Commercializing SAJF - lessons learnt in the US

ILA 2018 Workshop:
Sustainable aviation fuels – from principle to practice | Insights from DEMO-SPK and other projects

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First flight from continuous commercial production of SAJF, 10Mar’16
Fuel from AltAir Fuels, Paramount, CA (HEFA-SPK 30/70 Blend).
Since, being delivered to LAX fuel farm for everyone’s upload
Industry still counting on execution of SAJF, commensurate with progress on other pillars

SAJF & co-products technically viable – slowly being commercially developed
  - Opportunities actually continuing to expand
  - Feedstock availability might be pacing for some pathway families, but not envisioned to be an ultimate constraint

Key challenge is achieving price-point equivalency to petro-jet
  - Policy support has been shown to close some business cases
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Full range of activities ongoing to try to bring down cost, reduce risk, incentivize production, develop feedstocks, ...
  - Crude oil price and policy mechanisms will be key determinants
SAJF offtake agreements
Beyond numerous demonstration programs

- **AltAir Fuels**: Up to 5 M gpy from 2016 (LAX)
  - 3 yr agreement
  - 30/70 blend
  - Enabling LAX flts
  - Bioports on demand
    - Halmstad Arlanda
    - Bromma Goteborg

- **NEST**: 1% of GVA supply

- **Cathay Pacific**: 37.5 M gpy
  - 90-180 M gpy
  - 10 yr agreements

- **Fulcrum Bioenergy**: 50 M gpy

* AltAir also continues supplying fuel for multiple trial and research activities
SAJF offtake agreements
Beyond numerous demonstration programs

- RED ROCK BIOFUELS + Southwest = 3 M gpy each, 7 yrs (Bay Area, CA)
- FedEx
- Cathay Pacific + CHINA AIRLINES = A350 deliveries 10% blend (ex-TLS)
- SG Preston + jetBlue = 10M gpy, 10 yrs (JFK)
- QANTAS = 4M gpy, 10 yrs (LAX)
- DG Energy + GE Aviation = 0.5M gpy, 10 yrs

These offtakes/efforts represent >250 M gpy, and account for the total production slate of the first several commercialization efforts

19 June 2018
Other recent announcements

- gevo
- Lufthansa
- Brisbane Supply Demonstration
- MOU
- MSW-based FT-SPK evaluations
- BTL #1, Natchez, MS 1,400 bpd
- BRITISH AIRWAYS
- In negotiation
- HFP-HEFA collaboration
- Carinata supply development
- NESTE
- American Airlines
- Full production slate offtakes
- AGRISoma
- QANTAS
- Multiple Producers TBA (1/1/4+)
- World Fuel Services
- CAAFI
SAJF qualification status

Collecting Tier 1 & 2 Data & Developing Reports
- IH² (Shell / GSR / GTI)
- HFP-HEFA (HFP-HEFA Production Neste/Boeing)
- ATJ-SKA (Byogy, Swedish Biofuels)

Collecting Tier 3 & 4 Data & Developing Reports
- CHJ (ARA-CLG)
- F.O.G.

Currently In Phase 1 Review Process
- SAK Virent

Approved Fuels
- Annex A5 ATJ SPK (Iso-butanol and ethanol, 50% max)
- Annex A4 FT-SKA
- Annex A3 SIP
- Annex A2 HEPA
- Annex A1 FT-SPK

~15 Additional Processes

- F.O.G.
## Select additional approaches

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<thead>
<tr>
<th>Approach</th>
<th>Feedstock</th>
<th>Notes</th>
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<tr>
<td>1) IHI: HD HCs</td>
<td>HC oils from other bio-sources</td>
<td></td>
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<td>2) SBI: CGC PICFTR</td>
<td>Lipids - biodiesel</td>
<td>Shell partnership¹</td>
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<td>3) Tyton: CCL</td>
<td>Lipids</td>
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<td>4) Forge: Thermal Deoxyg.</td>
<td>Lipids</td>
<td>Demo plant being built in Ontario</td>
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... 11+ more using various other feedstocks and conversion processes

