Sustainable Alternative Jet Fuel Development & Commercialization

TRACK: Bio-Based Opportunities
The BIO-Economy: Fuels, Jobs and Power

Steve Csonka
Executive Director, CAAFI

First flight from continuous commercial production of SAJF, 10Mar’16. Fuel from AltAir Fuels, Paramount, CA (HEFA-SPK 30/70 Blend) Now being delivered to LAX fuel farm for everyone’s upload
Commercial Aviation’s CO$_2$ commitments
To decouple carbon growth from traffic increases

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”:
- CO$_2$ Standards
- MBMs – will monetize carbon
- Similar commitment from BizAv & DOD
SAJF Sustainable Alternative Jet Fuel
a.k.a. aviation biofuel, biojet, alternative aviation fuel

**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 LCA GHG reduction:** Benefit comes from leaving carbon molecules in the ground; Instead, utilizing the carbon already in the biosphere via recycling or dual use
Achieving net LCA GHG reduction
Reduction in carbon being introduced to biosphere

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
Why Aviation cares about SAJF
Sustainable Alternative Jet Fuel, a.k.a. biofuel, biojet

Aviation commitments
* Decouple carbon growth
* No other viable options!

Industry alignment on SAJF value proposition
* Net carbon relief!
* Supply surety, Price stability
* Energy security
* Lower “criteria pollutants”
* Improved energy mass density
* Minimal infrastructure impact
* Economic development

SAJF works! Challenges, yes ... but abundant options!
* Multiple feedstocks, conversion technologies, entrepreneurs
SAJF offtake agreements
Beyond numerous demonstration programs

- AltAir Fuels + United = 5 M gpy from 2016
  3 yr agreement
  30/70 blend
- World Fuel Services + Gulfstream =
  3 yr agreement
  Enabling LAX flts
- Sky NRG + KLM =
- Cathay Pacific + United =
- Fulcrum Bioenergy + =
- Air BP =
- Southwest + FedEx =
- Red Rock Biofuels

375M usg
90-180 M gpy
Over 10 yrs
50 M gpy
Over 10 yrs
3 M gpy each
going into Bay Area, CA

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SAJF offtake agreements
Beyond numerous demonstration programs

- Total + Amyris = 48 A350 deliveries 10% blend
- SG Preston + Cathay Pacific = 10M gpy, 10 yrs
- Gevo + jetBlue = Up to 40M gal Over 5 yrs (MOU)
- Neste + Lufthansa = (Bioport on demand)
- SkyNRG + OSL + KLM + SAS = (Salvage MSW work?)
- BRITISH AIRWAYS + Alaska Airlines = (HBE defunct, focus on new engagement)
What are these feedstock sources?

- **Fossil HC**
- **Lipids Plant & Animal**
- **Cellulose & Hemi- & Lignin**
- **Sugars & Starch**
- **Wastes & Syngas**

- **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**
**What are these feedstock sources?**

<table>
<thead>
<tr>
<th>Lipids</th>
<th>Cellulose</th>
<th>Sugars &amp; Starch</th>
<th>Wastes &amp; Syngas</th>
<th>CH4</th>
<th>CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant &amp; Animal</td>
<td>&amp; Hemi- &amp; Lignin</td>
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<tr>
<td><strong>Lipids</strong></td>
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<tr>
<td>Brassicaceae</td>
<td>Ag. Residues</td>
<td>Agave</td>
<td>Black liquor</td>
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<tr>
<td>Canola/Rape</td>
<td>Bagasse</td>
<td>Cassava</td>
<td>Brewery Waste</td>
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<tr>
<td>Camelina</td>
<td>Grasses</td>
<td>Corn</td>
<td>Coffee waste</td>
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<td>Carinata</td>
<td>Wood products</td>
<td>Sugar Beet</td>
<td>Comm/Ind. bio</td>
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<td>Mustards</td>
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<td>Sugar Cane</td>
<td>Food waste</td>
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<td>Pennycress</td>
<td>- short rotation</td>
<td>Sweet Sorghum</td>
<td>Manure</td>
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<tr>
<td>Corn (DGO)</td>
<td>- slash, trim</td>
<td>Sweet Tubers</td>
<td>MSW</td>
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<td>Castor</td>
<td>Other</td>
<td>Hydrolyzed</td>
<td>Non-recyc plastics</td>
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<td>Cull edibles</td>
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<td>Sludge</td>
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<td>Cuphea</td>
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<td>Syngas</td>
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<td>Euphorbia</td>
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<td>Waste carbon gases</td>
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<td>Hemp seeds</td>
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<td>Wood processing residues</td>
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<td>Pongamia</td>
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<td>Animal processing fats</td>
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*CH4, CO2*
First refinery online!
AltAir Fuels in Paramount, CA

