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Horizon Europe

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Jet fuel from hydrothermal liquefaction of abundant agricultural residues

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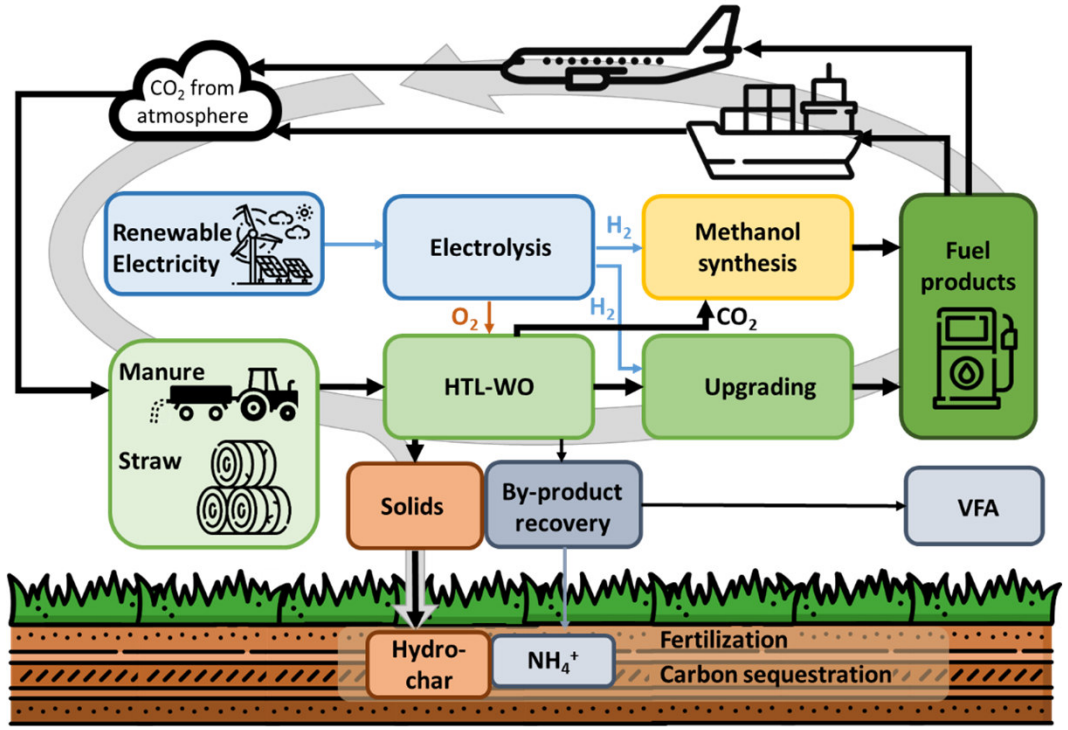
Horizon Europe CIRCULAIR (1/2023-12/2026)

