CAAFI – CORE-JetFuel Cooperation Workshop

Alexandria, Virginia
28Apr’16
The main aim of this workshop is to facilitate discussion among experts from the US and Europe in the area of alternative fuels for aviation. Topics of discussion intended to include:

* Policy options for large-scale deployment of SAJF
* Promising production technologies and value chains
* Impact of present low oil prices on investments in SAJF
* Harmonisation of sustainability requirements
* Coordination of SAJF stakeholder’s strategy
* Setting-up stakeholder initiatives for SAJF
  * Status in EU and lessons learnt from CAAFI
# Workshop Agenda, morning

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td><strong>Welcome to the Workshop</strong></td>
</tr>
<tr>
<td></td>
<td><strong>STEVE CSONKA, CAAFI, USA, RAINER JANSSEN AND DOMINIK RUTZ, WIP RENEWABLE ENERGIES, GERMANY</strong></td>
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<tr>
<td>09:10</td>
<td><strong>Introduction to CAAFI</strong>, <strong>STEVE CSONKA, CAAFI, USA</strong></td>
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<tr>
<td>09:30</td>
<td><strong>Introduction to CORE-JETFUEL</strong>, <strong>JOHANNES MICHEL, FNR, GERMANY</strong></td>
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<tr>
<td>09:50</td>
<td><strong>Alternative Aviation Fuels – Status in the US</strong>, <strong>STEVE CSONKA, CAAFI, USA</strong></td>
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<td>10:20</td>
<td><strong>Alternative Aviation Fuels – Status in Europe</strong>, <strong>REMY DENOS, EUROPEAN COMMISSION, DG ENERGY</strong></td>
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<tr>
<td>10:50 – 11:20</td>
<td><strong>Coffee break</strong></td>
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<tr>
<td>11:20 – 12:20</td>
<td><strong>Discussion Panel I: Supply Chain Development and Deployment of Alternative Fuels</strong></td>
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<td></td>
<td><strong>Introductory presentation US</strong>, <strong>NATE BROWN, FAA, USA</strong></td>
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<tr>
<td>11:30</td>
<td><strong>Introductory presentation EU</strong>, <strong>MARIA DE LA RICA JIMÉNEZ, SENASA, SPAIN</strong></td>
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<tr>
<td>11:40</td>
<td><strong>Discussion Panel I</strong></td>
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<tr>
<td></td>
<td><strong>M MODERATION: NATE BROWN, FAA AND MARIA DE LA RICA JIMÉNEZ, SENASA</strong></td>
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<tr>
<td></td>
<td><strong>PARTICIPANTS: ALL WORKSHOP PARTICIPANTS</strong></td>
</tr>
<tr>
<td>12:20 – 13:50</td>
<td><strong>Lunch break</strong></td>
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</table>
Workshop Agenda, afternoon

13:50 – 14:40 Discussion Panel II: Promising production technologies and value chains
13:50 Introductory presentation US, Zia Haq, U.S. Department of Energy, USA
14:00 Introductory presentation EU, Alain Quignard, IFPEN, France
14:10 Brief Introductory to the EU Project ITAKA, Inmaculada Gomez Jimenez, SENASA, Spain
14:15 Discussion Panel II
Moderation: Zia Haq, U.S. DOE and Alain Quignard, IFPEN / Andreas Sizmann, Bauhaus Luftfahrt
Participants: All workshop participants

14:40 – 15:30 Discussion Panel III: Sustainability
14:40 Introductory presentation US, Nancy Young, Airlines for America (A4A), USA
14:50 Introductory presentation EU, Horst Fehrenbach, IFEU, Germany
15:00 Discussion Panel III
Moderation: Nancy Young, A4A, USA and Johannes Michel, FNR, Germany
Participants: All workshop participants

15:30 – 16:00 Coffee break

16:00 – 16:30 Discussion Panel IV: Stakeholder initiatives for alternative aviation fuels – Progress and perspectives
16:00 Discussion Panel IV
Moderation: Steve Csonka, CAAFI and Maria de la Rica Jiménez, SENASA / Rainer Janssen, WIP Renewable Energies
Participants: All workshop participants

16:30 Summary
Lunch Options
Introduction to CAAFI
FAA Alternative Jet Fuel Activities

