Alternative Fuels in Aviation – Embraer View

Workshop on Aviation Alternative Fuels

ICAO – Montréal, Canada

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EMBRAER
Topics

• Today’s Aviation Fuel
• Motivation for Alternative Fuels
• Embraer Alternative Fuels Project
• Brazilian Biofuels - Background
• The Ethanol Ipanema Aircraft
• Final Comments
### Regular Flights, Passenger Configuration, in Service: 19,145 aircraft

#### Quantity of Aircraft

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Número de Aeronaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 a 10</td>
<td>10,550</td>
</tr>
<tr>
<td>11 a 20</td>
<td>6,253</td>
</tr>
<tr>
<td>21 a 30</td>
<td>1,660</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>682</td>
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<table>
<thead>
<tr>
<th>Region</th>
<th># Acft.</th>
<th>AverAge</th>
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</thead>
<tbody>
<tr>
<td>North America</td>
<td>7,025</td>
<td>11</td>
</tr>
<tr>
<td>Latin America</td>
<td>1,277</td>
<td>15</td>
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<tr>
<td>Europe</td>
<td>4,150</td>
<td>10</td>
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<tr>
<td>Russia &amp; CIS</td>
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<tr>
<td>Africa</td>
<td>711</td>
<td>16</td>
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<tr>
<td>Middle East</td>
<td>617</td>
<td>10</td>
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<td>Asia - Pacific</td>
<td>2,822</td>
<td>11</td>
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<tr>
<td>China</td>
<td>1,261</td>
<td>7</td>
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<tr>
<td>World</td>
<td>19,145</td>
<td>12</td>
</tr>
</tbody>
</table>

Source: BACK (Dez/07)
Aviation Fuel (Jet Fuel)

- Aviation have been powered by petroleum fuels for more than 60 years;
- Meet International Standards (Joint Operated System, ASTM 1655, DEF Stan 91-91, ANP 03/2006-QAV1) requirements;
- Meet distribution chain requirements.

New fuels shall comply with “Guidline for Qualification and Approval of New Turbine Fuels”

Drop-in fuel
Alternative Fuels in Aviation: Drivers

**Aviation Alternative Fuels**
- Biofuels
  - Ethanol
  - Biokerosene
- Synthetic Fuels
  - Fischer-Tropisch
- Cryogenic
  - Hydrogen
  - Methane

**Energy Efficiency**
- Aero Efficiency
- Operational Efficiency
- Structural Efficiency

**Global Warming Emissions**

**Oil Price**
- Jet Fuel
- Oil

**Oil Crisis - Availability**
Technical Investigation of Sustainable Aviation Biofuels

- Engine OEMs
- Fuel systems components OEMs
- Fuel companies
- Biofuels
- Authorities

EMBRAER acts as a process integrator.
Benefits of Biofuels

- **Economical Viability**
  - Biojet fuels will become as economically viable as crude oil prices rise.

- **Reduce dependence on crude oil**
  - Homeland security implications.

- **Burns cleaner**
  - Sulfur-free and reduced emissions.

- **Social Concerns**
  - Use of raw-material from low-income Brazilian farmers;
  - Employment of a Integrated Bioenergy System.
Biofuel - Concerns

Technical / Quality:

• Product Scale x Sustainability;

• Different performance & life-cycle emissions;

• Lack of technical data, operational experience and standards.
Brazilian Biofuels - Background

- 1975 – PROÁLCOOL implementation
- 1980 – PROSENE (biokerosene) - First patent for biodiesel and biokerosene production;
- 1984 – A successful flight using the biokerosene in an Embraer turboprop.
Bandeirante Flight with Biokerosene

Demo flight on October 23rd, 1984 (São José dos Campos to Brasília – 1100km). One engine was fed with biokerosene.
Ethanol in Brazil

• In 1979 the first car was sold fueled by ethanol;
• In the 80’, Brazil replaced the lead in the automotive gasoline by ethanol;
• In the 90´ government decision to add a higher proportion of ethanol in the gasoline;
• 2003 First flexible fuel vehicle was launched;
• Nowadays:
  • Almost 90% of the cars sold in Brazil are flexible;
  • Refueling pumps only have gasoline (or E25) and E100.
Embraer Ipanema Ethanol

First OEM to develop a 100% ethanol powered aircraft
Ethanol & Aviation - Embraer’s Ipanema

- 1972: Ipanema Type Certification
- 1985: Embraer started a market study - without go ahead
- 00’: New study, with the following drivers:
  - Excellent ethanol availability due to the car industry;
  - Avgas distribution in country side: availability, high prices;
- 2002: Program launch
- 2004: Certification;
- 1,069 Ipanema airplanes sold:
  - 64 new aircrafts
  - 177 retrofits

Total Ethanol Powered Aircrafts: 241
Main Modifications – Engine and Airframe

- Cold Start System;
- New Injection System;
- New Materials;
- Anti-corrosion protective coats / materials.
Uses for the Ipanema

• Ipanema has been used in:
  • Agricultural operations: application of fertilizers, pesticides and fungicides;
  • Fire fighting;
  • Combat of endemic disease vectors;
  • Cloud nucleation.

• 1\textsuperscript{st} Crop Season: 2005/2006
  • 144 ethanol fueled aircraft (127 retrofits);
  • More than 60,000 flight hours with ethanol;
  • More than 6,000 liters of ethanol used;
  • More than 4,000 liters of Avgas replaced.
Efficiency in Costs per Season

Costs in Million of US$

Ethanol aircraft fleet

AvGas Costs

Ethanol Cost

2.9

127 158 173 197

(Forecast: 2008/2009)
Environmental Advantages over the use of AvGas

Pb (Tetra-ethyl Lead) not emitted in the atmosphere

- Avgas replaced by ethanol
- Pb not emitted

<table>
<thead>
<tr>
<th>Year</th>
<th>Liters [millions]</th>
<th>Tetra-ethyl lead [ton]</th>
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<tbody>
<tr>
<td>2005/2006</td>
<td>4,0</td>
<td>-3,4</td>
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<tr>
<td>2006/2007</td>
<td>4,9</td>
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<td>2007/2008</td>
<td>5,4</td>
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<tr>
<td>2008/2009</td>
<td>6,2</td>
<td>-5,3</td>
</tr>
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</table>
Ipanema – National and International Awards

Scientific American Award as the Top 50 2005 innovations

Flight International Aerospace Industry Award in the General Aviation Category.
Ethanol – Challenges to Spread

• Presently used in general aviation;
• May find limited application for jet;
• Lack of worldwide supply and distribution structure;
• Presents challenges and limitations.
Final Comments

- Industry integration will foster technology deployment;
- Life Cycle Analysis will drive industry choice;
- Regional solution must worldwide requirements;
- Ethanol is a good solution for aviation niche.
Thank you!