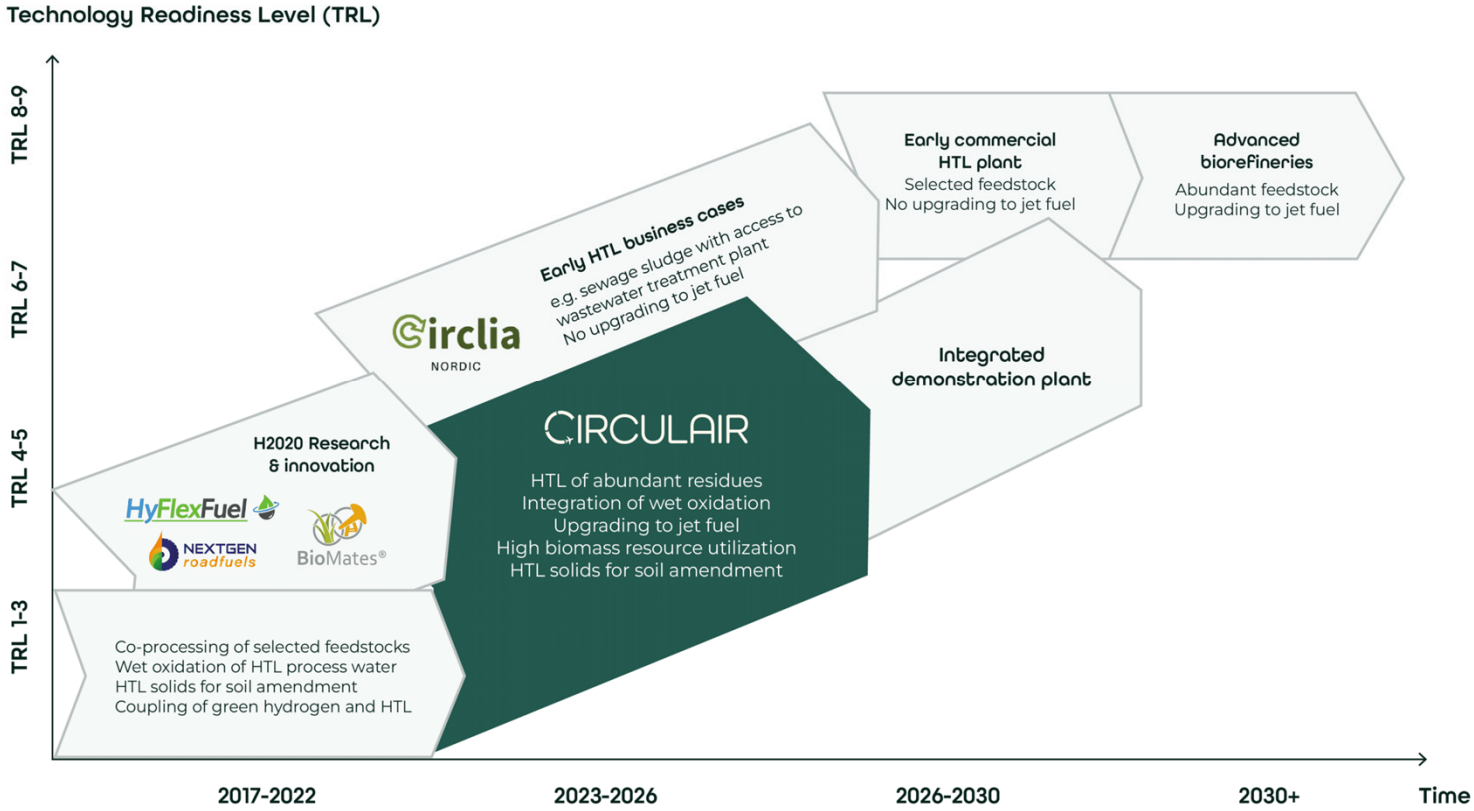
- CIRCULAIR demonstrates the production of jet fuel, methanol and further products from manure and straw via hydrothermal liquefaction (HTL)



www.project-circulair.eu

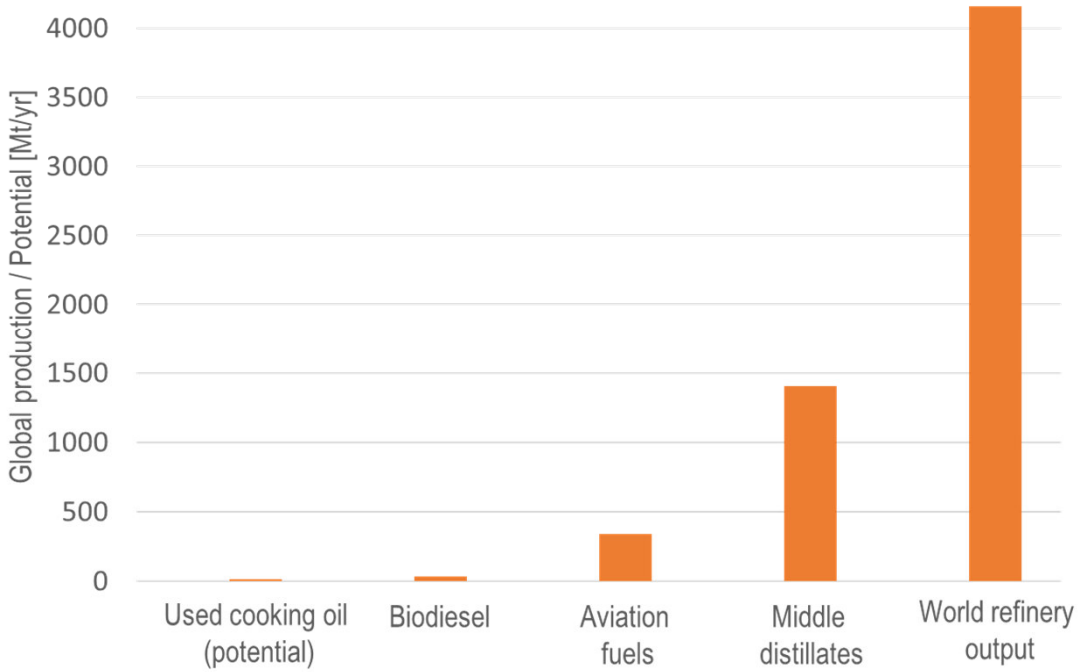
CIRCULAIR: Relation to H2020 and HTL commercialisation

