

Future Aviation Fuel Research at Bauhaus Luftfahrt

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Future Aviation Fuels: Collaborative research projects

- Research area Future Aviation Fuels at Bauhaus Luftfahrt contributes with system analyses to collaborative research projects:

- EU Solar Fuels:



- EU advanced biofuels:



- National PtL:



- Transition of refinery site & chemical industry:



JEThylen

Aviation's continued reliance on liquid fuels



LH₂ Regional Aircraft
Liquid hydrogen
Fuel cells / propellers

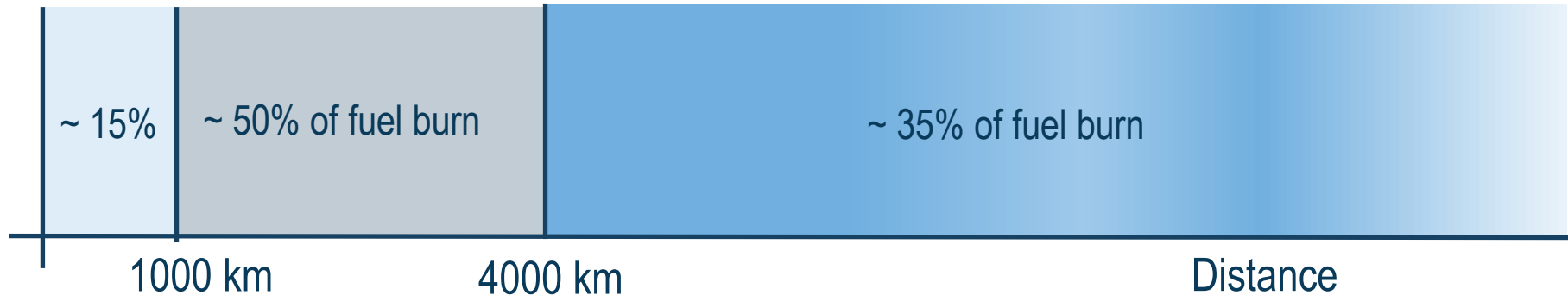


CENTRELINE:
Highly efficient
kerosene-powered
wide-body aircraft



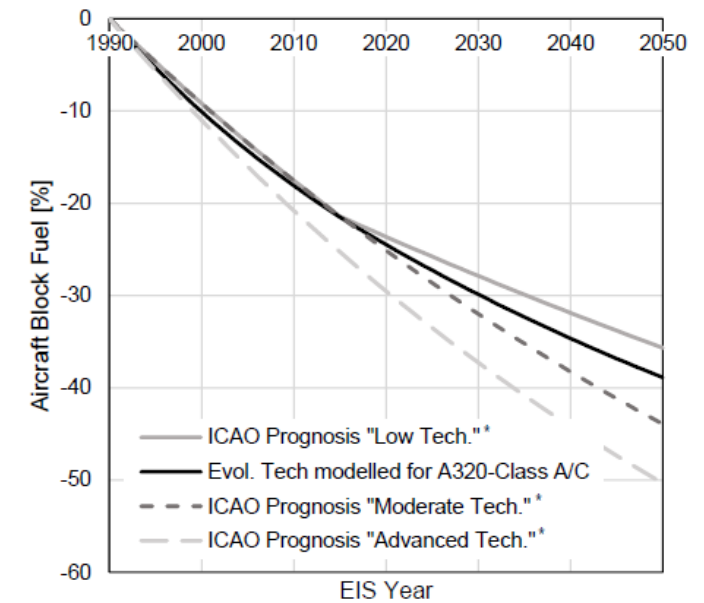
CoCoRe Projekt
Hybrid-electric commuter
High battery utilization

LH₂ wide-body aircraft
Liquid hydrogen
Gas turbines,
fuel cell hybrid options



Emission reduction via more efficient aircraft and operations

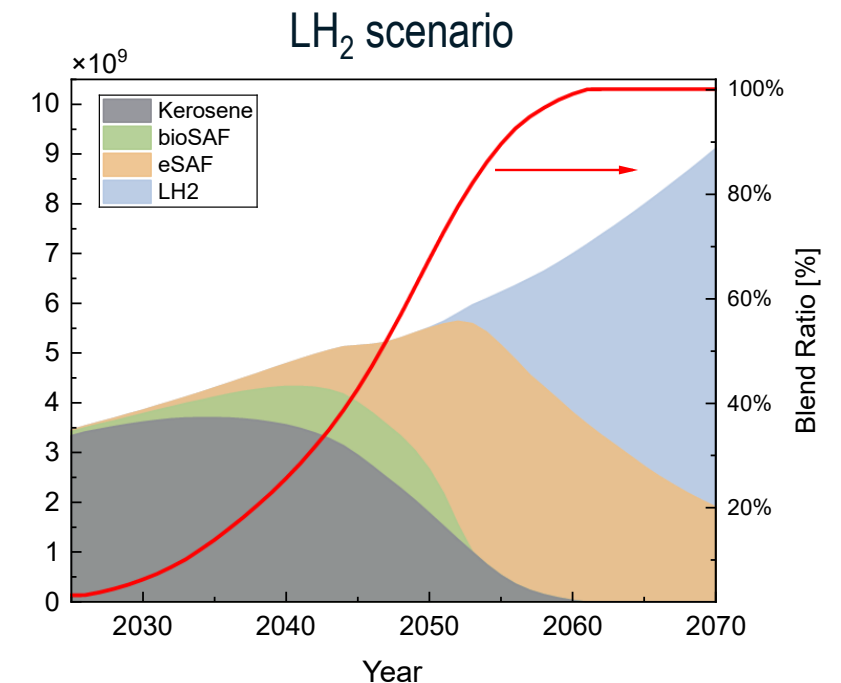
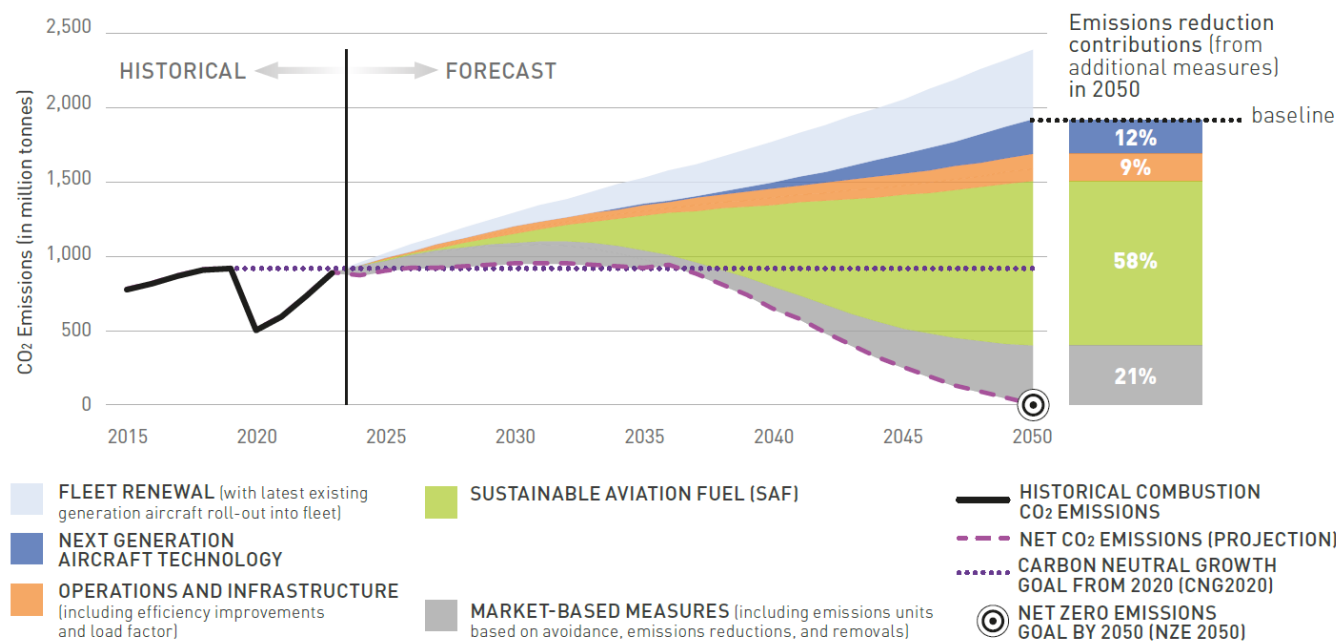
- **Specific fuel demand reduction via technical and & operational improvements: about 1% per year**
 - Reduced weight, improved aerodynamics, e.g. high aspect ratio wing
 - Innovative propulsion systems
 - Optimised routes, higher load factor (e.g. aircraft sharing)
- **Expectation: Further growth in fuel demand, as fuel savings do not compensate growing demand for air travel**



