Sustainable Alternative Jet Fuel - Progress & Challenges

Georgia Environmental Conference, 2016: Session 2.4: Sustainability in Aviation

Jekyll Island Convention Center
Wed, 24Aug’16
Com’l Aviation’s CO2 commitments
To decouple carbon growth from demand growth

This commitment is currently being converted into pending regulation through an ICAO/CAEP “basket of measures”:
* CO2 Standards
* MBMs – will monetize carbon

Similar commitment from BizAv & DOD

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An aviation industry coalition established to facilitate and promote the introduction of sustainable alternative jet 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.

SAJF: Sustainable Alternative Jet Fuel - Synthetic kerosene, primarily from renewable sources
SAJF
Sustainable Alternative Jet Fuel, a.k.a. biofuel, biojet

Alternative: Creating synthetic jet fuel by starting with a different set of hydrocarbons than petroleum … a synthetic comprised of molecules essentially identical to petroleum-based jet (in whole or in part) – enables drop-in approach – no changes to infrastructure or equipment

Sustainable: Doing so while taking Social, Economic, and Environmental progress into account

Jet Fuel: Delivering the properties of ASTM D1655

Net GHG reduction: Benefit comes from leaving more carbon molecules in the ground, but rather, taking them from the biosphere and/or re-using / recycling them
Achieving net LCA GHG reduction
Reduction in carbon being introduced to biosphere

CO₂

Petroleum based Jet
Achieving net LCA GHG reduction
Reduction in carbon being introduced to biosphere

Petroleum based Jet

Sustainable Alternative Jet Fuel
Achieving net LCA GHG reduction
Reduction in carbon being introduced to biosphere

Sustainable Alternative Jet Fuel

Net GHG reduction 65% 78%

WTW Life Cycle GHG Emissions, gCO₂e/MJ

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SAJF conversion processes
... or, “dispelling the fear of revisiting Chemistry 101”

Start with hydrocarbon / organic building-blocks

Deconstruct & remove extraneous molecules

Process to workable intermediates

Reformulate to appropriate C8-C16 molecules

Utilize standard refinery “finishing” processes

D7566 - SAJF Blending Components

D1655 – from petroleum and D7566 fuel blends
SAJF conversion mechanisms
Challenge ... doing it at the price of petroleum refining

Fossil HC
Lipids
Cellulose
Sugars & Starch
Wastes & Syngas

Challenges:
Gasify
Pyrolize
Torefy
Saccharify
Deconstruct Digest

Separate Ferment
Dehydrate
Catalyze
Process

FT
CH
CC
APR
HL
Oligomerize

Distill
Hydrotreat
Hydroprocess
Hydro-Isomerize

FT-SPK, HEFA-SPK, HFS-SIP, FT-SPK/A, ATJ-SPK, ...
### SAJF approved production pathways

<table>
<thead>
<tr>
<th>Approved</th>
<th>Syngas FT (FT-SPK)</th>
<th>50% max blend</th>
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<tbody>
<tr>
<td></td>
<td>Hydroprocessed lipids (HEFA-SPK)</td>
<td>50% max blend</td>
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<tr>
<td></td>
<td>Biochem sugars (HFS-SIP)</td>
<td>10% max blend</td>
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<tr>
<td></td>
<td>Syngas FT w/ aromatic alkylation (FT-SPK/A)</td>
<td>50% max blend</td>
</tr>
<tr>
<td></td>
<td>Isobutanol conversion (ATJ-SPK)</td>
<td>30% max blend</td>
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</tbody>
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* Another 7 processes progressing through ASTM
* Another 15 in early development
First refinery online!
AltAir Fuels in Paramount, CA

AltAir Fuels

- 40M gpy nameplate capacity in “Phase 1”
- Ownership evaluating 5-7X expansion in next 2-3 years
- SAJF being delivered to United (LAX), WFS (Gulfstream, et al):
- HDRD (F76) being delivered to Navy under DLA FY’16 contract
Overall industry summary:

- Industry aligned on need! Com’l, BizAv, US DOD
- Other challenges we’ve met:
  - Technical viability proven & versatile solutions identified
  - Modest amounts of SAJF coming online
    - AltAir from Mar’16, followed by three DPA facilities in ’18, ...
    - Several others in development
- Challenges remaining? Sure:
  - Risk, affordability, financing, execution, more feedstocks and processes
- Working a full range of Public-Private-Partnership activities to break down barriers, lower risk, facilitate supply
Where we’re working
CAAFI facilitation – broad and deep

Feedstock Development
Pathway Development
Sustainability
Price Point
Risk Reduction
Institutional Alignment
Analysis / Tools
Regional Engagement
Int’l Engagement

Research & Development
Certification & Qualification

Environmental
Business

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...via cooperative R&D efforts
Directly and through several PPPs

Feedstock Production
Feedstock Logistics
Fuel Conversion
Conversion Process Scale-up/Integration
Fuel Testing/Approval
Enable Production
End User/Buyer

USDA: BCAP & CIP, Feedstock Development Center Grants, AFRI/NIFA Caps
DOE & DOD: R&D grants
USDA & DOE: R&D grants, IBR
FAA & DOD: C/Q Fuel testing
FAA, DOD, & NASA: Enviro Analysis
USDA, USN, & DOE: Defense Production Act and Biorefinery Program
DOD/DLA & Airlines: fuel purchase
FAA: Guidance for Airports

DOE: FS&L, BRCs
ARPA-E: PETRO, TERRA, pheno-

USDA, FS&L, BRCs
ARPA-E: PETRO, TERRA, pheno-

FAJFRDS Released on 28Jul’16

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SAJF offtake agreements
... Airlines, OEMs, and more in process

- **United Airlines** + **AltAir Fuels** = 5 M gpy from 2016
- **Cathay Pacific** + **Fulcrum BioEnergy** = 90-180 M gpy Over 10 yrs
- **Alaska Airlines** + **Hawaii BioEnergy** = Supply from 2018
- **British Airways** + **Fulcrum BioEnergy** = 375M USg
- **Southwest Airlines** + **Solena** = 180M USg over 11 years
- **FedEx** + **Red Rock Biofuels** = 3 M gpy
- **FedEx** + **Red Rock Biofuels** = 3 M gpy

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Several entities are engaged in commercial development of existing and pending qualified pathways

CAAFI working with several producers in feasibility studies and business development efforts (Farm-to-Fly 2.0 State Initiatives)

Numerous high quality applications to DOE IBR and USDA CAP and Foundational programs

Other commercial-scale technology demos to occur in next 12 months that should prove to be enabling
Georgia - Robust Opportunities
... Feedstocks, Commercialization Ops., Demand

* Feedstocks – Purpose Grown
  * Row crops – e.g. Cull peanuts
  * Cover crops – e.g. Winter Carinata
  * Perennials
  * Forestry – plantation and residues

* Feedstocks – “Waste Streams”
  * MSW
  * Sanitary waste treatment, animal waste
  * Animal processing lipids
  * Industrial wastes

* Commercial Interests
  * Producers – LanzaTech, NuFuels, …
  * Offtakers – ATL operators, Gulfstream, …
Progress

First flight from continuous commercial production of SAJF
10Mar’16

- Solutions in development that deliver on sustainability goals: GHGs and the delivery of other environmental services
- Industry actively looking for partnerships that enable success
- Stay tuned for further announcements of progress!
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