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Is Aviation the next IMO?

Valentin Batteiger

S&P Global Platts 10th Middle Distillates Conference
31.01.2020 Antwerp

The Bauhaus Luftfahrt Approach

- **Founded in November 2005 by**

- **A non-profit research institution with long-term time horizon**
  - Strengthening the cooperation between industry, science and politics
  - Developing new approaches for the future of aviation with a high level of technical creativity
  - Optimizing through a holistic approach in science, economics, engineering and design

- **Going “New Ways“ for the mobility of tomorrow**

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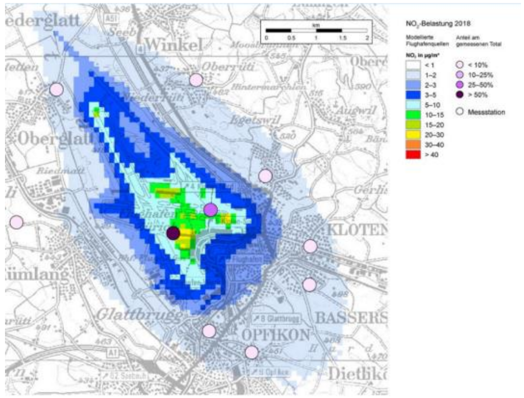
Outline

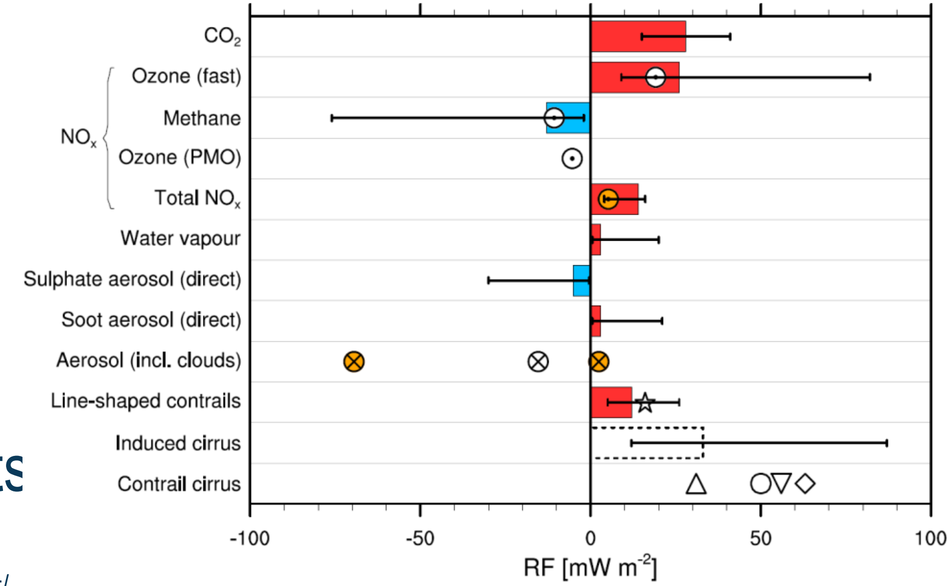
- How can the Sulphur and PM emissions be reduced in the aviation industry?
- Is biofuel the certain future?
- What expectations can be made for the future of jet fuel?

Measures and motivation to reduce sulphur/aromatic content

- **Sulphur and aromatic content can be reduced by hydro-desulphurization (HDS) and hydrodearomatization (HDA)**
  - Existing technology, commercial catalysts



- **Local air quality concerns at airports**
- **Non-CO_2 climate effect**
  - Order of magnitude comparable to CO_2 effect
  - Aromatics: Mainly contrails und cirrus
  - Sulphur: Contribution to contrails, but also cooling effects



Source: see e.g. https://www.topsoe.com/processes/hydrotreating/kerosene-hydrotreating; https://report.flughafen-zuerich.ch/2018/ar/de/luftqualitaet/
Grewe, *Mitigating the Climate Impact from Aviation: Achievements and Results of the DLR WeCare Project*, Aerospace 2017, 4, 34;

Pollutant emissions from aviation fuel combustion

- **Ground based and airborne measurements relate fuel composition to pollutant emissions**
  - **NOx and CO:** No significantly effected by fuel composition (mainly controlled by combustion process)
  - **Particle emissions:** Clear link to sulphur and aromatic content, clean fuels can reduce, but not eliminate particle emissions from current engines
  - **SO_2** is (obviously) linked to sulphur

Sources: T. Schripp et al, *Impact of Alternative Jet Fuels on Engine Exhaust Composition during the 2015 ECLIF Ground-Based Measurements Campaign*, Environ. Sci. Technol. 2018, 52, 4969−4978; Moore, *Biofuel blending reduces particle emissions from aircraft engines at cruise conditions,* Nature, Vol. 543, 411, 2017

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Current regulation on sulphur and aromatic content (Jet A-1)

- **Current regulations do not require low suphur/aromatic content**
- **Blends with synthesized kerosene: Minimum aromatic content required**

Maximum sulphur content by mass	
Gasoline (EN228)	**10 ppm**
Jet Fuel (ASTM 1655)	**3000 ppm**
Synthetic jet fuels (ASTM 7566)	**15 ppm**
Diesel (EN590)	**10 ppm**
Marine sector (IMO 2020)	**5000 ppm**
Marine sector (ECAS)	**1000 ppm**

Aromatic content	
Jet fuel (ASTM 1655)	**< $25\%_{vol}$**
Jet fuels containing synthesized hydrocarbons (ASTM 7566)	**Min. $8\%_{vol}$**
Blend components (ASTM 7566) **FT-SPK, HEFA, SIP, AtJ** **SPK with aromatics**	 **< $0.5\%_{mass}$** **< $20\%_{vol}$**

Abbreviation: FT-SPK: Fischer-Tropsch Hydroprocessed Synthezised Paraffinic Kerosene, HEFA: SPK from from hydroprocessed esters and fatty acids, SIP: synthesized iso-paraffins produced from hydroprocessed fermented sugars; AtJ: Alcohol-to-Jet SPK

