CAAFI Biennial General Meeting

Parade of Commercialization Efforts

Chris Wilcox
Gevo Incorporated
December 2018
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THINKING ABOUT THE CYCLE

More is possible!

For every 1BGPY of fuel:
- 5 Million MT of protein/feed could be produced
- 800Kt to 4 million MT of carbon could be captured in soil

Feed and Food

~5kg high protein feed/hydrocarbon gallon

Soil

100% of the nutritional value of corn is captured in the feed

Avg ~0.8 kg CO2 captured/gallon of Jet (range of 0-4kg/gal)
FACTS ON GEVO’S SUSTAINABLE AVIATION FUEL

• Gevo’s Alcohol to Jet Synthesized Paraffinic Kerosene (ATJ-SPK) pathway was approved by ASTM in April 2016
  – ASTM certified
  – Blend limit for ATJ-SPK is 50%
  – Drop-in alternative to conventional aviation fuel
  – No Sulfur, no particulates, and an undetectable freezing point
  – Higher energy density

• Gevo has demonstrated the use of 50/50 ATJ on an F/A-18 “Hornet” in supersonic flight in 2014

• Gevo flew the first flight ever utilize cellulosic feedstock for ATJ-SPK
GEVO’S FLY GREEN DAY AT O’HARE

• Worked with BP to supply O’Hare (for the first time) with Gevo’s ATJ
  – Blended, certified, pipelined to O’Hare Fuel Farm via commercial infrastructure

• First time renewable jet was supplied to O’Hare using on & off airport infrastructure

• Eight airlines and FedEx participated and flew the renewable fuel
  – Lufthansa
  – United Airlines
  – Etihad
  – Japan Airlines
  – Cathay Pacific Airways
  – Korean Air
  – Atlas Air

• Demonstrated and set the precedent that commercial supply logistics is possible
GEVO’S AND VIRGIN AUSTRALIA FLY GREEN IN BRISBANE

• Initial portion of a 12-18mo project

• Partnership between Virgin Australia, Gevo, Queensland Gov’t, Caltex, & Brisbane Airport

• First time renewable jet was supplied in Australia using the general fuel supply system

• Biojet has now been used to fuel 195 domestic and international flights out of Brisbane

• We (Gevo) feel Australia has tremendous long term potential in SAF
  – Proved out commercial logistics to hydrate and on-wing
  – Better understanding of associated costs
  – Provide momentum for future project development
GEVO’S AND AVFUEL FLY GREEN AT VAN NUYS

• Business Jets Fuel Green: A Step Toward Sustainability
  – Van Nuys is one of the worlds busiest general aviation airports

• Renewable jet fuel has a market outside airlines
  – Demand in general aviation and business travel

• A fully collaborative effort between:
  – Gevo
  – Avfuel Corporation
  – Bombardier Business Aircraft
  – Phillips 66
  – World Fuel Services

• Demonstrates the general aviation industries commitment to emissions reduction and aim for carbon neutrality from 2020 forward
Thank You
UOP Renewable Technology Solutions

Inedible Fats, Oils & Grease
- UOP Ecofining™ Process → Honeywell Green Diesel™
  - Green Jet (optional)
- UOP Renewable Jet™ Fuel Process → Honeywell Green Jet™
  - Green Diesel
- UOP Distillate Unionfining™ Process → Partial Green Diesel
  - Partial Green Jet

Petroleum Distillate
- RTP® (Pyrolysis) → RF Gasoline
- UOP FCC Co-Processing → RF Diesel

Biomass
- UOP FCC Co-Processing
Progress Producing Advanced Renewable Fuels

- Renewable Diesel/Jet is the third largest type of biofuel produced
  - 3.7% of global biofuels demand
  - 0.2% of global diesel & jet fuel demand
  - Predominantly diesel

- Renewable Jet (HEFA SPK) is being commercially produced using Honeywell UOP technology and is in use in regular commercial flights

- Five aviation biofuels currently approved by ASTM International
  - Additional aviation biofuels are being tested under ASTM
  - Includes testing by Honeywell

* Expected as of Nov 2018
Operating Plants Using UOP’s Renewable Fuel Technology

2013

- **Diamond Green Diesel**
  - 900,000 MTA Feed (18,000 BPD)
  - First New Ecofining Unit installed at Norco, Louisiana
  - **Expansion to 2,400,000 MTA (48,000 BPD) in progress**

2014

- **ENI #1**
  - 360,000 MTA Feed (7,200 BPD)
  - First refinery retrofit to Ecofining Unit at Venice, Italy
  - **Expansion to 560,000 MTA (11,200 BPD) in progress**

