CAAFI Perspectives on SAF status and commercialization acceleration!

✈ Opportunities and challenges for woody-based biofuels for SAF

Technical Advisory Committee of the

Biomass Research & Development Board

Steve Csonka
Executive Director, CAAFI
Capitol Skyline Hotel, Washington DC

First flight from continuous commercial production of SAF, 10Mar’16
Fuel from World Energy - Paramount (HEFA-SPK 30/70 Blend).

CAAFI - Sustainable Aviation Fuel
Agenda:

- Aviation background: commitments and progress
- Jet Fuel & SAF: Overview and fundamentals
- Conversion technologies
- Forestry Opportunities
- Forestry Challenges
- Thoughts for TAC consideration
- Discussion
Aviation Background
Aviation takes its environmental responsibility seriously ...

Decades of progress with:
- Airport community noise
- Tailpipe emissions
  - CO, UHC, Smoke, NOx
  - PM (recent addition)
- Fuel mileage std. (recent)
All have ratcheting stringency under ICAO CAEP oversight via global treaty
- Fuel efficiency
  Driven by inherent need to continuously improve aviation’s productivity and control operating costs, of which fuel is the highest expense category

Now facing the societal pressure of addressing GHGs and growth, especially while other sectors potentially shrink via incorporation of new technologies
Aviation takes its environmental responsibility seriously ... on GHGs too

Nearly identical commitments from Business Aviation

Industry commitments in 2009, 2019
### Aviation Industry Commitment to Action on Climate Change: 3 Goal Approach

<table>
<thead>
<tr>
<th><strong>GOAL 1</strong></th>
<th><strong>GOAL 2</strong></th>
<th><strong>GOAL 3</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-2020 AMBITION</td>
<td>IN LINE WITH THE NEXT UNFCCC COMMITMENT PERIOD</td>
<td>ON THE 2°C PATHWAY</td>
</tr>
<tr>
<td>1.5% ANNUAL AVERAGE FUEL EFFICIENCY IMPROVEMENT FROM 2009 TO 2020.</td>
<td>STABILISE NET AVIATION CO₂ EMISSIONS AT 2020 LEVELS WITH CARBON-NEUTRAL GROWTH.</td>
<td>REDUCE AVIATION’S NET CO₂ EMISSIONS TO 50% OF WHAT THEY WERE IN 2005, BY 2050.</td>
</tr>
</tbody>
</table>

**Four Pillars of the Commitment:**
- Technology
- Operations
- Infrastructure
- Market-Based Measures

SAF a key component of the Technology Pillar; enabler for GHG containment strategy
Why not simply aircraft / engine technologies?

* Each major engine OEM spending > $1B per year in R&D and product development to maintain or improve upon an ~ -2%/yr technology introduction trend … a tough task

---

Reducing Fuel Consumption
Where we wish to go

Technology alone (~ 1.5-2.0% aair) insufficient to keep up with projected traffic growth (~ 4-5% aagr)
ICAO regulates international aviation emissions via treaty (Chicago Convention)
- Regulations become individual country regulations upon adoption by individual States
- Establishes non-taxation of jet fuel for international use
  - Invokes ire of many suggesting aviation somehow gets a “free ride”
Aviation was the first world-wide industrial sector to make voluntary GHG commitments (even as a “hard-to-abate sector”), and called for ICAO to promulgation
- Key interest was to avoid patchwork of regulation that runs counter to treaty intent
- Key challenge is continued expected growth (especially in developing countries), of 4-5% aagr
ICAO recognizes “basket of measures” to address GHG reduction need
- Certification-based Fuel Mileage Standard going forward
- Established CORSIA – enables CNG2020 via use of SAF and Offsets
  - Could set the stage for domestic approaches
- Domestic emissions expected to be addressed via Paris commitments
Aviation efforts attract attention, positive and negative (active protagonists)
- Aviation lauded to spur others to action (e.g. IMO)
- Aviation demeaned as result of Paris commitments, and for not being more proactive
Aviation engaged! Maybe not to the level of some expectations, but tangibly!
SAF offtake agreements
Beyond numerous demonstration programs

Up to 5 M gpy from 2016 (LAX)
3 yr agreement
30/70 blend

Misc Flights, e.g. SFO

Bioports on demand, et al.

