The aviation sector‘s need for renewable fuels

Arne Roth
Future Technologies and Ecology of Aviation
Lead of Alternative Fuels
Outline

>> Climate protection targets and the resulting need for renewable jet fuel

>> Aviation-specific technical requirements and quantitative demand

>> Key criteria for renewable jet fuel

>> Economic competitiveness

>> Conclusions
Setting the scene: "Paris Agreement“ (COP 21)

>> 2015 United Nations Climate Change Conference (COP 21), Paris

“[…] holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels […]”

> 2 °C target: 66% probability @ 430 – 480 ppm CO₂ by 2100
> Today: 407 ppm already
> Reduction of annual emissions: 41 – 72% by 2050, 78 – 118% by 2100 (rel. to 2010)

Aviation industry’s targets (ATAG targets)

Source: UBA, LBST, BHL, 2016 adapted from ATAG 2012
Aviation industry’s targets vs. current demand

Growth outpacing efficiency gains
Annual increase in fuel consumption (and CO₂ emissions) 4 – 5% in 2014 – 2017 (IATA)

[Graph showing jet fuel consumption from 1990 to 2014 with a trend line indicating the 2005 level]

Source: U.S. Energy Information Agency (www.eia.gov)
Future development of demand and emissions?

Source: Lee et al., Bridging the aviation CO\textsubscript{2} emissions gap: why emissions trading is needed; Manchester Metropolitan University, 2013
A future “emissions gap” is very likely to occur that cannot be closed by efficiency measures alone.

Paradigm shift to renewable energy carriers required.

Source: Lee et al., Bridging the aviation CO₂ emissions gap: why emissions trading is needed; Manchester Metropolitan University, 2013
Aviation will continue to rely on liquid fuels

- Fully electric flight limited by battery mass
  - Bauhaus Luftfahrt Concept Study Ce-Liner
  - Task: Cover 80% of air traffic (900 nm range)
  - Would require specific energy > 1 kWh/kg

- Hybrid electric aircraft concepts still rely on liquid fuel
  - From fuel perspective: No change of primary energy carrier, essentially an efficiency measure

- Liquid cryogenic gasses (LH₂ and LNG)
  - Conceptually feasible, but most studies find no or marginal benefits, as turbines remain technology of choice

Sources: M. Hornung, Ce-Liner – Case Study for eMobility in Air Transportation, Aviation Technology, Integration and Operations Conference. Los Angeles. 12.8.2013
doi:2060/20150017039, Tupolev Tu-155 experimental aircraft: wikipedia
Renewable energy options for aviation

>> Aviation will continue to rely on liquid fuels

> Fully electric flight limited by battery mass
> Bauhaus Luftfahrt Concept Study Ce-Liner
> Tu-155: Cover 80% of air traffic (200 passengers)

Renewable jet fuel must be compatible with current a/c technology and fuel systems (drop-in)

> From fuel perspective: No change of primary energy carrier, essentially an efficiency measure

> Liquid cryogenic gasses (LH₂ and LNG)
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doi:2060/20150017039, Tupolev Tu-155 experimental aircraft: wikipedia
Technical requirements

Designation: D1655 – 10

Standard Specification for Aviation Turbine Fuels

> Developed based on assumption that jet fuel is produced from crude oil
> Conventional Jet A-1/Jet A composed of hydrocarbons
  > Alkanes (paraffins; linear, branched, cyclic)
  > Aromatics
Technical requirements

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Desgnation: D7566 – 12a

Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

- Requirements for synthetic components of drop-in capable alternative jet fuel:
  - Hydrocarbons (alkanes, aromatics)
  - No oxygenated compounds (alcohols, esters, etc.)
  - „Conventional“ boiling range
  - Diverse composition (for high blending ratio)
Technical requirements

Designation: D1655 – 10

Standard Specification for Aviation Turbine Fuels

**Developed based on assumption that jet fuel is produced from crude oil**

**Conventional Jet A-1/Jet A composed of hydrocarbons**
- Alkanes (paraffins; linear, branched, cyclic)
- Aromatics

Designation: D7566 – 12a

Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

**Requirements for synthetic**

Alternative (renewable) jet fuel must be a „synthetic version“ of conventional jet fuel

- No oxygenated compounds (alcohols, esters, etc.)
- „Conventional“ boiling range
- Diverse composition (for high blending ratio)
The „emissions gap“: How much is needed?

