Cleared for Offtake

Supplying Sustainable Aviation Fuels

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The Opportunity

The aviation industry has a key role to play in responding to the climate change challenge and is dedicated in its commitment to rise to that challenge. Airlines first agreed worldwide industry carbon targets in 2009 (for 1.5% efficiency improvements per year from 2009; carbon neutral growth from 2020; and 50% net reductions emissions from international aviation by 2050).

Since then it has introduced a number of improvements, including significantly more efficient aircraft, technologies and operations, as well as agreement on the world's first global, sectoral carbon market based measure: the new Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) led by ICAO: the UN body responsible for civil aviation.

Further improvements like electric aircraft are also in development, but these are likely to be a long way off routine use, especially for long haul commercial operators. It is widely agreed that the next, near-term changes will come from the fuel used to power the aircraft, that is, Sustainable Aviation Fuels (SAF).

Acknowledging this, there has been an increase in the development of new fuel technologies suitable for use in commercial aircraft. Several new fuels are now approved for use in commercial aviation without the need for any changes to engines or airframes – termed "drop-in" fuels.

What differentiates these fuels from fossil kerosene is that they can be produced using wastes, residues and renewable feedstocks and can meet robust sustainability standards. Some airlines are already using these fuels on commercial flights. The demand for SAF is rising and represents a new, exciting opportunity for companies and for the aviation industry as a whole.

From 2021, the CORSIA will recognise the use of SAF, opening up a global market for fuels technologies.

Companies interested in becoming involved in the SAF market need to consider a number of critical issues when developing their business plan.

Commercial Viability

As potential buyers, airlines are looking for projects that are able to demonstrate a pathway to commercialisation, particularly if those technologies are at higher technology readiness levels. This would include initial financial modelling, together with some idea of expected timelines and progress (e.g. from R&D, to pilot facility, to demo plant, to commercial production).

As fuel is such a big part of an airline's operating costs, airlines are also looking for commercial fuels that can become cost competitive relative to fossil kerosene over a period of time, particularly as they scale up and the technology is rolled out to achieve economies of scale.

Also bear in mind that most airlines see themselves as buyers of fuels and don't always get directly involved in fuel developments or investments. However, the right airline partnership may bring access to expertise and some airlines do have investments in infrastructure.

Note that some states do provide production support for 5 eligible fuels and the UK's Renewable Transport Fuel Obligation (RTFO) provides credits to some aviation fuels meeting relevant criteria.

The Sustainability of Aviation Fuels

As the names suggests, SAF must also meet specific sustainability standards. Governments often require suppliers of aviation to meet certain standards in order to qualify them as sustainable.

There are also voluntary sustainability standards which suppliers of aviation fuels can elect to meet. Members of UK group Sustainable Aviation and international group the Sustainable Aviation Fuel Users Group (SAFUG) are keen to actively support the most robust sustainability standards possible for new jet fuels and many are prioritising advanced, waste-based technologies

SUSTAINABLE AVIATION

Technical Qualification for Aircraft Compatibility

All new aircraft fuel technologies have to undergo extensive testing to demonstrate they can meet current aviation fuel technical performance specifications before they can be used on commercial and military aircraft.

ASTM International is a committee of leading industry experts and stakeholders, including the airframe, engine manufacturers (known in the trade as 'OEMs' – Original Equipment Manufacturers) and other specialists.

ASTM Committee members must thoroughly review performance test data and reach a consensus to qualify a new fuel type for commercial use.

This can be a lengthy process and may also be followed by the need to seek local or regional regulatory approvals (within Europe this is approved via the UK MoD's defence standard 91-091.)

Essentially, this means that new suppliers will need to understand the ASTM standard and other qualification processes as the technical and quality standards for jet fuel are rigorous. Within the SAF Special Interest Group (SIG) there are industry partners who are familiar with the process and may be able to provide some support.

Logistical Issues

Companies interested in supplying SAF need to clearly identify to prospective customers where they will operate in the value chain and how they might integrate their product into the existing supply chain. For example, airlines will want to understand how fuel can ultimately be delivered to airports and aircraft as a commercial 'drop in' fuel to existing infrastructure.