Halmstad
Arlanda
Bromma
Goteborg
Leeuwarden

37.5 M gpy

90-180 M gpy

50 M gpy

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

3 M gpy each, 7 yrs (Bay Area, CA)
10 M gpy, 10 yrs (JFK)
4 M gpy, 10 yrs (LAX)
24 M gpy, 10 yrs
SAF Supply collaboration
Supply from 2021
UK DfT F4C Funding: ATJ Development

* 100 M gpy by 2024 from 4 facilities

These offtakes/efforts represent >350 M gpy, and account for the total production slate of the first several commercialization efforts
Other recent announcements

- In negotiation
  - MSW-based FT-SPK evaluations
  - BTL #1, Natchez, MS
    - 1,400 bpd

- SAF Supply explorations
  - SAF Q4’18 restart at Porvoo,
    - ~33M gpy rate,
    - 330M gpy with Singapore
      by 2022

- Carinata supply development

- Up to 1M gpy, 5 yrs+
  - France & EU supply
  - Brisbane Supply Demonstration
Other recent announcements

- Full production slate offtakes
- New Aircraft Deliveries from Airbus and Boeing
- Customer funding of SAJF purchase from 2019
- Exploration of Greater ambition
- $2M for Grays Harbor, WA feasibility study

Multiple Producers, TBA
Gothenburg Refinery
Others, TBA
TBA
Multiple Producers & Suppliers
Airports and Airline Tenants
Northwest Advanced Biofuels
World Fuel Services
AVFUEL
SAS
Cathay Pacific
Alaska
JetBlue
Delta
China Airlines
Finnair
Port of Seattle International Airport
CAAFl
Commitments of Greater Ambition
Multiple airlines additionally committing to net zero by 2050

Obtain 30% of jet fuel from alternative sources by 2030; 06Nov’17

First U.S. Airline to Pledge to Reduce Own Emissions by 50% (vs. 2005) by 2050; 13Sep’18. $40M SAF Investment Fund; 27Oct’19

Norway's government introduces 0.5% blending mandate for advanced aviation biofuels from 2020; 04Oct’18 Sweden, Spain, ... to follow?

Moving forward with $350M expansion to enable 306M gpy total capacity & jet capacity of 150M gpy; 24Oct’18

Netherlands committed to transition all military aircraft to 20/80 AJF blend by 2030 and 70% by 2050; 23Jan’19

India’s SpiceJet commits to flying 100M passengers on SAF by 2030; 23Sep’19

Horizon 2030: offset 100% of domestic CO2 from 2020; reduce 2030’s CO2/pax-km by 50% from 2005; R&D for French SAF industry; 01Oct’19
Commitments of Greater Ambition
Airlines using passenger booking options to offset cost

Customer option to pay for incremental price of SAF of €29.50 on any flight

Customer option to pay for incremental price of SAF in 20-min blocks of flight time for €10 / block (up to 80% CO2 reductions); fuel being allocated to future flights

Compensaid – calculates specific cost of SAF for specific flights and enables customer to pay for incremental price

Customer option to pay for incremental price of SAF for 3 categories of flight: intra-Finland (€10), intra-EU (€20), International (€65); fuel being allocated to future flights
Paradigm changing announcements
Intent to help close price premiums

Clean Skies for Tomorrow Program

Resilient and Sustainable Aviation Fuel (RSAF) credit

Purchase of SAF for US-Netherlands flights (beyond offsetting employee travel)

SAF Now Consortium launch, 15Nov’19
Jet Fuel and SAF
Turbine fuel functional requirements
Foundation for aircraft’s certification basis

How does the aircraft use fuel . . .

