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Hydrothermal Liquefaction of Manure

-or-

How Might a Jet Airplane Fly Renewably in the Future?

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30.01.2026 - Thematische Session 3, Energieforschungsgespräche Disentis 2026

Empa Materials Science and Technology · PSI · ETH zürich · Fachhochschule Nordwestschweiz · Università della Svizzera italiana · zhaw · Universität Basel · EPFL · Scuola universitaria professionale della Svizzera italiana SUPSI · CASALE

Why HTL? Why Now?

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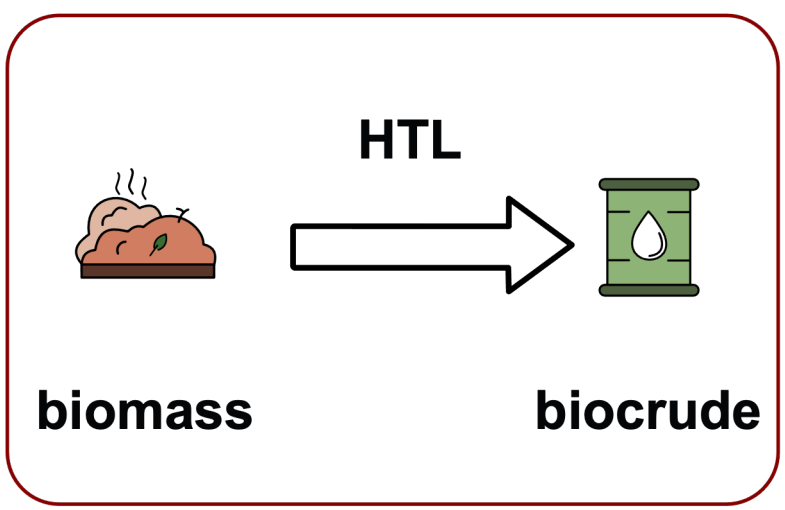
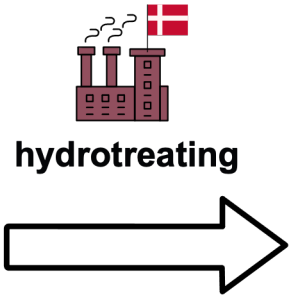
Decarbonizing the aviation sector is not immediately possible

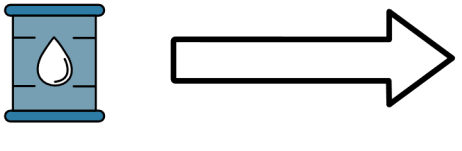
Growing energy availability concerns

https://www.rega.ch/21-neue-rega-helikopter, 27.1.2026
https://newsroom.swiss.com/willkommen-zu-hause-der-erste-a350-von-swiss-ist-in-zuerich-gelandet/, 27.1.2026

