Synergies between aviation and maritime decarbonization goals: co-production of aviation and shipping alternative fuels

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Summary

Aviation and maritime transport sectors are responsible for about 5% of global CO_2 emissions and have already defined strategies to reduce emissions. This work evaluates the synergies between these sectorial decarbonization goals through the co-production of alternative drop-in aviation and shipping fuels using integrated assessment models (IAM). Four technologies were evaluated: HEFA, ATJ, FT-SPK and e-SPK. All alternative fuels registered higher levelized costs than jet fuel prices, and at least 65% reduction in GHG emissions. Results of the integrated analysis enabled to identify whether aviation sector decarbonization goals lead to a baseline supply of low carbon alternative bunker fuels.

Abstract

The international aviation and maritime sectors are important contributors to global greenhouse gas (GHG) emissions (IEA, 2020). In this context, the international association of each sector has established strategies to deal with GHG emissions. The International Air Transport Association (IATA) goals include a 50% reduction in the carbon footprint by 2050 compared to 2005 levels (IATA, 2020). Likewise, the International Maritime Organization (IMO) proposes a reduction of 50% in GHG emissions in 2050 compared to 2008 absolute levels (ICCT, 2018).

Both sectors are usually referred to as hard-to-abate, given the lack of commercially available decarbonization technologies and expected growth in demand (SHARMINA, EDELENBOSCH, *et al.*, 2021). Although a set of measures has been proposed to reach the emissions reduction goals, they are unlikely to offset the expected activity growth for aviation and shipping. Hence, the development of renewable and carbon-neutral fuels is a crucial measure.

In these circumstances, biofuels and electrofuels can be promoted as alternatives to both sectors. Biofuels are produced through technologies that use biomass as the main input, while electrofuels are usually produced from electrolysis-based hydrogen, which could be used in different chemical syntheses. In both cases, there are routes mainly proposed to produce sustainable aviation fuels (SAF) that co-produce marine fuels, meaning that the decarbonization of the aviation sector can lead to a co-benefit in the maritime sector.

The analysis of such technologies in IAMs would provide a better understanding of the synergies between both sectors. Therefore, IAMs should consider the introduction of technologies able to coproduce aviation and shipping fuels, particularly because there are no alternatives in the short- to mid-term to decarbonize aviation and few technologies that can output only jet fuel components do exist.

This work aims to evaluate the synergies between the production of low carbon fuels for the aviation and shipping sectors from an IAM perspective. To this end, the characterization of technological routes capable of co-producing SAF and renewable bunker fuels is performed alongside a technoeconomic analysis.

The methodology encompasses three stages: (i) characterization of technological routes, (ii) techno-economic and environmental analysis, and (iii) integrated evaluation with the Brazilian IAM BLUES. Firstly, we assess possible technological routes to co-produce sustainable aviation and marine fuels: Hydrotreated Esters and Fatty Acids (HEFA), Alcohol-to-jet (ATJ), Fischer-Tropsch Biomass-to-liquids and electro- Synthetic-Paraffinic-Kerosene (e-SPK) (Figure 1). Different aspects of these pathways were evaluated, such as fuel production process, technology readiness and required inputs. Secondly, we investigate the economic (fuel levelized costs, capital expenditures, operational and maintenance costs) and environmental performance (life cycle GHG emissions) of biofuels and electrofuels. Lastly, these routes are implemented in the BLUES model, with their respective costs and yields. Hence, SAF production scenarios were created to meet the decarbonization goals for aviation and maritime sectors and the potential benefits and trade-offs that SAF production may cause in terms of low carbon fuel supply were evaluated.

