The role of renewables in decarbonising the aviation sector

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Introduction

Globally, aviation produced 915 million tonnes of carbon dioxide (CO_2) in 2019. The sector's emission contributes about 2% of the world's CO_2 emissions and about 12% of all transport emissions. Non-CO_2 emissions from aviation also have a significant climate impact, contributing almost two-thirds of net radiative forcing[1]. This is projected to double by 2050 in a business-as-usual scenario. Although the COVID-19 pandemic has affected the sector's emissions, the industry is likely to recover, reaching and exceeding pre-COVID emissions within a few years. The aviation sector consumed over 14 EJ in 2019, including civil aviation and non-commercial aviation (general, private and military use)[2], where international aviation accounts for 60% of the energy consumption, while remaining 40% for domestic aviation. Aircraft typically use jet kerosene, refined from crude oil. This counts to almost all (99.9%) the energy consumption for aviation, with aviation gasoline and sustainable aviation biofuels (SAFs) being the rest of the consumption.

Renewables provide options to decarbonise the aviation sector

Considering today's status with the added long-lasting impact of the pandemic, IRENA's 1.5ºC Scenario foresees that decarbonising the aviation sector requires major transitions in several components; such as the reduction of aviation demand and accelerated fuel efficiency improvements, a robust mixture of low-carbon fuels in the form of biojet fuels and synthetic kerosene, and the commercialisation of new electric and hydrogen aircraft. The fuel efficiency performance for airlines has improved on average 2% annually between 2009 and 2019[3]. This was largely the results of new generation aircraft and operational improvements. While improvement in fuel efficiency can curb carbon emissions in the short term, decarbonising the sector requires additional measures including new aircraft technologies (including electricity and hydrogen-powered aircraft), participation of sustainable aviation fuels (SAFs), the use of synthetic fuels supported by market-based measures, some of which was echoed by the International Civil Aviation Organization's (ICAO) commitment to address climate change[4].

Several options powered by renewable energy can be discerned: electric batteries and green hydrogen (both for short-haul flights only); synthetic fuels produced from green hydrogen (made from splitting water molecules into hydrogen and oxygen using renewable electricity) — also known as electrofuels or e-fuels; and biofuels (IRENA, 2020[5]).

1 https://www.sciencedirect.com/science/article/pii/S1352231009003574?via%3Dihub
2 https://www.iea.org/reports/world-energy-balances-overview
3 https://www.atag.org/component/factfigures
4 https://www.icao.int/environmental-protection/pages/climate-change.aspx
5 https://www.irena.org/publications/2020/Sep/Reaching-Zero-with-Renewables

Renewables based Sustainable Aviation Fuel (SAF)

Airlines can only fly with fuels that have been approved by the industry under the auspices of US-based standards organisation ASTM International. So far, these have been limited to biofuels and e-fuels (also known as powerfuels). SAF production covers less than 1% of the global jet fuel demand with around 100 million litres of SAF produced in 2021[6] .

Sustainable aviation fuel, including biojet, has recently increased its production as more countries and airlines commit to reduce their CO_2 emission through use of SAFs. They are commonly used as drop-in fuels, blended with fossil fuel jet kerosene, up to a maximum of 50%. Majority of the SAFs produced today are HEFA-SPK[7], while the other SAFs approved by ICAO have not yet reached commercialisation.

Developments in regional and national mandates — The European Union proposed in the ReFuelEU initiative fuel suppliers to include more SAF into jet fuel from 2030 to 2050[8]:

- 2% by 2025;
- 5% by 2030;
- 20% by 2035;
- 32% by 2040;
- 38% by 2045;
- 63% by 2050.

At country level, the USA has announced in September 2021 a goal of replacing all conventional jet fuel with SAF by 2050 — (projected at 130 billion liters per year), starting with SAF production of 12 billion liters annually by 2030 in co-ordination with Airlines for America. The UK has also announced a mandate to have at least 10% of their annual jetfuel production from SAF by 2030, and 75% by 2050[9].

The expansion in other regions of similar initiatives may rapidly scale up the demand for SAF and bring economies of scale enhancing its competitiveness.

Biofuels — The use of biojet fuels would comprise of 47% of the total fuel consumption, or around 204 billion liters of biofuels produced annually in the IRENA's 1.5°C scenario[10].

To date, nine pathways have received ASTM certification, which allows biojet fuel to be blended with petroleum-derived jet fuels or co-processed, but only one is said to be technically mature and commercialised — the process that uses vegetable oils, waste oils and fats (often used cooking oil) as its feedstock, known as HEFA-SPK (hydroprocessed esters and fatty acids synthetic paraffinic kerosene). More than 95% of biofuel flights to date have used HEFA-SPK fuel.

Global biofuels production totalled 150 billion litres in 2018, but just 17 million litres of advanced biofuels for aviation was produced, all from a single plant in California.[11]. Thus, rapid upscaling of biofuel for aviation is needed, and the share of aviation fuel in total biofuel must increase rapidly for a meaningful contribution. To significantly scale up production, alternative feedstocks such as lignocellulosic biomass, and technologies such as gasification with FischerTropsch (FT) and/or pyrolysis or hydrothermal liquefaction will be required.

IRENA surveyed leading advanced biofuel investors from Europe, Brazil, China and North America to obtain their perspectives on industry development and the main barriers for deployment.[12] A high-level overview of the findings show that concerns about the stability of regulation are dominant, including the level of blending mandates and subsidies. However, economic concerns are also key, including feedstock cost, conversion efficiency and capital expenditure. Public perception, notably, does not represent a major concern.

