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The aviation sector‘s need for renewable fuels

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

Outline

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- >> 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)

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>> 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 […]”

“Adoption of the Paris Agreement,” United Nations, Framework Convention on Climate Change (FCCC), Conference of the Parties, Paris, 2015.

Setting the scene: „Paris Agreement“ (COP 21)

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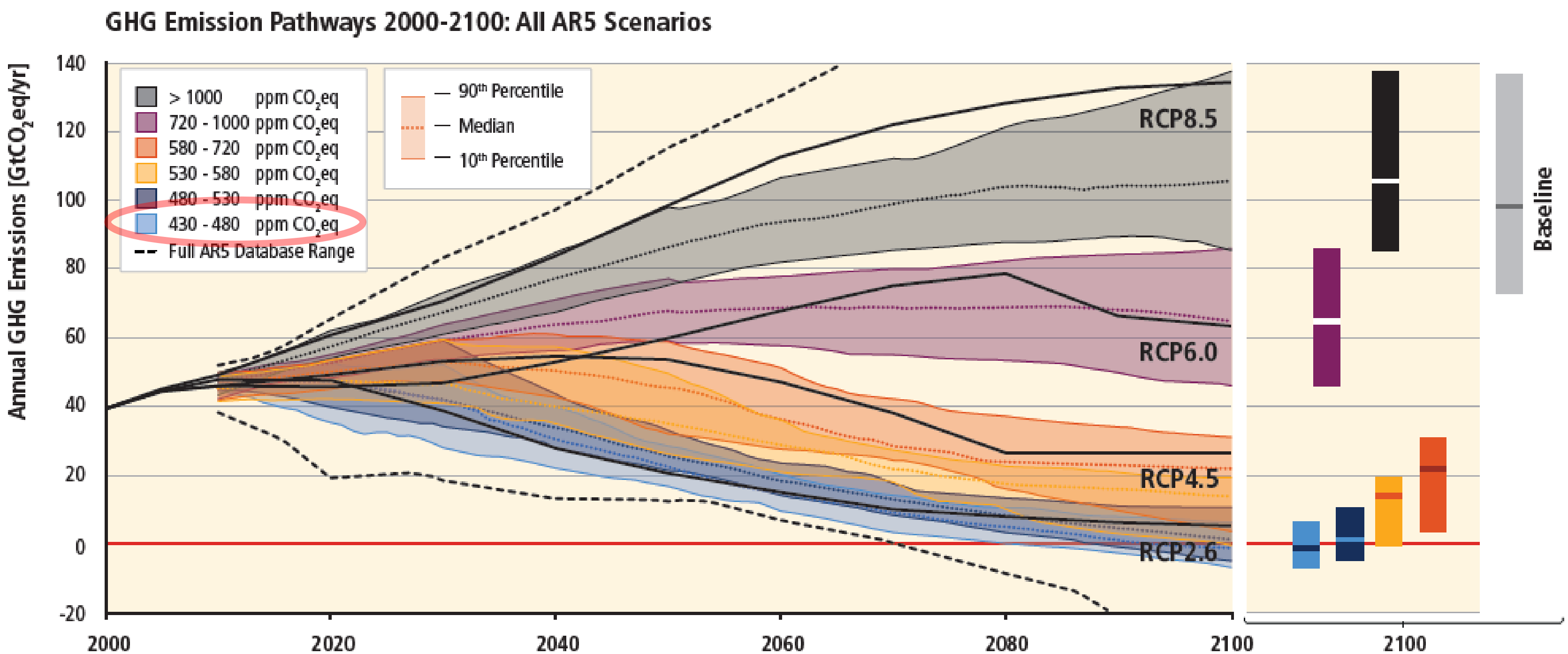
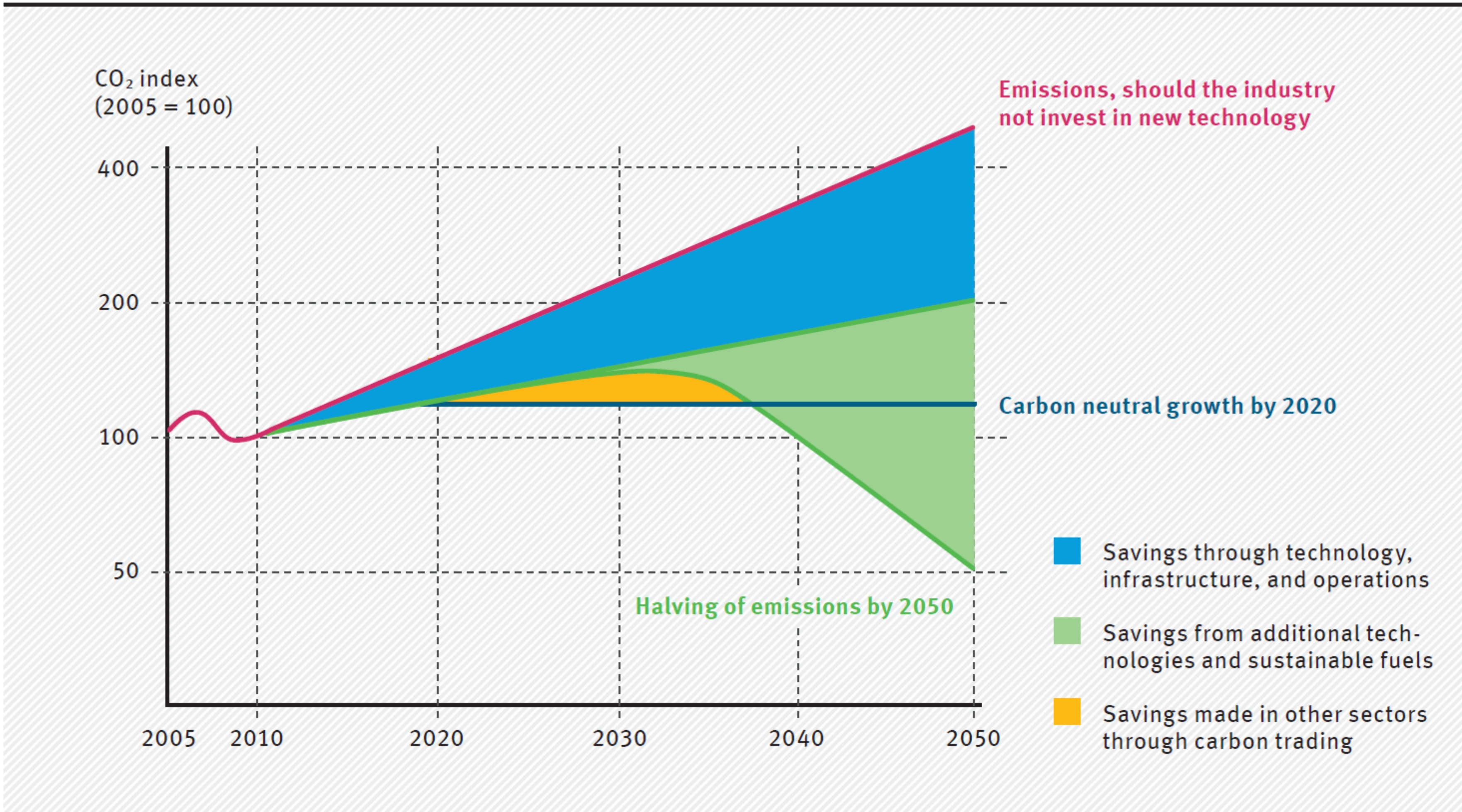