- As a coolant
- As a lubricant
- As a hydraulic fluid
- As a ballast fluid, swelling agent, capacitance agent, ...
- And finally, as an energy source

Need: Efficiency and safety paramount

- High energy content: volumetric & mass
- Stable: high flash point (no explosions), low freeze point (liquid at -40°C)
- Unique properties enable required Operability

Turbine fuel used for multiple purposes... So its creation has to be carefully controlled to get the right fit-for-use properties

ASTM D-1655
- Acidity
- Aromatics, max%
- Sulfur
- Distillation
- Flash Point
- Density
- Freeze pt
- Viscosity
- Heat of Combustion
- Copper strip corrosion
- JFTOT
- Existent gum
- MSEP
- Electrical conductivity

17 November 2019
A middle distillate refinery stream is used for jet fuel

* Comprised of mixtures of aliphatic and aromatic hydrocarbons with carbon numbers predominantly in the range of C7-C17, which is typically a mixture of:

  - ~25% / 11% normal / branched paraffins
  - ~30% / 12% / 1% mono- / di- / tri-cycloparraffins
  - ~16 / 5% mono- / di-nuclear aromatics

(25% max aromatics – air quality concern)

* A Gaussian distribution of hydrocarbons, represented as C12H23

There is no standard “formula” for jet fuel

* Composition that delivers the physical properties and performance-based requirements / characteristics of ASTM D1655 specification
Jet Fuel: a middle distillate refinery product

**Average Carbon Chain Length**
- Gas: 4
- Naptha (to Reformer): 8
- Gasoline: 8
- Kerosene (Jet Fuel): 12
- Gas Oil or Diesel: 16
- Lubricating Oil (to Cracking Unit): 36
- Heavy Gas Oil (to Cracking Unit): 44
- Residual (to Coker): 80

**Middle Distillate Market Fraction**
- ~11%
- ~35%
- ~54%

### Segment Observations

**Cars / Lt. Trucks / Misc.**
- Refineries optimized for gasoline
- Gas consumption \(\downarrow\) (CAFE pressure)
- Future ICE need octane boost
- \(\downarrow\) product life, \(\downarrow\) production runs

**Energy Options**
- Yes, Too Many!:
  - X-OH blends
  - Hybrids
  - CNG, LNG, H2
  - Fuel Cell, Electric

**Jet Aircraft**
- Minority volume; gas/diesel squeeze
- Jet consumption \(\uparrow\)
- Fuel requirements stringent – estab.
- \(\uparrow\) product life, \(\uparrow\) production runs

**Nothing practical:**
- Kerosene, from fossil or renewable H/C sources

**Trucks, O/R & HVs, Ships**
- Still need liquid fuels
- Diesel consumption ??
- Future C-IE need cetane boost?

**Energy Options**
- Yes:
  - Biodiesel blends
  - Hybrids
  - CNG, LNG, H2

*How Stuff Works*
Jet fuel usage will continue ... Through several decades, with tomorrow’s technology

CO₂ Reduction Roadmap & Goals

Aircraft model intros “2015-2020”
- E-Jet E2, MRJ, A220
- ARJ-21, C919, MC-21
- 737 Max, A320 Neo
- 787 FBO, A330 Neo
- A350 FBO
- 777-X

Business as usual

Tech Ops Infra
“Radical New Technologies” & Biofuels

SSBJ
SS Pax
NMA
737 & A320 Redux

15 year min production runs
20 year min useful service life following EIS

CO₂
Emissions

2005 2010 2020 2030 2040 2050
... and into the intro period of “Radical New Technologies”

**CO₂ Reduction Concepts**

- Brayton cycle entitlement (UHBR, GTF, UDF)
- Hybrid: gas turbine HP augmented w/ electrics
- Distributed propulsion / Ultra span concepts
  - New thermodynamic cycle concepts / Variable cycle
    - Dual fuel, new fuel (LNG, H₂, …)
  - Cryogenic Fuel - intercooled / variable cycle engines, supercooled conduction, associated tech, …
- Cryogenic fuels – unconventionally fully-electric
  - Battery/fuel-cells – conventionally fully-electric aircraft
    - Battery powered full electric (off by factor of 50)
  - Super-/hyper-sonic slingshot aircraft, scramjet
  - …