Typical sulphur and aromatic content in Jet A-1 samples

- Sulphur content: On average significantly below 3000 ppm
- Aromatic content: Distribution around 18%

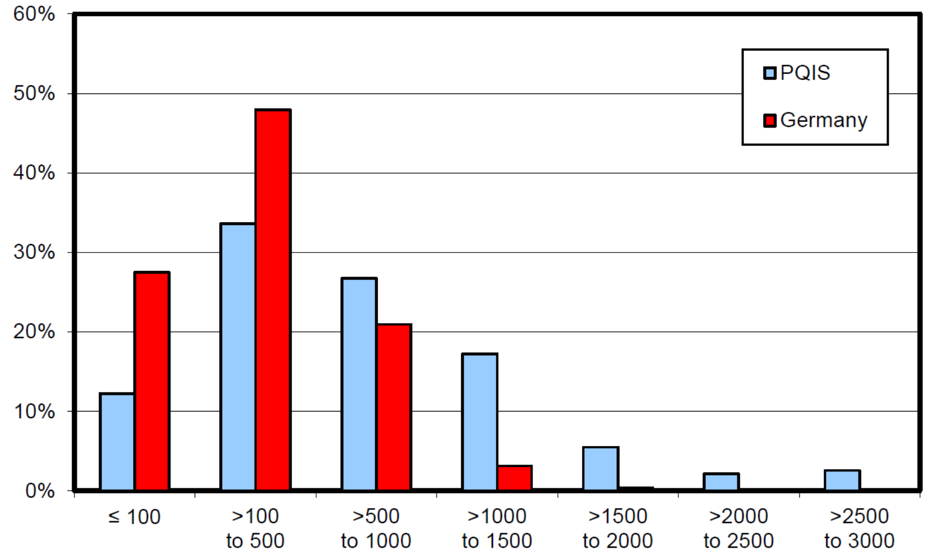

Figure 5: Distribution of sulphur content in ppm in 2013 PQIS Report and in Lufthansa study

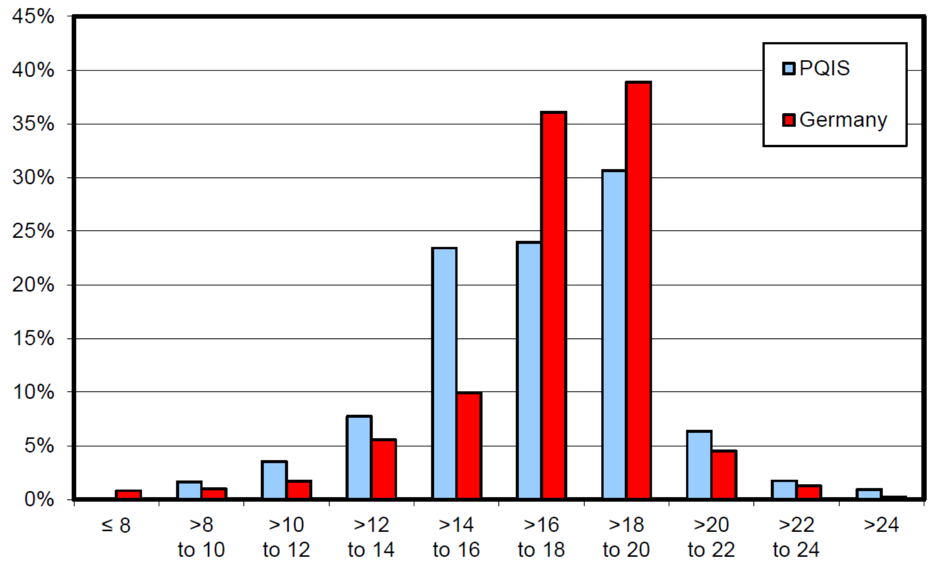

Figure 6: Distribution of aromatics content in vol% in 2013 PQIS Report and in Lufthansa study

Source: Alexander Zschocke, High Biofuel Blends in Aviation (HBBA), ENER/C2/2012/ 420-1, Final Report