• Testing
  ▪ Support Cert/Qual testing
  ▪ Improve Cert/Qual process (NJFCP)
  ▪ Emissions measurements

• Analysis
  ▪ Environmental sustainability
  ▪ Techno-economic analysis
  ▪ Future supply

• Coordination
  ▪ Interagency
  ▪ Public-Private
  ▪ State & Regional
  ▪ International
FAA Alternative Jet Fuel Activities

• **Testing**
  - Support Cert/Qual testing
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• **Coordination**
  - Interagency
  - Public-Private
  - State & Regional
  - International

**Testing**
- CLEEN Testing and Research Report Review
- Volpe BAA Testing
- A31 Alternative Jet Fuel Test & Evaluation
- A33 Alternative Jet Fuel Test Data Library
- SEMRS Jet Fuel Data Tracking
- A25-30, 34 National Jet Fuels Combustion Program

**Analysis**
- A01 Alternative Jet Fuel Supply Chain Analysis
- A13 ACCESS 2 Micro Physical Modeling with NASA
- A24 Emissions Data Analysis for CLEEN, ACCESS, and Other Recent Tests
- SEMRS Analysis
- Volpe Alternative Fuels Transportation Optimization Tool (AFTOT)
- Impacts of removing naphthalene from jet fuel (ASCENT - New)

**Coordination**
- CAAFI
- Farm to Fly 2.0
- Federal Alternative Jet Fuel Strategy
- International agreements
CAAFI – Public/Private Partnership
A reflection of the 23+B gpy US Jet “market pull”

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

An initiative that enables its diverse stakeholders to build relationships, share and collect data, identify resources, and direct research, development and deployment of alternative jet fuels
CAAFI Sponsors
From across the aviation enterprise
CAAFI mechanics

- FAA funds the Office of the Executive Director
- CAAF itself has no financial function or mechanisms
- Focals from each sponsor provide dedicated support
- Other sponsor members provide work-in-kind on an ad hoc basis
- CAAF members participate in work-team efforts
- We execute other work through the integrated interests of our partners through Public-Private-Partnerships
- Approaching our 10 year anniversary
How CAAFI works
Bringing interested parties together …

- Aircraft, Engine, Subsystem OEM’s
- Airlines, Military, Airport orgs.
- Fed & State Government Offices
- Academia, Gov’t Labs
- Supply Chain Partners
- Fuel Producers, Suppliers, Handlers

~800 Global Sponsors / Stakeholders

… to collaboratively stand-up a new industrial segment
CAAFI Work Teams

Research & Development
Enabling Multiple “Drop-in” Solutions

Certification / Qualification
Fostering ASTM D7566 Approval

Environmental
GHG LCA, PM2.5 Quantification, Sustainability

Business
Facilitating Deployment, Investment
Defining the full supply chain ...
...via cooperative R&D-D&D efforts
Directly and through several PPPs

Feedstock Production
Feedstock Logistics
Fuel Conversion
Conversion Process Scale-up/Integration
Fuel Testing/Approval Fuel Performance
Environment Assmt
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

9 May 2016
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
Steve Csonka
Executive Director, CAAFI
+1-513-800-7980
Csonka.CAAFI.ED@gmail.com
Steve.Csonka@caafi.org
www.caafi.org
Introduction to CORE-JetFuel
Alternative Aviation Fuels – Status in the US
* Industry aligned on need!

* 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

* Challenges remaining:
  * 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

9 May 2016
Airline offtake agreements
... and more in process

- United
- United
- Alaska Airlines
- Cathay Pacific
- British Airways
- Southwest
- FedEx
- AltAir Fuels
- Fulcrum BioEnergy
- Hawaii BioEnergy
- Solena Group
- Red Rock Biofuels

5 M gpy from 2016
90-180 M gpy Over 10 yrs
Supply from 2018
375M usg
180M usg over 11 years
3 M gpy
3 M gpy

9 May 2016
**SAJF approved production pathways**
Limited to paraffins thru ‘15 – other molecules pending

<table>
<thead>
<tr>
<th>Process</th>
<th>Blend Limit</th>
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<tbody>
<tr>
<td>Gasification &amp; FT (FT-SPK)</td>
<td>50% max blend</td>
</tr>
<tr>
<td>Hydroprocessed lipids (HEFA-SPK)</td>
<td>50% max blend</td>
</tr>
<tr>
<td>Biochem sugars (HFS-SIP)</td>
<td>10% max blend</td>
</tr>
<tr>
<td>FT-SPK/A</td>
<td>50% max blend</td>
</tr>
<tr>
<td>Isobutanol conversion (ATJ-SPK)</td>
<td>30% max blend</td>
</tr>
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</table>

