CAAFI – CORE-JetFuel Cooperation Workshop

Alexandria, Virginia
28Apr'16

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

CORE-JetFuel

Objectives

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**

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Workshop Agenda, morning

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

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**

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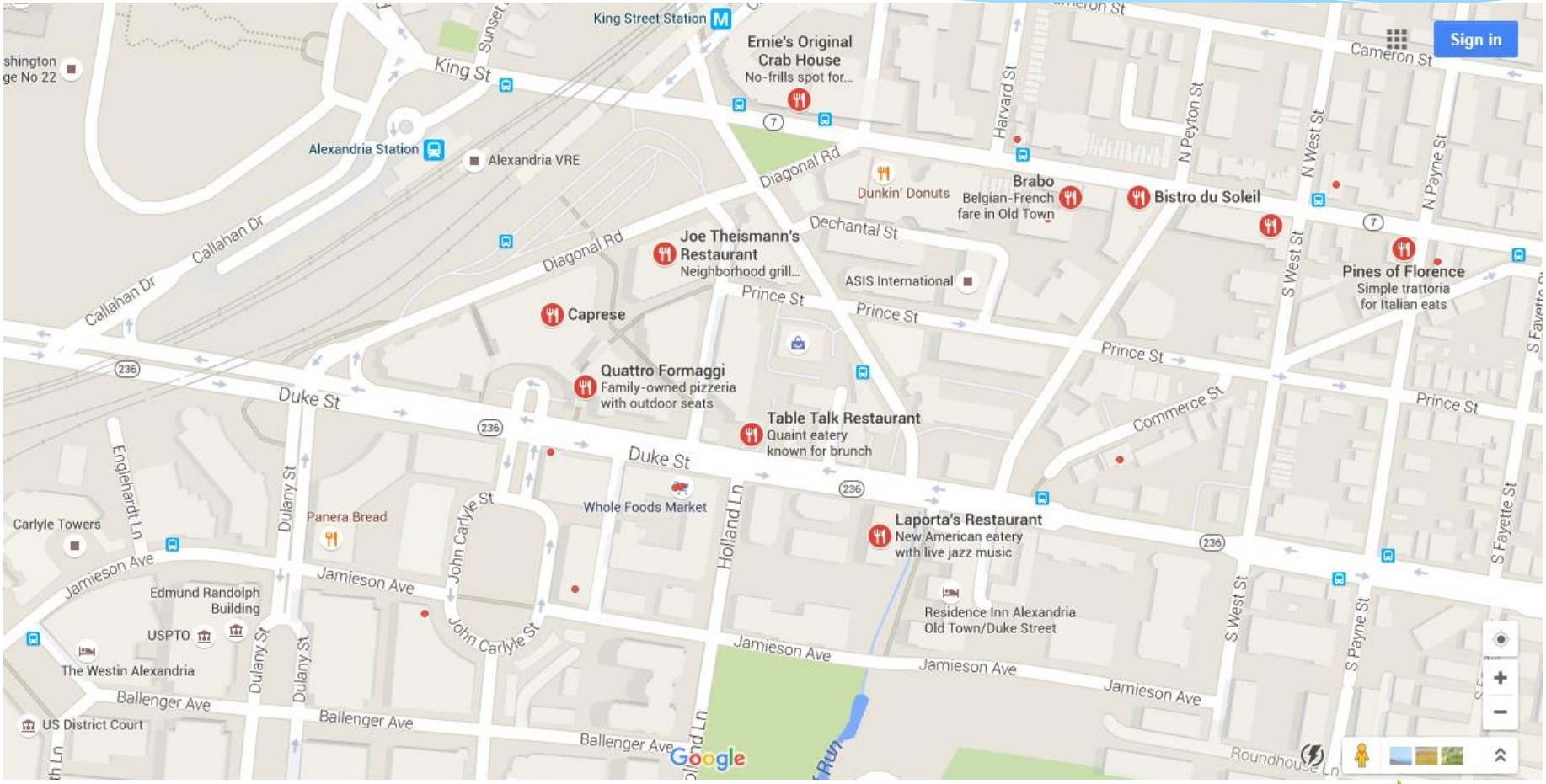
Lunch Options