* Ref.: Fleming & Lépinay, "Environmental Trends in Aviation to 2050", ICAO Aviation and Environmental Outlook, Chapter One, ICAO, 2019, pp 17-23.

Climate targets in aviation: Transition scenarios

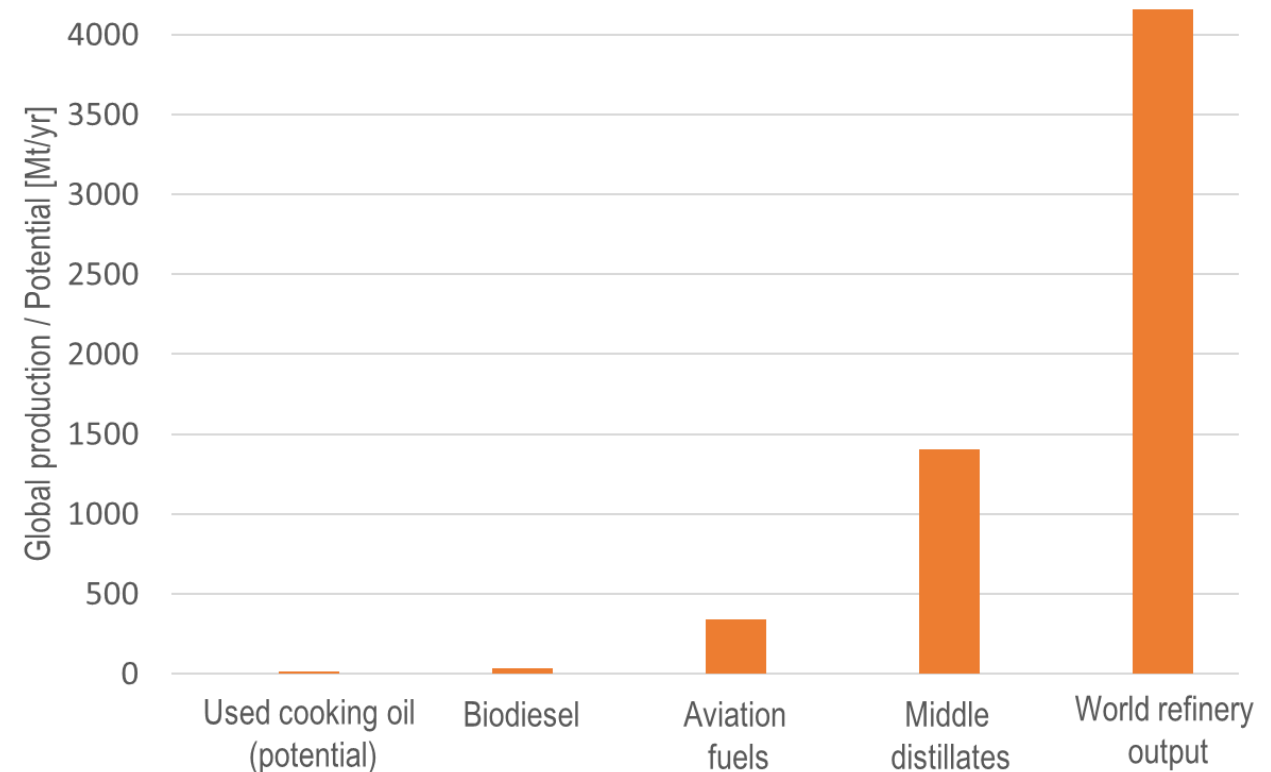
- **Large volumes of sustainable kerosene are required for decades**
 - Hydrogen aviation (entry into service, fleet renewal): Impact will come late, if it is coming...



Sources: Air Transport Action Group: Waypoint 2050, 3rd Edition January 2026; The Economics towards Climate Neutrality in Aviation, BHL 2025/26