- Roadmap: CIRCULAIR prepares the next wave of HTL commercialisation



Global Aviation Fuel Consumption in Relation (2019 Data)

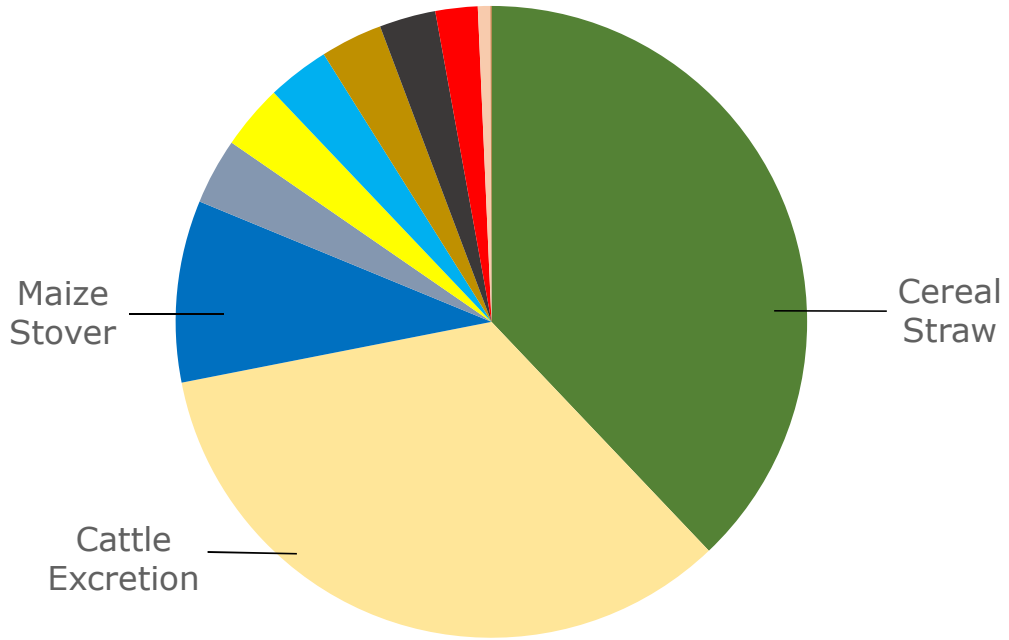
- Aviation fuels: About 8% of global refinery output
- Feedstock competition in middle distillate markets (diesel, marine & jet fuels)
  - Severe limitation for fuels from waste lipids (oils, fats & greases)
- Need for additional pathways
  - Biofuels from advanced feedstock
  - Synthetic fuels from H_2 and CO_2



Sources: IEA Key World Energy Statistics, Refining by product, 2019 data; Used cooking oil: EWABA; Biodiesel: UFOP

Quantification of feedstock potentials in EU-27 and UK

- **Cereal straw, cattle excretions and maize stover more than 80% of selected biogenic residues (forestry excluded here)**