How HTL Converts Biomass to SAF Precursors

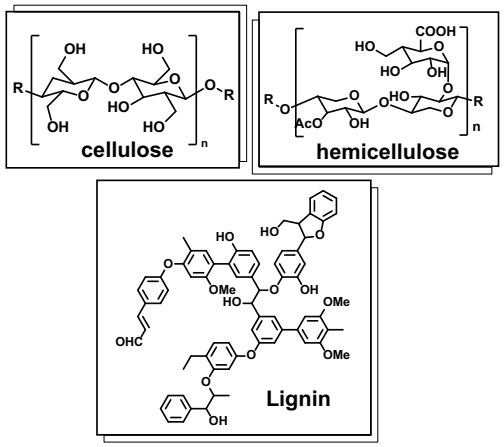


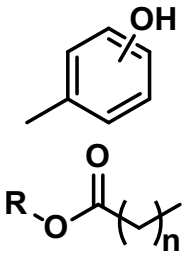




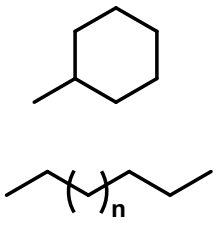
upgraded biocrude

SAF drop-in fuel





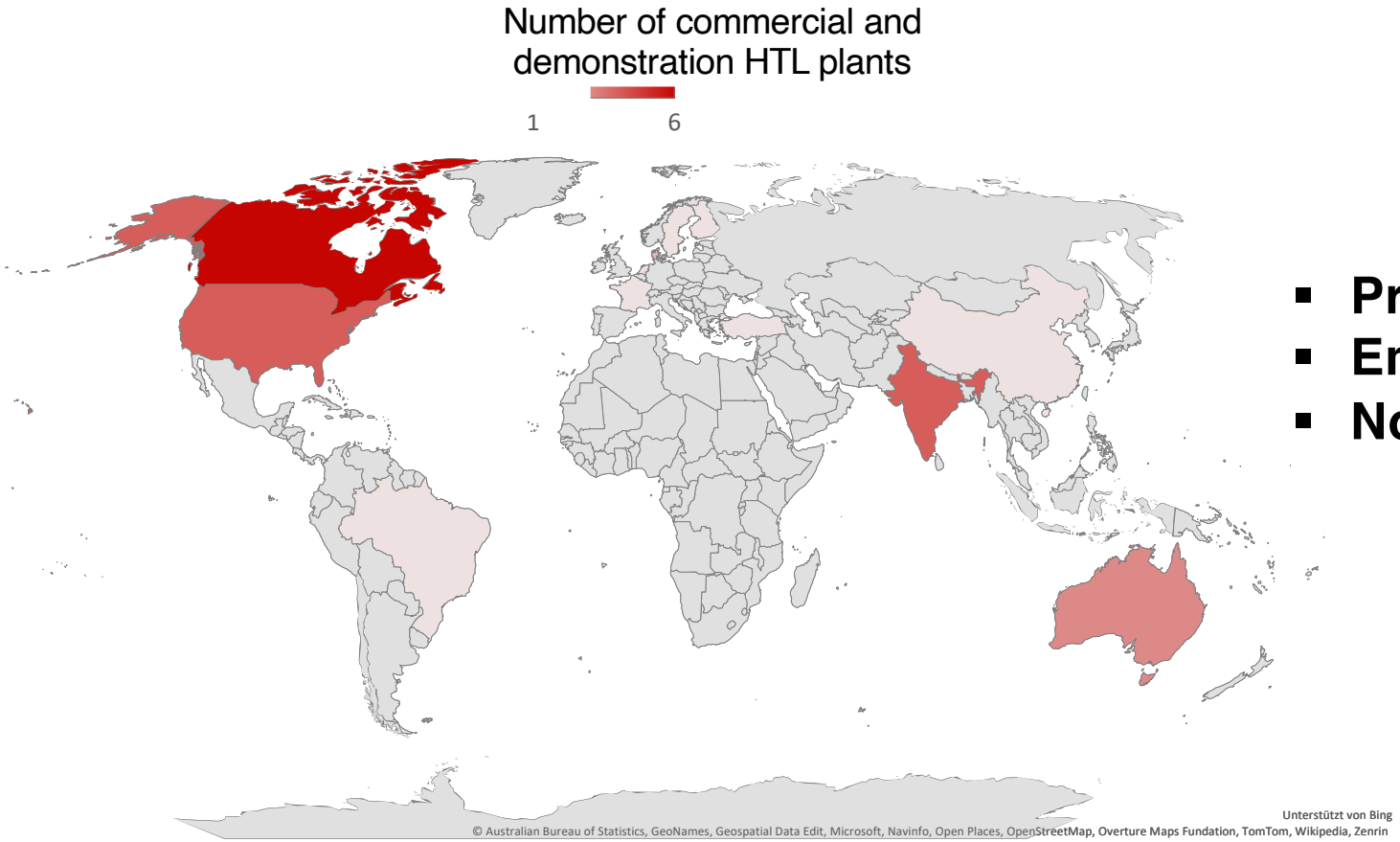
oxygenated small molecules



C_xH_y

C8-C16 hydrocarbons

Where Is HTL Today?

