Aviation Biofuel: Recent breakthroughs and long term prospects

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One Boeing, One Planet

“By improving the environmental performance of our products and operations, we ensure the vitality of Boeing as well as our customers, our industry and our communities worldwide. Together, we will continue to build a better planet.”

Jim McNerney
Chairman and CEO
The Boeing Company
By 2032, airlines will need more than 35,000 new airplanes valued at $4.8 trillion

Market value: $4.8T

2013 - 2032

New airplane deliveries by region

<table>
<thead>
<tr>
<th>Region</th>
<th>Airplanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia Pacific</td>
<td>12,820</td>
</tr>
<tr>
<td>Europe</td>
<td>7,460</td>
</tr>
<tr>
<td>North America</td>
<td>7,250</td>
</tr>
<tr>
<td>Middle East</td>
<td>2,610</td>
</tr>
<tr>
<td>Latin America</td>
<td>2,900</td>
</tr>
<tr>
<td>C.I.S.</td>
<td>1,170</td>
</tr>
<tr>
<td>Africa</td>
<td>1,060</td>
</tr>
<tr>
<td>World Total</td>
<td>35,280</td>
</tr>
</tbody>
</table>

Regional breakdown:
- Regional jets: 2%
- Single-aisle: 47%
- Small wide-body: 23%
- Medium wide-body: 22%
- Large wide-body: 6%
Global CO2 Emissions

Emissions by sector, 2000-2030
Millions tons CO$_2$ equivalent/year

- Air
- Other transport
- Forestry
- Buildings
- Agricultural and waste
- Industrial
- Power

Source: IPCC
Boeing’s Role and Actions

Boeing’s Role

- Protect our environment
- Assure industry growth
- Address customer’s top cost

Act as industry catalyst to accelerate commercialization

Core activities

- Support and Advocacy
- Feedstock and Pathway R&D
- Fuels approval
Boeing’s Global Biofuel Program
Key Activities

Working across Boeing and the industry to drive commercialization
# Broad Demand for Aviation Biofuel

<table>
<thead>
<tr>
<th>Test Flights 2008 - 2011</th>
<th>Early commercial flights 2011-2012</th>
<th>Ongoing operation 2013+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virgin Atlantic</td>
<td>KLM, Lufthansa, Thomson Airways</td>
<td>Boeing, Air New Zealand, TAM, Continental Airlines, Interjet, Etihad Airways, Aeromexico, Thai Airways, Air France</td>
</tr>
</tbody>
</table>
State of Aviation Biofuel Industry

- **Technically viable**
  - ASTM and Def Stan approved
  - High quality standard

- **In demand**
  - Airline support
  - In commercial use
  - Strong US Military Demand

- **Sufficient supply**
  - Refinery capacity small
  - Price premium
  - Limited sustainable feedstock
The continuing challenge

$30  $0.10

The price premium of aviation biofuel used for demo flights

The price premium that would eliminate 2012 airline profitability

Notes: Prices per gallon. $0.10 based on long term net margins of 1% and assumption of 1/3 of costs being fuel.
Global Green Diesel Production

Emerald Biofuels
85 M Gallons
LA

Diamond
Green Diesel
137 M Gallons
Norco, LA

Dynamic Fuels
75 M Gallons
Geismar, LA

Eni
100 M Gallons
Italy

Neste Oil
594 M Gallons
Singapore, Finland, Netherlands

Advanced biofuels, commercialized
Green Diesel is a drop-in fuel
HEFA is a premium fuel
The breakthrough

Green diesel is similar enough chemically to be blended directly into jet fuel

Dr Jim Kinder, Boeing Technical Fellow
Drop-in aviation biofuel, without the premium

Feedstock → Refining → Green Diesel → Distillation → Blend → Aviation market

Jet-A

Diesel market

Aviation market

Jet-A (min 50%)
Significant impact expected

**Competitive price**

<table>
<thead>
<tr>
<th>$/gal</th>
<th>32</th>
<th>$30</th>
<th>$20</th>
<th>$10</th>
<th>$0</th>
</tr>
</thead>
</table>

- Airline Purchases of HEFA
- Green diesel (no incentives)
- Green diesel (net incentives)

**Instant scale**

<table>
<thead>
<tr>
<th>M Gal</th>
<th>1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>51</td>
</tr>
<tr>
<td>2008</td>
<td>51</td>
</tr>
<tr>
<td>2009</td>
<td>102</td>
</tr>
<tr>
<td>2010</td>
<td>429</td>
</tr>
<tr>
<td>2011</td>
<td>669</td>
</tr>
<tr>
<td>2012</td>
<td>669</td>
</tr>
<tr>
<td>2013</td>
<td>806</td>
</tr>
<tr>
<td>2014F</td>
<td>935</td>
</tr>
</tbody>
</table>

1% of global jet fuel

1,000

Sometimes, the breakthrough is not in technology
Sustainable Biomass Research Consortium
Why is SBRC research important?

Our concept for biofuel production could be applied to the UAE and many other regions of the world.

97% of the Earth’s water is in the oceans

About 20% of the Earth’s land mass is desert ~25.5 million km²
The flagship project of the SBRC is the Integrated Seawater Energy and Agriculture System

The goal of this project is to demonstrate that the integrated process is sustainable and environmentally responsible with respect to land use, carbon emissions and discharge of other by-products such as aquaculture waste products.
Moving From Dreams to Reality

Aviation Biofuel Progress
- ASTM approval for commercial use
- Organized demand
- Favorable policy developments
- Commercial flights continue

Next Steps
- ASTM approval of green diesel blending
- Emphasis on policy continuity
- Research – expanded feedstocks/pathways
- Innovation – supply chain and commercial
Questions?