Waste-to-x: waste conversion processes into value-added products in biorefineries

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Introduction

At present, refineries produce oil derivatives with applications in different sectors (energy, fuels, petrochemicals, etc.). However, decarbonization plans foresee a future transformation of the sector in which oil will be replaced by more sustainable sources such as waste, transforming refineries into biorefineries based on a circular production model.

The increasing consumption of resources has generated such a large amount of waste that waste management and valorisation has gained prominence. Currently, incineration and composting are the main waste recovery operations carried out at EU, the former being highly polluting (Eurostat, 2023).

The need to find alternatives to oil as a raw material has led to the study of waste as an attractive substitute for the production of energy and other petrochemical products. The studies on these technologies focus on waste-to-energy processes with the main emphasis on obtaining energy from waste, but the intermediate products obtained from these processes (such as syngas or methane) have various applications outside the energy market, although the study of these other uses is more limited.

Nowadays, there is no homogenized terminology that refers to the whole set of processes for obtaining value-added products through the use of waste. Waste-to-energy is the most commonly used term. However, it is sometimes used as an all-encompassing term and sometimes as a synonym for incineration. The following concepts are intermingled:

- Waste-to-energy: focused on processes for obtaining energy
- Waste-to-liquid: focused on obtaining liquid fuels
- Waste-to-chemicals: focused on biofuels, biofertilizers, solvents
- Waste-to-materials: focused on obtaining chemicals and plastic polymers

In view of the growing demand for petroleum derived products, it is essential to accelerate the research of production processes using waste in order to advance in the transformation towards sustainable production. To facilitate this transformation, the use of a common terminology would help to streamline and align research in this area and facilitate the search for information among researchers.

Therefore, *waste-to-x* is proposed as a generic term for those waste valorisation processes that can be used within the biorefinery concept to obtain the various products currently obtained from oil, both for energy and material recovery.

Material and methods

A study was carried out in order to bring together the different *waste-to-x* processes under a single concept, based on the waste that can be used as raw material, the products obtained (x) and their application in the final market. For this study, the following phases have been completed:

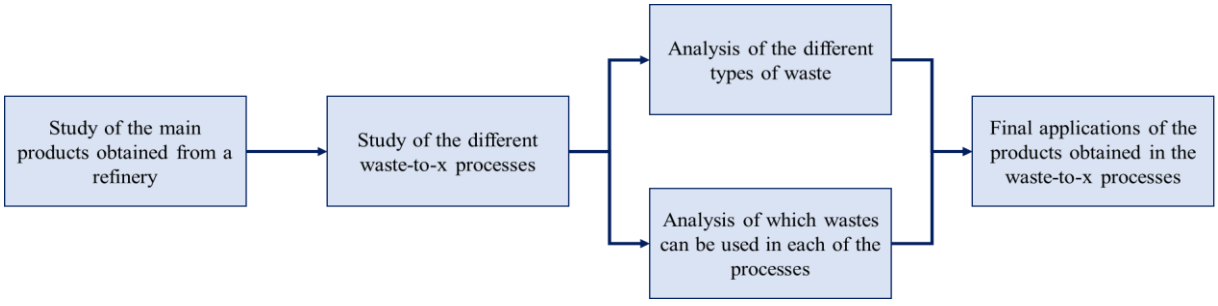

Figure 1. Phases of the study

Results and discussion

The use of waste as a raw material for energy production is a common practice since incineration is a widely used process. This process is currently criticised for its negative environmental effects and therefore there is a desire to promote more sustainable carbon neutral processes. The documentation studied on *waste-to-x* processes focuses on obtaining energy and fuels with similar characteristics to current ones in order to replace them, although they can also be used to obtain other types of products based on the starting waste.

The type of urban waste used in *waste-to-x* processes can be classified into lignocellulosic biomass, organic waste, fats and oils, textiles, plastics, alcohols and landfill waste, the latter referring to waste that is rejected after the previous classification and ends up in landfills without any type of use. Depending on the type of input waste, different *waste-to-x* processes can be used and the results obtained will be different.