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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

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  - International

- 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

- 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
- A32 Worldwide Life Cycle Analysis (LCA) of Greenhouse Gas (GHG) Emissions from Petroleum Jet Fuel
- SEMRS Analysis
- Volpe Alternative Fuels Transportation Optimization Tool (AFTOT)
- Impacts of removing naphthalene from jet fuel (ASCENT - New)

- 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*

Synthetic kerosene, primarily from renewable sources

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

Airlines for America™

We Connect the World

CAAFI mechanics

* FAA funds the Office of the Executive Director
* CAAFI 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
* CAAFI 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 …

Airlines, Military, Airport orgs.

Aircraft, Engine, Subsystem OEM's

Academia, Gov't Labs

Supply Chain Partners

Fuel Producers, Suppliers, Handlers

Fed & State Government Offices

~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

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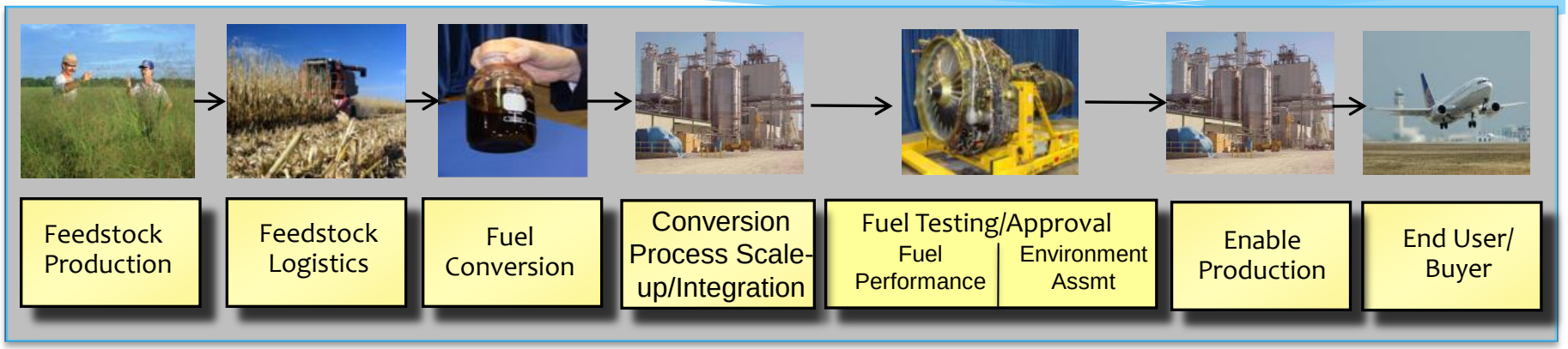
Defining the full supply chain …