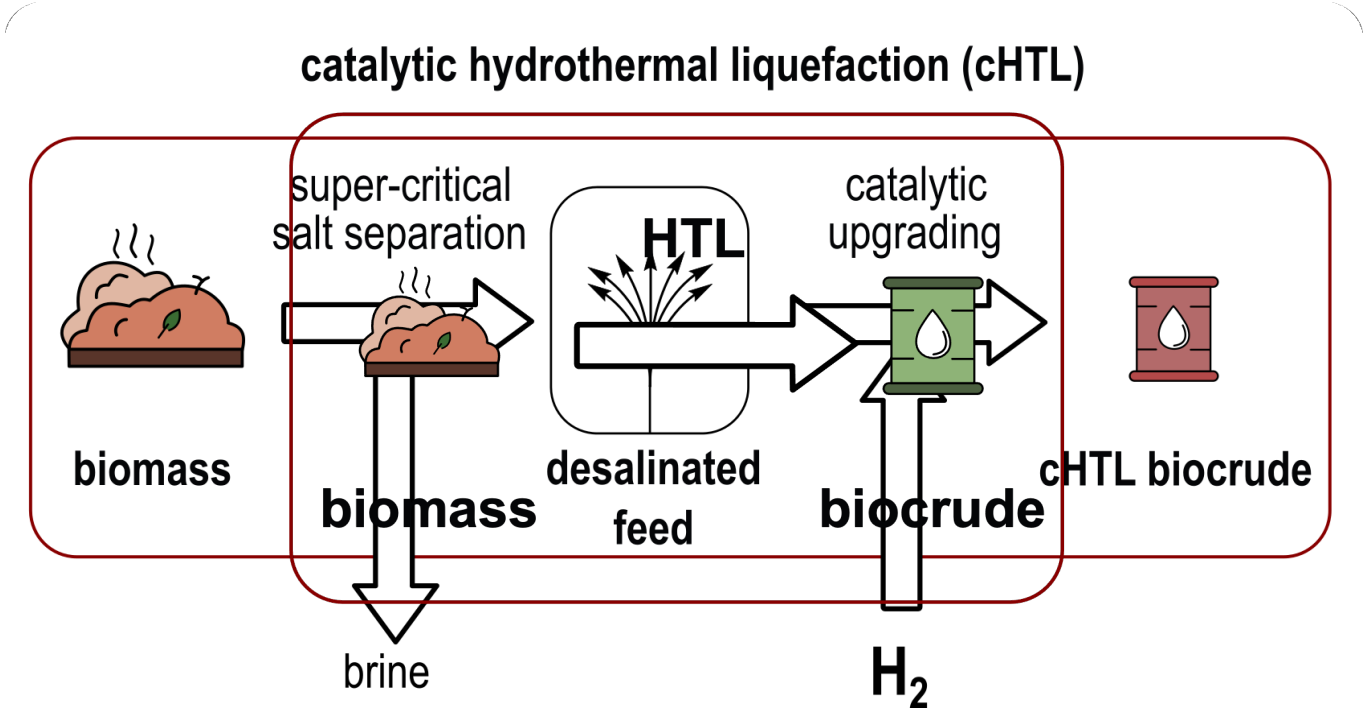


- **Primary woody biomass**
- **Emerging technology**
- **No feed-to-SAF process yet**

https://www.ieabioenergy.com/blog/publications/commercial-status-of-direct-thermochemical-liquefaction-technologies/

F. Vogel, Energie aus Biomasse, Band 2, Kapitel 8: Hydrothermale Verfahren, Springer H. Duc Pham et al, Biomass and Bioenergy, **2025**, 201, 108151

Improvements Developed Within reFuel.ch



- **Integrate salt separation into HTL**
- **Co-feed H_2 to facilitate deoxygenation and hydrogenation**
- **Demonstrate feasability at TRL4 in a continuous flow process**

R. Wang, R. Deplazes, F. Vogel, D. Baudouin, *Ind. Eng. Chem. Res.* **2021**, 60, 10, 4072 – 4085

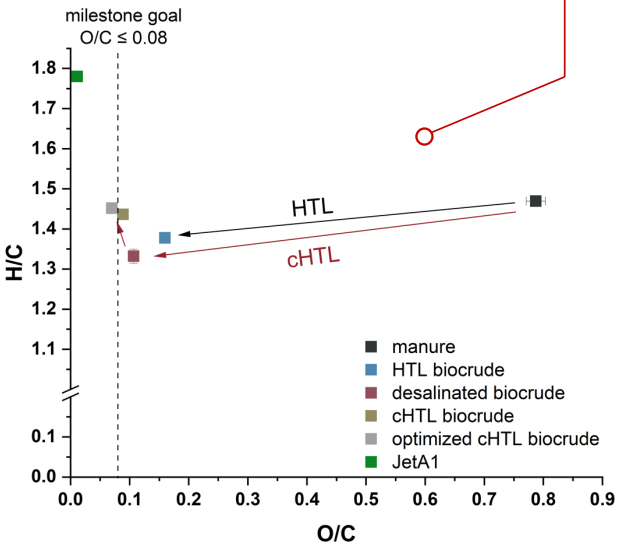
Progress of HTL at PSI/FHNW

Optimize conditions and identify catalysts for cHTL in batch mode

Operate continuous cHTL production at TRL 4 (kg/h)

Hydrotreatment of the cHTL biocrude

2025 | 2026 | 2027



TRL 2

TRL 4

https://www.sulzer.com/en/shared/applications/hydrotreating-process

project partners
AAU Denmark

Challenges in Biomass Utilization

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Economy of scale is missing

- How much biomass is required per A350-900 long-haul flight?
- **113 t Jet A1** max tank capacity
- Approximately **~1800-2000 t biomass/flight**
- **~200-400 long-distance flights/year** (4.4 Mt manure,)