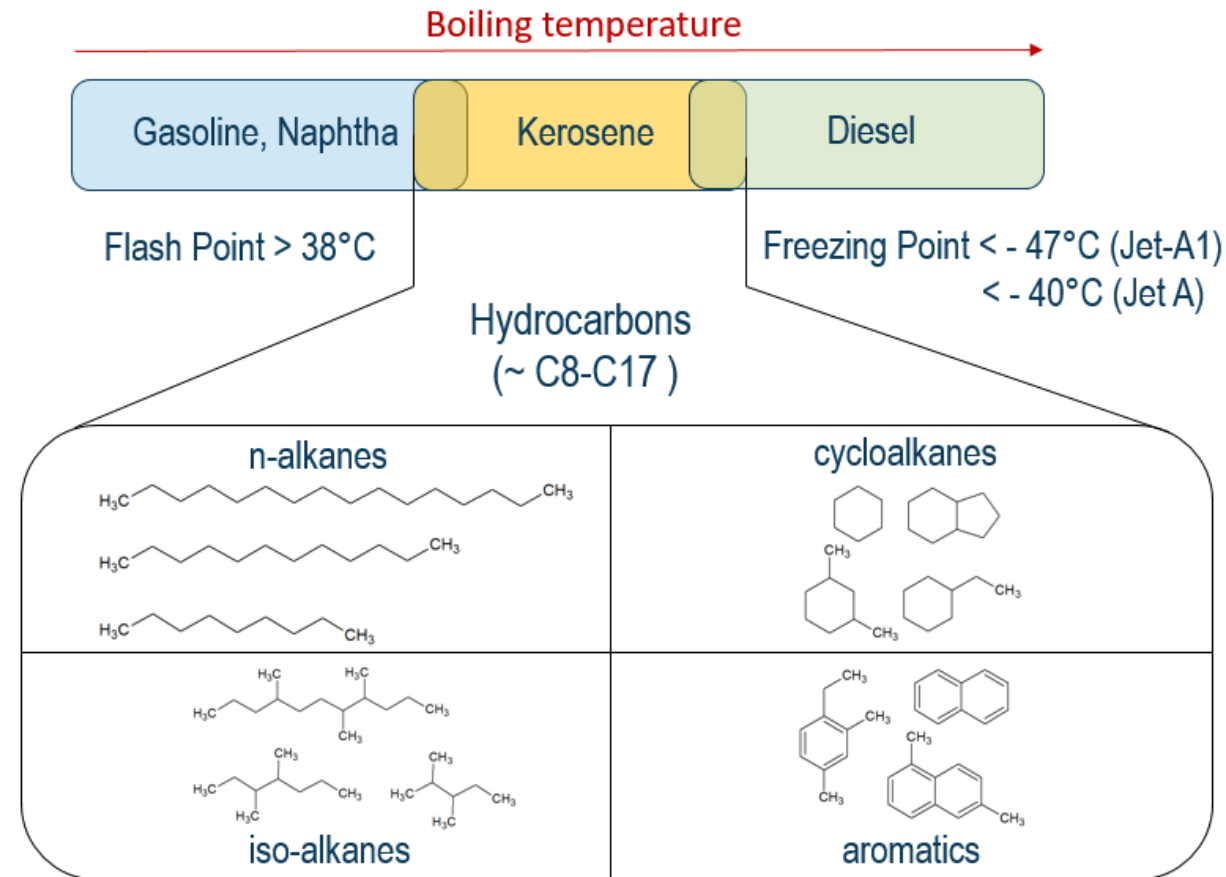
Scales & competition in middle distillate markets

- **Jet fuel: About 8% of global refinery output**
- **Significant feedstock composition in middle distillate markets**
 - Diesel, marine, aviation
 - In particular: Waste fats, oils & greases
- **Need for large additional potentials**
 - Advanced biofuels
 - Fuels from H₂O & CO₂



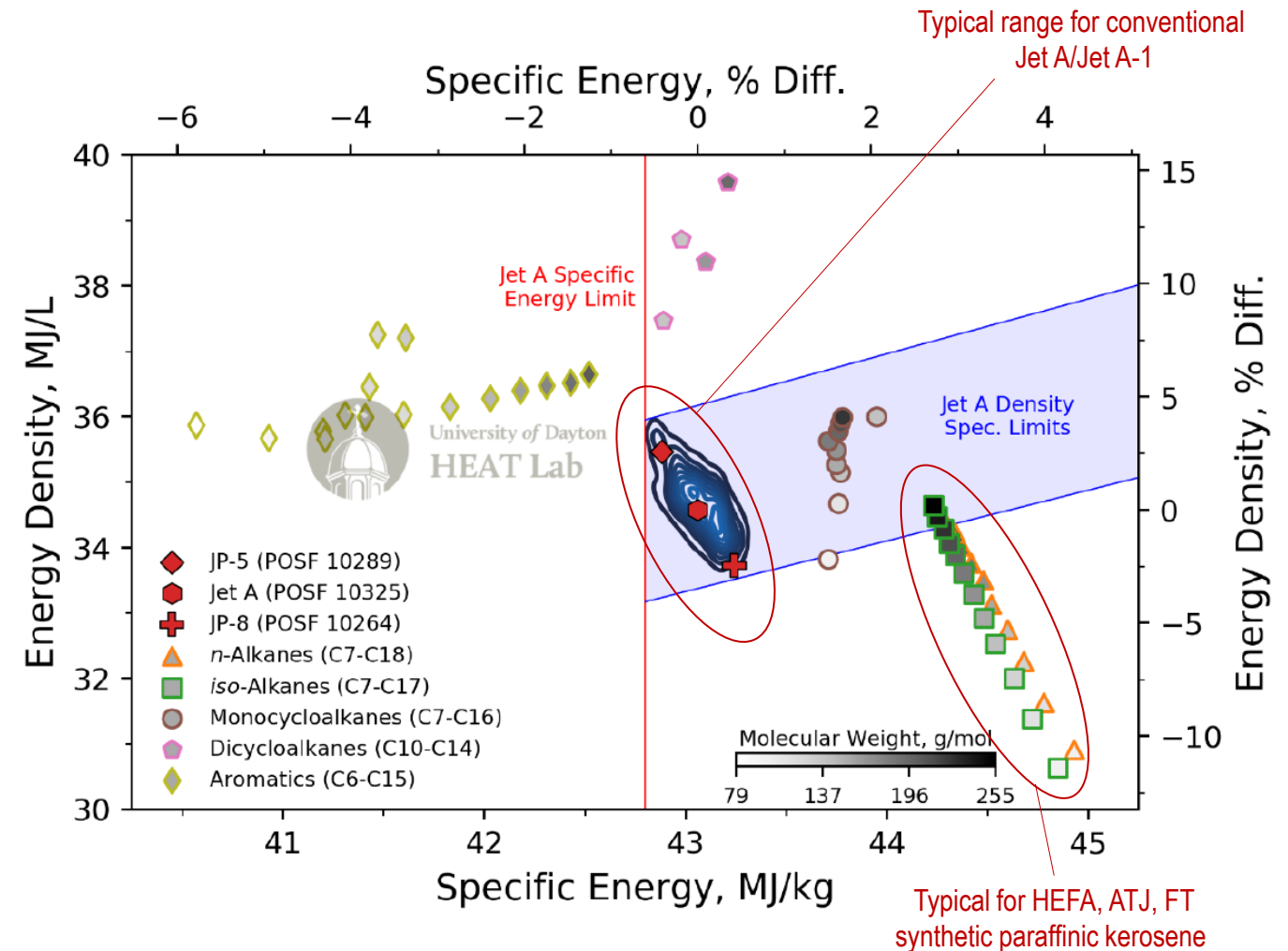
Kerosene as turbine fuel for aviation

- Almost all civil aircraft and helicopters are driven by gas turbines
- Kerosene range fuels chosen due to
 - Availability considerations
 - Global ground operation under various climatic conditions
 - Harsh ambient conditions at cruise altitude
- Most relevant jet fuel specifications
 - Jet A / Jet A-1 according to ASTM D1655