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

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

EPA: Renewable Fuel Standard

DOD/DLA & Airlines: fuel purchase

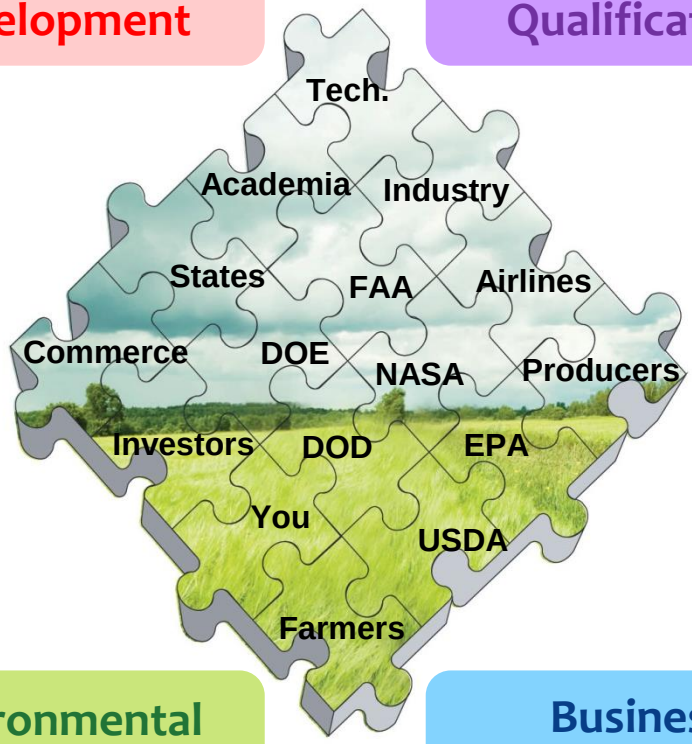
FAA: Guidance for Airports

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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FUELING SOLUTIONS FOR
SECURE & SUSTAINABLE AVIATION

Introduction to CORE-JetFuel

Alternative Aviation Fuels – Status in the US

Overall industry summary:

- 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

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Airline offtake agreements
… and more in process

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

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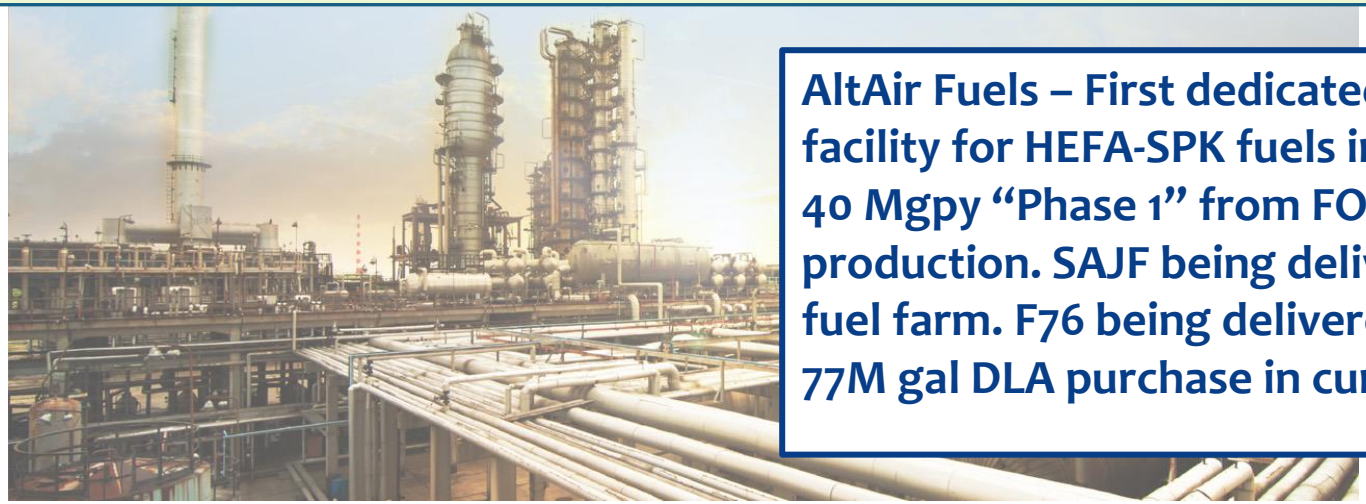
SAJF approved production pathways
Limited to paraffins thru '15 – other molecules pending

Approved

* Gasification & FT (FT-SPK)	50% max blend
* Hydroprocessed lipids (HEFA-SPK)	50% max blend
* Biochem sugars (HFS-SIP)	10% max blend
* FT-SPK/A	50% max blend
* Isobutanol conversion (ATJ-SPK)	30% max blend



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.