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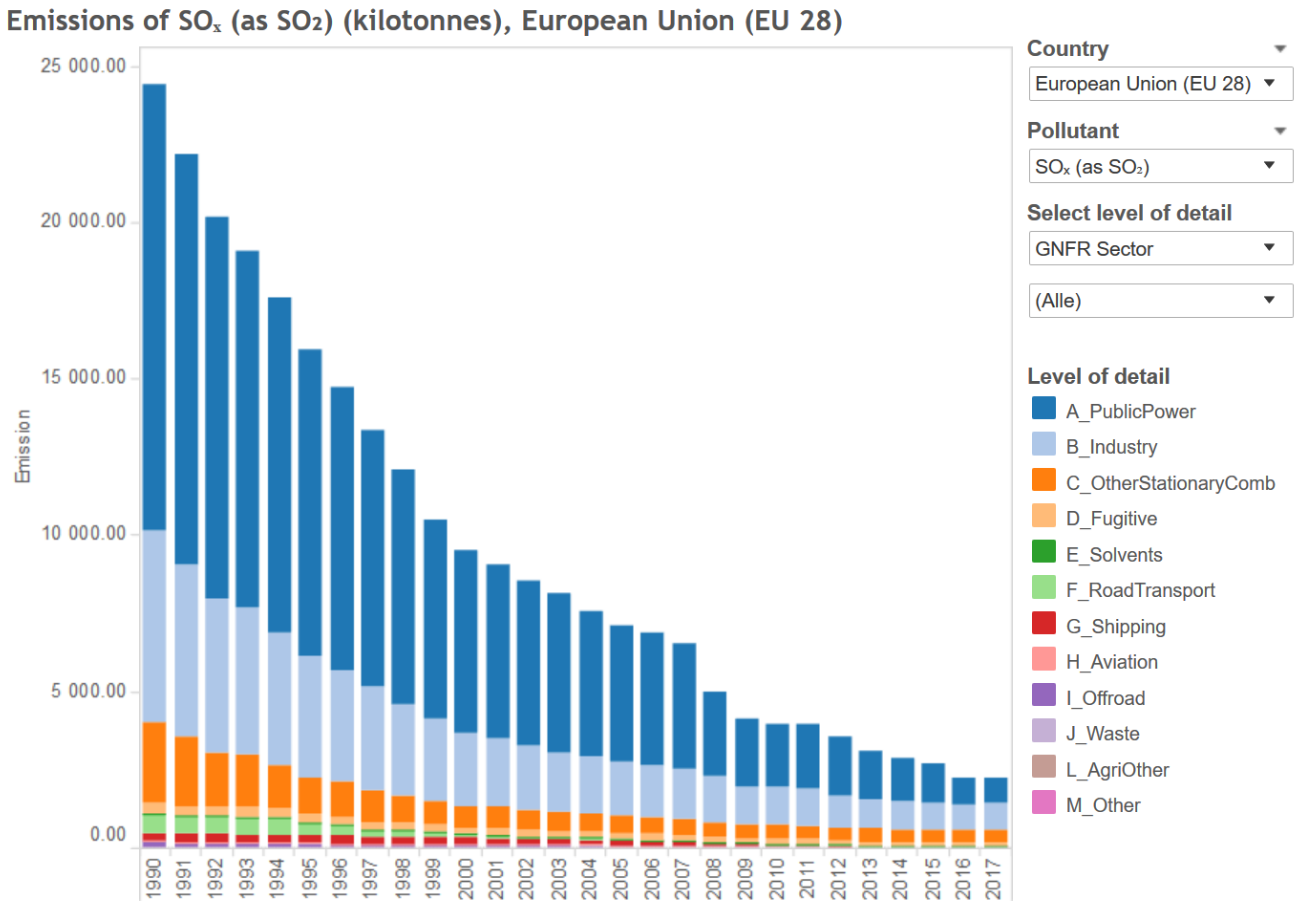
Reduction of SO_2 emissions is effective when regulated

- **Policy measures to reduce SOx emissions are effective**
- **Likely reasons:**
  - Profound environmental concerns
  - Technical solutions are available at tolerable cost



The data presented in this data viewer uses the GNFR14 and NFR14 nomenclature and is the officially reported data submitted up to 20 June 2019.

Source: Centre on Emission Inventories and Projections / Environment Agency Austria
www.ceip.at/ms/ceip_home1/ceip_home/data_viewers/official_tableau/

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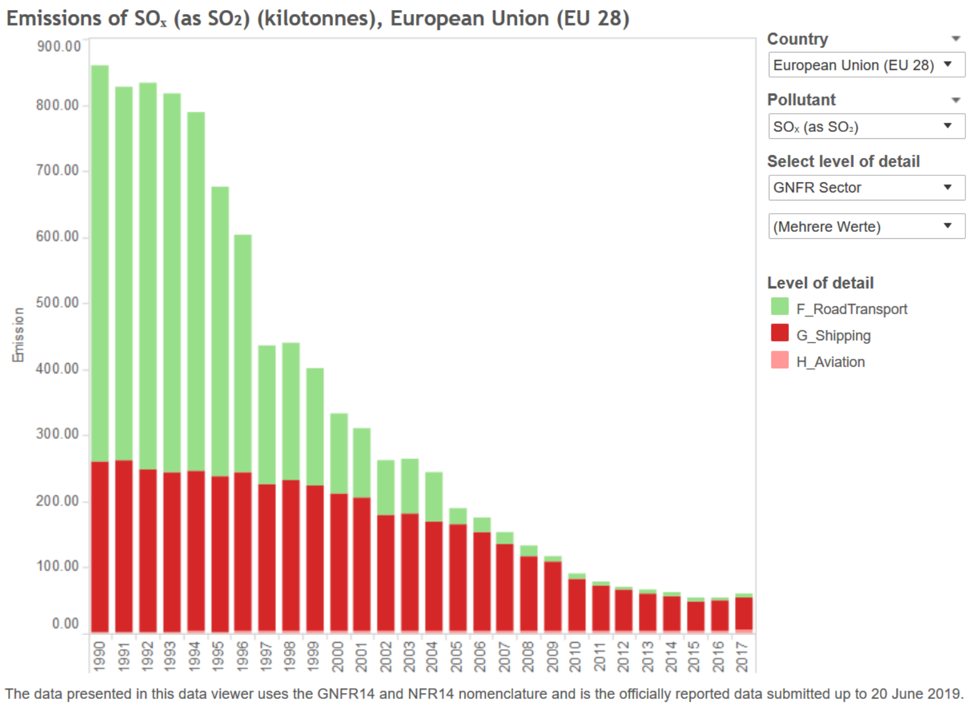
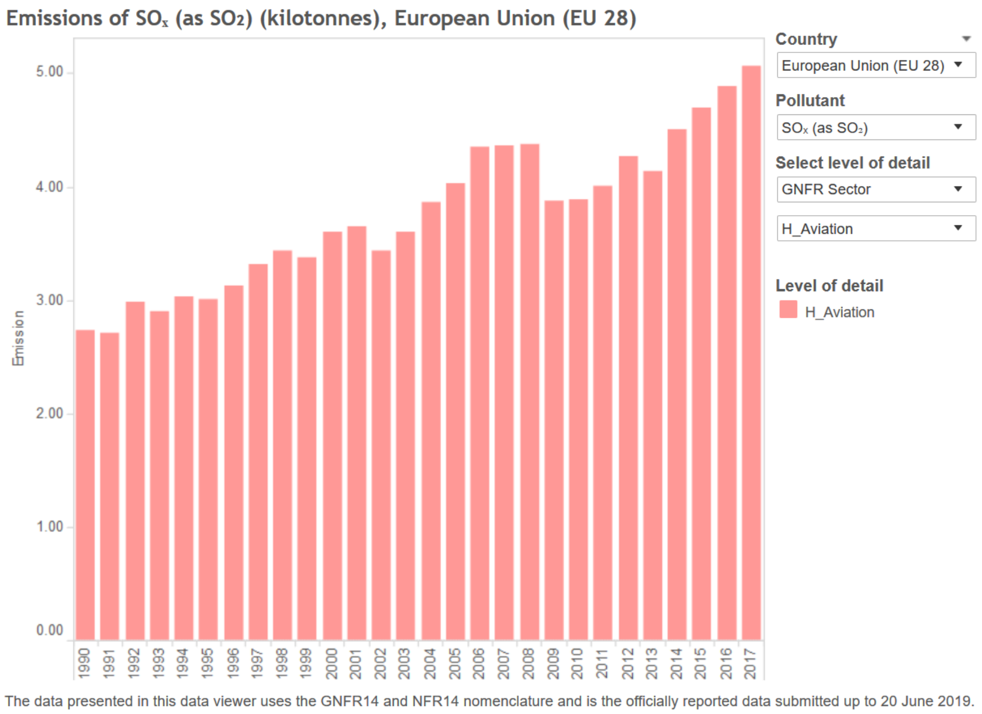
Reduction of SO_2 emissions is effective when regulated