Residue	t/dm	%
Cereal Straw	111,218,767	37.90
Cattle Excretions	99,833,871	34.02
Maize Stover	27,303,796	9.31
Pigs Excretions	9,894,913	3.37
Biogenic Municipal Waste	9,701,468	3.31
Sewage Sludge	9,331,943	3.18
Oilseed Rape Straw	9,315,992	3.17
Sunflower Straw	8,495,328	2.90
Sugarbeet Leaves	6,294,350	2.15
Rice Straw	1,948,126	0.66
Poultry Excretions	86,004	0.03
Total	**293,424,558**	**100.00**

Based on maximum technical biomass potential

Source: F. Bellot, DBFZ, HyFlexFuel Final Workshop 2021, https://www.hyflexfuel.eu/wp-content/uploads/11_2021-09-24_HFF_Final_Workshop_DBFZ_v1_Bellot_FINAL.pdf

HTL feedstock potentials: Wastes and residues in EU

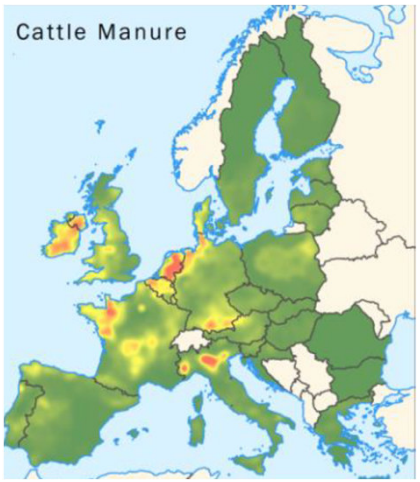
- ***H2020 HyFlexFuel/DBFZ: Spatial analysis of residue and waste availability in Europe***
  - **Feedstock density maps available for: Animal excretions, agricultural residues, sewage sludge…**
- ***Conversion to theoretical annual fuel production potentials (HyFlexFuel yield model):***
  - **Agricultural by-products: 26-29 Mt**
  - **Animal excretions: 10-26 Mt**
  - **Sewage sludge: 3 Mt**

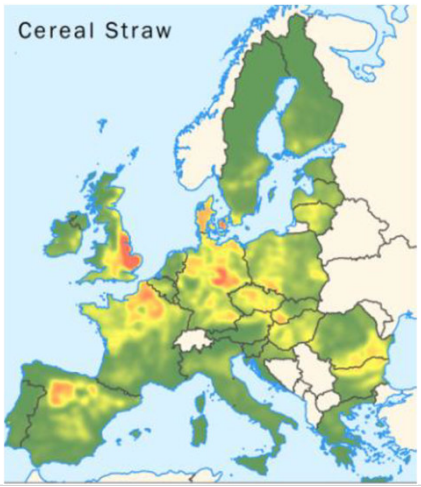
Potentials refer to mixtures of liquid hydrocarbons!

- ***Potentials are significant, but limited***

>> Increase fuel yield (high carbon utilization)