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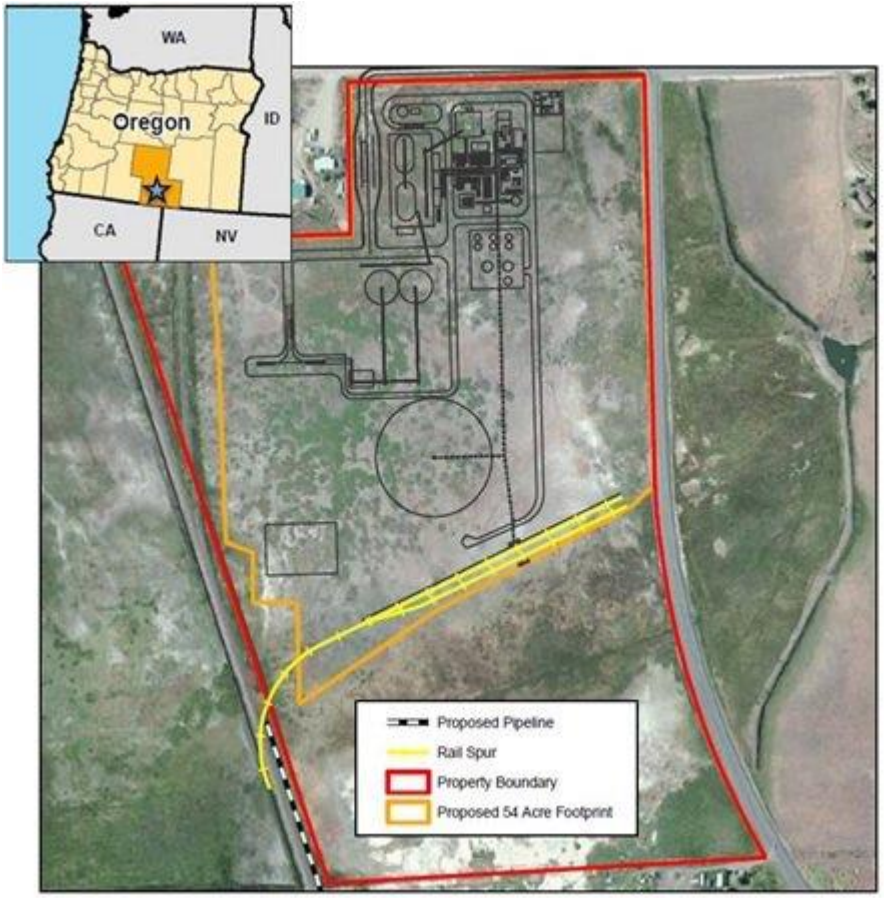
DPA Program

* 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.

DPA Recipient: Red Rock Biofuels

* 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

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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

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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/

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Other commercial activity

* 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

ASTM D7566 qualification activity

	Approach	Feedstock	Notes
In- Process	FT-SPK/A (annex A4)	Cellulose – syngas & alkylation	approved 4Q'15
	ATJ-SPK (annex A5)	Sugars – isobutanol	approved 2Q'16
	CH	Lipids	ARA: Step 3
	HEFA Expansion	Lipids – renewable diesel	R.R. in devel.
	SK/SAK (CCS-APR)	Sugars	Virent: Steps 4/1
	HDCJ (pyrolysis)	Cellulose – biocrude	LanzaTech, UOP
	Co-processing	Biocrude	Chevron, BP, Phillips66
	CATJ-SKA	Sugars – alcohols	Byogy, LT, SwB
			Vertimass, Poet ?
	ATJ-SPK expansion	Sugars – ethanol / xOH	GranBio, UOP, LT, SwB

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ASTM D7566 pipeline

Pre-Pipeline

Approach	Feedstock	Notes
1) CHyP (syngas, non-FT)	Cellulose	Proton Power
2) Microbial conversion	Sugars - isobutene	Global Bioenergies
3) HTL	Cellulose	Algenol, Genifuel, Sapphire
4) Catalytic HTL	Cellulose	Licella, Muradel, QUT
5) SBI CGC PICFTR	Lipids - biodiesel	SBI Bioenergy
6) CCL	Lipids	Tyton
7) Hydrogenotrophic Conv.	CO_2 / Producer Gas	Kiverdi
8) Cyanobacterial Prod.	CO_2	Joule
9) STG+ GTL	c1-c4 Gas / Syngas	Primus
10) Acid Deconstruction	Cellulose	Mercurius
11) Thermal Catalytic Conv.	Cellulose	Shell/CRI/IH2
12) Thermal Deoxyg.	Lipids	Forge Hydrocarbons
13) Ionic Liquid Decon.	Cellulose	JBEI, tbd
14) Metal Catalytic Conversion	Cellulose	Purdue research
15) Enzymatic Conversion	Lignin	GLBRC & JBEI

