SAJF Commercialization Progress Overview

MN Working Lands Meeting

Discussion Session:
Markets for innovative oil seed crops
- Overview of perspectives from CAAFI and Aviation

Steve Csonka, Executive Director, CAAFI
Commercial Aviation’s CO₂ commitments
To decouple carbon growth from demand growth

Biofuels a key component of GHG containment strategy

These 3 industry commitments are currently being converted into regulation through an ICAO/CAEP “basket of measures”:

- CO₂ Standards
- MBMs – will monetize carbon
- Similar commitment from BizAv & DOD

Aviation’s emissions reduction roadmap

- CO₂ Emissions (relative to 2005 levels)
- 1.5% annual fuel efficiency improvements
- Biofuels + add’l Tech
- CNG 2020
- No action
- -50% by 2050

(schematic)
How much SAJF is needed (USA)?

Total US jet fuel supply (satisfying all uses: Com’l, DoD, BizAv, GA):

- 2016: 1.61 M bpd = 24.814 B gpy (Worldwide >87 B gpy)
- 2017: trending at 1.65 M bpd (+2.5%)

CAAFI Bogey set by implementation targets of CNG2020 (CORSIA)

The offsetting of growth in International operations could result in targeting annual, incremental production of 200-400 M gpy of neat SAJF. Volume can change significantly with assumptions, as well as demand from International carriers for US uplift.
SAJF qualification status

Currently In Phase 1 Review Process

- IH² (Shell / GSR / GTI)
- HDCJ (SkyNRG et. al)
- ATJ-SKA (Byogy, Swedish Biofuels)
- SAK Virent

Collecting Tier 1 & 2 Data & Developing Reports

- HFP-HEFA (HFP HEFA addition Neste/Boeing)

Collecting Tier 3 & 4 Data & Developing Reports

- F.O.G. (ARA-CLG)

Approved Fuels

- Annex A5
  - ATJ SPK (Isobutanol)
- Annex A4
  - FT-SKA
- Annex A3
  - SIP
- Annex A2
  - F.O.G.
- Annex A1
  - FT-SPK

- ~15 Additional Processes

- ATJ-SPK (exp to annex A5) (LanzaTech)

- F.O.G.
## Select “additional processes”
Targeted for additional cost reductions

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

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<tr>
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<th>Feedstock</th>
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<td>1) Co-processing</td>
<td>F.O.G.</td>
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<td>* Successfully balloted. Sets the stage for other entities to follow, by sending biocrude to the refineries for finishing, e.g.:</td>
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<tr>
<td>2) Co-processing</td>
<td>Biocrude</td>
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¹ This now gives Shell a footprint with cellulose (IH2), sugars (Virent), and F.O.G.

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Techno-economic assessments don’t address total value

Expectation that viability will be enabled via other revenue (feed / proteins), other services, and integration with existing facilities and industries
SAJF offtake agreements
Beyond numerous demonstration programs

- **AltAir Fuels**: Up to 5 M gpy from 2016 (LAX)
- **United**: 30/70 blend
- **SkyNRG Nordic**: 3 yr agreement Enabling LAX flts
- **Gulfstream**: Bioports on demand
- **KLM**: Halmstad Arlanda Bromma Goteborg
- **NESTE**: 1% of GVA supply
- **Geneve Aéroport**: 37.5M gpy
- **Cathay Pacific**: 90-180 M gpy
- **United**: 50 M gpy
- **Air BP**: 10 yr agreements

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

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

- MOU
- Brisbane Supply Demonstration
- MSW-based FT-SPK evaluations
- BTL #1, Natchez, MS 1,400 bpd
- HFP-HEFA collaboration
- Carinata supply development
- Full production slate offtakes

- gevo
- Lufthansa
- Virgin Australia
- BRITISH AIRWAYS
- In negotiation
- VELOCYS
- Neste
- American Airlines
- Quantas
- Agrisoma
- Multiple Producers TBA (1/1/4+)
- World Fuel Services

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Commercialization in-development

Renewable Diesel & Jet from F.O.G.

* Emerald (DPA recipient, HDRD focus)
* AltAir build-out (3-5X)
* Diamond Green (expansion underway)
* SG Preston (duplicate facility plan)
* ARA licensing build-out (multiple efforts)
* UOP licensing - new / refinery retrofit
* Neste, REG, UPM, ... potential pivots to HDRD / HEFA
* Unlocking of renewable diesel and refinery co-processing

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

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Commercialization intent - F.O.G.
“Declared” nameplate capacities: significant opp’ty

HDRD and SAJF Capacity Outlook

If all addressed via oilseeds:
- 1.5 to 2.0 M acre/yr
- 1.75x more if refinery co-processing gets traction

Announced plans of commercialization entities

Production Acreage Required
(million acres)
at 200 / 150 gal/acre

Significantly more at lower yields of some targeted oilseeds

Ignores 0.5B gpy additional expected biodiesel production!
Lipid feedstocks
Potentially enabling of significant production ...

* Multiple conversion processes (3+3 additional)
* Multiple feedstock developers
* Multiple producers
* Multiple low LUC/ILUC agri-based feedstocks, plus:
  * White Grease, Poultry Fat, Tallow
  * UCO / Yellow Grease
  * Brown Grease, Biosolids
* Easier supply chain scale-up leveraging biodiesel and HDRD production concepts
* Lowered H2 cost & availability (from NG) helps

Targeting most sustainable solutions:
Low, or Zero, impact LUC/ILUC & F-v-F solutions;
Environmental Services a plus.
Winter “cover” oilseeds
Huge production potential without ILUC...

- Carinata below freeze line
  - 12-20 M acres
- Pennycress above freeze line, in regions with sufficient precipitation
  - 40+ M acres
- Camelina above freeze line, perhaps targeted at lower precip regions
- All need further varietal and agronomic development

Targeting most sustainable solutions:
Low, or Zero, impact LUC/ILUC & F-v-F solutions; Environmental Services a plus.
2018 CBGM, Washington DC, 04-06Dec
In conjunction with:
  ASCENT Yr 5 Symposium
  NJFCP YE meeting
  State Initiative Stakeholders Forum

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