> 2 °C target: 66% probability @ 430 – 480 ppm CO_2 by 2100
> Today: 407 ppm already
> Reduction of annual emissions: 41 – 72% by 2050, 78 – 118% by 2100 (rel. to 2010)

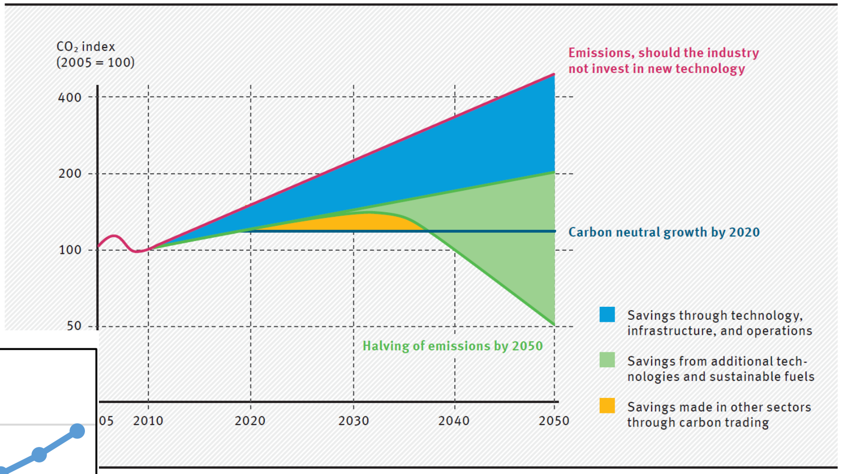
"Assessing Transformation Pathways," in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, 2014

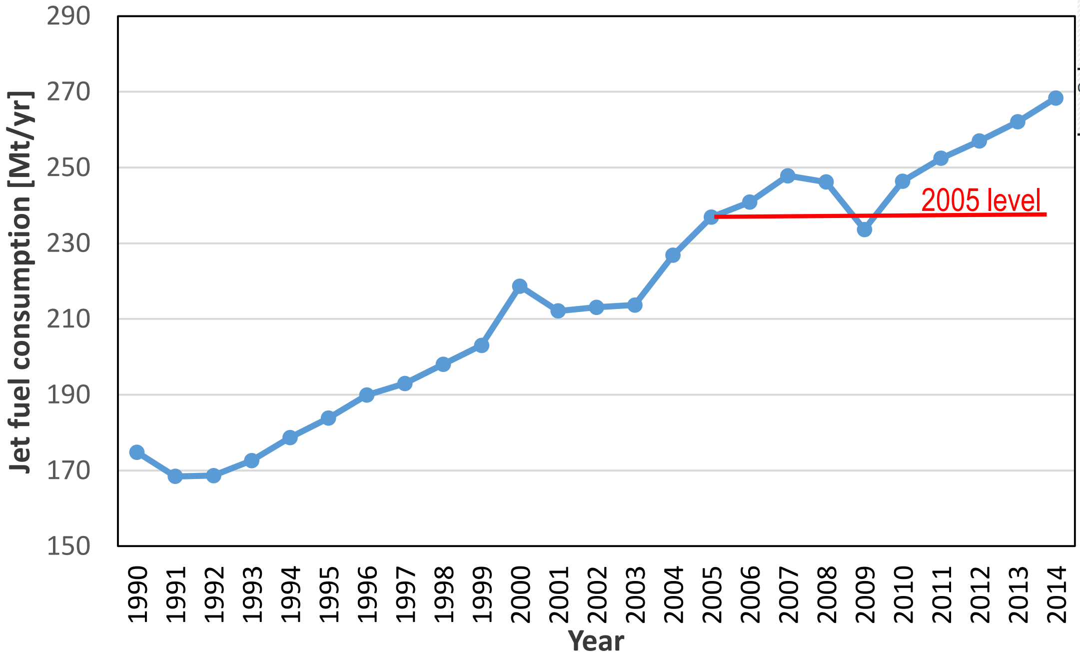
Aviation industry's targets (ATAG targets)



Source: UBA, LBST, BHL, 2016 adapted from ATAG 2012

Aviation industry's targets vs. current demand





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

- Growth outpacing efficiency gains
- Annual increase in fuel consumption (and CO_2 emissions) 4 – 5% in 2014 – 2017 (IATA)

Future development of demand and emissions?

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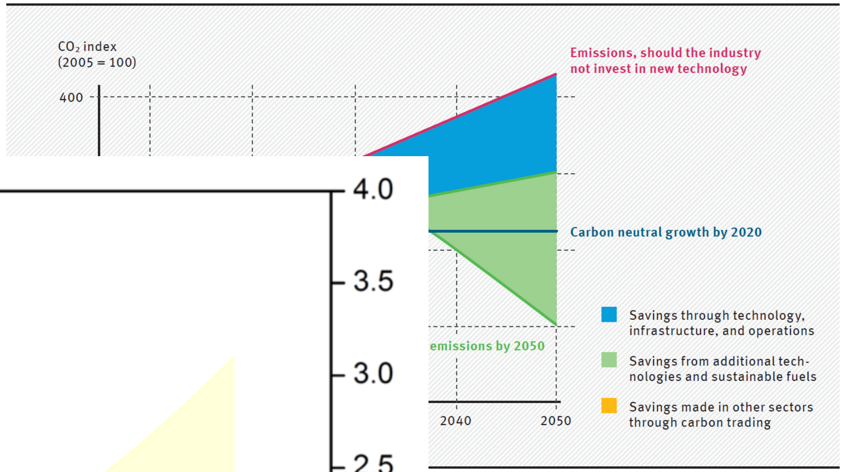