**Potential Break Points, e.g.:**

- Aircraft / engine configuration changes drive terminal / runway changes?
- Duplicate fueling systems
- New hydrant systems / new airports
- Quick charge/change aircraft configs

**Potential 30-70 pax regional LEV / ZEV aircraft family?**

**CO₂ Emissions Reduction Concepts Introduction**

2030  |  2040  |  2050  |  2060  |  2070
SAF (Sustainable Aviation Fuel) 
a.k.a. aviation biofuel, biojet, alternative aviation fuel

**Aviation Fuel:** Maintains the certification basis of today’s aircraft and jet (gas turbine) engines by delivering the properties of ASTM D1655 – Aviation Turbine Fuel – enables drop-in approach – no changes to infrastructure or equipment, obviating incremental billions of dollars of investment

**Sustainable:** Doing so while taking Social, Economic, and Environmental progress into account, especially addressing GHG reduction

**How:** Creating synthetic jet fuel with biochemical and thermochemical processes by starting with a different set of carbon molecules than petroleum ... a synthetic comprised of molecules essentially identical to petroleum-based jet (in whole or in part)
Achieving net Lifecycle GHG Reductions with SAF

Petroleum based Jet

\[ C_m H_n \]

\[ \text{CO}_2 \]

Sustainable Aviation Fuel

Result is a net reduction of additional carbon being introduced into our biosphere

Continuing to pull additional carbon from the ground and releasing it into the atmosphere as CO\(_2\)

Acquiring the majority of our carbon from the atmosphere, via biology, turning it back into fuel

17 November 2019
Achieving net Lifecycle GHG Reductions with SAF

Sustainable Aviation Fuel

- Policy rewards reductions >50%
- Many solutions in the 60-80% range
- Some solutions achieve >100% via carbon sequest’n or other emission reduction

Acquiring the majority of our carbon from the atmosphere, via biology, turning it back into fuel
Overall industry SAF summary:

- No opportunities for liquid hydrocarbon replacement in next several decades for majority of worldwide fleet
- SAF are key for meeting industry’s GHG commitments – decoupling carbon from aviation’s growth
  - Delivers net GHG reductions of 65-100%, plus other enviro services
  - Aviation enterprise aligned; 26B gpy US & 90B GPY worldwide opportunity
  - Many are working to foster, catalyze, enable, facilitate, participate
  - Segment knows how to make it; Activities from FRL 1 to 9
  - Pathway identified for fully synthetic (50% max blend today)
  - First facilities on-line, producing SAF at various run-rates
  - CORSIA monetizes carbon specifically to aviation enterprise
  - Commercial agreements being pursued, fostered by policy / other approaches
  - Making progress, but still significant challenges – only modest production
    - SAF Refineries: 2 full time; 2 batch mode; 3 in construction; multiple in FEED
  - Focus on enabling commercial viability - Potential for acceleration a function of engagement, first facilities’ success replication, additional technologies
No technology on the horizon to decarbonize current / advanced commercial aircraft (>100 seats)

- Energy and Power densities of batteries and electrical systems are 50X off the levels needed to replace hydrocarbon fuels
- No fuel switches (X-OHs, diesel, LNG, CNG, H₂, …) appear viable

So, for the next 3-4 decades, we’re forced to look primarily to the fuel to enable carbon reduction for mainstream commercial aircraft

Even if we see hybrid or electric applications enter service as a regional turbo-prop replacement, this family of aircraft is only responsible for a small fraction of today’s GHGs.

SAF – Maintaining our license to grow!

SAF – Perhaps maintaining our license to exist!