2016

- **World Energy / AltAir**
  - 150,000 MTA Feed (3,000 BPD)
  - First refinery retrofit to UOP Renewable Jet Fuel Unit at Paramount, California
  - **Produces Green Jet and Green Diesel**
  - **Expansion to 1,000,000 MTA (20,000 BPD) announced**

2018 Expected

- **ENI #2**
  - 720,000 MTA Feed (14,400 BPD)
  - Second refinery retrofit to Ecofining Unit at Gela, Italy
  - **Under Construction**

Each owner is implementing additional projects using UOP technology.
UOP Renewable Technology Solutions

- **UOP Ecofining™ Process**
  - Honeywell Green Diesel™
  - Green Jet (optional)

- **UOP Renewable Jet™ Fuel Process**
  - Honeywell Green Jet™
  - Green Diesel

- **UOP Distillate Unionfining™ Process**
  - Partial Green Diesel
  - Partial Green Jet

- **RTP® (Pyrolysis)**

- **UOP FCC Co-Processing**
  - RF Gasoline
  - RF Diesel

Proven Technologies for Feedstock Flexible Drop In Fuels
Renewable Fuels from Co-Processing of RTP Bio-Crude

Biocrude

Vacuum Gas Oil (VGO)

Utilize existing refinery assets & infrastructure

Partially renewable products sent downstream

LPG

Cat Gasoline

Light Cycle Oil (LCO)

Main Column Bottoms (MCB)
Supply Chain Consists of Multiple Steps

1. Forest residues, saw dust, agricultural residues
2. RTP unit to convert wood to RTP green fuel near biomass
3. RTP green fuel to refinery by truck, rail or ship
4. RTP green fuel to FCC unit for conversion to transport fuels
5. Renewable fuels to market

Forestry / Biomass company scope

Oil Refinery scope

Envergent

Honeywell UOP

UOP is Addressing Challenges in Refinery Implementation
Commercial Status

- Three commercial-scale FCC co-processing trials completed
- Multiple full-scale installations of technology scheduled in 2018/19
  - USA
  - Europe
- Regulatory recognition and verification
  - Completion of US EPA Part 80 Facility Registration for co-processing application
  - Completion of ISCC certification for recognition of biofuel in Europe
Increasing Green Diesel and Green Jet activity across the globe
  • North America/Europe/Middle East/Asia
  • New units as well as revamps
  • DHT co-processing

Growing interest from refiners for FCC co-processing
  • Numerous projects to implement tech in US and Europe underway

Driven by:
  • Climate change and GHG reduction commitments
  • Air pollution mitigation
  • Corporate social responsibility
  • Continuing development of new technology pathways

The Future Of Biofuels Is Bright
No Carbon Left Behind: Alcohol-to-Jet
Alcohol-to-Hydrocarbons

Ethanol → Dehydration → Oligomerization → Hydrogenation → Fractionation → Jet & Diesel

Ethanol → Ethylene → C4- C24 Olefins → + H2 → Paraffins and IsoParaffins

Energy Efficiency & Renewable Energy

Boeing

Carbon Smart™
LanzaJet Property Highlights

<table>
<thead>
<tr>
<th>Fuel Property</th>
<th>Jet A Spec</th>
<th>LanzaTech ATJ-SPK</th>
<th>50/50% v with Jet A</th>
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<tbody>
<tr>
<td>Freeze Point, °C</td>
<td>-40 max</td>
<td>-61</td>
<td>-54</td>
</tr>
<tr>
<td>Energy Density, MJ/kg</td>
<td>42.8 min</td>
<td>44.4</td>
<td>43.8</td>
</tr>
<tr>
<td>Thermal Stability</td>
<td>Baseline</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Viscosity @ -40 °C mm²/sec</td>
<td>12 max</td>
<td>7.0</td>
<td>9.3</td>
</tr>
<tr>
<td>Hydrogen %</td>
<td>13.4 min</td>
<td>15.1</td>
<td>14.5</td>
</tr>
<tr>
<td>Aromatics %</td>
<td>8 min, 25 max</td>
<td>Nil</td>
<td>8.8</td>
</tr>
<tr>
<td>Sulfur, total mass %</td>
<td>0.30 max</td>
<td>&lt;0.001</td>
<td>0.02</td>
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Meets or Exceeds Critical Jet Fuel Specifications
Neat fuel primarily isoparaffins with <0.2% aromatics

Carbon number range similar to conventional jet fuel and other SPK’s

On April 1, 2018 ASTM Intl. revised D7566 ATJ SPK Annex A5
• Added Ethanol as a feedstock
• Increased final blend ratio to max 50 %
Low Carbon Jet Benefits

- **Reduction in Sulfur Level**
  - Conventional Jet: 3000 ppm
  - Lanzajet: < 1 ppm

