Sustainable Aviation Fuels: A Market Opportunity

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(CAAFI)

First flight from continuous commercial production of SAF, 10 March 2016

Fuel from World Energy - Paramount (HEFA-SPK 30/70 Blend).

Only facility offering continuous production of SAF at present. Other batch production is occurring due to extreme customer interest.
CAAFI - Public/Private Partnership
A reflection of the 26+B usg U.S. Jet “market pull”

An aviation industry coalition established to facilitate and promote the introduction of alternative aviation fuel

Goal is development of non-petroleum, drop-in, jet fuel production with:

* Equivalent safety & performance
* Comparable cost
* Environmental improvement
* Security of energy supply for aviation

Enables its diverse stakeholders to build relationships, share and collect data, identify resources, and direct research, development and deployment of alternative jet fuels

www.caaфи.org
SAF a key component of the Technology Pillar; enabler for GHG containment strategy.

- **GOAL 1**: +1.5%/2.0% annual efficiency
- **GOAL 2**: CORSIA (Cockpit Reporting and Operational Safety Information Analysis)
- **GOAL 3**: -50%

Through new technology, improved operational measures, and more efficient infrastructure, the industry has avoided 8.5 billion tonnes of CO₂ since 1990.

Emissions trajectory if we were still operating at the same efficiency levels as in 1990.

Savings already achieved.

Where emissions would be if efficiency does not improve from today.

With constant efficiency improvement through the pillars of technology, operations, and infrastructure.

With gradual introduction of radical new technologies and sustainable alternative fuels.


Beginner’s Guide to Sustainable Aviation Fuel
Business Aviation made similar commitments.
SAF (Sustainable Aviation Fuel)  
a.k.a. aviation biofuel, biojet, alternative aviation fuel  

**Aviation Fuel:** Maintains the certification basis of today’s aircraft and jet (gas turbine) engines by delivering the properties of ASTM D1655 – Aviation Turbine Fuel – enables drop-in approach – no changes to infrastructure or equipment, obviating incremental billions of dollars of investment

**Sustainable:** Doing so while taking Social, Economic, and Environmental progress into account, especially addressing GHG reduction

**How:** Creating synthetic jet fuel with biochemical and thermochemical processes by starting with a different set of carbon molecules than petroleum … a synthetic comprised of molecules essentially identical to petroleum-based jet (in whole or in part)
SAF are becoming increasingly technically viable
- Aviation now knows we can utilize numerous production pathways
  (7 approved, 6 in-process, >15 in pipeline)
- Enabling use of all major sustainable feedstocks
  (lipids, sugars, lignocellulose, hydrogen & carbon sources, circular-economy byproduct streams)
- Utilizing thermo-chemical and bio-chemical conversion processes to produce pure hydrocarbons, followed by standard refinery processes
- Following blending with petro-jet, SAF is drop-in, indistinguishable from petro-jet
- Some future pathways expected to produce SAF blending components that will need less, or zero, blending
- Expanding exploration of renewable crude co-processing with refineries
- Continuing streamlining of qualification – time, $, methods
Where we stand on U.S. SAF consumption
Initiation under way, still early

* Four years of sustained commercial use
* Commercial & General Aviation engaged
* Two facilities in operation
* Two facilities under construction, others in development
* Cost delta still a challenge, with policies favoring renewable diesel
* In spite of that ... we still have $6.5 B in airline offtake commitments for >350M gpy ... with more in development

U.S. SAF Procurements*

Credit: FAA
*Reflects voluntarily reported data on use by U.S. airlines, U.S. government, manufacturers, other fuel users, and foreign carriers uplifting at U.S. airports.
^2017-2019 calculation includes reported EPA RFS2 RINs for jet fuel.
### Worldwide SAF production capacity forecast

**Announced intentions***

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*Not comprehensive; CAAFI estimates (based on technology used & public reports) where production slates are not specified.
SAF offtake agreements
Beyond numerous demonstration programs

- Initial 40M gpy nameplate facility
  With 25M gpy SAF capacity

* 24Oct’18: Moving forward with $350M Paramount expansion to enable 306M gpy total capacity & jet capacity of 150M gpy; Fuel production expected by YE’22

neat quantities

Up to 5 M gpy from 2016 (LAX)

Second 5-year agreement from 2020, 30/70 blend

1.8M g over 12 months

Misc Flights, e.g. SFO

Biports on demand, et al.