SAF – enables radical-new-tech to enter the system as its own natural pace – as it becomes technically and financially viable!
SAF Conversion Technologies
Biochemical conversion processes use various microorganisms that convert feedstocks to hydrocarbon chemicals.

Thermochemical processes use heat and pressure, often with various types of catalysts, in various types of reactors. Examples of these reactions include:

- Deconstruction: Torrefaction, Pyrolysis, Gasification (in increasing energy levels), dehydration
- Reconstruction: oligomerization, Fischer Tropsch synthesis, hydroprocessing
- Fuel Finishing: taking H-C molecules, and making them suitable for use as a jet fuel blending agent, in part or in whole, using typical refinery processes: hydrotreating, hydro-isomerization, hydro-cracking
Materials that contain hydrogen and carbon are converted to SAF by using biochemical and thermochemical transformation processes to create jet fuel molecules.

These are often referred to as feedstocks.

Nature gives us 3 families of hydrogen and carbon containing compounds by converting atmospheric CO2 and water:

- Lipids - e.g. fats (animal), oils (various plants), greases
- Sugars - sugar cane, sweet sorghum, sugar beets, tubers
- Lignocellulose – cellulose, hemicellulose, lignin

There are several human activities that also produce waste or byproduct streams that also contain hydrogen and carbon.
SAF conversion processes
... or, “dispelling the fear of revisiting Chemistry 101”

- Start with hydrocarbon / organic building-blocks
- 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
SAF conversion mechanisms
Challenge ... doing it at the price of petroleum refining

Fossil HC Lipids Cellulose Sugars & Wastes & CH4 CO2
Plant & Animal Hemi- & Starch Syngas

Gasify Pyrolize Torefy Saccharify Deconstruct Digest
Separate Ferment Dehydrate Catalyze Process

FT CH CC APR HL Oligomerize
Distill Hydrotreat Hydroprocess Hydro-Isomerize

FT-SPK, HEFA-SPK, HFS-SIP, FT-SPK/A, ATJ-SPK, ...
Aviation industry path to SAF

* **ASTM D1655 - Standard Specification for Aviation Turbine Fuels**
  * A1.1.2 ... Aviation turbine fuels with synthetic components produced in accordance with Specification D7566 meet the requirements of Specification D1655.

* **ASTM D4054 - Standard Practice for Qualification and Approval of New Aviation Turbine Fuels**
  * 1.1 This practice covers and provides a framework for the qualification and approval of new fuels and new fuel additives for use in commercial and military aviation gas turbine engines...

  * 1.2 ... Aviation turbine fuel manufactured, certified and released to all the requirements of this specification, meets the requirements of Specification D1655 and shall be regarded as Specification D1655 turbine fuel.
ASTM D4054 SAF Qualification Status

Exploratory Discussions


Virent SK (Inactive)

Virent SAK

Tier 1

Specifications

Shell IH²

ATJ-SKA (Byogy, Swed Biofuels)

Tier 2

Fit-for-Purpose Properties

Phase 1 ASTM Research Report

OEM Review & Tier 3 & 4 Requirements

HFP-HEFA (Green Diesel)

(Tier 2.5 Initial Test Case)

Tier 3

Component/Rig Testing

Tier 4

Engine/APU Testing

Phase 2 ASTM Research Report

OEM Review & Approval

Annex A1 FT-SPK

Annex A2 HEFA-SPK

Annex A3 HFS-SIP

Annex A4 FT-SPK/A

Annex A5 ATJ-SPK (Isobutanol & ethanol)

Lipids Co-processing (D1655)

FAA Review

Accept

ASTM Review & Ballot

ASTM Specification

ASTM Balloting Process

Re-Eval As Required

ARA CHJ

IHI Bb-Oil HEFA

FT Co-processing (D1655)

