

CIRCULAIR

Coupling jet fuel from abundant agricultural residues to green hydrogen, a system perspective.

Valentin Batteiger, Christina Penke,
Leonard Moser, Bauhaus Luftfahrt

1st ICSAR, 9.7.2025, Dublin



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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)



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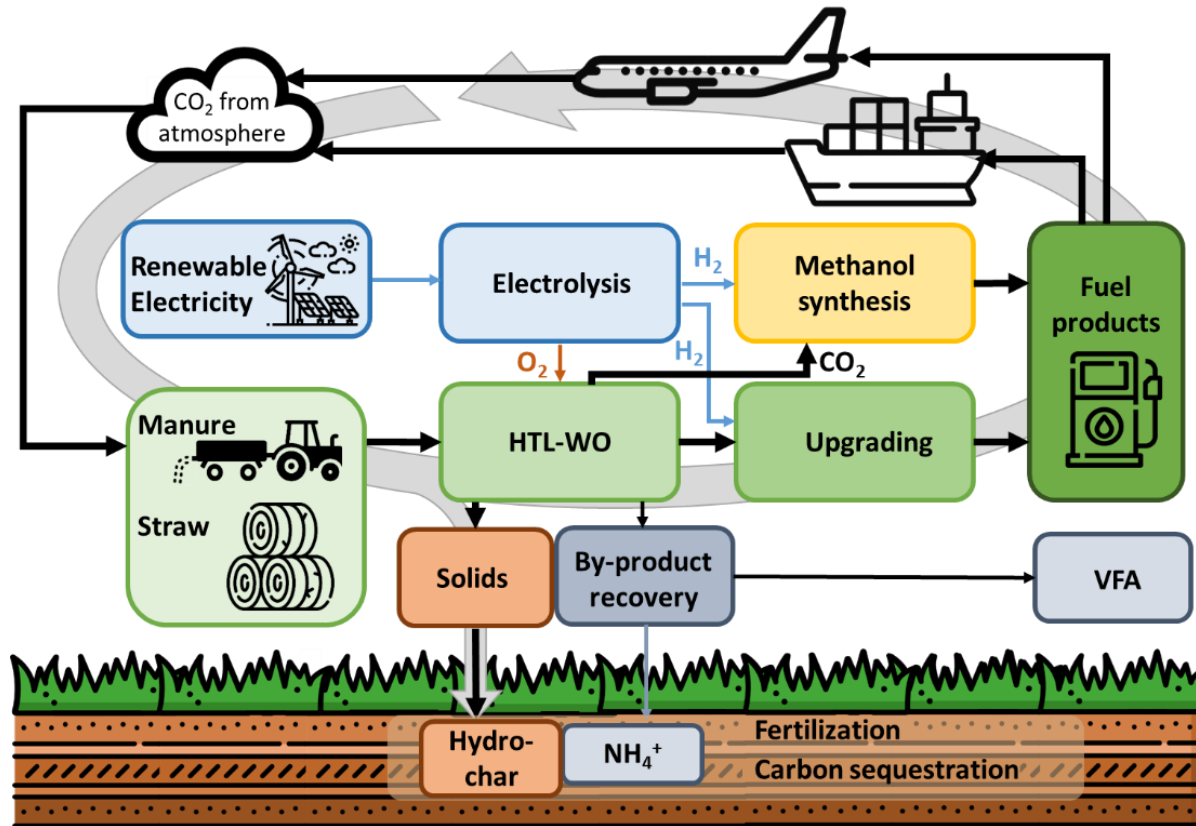
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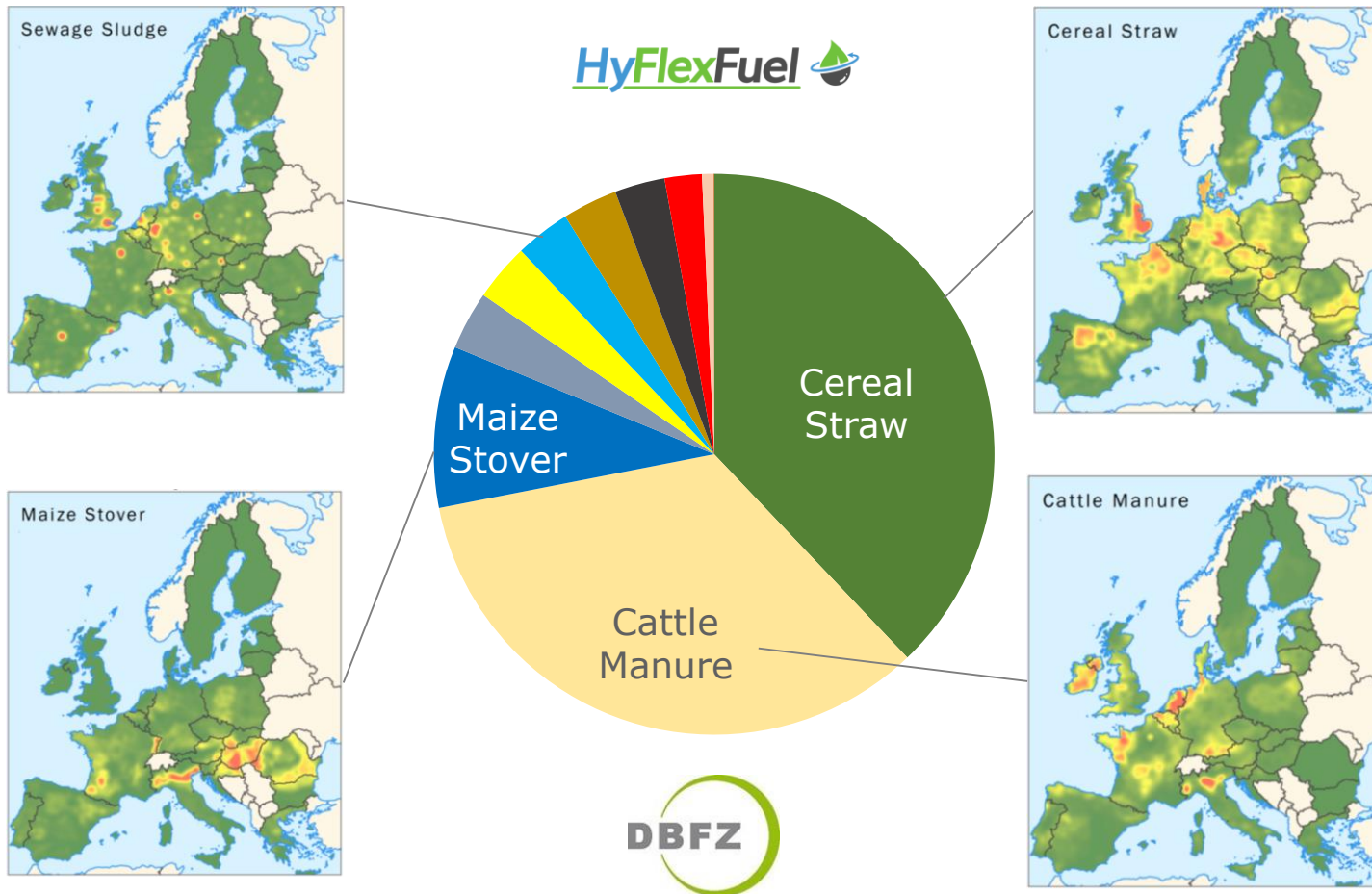
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HTL-WO: Hydrothermal liquefaction (HTL) coupled to wet oxidation (WO) of HTL process water
VFA: Volatile Fatty Acids, here: mainly acetic acid from WO process water