Philosophy behind 'drop-in' fuels (ASTM D7566)

- Synthetic aviation fuels have different composition
- Drop-in fuel philosophy:
 - ASTM D7655 defines batch specifications for synthetic blend components (Annexes)
 - Basic specifications for final blend almost identical to Jet A/Jet A-1
 - Final blend can be used in existing aircrafts & infrastructures

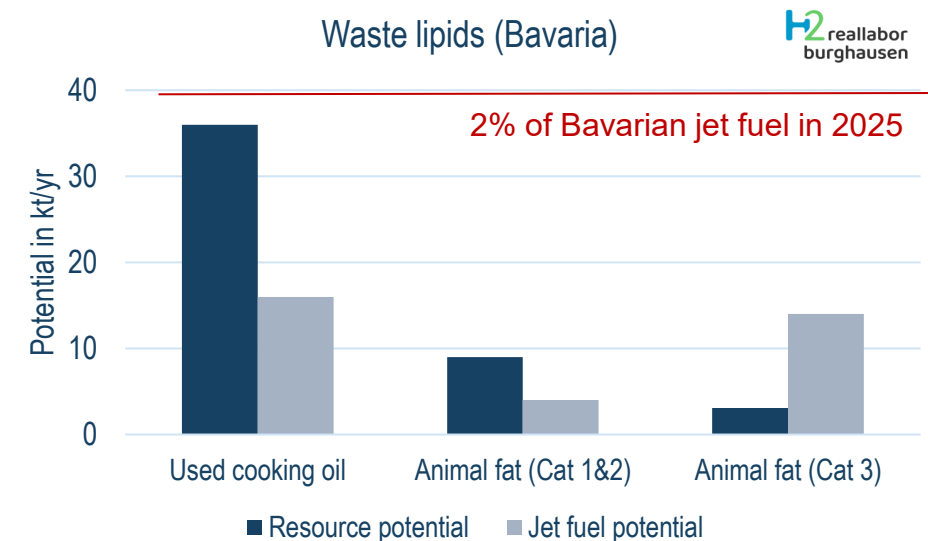
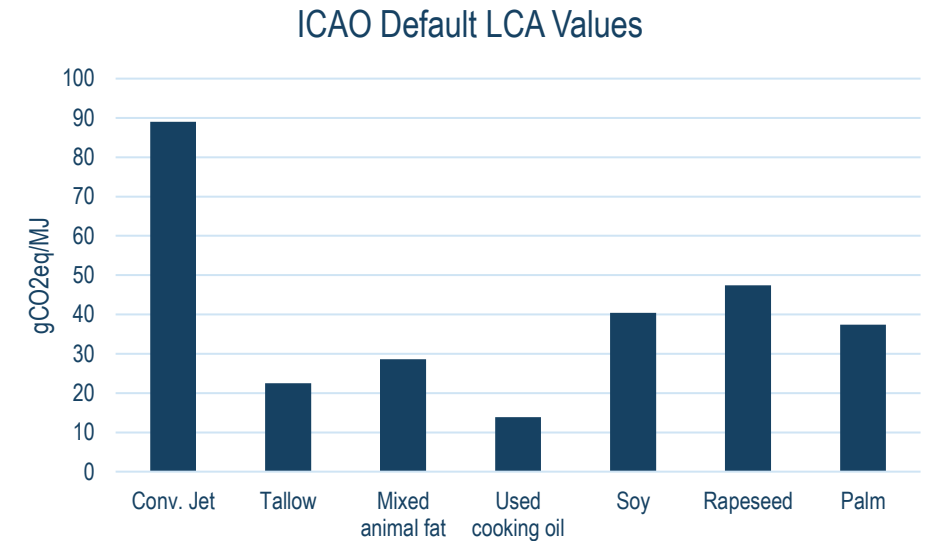


Fuel approval and qualification: Current and future pathways

- **Eight pathways approved up to 50% blend ratio (ASTM D7566)**
 - Synthetic paraffinic kerosene: **FT, HEFA, ATJ**; with aromatics: FT-SPK/A, ATJ-SKA
- **Co-processing of lipids (fats, oil, greases) and FT syncrude**
 - Up to 5% (ASTM D1655), or up to 15% (Def Stan 91-091)
- **Relevant future perspectives:**
 - Fully synthetic drop-in fuel (fully fleet compatible)
 - “Jet X”: Fully synthetic fuel with low aromatic content (requires new specification)
 - “General Annex”: General specification for new pathways at low blend ratio
 - Removal of sulphur and aromatics by hydroprocessing of conventional jet fuel

HEFA and co-processing of lipids

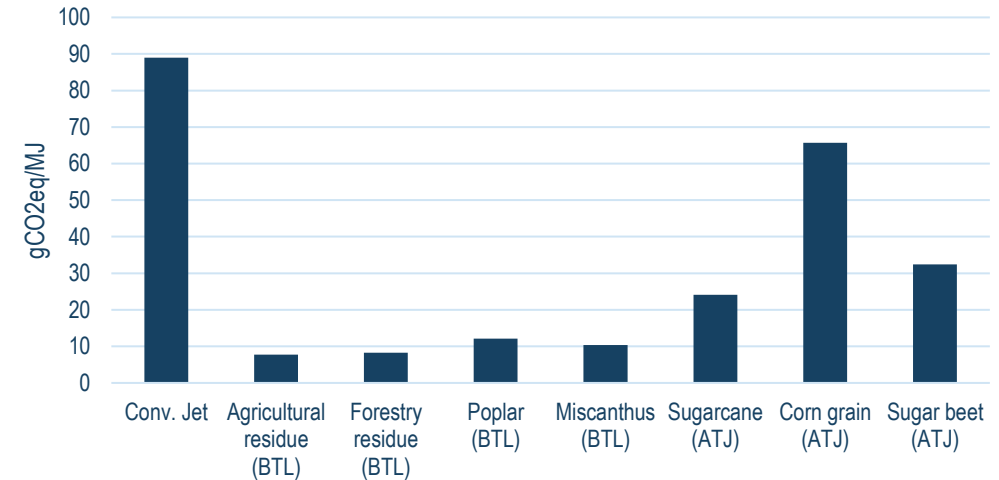
- **Key benefits**
 - Existing capacity: Mature, well-trusted technology
 - Established feedstock supply chains (biodiesel)
- **Challenges (plant oils)**
 - Cost vs. crude oil, feedstock eligibility
 - Sustainability concerns, limited GHG reduction
 - Competing pathways usually more area-efficient
- **Challenges (waste fats, oils & greases)**
 - Limited feedstock availability, fraud, protectionism