Translation of GHG reduction targets into requirements w.r.t. alternative fuels

- Estimation of future jet fuel demand
- 4% annual growth
- 1.5% annual efficiency gain
- Tripling of fuel demand by 2050:
  - 600 Mt/yr (World)
  - 130 Mt/yr (EU)

Pertinent literature available, for example:

The „emissions gap“: How much is needed?

Translation of GHG reduction targets into requirements w.r.t. alternative fuels

2050

For 50% GHG emission rel. to 2005:
- 83% spec. GHG emissions of entire fuel mix (Europe: 130 Mt/yr; World: 600 Mt/yr).

Pertinent literature available, for example:

Key criteria for renewable jet fuel

**Suitability**
- Drop-in capability
- (liquid hydrocarbons in jet fuel range; „sustainable versions“ of conventional jet fuel)

**Sustainability**
- Highly favorable GHG balance
- No violation of other sustainability principles

**Scalability**
- Several 100 Mt per year
- Essentially full substitution

**Economic competitiveness**
- Under given economic boundary conditions

PtL-derived jet fuel (potentially) meets all „S“ criteria;
But economic competitiveness is only possible under regulated market conditions.
Economic competitiveness

Source: U.S. Energy Information Agency (www.eia.gov)

**Production pathway** | **Feedstock** | **MFSP (EUR L⁻¹)**
--- | --- | ---
HEFA | Soybean oil | 1.04
 | Used cooking oil | 1.02
Gasification/FT | Municipal solid waste | 1.00
 | Forestry residues | 1.33
 | Wheat straw | 1.93
AtJ | Forestry residues | 1.82
 | Wheat straw | 2.74
DSHC (SIP) | Forestry residues | 3.65
 | Wheat straw | 4.91
Power-to-Liquids (PtL) | Electric energy, CO₂, water | 1.47
Solar-thermochemical | Solar heat, CO₂, water | 2.23

Sources:
de Jong et al., *Biofuels, Bioprod. Biorefining* 2015, 9 (6), 778–800.

>>> Renewable jet fuel (biogenic and non-biogenic) currently not competitive
Renewable Jet Fuel: Situation today

**ASTM certification**
- FT-SPK, HEFA-SPK, SIP, AtJ

**Renewable fuels in civil aviation**
- Lufthansa 2011 (burnFAIR project; HEFA-SPK)
- Many other airlines with similar projects

**Airports: Regular supply**
- Alternative jet fuel in common hydrant systems
- Oslo Airport, Los Angeles, Toronto (others to follow)

**Off-take agreements**
- Fulcrum (FT-SPK from MSW): Cathay Pacific (1.52 Mt) & Air BP (1.4 Mt) over 10 years
- Red Rock Biofuels (FT-SPK from forestry residues): FedEx & Southwest Airlines over 8 years
Renewable Jet Fuel: Situation today

>> ASTM certification
   > FT-SPK, HEFA-SPK, SIP, AtJ

>> Renewable fuels in civil aviation
   > Lufthansa 2011 (burnFAIR project; HEFA-SPK)
   > Many airports: Regular supply of alternative jet fuel in common hydrant systems
   > Oslo Airport, Los Angeles, Toronto (others to follow)

BUT: Renewable aviation fuels mainly used on a project basis

>> Airports
   > Alternative fuel supply

>> Off-take agreements
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Conclusions

As all other sectors, aviation has to drastically reduce its GHG emissions.

Aviation needs renewable drop-in fuels to meet its GHG targets.
  > „Renewable versions“ of conventional jet fuel

Renewable jet fuel production must be scalable AND sustainable.
  > Sustainable in terms of emissions, water and land use, social issues etc.

PtL-derived jet fuel holds great potential.
  > Suitable, scalable and potentially sustainable

Economic competitiveness is key challenge.
  > Not necessarily cost competitiveness
  > Sustainable and scalable options generally more expensive than conventional jet fuel
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