Commercial Airplanes

Aviation and Sustainable Biofuel

Presented by
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Biofuels Strategy
Boeing Commercial Airplanes

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A New Vision for Aviation

Why Aviation Biofuel?

First industry steps

Boeing’s Role
Global CO2 Emissions

Emissions by sector, 2000-2030
Millions tons CO₂ equivalent/year

Air
Other transport
Forestry
Buildings
Agricultural and waste
Industrial
Power

Small but growing share of emissions

Source: IPCC
Fuel largest airline cost and rising

Rising fuel prices

Airline operating costs

Sources: EIA
1. US Gulf Coast Jet 2. Airline Related Operating Costs based on US Majors 777-200ER fleet
# Energy Options for Aviation

## Energy Requirements

<table>
<thead>
<tr>
<th>Global Infrastructure Compatibility</th>
<th>High Energy Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>✗</td>
</tr>
<tr>
<td>Rail</td>
<td>✗</td>
</tr>
<tr>
<td>Sea</td>
<td>✔</td>
</tr>
<tr>
<td>Sky</td>
<td>✔ ✔</td>
</tr>
</tbody>
</table>

## Energy Options

- **Liquid Fuels**
- **CNG**
- **Solar**
- **Hybrid/Battery**

### Energy Density (MJ/kg)
- **Low**
- **High**

### Global Infrastructure Compatibility
- **1. Defined as the combination of airport and airplane technology compatibility.**

### Sources (see appendix for detail)
- **Battery**: Stanford University, Global Climate and Energy Project. *A Technical Assessment of High-Energy Batteries for Light-Duty Electric Vehicles. GCEP Energy Assessment Analysis Fall 2006*

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**Liquid Fuels Only Realistic Near Term Option**

1. Defined as the combination of airport and airplane technology compatibility.
# Sustainability is Critical to Success

## Key Sustainability Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doesn’t contribute to indirect impacts</td>
<td>Assurance of environmental benefit</td>
</tr>
<tr>
<td>Positive GHG impact</td>
<td>Socio-economic</td>
</tr>
<tr>
<td>3rd party standards and audits</td>
<td>Moral license</td>
</tr>
<tr>
<td></td>
<td>Credit opportunity</td>
</tr>
</tbody>
</table>

1. Other requirements include land use changes, water use, land rights, labor rights.
2. Examples include RSB, FSC, etc.
3. Examples include EU ETS avoidance and US RINs.
A Way Forward

Why Aviation Biofuel?

First industry steps

Boeing's Role
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

Supply is the main challenge
Biofuel Technical Properties

Lower GHG Emissions\(^1\)

- Fossil Jet-A: 100% (\(-60\%)\)
- Biofuel: 20%

Higher Energy\(^2\)

- Fossil Jet-A: 43.3 BTU/Kg
- 50-50 Blend: 43.8 BTU/Kg
- 100% Biofuel Jet-A: 44.0 BTU/Kg

Stricter Standard

<table>
<thead>
<tr>
<th></th>
<th>Fossil(^3)</th>
<th>Bio(^4)</th>
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</thead>
<tbody>
<tr>
<td>Min</td>
<td>☒</td>
<td>☑</td>
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<tr>
<td>% Aromatics</td>
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<td>Water</td>
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<tr>
<td>Halogens</td>
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<td>Metals</td>
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<tr>
<td>Nitrogen</td>
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</tbody>
</table>

Biofuel as good or better than traditional fossil

Source: Joint Boeing, UOP, USAF research report, v5.0
Note: Based on currently approved ASTM fuels
1. GHG, Greenhouse Gas. Based Jatropha study in Brazil.  2. As seen from early testing results and field trials.  3. ASTM D1655 4. ASTM D7566
## Broad Demand for Aviation Biofuel

### Test Flights
2008 - 2011
- Virgin Atlantic
- NAVY
- Air New Zealand
- TAM
- Continental Airlines
- Boeing
- JAL
- Air China
- U.S. Air Force

### Early commercial flights
2011-2012
- KLM
- Thomson Airways
- Lufthansa
- United
- Finnair
- Alaska Airlines
- Interjet
- ETIHAD Airways
- AeroMexico
- THAI
- Air France

### Ongoing operation
2012+

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### Demand is not a constraint

1. 1, 525 as of February 2012

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**“If you build it, we will buy it”**

- Bill Ayer  
  Former Alaska Airlines  
  CEO on biofuel

**“The biggest obstacle we'll have to achieving our targets is simply supply”**

- David Cush  
  Virgin America CEO on biofuel targets
Sources for Aviation Biofuel

Sources of Fuel

- Algae
- Cellulosic
- Sugars
- Waste
- Oilseeds

Expected Availability

No single "winning" pathway

Marketplace will determine future mix of fuel sources
Boeing’s Role in Making Biofuel a Reality

Why Aviation Biofuel?

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The Boeing Role
Boeing Role

Act as industry catalyst to accelerate commercialization

Protect our environment

Assure industry growth

Address customer’s top cost
Biofuel Global Policy Goals

Vibrant biofuel marketplace

- Level playing field for jet fuel
- Sustainability Standards
- Attractive conditions for investment
Recent and Active Biofuel Projects

- ASTM & DEF STAN approval
- SAFUG\(^1\) established
- Commercial flights from June, 2011
- Focused regional development projects
- Biofuel roadmaps published

1. Sustainable Aviation Fuel Users Group