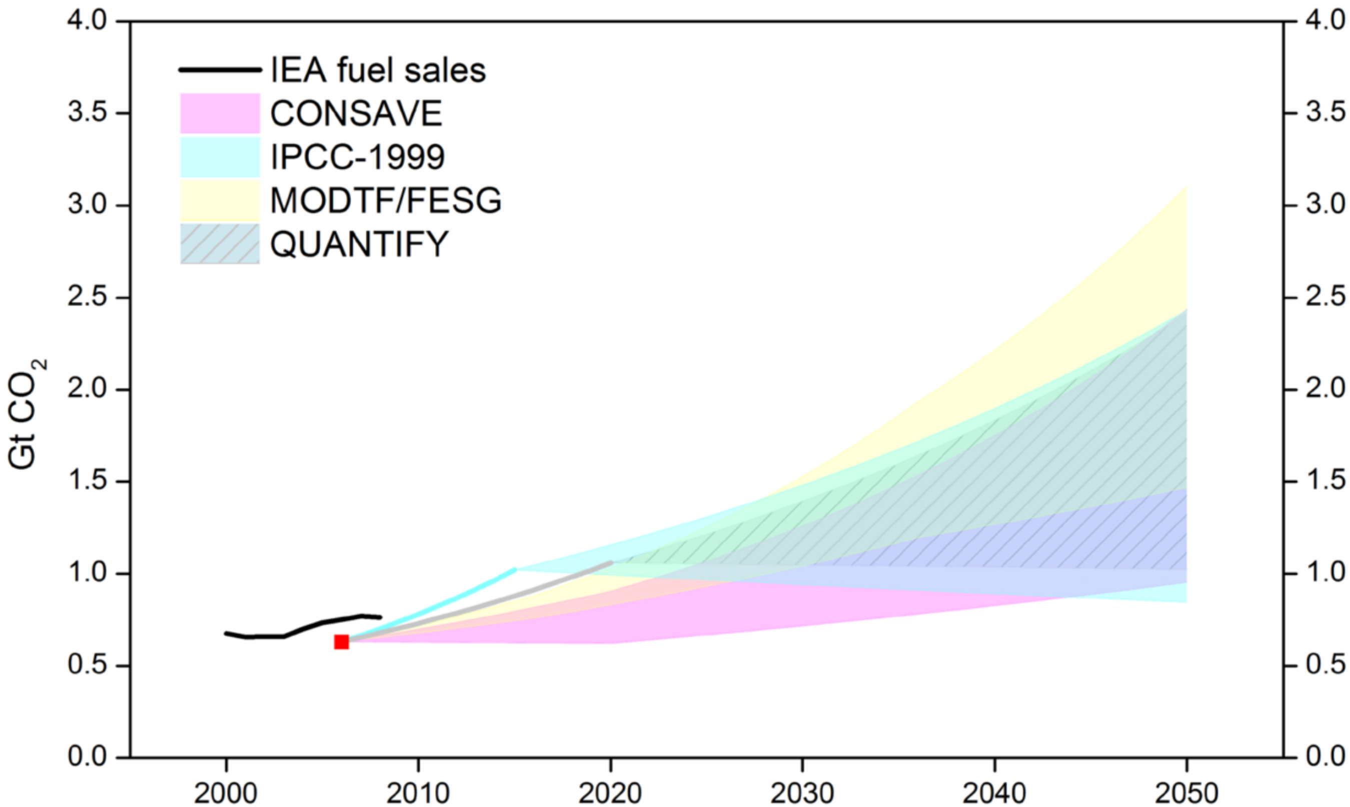

Source: Lee et al., Bridging the aviation CO_2 emissions gap: why emissions trading is needed; Manchester Metropolitan University, 2013

Future development of demand and emissions?