>> Increase selectivity to target products

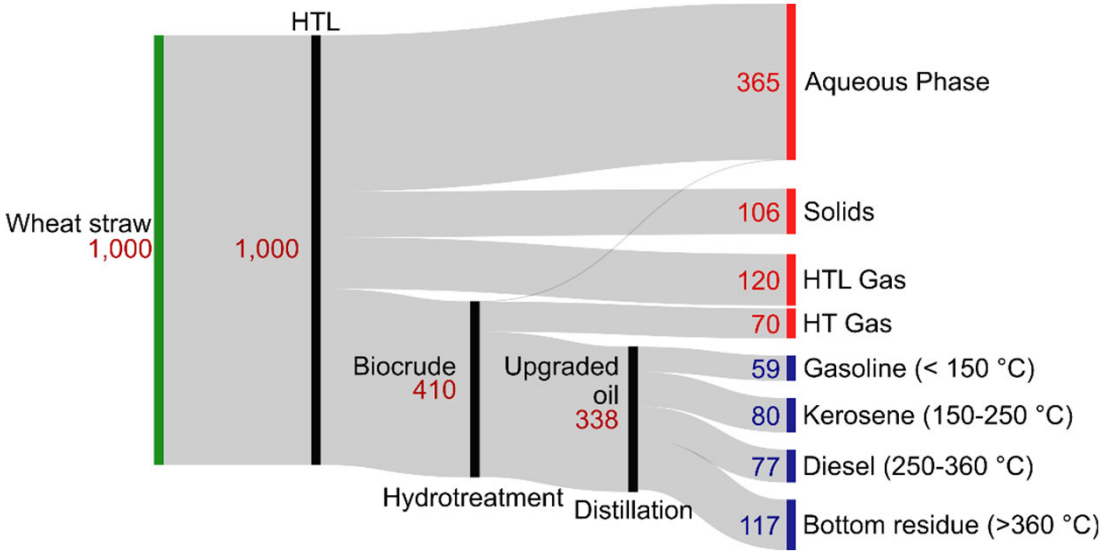


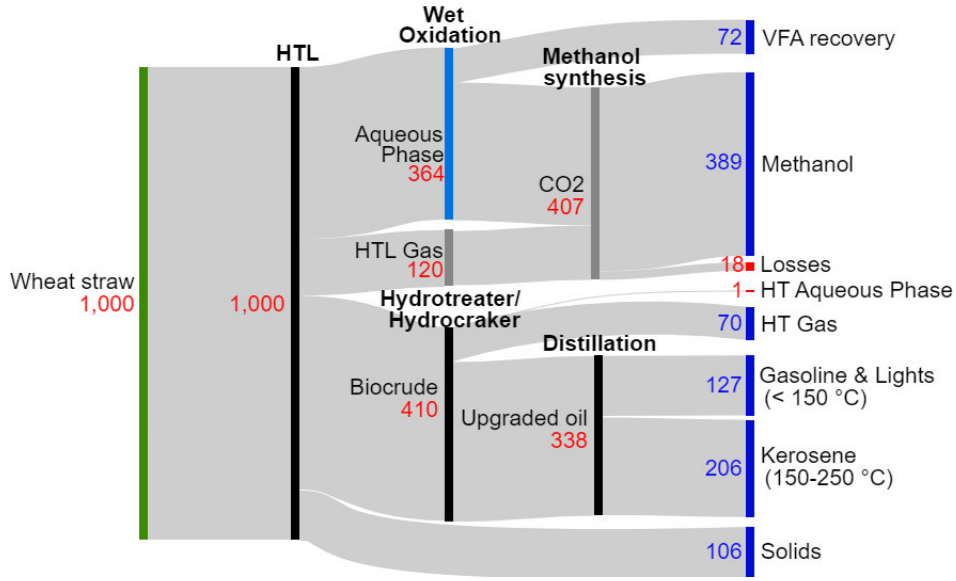


Sources: Horschig et al. *Regional feedstock potentials and preference regions for HTL projects*, HyFlexFuel Public Deliverable 2019.
F. Bellot, DBFZ, HyFlexFuel Final Workshop 2021

CIRCULAIR: Ambition beyond state-of-art

- Integration of HTL with wet oxidation of HTL process water
- Nearly-complete biomass utilization:
  - Recovery of suitable products from all major by-product streams
- Biocrude upgrading: Large kerosene fraction, fulfill jet fuel specifications





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Note: Numbers within the shown carbon balances are indicative to explain the concept. Please do not cite or quote.

CIRCULAIR Main Objectives

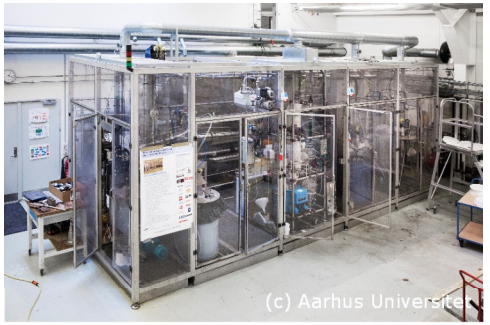
OBJECTIVES

1. Develop and demonstrate a cost-effective pathway to biofuel production from abundant feedstock
2. Produce **a high share of** on-specification jet fuel from HTL biocrudes
3. Prepare near-complete biomass utilisation by coupling with green hydrogen
4. Enable negative contributions to the green house gas (GHG) balance of HTL fuel production