Fuel Economics, Commercialisation and Scale Up

Fuel is generally the largest contributor to an airline's operating costs. They will therefore look for commercial fuels that will be affordable relative to fossil kerosene prices in the future, particularly as production is scaled up and the technology is rolled out. In recent years aviation kerosene has been trading in the range of $500-$700 per tonne. SAF supply chains tend to be significantly more costly, however, the introduction of various policy support mechanisms may help bridge this gap.

Partnerships with UK Airlines

Developers should bear in mind that most airlines are simply buyers of fuels and often don't get directly involved in fuel developments or investments. However history of some airline partnerships has demonstrated that they can help access the expertise needed to scale up sustainable jet fuel developments.

Although not commonplace, some airlines have invested in fuel companies, have helped support development, and/or have provided long-term 7 offtake contracts.

Examples of partnerships between UK airlines and sustainable fuel developers:

- Virgin Atlantic and LanzaTech: **In partnership since 2011 and committed to producing the world's first jet fuel derived from waste industrial gases from steel mills and other waste streams. The airline flew the first commercial flight with LanzaTech's jet fuel in 2018 to demonstrate the commercial viability of the fuel.**
- British Airways and Velocys: **In partnership since 2017, together the two companies plan to design a series of plants that convert household waste into renewable jet fuel.**
- British Airways and LanzaJet: **British Airways has invested in SAF technology provider and SAF producer LanzaJet as the company builds its first commercial scale plant in Georgia, USA and will purchase SAF from LanzaJet's plant to power a number of the airline's flights from late 2022. The agreement also involves LanzaJet conducting early stage planning for a potential large scale commercial SAF biorefinery in the UK.**

Policy Support

A number of countries already have policy support in place for SAF and many other countries are well advanced in developing proposals. In the case of the UK, the Department for Transport supports SAF supply through the revised RTFO, which came into effect in April 2018.

There are also ongoing discussions within ICAO to provide policy measures to encourage early stage investments. There is a growing international market for SAF, especially beyond 2020 when the global CORSIA regulations come into effect.

The purchase of CORSIA compliant SAF will provide airlines a mechanism to reduce their CORSIA obligations. Under the RTFO, fuel suppliers in the UK able to provide high quality "drop–in" fuels based on waste feedstocks could be eligible for incentives known as Dev-RTFCs which are provided to certain feedstocks meeting the UK's sustainability criteria for developmental fuels. *Note this incentive does not apply to fuels based on used cooking oil.*

This tradable certificate provides an additional income for the producer that should allow the fuel to be produced and sold at a price closer to the market price for existing fossil fuel.

In addition, feedstocks not on the developmental fuels list can also qualify for standard RTFCs provided that the fuel can meet the UK's sustainability requirements. Full guidance on the revised RTFO can be found here.

There are a number of other initiatives that can provide support for fuel developers.

Note that this is not an exhaustive list.

Innovate UK offer a range of business grant funding schemes to support various stages of development and types of production pathways.

EPSRC offer a range of funding programmes for academics at various stages of their career. EPSRC will fund projects focused on the development of low carbon fuels.

BBSRC offer a range of funding programmes for academics at various stages of their career. BBSRC will fund projects focused on the development of low carbon fuels using biotechnology and biosciences.

Devolved Administrations offer grant funding for businesses and academics:

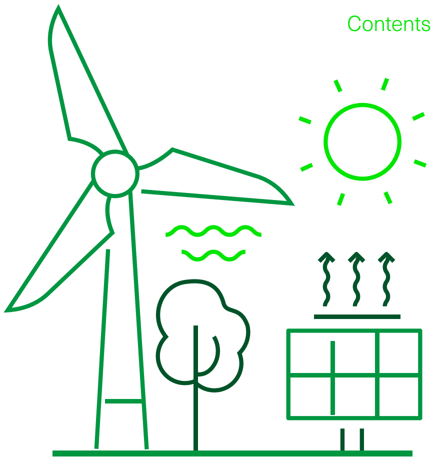
- **Invest Northern Ireland**
- **Welsh Government**
- **Scottish Enterprise**

Technical Assistance

The following organisations offer a range of technologies and processes to support the scale up of fuel production:

- **High Value Manufacturing Catapult**
- **BioPilotsUK**

Sustainability



Feedstock and process sustainability is of the utmost importance to airlines buying SAFs. We encourage technology developers to consider feedstock sourcing environmental and social sustainability as early as possible, independent of the fuel development stage being undertaken.