- **Striking effect in road transportation, SO_2 emissions from aviation are rising with fuel consumption (from a low baseline)**





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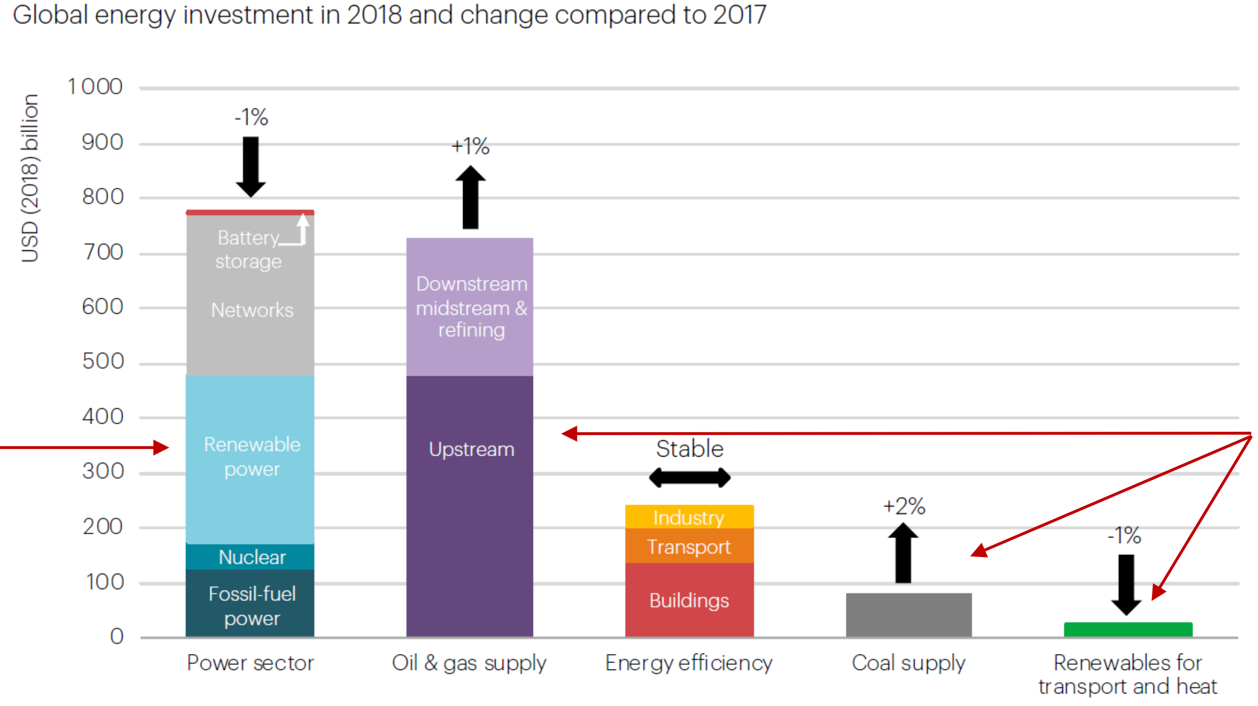
Outline

- How can the Sulphur and PM emissions be reduced in the aviation industry?
- **Is biofuel the certain future?**
- What expectations can be made for the future of jet fuel?

Is biofuel the certain future?

- Biofuels are the only near-term alternative for renewable jet fuel (HEFA/ATJ)
- But investment in biofuels are not in line with ambitious scale-up

Power Sector:
Investments redirected towards renewables
Continued policy support



Transport & Fuels:
Persistent fossil dominance
Adaption of policies due to sustainability concerns

Source: IEA World Energy Investment 2019, iea.org/wei2019. Allrights reserved.

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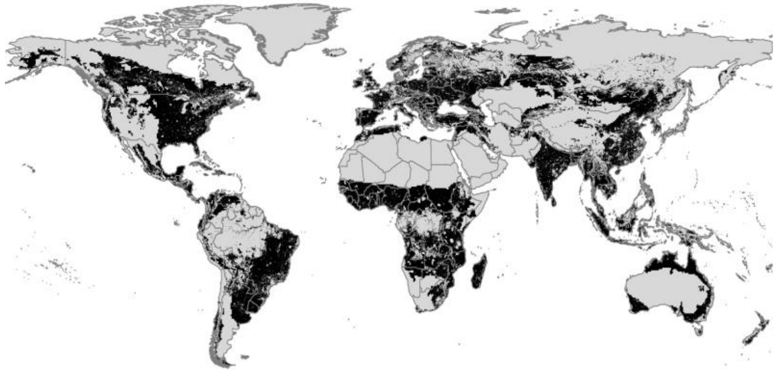
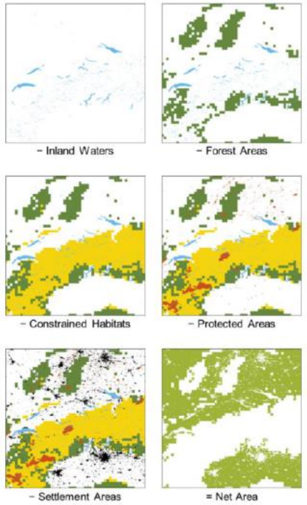
Are biofuels scalable towards jet fuel demand?