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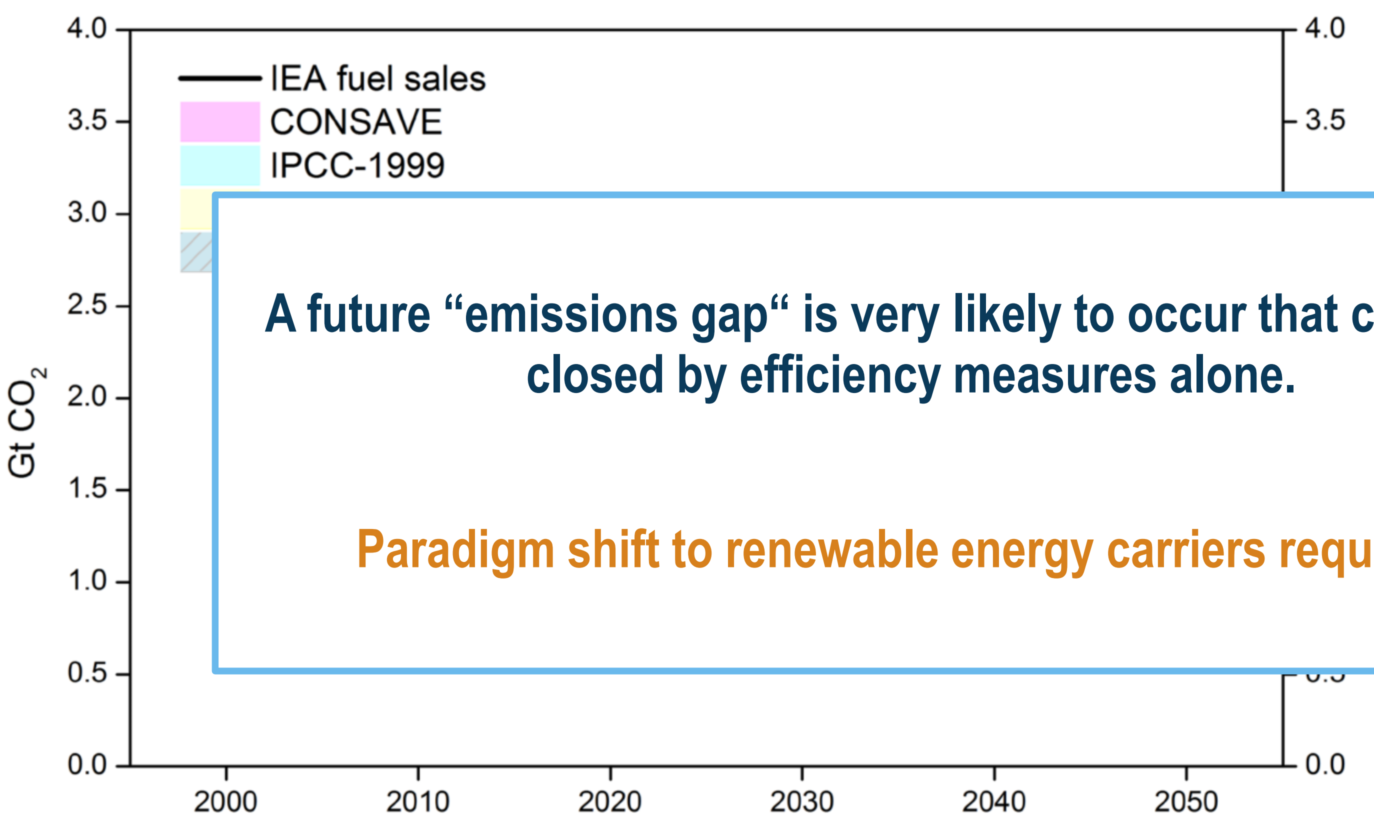

