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Low-Carbon Aviation Fuels

Overview

- Low-carbon fuels could reduce UK aviation CO_2 emissions by 5%–30% by 2050.
- Biofuels vary by the inputs and processes used to produce them. They face environmental sustainability challenges around land use and overall emissions.
- Electro-chemical fuels have significant technical potential but are currently costly.
- Hydrogen is being investigated as a fuel for short-haul aircraft but faces significant challenges due to its low energy density.
- Incentives and targets can accelerate the uptake of low-carbon aviation fuels.

This POSTnote reviews the main types of low-carbon aviation fuels and their potential for use, as well as associated challenges and opportunities. It supplements POSTnote 615.

Background

Low-carbon aviation fuels can replace and/or be blended with conventional aircraft fuel (jet fuel) to reduce greenhouse gas (GHG) emissions from flights. Estimates suggest that they could mitigate between 5% and 30% of carbon dioxide (CO_2) emissions from UK aviation by 2050.[1–3] This assumes that these fuels will replace 5%–40% of jet fuel and produce 60%-100% less CO_2 emissions.[1,3] The level of emissions reduction depends on the raw materials and processes used to produce these fuels.

There is consensus among stakeholders that low-carbon aviation fuels are a plausible solution for mitigating aviation emissions. They do not require major changes to aircraft or airports and could in theory be implemented immediately. They can be used in long-haul flights, where other options for mitigating emissions are limited. [4–6] Between 2008 and June 2019, around 200,000 flights ran on some amount of low-carbon fuels.[7,8] Several airlines have invested in these fuels, seven airports supply them and six production methods are currently certified, with more under review.[9–11]

To date, the uptake of low-carbon aviation fuels has been low. In 2017, approximately 7 million litres of alternative jet fuel were produced globally, equivalent to 0.002% of total fuel consumption by aircraft that year.[12,13] The main barriers are the high production costs.[1,14] Low-carbon aviation fuels are more expensive than jet fuel, which is exempt from taxes under international convention.[15] Producers of new fuels require high levels of upfront capital investment and the removal of investor risk when introducing new technologies and building production plants.

Aviation fuels need to be very energy dense (able to produce a large amount of energy from a small amount of fuel). This, and the stringent safety requirements for aviation, mean that timelines for developing and certifying fuels are long. Existing safety standards require low-carbon aviation fuels to be blended with at least 50% jet fuel.[16] Aviation also competes for low-carbon fuel technologies with the automotive sector, where incentives are clearer and returns from fuel sales are higher.

Overview of Fuels

Fuels that generate at least 60% fewer GHG emissions than jet fuel and meet certain environmental sustainability criteria are considered low-carbon.[1] They include biofuels and electro-chemical fuels (referred to by industry as "sustainable aviation fuels") as well as hydrogen. Electro-chemical and biofuels are chemically identical to jet fuel but are produced from different raw materials and processes.[17]

Biofuels

Biofuels are made from biomass (organic matter such as vegetation or organic waste), which absorbs CO_2 over its lifetime. Burning biofuels in aircraft can theoretically reduce the amount of CO_2 emitted over the lifecycle of the fuel (from plant growth to fuel use), compared to jet fuel. Biofuels can be produced from crops or organic waste.[18] The Committee on Climate Change (CCC) has suggested that biofuels could replace 5%–10% of UK jet fuel use by 2050.[19]

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Crops for biofuel production can be purpose-grown energy crops (such as camelina) or food crops, such as corn and sugarcane. Growing these requires land-use change, causing GHG emissions through vegetation loss or soil changes.[20,21] They may compete with food production for land and water resources, and cause the conversion of natural habitats to agricultural land. Their large-scale use could increase risks for global food security and biodiversity.[22] Research on producing biofuels that do not compete with food crops is ongoing.[23]

Second-generation biofuels can also be made from waste, such as municipal solid waste (waste from homes and businesses), waste oils or fats, or cellulosic waste (agricultural or forestry residue).[23] These fuels face fewer concerns around land use, but their production is constrained by the low availability of waste in the UK.[24] For example, municipal solid waste is usually designated for other uses, such as electricity production, as part of long-term contracts with local authorities.[24]

Despite being lower-carbon alternatives, biofuels also result in GHG emissions across their lifecycle. The emissions saved by using aviation biofuels varies widely (18%–95% compared with jet fuel), depending on the raw material and production process.[25] Other sectors, such as road transport and electricity production, compete with aviation for the use of biomass. Aviation biofuels can incur high transport costs due to the required volumes of raw materials, particularly if these are not readily available.[26,27]

Electro-chemical Fuels

Electro-chemical fuels (sometimes known as synthetic or "power-to-liquid" fuels, or Renewable Fuels of Non-Biological Origin) are formed from CO_2 and water. They are produced by using electricity to break down water and obtain hydrogen, which reacts with CO_2 to form a gas (syngas). This gas is then converted into a liquid fuel and by-products, which can be used to make soaps or plastics.[28] The CO_2 can be obtained from a waste product (from industrial processes) or from the atmosphere through a 'direct air capture' process (POSTnote 549).[29] Electro-chemical aviation fuels have generated interest as a potential method for carbon capture and utilisation (POSTbrief 30). Carbon capture is regarded as necessary for offsetting CO_2 emissions from aviation. However, the CCC suggests that storing captured carbon is more efficient and cost-effective than producing fuel with it.[19]

Electro-chemical fuels have significant technical potential to mitigate aviation emissions. They do not face challenges around land-use change, and production would be carbon-neutral if it uses renewable electricity.[30] However, they are in early development stages and are 2–5 times more expensive than jet fuel.[14,31] They also require large volumes of low-carbon electricity for production.[14] Many stakeholders call for investment and government support to reduce early-stage risks of these fuels.

Hydrogen

Hydrogen can be combusted as a liquid or compressed gas fuel to directly power aircraft engines. Alternatively, it can be used in a fuel cell to produce electricity to power electric aircraft. In both cases, hydrogen aircraft are not expected to be available commercially until after 2050.[32] The only option for long-haul hydrogen flights would likely be a liquid fuel, because fuel cells require batteries, the weight of which currently prohibits their use across long distances. However, fuel cells could be used to power aircraft taxiing, or in an aircraft's auxiliary power units (which power functions other than flight). Some airlines and companies are working on demonstrator fuel cell aircraft, and a €4 million European project is examining liquid hydrogen in aviation.[33–35]

A number of challenges exist in developing hydrogen aircraft. Combusting hydrogen does not emit CO_2, but releases roughly twice as much water vapour as jet fuel. Water vapour has an overall warming effect on the climate.[32] Infrastructure to produce and supply hydrogen to aircraft at scale is currently undeveloped and would be costly. Hydrogen only has a quarter of the energy density of jet fuel and thus requires much more storage space. There are safety and public perception considerations around the transport, handling and storage of hydrogen on aircraft.[36–39]

Policy for Supporting Low-Carbon Fuels

Policy and regulation to incentivise low-carbon aviation fuel use could help reduce development costs.[14] There is currently no international policy mandating the use of low-carbon aviation fuels. The International Civil Aviation Organization (ICAO), the UN agency for aviation, provides guidance for the development and use of these fuels. The EU Renewable Energy Directive, which sets targets for the use of low-carbon transport fuels, does not currently obligate member states to use low-carbon aviation fuels.[40]

Some countries have set policies for low-carbon aviation fuels. Norway mandates airlines use progressively lower percentages of jet fuel in their flights.[41] The US federal Renewable Fuel Standard (RFS) mandates an increasing volume of renewable fuels to replace jet fuel.[42] California's Low-Carbon Fuels Standard offers incentives for the production of alternative aviation fuels.[43,44] Wider support policies include the Government of Canada's low-carbon aviation fuels competition which includes a commitment to use the winning fuel in its federal air fleet.

As a global authority on aviation fuels certification, the UK has capacity to accelerate the production and uptake of low-carbon aviation fuels.[1] Some industry actors have called for the UK Government to establish an Office for Sustainable Aviation Fuels to manage policy and funding for low-carbon aviation fuels.[45–47] The UK Renewable Transport Fuel Obligation (RTFO) provides incentives for low-carbon aviation fuels (including electro-chemical fuels), but not a specific target for their uptake.[48] The CCC have advised that the RTFO focus more strongly on low-carbon aviation fuels, but others argue against this while jet fuel is tax exempt.[49,50] In 2017, the UK Department for Transport (DfT) launched a competition providing £22 million in grant funding to scale up low-carbon aviation fuel technologies.[51] Industrial stakeholders have expressed concerns about a lack of government coordination on low-carbon aviation fuels. Successful low-carbon fuel policies in other countries have emphasised government coordination and stakeholder engagement.[52–54]

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Luciana Maria Miu for researching this briefing, to the Natural Environment Research Council for funding her parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Jack Miller.

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