- **Bottom-up estimate of agricultural land availability**
  - Exclusion of land areas (sustainability criteria)
  - Subtraction of land area for food and fodder cultivation
- **Matching crop-specific productivity maps (20 energy crops)**
- **SPK theoretical potential:**
  - > 1000 Mt/yr based on 2005 data sets
- **Similar efforts underway to estimate production potentials from wastes and residues (H2020 HyFlexFuel)**



Source: F. Riegel at el. Global Assessment of Sustainable Land Availability for Bioenergy and Food Production, 27th European Biomass Conference and Exhibition, Lisbon, May 2019
DBFZ/BHL: Public report Regional feedstock potentials and preference regions for HTL projects (to be published), www.hyflexfuel.eu

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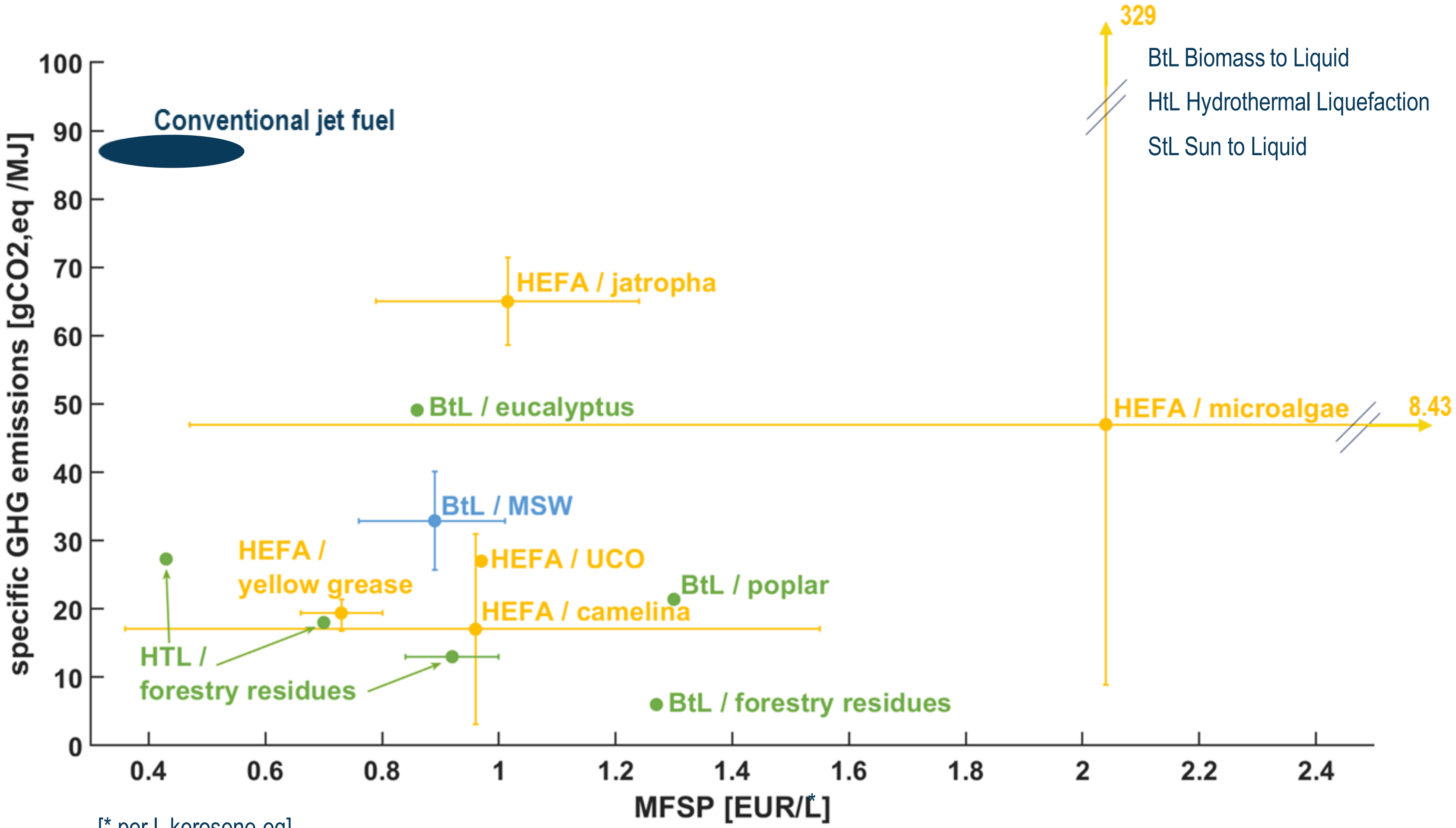
Cost and GHG performance of biofuels