Cost-effective path to biofuels from abundant feedstock

- HTL increasingly perceived as prime option for wet waste conversion to biofuels
- CIRCULAIR addresses HTL's process water challenge
  - Wet oxidation (WO) to reduce COD of HTL process water
  - Exothermal WO can cover a high share of process heat demand
  - CIRCULAIR target: Autothermal HTL

48 h continuous operation demonstrated in H2020 HyFlexFuel



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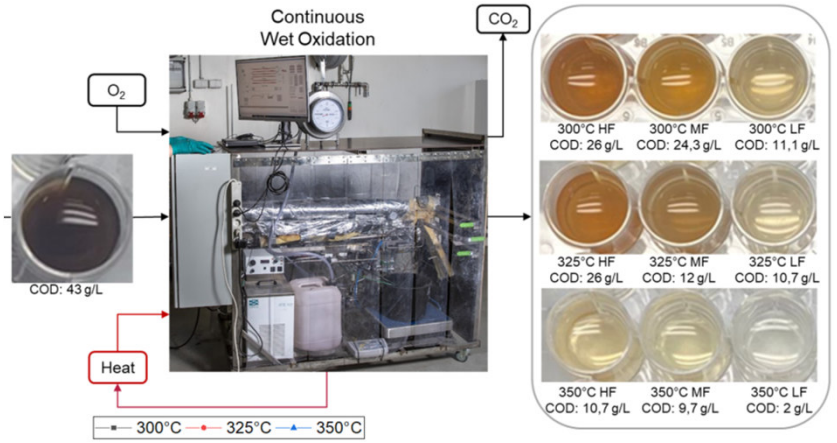
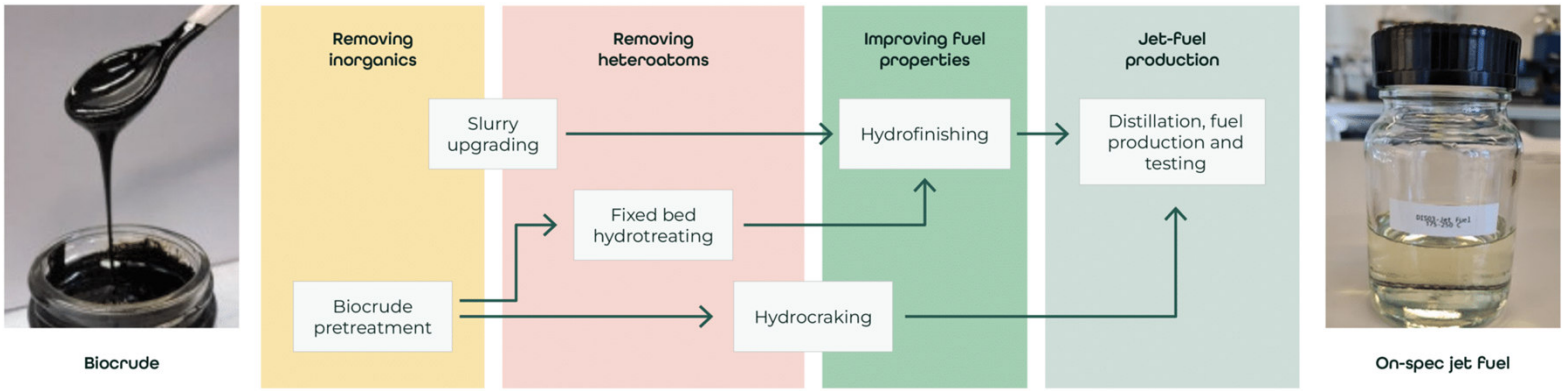
HyFlexFuel