ATJ, BTL, Biogas Reforming

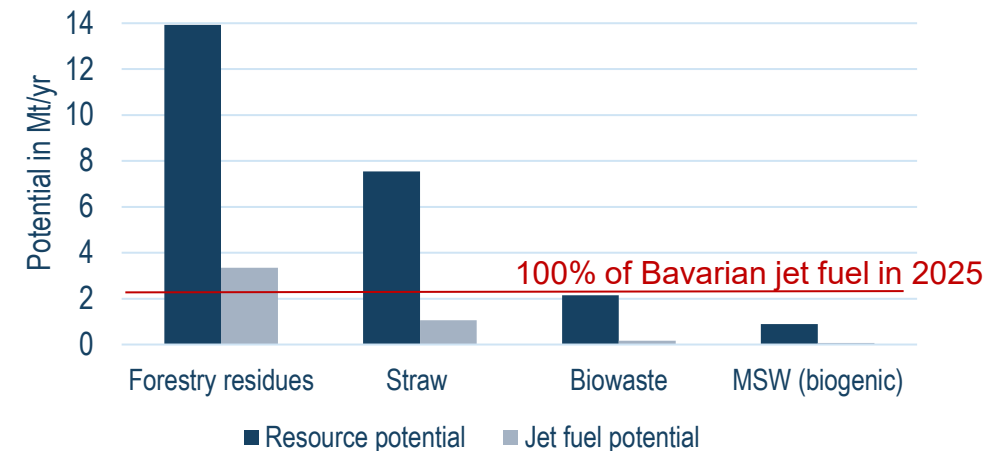
- **Alcohol-to-Jet (ATJ)**
 - Technologically mature pathway
 - Main challenges: Feedstock eligibility & cost
- **Biomass gasification & fuel synthesis (BTL)**
 - Large feedstock potential, low carbon intensity
 - Feedstock logistics, technical maturity, complexity
- **Biogas reforming & fuel synthesis (bGTL)**
 - Robust pathway for broad range of feedstock
 - Competitiveness with more direct options?

ICAO Default LCA Values



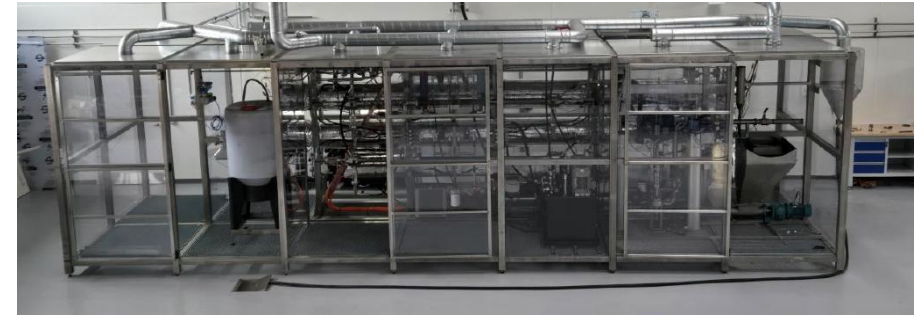
Selected residues for BTL conversion (Bavaria)

H2 reallabor burghausen

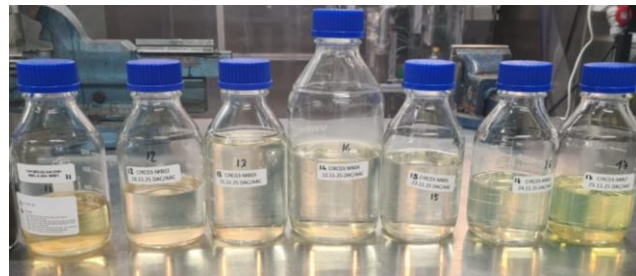


Advanced biofuels: Direct liquefaction pathways

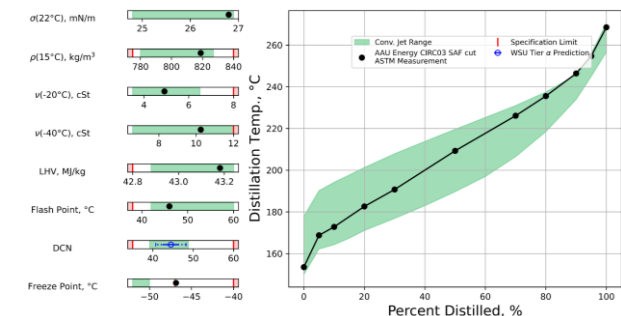
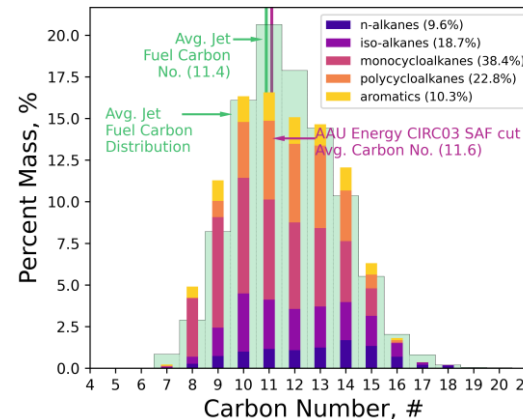
- **Pyrolysis and hydrothermal liquefaction**
 - Potentially cost effective & feedstock flexible
 - Maturity: R&D, upscale and fuel approval still required
- **Pyrolysis example: BioTheRos**
- **HTL example: EU-Horizon Europe project CIRCULAIR (next presentation)**



HTL-WO pilot plant (Aarhus University)



Upgraded HTL fuel products (Aalborg University),
kerosene samples characterized (N < 2 ppm).



Prescreening of CIRCULAIR jet fuel sample
(Credit: Washington State University)