Biomass ≠ Biomass

- **Challenging waste biomass** (manure, sewage sludge, food waste) is underutilized
- **Sulfur** in the feed
- **Low feed flexibility** in commercial plants (primarily wood)

No clear industrial actors in Switzerland

- Unclear location and scale for future (c)HTL plants
- Lack of commitment from the private sector

Summers, S., Yang, S., Si, B. *et al. Nat Commun,* **2025**, 16, 9570

https://education.nationalgeographic.org/resource/biomass-energy/
Reference: Werner, S., et al. (in preparation). *Assessing Eutrophication Impacts from Swiss Agriculture: A Comparison of Manure and Digestate Use as Organic Fertilizers.* Unpublished manuscript.

Take-Home Message

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- **HTL of manure can be supported by catalytic processes to reduce the oxygen in biocrude oils**
- **Transitioning cHTL with integrated salt separation to TRL4 is ongoing**
- **Fuel precursor production by HTL has a considerable potential in Switzerland to aid in the energy transition and in securing fossil fuel alternatives locally**

ACKNOWLEDGEMENT

The research published in this presentation was carried out with the support of the Swiss Federal Office of Energy as part of

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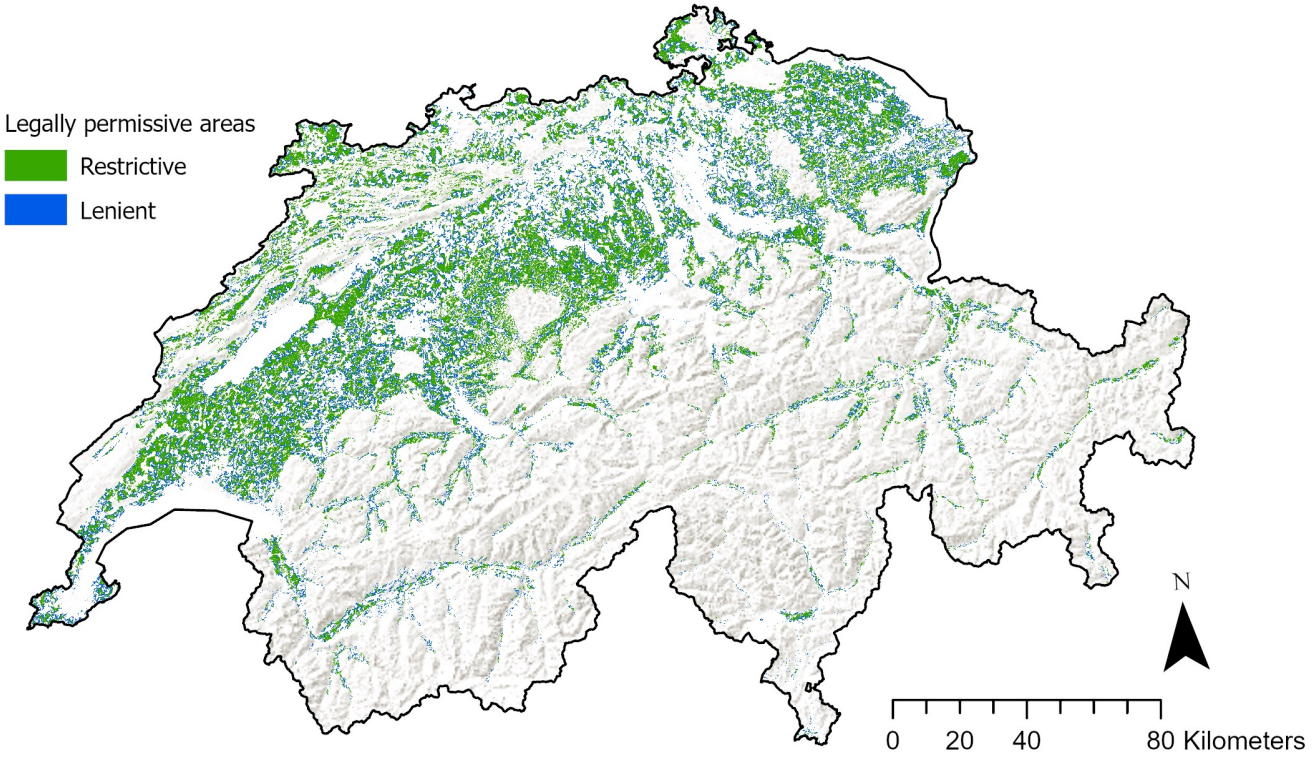
The authors bear sole responsibility for the conclusions and the results presented.