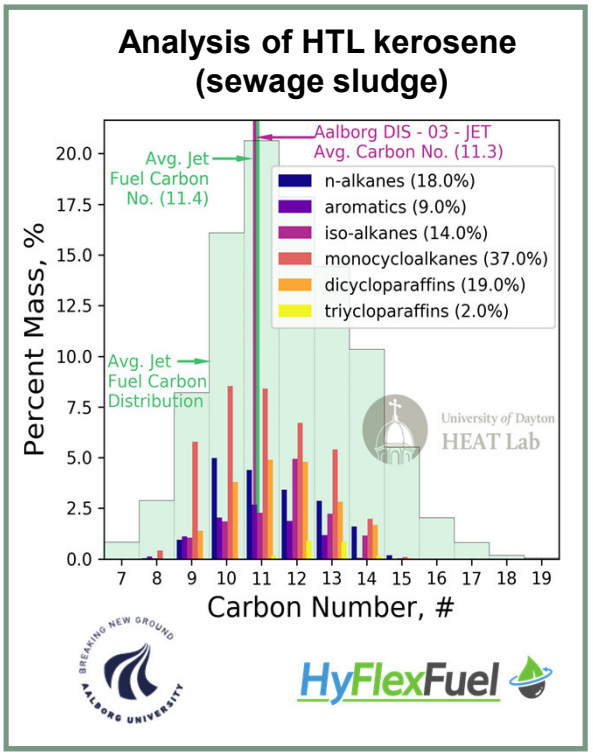


Source: Anastasakis et al., *Continuous Hydrothermal Liquefaction of Biomass in a Novel Pilot Plant with Heat Recovery and Hydraulic Oscillation*, Energies 2018, *11*(10), 2695
Biller; Wet Oxidation as an Enabling Technology for Hydrothermal Liquefaction, pyroliq conference 2023

High share of on-specification jet fuel from HTL biocrude

- Tailored upgrading schemes to convert the HTL biocrude to on specification jet fuel
  - Hydrocracking of distillation residue to achieve a high share of jet fuel