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Quantification of residues & wastes in EU-27 & UK



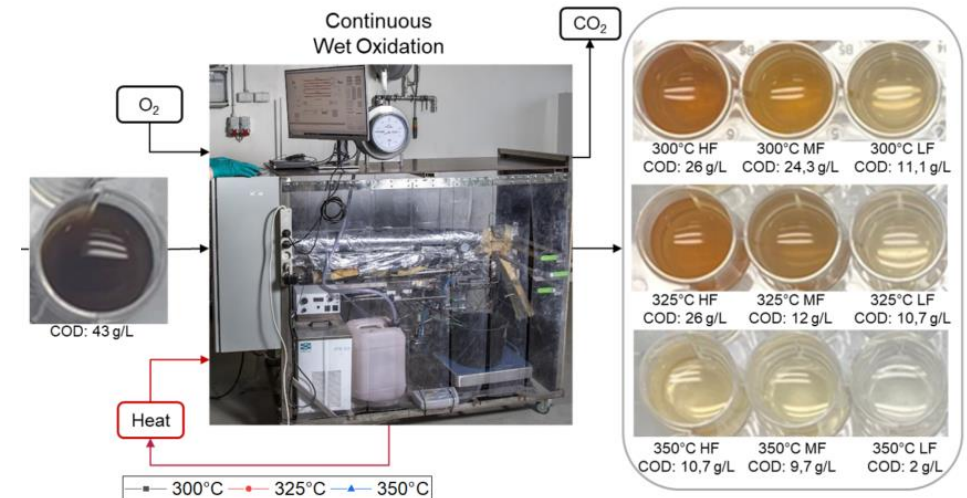
Residue	t/dm	%
Cereal Straw	111,218,767	37.90
Cattle Excretions	99,833,871	34.02
Maize Stover	27,303,796	9.31
Pigs Excretions	9,894,913	3.37
Biogenic Municipal Waste	9,701,468	3.31
Sewage Sludge	9,331,943	3.18
Oilseed Rape Straw	9,315,992	3.17
Sunflower Straw	8,495,328	2.90
Sugarbeet Leaves	6,294,350	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 (Forestry excluded)

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

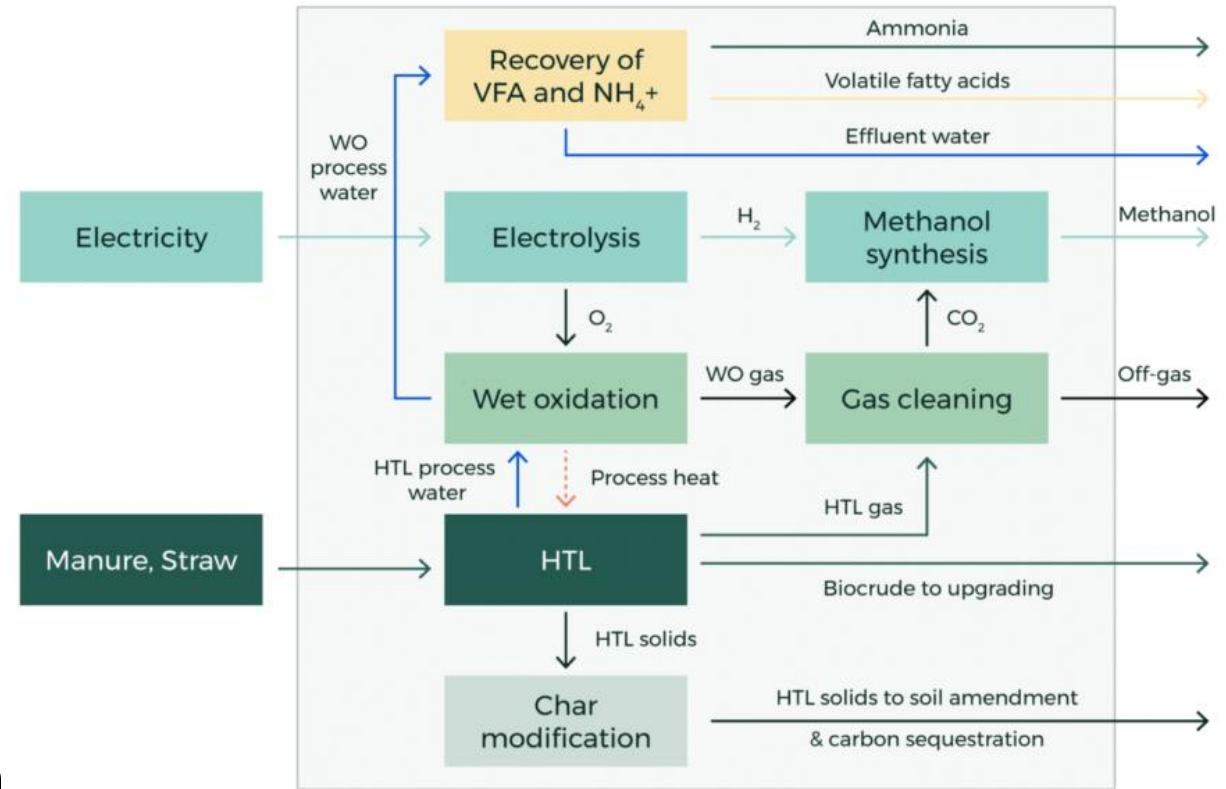
Cost-effective path to biofuels from abundant feedstock

