Biofuels in Defense, Aviation, and Marine

Bioenergy Technologies Office Peer Review

Zia Haq
U.S. Department of Energy
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DPA Initiative Goals

• In June 2011, Secretaries of Agriculture, Energy, and Navy signed MOU to commit $510M (up to $170M from each agency) to produce hydrocarbon jet and diesel biofuels in the near-term. This initiative sought to achieve:
  o Multiple, commercial scale integrated biorefineries
  o Cost-competitive biofuel with conventional petroleum (w/o subsidies)
  o Domestically produced fuels from non-food feedstocks
  o Drop-in, fully compatible, MILSPEC fuels (F-76, JP-5, JP-8)

• DoD uses approximately 5 billion gallons of fuel annually and represents a key market adopter for advanced biofuels technologies

• Navy solicitations via Defense Logistics Agency to purchase biofuel blends through regular procurement contracts as long as they meet cost and performance criteria
### Fuels for Distillate and Jet Market

#### US Liquid Fuels and Products Market Size (billion gallons/year)

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2040</th>
<th>Growth Rate 2012 – 2040 (%/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>134</td>
<td>105</td>
<td>-0.9%</td>
</tr>
<tr>
<td>Diesel</td>
<td>57</td>
<td>71</td>
<td>0.8%</td>
</tr>
<tr>
<td>Liquefied Petroleum Gas&lt;sup&gt;1&lt;/sup&gt;</td>
<td>36</td>
<td>42</td>
<td>0.6%</td>
</tr>
<tr>
<td>Other&lt;sup&gt;2&lt;/sup&gt;</td>
<td>30</td>
<td>39</td>
<td>0.9%</td>
</tr>
<tr>
<td>Jet Fuel</td>
<td>21</td>
<td>24</td>
<td>0.5%</td>
</tr>
<tr>
<td>Residual fuel oil</td>
<td>5</td>
<td>6</td>
<td>0.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>283</strong></td>
<td><strong>287</strong></td>
<td></td>
</tr>
</tbody>
</table>

1. Includes ethane, natural gasoline, and refinery olefins.
2. Includes kerosene, petrochemical feedstocks, lubricants, waxes, asphalt, and others commodities.


- Defense – Facilitating commercial scale production capacity
- Aviation – Testing and certification of alternative fuels
- Marine – Meeting environmental regulations
DPA Initiative – Accomplishments/Milestones

- In May 2013, four projects were selected for Phase I awards with $30M from DoD funds - Phase I was an 18 month effort to accomplish front end engineering design, site selection, and permitting tasks.

- Successful projects have been selected to go on to Phase II (construction, equipment purchases, and commissioning) if funds are available. A down-select from four to three projects was announced September 2014:
  - **Emerald Biofuels** - hydro-treating and upgrading of fats, oils and greases
  - **Fulcrum Brighton Biofuels** – municipal solid waste gasification followed by Fischer-Tropsch conversion to jet fuel
  - **Red Rocks Biofuels** – forest biomass and wood wastes gasification followed by Fischer-Tropsch conversion to diesel and jet
### Down-Select for Phase 2

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Feedstock</th>
<th>Capacity (million gallons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fulcrum</td>
<td>McCarran, NV</td>
<td>Municipal solid waste</td>
<td>10</td>
</tr>
<tr>
<td>Emerald</td>
<td>Gulf Coast</td>
<td>Fats, oils, and greases</td>
<td>82</td>
</tr>
<tr>
<td>Red Rock</td>
<td>Lakeview, OR</td>
<td>Woody biomass</td>
<td>12</td>
</tr>
</tbody>
</table>

- Production anticipated to begin in 2016/2017.
- Fuels are approved for use as jet fuel by ASTM at up to 50/50 blends.
- Fuels successfully demonstrated during Rim of the Pacific (RIMPAC) demonstration in 2012 for ships and planes.
- Fuels can be utilized in Navy’s warfighting platforms with no degradation to performance or mission.
Fulcrum Bioenergy

Proprietary, Proven & Efficient Fuels Process

Material Processing Facility Prepares MSW for Fuels Process

Steam Reforming Gasification System Converts MSW to Synthesis Gas

Fischer-Tropsch Process Converts Synthesis Gas to Jet Fuel & Diesel
Pilot Plant Test of Fulcrum Process

Technology Guaranteed Performance

- 120-Day Continuous Integrated MSW-to-Fuels Test Required by Project Lender
- Test Confirmed the Performance and Reliability of Fulcrum’s Process
- Fuel ASTM Certified
- Completed Full FEED for Sierra
- Secured Fixed-Price, Performance Guaranteed EPC Contract
Red Rock Biofuels

RRB Improved Conventional Tech to Use Biomass, Enabling “Carbon Reuse” as Liquid Fuels

1. Fischer-Tropsch
   Germany, 1930’s
   Gasification
   England, early 1800’s
   (Baltimore Gas Works, 1816)
   Hydroprocessing
   Russia, 1930’s

2. Sasol, Shell & Others
   Coal or natural gas feed only;
   no ability to scale down

3. Red Rock Biofuels
   Modular and Scalable;
   Biomass/NatGas flexible
Red Rock Biofuels

FEED/FEL 3 Design & Engineering by FLUOR

Velocys

Woody Biomass → Gasifier → Fischer-Tropsch → Hydroprocessing → Jet & Diesel

136,000 Dry tons/yr

15.1 million gallons/yr
As fuels become available Navy will make advanced drop-in biofuels a regular part of its bulk fuel procurement.