AltAir Fuels – First dedicated US production facility for HEFA-SPK fuels in Paramount, CA, 40 Mgpy “Phase 1” from FOG. Currently in production. SAJF being delivered to the LAX fuel farm. F76 being delivered to Navy via 77M gal DLA purchase in current fiscal year.
The Defense Protection Act was established in 1950 for the purpose of providing investments in anything America needs, but doesn’t have at scale, for national security.

In 2012, the President and Secretary of the Navy determined that alternative fuels met this criteria.

The Navy entered into an MOU with DOE and USDA to fund the commercialization of 3 fuel production facilities with a combined nameplate production level of 104M gpy. The agencies jointly funded the program at ~$510M over 3 years, and such funding has been appropriated by Congress.
140,000 dry tons of woody biomass

12 million gallons per year of renewable, liquid transportation fuels

3M gpy SAJF offtake agreement from each of Southwest Airlines and FedEx

$70 million DPA Title III award for ~$200 million refinery

TCG Global gasifier
Velocys FT reactors
Haldor Topsoe upgrading

Courtesy Biofuels Digest
DPA Recipient: Fulcrum Bioenergy

- 147,000 tons of post-recycled waste
- Converted into 11 M gpy liquid fuels & power
- Cathay Pacific and United Airline agreements for supply of >465M usg over 10 years from multiple facilities

DPA Phase 2 winner
USDA Loan Guarantee
Waste agreements comprising ~4% of total landfill volume

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

9 May 2016
DPA Recipient: Emerald Biofuels

- 88 M gpy biodiesel capacity from lipids
- Development program to achieve >500M gpy portfolio

Non-edible oil feedstocks
Honeywell UOP Green Diesel/Jet Technology
Port Arthur, TX

Courtesy Beaumont Enterprise, photo by Jake Daniels
https://emeraldonellc-public.sharepoint.com/
Several entities are engaged in commercial development of existing and soon-to-be qualified pathways

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

Other commercial-scale technology demos to occur in next 12 months
<table>
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<tr>
<th>Approach</th>
<th>Feedstock</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>FT-SPK/A (annex A4)</td>
<td>Cellulose – syngas &amp; alkylation</td>
<td>approved 4Q’15</td>
</tr>
<tr>
<td>ATJ-SPK (annex A5)</td>
<td>Sugars – isobutanol</td>
<td>approved 2Q’16</td>
</tr>
<tr>
<td>CH</td>
<td>Lipids</td>
<td></td>
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<tr>
<td>HEFA Expansion</td>
<td>Lipids – renewable diesel</td>
<td>ARA: Step 3</td>
</tr>
<tr>
<td>SK/SAK (CCS-APR)</td>
<td>Sugars</td>
<td>R.R. in devel.</td>
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<tr>
<td>HDCJ (pyrolysis)</td>
<td>Cellulose – biocrude</td>
<td>Virent: Steps 4/1</td>
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<tr>
<td>Co-processing</td>
<td>Biocrude</td>
<td>LanzaTech, UOP</td>
</tr>
<tr>
<td>CATJ-SKA</td>
<td>Sugars – alcohols</td>
<td></td>
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<tr>
<td>ATJ-SPK expansion</td>
<td>Sugars – ethanol / xOH</td>
<td>GranBio, UOP, LT, SwB</td>
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9 May 2016
### Approach

