Sustainable biorefining platform by HTL

Cost- and resource effective low-carbon jet fuels, BioCCS/CCU implementation and circular economy

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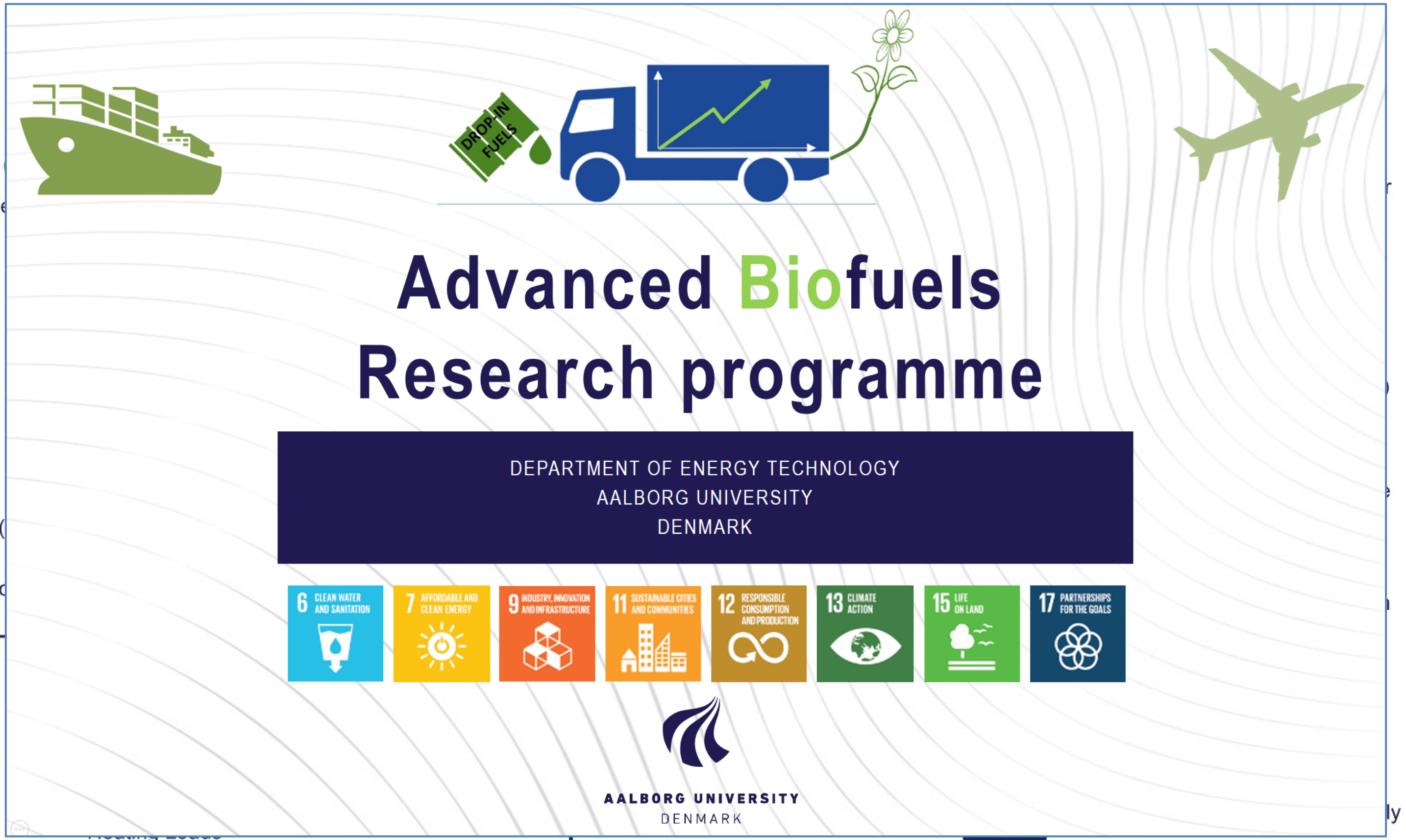
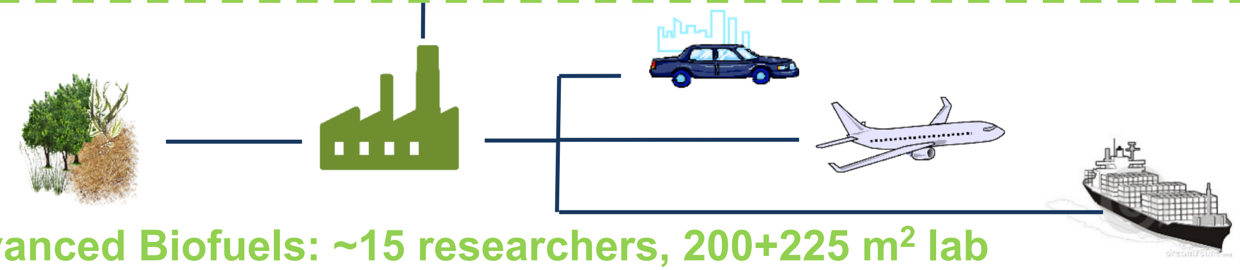




