HBBA Study: Background and Fuels used

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HBBA Study and BioJetMap Workshop

Brussels, 11. February 2015

Background: Bio kerosene specifications

- Bio kerosene specifications relevant for Europe:
  - ASTM D1655 and D7566 (US specifications)
  - DefStan 91-91 (European specification)
- Agreement between ASTM and DefStan that US has lead in synthetic kerosene matters, and DefStan reflects US decisions
- ASTM D1655: Standard specification for Jet A-1 kerosene for civil aviation use
- ASTM D7566: Specification for
  - Synthetic kerosene
  - Blends of synthetic and conventional kerosene
- Blends meeting ASTM D7566 are by definition ASTM D1655 kerosene and can be used like conventional kerosene

ASTM INTERNATIONAL Standards Worldwide

Background: Requirements for blends with synthetic kerosene

- Must meet ASTM D1655 requirements

- Limit of maximum content of synthetic kerosene
  - 50% for FT- and HEFA-kerosene, 10% for SIP fuel
  - Express intention of ASTM to eventually remove these limits

- Minimum aromatics content
  - 8 vol% / 8.4 vol% depending on test method
  - Required to preserve tightness of seals and valves

- Minimum distillation curve gradient requirements
  - $T_{50} – T_{10}$ at least 15°C
  - $T_{90} – T_{10}$ at least 40°C

- Minimum BOCLE value of 0.85 mm

- Maximum viscosity at -40°C 12 mm²/sec

Background: Implications for blending

Even if

- the neat synthetic kerosene conforms to ASTM D7566,
- not every 50%/50% blend with conventional kerosene will meet ASTM D7566

- Some specification parameters for the neat synthetic kerosene are outside the specification range for the blend
  - Aromatics content
  - Density
  - Must be compensated by conventional kerosene

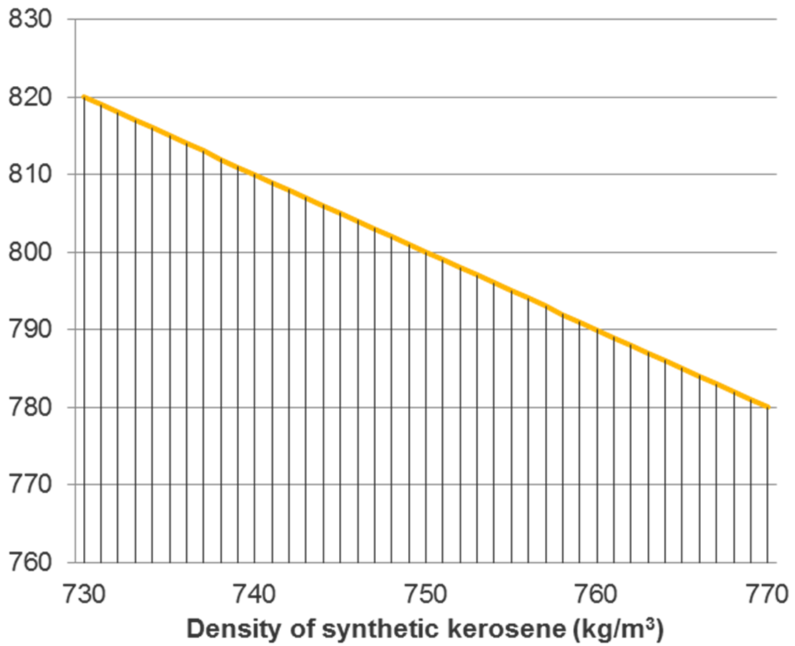
- Conventional kerosene does not have to meet the additional ASTM requirements
  - Distillation curve requirements
  - Viscosity at -40°C

- Possible blending ratios depends on exact properties of both the conventional and the bio fuel