In the EU and UK, fuels manufactured using agricultural crops are likely to be subject to new restrictions after 2020. This is principally due to concerns over displacement of food production, and direct as well as Indirect Land Use Change (ILUC) issues - climate impacts resulting from expansion of production of vegetable oil crops. Present UK incentives thus prioritise feedstocks derived from wastes and residues.

Sustainable Aviation has the following broad sustainability aims in developing new supply chains:

- **Meet stringent sustainability standards with respect to land, water, and energy use;**
- **Avoid Direct and Indirect Land Use Change (ILUC) impacts, for example tropical deforestation;**
- **Do not displace or compete with food crops;**
- **Avoid negative human impacts and provide positive socio-economic effects;**
- **Exhibit minimal impact on biodiversity.**

To demonstrate that sustainability aspects have been taken into account, suppliers should apply a robust sustainability standard, such as the one provided by NGO preferred Roundtable on Sustainable Biomaterials (RSB).

While airlines will look for RSB certified commercial supply, they won't necessarily expect suppliers to be certified while still in development. *Please note that although not all RSB principles may apply to every technology at the moment, we recommend approaching RSB to determine how their standard may be applied to your fuel.*

Sustainable Aviation and the international Sustainable Aviation Fuel Users Group can also provide useful background on the sustainability standards expected from new jet fuels. As fuel buyers, UK airlines for example are particularly interested in advanced fuels made from sustainably sourced local waste streams. This has the added benefit of offering a lower cost and sustainable feedstock.

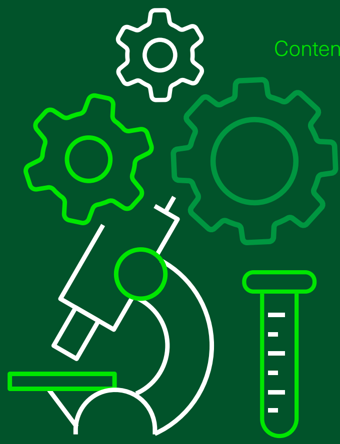
ICAO is in the process of developing SAF sustainability standards for CORSIA compliant fuels and initially these will be based on product greenhouse gas accounting and the protection of high carbon stock lands. The methodology also takes account of indirect land use change. The work on other aspects of sustainability is still under development and suppliers will need to stay aware of the latest developments.

International Civil Aviation Organisation's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

CORSIA was agreed by ICAO in 2016. From 2021 airlines will be required to purchase offset "emission units" or sustainable aviation fuels, to account for their share of global growth in CO2 emissions and address the industry-agreed target of carbon neutral growth (CNG). At the time of writing, the scheme has agreed methods for measuring the carbon performance of new fuels.

However, a number of other broader sustainability measures are still under development. At present, these methods have not been published and as such we would advise using RSB as a guide.

Technical Details



Aviation jet fuel is a high performance distillate fuel which must meet rigorous standards and quality assurance. It is a multipurpose fluid that serves many roles, including being the source of energy on an aircraft and a primary heat transfer fluid.

- **It must have high energy density and purity, good cold flow properties down to -47°C and remain a liquid at high temperatures.**
- **It must also have good thermal stability to ensure that it does not break down and foul control system units.**
- **It must exhibit low volatility to be safe during fuelling operations, but must also combust when required in the engine.**
- **The fuel will come in contact with a wide range of materials and so must be compatible with all of them.**
- **The fuel must not cause unacceptable levels of smoke and emissions during combustion.**

Of further note is the fact that any additives used to modify characteristics of the fuel are carefully controlled. In short, new fuels must perform as well or better than existing fossil jet.

Some key fuel requirements for example, are as follows:

Property	Unit	Specification
Flash point	°C	38
Freezing point	°C	-47
Combustion heat	MJ/kg	42.8 (minimum)
Viscosity	mm^2/s	8.0 (maximum)
Sulpher content	%	0.30
Density	kg/m^3	775-840

(Note: this does not represent the full specification)

These properties and requirements are controlled by specifications. During transport and storage, strict quality assurance is in place to ensure the fuel remains compliant with the specification, free from contamination, and fit for purpose at the point of use.