Advanced Biofuels: ~15 researchers, 200+225 m² lab

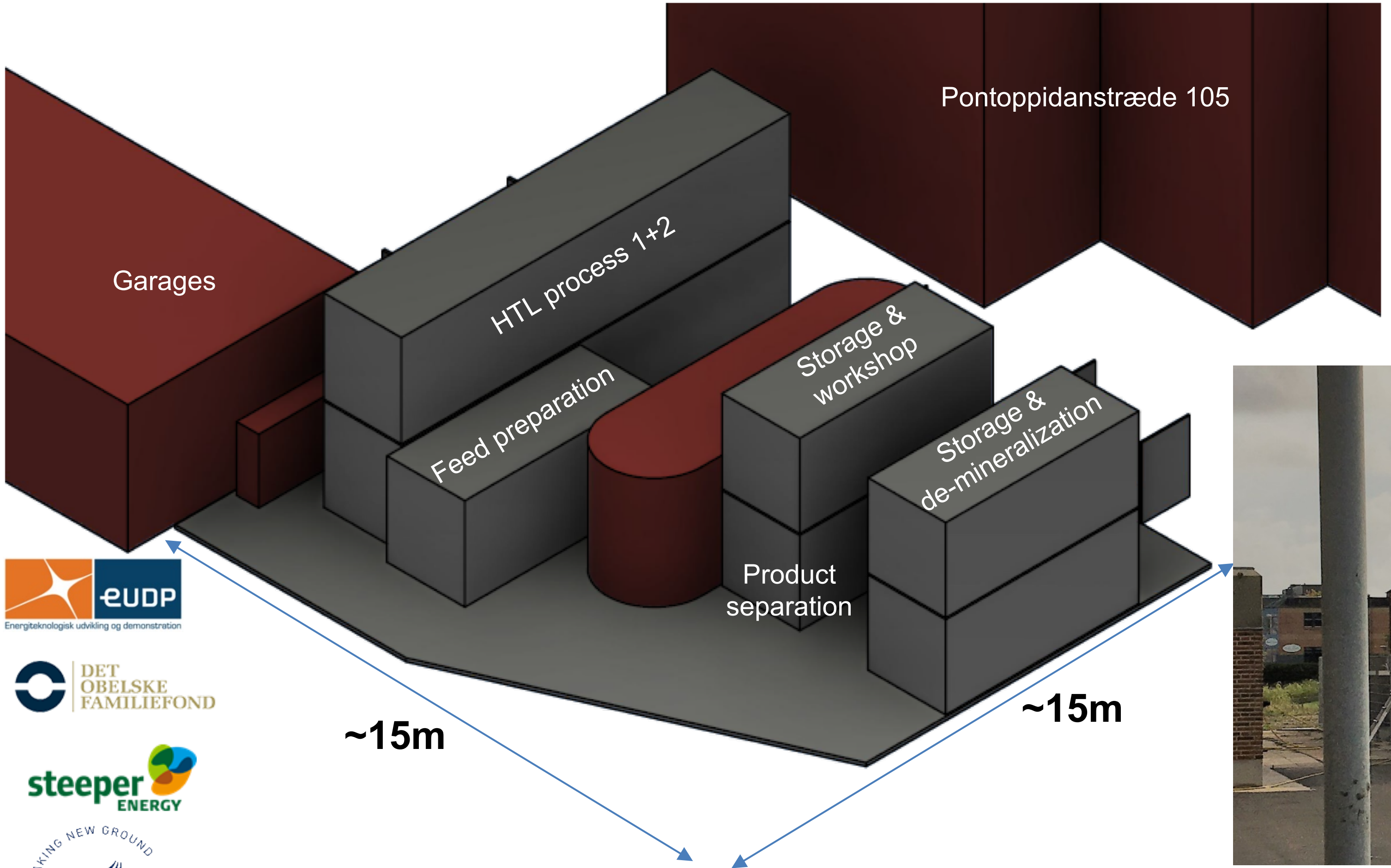
John K. Pedersen
Head of Department

Lab. Facilities:
Power Electronic Systems
Drive Systems Tests
Fluid Power
Smart Energy Systems Lab
Power Systems & RTDS
Micro Grid
High Voltage
Medium Voltage
PV Convert & Systems
Fuel Cell Systems
Battery Test
EMC
Vehicles Test Lab
Biofuel production and characterization Facilities
Proto Type Facilities

App. 60 faculty members
App. 100 PhDs
More than 30 guest researchers
App. 30 TAP
App. 360 students

Pilot scale HTL facility – CBS1

- Continuous Hydrothermal Liquefaction (HTL) facility (CBS-1)
- 25-50 kg/h feed, processing conditions up to 500 °C, 350 bar
- Oil production capacity: 1-5 kg/h (0.3 bpd)
- Designed in collaboration with and constructed by Steeper Energy
- Commissioned 2013, recommissioned 2018 with improved up- and downstream handling



Research activity overview

HyFlexFuel — Bauhaus Luftfahrt Neue Wege.

HTL→ fuels

4refinery — SINTEF

HTL & pyrolysis oils → co-refining → fuels

Innovationsfonden — FLABBERGAST B JET FUEL — Aalborg Universitet

Long chain esters as aviation fuel blendstock

ENSYSTRA — Energy system transition of the North Sea region — university of groningen