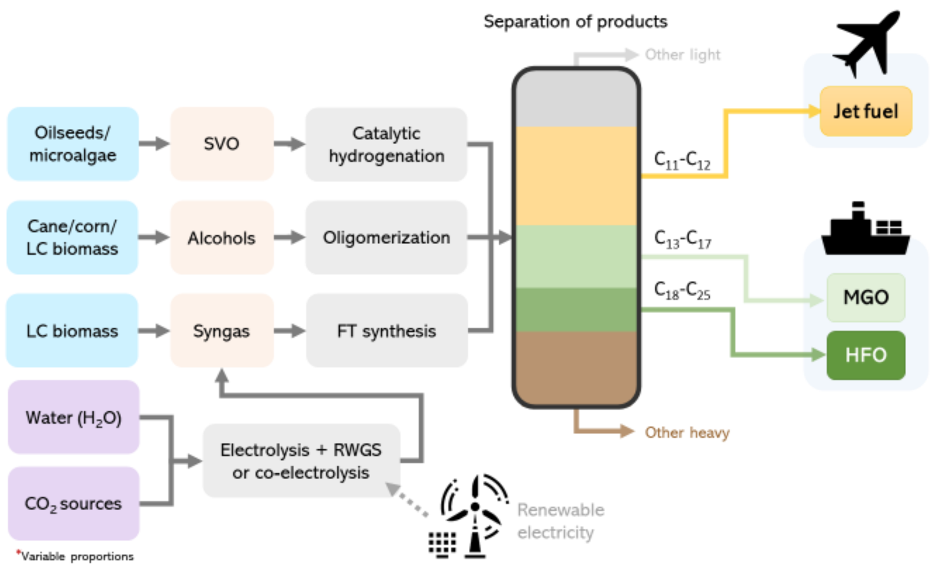

Figure 1: Jet and bunker/diesel fuel co-production technologies.

HEFA, FT_SPK and ATJ are certified biojet production routes approved for blend of up to 50% with conventional jet fuel (IATA, 2019). Among all certified technologies, only HEFA has reached the commercialization status (TRL 9[1]). Currently, ten HEFA plants are in operation and produce 5 billion liters of fuel (mostly renewable diesel) per year. FT-SPK and ATJ reached TRL 7, which

[1] The technology readiness level (TRL) is a measure system that evaluates the maturity level of technologies and goes from level 1 (lowest) to nine (highest).

means that the processes have been demonstrated in an operation environment. Several companies are involved in their development, such as Red Rock Biofuels, Velocys, Byogy, Total, among others. In contrast, e-SPK is still in validation stage and companies like Air to Fuels, Zenid and Norsk e-fuel are working to develop e-fuels (TRL 5).

FT-SPK registered higher jet fuel yields (up to 80%), followed by ATJ, HEFA and e-fuels (up to 76%, 55% and 38%, respectively). In contrast, e-SPK stands out as the pathway with higher diesel or bunker yields (54%), followed by FT-SPK, HEFA and ATJ (46%, 26% and 20%, respectively). Naphtha is also co-produced in all processes (up to 30%). An interesting feature of HEFA pathway is the possibility of diesel production optimization through the bypass of the hydroisomerization/hydrocracking step.

All pathways registered LCOF below jet fuel prices[2] (Figure 2). Among biofuels, price levels were within the same ranges. ATJ registered the lowest (US$ 22/GJ) and greatest LCOF (US$ 93/GJ). LCOF for e-SPK is almost 10 times higher than for biofuels and at least 15 times higher than conventional jet fuel price. However, fuel costs are highly dependent on feedstock and inputs considered.