- HTL is perceived as favourable 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 process heat demand for HTL
 - CIRCULAIR target: Autothermal HTL



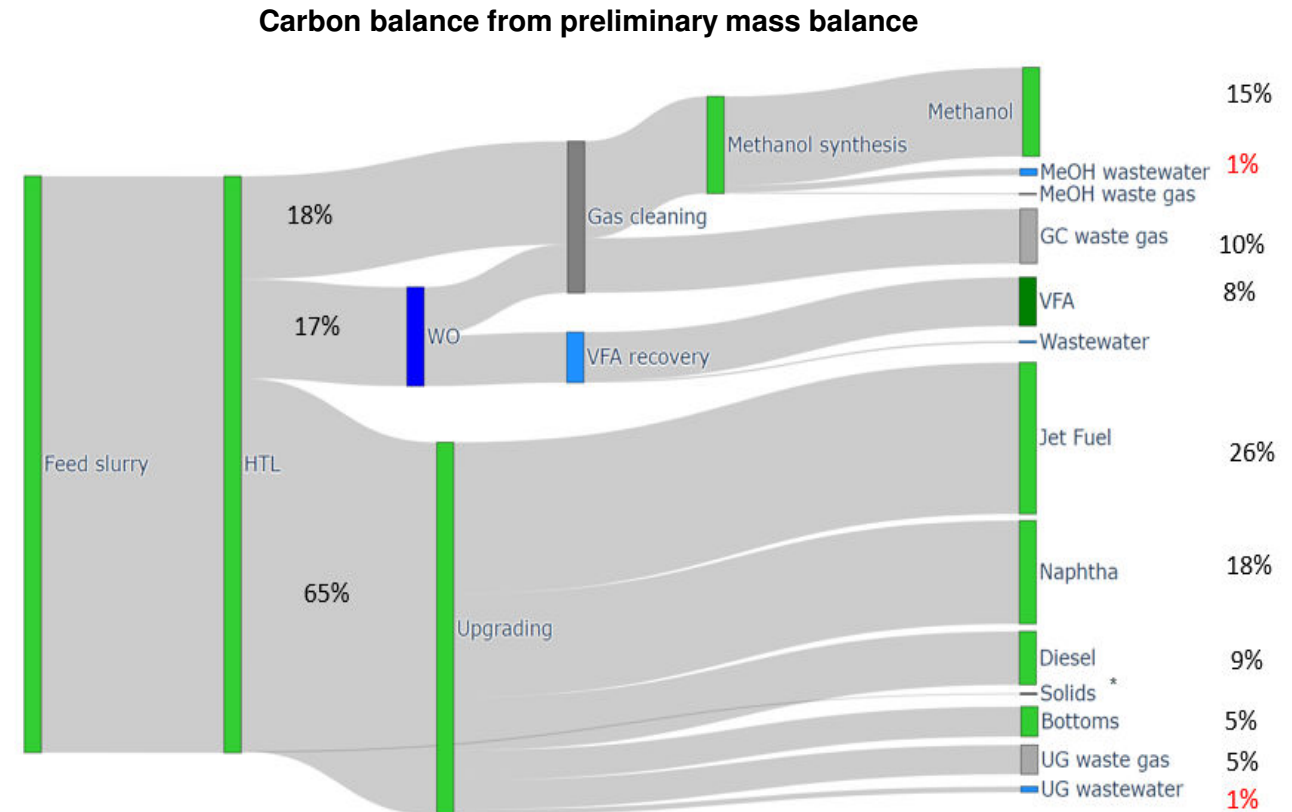
Product recovery for high biomass resource utilisation

- Recovery of VFA and NH_4
 - Main product acetic acid
- Utilization of HTL solids
 - For soil amendment & carbon sequestration
- Methanol synthesis from CO_2 streams and green H_2
 - HTL & WO gas contains mainly CO_2
 - CIRCULAIR investigates gas cleaning and plans a demonstration of methanol synthesis



Biomass resource utilization (carbon balance)

