Global economic and environmental impacts of deploying synthetic jet fuels in the aviation sector

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Overview

As pressures related to climate change increase year after year, all sectors of the global economy must engage in their decarbonation. Hard-to-abate sectors are involved in this race, including the aviation sector, which committed in 2021 to net-zero emission operations by 2050 (IATA, 2021). To achieve this goal, the International Air Transport Association (IATA) intends to rely on four actions: use cost-competitive sustainable aviation fuels (SAFs), improve traffic management efficiency, improve aircraft's efficiency, and compensate residual emissions through carbon removal techniques including carbon capture and storage (CCS) solutions. SAFs are playing a great role in this IATA plan, representing 5,2% of fuel consumption in 2030 and 65% in 2050. They denote the low-carbon alternative fuels to conventional kerosene and jet fuels, comprising biofuels, synthetic fuels, hydrogen, and electricity. From this list, biofuels and synthetic fuels are categorized as 'drop-in fuels' as they meet the international standardized specifications of conventional jet fuels, thus not requiring the propulsion engine of the aircraft to be changed. For logistic concerns, this property of drop-in fuels makes them a promising solution for continuing to operate the existing fleet, while hydrogen and electricity propulsion requires a complete redesign of engines and aircraft (Dahal et al., 2021). However, both bio-jet fuels and synthetic fuels face serious challenges. On the one hand, the production of biofuels requires substantial amounts of water and land (Schmidt and Weindorf, 2016), potentially compromising food and water security. On the other hand, synthetic fuels, made of carbon dioxide (CO_2) and hydrogen (H_2), are today immature and expensive production technologies (Chauvy et al., 2019). Despite these obstacles, industrial companies show interest in utilizing and enhancing the CO_2 they capture (ScotProject, 2022) because it could represent a source of revenue and avoid the cost penalty of the storage of CO_2 (Hepburn et al., 2019). Notably, the cement industry is involved in several projects to capture and valorize the CO_2 emitted from the calcination reaction into synthetic fuels, such as the Westküste and the C2PAT projects. Although the production of CO_2-based jet fuels seems attractive, it is uncertain if such CO_2 utilization technologies would have a sufficient impact on greenhouse gas (GHG) emissions mitigation. Moreover, SAF deployment could increase jet fuel prices drastically. In this study, we explore the trade-offs between GHG emissions mitigation and the economics of air transportation, including the aviation fuel sector.

Methods

To carry out this study, we enhance the MIT Economic Projection and Policy Analysis (EPPA) model (Chen et al., 2016; Paltsev, 2005). EPPA is a multi-region multi-sector computable general equilibrium (CGE) model of the world economy. The model provides projections of world economic development at a regional and sectoral level, including the economic implications of GHG emissions, conventional air pollution, land-use change, food demand, and natural resource use. It simulates the evolution of economic, demographic, trade and technological processes involved in activities that affect the environment. The EPPA model chooses the least-cost production opportunities based on normal profit conditions (the cost of inputs should not exceed the price of the output), market clearance conditions (supply must equal demand), and income balance conditions (expenditures must equal income, accounting for savings, subsidies and taxes). Therefore, production technologies are chosen based on their relative competitiveness.

To examine in detail specific technologies, we develop the EPPA7-A model to investigate the decarbonation of the air transport and aviation fuel sectors (Winchester et al., 2013). In this version, the jet fuel sector has been separated from the Refined oil sector including several biofuel production pathways, of which the hydroprocessed esters and fatty acids (HEFA) process is the only one generating bio-based jet fuels. The technology combines oilseed crops with capital and labor and other intermediate inputs using a series of nested constant elasticity of substitution (CES function). In the same framework, we introduce a new advanced technology for the aviation fuel sector, *i.e.* the conversion of CO_2 into jet fuel through a Fischer-Tropsch (FT) reaction. This process needs to utilize pure streams of CO_2, which can be captured either from the industry sector or the burning of biomass. Additionally, it requires renewable hydrogen, which is not modeled in this version of EPPA. Therefore, the backstop technology process combines CO_2 with electricity (to produce hydrogen) with capital and labor to produce a slate of fuels comprising diesel, gasoline and jet fuel. The techno-economic performances of the integrated electrolysis-FT process are based on the findings of (Albrecht et al., 2017) and (Schmidt et al., 2017).

Results

With this modeling, our aim to investigate the economic and environmental impacts of the deployment of synthetic jet fuels will be explored through several scenarios of global temperature stabilization. In each of the scenarios, we will focus on the analysis of several main indicators:

1. Deployment of jet fuels in different regions;
2. the profile of jet fuel prices ($/gallons);
3. the fuel type use;
4. the life-cycle CO_2 emissions of aviation fuels, to capture the environmental efficiency of SAFs. This indicator considers the indirect emissions of electricity consumption and the origin of CO_2.

According to the 2°C climate target, the first scenario (SAF65) is in line with IATA's ambition to decarbonize the aviation sector by fueling aircraft with 65% of SAFs by 2050. In this scenario, the model is free to choose the cheapest jet fuel production capacities to invest in, with respect to the constraints on renewables potentials. The second scenario (SAF100) assumes a complete reliance on SAFs by 2050 in order to capture the additional effort to meet a more ambitious target for air transportation and the aviation fuel sector. In these two scenarios, we will analyse the progressive penetration of SAFs in jet fuel yield over the 21st century, in order to understand the possible timeline of SAFs deployment. Besides, we define two additional extreme scenarios in which we assume, on the one hand, aircraft are only fueled with FT fuels (SAF100-FT), and on the other hand, aircraft are only fueled with bio-based jet fuels (SAF100-BIO). Those two scenarios are voluntary pushed to the extreme to find out the possible shortcomings or opportunities of the two routes. As part of the FT fuels can be generated from fossil CO_2 coming from the industry sector, additional negative emissions would be required to meet the climate target. Consequently, we will compare the amounts of negative emissions in the SAF100-FT scenario and the SAF100-BIO scenario.

Conclusions

Our study explores two main issues related to the energy transition. The first one is an assessment of the competitiveness of FT fuels and biofuels by evaluating the impacts on jet fuels prices and the market shares of SAFs over time. The second is to understand the environmental and technological impacts of a massive investment in carbon capture and utilization technologies, in a world where industrialists are increasingly interested in this mitigation solution.

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