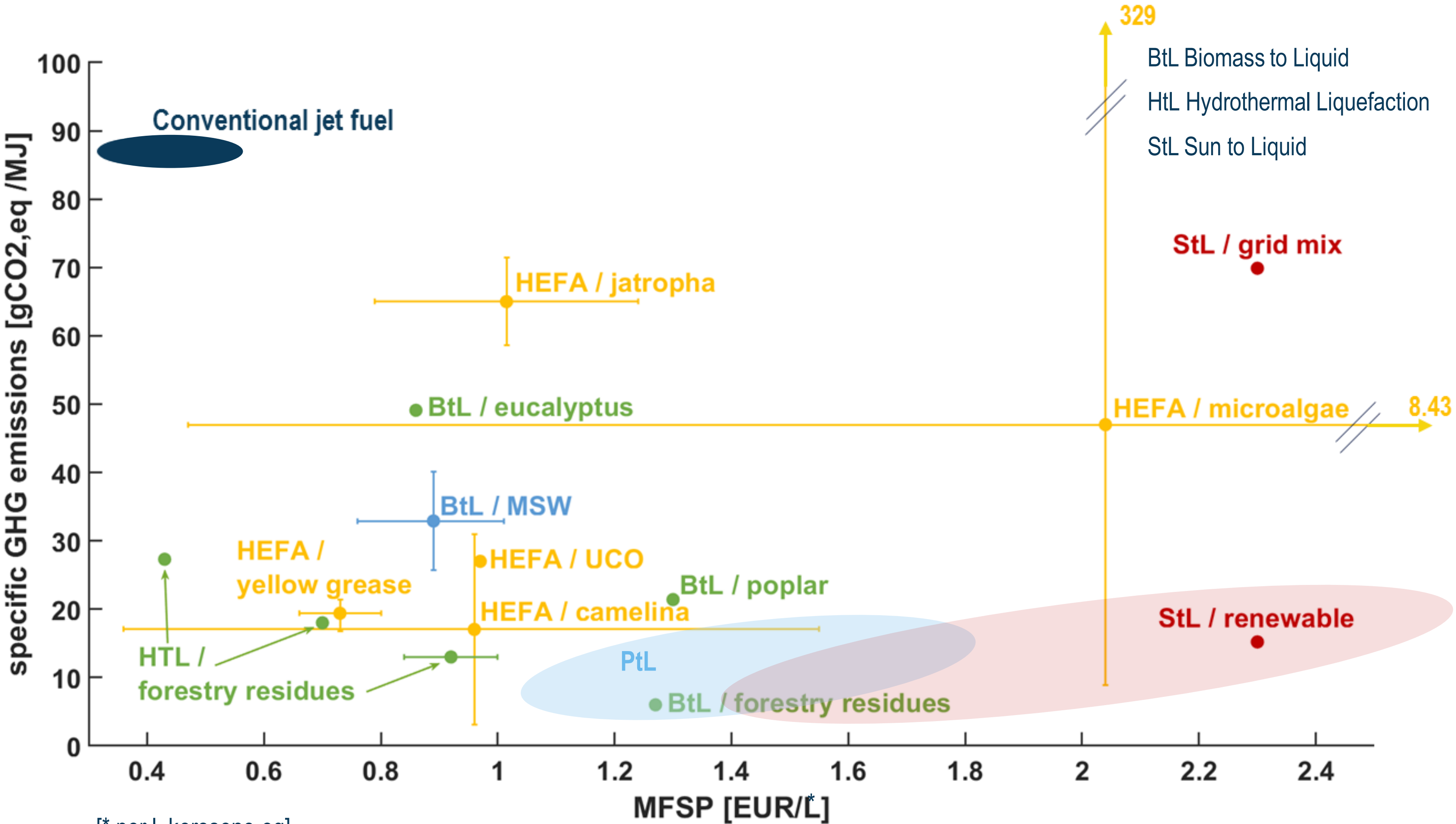
[* per L kerosene-eq]

BtL Biomass to Liquid

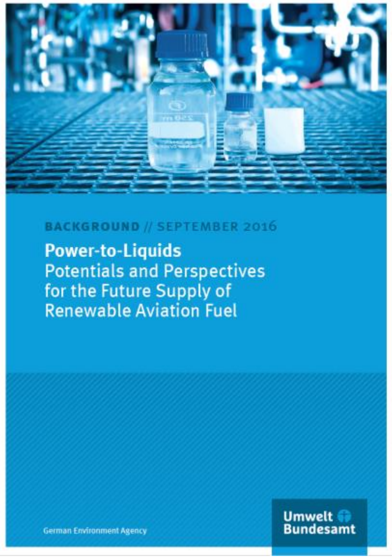
HtL Hydrothermal Liquefaction

StL Sun to Liquid

Upcoming competition from renewable fuels



[* per L kerosene-eq]



Sources: LBST and BHL: *Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel*, Background Paper 2016 http://bit.ly/2cowOyf, P. Schmidt, *Power-to-Liquids as Renewable Fuel Option for Aviation: A Review*, Chem. Ing. Tech. 2018, 90, No. 1–2, 127, www.sun-to-liquid.eu