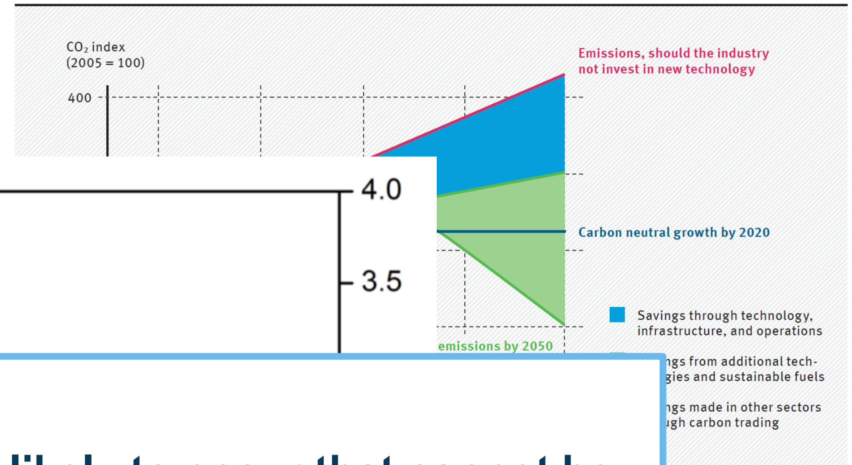

A future "emissions gap" is very likely to occur that cannot be closed by efficiency measures alone.

Paradigm shift to renewable energy carriers required.

Source: Lee et al., Bridging the aviation CO_2 emissions gap: why emissions trading is needed; Manchester Metropolitan University, 2013

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
  - > 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 (LH_2 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
EU-H2020 Project Centreline: http://cordis.europa.eu/project/rcn/209713_en.html; M.K. Bradley, *Subsonic Ultra Green Aircraft Research: Phase II N+4 Advanced Concept Development*, 2012. 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

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 (LH_2 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
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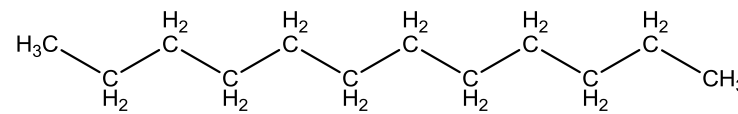
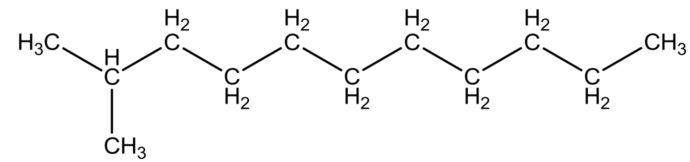
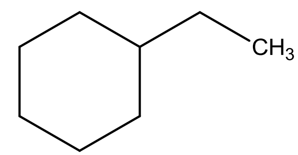
Technical requirements

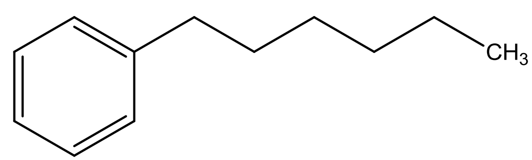
Designation: D1655 – 10

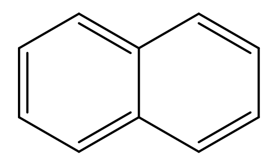
Standard Specification for Aviation Turbine Fuels[1]











- ***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

ASTM INTERNATIONAL

Designation: D1655 – 10

Standard Specification for Aviation Turbine Fuels[1]

ASTM INTERNATIONAL

Designation: D7566 – 12a

Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons[1]

- >> ***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

- >> ***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

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Designation: D1655 – 10

Standard Specification for
Aviation Turbine Fuels[1]

Designation: D7566 – 12a

Standard Specification for
Aviation Turbine Fuel Containing Synthesized Hydrocarbons[1]

>> *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

>> *Requirements for synthetic*

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

> No oxygenated compounds (alcohols, esters, etc.)

