Sustainable Aviation Fuel from Ethanol

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LanzaTech Sustainable Aviation Fuel: ATJ-SPK from Ethanol

Ethanol → Dehydration → Oligomerization → Hydrogenation → Fractionation → Jet & Diesel

Ethanol → Ethylene → \( \text{C}_4^- \text{C}_{24} \) Olefins + H\(_2\) → Paraffins and IsoParaffins
Development and Scale Up Timeline

2010-2012: Initial Research and Proof of Concept
- 2010: PNNL
- 2011: DARPA
- 2011: FAA
- 2012: DOE

2011+: Collaboration with Industry Leaders
- Virgin Atlantic
- HSBC
- Boeing
- RSB

2014-2017: Scale up and Fuel Production
- Freedom Pines pilot facility
- 4,000 gallons of jet produced
- DOE demo funding

2016-2018: ASTM
- ASTM SAF Standard including Ethanol as Feedstock for Jet Published April 2018
- Based on LanzaTech data

2018+: Flight Demos and Demonstration Scale Fuel Production
- First Commercial flight on October 2, 2018
- DOE Demonstration Plant
LanzaJet: Taking Off

Waste Gas Ethanol from RSB Certified Facility
Grain Ethanol

✓ 4,000 gallons Jet
✓ 600 gallons Diesel

Fuel Property

<table>
<thead>
<tr>
<th>Jet A Spec</th>
<th>LanzaTech ATJ-SPK</th>
<th>50/50% v with Jet A</th>
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</thead>
<tbody>
<tr>
<td>Freeze Point, °C</td>
<td>-40 max</td>
<td>-61</td>
</tr>
<tr>
<td>Energy Density, MJ/kg</td>
<td>42.8 min</td>
<td>44.4</td>
</tr>
<tr>
<td>Thermal Stability</td>
<td>Baseline</td>
<td>Excellent</td>
</tr>
<tr>
<td>Viscosity @ -40 °C mm²/sec</td>
<td>12 max</td>
<td>7.0</td>
</tr>
<tr>
<td>Hydrogen %</td>
<td>13.4 min</td>
<td>15.1</td>
</tr>
<tr>
<td>Aromatics %</td>
<td>8 min, 25 max</td>
<td>Nil</td>
</tr>
<tr>
<td>Sulfur, total mass %</td>
<td>0.30 max</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

April 1, 2018
D7566 ATJ SPK Annex A5
✓ Ethanol feedstock
✓ Final blend ratio to max 50 %

October 3rd 2018 First Commercial Flight

4 Flights on 92% LanzaJet SPK
>80-90% Lower Contrails and Soot Particles
Path to Economic Volumes

2015 Lab Scale

2016 Pilot Scale

2020 10M gpy

2022 30M gpy x3
Ethanol from Recycled Carbon

Industrial Off Gas
Biomass, MSW Syngas

Gas Feed Stream

Proprietary Microbe

Compression
Fermentation

Recovery
Product Tank

C
LanzaTech-Sekisui
MSW → Ethanol
Demonstration
2014-2019
35k MTA
Biomass Syngas
ICAO STOCKTAKING SEMINAR TOWARD THE 2050 VISION FOR SUSTAINABLE AVIATION FUELS

Commercialization: Industrial Off Gases

China
48k MTA

Belgium
62k MTA

South Africa
52k MTA

India
34k MTA
Global ATJ-SPK Potential from Wastes and Residues Alone

- Residual Biomass: ~360 B gpy
- Steel Mill Offgas: ~30 B gpy
- Municipal Solid Waste: ~18 B gpy
- Refinery Offgas: ~2 B gpy
- Ferro-Alloy: ~0.5 B gpy
Building A Sustainable Aviation Fuel (SAF) Sector

- **Technical Support**
  - Continued (and expanded) support for stringent technical approval process

- **Supply Chain Support**
  - Support for development, collection, transportation, and storage of sustainable feedstocks
  - Infrastructure for SAF transportation, storage, blending, and distribution

- **Technology and Project Support**
  - R&D grants for technology and feedstock development, sustainability and systems analysis, ...
  - Grants and low-cost finance to offset capital costs of scale up (piloting and demonstration)
  - Assistance for project development, feasibility studies, environmental approvals, sustainability assessment
  - Guaranteed or low-cost debt to reduce capital risk of first commercial plants

- **Policy Support**
  - Stable alternative fuel policies that drive SAF demand
  - Most SAF technologies can produce gasoline and/or diesel as well as jet (and marine)
  - Mandates and incentives that at least level the playing field for SAF