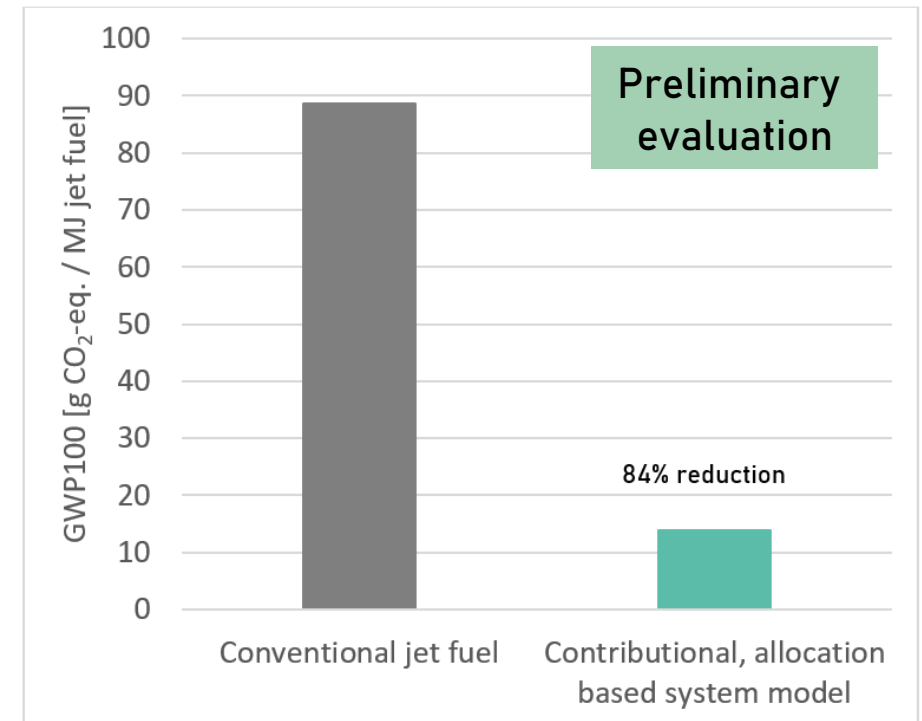
- Initial process modelling based on sub-models for
 - Hydrothermal liquefaction & wet oxidation (WO)
 - Biocrude Upgrading
 - Methanol synthesis
- HTL gas & aqueous phase contain a significant fractions of carbon from feed slurry
 - Methanol synthesis from CO₂ streams increases feedstock utilization significantly



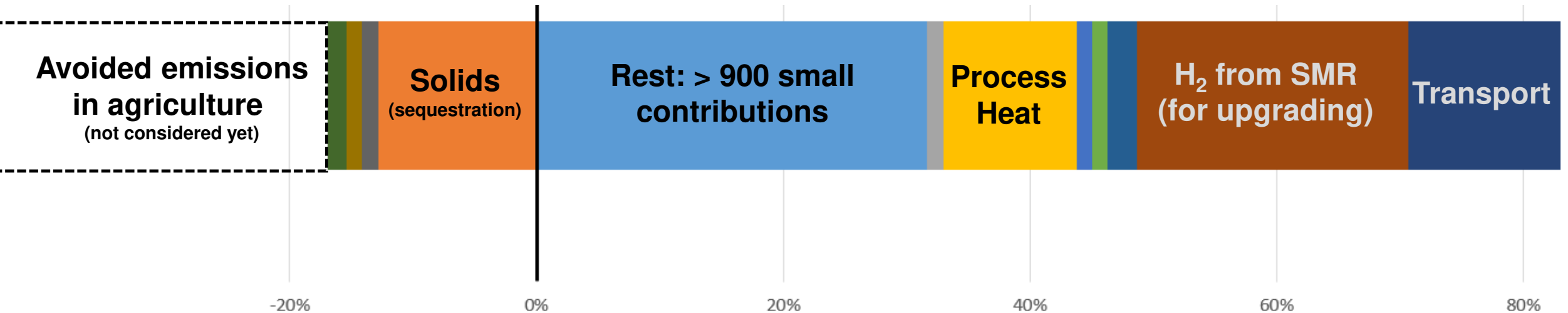
* Solids formation is underestimated by the model and needs to be adapted according to experimental findings from the CIRCULAIR implementation

Preliminary results from CIRCULAIR system analyses

- Two-step approach:
 - Initial modelling & initial evaluation of fuel production cost and LCA
 - Refined modelling and final system analyses (upcoming)
- Initial LCA results:
 - 84% reduction in GWP100*
 - Enabled by renewable heat for HTL (from WO) and green H₂
 - Green methanol improves result for fuel mix
 - Compliant with EU Renewable Energy Directive
 - > 65%/70% reduction for biofuel/ e-fuel