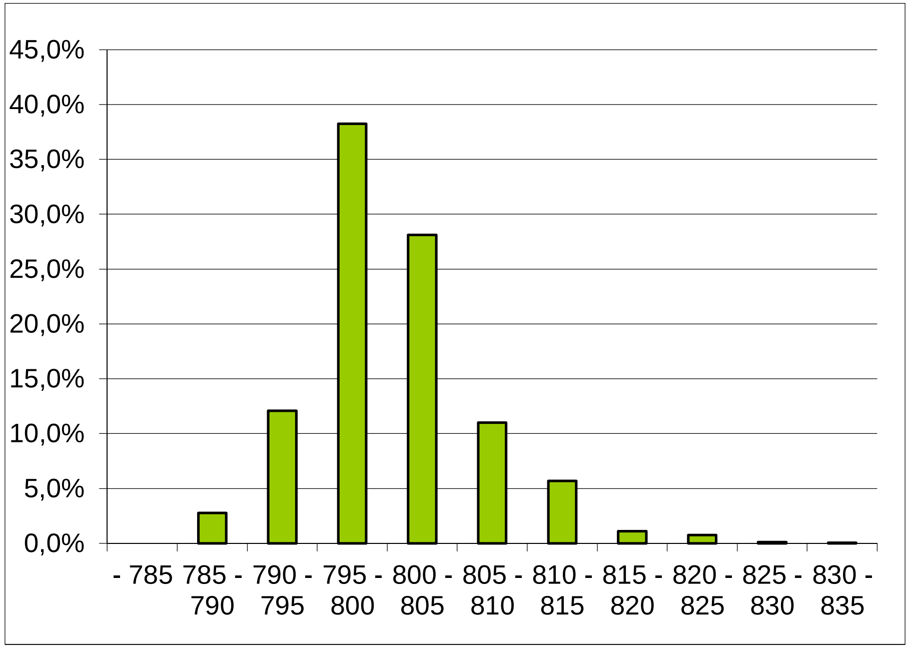
Background: Practical example of implications

- Density range of HEFA- and FT-material: 730 kg/m³ to 770 kg/m³
- Minimum density for blend: 775 kg/m³

Requirements on density of conventional kerosene if 50% blend ratio is to be achieved



Distribution of density in German kerosene, by batch



Background: Economic and political considerations

- Once we move to large scale bio kerosene production, blend ratios will need to be large

- Analysis costs will be a major factor unless blend ratios are large
  - Extra analysis of ASTM 7566 required after blending
  - Costs per analysis several 1,000 Euros
  - Usually performed for large batches of thousands of tonnes
  - Uneconomic if needed to blend in a few tons of bio kerosene

- Blending logistics will be challenging unless blend ratios are large
  - To blend 200,000 tons of bio kerosene at 50% requires 200,000 tons of conventional kerosene
  - To blend 200,000 tons of bio kerosene at 5% requires 3.8 million tons of conventional kerosene – basically all the kerosene produced in Germany

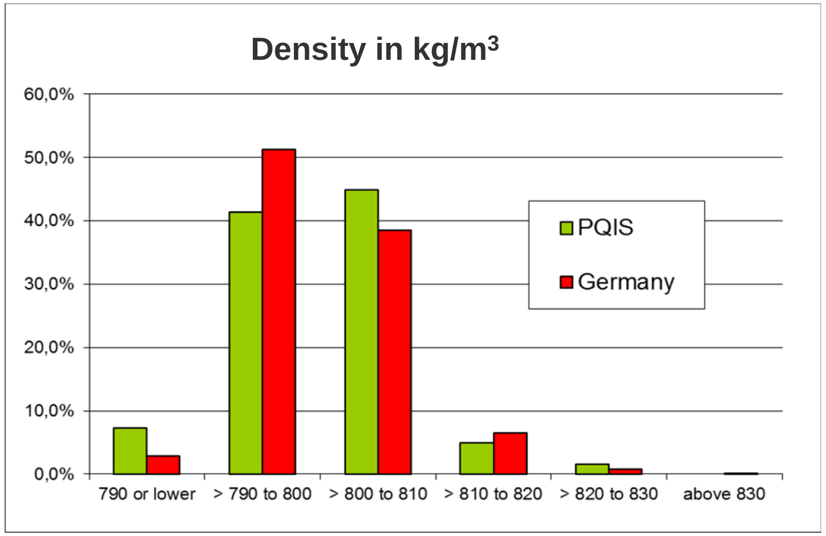
- The maximum amount of kerosene a nation can replace is limited by the blend ratio practically achievable. It will be seriously limited unless blend ratios are large.

