Commercial Aviation and Sustainable Fuels
The Path to Viability

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Typical jet fuel chemistry

**Paraffins (75-95%)**
- Normal Paraffins
- Iso-paraffins
- Cyclic Paraffins

**Aromatics (<25%)**

**Olefins (<5%)**

**Sulfur, Nitrogen, Oxygen Containing Compounds**

Acids, phenols, etc
The Technology Landscape
Fuel approvals will further expand supply

Approved

- Fischer-Tropsch (2009)
- HEFA (2011)
- Direct fermentation of sugar (2015)
- Isobutanol to jet (2016)
- FT-SKA (2016)

In the “pipeline”

- Green Diesel
- Hydrotreated depolymerized cellulosic
- Catalytic hydrothermolysis
- Catalytic sugar
- Alcohol to jet (ethanol)
- Many others…
ASTM fuel approval process - ASTM D4054

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- *(BOEING, AIRBUS, GE, Honeywell)*

- OEM Approval
  - Incorporate into Fuel Specification with FAA Consensus

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Biofuel and the Jet Specifications

Fossil Jet-A/A1
Produced to Def Stan 91-91 or D1655

100% Biofuel
Tested to an Annex in D7566

Jet-A/A1 Biofuel Blend
Recertified to D1655 or designated as Def Stan 91-91

D7566 Annex also defines feedstock and process

1. ASTM D1655 and D7566 standards cover a wide variety of fuel properties and specify which tests should be conducted to verify these.
Costs of biofuel near and longer term

Near term premium, but moving closer to parity.

Source: Bloomberg New Energy Finance, March 2012

1. Based on oil price of $100/bbl
2. Converted to jet via hydrotreatment
3. Converted via pyrolysis and hydrotreatment
4. Converted using gasification and Fischer Tropsch. No plants expected to be built by 2014 and thus no cost included.

Note: In 2018 cost estimates, BNEF assumed all but algae pathway have reach full commercialization.
3 major levers drive long-term trends

- Oil price
- Emissions costs
- Biofuel technology costs
Green diesel: Aviation biofuel breakthrough

- Used today in ground transportation
- 1.2+ billion gallons production capacity in US, Europe, Brazil, Asia
- Chemically similar to “HEFA” biofuel approved in 2011
- Price approaches Jet A, including government incentives
- Boeing tested 15% green diesel blend with ecoDemonstrator 787
- Reduces CO₂ by 50-90%, according to Neste Oil
Boeing’s Role and Actions

**Boeing’s Role**

- Protect our environment
- Act as industry catalyst to accelerate commercialization
- Assure industry growth
- Address customer’s top cost

**Core activities**

- Support and Advocacy
- Feedstock and Pathway R&D
- Fuels approval
Boeing global biofuel engagements

1. Pacific Northwest roadmap
2. Midwest biofuel initiative
3. Green diesel commercialization
4. Renewable Fuel Standard advocacy
5. Brazilian Biojetfuel Platform
6. Joint biofuel research with Embraer
7. GOL biofuel flights
   * Global coordination for Sustainable Aviation Fuel Users Group

8. Virgin Atlantic / LanzaTech collaboration
9. AIREG Membership
10. Nordic Initiative for Sustainable Aviation
11. South African Airways biofuel collaboration
12. Australia biofuel roadmap
13. Southeast Asia smallhold farm initiative
14. UAE project with Etihad and Masdar
15. BIOjet Abu Dhabi with Etihad
16. Biofuel R&D in China
17. “Gutter oil” facility with COMAC
18. Hainan Airlines commercial flight
19. Japan biofuel roadmap
Moving From Dreams to Reality

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

Next Steps
- Expanded ASTM approval
- Emphasis on policy continuity
- Research – expanded feedstocks/pathways
- Innovation – supply chain and commercial
Boeing is committed to a sustainable future