17 November 2019
### ASTM D4054 pipeline examples

<table>
<thead>
<tr>
<th>Approach</th>
<th>Feedstock</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATJ Expansion</td>
<td>Alcohols (via sugars)</td>
<td>Swedish Biofuels*, Byogy</td>
</tr>
<tr>
<td>HDCJ (direct or co-processing)</td>
<td>Lignocellulose</td>
<td>Ensyn/Envergent, REC Global Bioenergies*</td>
</tr>
<tr>
<td>Microbial conversion</td>
<td>Isobutene (via sugars)</td>
<td>Steeper, Genifuel, ...</td>
</tr>
<tr>
<td>HTL</td>
<td>Lignocellulose</td>
<td>Licella, Muradel, QUT Forge Hydrocarbons*</td>
</tr>
<tr>
<td>Catalytic HTL</td>
<td>Lignocellulose</td>
<td>SBI Bioenergy / Shell Mercurius</td>
</tr>
<tr>
<td>Thermal Deoxygenation</td>
<td>Lipids</td>
<td></td>
</tr>
<tr>
<td>SBI CGC PICFTR</td>
<td>Lipids - biodiesel</td>
<td></td>
</tr>
<tr>
<td>Acid Deconstruction</td>
<td>Lignocellulose</td>
<td></td>
</tr>
<tr>
<td>Bio-TCat (thermal catalytic)</td>
<td>Lignocellulose</td>
<td></td>
</tr>
<tr>
<td>CCL</td>
<td>Lipids</td>
<td></td>
</tr>
<tr>
<td>CHyP (syngas, non-FT)</td>
<td>Lignocellulose</td>
<td></td>
</tr>
<tr>
<td>Hydrogenotrophic Conv.</td>
<td>CO2 / Producer Gas</td>
<td></td>
</tr>
<tr>
<td>Cyanobacterial Prod.</td>
<td>CO2</td>
<td></td>
</tr>
<tr>
<td>STG+ GTL</td>
<td>c1-c4 Gas / Syngas</td>
<td></td>
</tr>
<tr>
<td>Ionic Liquid Decon.</td>
<td>Lignocellulose</td>
<td></td>
</tr>
<tr>
<td>Metal Catalytic Conversion</td>
<td>Lignocellulose</td>
<td></td>
</tr>
<tr>
<td>Enzymatic Conversion</td>
<td>Lignin</td>
<td></td>
</tr>
<tr>
<td>PtL</td>
<td>H2, point source CO2, low carbon power</td>
<td></td>
</tr>
</tbody>
</table>

* Recent outreach to CAAFI R&D Team, ASCENT C.H. and/or OEMs
Why we care about the pipeline

* We need expanded **SAF affordability**
  * Processes applicable to lower cost, available feedstocks, low CI
  * R&DD applicable to CapEx, OpEx

* We need expanded **SAF availability**
  * Available for processing world-wide, with regionally available sustainable feedstocks

* We need commercialization activity / fuels **soon, not in 2030+**
  * Leverage existing biofuel infrastructure or adjacent production
  * Some will shift strategies and may never produce jet fuel (Amyris), or produce compounds of lesser interest (Virent)
Aviation climate targets may drive 3 million hectares of deforestation

The aviation industry’s climate targets are likely to lead to a dramatic increase in demand for palm oil and soy for aviation biofuels. A new report concludes that this may result in 3.2 million hectares of tropical forest loss – an area larger than Belgium.

Published: 01.10.2019

- Extrapolation and pet-peeves lead you to extraordinary theories and positions
- Aviation has embraced verifiable sustainability and standards, and has shunned some more controversial solutions

No single feedstock is targeted or sufficient
Forestry Opportunities
Potential for U.S. SAF build-out

SAF from several prevalent waste stream feedstocks

(GPY, using standard conversion efficiencies and viable SAF fractions)