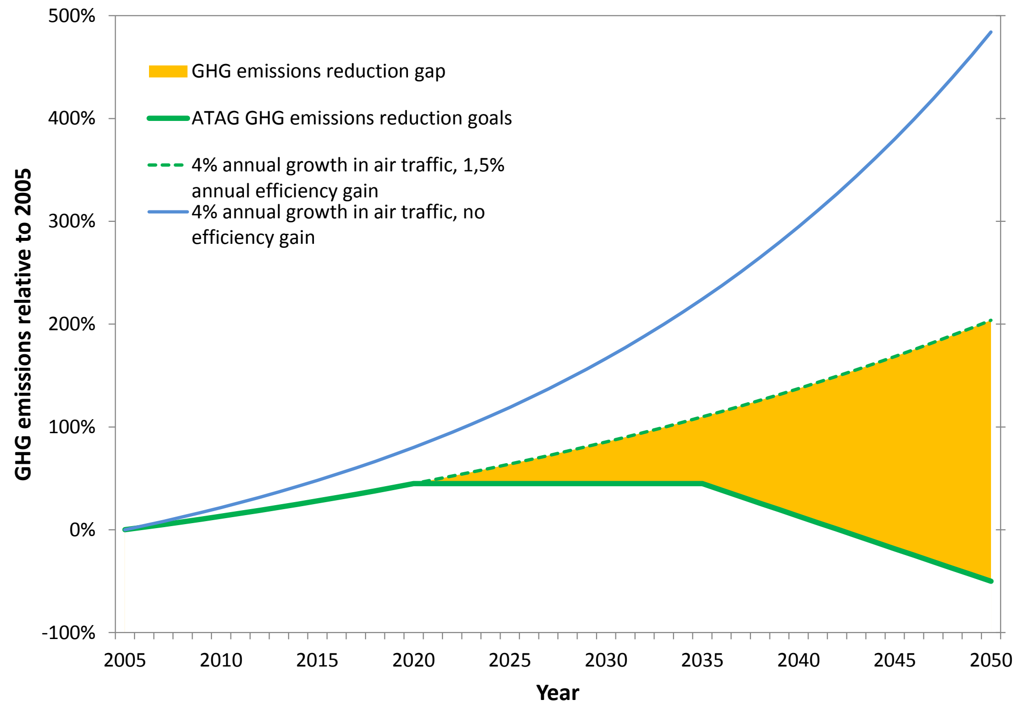
> „Conventional" boiling range

> 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:

Ploetner at el. "Fulfilling long-term emission reduction goals in aviation by alternative fuel options: An evolutionary approach", 2018 Aviation Technology, Integration, and Operations Conference, AIAA Aviation Forum, (AIAA 2018-3990), https://doi.org/10.2514/6.2018-3990.

The „emissions gap“: How much is needed?

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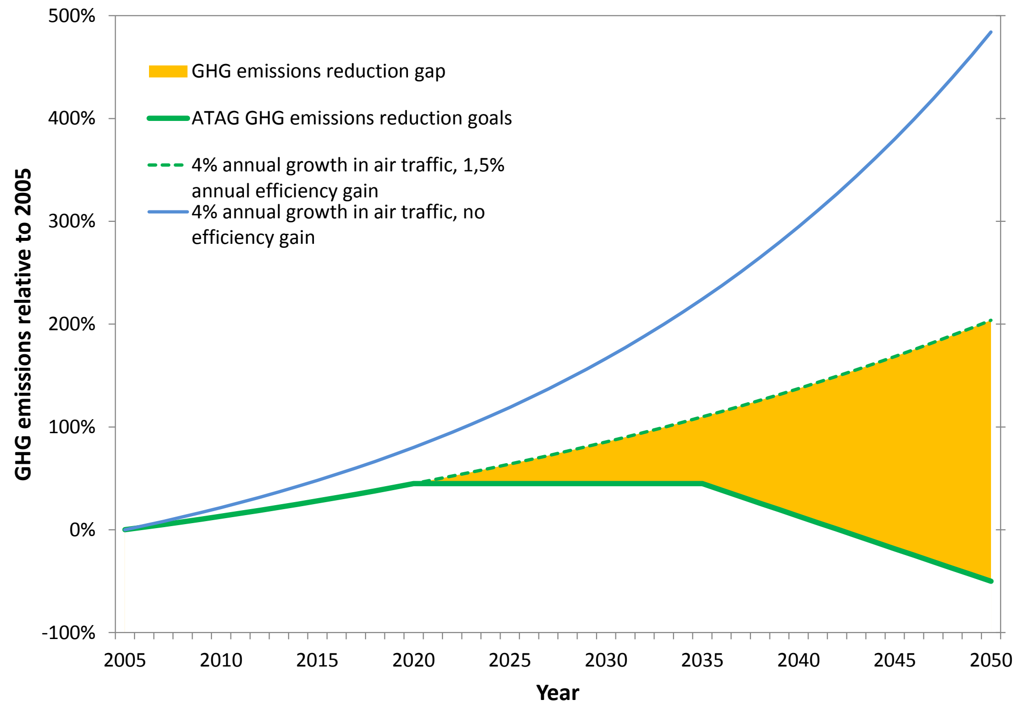
>> ***Translation of GHG reduction targets into requirements w.r.t. alternative fuels***