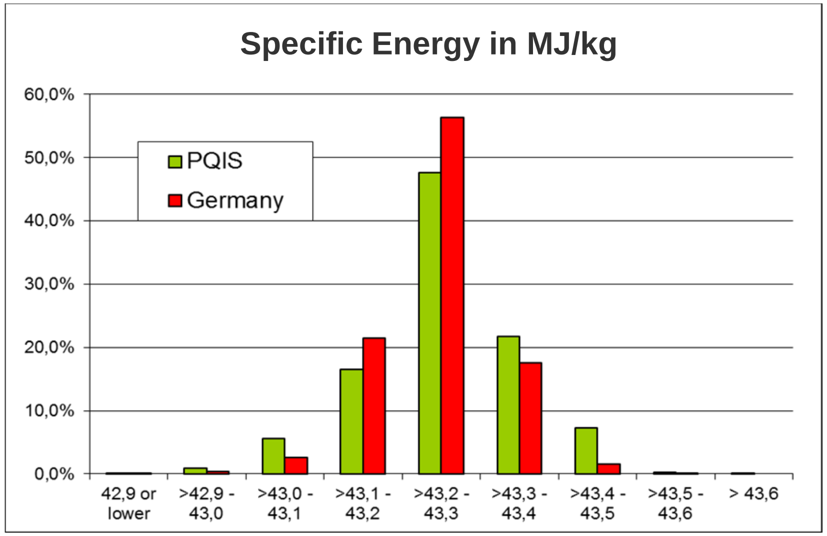
Scope of HBBA study

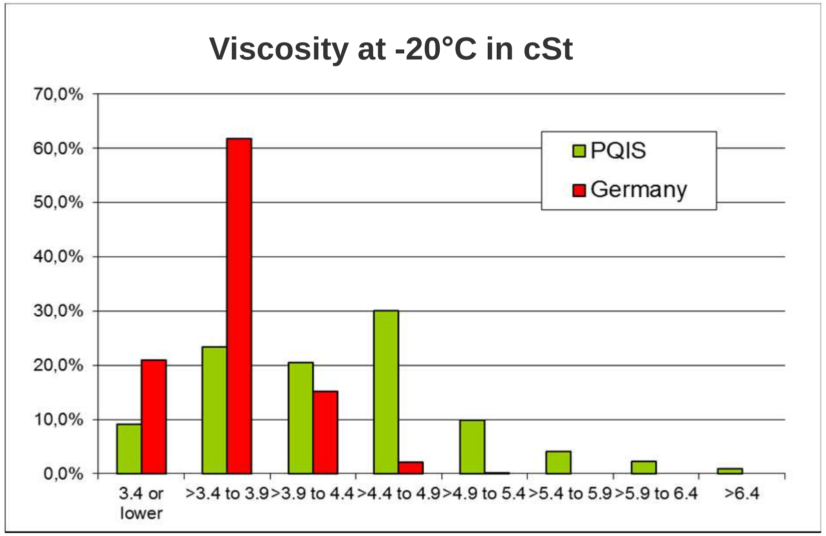
- HBBA: High Biofuel Blends in Aviation
- Tendered by European commission as ENER/C2/2012/420-1
- Study jointly conducted by Lufthansa and WIWeB
- Main Task: ASTM D7566 analysis of blends of
  - various samples of conventional kerosene, spanning a broad range of properties, and
  - various kinds of bio kerosene either already certified, or undergoing certification

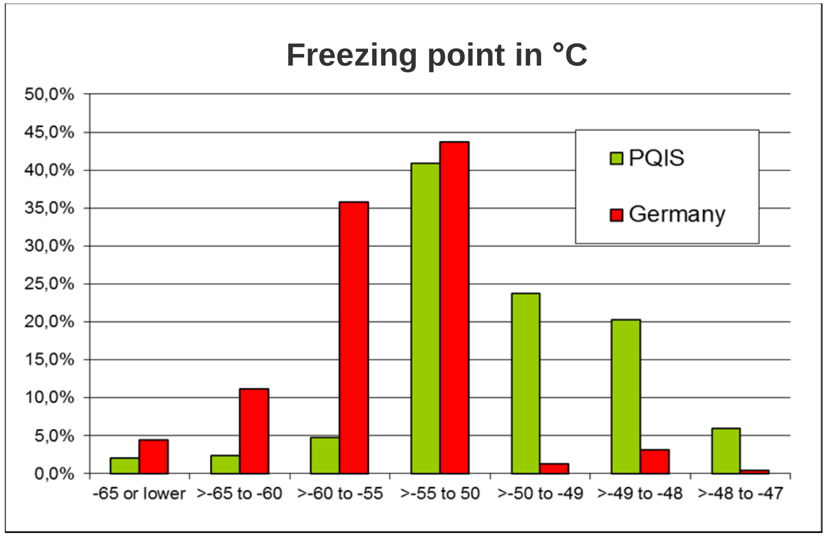
  with a focus on blend ratios of 50% and higher.
- Other tasks:
  - Effects of the synthetic fuels on elastomers
  - Effects of adding aromatics on ASTM D7566 parameters
  - Emissions testing
  - Provide data base for researchers and practical users