3.8 B  Wet Waste (manures, sanitary, misc streams)
3.1 B  MSW (municipal solid waste: wood, paper, yard, plastics, textiles, food)
6.1 B  Agricultural residues (primary crop residues only, 31% removal)
0.4 B  Forestry residues (30% of production uncommitted)
0.8 B  F.O.G. (Fats oils and greases: estimates vary significantly, up to 3.0B)
1.3 B  Industrial off-gases (steel, aluminum, petroleum)
_x.x B  Other (C&D waste, telephone poles, rail ties, invasive tree removal)
~15.6 B  Current Total Potential (approx. 58% of 2019 U.S. demand)

Plus, low ILUC purpose-grown crops
Plus, ...
Advantages

- Relative homogeneity, steadiness of supply
- Some aggregation already occurs
- Timber basins no longer supporting viable paper industry and need economic development opportunities – offer incentives
- Significant acreage: NW, SE, NE

Producers are finding sustainable approaches

- Direct use of residues:
  - FT, Pyro co-processing, IH², HTL,
- Use of hydrolyzed sugars
- Use of lignin
- Use of Tall Oil (from Kraft pulp production)
  - UPM – making diesel today, SAF tomorrow?
- Considering some very unique supply-chain approaches, including densification / intermediates

General forest residue opportunities

Red Rock: FT
Velocys: FT
Anellotech: Bio-TCat
Biodico: hybrid
Shell/IH² customers: HTL (e.g. Synsel)
D’Arcinoff: FT
Eco-Options Energy: hybrid biocatlytic
Envergent: Pyro
Expander: FT
Gasosyn: FT
Greenfield: hybrid
Juniper: FT
Licella: HTL
Loring: hybrid
Mercurius: REACH
NuFuels: FT
Proton: hybrid
Renovare: AD-biogas-FT
US Advanced Bio-Fuels: FT
USA Bioenergy: FT
Vertimass: ATJ’
Steeper: HTL
**DPA Recipient: Red Rock Biofuels**

“Groundbreaking” 18Jul’18, First Fuel YE 2020

- 15.1 M gpy of renewable, liquid transportation fuels – FT process
  - From 167,000 bdtpy of woody biomass (22% of wood waste in 125 mi radius)
  - 3M gpy SAJF offtake agreement from each of Southwest and FedEx
  - $70 million DPA Title III award for ~$320+ million refinery
- Replicable approach targeting 10 additional sites
  - E.g. – timber basins in the Pac NW (see next)

*Courtesy Biofuels Digest*
Velocys Mississippi Bayou Fuels project: RFS-2 compliant woody biomass to fuels at full scale

Input: Waste Biomass
Output: 25 million gallons per year
Permitting complete
Arkansas Renewable Fuels Plant Summary

The Place
FOREST PRODUCT INDUSTRY IN ARKANSAS

The Incentives

Physical Product
- $2.03
- 25%

Federal Blend Credit
- $1.00
- 13%

Federal RIN
- $3.07
- 38%

CA LCFS
- $1.89
- 24%

The Project

Forest Residues
- Waste products exclusively from responsible management of sustainable plantation forests.
- High availability of RFS2 compliant feedstock available in Arkansas.

Advanced Biorefinery
- Low carbon footprint LCFS compliant plant using only technologies that have already been financed and deployed in plants nearing construction completion for renewable fuel production.

ASTM Certified Diesel
- High value D3/D7 federal and state LCFS credits, and ~ 23 million gallons per year of premium drop-in renewable heavy transport fuel and naphtha.

The Delivery

Product offtake agreement secured
- Technology providers selected
- Independent owner's engineer evaluation
- EPC firm short-list established
- Candidate sites selected and in evaluation
- Feedstock suppliers secured
- Performance guarantees established

TRI Gasifier
Johnson Matthey FT & Upgrading

USA BioEnergy
Forestry Challenges
General challenges

* Volumes of policy-viable amounts; without policy, business case difficult
* Aggregation
  * Amounts from processing and mills are not “huge”
  * Collection of thinnings, and allowable thinning, tbd
  * NARA in-depth look at most commonly unused/wasted supply – slash piles
* Hauling (cost of moving air and water, nuisance issues)
* Although desire to use undergrowth (CA fire abatement) or dead material (BANR) is strong, have yet to see full business case pencil-out
* Coppicing plantations
  * Establishment costs and time-to-harvest delay
  * AHB ongoing effort to find workable solutions
* Energy densification technologies unproven or unintegrated – will potentially stay that way with uncertainties above, continued public deification of forests, forests used for “generating offsets,” …
* Competition from pellets, mass-burn, …
Policy treatment inequity