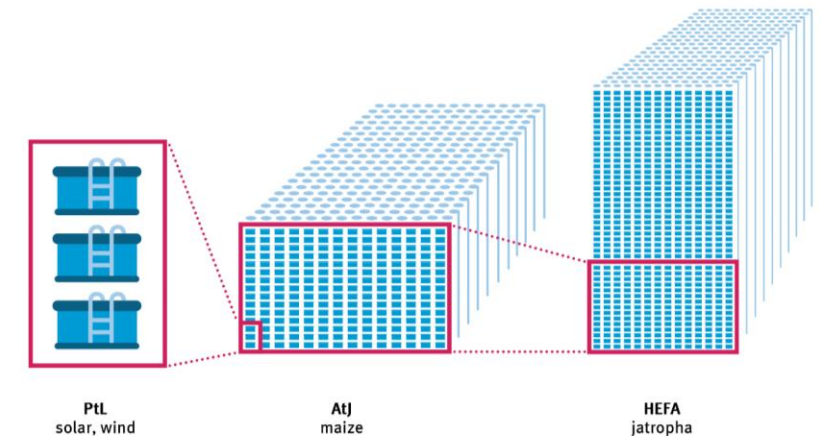
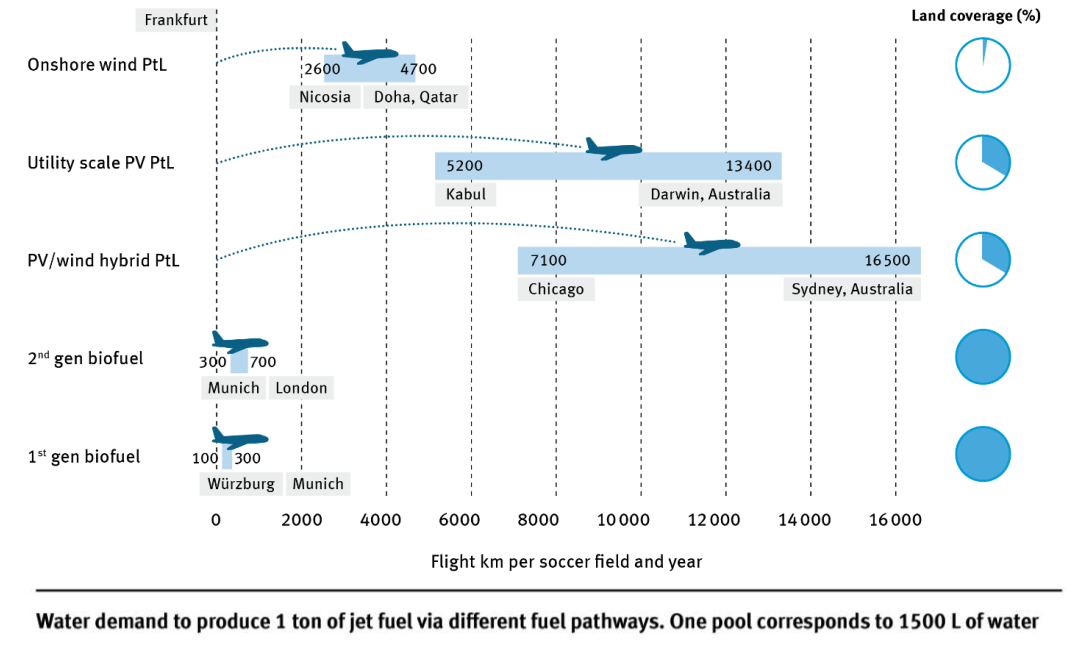
E-Fuels: Benefits & challenges

- **Key benefits**

- High production potential
- Low water demand
- Low GHG intensity >> requires low-carbon electricity and sustainable carbon supply

- **Key challenges**

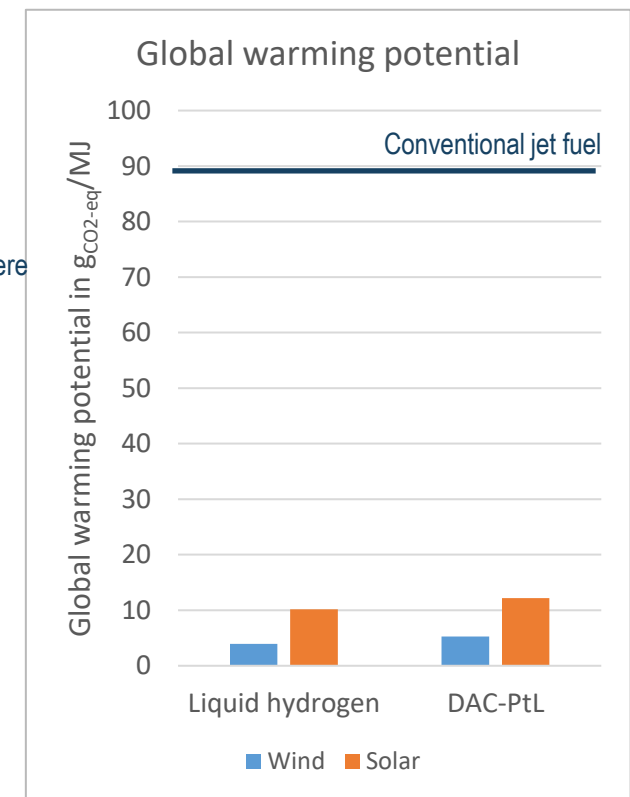
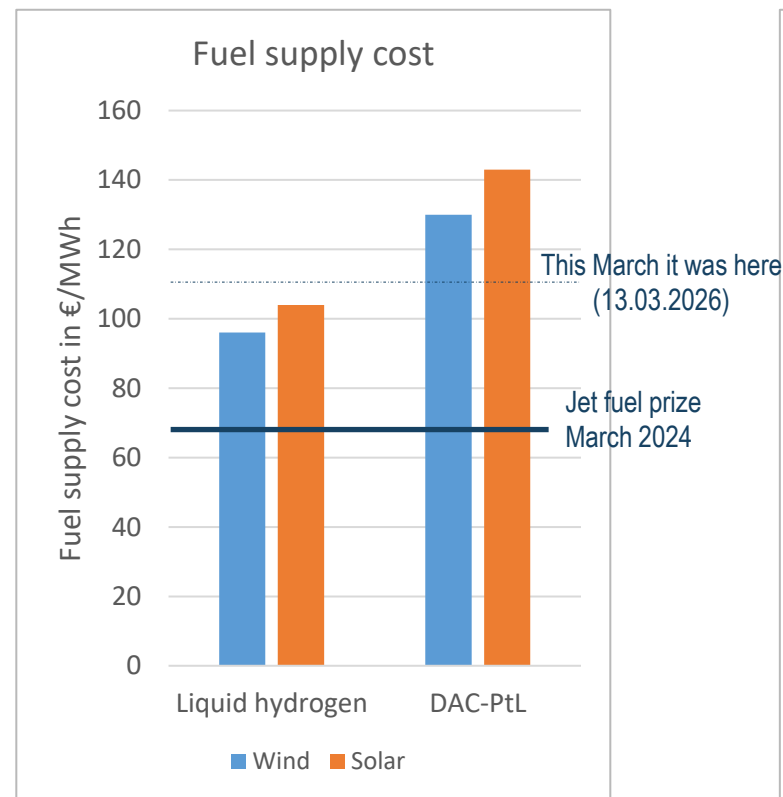
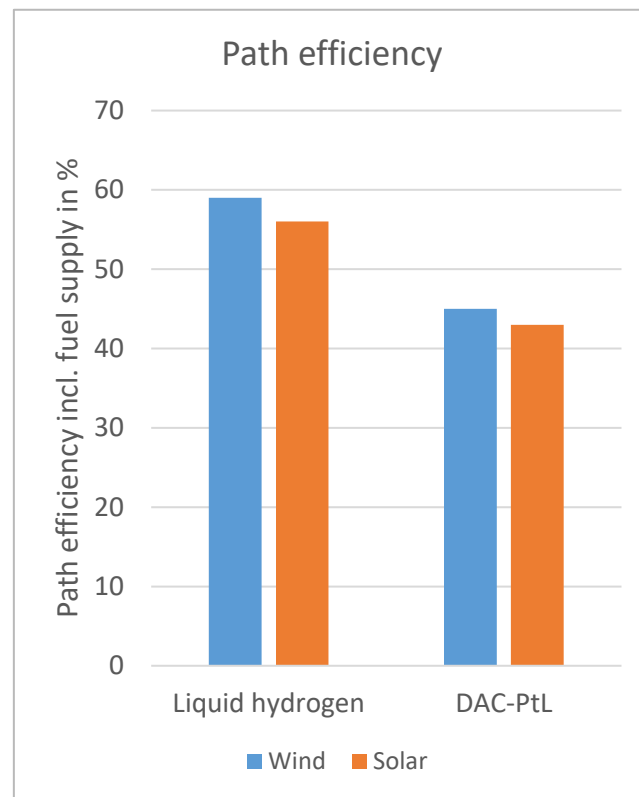
- High fuel production cost
- Complexity of projects & economies of scale
- Uncertainties about off-take



