Biofuels or e-Fuels: Which Are Better as SAF (Sustainable Aviation Fuels)?

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According to the International Energy Agency (IEA), 38.1 Gt of CO_2 were emitted worldwide in 2024, around 22% of which originated from the transport sector. The IEA has foreseen a significant reduction in the contribution of fossil fuels in this sector in order to reach the ambitious target of net-zero emissions by 2050. This transition is expected to rely on the widespread use of electricity, hydrogen, and renewable fuels. The latter include both advanced biofuels, produced from waste biomass, and some RFNBOs (Renewable Fuels of Non-Biological Origin), such as e-methanol, e-gasoline, e-kerosene, and e-diesel, obtained from captured CO_2 and renewable electricity [1].
Among transport sectors, shipping and aviation are characterized by the highest growth in fuel demand. Moreover, aviation is particularly difficult to electrify, and the use of hydrogen as a direct fuel raises several concerns. Therefore, bio-jet fuels and e-kerosene represent viable options for aviation decarbonization. The ReFuelEU Aviation regulation adopted by the EU in 2023 requires a minimum share of sustainable aviation fuels (SAF), defined as low-carbon substitutes for kerosene made from biofuels, recycled carbon fuels, or e-fuels [2]. This share will reach 6% of total aviation fuel consumption by 2030 and is expected to increase to 70% by 2050. As a consequence, the SAF industry is rapidly expanding.

SAF production routes

SAF is currently produced through four main technological pathways:

1. **Hydroprocessed esters and fatty acids (HEFA)**
2. **Alcohol-to-jet (AtJ)**
3. **Gasification to syngas followed by Fischer–Tropsch (FT) or methanol synthesis**
4. **Power-to-Liquid (PtL) processes for e-kerosene production**

HEFA uses feedstocks such as vegetable oils or waste and residue lipids, including used cooking oil and animal fat .
AtJ includes routes starting from bio-alcohols such as ethanol, isobutanol, or methanol. Gasification of waste, including municipal solid waste and biomass residues, produces CO/H_2 syngas, which is subsequently converted into hydrocarbons via the FT reaction or into methanol. Finally, PtL processes produce e-fuels through the hydrogenation of captured CO_2 using hydrogen generated from renewable electricity.
Among these pathways, HEFA is currently the most mature technology, with several industrial-scale plants already in operation, followed by AtJ and gasification/FT routes. PtL, despite its clear advantages in terms of sustainability, has not yet reached large-scale commercial deployment [3].
The most significant criticisms of the SAF industrial sector—such as high production costs, limited availability of sustainable feedstocks, and concerns regarding the actual environmental impact of certain pathways—will be discussed in the presentation.

Keywords
Aviation; Decarbonization; Advanced Biofuels; Sustainable Aviation Fuel; Bio-Jet; e-Kerosene

References
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[2] European Commission, ReFuelEU Aviation, https://transport.ec.europa.eu/transport-modes/air/environment/refueleu-aviation_en
[3] CENA Hessen (2025): *CENA SAF-Outlook 2025–2030 – Volumes, Technologies and Markets for Sustainable Aviation Fuels*; cut-off date for the analysis: December 31, 2024.