RFS-2 - Vagaries of the definition of allowable biomass

- Issues being worked by ABFA (CARRI), A4A, BIO, et al.
  - Bio-intermediates; Co-processing
  - Blending & Mass allocation
  - Federal land – special purpose
  - Thinning defn.

RFS: The green boxes indicate which sources are eligible; the red boxes indicate sources that are ineligible. Courtesy FOREST2MARKET
Observations for discussion
SAF progress - technical

- SAF are becoming increasingly technically viable
  - Aviation now knows we can utilize numerous production pathways (5 approved, others pending)
  - Enabling use of all major sustainable feedstocks (lipids, sugars, lignocellulose, H&C slip-streams)
  - Following blending, fuel is drop-in, indistinguishable from petro
  - Some future pathways will produce blending components that will need less, or zero, blending
  - Expanding exploration of renewable crude with refiners
- Significant “pipeline” of new production pathways
- Continuing streamlining of qualification – time, $, methods
Airline engagement continues, strongly with key instigators

- BizAv and Corporation engagement initiated and expanding

Other convening activities

- Fuel Suppliers – new business opportunities
- Refiners – maintaining markets and meeting policy obligations
  - Co-processing activities
- NGOs – assisting w/ demand aggregation & market signals
- Airports – misc explorations, starting w/ infrastructure evaluations
- Feedstock development – flight demos whet investor interest
- SAF & HDRD Producers – continuous stream of exploration and announcements
- OEMs have their own fuel needs – another buyer group
The path to SAF commercialization has perhaps commenced
- In production; in construction; in final design; in conceptualization
- Some will be readily replicable
- May be able to leverage existing refineries, as well as alcohol and renewable diesel production facilities

The primary impediments to rapid growth:
- A production cost delta versus petroleum-jet, and;
- Competition from diesel (road and maritime), and;
- A policy environment that may not close cost delta, creates market distortions, and continues to foster uncertainty

Given a policy framework and/or societal engagement that addresses the above, SAF is perhaps on the cusp of rapid expansion and replication
Other SAF-linked jeopardies

“Taking a plane is the fastest and cheapest way to fry the planet”

* Calls for punitive measures to truncate demand
  * Calls for renegotiation of Chicago Convention to enable taxing
  * Progressive tax structures on # of trips
  * Elimination of frequent flyer programs

* Calls for reduction in flying (persons and corporations)
  * Fostering of social flight shaming (Sweden - flygskam)

* Calls for conversion of short-haul to trains, or even for elimination of domestic flying (UK)

* Forcing mandates, or potentially in-sector carbon reductions

* Policy schemes (carbon pricing) are not targeting use of funds for in-sector technology development
Thoughts for TAC Consideration
Although aviation can perhaps be doing more themselves, they need, and merit, assistance to enable commitment:

- Targeted & improved policies; level/advantaged playing field with diesel
- Stable policy that encourages funding
  - Jet fuel use continues through 2060, SAF offers GHG reductions now
- Assistance with R&D, D&D
  - Solid – liquid interface; pumping; reactor introduction
  - Additional catalytic approaches; separation tech
  - Densification concepts (technologies, process/equipment, supply chains)
  - D&D for additional pathways sorely lacking at present
  - The omni-present lignin valorization
- Brownfield development
- Forestry residues are expected to be part of the solution
Steve Csonka
Executive Director, CAAFI
+1-513-800-7980
Csonka.CAAFI.ED@gmail.com
Steve.Csonka@caafi.org
www.caafi.org