Source: BHL, LBST, *Power-to-Liquids – A scalable and sustainable supply perspective for aviation*, Background Paper 2022 www.umweltbundesamt.de/publikationen/power-to-liquids

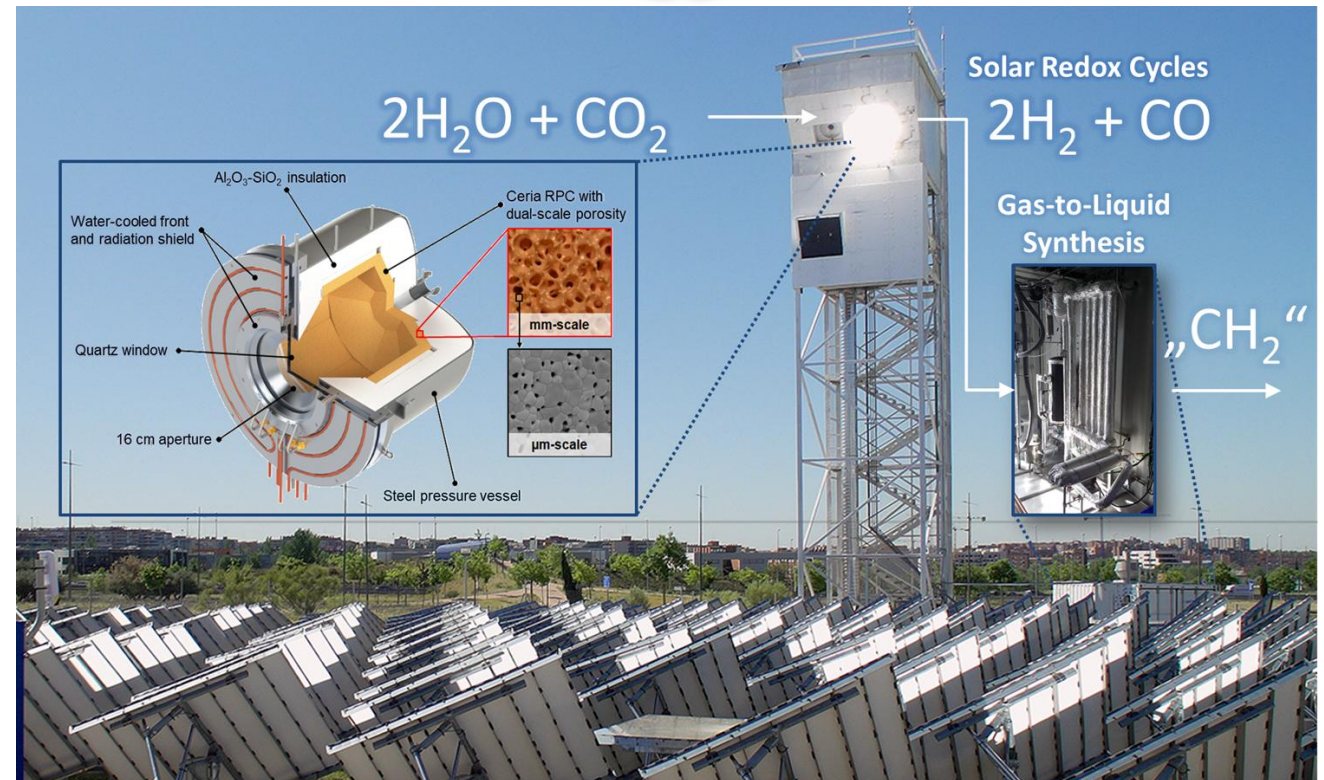
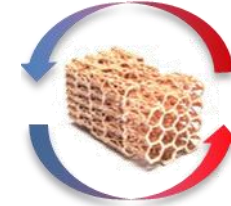
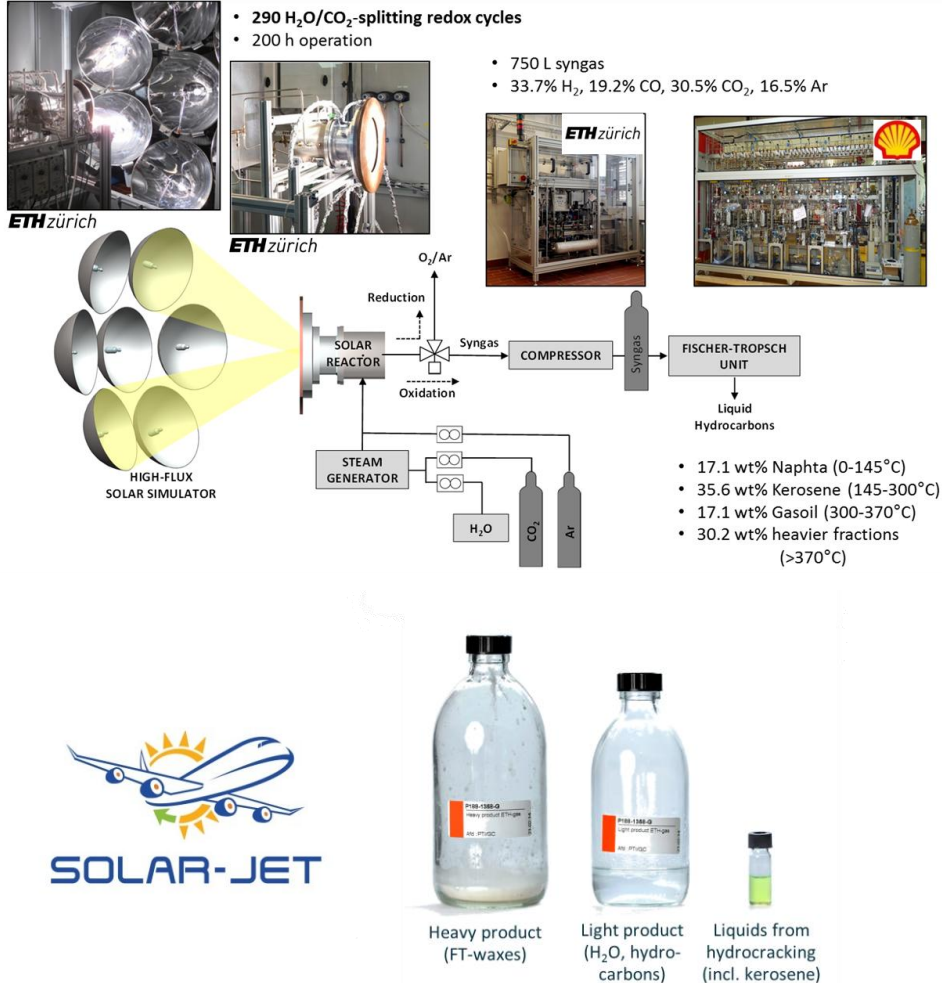
Liquid H₂ supply perspective for future H₂ aviation