Fuel properties can have a profound effect on aircraft and engine performance, efficiency, emissions, cost of ownership, and critically, safety. Fuel specifications form part of an aircraft's certification and must be adhered to.

Fuel specifications are not a true material specification, nor do they test for every property. They are batch certifications used to check production quality and assume that the fuel product has already been proven to be acceptable when made to a defined process. For this reason, when a new fuel blend, fuel blendstock, or additive is offered to the industry it must go through a rigorous evaluation to ensure that it behaves within acceptable limits so as to never affect aircraft safety or performance. Fuel specifications are predominantly managed by two authorities – the US based ASTM, and the UK Ministry of Defence.

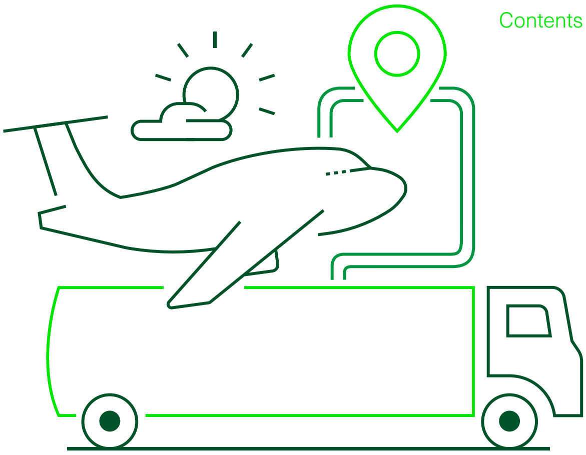
A synthetic kerosene fuel can only be approved for use once this evaluation is complete. At this point it is considered technically equivalent to conventional fuels and does not require any special limitations in use. It can then be called a "drop-in" fuel.

At this stage, five fuels have been certified under the US based ASTM D7566 fuel standard. These fuels are evaluated and if acceptable, approved by the equivalent UK specification: UK MoD Def Stan 91-091.

The fuels are all hydrocarbons which must be blended with fossil jet fuel prior to use in commercial aviation. At this time, blend ratios for each new product are defined and may be up to 50% with conventional fossil kerosene.

Further information on the ASTM fuel certification process is available here

Logistics



Airlines will ultimately want to understand how fuel will be delivered to airports and aircraft as a commercial "drop in" fuel. Presently, all approved synthetic fuels must be blended with a certified fossil Jet-A1 component prior to delivery at the airport.

This is likely to raise a number of logistical issues since fuel infrastructure is typically owned or controlled by third parties. SA members may be able to provide support in overcoming these issues.

It is important for technology developers to consider both the logistics of delivering feedstock to the processing plant as well as fuel delivery.

For reasons of both sustainability and economics, it is helpful if fuel production facilities are situated close to sources of feedstock. Both fuel and feedstock delivery must be accounted for as part of the lifecycle greenhouse gas emissions of a new fuel.

Fuel can be distributed by pipeline and an overview of the UK's jet fuel pipeline network is available here. Fuel may also be distributed by rail and road. It is important to note that unless certified under Def Stan 91-091, fuel cannot be stored within or distributed by UK infrastructure, including pipelines, hydrants, and integrated tanks.

Airlines will also want to be able to use sustainable jet fuel in order to take advantage of alleviations offered to them under the EU Emissions Trading Scheme. EU rules for eligibility under this scheme are considered on the basis of a "modified mass balance".

This means that whilst it is not necessary to prove that a certain percentage of fuel on a specific flight is sustainable, the airline must prove that there is a physical link between the delivery of fuel into the fuel distribution system and the airport. An example would be that for an airline using London Heathrow as a hub airport, it is necessary to show that a sustainable jet blend is delivered in to Heathrow's fuel hydrant system.

Helpful Links:

IATA Guidance Material for Sustainable Aviation Fuel Management

Sustainable Aviation Fuels Road Map: Chapter 4

Glossary of Terms

Advanced Fuel:

Advanced fuels are produced by more complex processing technologies that are able to process wastes, residues and other feedstock types. These successors to first generation of sustainable fuels usually yield higher greenhouse gas savings and often avoid the land use concerns associated with many first generation technologies and feedstocks.