- **Reduction in Aromatics**
  - Conventional Jet: 8-25%
  - Lanzajet: 0%

- **Increase in Energy Density MJ/kg**
  - Conventional Jet: 42.8
  - Lanzajet: 44.4
Recycling Carbon

Industrial Off Gas
Biomass, MSW Syngas

Gas Feed Stream
Compression
Fermentation
Recovery
Product Tank

Proprietary Microbe

Carbon Smart™
>100 tons ethanol per day
## Potential AtJ from Gas Fermentation

### Totals/year

<table>
<thead>
<tr>
<th></th>
<th>Relative to Today</th>
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<tbody>
<tr>
<td>270B Gallons AtJ</td>
<td>&gt; today’s aviation fuel use</td>
</tr>
<tr>
<td>~63,000 planes on the ground</td>
<td>~250% of commercial flights</td>
</tr>
<tr>
<td>1.7B tonne CO₂</td>
<td>~5% of Anthropogenic Global CO₂</td>
</tr>
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</table>

### Significant AtJ Potential
Path to Economic Volumes

2015
Lab Scale

Pacific Northwest
National Laboratory

2016
Pilot Scale

Freedom Pines Biorefinery

2020
10M gpy

LanzaJet

Freedom Pines Biorefinery

2022
30M gpy x3

Energy Efficiency & Renewable Energy

Carbon Smart™
"The fight is won or lost far away from witnesses - behind the lines, in the gym and out there on the road, long before I dance under those lights."

Muhammad Ali
Velocys Alternative Jet Fuels
CAAFI Biennial General General Meeting
Velocys – the renewable fuels company

- Technology demonstrated at commercial scale
  - Provides foundation for development of integrated biorefineries being pursued by Velocys and its partners

- Team with exceptional experience of designing, commissioning and operating synthetic fuel facilities

- Traded on AIM market of London Stock Exchange (VLS.L)
Renewable fuels from alternative feedstocks

- Velocys is developing a series of renewable fuels plants in the U.S. and U.K.
- Gasification through FT pathway supports a range of feedstocks, including forestry residues, agricultural wastes, and municipal solid waste
- ~24m gpy project in Mississippi entering FEED
- Project in the U.K. currently in pre-FEED
Using established technologies

**Feedstock conditioning facility**
- Physical preparation of the feedstock

**Gasifier**
- Thermally and chemically break the material into its component parts to produce syngas

**Syngas clean-up**
- Physically and chemically remove impurities from the syngas

**Fischer Tropsch (FT)**
- Chemically react the syngas to form long chain hydrocarbons

**Hydrocracker**
- Chemically cut the long hydrocarbons to form jet fuel and naphtha

**Waste Streams**
- Syngas
- Clean syngas
- FT product
- Finished products
Our route to jet fuel from waste reduces lifecycle greenhouse gas emissions by >70%.

Meets specifications for synthetic paraffinic kerosene (SPK)
- Globally approved at up to 50% in commercial aviation (Jet A1/Jet A)

Widespread use would improve air quality around airports
- Over 90% reduction in emissions of particulate matter and sulphur
- Over 20% reduction in carbon monoxide
- Over 30% reduction in hydrocarbons

FT diesel (left) versus conventional diesel (right)
Bayou Fuels – Mississippi Project

• Velocys is developing a 24 mmgy woody biomass to middle distillate bio-refinery in Natchez, MS.

• Utilizes forestry residues and waste to achieve mid 20s CI

• Permitting underway with “FONSI” for environmental assessment

• Extensive pre-FEED engineering work combined with integrated demonstration unit has materially de-risked the project

• Currently engaged in partnering exercise, expect to commence FEED in 2019 with FID in 2020
Renewable jet fuel from household waste
Project to build U.K.’s first commercial waste-to-fuels plant

- Over 70% reduction in greenhouse gases
- Around 30,000T/year of clean “drop-in” fuel
- Sustainable feedstock - avoids ~400,000T/year of non-recyclable waste going to landfill
- Around 100 full time operational roles
Partners bring key strengths for U.K. project

Project is aligned to the partners’ core strategies
— All invested in project development
— Intend to underpin revenues through long term commercial feedstock / offtake agreements

Market pull (renewable fuels critical to achieving carbon footprint reduction)

Technical expertise and fuels offtake capability (strategic intent to improve sustainability of fuels)

Proven process combined with development and delivery of operational renewable fuels plants. Leading the UK project on behalf of the partners
U.K. Project status

- Project passed second stage gate in June 2018, securing £4.9M to support next stage
- Pre-FEED engineering contractor kicked off carrying out optioneering studies
- Site selection in progress
- Developing feedstock sourcing strategy
- Understanding financing requirements through active engagement
Velocys Roadmap
Building a Portfolio

- Velocys sees a pathway for a series of bio refineries that deliver over 200mm gallons of renewable fuels (middle-distillates) in less than 10 years