- DAC-PtL & LH₂ production in Ireland/Morocco & supply to Frankfurt airport



Source Jet Fuel Price: <https://www.iata.org/en/publications/economics/fuel-monitor>

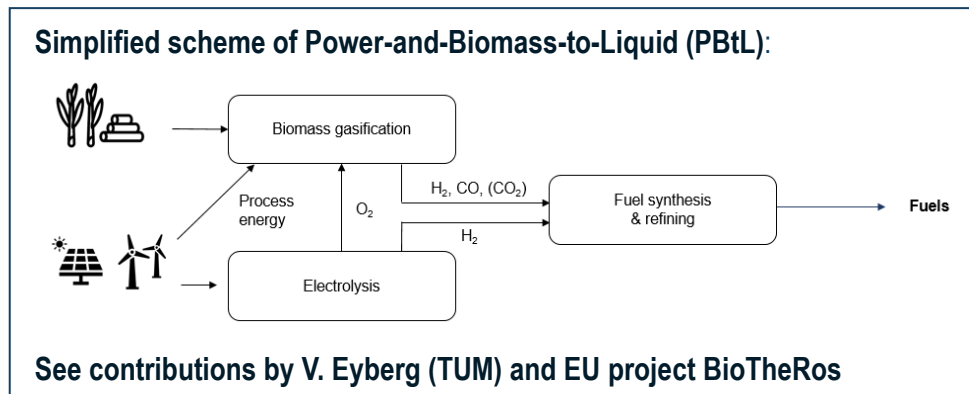
Solar fuel research: From lab to scale-up



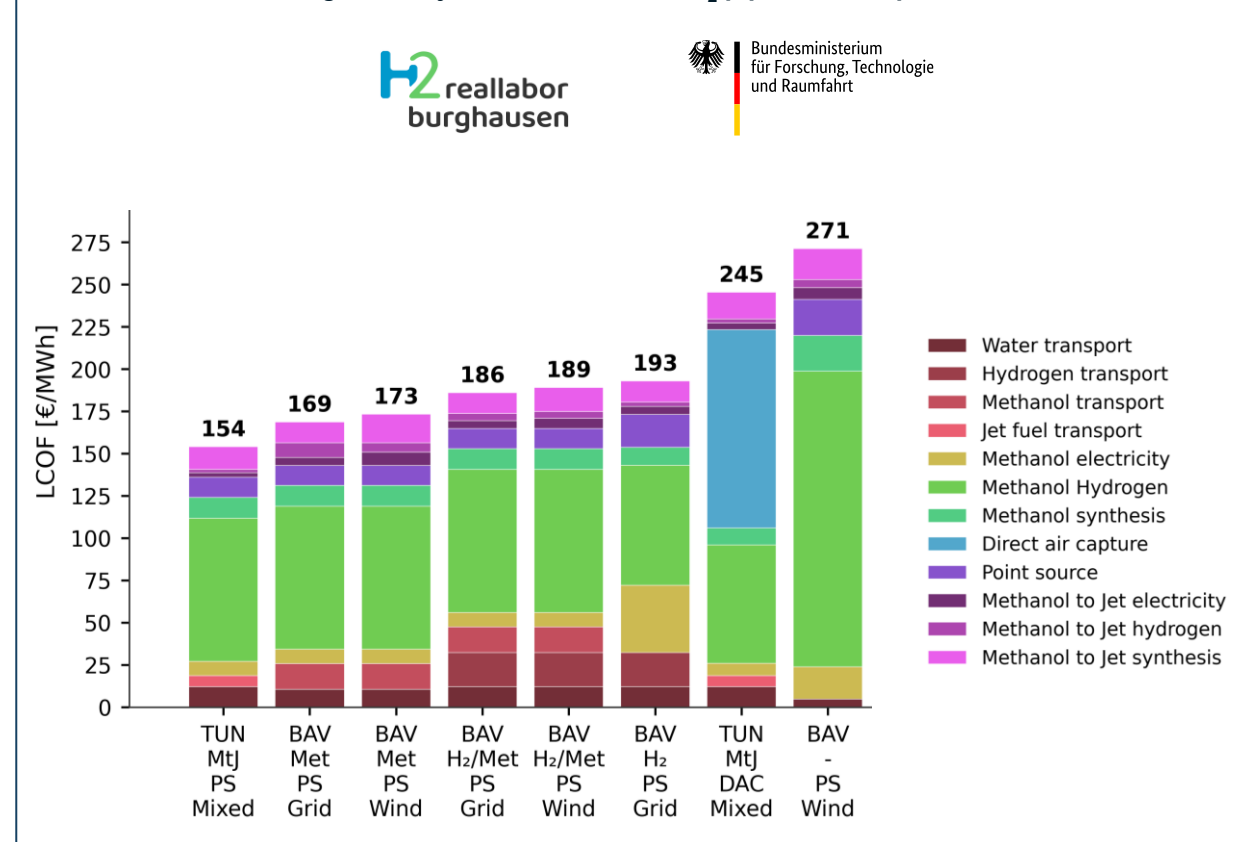
Funded by
the European Union

Coupling biomass and green H₂: PBtL & further hybrid pathways

- **Synergies & benefits**
 - Increased yield per unit biomass
 - Secured carbon supply for e-fuels
- **Coupling to H₂ pipelines infrastructure**
 - Potential: Connect regions with abundant biomass to low-cost green H₂ production



Methanol-to-Jet: Investigation of jet fuel, methanol & H₂ pipeline transport from Tunisia to Bavaria



Summary

- Aviation needs large amounts of liquid fuels to achieve climate targets
- HEFA & co-processing of lipids play an important role in early transition, but the availability of sustainable feedstock is severely limited
- ATJ taps into different feedstock bases, relies often on food & feed crops
- Lignocellulosic biomass is available in large quantities, but suitable conversion pathways are less mature than HEFA and 1st Generation ATJ
- RFNBOs promise better sustainability at scale, challenges relate to production cost, financing of complex projects and carbon supply
- Relevant synergies between green hydrogen and biomass conversion