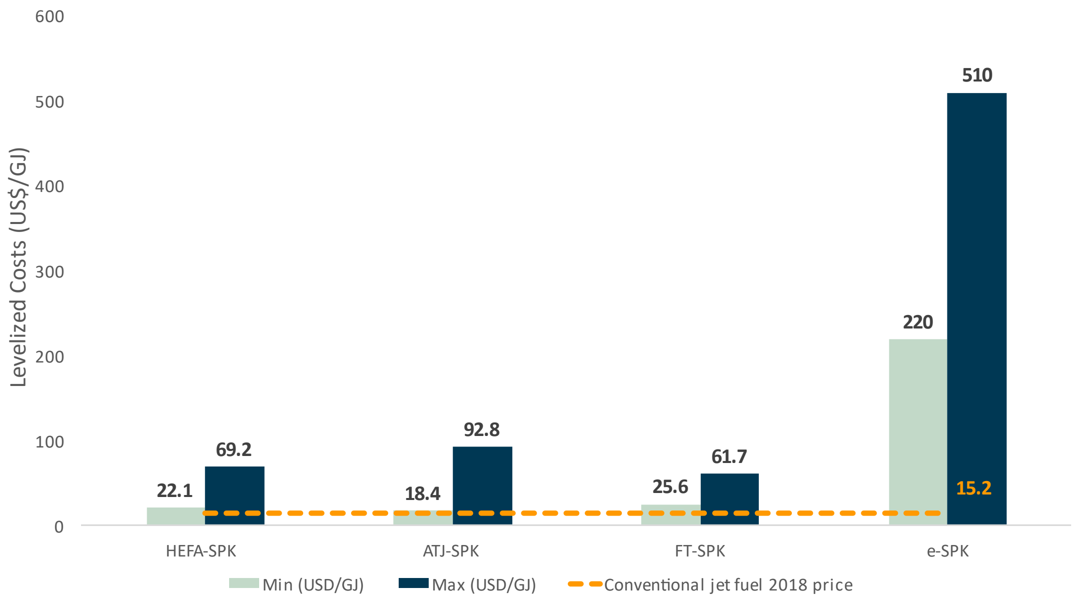

Figure 2: Levelized costs of fuel production technologies.

Regarding their GHG emissions, all alternative fuels registered reduced life cycle emissions compared to fossil jet fuel (Figure 3). FT-SPK stands out with the best environmental performance (up to 94% emissions reduction), followed by HEFA (80%), ATJ (80%) and e-SPK (65%). e-SPK emissions are mainly associated with increased energy consumption in fuel conversion. Also, environmental performance of biofuels depends on the feedstock chosen and possible land use change impacts.

[2] 2018 levels (INDEXMUNDI, 2018).

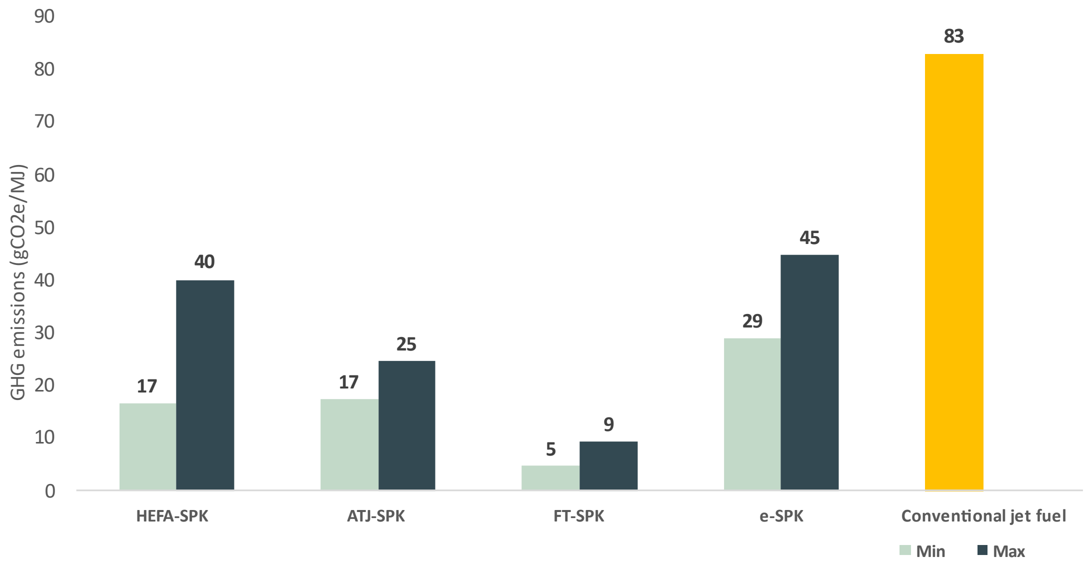

Figure 3: Lifecycle GHG emissions for alternative fuels production.

Results of the integrated analysis enabled to identify to which extent the aviation sector decarbonization goals lead to a baseline supply of low carbon alternative bunker fuels. Also, IAMs could identify the resources competition among sectors and the limits in fuel production scales. However, all technologies evaluated will face significant challenges until they can produce aviation and maritime biofuels in commercial scales.

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