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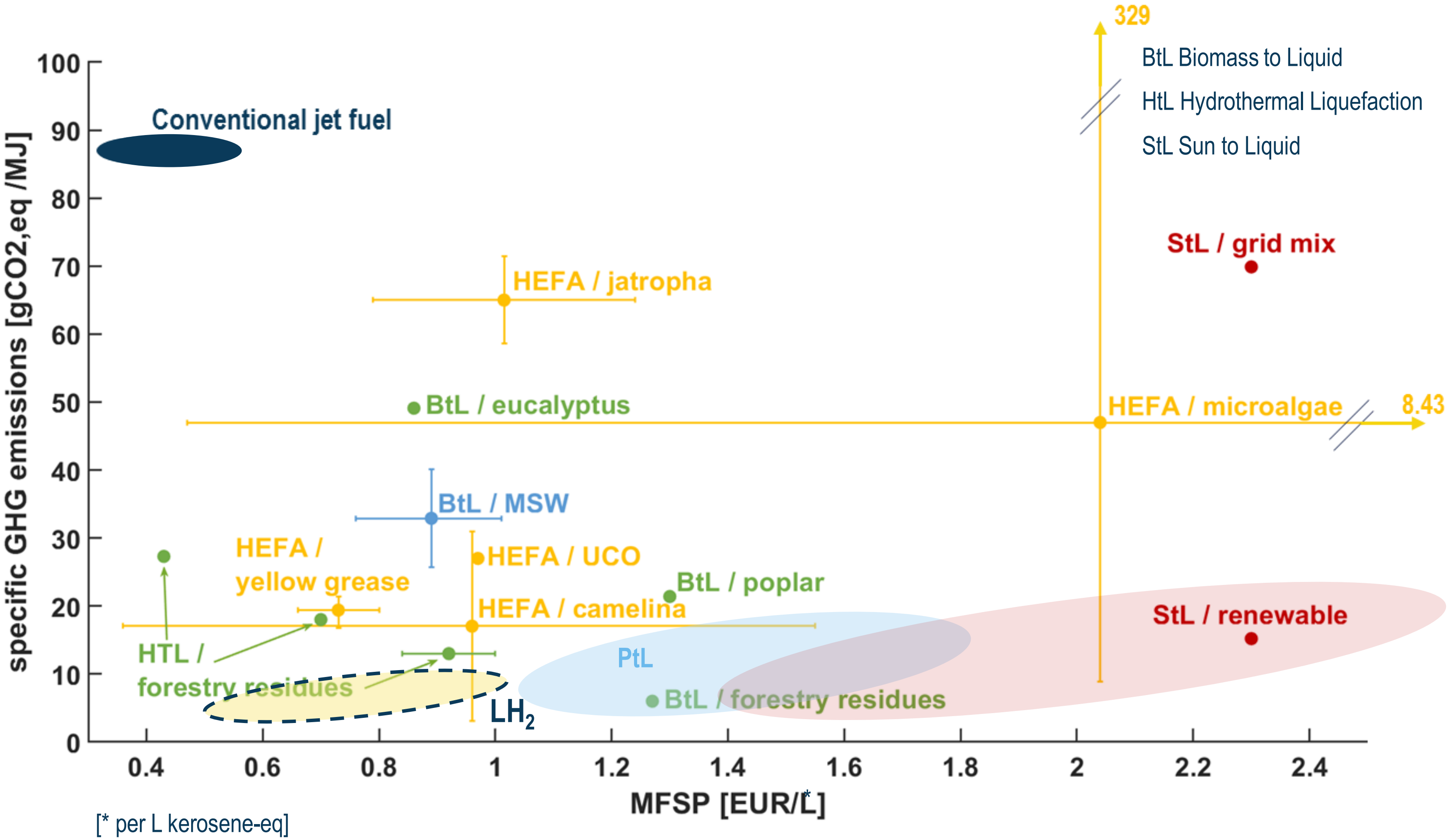
Upcoming competition from renewable fuels



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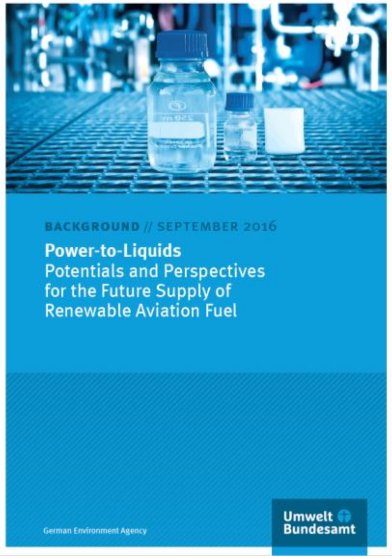

Sources: LBST and BHL: *Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel*, Background Paper 2016 http://bit.ly/2cowOyf, P. Schmidt, *Power-to-Liquids as Renewable Fuel Option for Aviation: A Review*, Chem. Ing. Tech. 2018, 90, No. 1–2, 127, www.sun-to-liquid.eu

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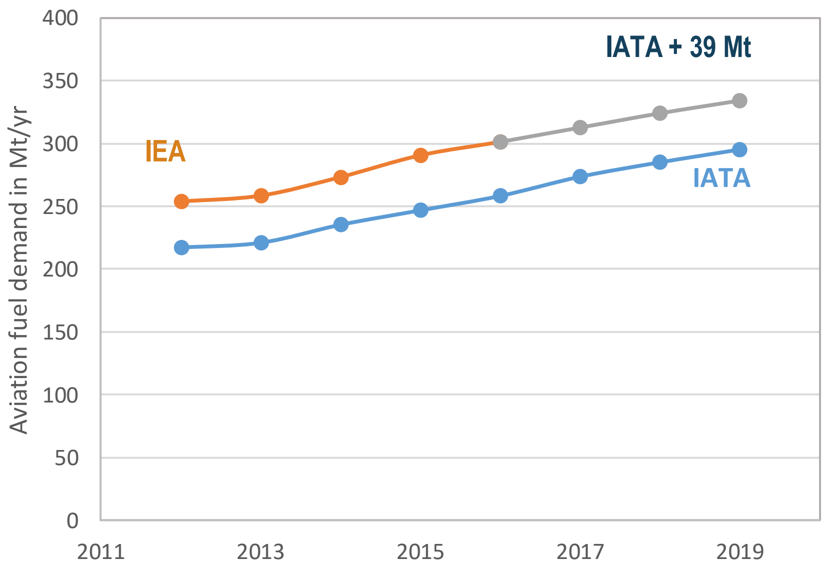
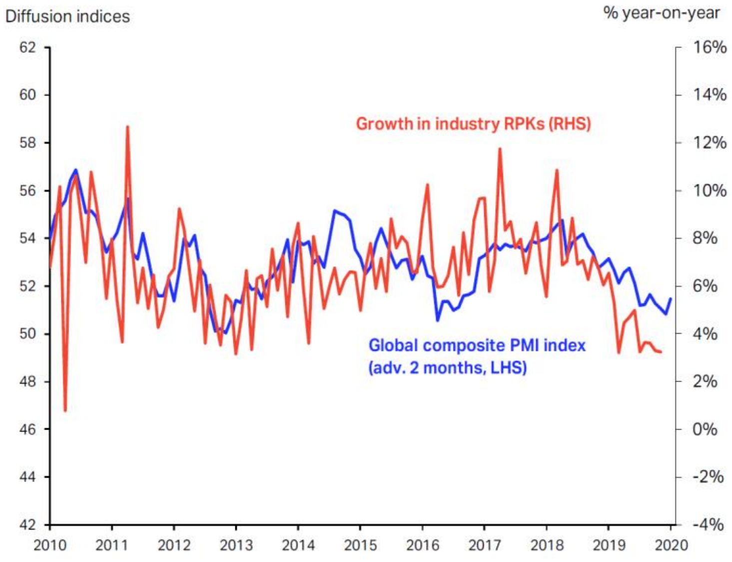
Outline