Halmstad
Arlanda
Bromma
Goteborg
Leeuwarden
SAF offtake agreements – pg 2
Beyond numerous demonstration programs

Porvoo SAF Q4’18 restart supplied to:
- Swedish Airports - SAS;
- Mobile, Hamburg – Airbus;
- Frankfort – Lufthansa;
- Amsterdam – KLM;
- Zurich – WEF;
- Helsinki – Finnair;
- Stockholm – Emirates, Swedavia;
- SFO - American, Alaska, and JetBlue

* Moving forward with significant expansion at Singapore and feasibility study at Rotterdam to enable ~480M gpy by 2023

* Initial 34M gpy capacity

Neat quantities not announced
SAF offtake agreements – pg 3
Beyond numerous demonstration programs

neat quantities
Up to 1M gpy, 5 yrs+ / France & EU supply;

Various Business Aviation airports FBOs

10M gpy, from 2022/2023
term/blend unspecified

Unspecified SAF distribution rights

* 3-4 facilities, utilizing ethanol conversion bolt-on approach
Beyond numerous demonstration programs

SAF offtake agreements – pg 4

* Initial 11M gpy nameplate facility, remainder at 2-3X in size

#1 Sierra *

Per statements made at ABLC 2020

#2 Gary, IN @ 3x capacity

Then replication in Houston, UK, WA state, CA state, Australia

Additional sites aligned with investor airlines’ US focal cities previously discussed
SAF offtake agreements – pg 5
Beyond numerous demonstration programs

- Red Rock Biofuels
- Southwest
- FedEx
- SG Preston
- JetBlue
- Qantas
- SkyNRG
- KLM
- LanzaTech
- ANA
- Suncor
- Virgin Atlantic
- Mitsu

neat quantities

3 M gpy each, 7 yrs (Bay Area, CA)
10M gpy, 10 yrs (JFK)
4M gpy, 10 yrs (LAX)
24M gpy, 10 yrs
SAF Supply collaboration
Freedom Pines, supply from 2022, 10M gpy nameplate
UK DfT F4C Funding: ATJ Development

*100M gpy by 2024 from 4 facilities
SAF offtake agreements – pg 6
Beyond numerous demonstration programs


SAF CONSORTIUM + Air Transat = Detail tbd; Montreal East pilot facility approaching completion
Airline commitments of greater ambition

Obtain 30% of jet fuel from alternative sources by 2030; 06Nov’17
First U.S. Airline to Pledge to Reduce Own Emissions by 50% (vs. 2005) by 2050; 13Sep’18. $40M SAF Investment Fund; 27Oct’19
Commits to flying 100 M passengers on SAF by 2030; 23Sep’19
Horizon 2030: offset 100% of domestic CO2 from 2020; reduce 2030’s CO2/pax-km by 50% from 2005; R&D for French SAF industry; 01Oct’19
Net-zero carbon by 2050, offsetting all domestic emissions by 2020; 10Oct’19
Net-zero carbon by 2050, CNG from 2020 on all emissions, $33M investment in SAF by 2030, matching of customer offsets; 25Nov’19
Reduce its net emissions by 50% from 2019 by the end of 2025, and achieve carbon neutrality by 2045 at the latest; 09Mar’20
SAF corresponding to the total jet consumption used in all SAS domestic flights, by the year 2030; 14Nov’19
Net Zero by 2040, and 100% renewable operations by 2025
Improve carbon efficiency by 45% by 2030 (16-28% SAF usage, or up to 500M liters)

Multiple airlines now committing to net zero carbon by 2050 (NZC’50).
Pressure to look at more progress by 2035.
Commitments of Greater Ambition
Airlines using passenger booking options to offset cost

Customer option to pay for incremental price of SAF of €29.50 on any flight

Customer option to pay for incremental price of SAF in 20-min blocks of flight time for €10 / block (up to 80% CO2 reductions); fuel being allocated to future flights

Compensaid – calculates specific cost of SAF for specific flights and enables customer to pay for incremental price
On select flights, CHF80 to offset carbon, 5% of which goes to SAF via Compensaid

Customer option to pay for incremental price of SAF for 3 categories of flight: intra-Finland (€10), intra-EU (€20), International (€65); fuel being allocated to future flights
Other commitments of greater ambition

Norway's government introduces 0.5% blending mandate for advanced aviation biofuels from 2020; 04Oct’18

Netherlands committed to transition all military aircraft to 20/80 AJF blend by 2030 and 70% by 2050; 23Jan’19

France, in alignment with EU Green Deal goals, announces SAF targets: 2% of SAF from 2025, 5% in 2030 and 50% in 2050; 27Jan’20

DG Move have now put together a comprehensive "roadmap" as a potential way forward for an integrated approach for policy intending to foster SAF commercialization in the European Union - ReFuelEU

Sweden's government introduces GHG reduction mandate for jet fuel, from -0.8% in 2021 to -27% in 2030; Fossil free by 2045; 11Sep’20
First facilities on-line, producing SAF at various run-rates

Commercial agreements being pursued, fostered by policy and other unique approaches

Line of sight to first billion gallons, but reflecting only 1% of market need

Making progress, but still significant challenges – only modest production: focus on enabling commercial viability

Potential for acceleration a function of engagement, offtakes, first facilities’ success replication, policy, ...

... and additional technologies that lower production cost, lower capital, enable byproduct revenue
SAF: from a diverse set of world-wide feedstocks
Wastes, residues, purpose grown, circular-economy byproducts
Thank You
Chris Tindal
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