Innovationsfonden — C3BO — Aalborg Universitet

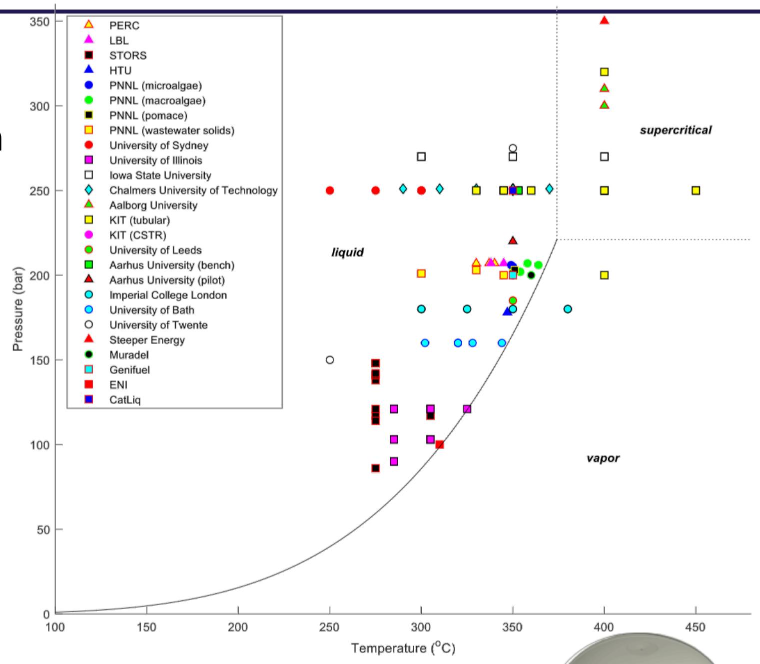
Fundamental studies in HTL

NEXTGEN roadfuels — Aalborg Universitet

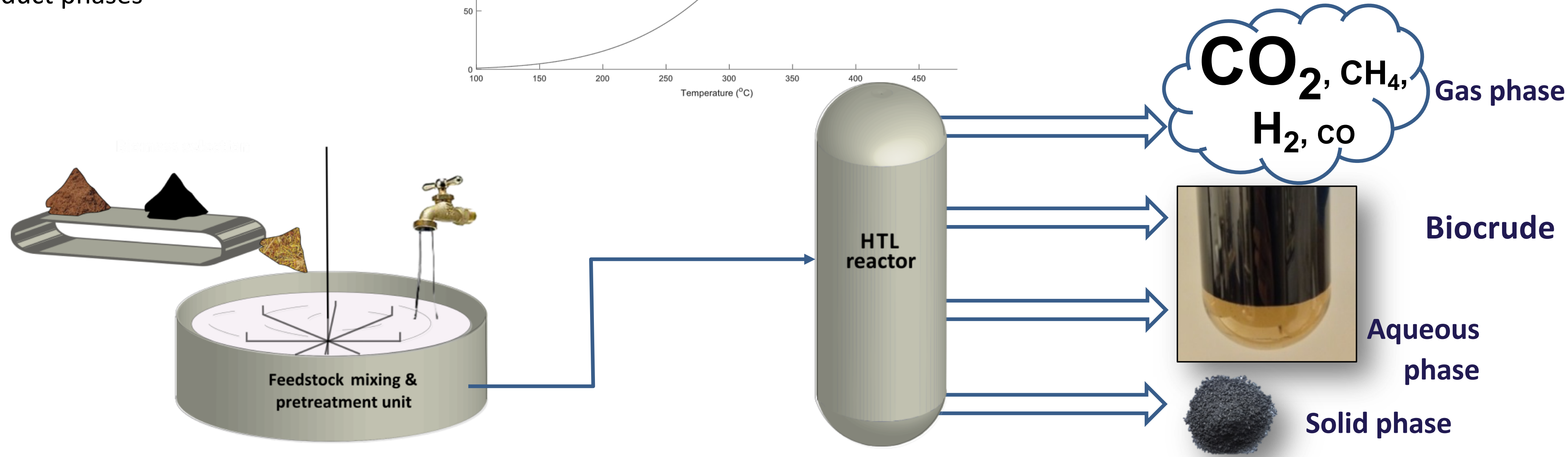
HTL → road transport fuels

HydroThermal Liquefaction – efficient production of liquid energy intermediates

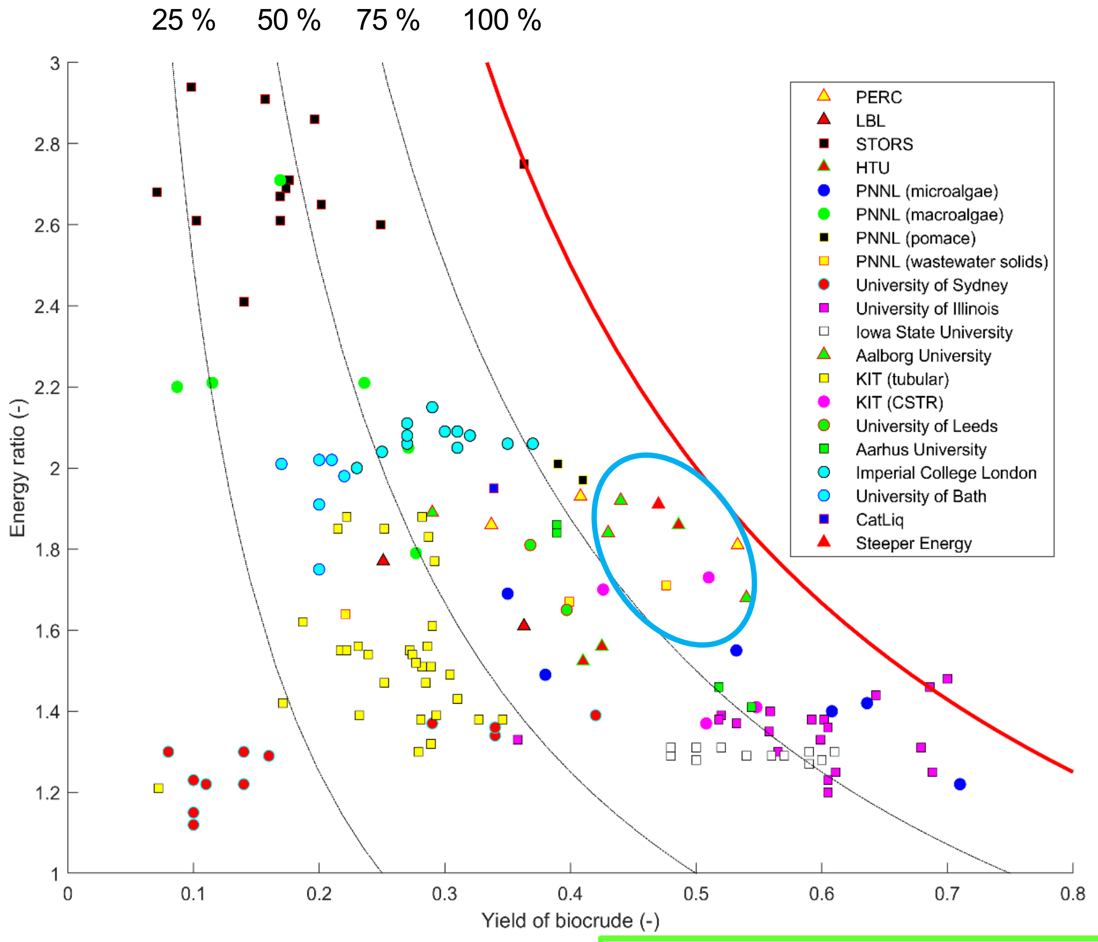
- Processing of biomass in an aqueous medium
- Extreme feedstock flexibility
- Wet or dry biomass
- Four product phases

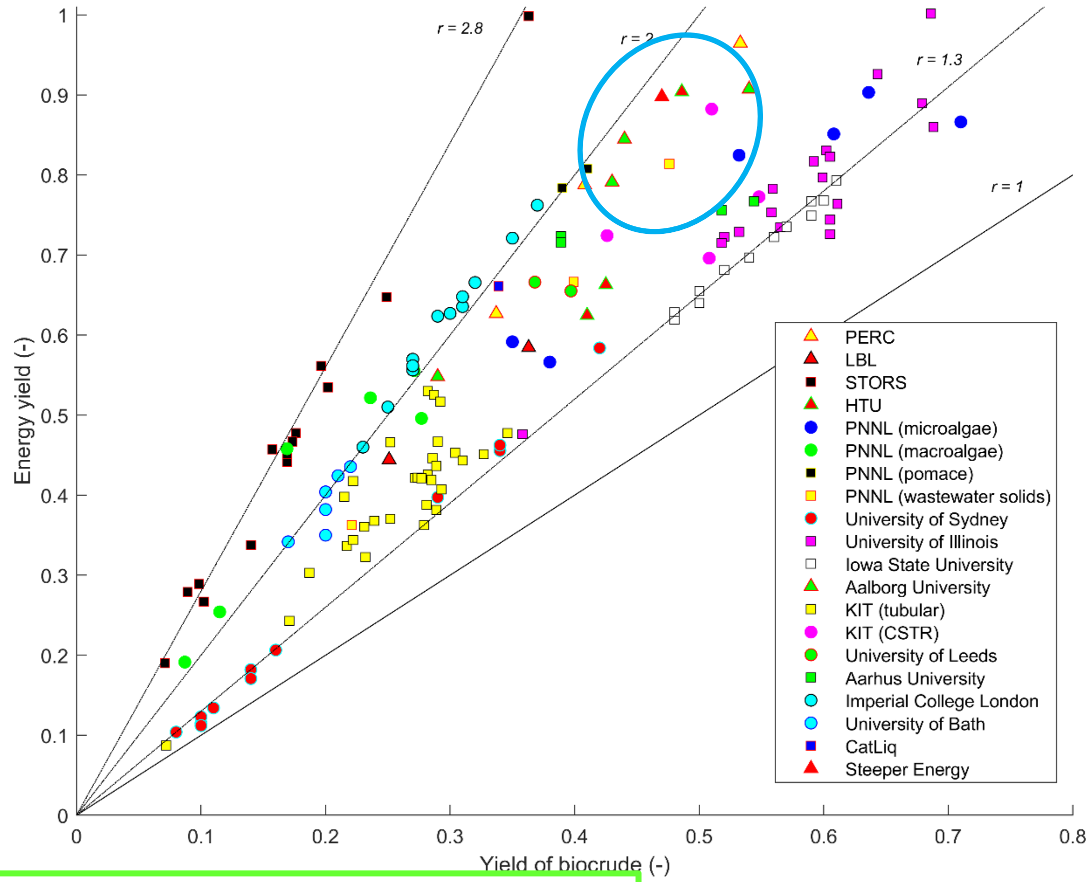


High pressure
Medium temperature



Effectiveness evaluation of HTL

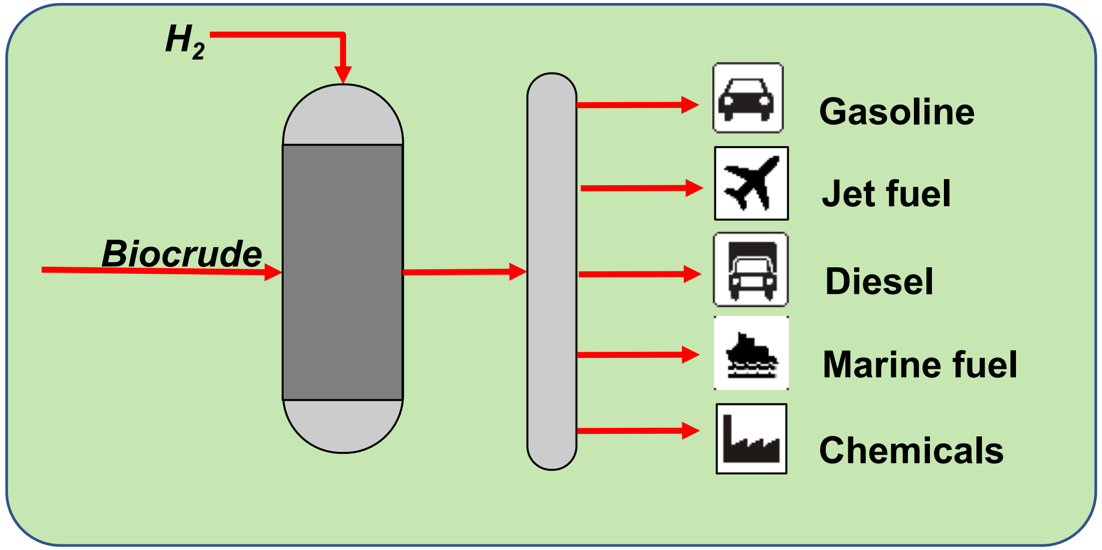




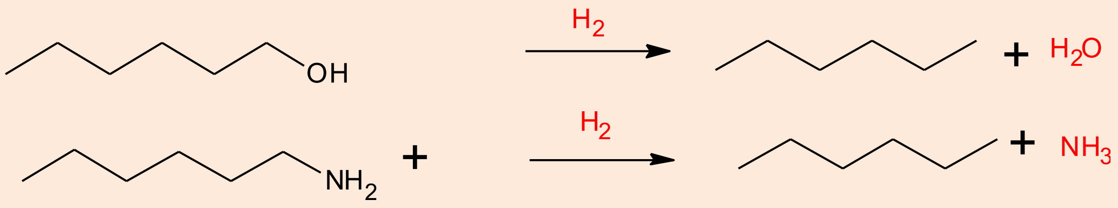
For all types of feedstocks HTL is an efficient upcycler!
Supercritical HTL superior in energy yield

Castello, Pedersen, Rosendahl (2018). Energies MDPI. https://doi.org/10.3390/en11113165

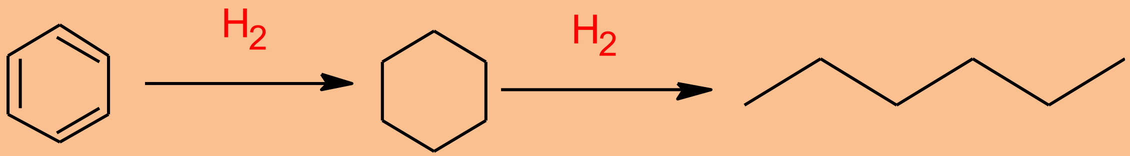
Upgrading to drop-in fuels



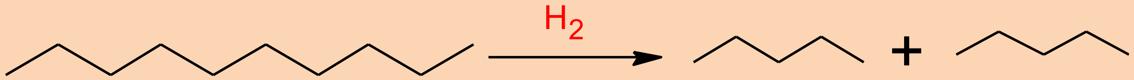
Heteroatoms removal



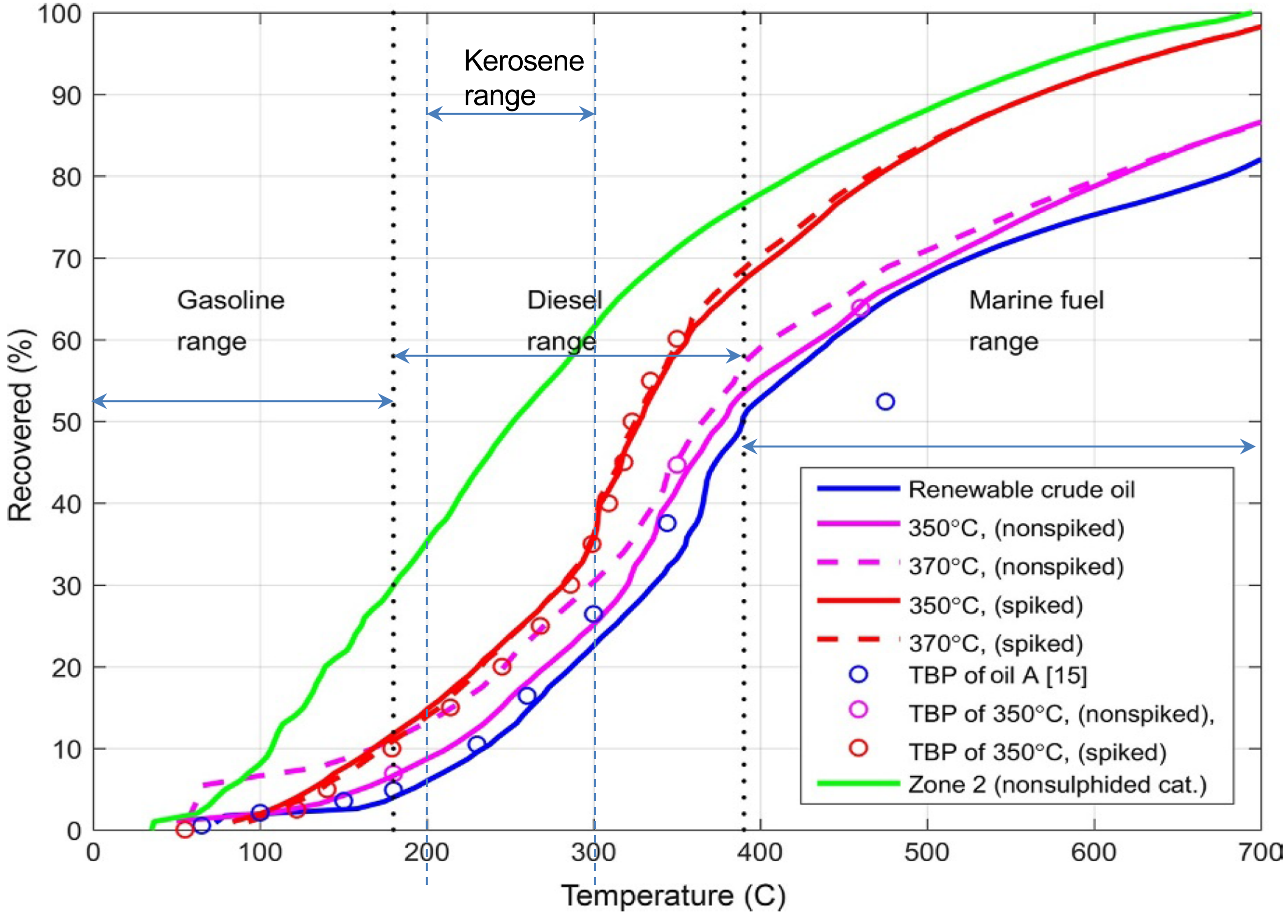
Hydrogenation

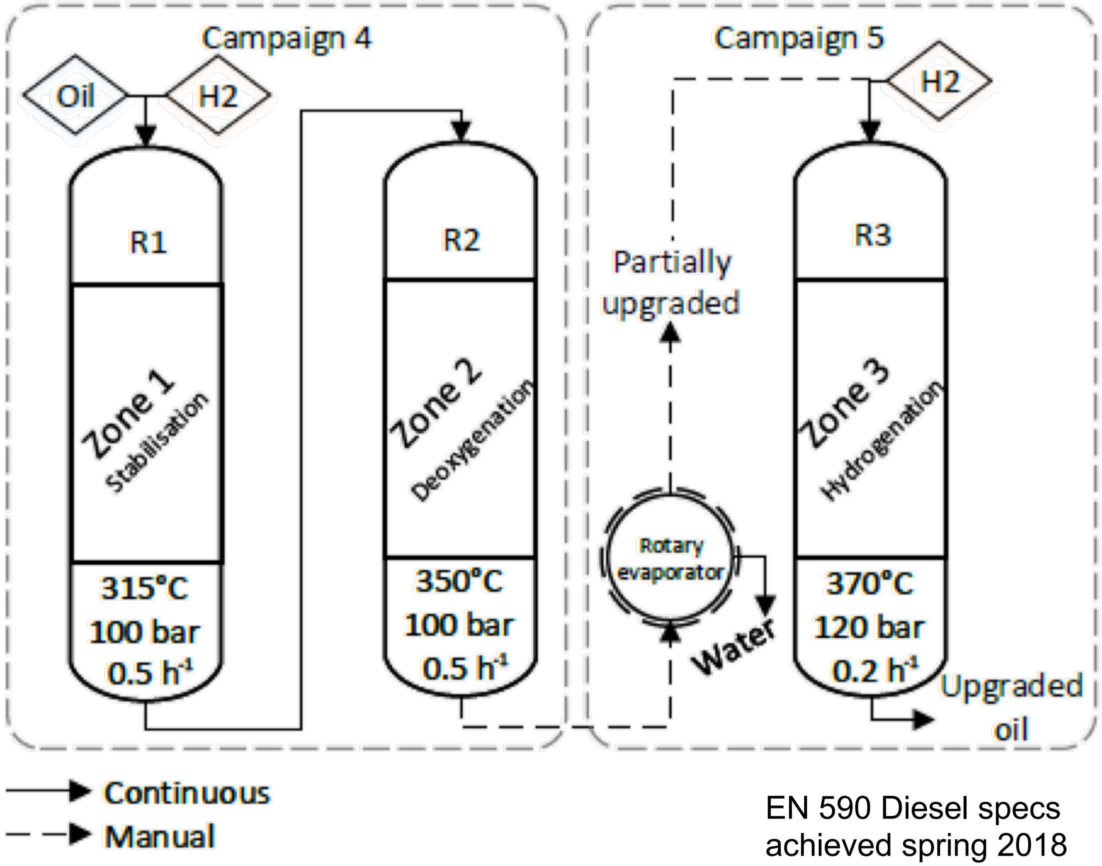


Hydrocracking



Lignocellulosic-based HTL biocrude and upgraded product



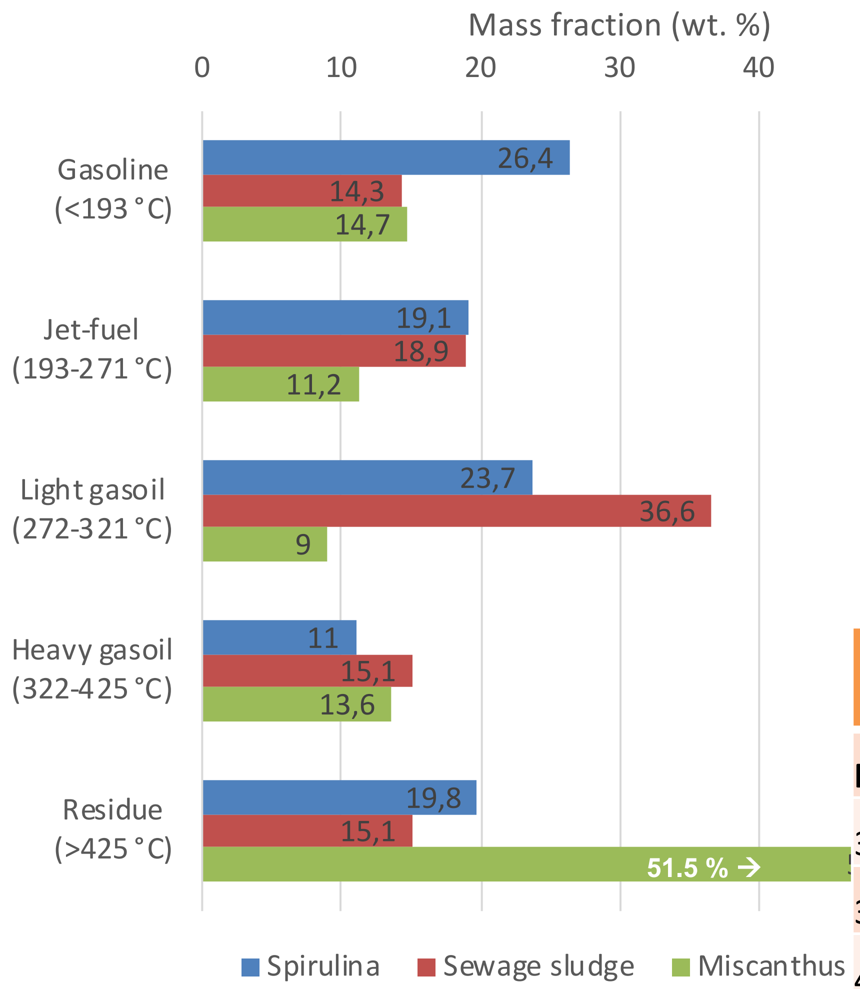


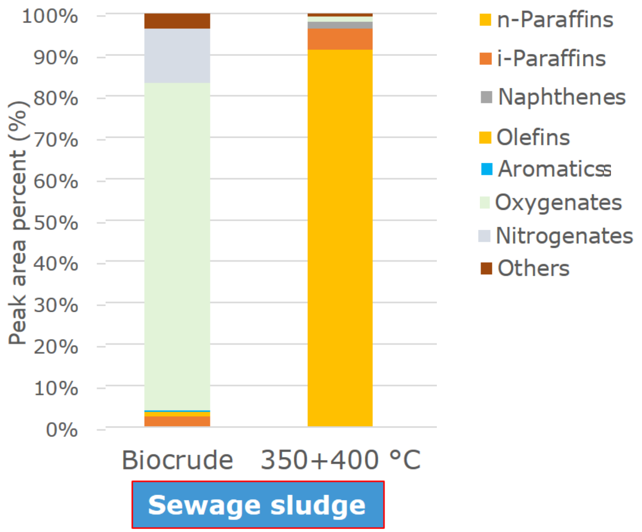
EN 590 Diesel specs achieved spring 2018

Hydrofaction™

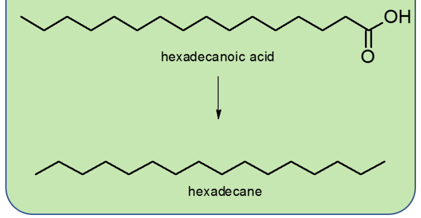
Jensen et al, Hydrofaction™ of Forestry Residues to Drop-in Renewable Transportation Fuels. In *Direct Thermochemical Liquefaction for Energy Applications* edited by L. Rosendahl, ISBN: 9780081010259, pp. 319-345, 2018.

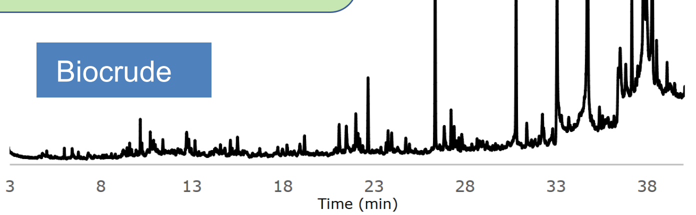
Production of fuel fractions from different feedstocks@subcrit HTL

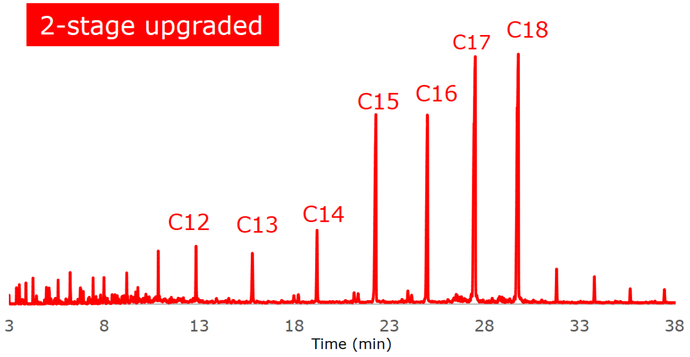




- Large part of the sewage sludge biocrude is constituted by fatty acids. especially in the range C12-C18
- The upgrading converts fatty acids into straight-chain alkanes
- High potential in the jet-fuel and diesel range





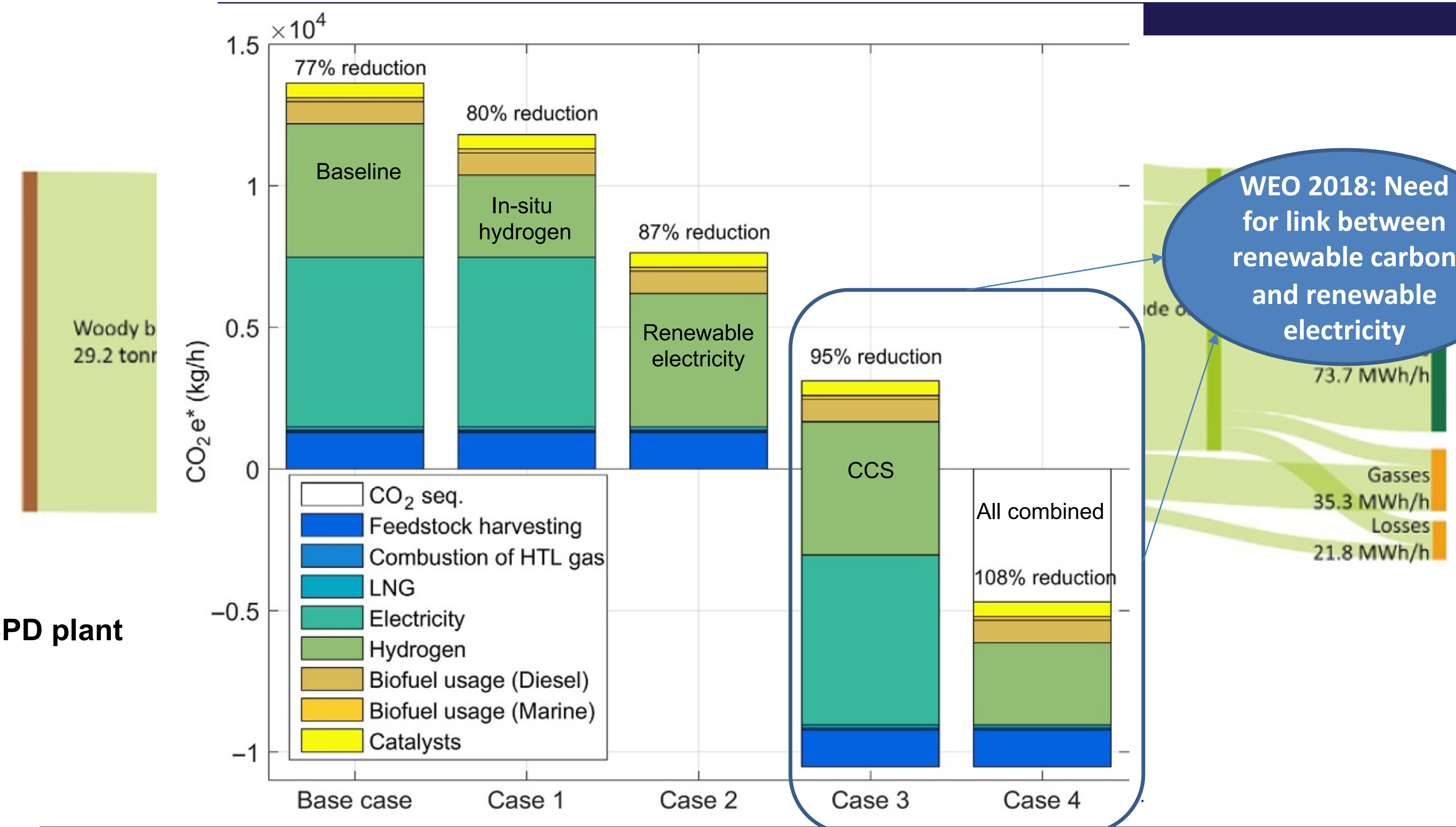


Sewage sludge	C (wt. %)	H (wt. %)	N (wt. %)	O* (wt. %)
Raw biocrude	74.5	10.6	3.9	11.0
350 °C-40 bar	83.1	12.1	3.6	1.2
350 °C-80 bar	84.1	13.4	2.5	0.0
400 °C-80 bar	85.3	13.8	0.9	0.0
350+400 °C-80bar	85.2	14.5	0.3	0.0