- How can the Sulphur and PM emissions be reduced in the aviation industry? What are the alternative options?
- Is biofuel the certain future?
- **What expectations can be made for the future of jet fuel?**

Aviation fuel demand will likely grow

- **Fuel demand and revenue person kilometers on continued growth pathway**





Sources: IATA Economics, IATA Monthly Statistics, Markit

- **Industry market forecasts expect growth beyond efficiency improvements**
- **Current market vs. world population: ~ 1160 km per person and year**

Source: Data derived from most recent issues of IEA “Key world energy statistics” and IATA “Economic performance of the airline industry” biannual reports; Growth in industry RPK derived from IATA “Air passenger market analysis, November 2019”; https://webstore.iea.org/statistics-data www.iata.org/publications/economics www.worldometers.info/world-population

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Prospects and limitations of electric flight

- **Electric flight limited by battery mass**
  - Concept Ce-Liner, target: Cover 80% of air traffic (900 nm)
  - Requires battery specific energy density > 1 kWh/kg
- **Hybrid/Turbo-electric concepts**
  - From fuel perspective: No change in primary energy carrier
- **Urban and Intra-Urban air mobility**
  - Viable concepts for short duration flights
  - Substitution of conventional aircraft in niche markets
  - Novel opportunities for more radical designs

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; www.harbourair.com/harbour-air-and-magnix-announce-successful-flight-of-worlds-first-commercial-electric-airplane/; www.airbus.com/newsroom/stories/Vahana-has-come-to-an-end.html

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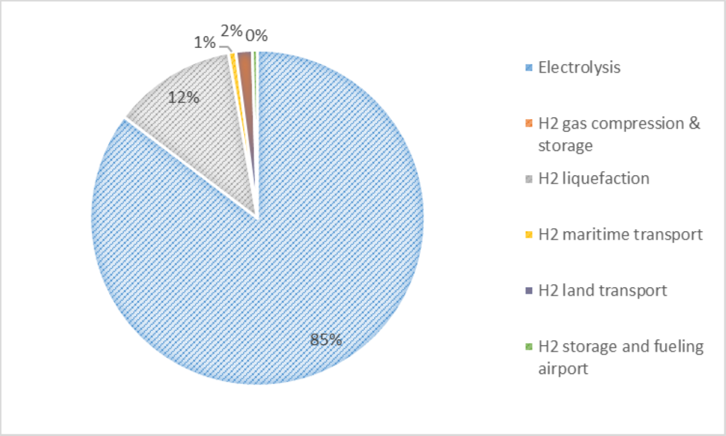
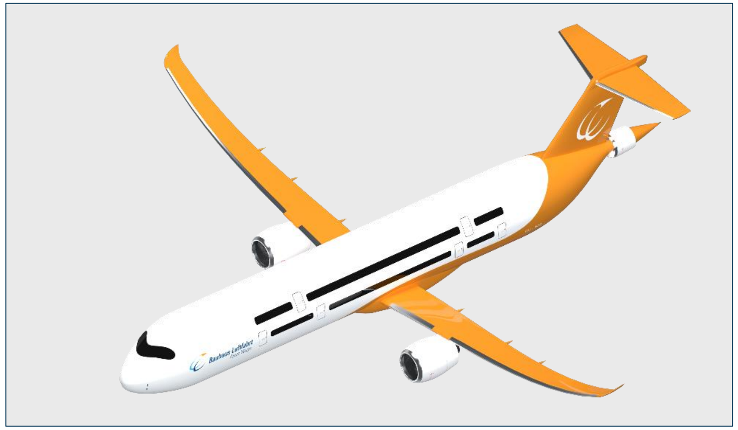
Prospects for hydrogen as aviation fuel (long haul)

- **Interdisciplinary Design Project Hy-ShAir**
  - Focus on the long-haul air transport market
- **Supply perspective for electricity derived fuels**
  - Benefits of LH_2 production vs. synthetic fuel production can overweigh penalties of LH_2 logistics
- **HyLiner – Hydrogen powered long haul aircraft**
  - Combustion of LH_2 in gas turbine
  - Comparable energy demand at aircraft level
  - Potential for implementation of annexed technologies





Sources: C. Penke et al. Pathways and environmental assessment for the introduction of renewable hydrogen into the aviation Sector (to be published) ; F. Troeltsch - Concept for a hydrogen-powered long-haul aircraft, Bauhaus Luftfahrt Symposium, 8.5.2019

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Key conclusions

- **Sulphur and aromatic content linked to air quality and non-CO_2 climate effect**
  - De-sulphurization and de-aromatization is technically feasible
- **Biofuels are the only short term renewable fuel option**
  - Scalability of biofuels is questionable
- **Synthetic fuels from H_2O and CO_2 provide a scalable perspective**
- **Battery electric flight is attractive for short durations and distances**
- **Liquid hydrogen may provide another alternative to liquid hydrocarbon fuel in the long-term future**

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SUN-to-LIQUID

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Thank you for your attention

Contact:
Dr. Valentin Batteiger
valentin.batteiger@bauhaus-luftfahrt.net
+49 89 3074-84961

Bauhaus Luftfahrt e.V.
Willy-Messerschmitt-Str. 1
82024 Taufkirchen, Germany