The analysis of the *waste-to-x* processes was based on knowledge of the processes, the type of waste that can be introduced in each of them, the conditions necessary to be able to carry out the process and the need or not to carry out pre-treatments. *Waste-to-x* processes are classified as direct (RDF and landfill gas), thermochemical (incineration, pyrolysis, gasification, liquefaction), biochemical (anaerobic digestion, composting, MFC, fermentation) and chemical (transesterification) (Malav et al., 2020) (Tun et al., 2020) (Nizami et al., 2017) (Nuss et al., 2012).

As a final result of the analysis, the final product obtained has been studied (electricity, heat, biofuels, syngas, different gases...) and the final application of these products in the market, beyond the energy sector, such as the production of olefins, methanol, ethanol, polymers as can be seen in the Figure 2:

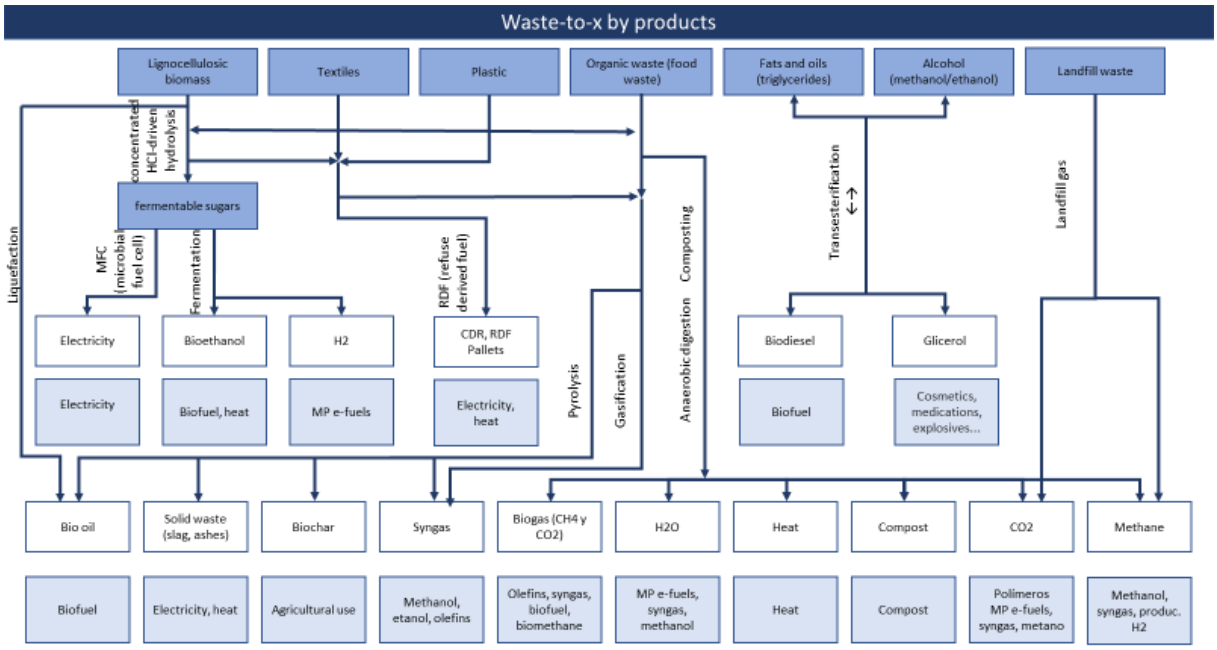

Figure 1 Summary tree of *waste-to-x* processes

Conclusion

In view of the constant increase in the consumption of petroleum products and the necessity to obtain these products from more sustainable sources, it is essential to study *waste-to-x* processes in order to contribute to the decarbonization of refineries and the reduction of landfill waste. In addition, research is also needed to obtain other petrochemical products that are widely used, to promoting the valorisation of waste to obtain energy. Given the need to accelerate research in this area, it is important to define a common terminology to facilitate the search for information and favour the dissemination of knowledge and research results.

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