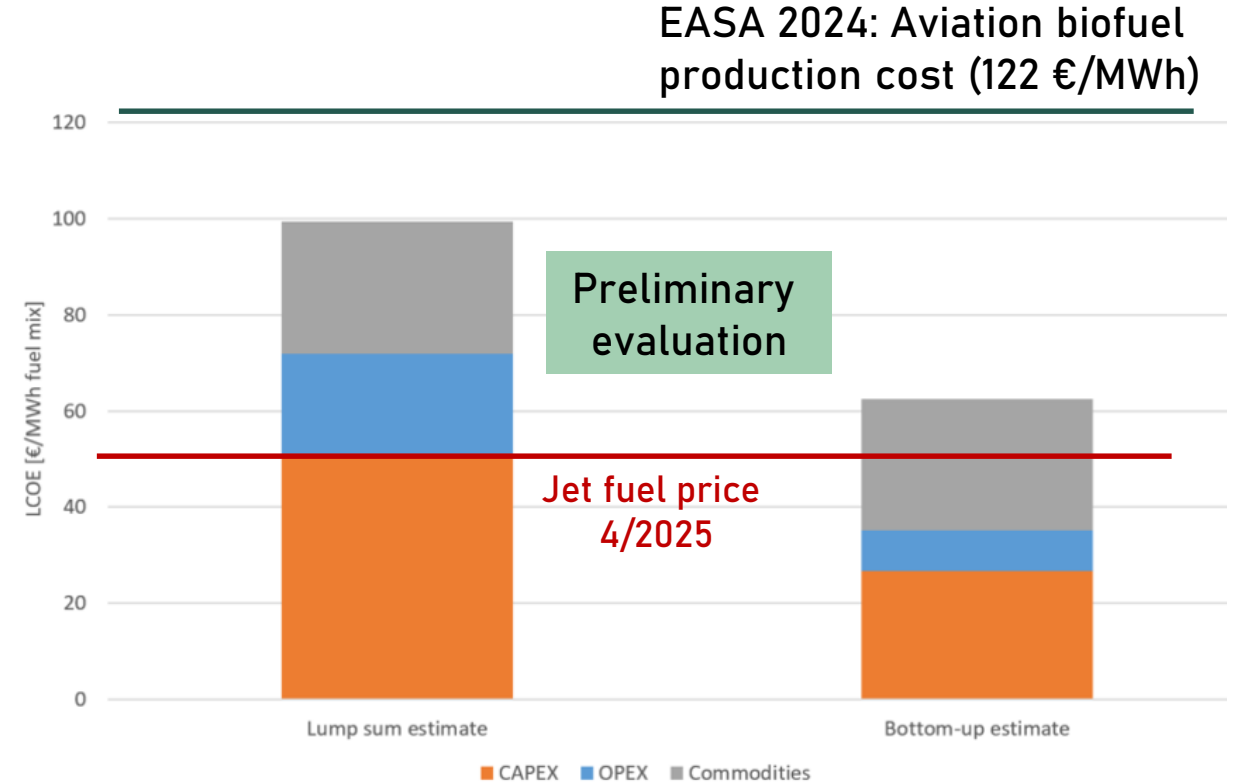
LCA detail: Main contributions to net emissions



- **Positive contributions:**
 - Many small contributions; Fossil energy use for: SMR, transport & heat
- **Negative contributions:**
 - Contribution by HTL solids needs more consideration (likely underest.)
 - Avoided emissions from manure handling practice (not yet considered)