6 https://www.iata.org/en/programs/environment/sustainable-aviation-fuels/
7 Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene (HEFA-SPK)
8 https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3525
9 https://www.nortonrosefulbright.com/de-de/wissen/publications/f81d3390/new-regulatory-initiatives-supporting-sustainable-aviation-fuel
10 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_World_Energy_Transitions_Outlook_2021.pdf
11 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Sep/IRENA_Reaching_zero_2020.pdf
12 https://www.irena.org/publications/2021/Jul/Reaching-Zero-with-Renewables-Biojet-Fuels

E-fuels — According to IRENA, the use of synthetic kerosene will also be needed in a 1.5°C Paris Agreement aligned secenario, where they would comprise up to 23% of fuel use by 2050 with almost 100 billion liters of fuel required.[13]

Synthetic kerosene, also known as power-to-liquids (PtL), are drop-in fuels that, in theory, can provide very low-carbon-intensity transport fuels. The key process step is the utilisation of renewable energy sources (wind, hydro, solar) to electrolyse water and produce hydrogen. When the "green" hydrogen is combined with "green" or waste carbon sources, CO or CO_2, via processes such as FT synthesis, hydrocarbon fuels can be produced, including a jet fraction. The CO/CO_2 can also be obtained via direct air capture. Power-to-liquids are ASTM certified since 2009 for 50% blends. The ability to capture CO_2 at low cost is critical, as is the availability of low-cost renewable power to produce hydrogen.

Electric aircraft

The introduction of novel aircraft running on hydrogen and electricity (or hybrid) for regional short-haul flights is expected to take place by 2035.

Electrically assisted propulsion involves the use of electric motors to drive some or all of the propulsion on an aircraft. Typically, propulsion relies on electric energy storage (e.g. batteries), hybrid energy (e.g. a mix of electric and fuel-based propulsion) or turboelectric (e.g. fuel-based energy). Electric aircraft are already being assessed for their potential over short distances, such as vertical take-off and landing, for urban transport or for short distances over mountainous terrain. They can be fully carbon neutral if powered by 100% renewable electricity.

ICAO lists 27 electric planes currently in development by companies such as Boeing and Airbus, as well as five hybrid-electric models that would be partly propelled by electric motors. Given today's batteries, this option is only feasible for small planes for short range flights (several hundred kilometers range).

Aircraft can use hydrogen either as a fuel for a jet engine or to supply a fuel cell that can provide electricity for propulsion[14]. When used as a fuel, hydrogen must be compressed or stored as a cryogenic liquid, with safe storage and refuelling recognised as critical steps. The main problem is that the hydrogen storage would take substantial space and the planes need to be redesigned for this. This is a process that would take decades. The world's first four-seat passenger aircraft powered by a hydrogen fuel cell took off for the first time in 2016. The plan is to at least double the performance of the fuel cell over time, and to store hydrogen three times more efficiently. Airbus recently announced a target of enabling the "first climate-neutral, zero-emissions commercial airplanes up to cruising altitude within the next 15 years". They suggest that two types of aircraft will be available by this time: a 200-passenger aircraft that can fly up to 3 700 km or 2 000 nautical miles, and a 100-passenger aircraft that can fly up to 1 850 km or 1 000 nautical miles[15]. In IRENA's 1.5°C Scenario, both electric and hydrogen aircraft can potentially replace 35% of short haul flights of less than 1100 km.

Priority action areas

Decarbonising the aviation sector by 2050 is not possible without significant commitments from aircraft manufacturers, airlines and national governments to shift towards carbon-neutral technologies. While improvement in fuel efficiency can curb carbon emissions in the short term, decarbonising the sector requires additional measures including new aircraft technologies (including electricity and hydrogen-powered aircraft), participation of sustainable aviation fuels (SAFs), and the use of synthetic fuels.

Large investments into sustainable aviation fuel (SAFs) supply chain and production facilities around the world is clearly needed. Regions with strategic transport hubs, technological capacity, and abundant bioenergy potential could benefit as exporter and refueling hub for biojet fuels, as seen in future SAF production plants in USA, Brazil, Singapore and the Nordic Region. Regulatory

13 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_World_Energy_Transitions_Outlook_2021.pdf
14 https://www.researchgate.net/publication/331430429_Comprehensive_investigation_on_hydrogen_and_fuel_cell_technology_in_the_aviation_and_aerospace_sectors
15 https://www.emarketer.com/content/small-electric-aircrafts-making-inroads-tech-limitations-mean-long-flights-still-decades-away

frameworks that assesses the fuel's sustainability should also be strengthened, as is currently being done under ICAO's Carbon Offsetting & Reduction Scheme for Aviation (CORSIA)[16]. The same applies to regions with abundant renewable electricity potential that could be used to produce green hydrogen and derive synthetic fuels from. With increased commitments and market-based measures such as in the EU (EASA, EEA, EUROCONTROL, 2019), biojet fuels and synthetic kerosene have the potential to be cost-competitive with jet kerosene by 2050.

For future aircraft propulsion technologies, more concentrated efforts in research and innovation is required before electricity and hydrogen powered aircraft can be fully commercialised in the short-haul segment by 2035. This is particularly pertinent for high-density battery technologies, where the battery storage limits the size and range of electric aircraft. Finally, airlines and governments should continue to support ICAO's CORSIA scheme and target of carbon neutral growth from 2021 (ICAO, 2020), while also taking the view that curbing the global appetite and demand for flying is the simplest yet necessary step towards decarbonisation.

16 https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx