Report: UK net zero aviation ambitions must resolve resource and research questions around alternatives to jet fuel

April 5 2023

Fuel Type	Advantages and disadvantages	Resource implications
Biofuels (energy crops and waste)	CO_2 produced but is mitigated by CO_2 capture in the biomass, but little modification of infrastructure or aircraft required. Land availability, for energy crops, and resource availability for wastes, is challenging.	Energy crops considered – rapeseed, miscanthus, and poplar wood – would require **more than 50% of the UK's available agricultural land** to replace aviation fuels. 'Waste' feedstocks including sewage, solid municipal waste, or forestry residues, could contribute towards net zero fuel demand, but there is competition from established markets for these feedstocks and significant investment in fuel production and collection infrastructure is required.
Hydrogen	No CO_2 produced from the aircraft, significant renewable electricity needed for 'green' hydrogen. Substantial modification of aircraft and infrastructure, and assurance of safety and non-CO_2 effects, needed.	Producing enough green hydrogen to replace current fossil aviation fuel would require around **2.4 to 3.4 times** the UK's annual renewable electricity generation (2020).
Ammonia	No CO_2 produced from the aircraft, but greater renewable electricity requirement than hydrogen. Substantial modification of aircraft and infrastructure, and assurance of safety and non-CO_2 effects, needed.	Producing 'green' ammonia as a jet fuel would require **2.5 to 3.9 times** the UK's annual renewable electricity generation (2020).
Synthetic fuels	Would produce CO_2 from the engine but, like biofuels, would require minimal modification of existing aircraft. Efuel production is energy intensive and to be considered 'net zero' would require green hydrogen as a feedstock and capture of CO_2.	When done sustainably using renewable electricity, this would require **5 to 8 times** the UK's 2020 renewable electricity capacity (excluding biofuels).

Credit: Royal Society

Producing sustainable aviation fuel to supply the U.K.'s "net zero" ambitions would require enormous quantities of U.K. agricultural land or renewable electricity to keep flying at today's levels, a briefing by the U.K. science academy, the Royal Society, has warned.

The Net zero aviation fuels: resource requirements and environmental impacts report warns there is no single, clear, sustainable alternative to jet fuel able to support flying on a scale equivalent to present day use.

The report explores these resource availability challenges, as well as likely costs, life-cycle impacts, infrastructure requirements and outstanding research questions across four fuel types, green hydrogen, biofuels (energy crops and waste), ammonia and synthetic fuels (efuels). (Note: Batteries were not considered as aircraft powered solely by batteries are not expected to reach the energy density requirements of long-distance commercial flight by 2050.)

It estimates that meeting existing U.K. aviation demand entirely with energy crops would require about half of U.K.'s agricultural land. While producing sufficient green hydrogen fuel would require 2.4–3.4 times the U.K.'s 2020 renewable (wind and solar) electricity generation.

While each fuel type has advantages and drawbacks, the findings underscore the challenges of decarbonizing aviation, especially when resources are likely to be in global demand for a range of "net-zero" objectives.

The report also identifies significant research requirements in scaling up net zero fuels, from storage and handling, to environmental impacts including CO_2 and non-CO_2 emissions.

Addressing these challenges requires global coordination, particularly for navigating the transition period between current and future generation aircraft.

"Research and innovation are vital tools for the delivery of net zero," said Professor Graham Hutchings FRS, Regius Professor of Chemistry, Cardiff University, and chair of the report working group. "But we need to be very clear about the strengths, limitations, and challenges that must be addressed and overcome if we are to scale up the required new technologies in a few short decades.

"This briefing tries to pull together those realities, to allow policy makers to understand the future resource implications of today's policy and R&D decisions and to support international dialogue on this global technology transition."

Global aviation CO_2 emissions were approximately 1,000 million metric tons per year in 2018/19, representing 2.4% of global emissions, dropping in 2020 to 600 million metric tons and increasing in 2021 to 720 million metric tons. U.K. aviation (international and domestic) accounted for 8% of U.K. greenhouse gas emissions in 2019.

The U.K. has committed to scale up manufacturing of sustainable aviation fuels (SAFs) and make domestic flying "net zero" by 2040, but aviation is growing globally, and is one of a number of sectors needing to decarbonize.

While alternative aviation fuels will likely have an increased cost, persisting with traditional kerosene jet fuel is likely to become increasingly expensive as decarbonization in other sectors accelerates, the report notes.

Life cycle assessment

Life cycle assessment of the fuel options in the report considered their environmental impacts including emissions beyond CO_2 from fuel production to pump, or fuel production to exhaust (known as wake). However, accounting for emissions and environmental impacts depends in part on the assumptions made and availability of data on their use and production.

Despite increasing investment in ammonia and hydrogen fuels, data on emissions are limited in the public domain—in part because of the immaturity of these technologies—so these projections will need to be continually updated as engine data from laboratory, and real-world testing develops.

Research will also be important to understand the impact of non-CO_2 emissions from jet engines, and the formation of contrails, which currently contribute significantly to warming by aviation globally. Alternative fuels may reduce these effects, but there are significant uncertainties over this.

Wider considerations, including the development of new airframes to permit hydrogen or ammonia storage, the refueling infrastructure, and safe refueling and storage protocols would also need to be investigated and adopted globally.

"How fossil fuel alternatives are produced is critical, as is how we measure their sustainability across the entire cycle of their use," Professor Marcelle McManus, Director of the Institute for Sustainability, University of Bath and a working group member.

"We need consistency, and we need to apply this globally, because adopting any of these new technologies will create demands and pressures for land, renewable energy or other products that may have knock on environmental or economic effects."

More information: Net zero aviation fuels: resource requirements and environmental impacts: royalsociety.org/topics-policy … zero-aviation-fuels/

Provided by Royal Society