Circular economy: sustainable aviation fuel from waste

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1. Introduction

The indiscriminate use of resources, the accumulation of huge quantities of waste and the greenhouse gas emissions, are heavily contributing to the climate change. In 2022 36.9 Gt CO_2 were emitted in the world, 21.3 % due to the transport sector. In order to decarbonize the transport sector by reducing the utilization of fossil fuel, IEA has foreseen a widespread use of renewable fuels produced from waste, beside electricity and hydrogen [1]. Renewable fuels includes both advanced biofuels, produced from waste biomass, and some RFNBOs (Renewable Fuels of Non-Biological Origin): i.e. e-Methanol, e-Gasoline, e-Kerosene, e-Diesel, obtained by captured CO_2 and renewable electricity [2].

2. Waste biomass

The amount of biomass potentially available for the production of biofuel is huge. Comparing 32 independent studies IRENA estimated and average amount of energy recoverable from waste biomass in 2050: 340 EJ/y [3], much over the amount foreseen by IEA for the transport sector (i.e. 76 EJ [1]). Also in Europe the amount of waste biomass is significant. According to [4], already in 2020 an amount of waste biomass equivalent to 18 EJ was available.

3. Advanced Biofuels

Despite of the availability of huge amount of waste biomass, still in 2021 most biofuels consumed in the EU were food crop-based, i.e. produced from raw materials competing with the food sector. For this reason, critical issues from an ethical point of view have raised and the EU RED (Renewable energy Directive), introduced since 2009, has evolved by promoting the advanced biofuels, produced from waste biomass, according to a circular economy approach. The recent adopted revision RED III (November, 20, 2023), has confirmed the cap at 7% for the food-crop based biofuels, increasing the targets for advanced biofuels, RFNBOs, hydrogen and electricity.

4. Sustainable Aviation Fuel (SAF)

A particular attention is now deserved to the aviation transports as, among the other sectors, are characterized by the largest GHG emission growth rate. Besides, aviation is a sector difficult to electrify, so sustainable biofuels present a viable option for decarbonization. ReFuelEU Aviation [5] requires all fuel suppliers at EU airports to supply a minimum share of sustainable aviation fuels (SAF) that are low-carbon substitutes for kerosene, made either from biofuels, recycled carbon fuels or e-fuels. The minimum share of SAF should increase from 2 % in 2025 to 70 % in 2050. The EU definition of SAF is subject to the sustainability criteria of RED III. The estimated EU supply of SAF was less than 0.05 % of jet fuel demand in EU in 2020. Demand for aviation fuel at EU airports is expected to be around 46 Mtoe in 2030, from around 26 Mtoe in 2021. The new ReFuelEU Aviation legislation set the required SAF level for 2030 at 6 %. In order to reach this target, approximately 2.76 Mtoe of SAF would be required, while the potential SAF production capacity in 2020 in the EU was around 0.24 Mtoe [6]. Hence the SAF industry is at an early stage of development., but a rapidly growing sector.

5. SAF production technologies

Sustainable aviation fuel is typically produced in a purpose-built plant, according to four main technology pathways that are mainly attracting industry attention: hydroprocessed esters and fatty acids (HEFA); alcohol-to-jet (AtJ); gasification/Fischer-Tropsch (gas/FT); and Power-to-Liquid (PtL) to produce e-Kerosene [7].

Hydrogenated esters and fatty acids (HEFA) utilizes as feedstocks waste and residue lipids, such as used cooking oil, as well as purposely grown oil cultivars, such as jatropha, grown on marginal land.

Alcohol-to-jet includes the routes starting from an alcohol obtained from any waste biomass (e.g. agricultural waste such as wheat straw or corn stalks, agroforestry residues, biomass cultivated for energy use on marginal land such as miscanthus, aquatic biomass, the organic fraction of domestic waste, sludge from water purification plants, and livestock sewage), such as ethanol, butanol, methanol.

Gasification/Fischer-Tropsch uses similar feedstock as alcohol-to-jet plus municipal solid waste, the feedstock is gasified to produce syngas which is subsequently transformed to or hydrocarbons by the FT reaction or methanol.

Finally Power-to-Liquid which valorize captured CO_2 reacted with green H_2, produced from renewable electricity.

Hydrogenated HEFA is the only mature technology so far, being an evolution of the already consolidated technology HVO for renewable diesel production. The other technologies are still at a semicommercial or pilot stage. In particular, despite the obvious advantages in terms of sustainability, e-fuels have not yet reached large-scale commercialization, due to the high complexity of the technologies involved and the high production costs.

The presentation will illustrate the most salient technological aspects of this industrial sector.

References

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Keywords
Transport Sector Decarbonization; Advanced Biofuels; Sustainable Aviation Fuel; e-Kerosene.