value chemicals such as lubricant bases and blue hydrogen. Thanks to the low energy requirements, the presence of a DEA-based CCUS section and an AG2S unit, together with the lubricants production which act as carbon sink, the process minimizes the environmental impact, showing lower CO2 emissions compared with other thermal treatments. A first industrial plant is at the EPC phase at the Itelyum Regeneration plant in Lodi.

## References

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