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<tr>
<th></th>
<th>Feedstock</th>
<th>Notes</th>
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<tbody>
<tr>
<td>1</td>
<td>CHyP (syngas, non-FT)</td>
<td>Proton Power</td>
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<tr>
<td>2</td>
<td>Microbial conversion</td>
<td>Global Bioenergies</td>
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<tr>
<td>3</td>
<td>HTL</td>
<td>Algenol, Genifuel, Sapphire</td>
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<tr>
<td>4</td>
<td>Catalytic HTL</td>
<td>Licella, Muradel, QUT</td>
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<tr>
<td>5</td>
<td>SBI CGC PICFTR</td>
<td>SBI Bioenergy</td>
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<tr>
<td>6</td>
<td>CCL</td>
<td>Tyton</td>
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<tr>
<td>7</td>
<td>Hydrogenotrophic Conv.</td>
<td>Kiverdi</td>
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<tr>
<td>8</td>
<td>Cyanobacterial Prod.</td>
<td>Joule</td>
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<tr>
<td>9</td>
<td>STG+ GTL</td>
<td>Primus</td>
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<tr>
<td>10</td>
<td>Acid Deconstruction</td>
<td>Mercurius</td>
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<tr>
<td>11</td>
<td>Thermal Catalytic Conv.</td>
<td>Shell/CRI/IH2</td>
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<tr>
<td>12</td>
<td>Thermal Deoxyg.</td>
<td>Forge Hydrocarbons</td>
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<tr>
<td>13</td>
<td>Ionic Liquid Decon.</td>
<td>JBEI, tbd</td>
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<tr>
<td>14</td>
<td>Metal Catalytic Conversion</td>
<td>Purdue research</td>
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<tr>
<td>15</td>
<td>Enzymatic Conversion</td>
<td>GLBRC &amp; JBEI</td>
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### Notes

- ASTM D7566 pipeline
- 9 May 2016
Why do we care about the pipeline

* We need SAJF affordability
  * Processes applicable to lower cost, available feedstocks
  * Lower CapEx, OpEx

* We need SAJF availability
  * Available for processing regionally, world-wide, with available, applicable feedstocks

* We need commercialization activity / fuels soon
  * Leverage existing biofuel infrastructure or adjacent production

* Feedstock development cannot realistically progress to scale with the potential for offtake from a fuel producer
Ex: Lipid pathway applicability
Conversion of fats, oils & greases

SAJF Pathways

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

- 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 5 x 120 M gpy (77% jet)
Ex: Lipid pathway applicability
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SAJF Pathways

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

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SAJF Pathways

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

- Hydrotherm oils (CH) → ARA - unique value prop. - 100% drop-in
- Renewable Diesel → Unlock existing 1 B+ gpy RD production
  Front-end: Blend with crude
  Mid: FCC, HC, Coker?
  Back-end: Hydroprocessing ✓
- Refinery Co-processing
- SBI → Unlock existing biodiesel production, no H2 need
- Forge, Tyton, ... → Toward improved affordability
Sustainable lipid feedstocks
HEFA TEA: feasibility is in the feedstock economics ...

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

Targeting most sustainable solutions:
Low, or Zero, impact LUC/ILUC & F-v-F solutions; Environmental Services a plus.
**Recent focus on “waste” evaluations**

And similar concepts with enviro-services co-benefits

- Overcomes challenges associated with “classical” feedstocks – primarily price
- Avoids some challenging issues with “biofuels”
- Solves other landfill / conversion related issues
- Enables technical proving for later conversion to biomasses
- Matches interests of other constituencies

**Examples:**  
- MSW (alone could satisfy aviation)  
- Sanitary waste treat.  
- Animal waste  
- Animal processing  
- Industrial wastes  
- Forestry residuals

9 May 2016
Aviation as a first mover and dedicated long-term offtaker

Fuel production at petroleum pricing parity (policy as needed)

FAA: Aspirational 1B gpy by 2018
* 20 M gpy facility in each of 50 states (AltAir is 40 M gpy jet and diesel)
* Translated to F2F2 goal of standing-up feedstocks to enable 1B gpy

DLA as a regular offtaker:
* Navy: 50 percent of total Navy energy consumption afloat by 2020
* AirForce: 50 percent of total non-contingency consumption by 2025

First real test is CNG2020: => as low as 282M gpy in US

Project engagement from each:
* State, Airline, OEM, key BizAv player

Significantly reduce technology & execution risk to unlock capital
With focused effort!

- Abate challenges & help stand-up a new industrial sector!
  - Affordable, abundant feedstocks – worldwide
    - Existing, new, traditional, unconventional, futuristic
  - Cost effective conversion technologies – enabling use of all appropriate feedstocks
  - Infrastructure, partners in the existing petro-jet space
  - All the adjacencies: finance, policy, insurance, R&D, BD, feasibility projects, D&D, ...
- Enlist the assistance of partners and those who share common goals
Alternative Aviation Fuels – Status in the EU