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<td>1) Co-processing</td>
<td>Lipids</td>
<td>Chevron, BP, Phillips66</td>
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<td>* Just approved. Sets the stage for other entities to follow, by sending biocrude to the refineries for finishing; at present, this approach does not allow RFS RINS credit</td>
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<td>2) Co-processing</td>
<td>FT Biocrude</td>
<td>Fulcrum</td>
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<td>Other Biocrude Processes</td>
<td>TBD</td>
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1 This now gives Shell a footprint with cellulose (IH²), sugars (Virent), and lipids
Significant “pipeline” of new production pathways

Industry continues to develop bio-chemical, thermo-chemical, and other hybrid approaches for converting non-petroleum hydrogen & carbon sources to jet fuel

To be ultimately successful, aviation must be able to use feedstocks from locations around the globe, and from multiple conversion pathways, in distributed production

- Fats, oils, greases
- Lignocellulose
- Sugars & Starches
- Various H&C waste streams and industrial slip-streams
Between execution of offtake agreement, and initial delivery, fuel producer works collaboratively with customer, suppliers, and distribution network to define:

- Access to petro-jet
- Blending concept
- Delivery concept(s) and other logistics

In each case, viable approaches have been developed

- In almost every case, some unique approaches may be required

At the point of delivery, the SAJF is treated as any other jet fuel, compliant with ASTM D1655, and indistinguishable from petro-jet
Additionally, several demonstration activities have been explored / executed, e.g.:

- This week’s demonstration project at YYZ, sponsored by GARDN and Air Canada, executed by a team of participants led by Waterfall Group – creating lessons learned to be broadly shared with industry

- Work by SkyNRG, World Fuel Services, et al. to supply fuel for various demonstration efforts, or demonstration flights

- Airports also, with the assistance of other industry players, now exploring both:
  - Infrastructure approached to help facilitate delivery
  - Other means of incentivizing supply
First dedicated US production facility for HEFA-SPK (primarily HDRD, and reformate blending components) fuels with ongoing production

- Repurposing of Alon asphalt refinery, now owned via World Energy
- Tallow and waste FOG

* 40M gpy nameplate capacity in “Phase 1”
* SAJF being delivered to airlines and suppliers
  * United (LAX), WFS (Gulfstream), SkyNRG (KLM), others
* HDRD (F76) being delivered to Navy under DLA FY’18 contract
* Ownership evaluating ~5X expansion opportunity
DPA Recipient: Fulcrum Bioenergy

"Groundbreaking" planned 16 May ‘18, First Fuel 2020

* 10.5 M gpy syncrude production plus power – FT process
  * From 200,000 tons of post-recycled waste
* Subsequent plants at 3-6X size; targeting 8 plants by 2022 delivering 300 M gpy middle distillates

TRI Gasifier, EFT FT unit Waste agreements comprising ~4% of US total landfill volume

Replication approach ➔

Courtesy Fulcrum-Bioenergy
http://www.fulcrum-bioenergy.com/index.html

19 June 2018
15.1 M gpy of renewable, liquid transportation fuels – FT process
* From 136,000 tpy of woody biomass
* 3M gpy SAJF offtake agreement from each of Southwest Airlines and FedEx
* $70 million DPA Title III award for ~$200 million refinery
* Replicable approach targeting 10 additional sites
  * E.g. - working with CAAFI in southeast F2F2 State Initiative
U.S. Commercialization, & in-development
HDRD & SAJF from lipids/F.O.G.

* Diamond Green: Norco, LA
* REG: Geismar, LA
* AltAir/World Energy: Paramount, CA
* AltAir Build out (3-5X)
* Diamond Green expansion
* SG Preston (duplicate 240 M gpy facilities)
* ARA licensing build-out (4+ activities)
* UOP licensing for refinery retrofit(s)
* Unlocking of renewable diesel and Neste, REG, UPM, ... potential pivots
* Refinery co-processing

Greater than 1B GPY capacity by 2021 ?!
... necessitates serious engagement with purpose grown oilseed & F.O.G. development / expansion
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