Aviation Fuel:

Current aviation fuel, a kerosene-type fuel, commonly referred to as Jet A-1 or Jet A. Jet A-1 is suitable for most turbine engine aircraft. It has a flash point of 38°C and a freeze point maximum of -47°C. Jet A is only available in North America and has a higher freeze point (-40°C).

Bio-derived fuel:

Generally used to describe non fossil fuels derived from biomass, but it's important to note that the sustainability of some of these can vary significantly depending on their source and processing.

"Drop-in" Fuels:

A fuel that can be used with current aircraft and engine technology and does not require modifications to aircraft engines and fuel systems and ground supply infrastructure.

Fossil Fuel:

General term for buried combustible geological deposits of organic materials, formed from decayed plants and animals that have been converted to coal, natural gas or crude oil by exposure to heat and pressure in the Earth's crust over hundreds of millions of years.

Jet A1:

See aviation fuel above.

Low Carbon Fuel:

Fuels that provide high greenhouse gas lifecycle savings (>60%) when compared with their fossil equivalents.

Sustainable Fuel:

'Sustainable fuel' can be derived from biomass, but could also be derived from other sustainable sources that have a lower overall carbon footprint than fossil- or some biomass-derived fuels – such as fuels made from bio or non-bio waste streams.

Synthetic Aromatic:

A manufactured aromatic hydrocarbon product, i.e. one that contains alternating single and double bonds between carbons. The simplest form of which is known as a benzene ring with six carbon and six hydrogen atoms. Some aromatic compounds in Jet fuel contain more complex fused benzene compounds.

Synthetic Fuel:

A manufactured hydrocarbon product which is chemically similar to the fossil equivalent that can be substituted for or mixed with other aviation fuels. It may or may not be produced from sustainable feedstock.

Synthetic Paraffinic Kerosene:

A manufactured blend comprising iso paraffins, normal paraffins and cyclo paraffins.

Useful Acronyms

ASTM	ASTM International. Previously known as American Society for Testing and Material. Owner of the major Jet fuel specifications ASTM D1655, ASTM D7566, ASTM D4054.
ATAG	Air Transport Action Group
ATJ	'Alcohol to Jet' technology
CAA	UK Civil Aviation Authority
CAAFI	Commercial Aviation Alternative Fuels Initiative
CCC	UK Committee on Climate Change
CH	Catalytic Hydrothermolysis
CLEEN	Continuous Lower Energy, Emissions and Noise Programme (US)
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CtL	Coal to liquid technology
DEF STAN	UK Defence Standard
DOD	US Department of Defense
EASA	European Aviation Safety Agency
EI	Energy Institute
EPFL	Ecole Polytechnique Fédérale de Lausanne
EU RED	EU Renewable Energy Directive
FAA	US Government's Federal Aviation Administration
FQI Fuel	Quantity Indication
JIG	Joint Inspection Group
GBP	Pound Sterling
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GtL	Gas to Liquid technology
HDCJ	Hydro treated depolymerized cellulosic jet

GBP	Pound Sterling
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GtL	Gas to Liquid technology
HDCJ	Hydro treated depolymerized cellulosic jet
HEFA	Hydrogenation of esters and fatty acids
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation. The UN agency responsible for civil aviation.
ILUC	Indirect Lane Use Change
JIG	Joint Inspection Group
LCA	Life Cycle Analysis
MBMs	Market based measures
NNFCC	National Non Food Crops Centre
RSB	Roundtable on Sustainable Biomaterials
SAF	SIG Sustainable Aviation Fuel Special Interest Group (KTN)
SAK	Synthetic Aromatic Kerosene
SIP	Synthesized Iso-Paraffinic (fuel)
SK	Synthetic Kerosene
SPK	Synthetic Paraffinic Kerosene
UCO	Used Cooking Oil
WWF	World Wildlife Fund for Nature

Find out More

ktn-uk.org/transport/sustainable-aviation

sustainableaviation.co.uk

Connecting for Positive Change

The Knowledge Transfer Network (KTN) helps businesses get the best out of creativity, ideas and the latest discoveries, to strengthen the UK economy and improve people's lives.

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SUSTAINABLE AVIATION

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