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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

Approved

- 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)

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In- Process

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

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In- Process

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

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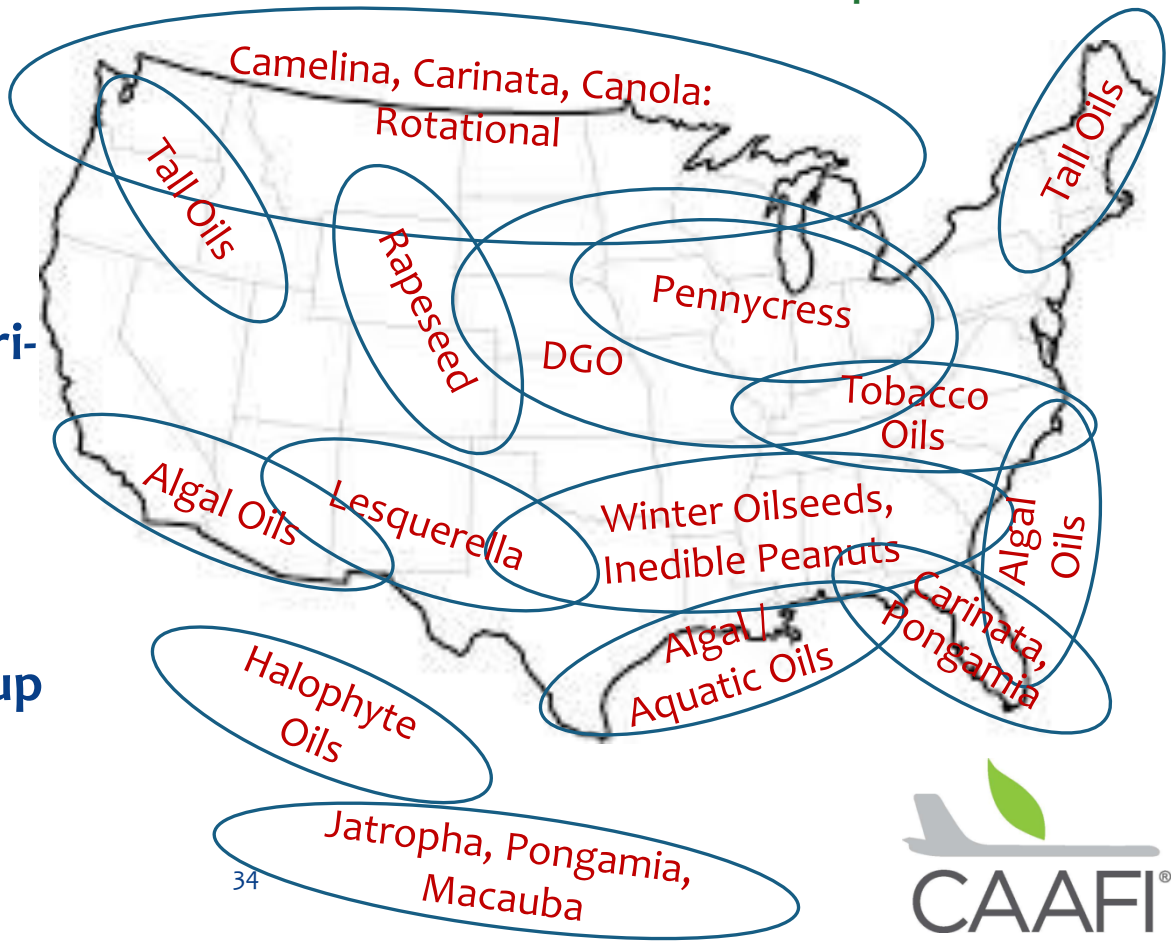
Sustainable lipid feedstocks
HEFA TEA: feasibility is in the feedstock economics …

- 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**

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Summary – programmatic goals & plans

- 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

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How do we get significant SAJF?

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

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