>> ***2050***

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



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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

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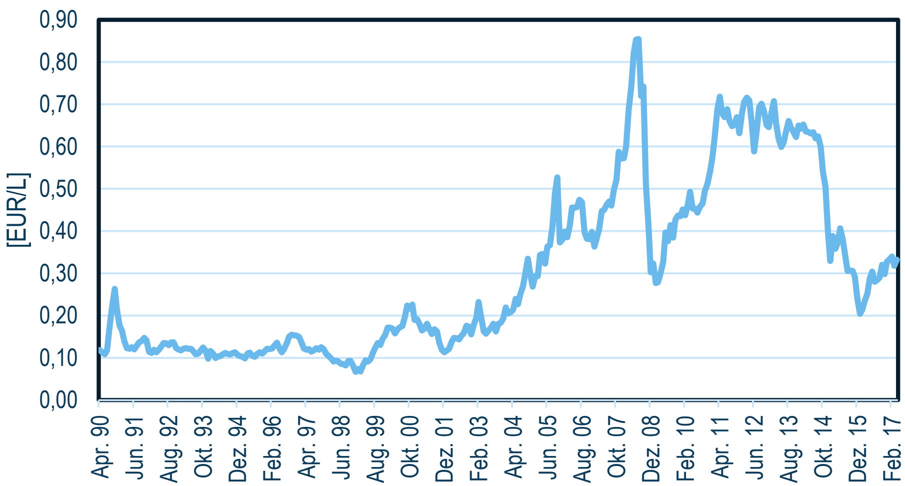
US jet fuel spot price



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, CO_2, water	1.47
Solar-thermochemical	Solar heat, CO_2, water	2.23

Sources: Bann et al., *Bioresour. Technol.* **2017**, *227*, 179–187.
de Jong at al., *Biofuels, Bioprod. Biorefining* **2015**, *9 (6)*, 778–800.
Schmidt et al., *Chemie Ing. Tech.* **2018**, *90 (1–2)*, 127–140.
Falter at el., *Environ. Sci. Technol.* **2016**, *50 (1)*, 470–477.

>> *Renewable jet fuel (biogenic and non-biogenic) currently not competitive*

Renewable Jet Fuel: Situation today

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>> ASTM certification

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

>> Renewable fuels in civil avation

> 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

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>> *ASTM certification*

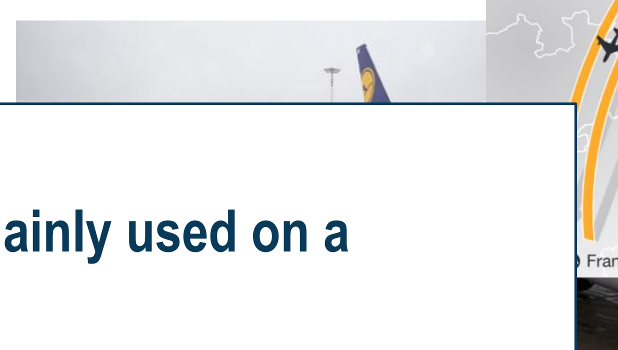
> FT-SPK, HEFA-SPK, SIP, AtJ

>> *Renewable fuels in civil avation*

> Lufth
> Many

>> *Airpo*

> Alter
> Oslo Airport, Los Angeles, Toronto (others to follow)



BUT: Renewable aviation fuels mainly used on a project basis

No large-scale implementation in day-to-day operation realized to date

>> *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

Conclusions

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>> *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

Contact

>> Arne Roth

Lead of Alternative Fuels

Bauhaus Luftfahrt e.V.

Willy-Messerschmitt-Str. 1

82024 Taufkirchen

Germany

>> Tel.: +49 (0) 89 3 07 48 49 – 46

Fax: +49 (0) 89 3 07 48 49 – 20

arne.roth@bauhaus-luftfahrt.net

>> http://www.bauhaus-luftfahrt.net