Current State of Alternative Jet Fuel Deployment

16 July 2019
Sustainable Aviation Fuel Production

* Three years of sustained commercial production and airline use
* >1.2 million gallons in 2018 from additional producers, users, and airports
* New fuels under evaluation & construction of new facilities under way
* Potential for 250+ million gallons/year in <five years

**U.S. Sustainable Aviation Fuel Procurements***

![Graph showing annual fuel purchases from 2007 to 2018 for commercial and government sectors.](image-url)

- Gevo & AvFuel
- World Energy, Qantas & Agrisoma (LAX)
- Lanzatech & Virgin Atlantic (MCO)
- World Energy Paramount & United Airlines (LAX, SFO)
- World Energy Paramount & SkyNRG with KLM, SAS and Bombardier (LAX, SFO, BDL)
- World Energy Paramount & Gulfstream (SAV)
- Air BP, Airbus & JetBlue at BFM
- Dept. of Defense Testing
- FAA CLEEN program testing

Notes:

*Reflects voluntarily reported use by U.S. airlines, U.S. government, manufacturers, other fuel users, and foreign carriers uplifting at U.S. airports.
Sustainable Aviation Fuel Production Facilities

* as of June 2019

Note: The specific fraction of the total capacity dedicated to SAF will likely be based on market conditions.

- **Red Rock Biofuels**
  - Expected in Service: 2020
  - Expected Total Fuels Capacity (MGY): 15

- **Fulcrum Bioenergy**
  - Expected in Service: 2020
  - Expected Total Fuels Capacity (MGY): 10.5

- **World Energy Paramount**
  - In Service Since: 2016
  - Total Fuels Capacity (MGY): 40
  - Expected Total Fuels Capacity After Expansion (MGY): 306

- **Gevo**
  - In Service Since: 2011
  - Total Fuels Capacity (MGY): 0.07

- **Fulcrum Bioenergy**
  - Expected in Service: 2021
  - Expected Total Fuels Capacity (MGY): 33

- **SG Preston**
  - Expected in Service: 2021
  - Expected Total Fuels Capacity (MGY): 240

- **LanzaTech**
  - Expected in Service: 2019
  - Expected Total Fuels Capacity (MGY): 10

Status:
- Green: Commercial Jet/Diesel Operation
- Blue: Under Construction-Commercial Jet Capable
- Red: Planned Commercial-Jet Capable
- White: Planned Commercial-Jet Capable Expansion
SAF and Renewable Diesel Production Facilities

Note: Some fraction of renewable diesel could be converted to SAF production and/or the aviation industry is evaluating the use of renewable diesel as a blending component for jet fuel.

* as of June 2019
Current SAF Commercial Production & Offtake Agreements

- Began commercial production in 2016 supplying LAX
- Over 1 Million gallons per year of SAF since 2016
- Moving forward with $350M expansion to enable 306M gpy total capacity, including infrastructure for jet capacity of 150M gpy; 24Oct’18

* WEP also continues supplying fuel for multiple trial and research activities

neat quantities

Up to 5M gpy from 2016 (LAX) (renewed up to additional 10M for 2019-2020)

3 yr agreement

30/70 blend

3 yr agreement

Enabling LAX flts

16 July 2019

An offtake agreement is an arrangement between a fuel buyer and fuel producer to purchase a portion of the fuel producer’s future production.
United is the only U.S. airline flying on SAF on a continuous basis

United began flying World Energy's SAF from its Los Angeles hub in March 2016.

Through the end of 2018, United has flown the equivalent of over 2,700 SAF flights.

United has bought 3 million gallons of SAF from World Energy, more than any other airline in the world.

World Energy’s SAF provides a greater than 60% reduction in CO₂ emissions on a lifecycle basis when compared to traditional jet fuel.

The SAF is made from tallow, an inedible substance made from beef fat.

This project created 65 new jobs at the previously idle refinery in Paramount, California.
**Under Construction SAF Commercial Production Facilities & Offtake Agreements**

- **RED ROCK BIOFUELS**
- **Southwest**
- **FedEx**
- **Cathay Pacific**
- **UNITED**
- **air bp**
- **JAL Airlines**
- **Marubeni**
- **LanzaTech**
- **ANA**
- **virgin atlantic**

- **neat quantities**
  - 3 M gpy each, 7 yrs (Bay Area, CA)
  - 37.5M gpy
  - 90-180 M gpy
  - 50 M gpy

- **10 yr agreements**
  - Project Development, License, and Offtake
  - Supply from 2021
  - UK DfT F4C Funding: ATJ Development

* 100M gpy by 2023 from 4 facilities
In 2015 United invested $30 million in Fulcrum BioEnergy to convert municipal solid waste (MSW) into SAF

• Capture recyclables, generate renewable electricity credits, and produce fuel
• Greater than 80% reduction in CO₂ lifecycle emissions
• Co-develop up to five facilities (first SAF facility: Gary, Indiana)
• 900 million gallons over 10 years
Q: What about the price premium?
A: Starting in 2021, airlines will assumedly be open to paying a premium commensurate with the price of carbon associated with CORSIA offsets

- Avoided costly startup expenses, so reduced need for cost recovery or to advance down the learning curve
- Cost/risk-sharing agreement

- Using MSW as feedstock at no cost; some studies show that feedstock is as much as 80% of the cost
- Bringing in investors from across the value chain who receive different benefit streams

*CAAFI has changed the answer to the question from the original slide*
U.S. SAF Offtake Agreements

- neat quantities

- Up to 1M gpy, 5 yrs+

- Brisbane Supply Demonstration

- 10M gpy, 10 yrs (JFK)

- 4M gpy, 10 yrs (LAX)

- MSW-based FT-SPK evaluations

- BTL #1, Natchez, MS 1,400 bpd
International SAF Offtake Agreements

neat quantities

Carinata supply development

24.6M gpy, 10 yrs

SAJF Supply collaboration

New Aircraft Deliveries from Airbus and Boeing

Customer funding of SAF purchase from 2019
Other recent announcements

NESTE

Restarted SAF production at Porvoo

Multiple Producers, TBA

Gothenburg Refinery

American Airlines

SAF Supply exploration

MOU to design & implement adoption

Collaboration on supply expansion

Full production slate offtakes

Long-term supply negotiation (from 2023). Fueling all domestic flights by 2030.

16 July 2019
Other recent announcements

- Total | AMYRIS + Cathay Pacific | Alaska
- Other, TBA
- New Aircraft Deliveries from Airbus and Boeing

- jetBlue | CHINA AIRLINES
- TBA
- Customer funding of SAJF purchase from 2019

- Multiple Producers & Suppliers + Finnair
- Exploration of Greater ambition

- DG Energy + GE Aviation
- 0.5M gpy, 10 yrs

16 July 2019
For more information regarding the current state of alternative jet fuel development visit caafi.org