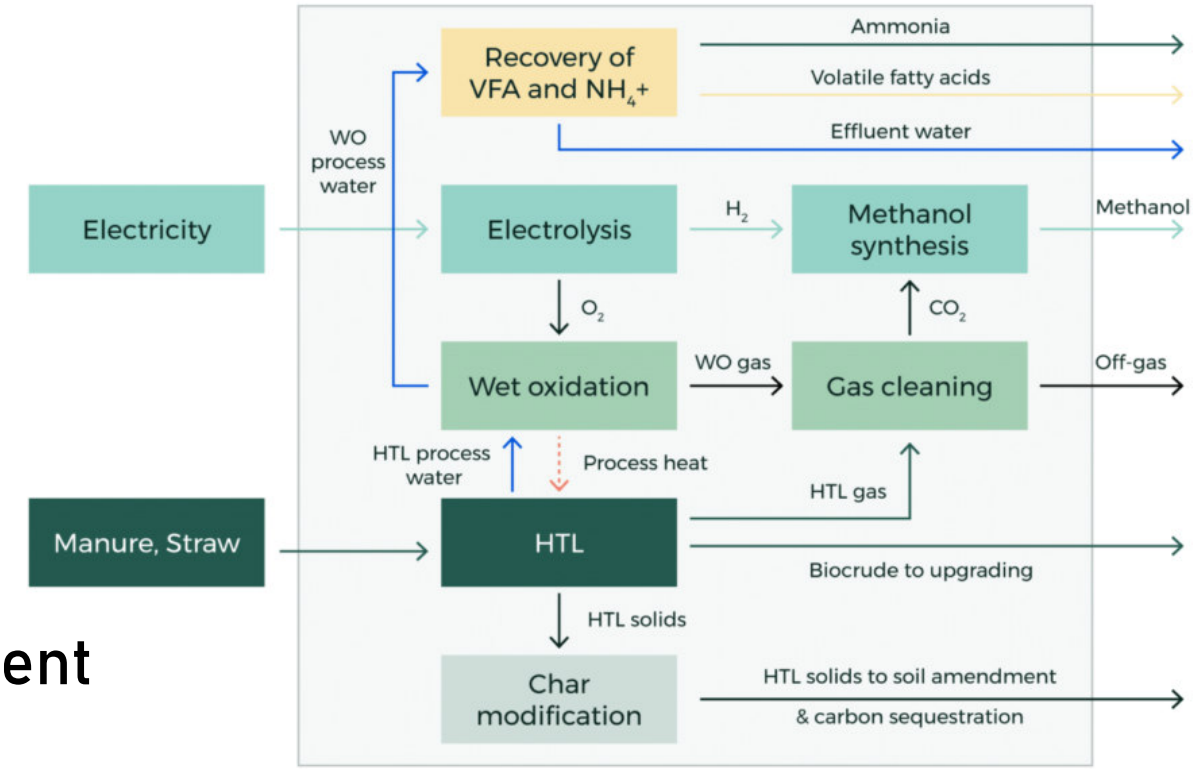




Source: Castello, *Hydroprocessing of HTL biocrudes to liquid fuels: Lessons learned and milestones achieved*, HyFlexFuel Final Project Workshop, 2021

Coupling with PtX for near-complete biomass utilisation

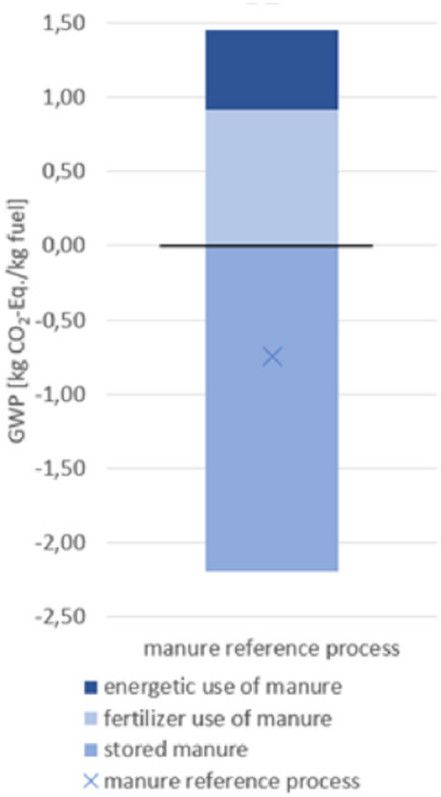
- Wet oxidation (WO): Energetic use of HTL process water
- CO_2-recovery from HTL gas and WO gas
- Conversion of CO_2 to methanol using green H_2
- Recovery of VFA and NH_4 from process water after wet oxidation
- HTL solids for soil amendment



PtX: Power-to-X (X stands for methanol here), VFA: Volatile Fatty Acids, WO: Wet oxidation, HTL: Hydrothermal liquefaction

Negative contributions to the GHG balance of HTL

- HTL solids for carbon sequestration
  - CIRCULAIR investigates the utilisation of (stabilized) HTL biochars for soil amendment in agriculture
- Change in manure handling practise
  - Avoided emissions from manure storage can exceed forgone credits (energetic use, fertilizer use)
- Further potential options:
  - HTL of perennial grasses (increased soil carbon)
  - Sequestration of CO_2 streams from HTL conversion (BECCS as alternative to utilization of CO_2)



Source: Moser, *Life-cycle assessment of renewable fuel production via hydrothermal liquefaction of manure in Germany*, Sustainable Energy Fuels, 2023

Summary and Conclusion

- Liquid fuels are needed to achieve climate targets in aviation & shipping
  - Specific need for fuels from advanced biomass feedstock, wind & solar
- HyFlexFuel demonstrated HTL conversion & upgrading (various feedstock)
  - Commercialization underway for selected cases such as sewage sludge
- Horizon Europe CIRCULAIR, perspective:
  - HTL conversion of abundant agricultural residues (manure, straw)
  - Address HTL's process water challenge by wet oxidation
  - Maximize jet fuel yield & quality by appropriate upgrading schemes
  - Enable almost complete feedstock utilization by coupling with green H_2 and further product recovery
  - Close knowledge gaps regarding the use of HTL solids for soil amendment and carbon sequestration

Thank you!

For questions,
please contact:

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