USDA has awarded Fulcrum a $105 million Biorefinery Assistance Program loan guarantee through Bank of America for construction of their facility. The total project cost is $266 million. 147,000 tons/year of MSW will be gasified to synthesis gas followed by Fischer-Tropsch conversion to jet fuel.

Cathay Pacific Airways has become an investor in Fulcrum and has negotiated a 10 year supply agreement for jet fuel.

Southwest Airlines has signed a fuel purchase agreement with Red Rock for 3 million gallons/year of jet fuel. Blended product will be used at Southwest’s Bay Area operations. 140,000 dry tons/year of woody biomass feedstock will be converted into renewable jet, diesel, and naphtha.
Relevance of DPA to DOE - Commercialization Pipeline

• DOE involvement is essential in both the DPA and internal demonstration and deployment activities

• DPA strength is commercialization (each facility producing 10 million gallons/year or more, capital cost $200 - $400 million each, selling fuels to the market) – requires leveraging of funds among multiple agencies due to cost

• DOE strength is pilot and demonstration of innovative technologies (facilities producing fuels in batch or campaign mode, capital cost $25 - $150 million each, using fuels for testing/certification purposes)

• DOE investment in demonstration and deployment activities places conversion technologies at the beginning of the pipeline that subsequently becomes eligible for DPA funding
• We appreciate the hard work in approving alternative fuels and commitment to sustainable growth made by the aviation industry.

• DOE is actively committed to accelerating the adoption of alternative fuels by this market.

• In 2013, USDA and FAA made a commitment to the aviation industry to help meet their goals with the Farm to Fly 2.0 agreement. This effort seeks to enable the use of commercially viable and sustainable renewable jet fuel in the United States.

• In July 2014, Secretary Moniz signed an amendment officially making DOE the newest partner agency in this significant initiative.

• Welcome input on specific areas of collaboration for DOE via F2F2
Criteria for Alternative Fuels in Aviation

- Engine re-light at altitude, polar climate, in winter - transport properties of alternative fuels and/or blends have to be within acceptable limits (viscosity, freeze point, fluid flow at low temperatures)
- Flame stability – compounds in alternative fuels should not adversely impact flame stability
- Energy content – should be as high as fossil derived jet fuel or higher
- Emissions
  - Aromatics – too much can cause soot, too little can cause seal swell problems which becomes a maintenance issue
  - Greenhouse gas emissions should be lower than fossil derived jet fuel on a life cycle basis
Status of ASTM Certification of Alternative Jet Fuel

- ASTM Certification in process with task forces
  - Alcohol to jet – synthetic paraffinic kerosene (bio/thermochemical butanol) with annex for ethanol – Gevo, Lanzatech, Cobalt, Swedish Biofuels, Byogy
  - Synthetic kerosene/synthetic aromatic kerosene – catalytic conversion of sugars and aqueous phase reforming to jet fuel – Shell/Virent
  - Catalytic hydro-thermolysis of lipids to jet fuel – ARA
  - Hydro-treated esters and fatty acids+ (HEFA)+ - wider cut HEFA with renewable diesel – Boeing
  - Pyrolysis from lignocellulosic feedstocks – UOP, Kior
  - Fischer-Tropsch synthetic kerosene with aromatics – Sasol, Rentech
  - Co-processing – multiple approaches – Chevron, BP, Phillips 66

- Pathways in future that could enter pipeline
  - Vertimass – catalytic conversion of alcohols
  - Global Bioenergies – biochemical production of isobutene
  - Algenol – hydrothermal liquefaction of algae
  - Kiverdi – biochemical conversion of wastes
GCxGC - Dividing Up The Hydrocarbon Pie

Substituted cyclohexane

1-propylbenzene


Fractions can vary!

Source: Dr. Timothy Edwards, Air Force Research Laboratory
Jet A, JP-8 Composition Variations

PQIS 2011 aromatics

Aromatics (D1319), vol %

Source: Dr. Timothy Edwards, Air Force Research Laboratory
GCxGC – Paraffinic Fuels

Source: Dr. Timothy Edwards, Air Force Research Laboratory
Airline Off-take Agreements – More in Process

- United + AltAir Fuels = 5 M gpy from 2014
- Alaska Airlines + Hawai BioEnergy = Supply from 2018
- Cathay Pacific + Fulcrum Bioenergy = 370M usg
- British Airways + Solena = 180M usg over 11 years
- Southwest + Red Rock Biofuels = 3 M gpy

18 March 2015
Benefits of Aviation Biofuels

https://www.youtube.com/watch?v=_MCAgQLAvVI
Marine Emission Control Areas (ECA)