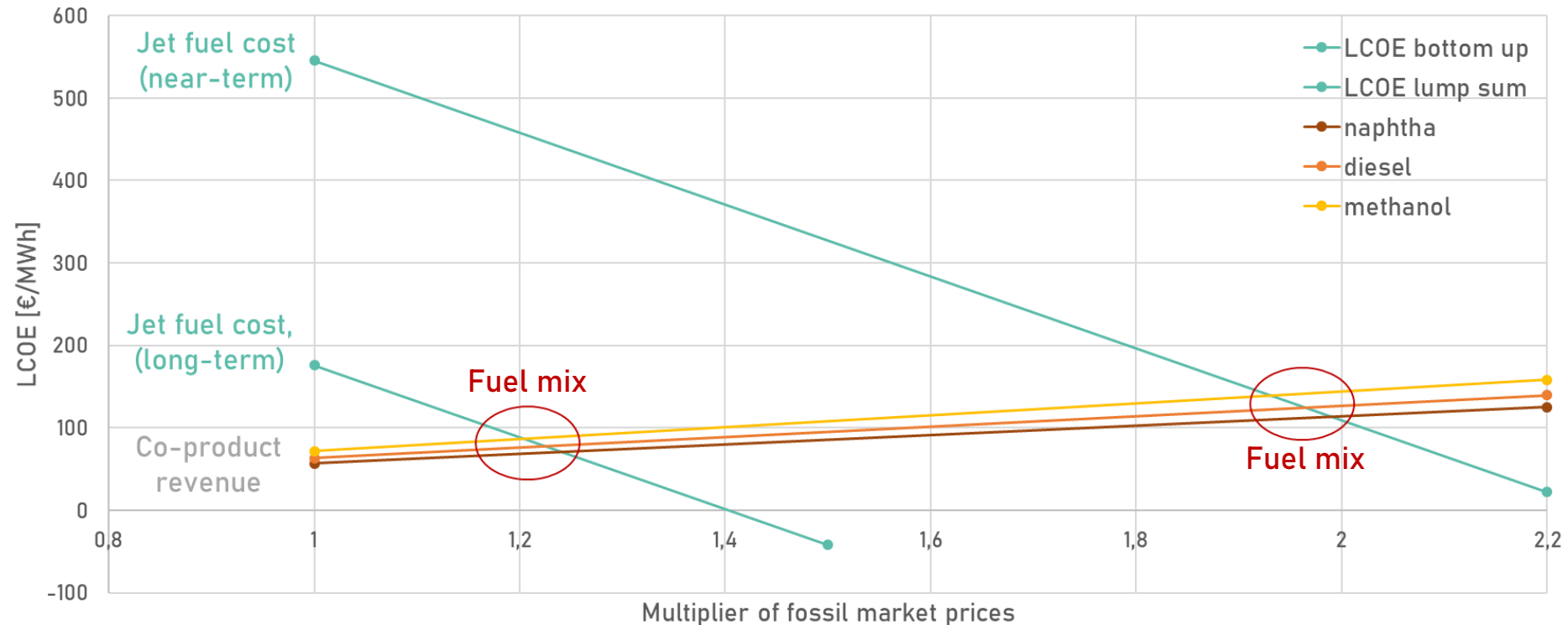
Techno-economic analysis: Preliminary result

- Production cost evaluated for mix of fuel products
 - Various HTL fuels and methanol
- Preliminary result (LCOE)
 - 99 €/MWh (near-term CAPEX estimate for HTL-WO)
 - 62 €/MWh (long-term estimate)
 - Isolated cost for methanol synthesis: ~114 €/MWh
 - Methanol synthesis slightly increases near-term cost estimate for fuel mix



TEA detail: Importance of co-product revenues

- CIRCULAIR: Multi-product pathway including green methanol
 - Jet fuel production cost are highly sensitive to co-product revenues
 - Expected revenues for green methanol need to justify CO₂ utilization



- **CIRCULAIR, perspective:**
 - HTL conversion of abundant agricultural residues (manure, straw)
 - High feedstock utilization by methanol synthesis from H₂ & CO₂ streams
- **Initial insights from preliminary TEA and LCA**
 - Utilization of HTL gas and aqueous phase increases carbon efficiency
 - Deep reduction in GWP via renewable heat from WO and green H₂
 - Remaining emissions are linked to residual fossil energy use and many small contributions
 - Avoided emissions & solids sequestration may enable negative GHG balance
 - Initial production cost estimate in line with 1st generation biofuels
 - High sensitivity on co-product revenues, in particular: Revenues for green methanol need to justify envisaged CO₂ utilization scheme

Visit <https://project-circulair.eu/> for further information on

- a demonstration of HTL-WO in a pilot plant
- nice work on upgrading HTL biocrudes and utilization schemes for all major product streams
- results from upcoming system analyses
- CIRCULAIR events & dissemination activities

Thank you!

For questions,
please contact:

CIRCULAIR

Coordinator

Valentin Batteiger,
Bauhaus Luftfahrt
contact@project-circulair.eu
Phone: +49 89 3074-84961

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