The fuels: Property spectrum of conventional Jet A-1 kerosene I

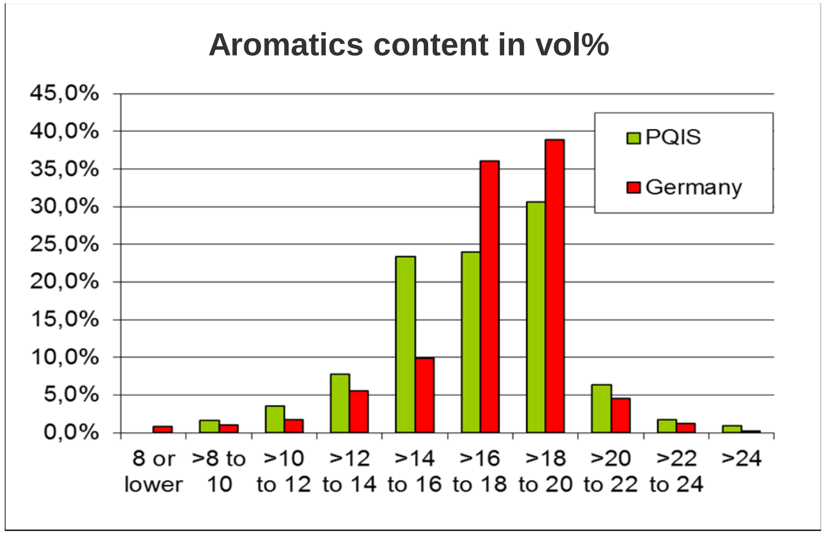


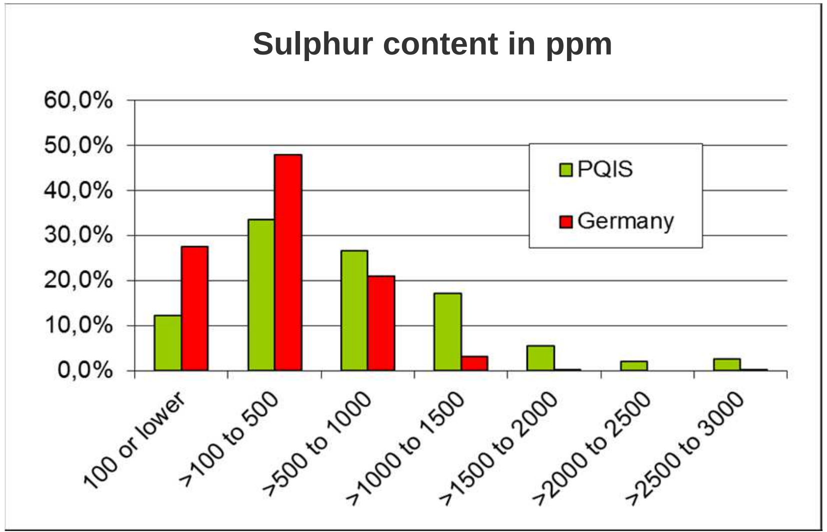


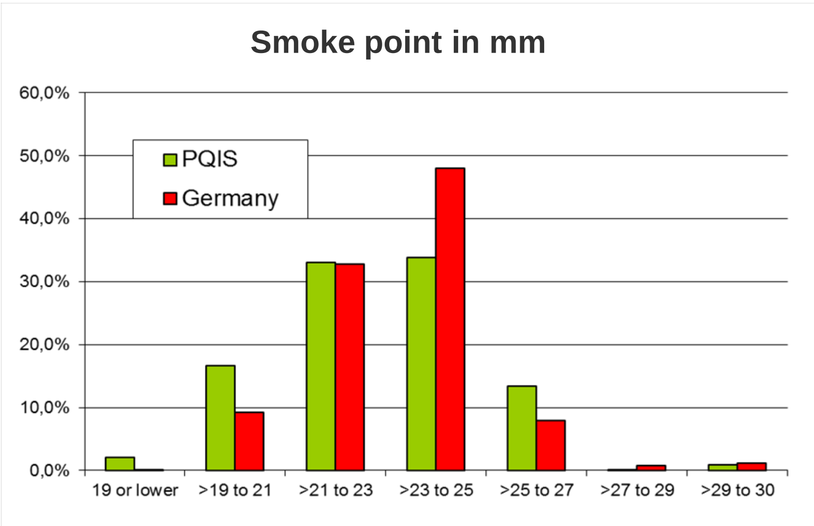




The fuels: Property spectrum of conventional Jet A-1 kerosene II





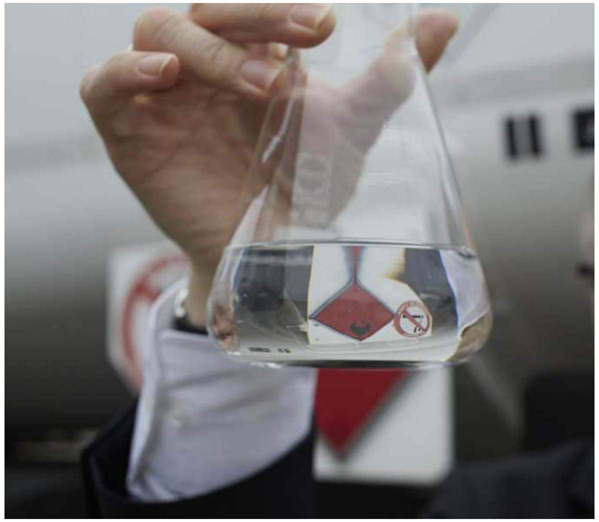


The Fuels: Conventional kerosene used in HBBA study

- Fuels at ends of observable property range identified during Lufthansa analysis of 2011 fuel properties as part of burnFAIR project
- Five samples requested from German refineries and received at WIWeB in 2013
- Comparing with data from other studies indicates that these samples adequately represent property extremes for Jet A-1 available worldwide, except for freezing point and viscosity, where US values are higher

	World Fuel Sampling Program		HBBA Study sample	
	Minimum	Maximum	Minimum	Maximum
Density	788.7	820.6	789.0	818.6
Freezing Point	-71	-46.2	-89.4	-49
Viscosity at -20°C	2.8	6.0	3.008	4.357
Specific Energy	42.85	43.22	43.073	43.391
Sulfur Content	7	2,453	10 or less	1,000
Aromatics	11.8	21.8	13.7	21.6

The Fuels: Bio kerosene used in HBBA study



- Fuel from six separate production pathways used in study
  - Fischer-Tropsch SPK (CTL, provided by Sasol)