- **North American ECA**
  - Adopted by IMO: March 26, 2010
  - Entry-into-force: August 1, 2011
  - Enforcement: August 1, 2012 (Reg. 14.7)

- **U.S. Caribbean Sea ECA**
  - Adopted by IMO: July 15, 2011
  - Entry-into-force: January 1, 2013
  - Enforcement: January 1, 2014 (Reg. 14.7)
Marine Fuel Oil Requirements

MARPOL (International Convention for the Prevention of Pollution from Ships) Annex VI Regulation 14 and 18: SOx and PM emissions and fuel oil availability and quality

Shipboard Requirements

- Fuel Oil:
  - Sulfur Content Caps
  - Fuel Quality Standards

- Operations:
  - Bunker Delivery Notes & Samples
  - Fuel Oil Change-Over Procedures
  - Fuel Oil Change-Over Logbook Entries

<table>
<thead>
<tr>
<th>Annex VI, Reg. 14 Fuel Oil Sulfur Content Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECA Sulfur Content Cap</td>
</tr>
<tr>
<td>Effective Date</td>
</tr>
<tr>
<td>July 1, 2010</td>
</tr>
<tr>
<td>January 1, 2015</td>
</tr>
<tr>
<td>Global Sulfur Content Cap</td>
</tr>
<tr>
<td>January 1, 2012</td>
</tr>
<tr>
<td>January 1, 2020</td>
</tr>
</tbody>
</table>
Engine NOx Requirements for January 1, 2016

• Tier III NOx-January 2016 applies to vessels with keels laid after 1/1/2016
• Will require after treatment - Selective catalytic reduction, exhaust gas recirculation, water injection strategies, dual fuel diesel/natural gas engines
• Applies in ECAs only (Tier II otherwise)
• U.S. domestic law implementing Annex VI—calls for joint enforcement by two separate U.S. government agencies.
• Coast Guard has the lead on vessel inspections.
• EPA has the lead on shoreside fuel supplier inspections, and on violations that are referred to EPA by the Coast Guard for enforcement.
Fuel Oil Nonavailability

- A vessel is expected to use compliant fuel when operating in the ECAs.
- If a ship owner is not able to obtain compliant fuel because it is not available, a Fuel Oil Non-Availability Report (FONAR) must be submitted.
- A FONAR is not a waiver! It is a formal statement of noncompliance.
- If 0.10% (1,000 ppm) is not available, another ECA-compliant fuel must be used if it is available.
- ECA-compliant fuel will not be deemed “unavailable” for the purposes of a FONAR if another compliant fuel is available, for example a low sulfur marine distillate (MGO/MDO) below 1,000 ppm).
Maritime Fuel Issues Under Development

- Vessel fuel oil sampling program.
- Flyovers and other technology based targeting and compliance assurance efforts.
- Additional information at Coast Guard Homeport: www.Homeport.USCG.mil
  Select the following links: Missions > Domestic Vessels > Domestic Vessel General > MARPOL ANNEX VI
  - CG-543 Policy Letter 09-01 (Annex VI Implementation)
  - CG-CVC Policy Letter 12-04 (ECA Compliance)
  - CG-CVC Policy Letter 13-02 (IEE/SEEMP)
- EPA MARPOL Annex VI - http://www2.epa.gov/enforcement/marpol-annex-vi
- EPA Ocean Going Vessels Air Emissions Web Page: http://www.epa.gov/otaq/oceanvessels.htm
SOx Ship Emissions

2009 Mobile Source SOx Inventory

- C3 Marine: 80%
- Locomotive: 2%
- Aircraft: 1%
- Highway: 5%
- Diesel NR: 4%
- Other NR: 2%
- Diesel Marine <30 l/cyl: 6%

2030 Mobile Source SOx Inventory (without ECA controls)

- C3 Marine: 95%
- Locomotive: 0%
- Aircraft: 1%
- Highway: 3%
- Diesel NR: 0%
- Other NR: 1%
- Diesel Marine <30 l/cyl: 0%

NOx Ship Emissions

2009 Mobile Source NOx Inventory

- Highway: 51%
- Aircraft: 1%
- Locomotive: 10%
- Diesel NR: 14%
- Other NR: 5%
- Diesel Marine <30 l/cyl: 9%
- C3 Marine: 10%

2030 Mobile Source NOx Inventory (without ECA controls)

- C3 Marine: 40%
- Diesel Marine <30 l/cyl: 7%
- Other NR: 5%
- Diesel NR: 8%
- Highway: 29%
- Locomotive: 8%
- Aircraft: 3%

PM$_{2.5}$ Ship Emissions

**2009 Mobile Source PM$_{2.5}$ Inventory**

- Diesel NR: 27%
- Other NR: 14%
- Diesel Marine <301/cyl: 7%
- Highway: 24%
- Locomotive: 6%
- Aircraft: 5%
- C3 Marine: 17%

**2030 Mobile Source PM$_{2.5}$ Inventory (without ECA controls)**

- C3 Marine: 48%
- Locomotive: 2%
- Aircraft: 7%
- Highway: 20%
- Other NR: 15%
- Diesel NR: 5%
- Diesel Marine <30 1/cyl: 3%