- First dedicated US production facility for HEFA-SPK and HDRD fuels with ongoing production
- Repurposing of Alon refinery
- Tallow feedstock initially

- 40M gpy nameplate capacity in “Phase 1”
- SAJF being delivered to airlines and suppliers
  - United (LAX), WFS (Gulfstream), SkyNRG (KLM)
- HDRD (F76) delivered to Navy under DLA FY’16 contract
- Ownership evaluating expansion in next 2-3 years
DPA Recipient: Red Rock Biofuels

- 16 M gpy of renewable, liquid transportation fuels – FT process
  - From 175,000 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

TCG Global gasifier
Velocys FT reactors
Haldor Topsoe / Valero upgrading

Courtesy Biofuels Digest
27 February 2017
10-11 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

Replication approach

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

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

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DPA Recipient: Emerald Biofuels

- Emerald One: 88 M gpy HDRD capacity from conversion of lipids
- Development program to achieve >500M gpy portfolio

Non-edible oil feedstocks
Honeywell UOP Green Diesel/Jet Technology
Gulf Coast

Courtesy Beaumont Enterprise, photo by Jake Daniels
https://emeraldonellc-public.sharepoint.com/
The proposed IBPE must bring online at least 10 M gpy of capacity with the capability to produce MILSPEC compatible biofuel. Potential for $55M project assistance, with the requirement of a 50/50 or greater cost share from the private sector.  

... To create a new Green-Field facility, or expand/modify an existing Brown-Field facility comprised of partners within the complete value chain.

Industry Roundtable next week

DATE: Wednesday, March 1, 2017
TIME: Arrival: 7:30 a.m., Program runs: 8:00 a – 11:00 a
LOCATION: USDA Jefferson Auditorium, USDA South Building, 14th and Independence, Washington DC 20250
Production in development

* Existing DPA Awardees
  * Red Rock, Fulcrum, Emerald, and their build-out plans
* AltAir Build out (~5X)
* SG Preston (5 facilities in first tranche)
* ARA licensing and build-out
* Neste, REG, UPM pivots
* Unlocking of renewable diesel and refinery co-processing
* Initiating activities of Amyris/Total, Gevo, and LanzaTech, et al.
* Other commercial-scale technology demos to occur in next 12 months that should prove to be enabling
Ex: Lipid pathway applicability
Conversion of fats, oils & greases

SAJF Pathways

- FT-SPK, FT-SPK/A
- HEFA-SPK
- HFS-SIP
- ATJ-SPK

- Hydrotherm oils (CH)
- Renewable Diesel
- Refinery Co-processing
- SBI
- Forge, Tyton, ...

Approved

HW UOP: Ecofining / GreenJet
Neste: NEXBTL
UPM:

SAJF Intentions (first facilities)
- AltAir Fuels 40 M gpy (30% jet)
- Emerald Biofuels 88 M gpy
- SG Preston 120 M gpy (77% jet)

In-Process & Pipeline

ARA - unique value prop. => 100% drop-in
Unlock existing 1 B+ gpy HDRD production
Front-end: Blend with crude
Mid: FCC, HC, Coker?
Back-end: Hydroprocessing
Unlock existing biodiesel production
Toward improved affordability

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Lipid feedstocks
Potentially enabling of significant production ...

* Multiple conversion processes
* Multiple feedstock developers
* Multiple producers
* Multiple low LUC/ILUC agri-based feedstocks, plus:
  * White Grease, Chicken Fat, Tallow
  * UCO / Yellow Grease
  * Brown Grease, Biosolids
* Easier supply chain scale-up leveraging biodiesel and RD production capacity
* Lowered H2 cost & availability helps

Targeting most sustainable solutions:
Low, or Zero, impact LUC/ILUC & F-v-F solutions;
Environmental Services a plus.
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