Status of Sustainable Biofuel Efforts for Aviation

Presenter: Tim Rahmes
email: timothy.f.rahmes@boeing.com
Agenda

- Motivations
- Fuel Development
- Commercial Aircraft Approach
- The Path Forward
Why Boeing is concerned about sustainable biofuels?
Customers & Alternative Fuels

- Airline customers are hopeful about alternative fuels for 3 reasons:
  1. Environmental: CO$_2$ emissions
  2. Fuel availability
  3. Potential benefit to fuel costs

DoD customers are interested in these as well

Boeing’s approach is to demonstrate feasibility, identify sustainable biofuel sources, and promote viable commercial markets
Plant-based feedstocks naturally remove CO\textsubscript{2} from the atmosphere

Petroleum releases CO\textsubscript{2} that has been locked underground

- Plant feedstocks re-absorb CO\textsubscript{2} emissions as they grow

- Petroleum-based fuel

- Plant-based fuel
Fuel
Development
Viable and sustainable feedstock alternatives

- **Jatropha** ready: 2-4 years
  - Benefits
    - Uses marginal land
    - Agronomy is sufficiently advanced
  - Challenges
    - Warm climates only
    - Mechanical harvesting not yet mature

- **Algae** ready: 8-10 years
  - Benefits
    - High productivity
    - Potential for scale
  - Challenges
    - Major process tech. innovation needed
    - GMO risks

- **Halophytes** ready: 2-4 years
  - Benefits
    - Uses desert land and salt water
    - Part of system designed for GHG reduction
  - Challenges
    - Proven at pilot scale to-date
    - Improve agronomy for cost reduction

- **Camelina** ready: now
  - Benefits
    - Ready-to-go
    - Can integrate with traditional agriculture
  - Challenges
    - Limited total potential owing to yield
    - Somewhat tied to grain market swings

- **Viability is based on timing, technology and local resources.**
- **Sustainability criteria guides acceptable feedstock selection.**
Typical Jet Fuel

Ideal Carbon Length C8-C16

**Paraffin's**
- 70%-85%
- Normal Paraffin's
  - \( \text{H}_3\text{C} - \text{CH} = \text{CH} - \text{CH}_3 \)
- Iso-paraffin's
  - \( \text{CH}_3 - \text{CH} - \text{CH} = \text{CH} - \text{CH}_3 \)
- Cyclic Paraffin's

**Aromatic's**
- < 25%
- \( \text{CH}_3 - \text{C} \equiv \text{C} - \text{CH}_3 \)

**Olefin's**
- (<5%)
- \( \text{CH}_2 = \text{CH} - \text{CH} = \text{CH} - \text{CH}_2 \)

**Sulfur, Nitrogen, Oxygen Containing Compounds**
- Acids, phenols, etc

The industry needs fuels with composition similar to above (i.e. a replacement or “drop-in” fuel)

For biofuel flights & engine tests:
Paraffins were produced from plant oils and blended with Jet A at 50% ratio.
Processes that create Synthetic Paraffinic Kerosene (SPK)

GTL/CTL/BTL: Use the F-T “Fischer-Tropsch” Process

Biofuel: Hydrotreating/hydrocracking Process

HRJ = Hydrotreated Renewable Jet

Jet fuel can be produced with the same class of compounds (paraffin's) whether the starting material was made via a FT process or a bio-derived oil.
UOP’s Renewable Jet Process Chemistry

- Natural oils contain oxygen, have high molecular weight.
- First reaction removes oxygen – product is diesel range waxy paraffins
- Second reaction “cracks” diesel paraffins to smaller, highly branched molecules
- End product is same as molecules already present in aviation fuel
- End product is independent of starting oil

Feedstock flexible, but with consistent product properties
Boeing Commercial Aircraft approach to sustainable biofuels
Boeing has partnered to enable sustainable biofuel flight tests

- Demonstrate technical feasibility
- Identify sustainable biofuel sources
- Promote development of viable commercial markets
### Fuel Property Testing

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**Interesting Results for all 50% SPK blends:**
- **Heat of Combustion:** On a mass basis are ~1% higher than typical jet fuel
- **Density:** A key parameter limiting higher blends under current specification
  - (e.g. renewable aromatics are possible fix for this)
- **Dielectric:** A fit-for-use property with ramifications to Fuel Quantity Indication Systems (FQIS)

3 fuels met all performance specifications at a 50% blend with jet fuel.
The CFM Engine Technical Program

- Ground testing at Peebles, OH
- CFM56-7B development engine
  - Back-to-back runs comparing Jet A, 50%, and 25% biofuel blends

- Performance testing consisted of measuring SFC at several power settings from ground idle to take-off

- Operability testing
  - Start times, Lean-blow out margin, and accel/decel times are within expected variation
  - Specific Fuel Consumption (SFC) improvement noted.
  - No engine deterioration noted.

- Emissions testing also conducted for regulated emissions species
  - Results mainly within expected variation of jet fuel, but some benefit is possible

Inlet Turbulent Control Structure  Emissions Probe
Pratt & Whitney Technical Program

- Ground testing in Mississauga, Ontario, Canada

- PW615 tested with Jet A-1, 50% and a 100% blends

- Engine performance
  - Controllability, engine start, flame-out, and fuel flows within expected variation
  - No engine degradation evident via performance or hardware inspection

- Emissions
  - Emissions of each species were compared for all 3 fuels used
  - No significant change in Hydrocarbon (HC), Carbon Monoxide (CO), or Nitrogen Oxides (NOx)
  - Smoke number decreased as the percentage of alternate fuel to Jet A-1 was increased
Commercial Biofuel Program Summary

- Encouraging sustainable biofuel development for aviation
- Demonstrating biofuel production, test, and operability
- Working with fuel suppliers, engine companies, & customers
- A team effort is underway to address industry concerns about:
  - CO₂, fuel availability and cost

Evaluate & select 2nd generation feedstocks
Identify & pilot processing methods
Help create “drop-in” lower CO₂ lifecycle, sustainable biofuel

Flights & Engine Tests
The Path Forward
Bio-derived jet fuel certification in work

**ASTM D 1655**

- BTL fuels likely to be certified up to 50% blend
  - Data shows chemical equivalence between F-T fuels from different feedstocks (CTL, GTL, CBTL, BTL)
  - Certification possibly in 2009

- HRJ fuel samples have been evaluated from many sources
  - Results are very similar to F-T fuels
  - Certification possibly in 2010
Sustainable biofuels – Boeing’s plan and approach

Achieve near-term market viability of sustainable biofuels for commercial aviation

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