    n- and iso-paraffins
  - HEFA SPK (provided by UOP)
    n- and iso-paraffins
  - SIP fuel (provided by Total / Amyris)
    C15 iso-paraffins
  - ATJ-SPK (provided by Gevo)
    n- and iso-paraffins
  - ATJ-SKA (provided by Swedish Biofuels)
    fully synthetic kerosene
  - CH kerosene (provided by ARA)
    fully synthetic kerosene
- Only limited set of blend analyses conducted for fully synthetic fuels
- SIP kerosene blended at 10% to 50%, others at 50% to 100%

The fuels: Bio kerosene not covered

- Three further production pathways at Research Report stage:
  - HDCJ / Pyrolysis (certification lead: KioR)
    Mixed composition, aromatics content ca. 50%
  - HDO-SK (certification lead Virent / Shell)
    M*ixed composition, cycloparaffinic content ca. 80%*
  - HDO-SAK (certification lead Virent / Shell)
    100% aromatics
- Inclusion in lab part of study not possible due to unavailability of material

- Boeing 'Green Diesel' approach too late for inclusion
  - Involves use of HEFA diesel fraction as low-level blend component
  - No real description available until December 2014
  - Last fuel shipment accepted for inclusion in HBBA study: July 2014

- Co-processing not relevant for study as no blending with kerosene is involved