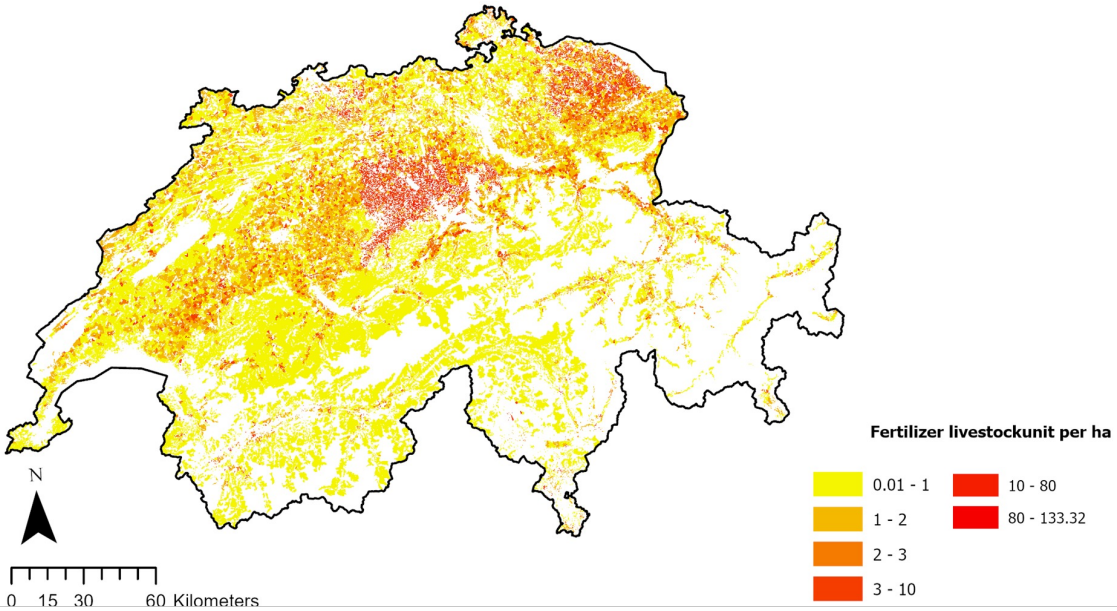
Legally permissive areas



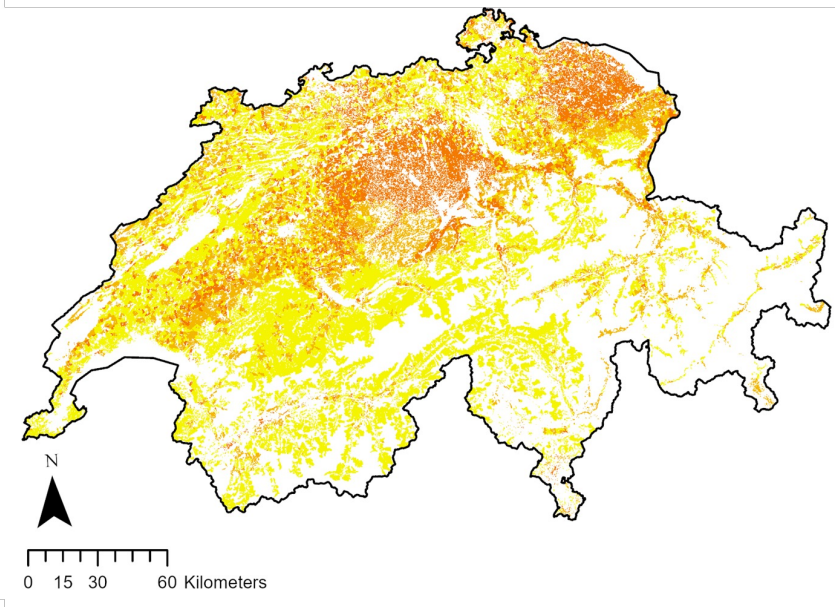
Full credit for this slide goes to Sandrine Werner, ETHZ, ESD

Manure logistics for field application

No transport



Transport



- Manure transport (farm-to-field transport)
- The current average transport distance is 11 km (minimum of 0.8 km and maximum of 29.2 km)
- Total manure transported: approximately 4.4 million tonnes
- Logistics of manure is a key factor for balancing nutrient application across regions

Full credit for this slide goes to Sandrine Werner, ETHZ, ESD

Reference: Werner, S., et al. (in preparation). *Assessing Eutrophication Impacts from Swiss Agriculture: A Comparison of Manure and Digestate Use as Organic Fertilizers*. Unpublished manuscript.