** Oxygen by difference*

Castello et al (2019). Manuscript in preparation, Renewable Energy

Hydrofaction™ energy flows and GHG reduction potential

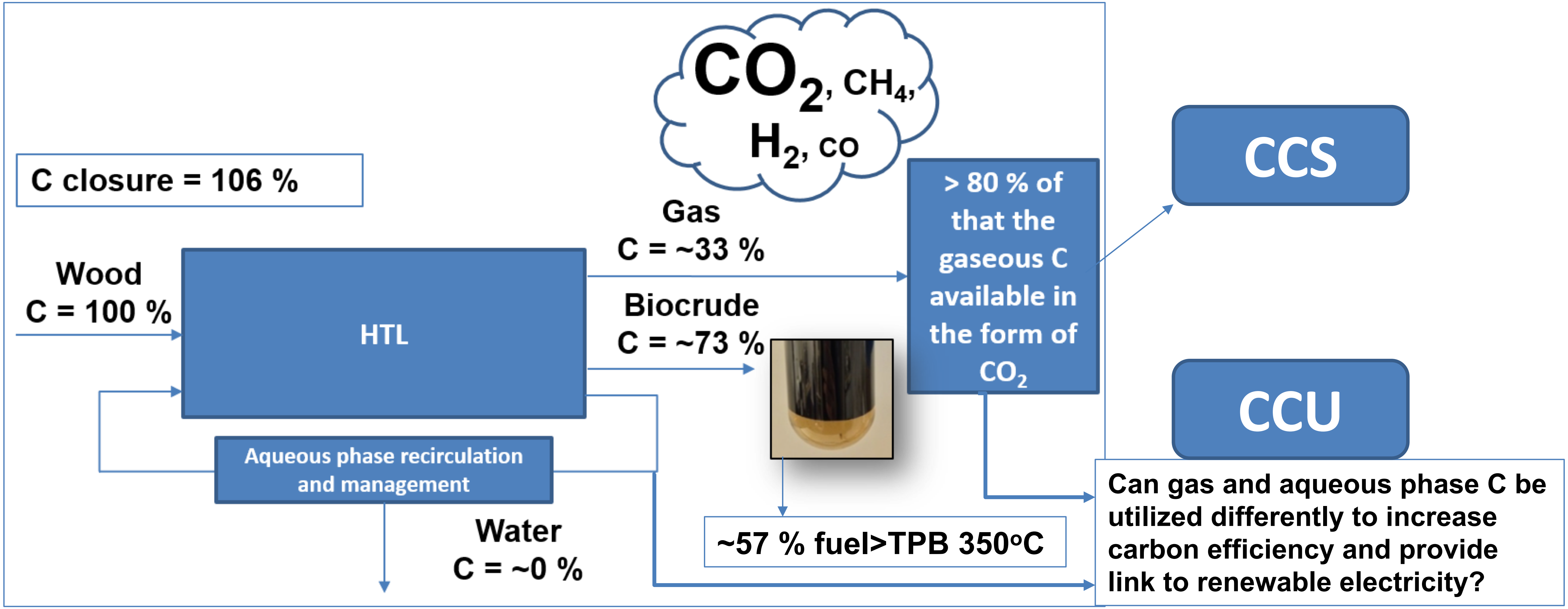


WEO 2018: Need for link between renewable carbon and renewable electricity

2000 BPD plant

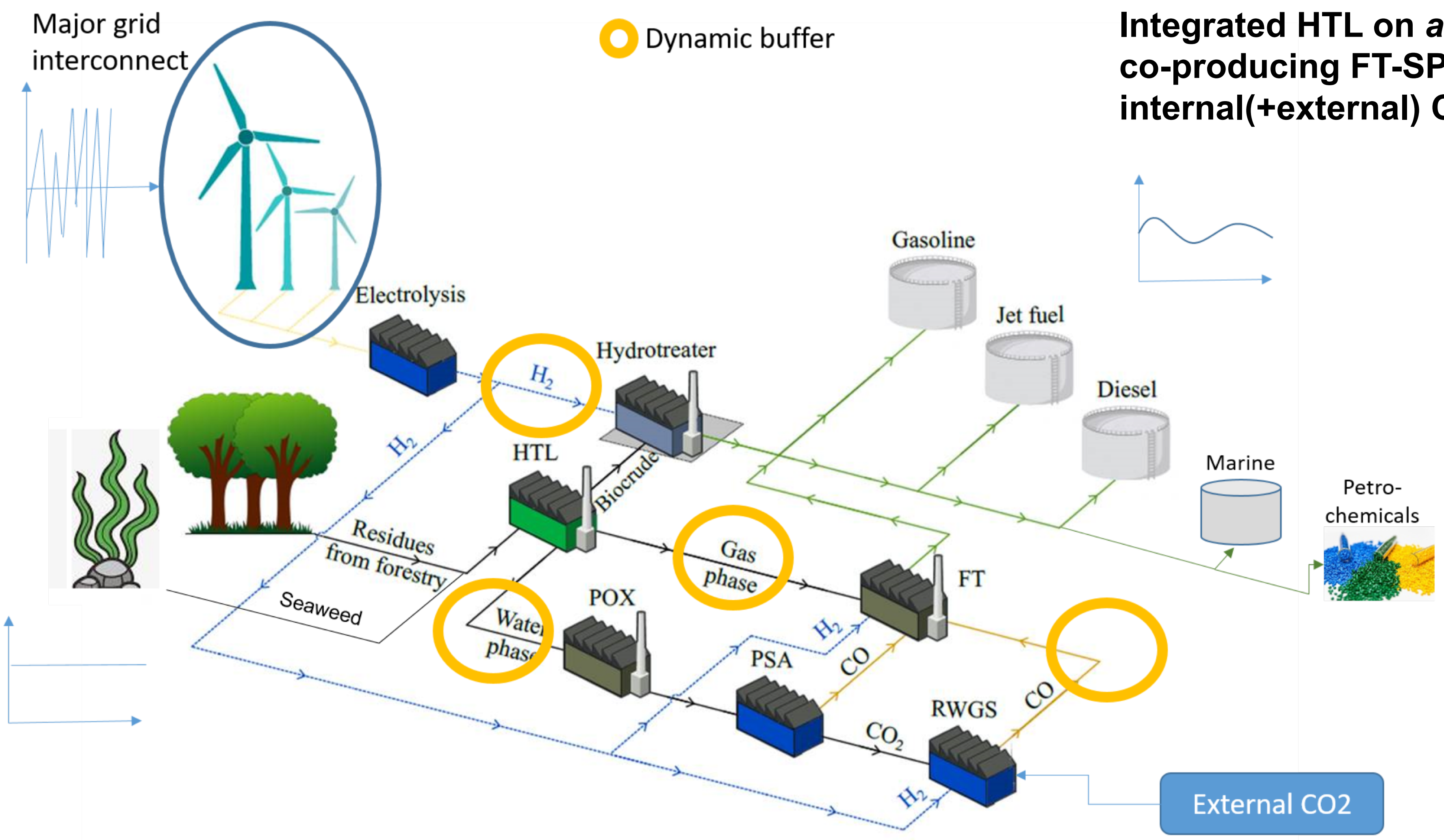
Jensen et al, Hydrofaction™ of Forestry Residues to Drop-in Renewable Transportation Fuels. In *Direct Thermochemical Liquefaction for Energy Applications* edited by L. Rosendahl, ISBN: 9780081010259, pp. 319-345, 2018.

HTL Carbon balances



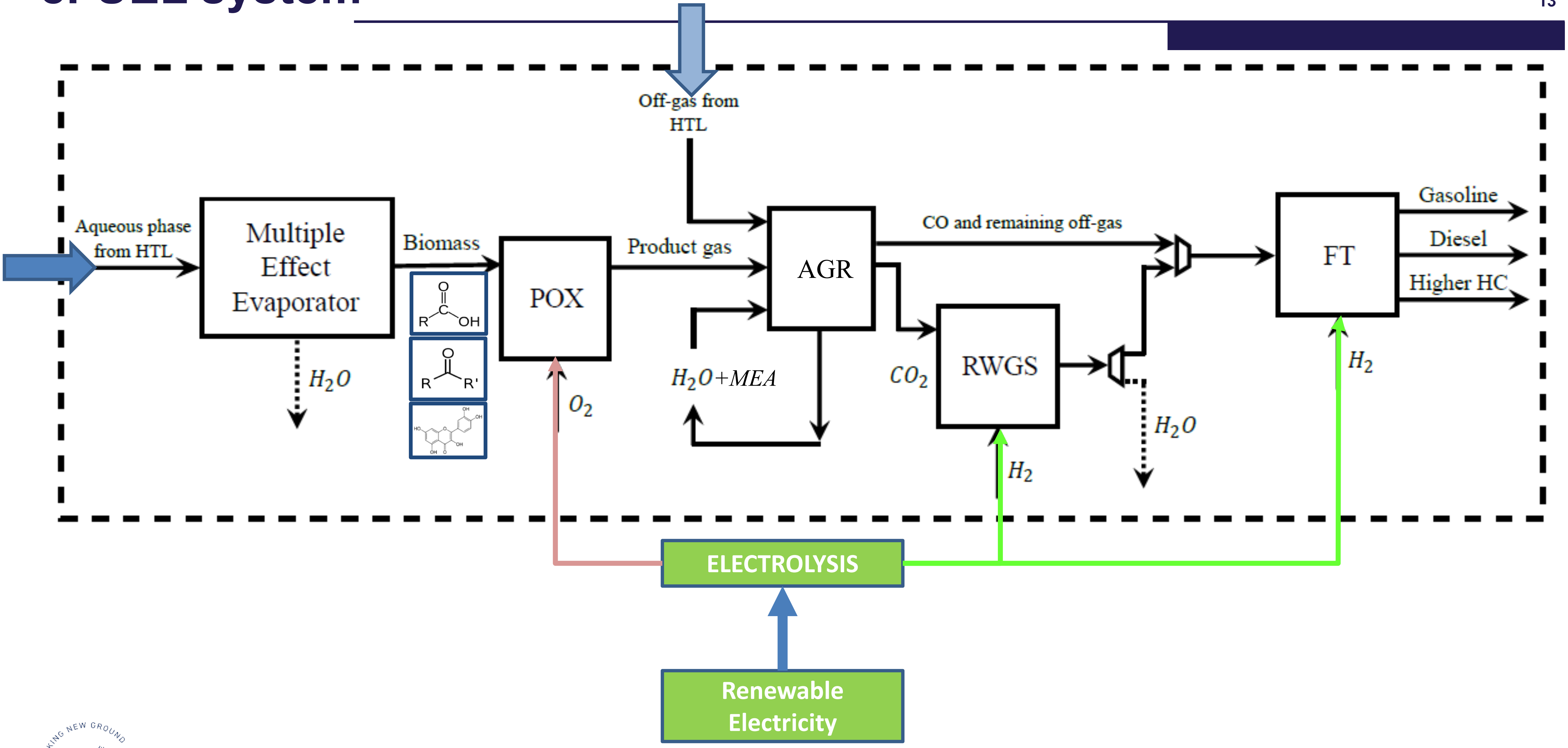
Electro-HTL …

Integrated HTL on *any* feedstock co-producing FT-SPK/A with internal(+external) CO_2 stream

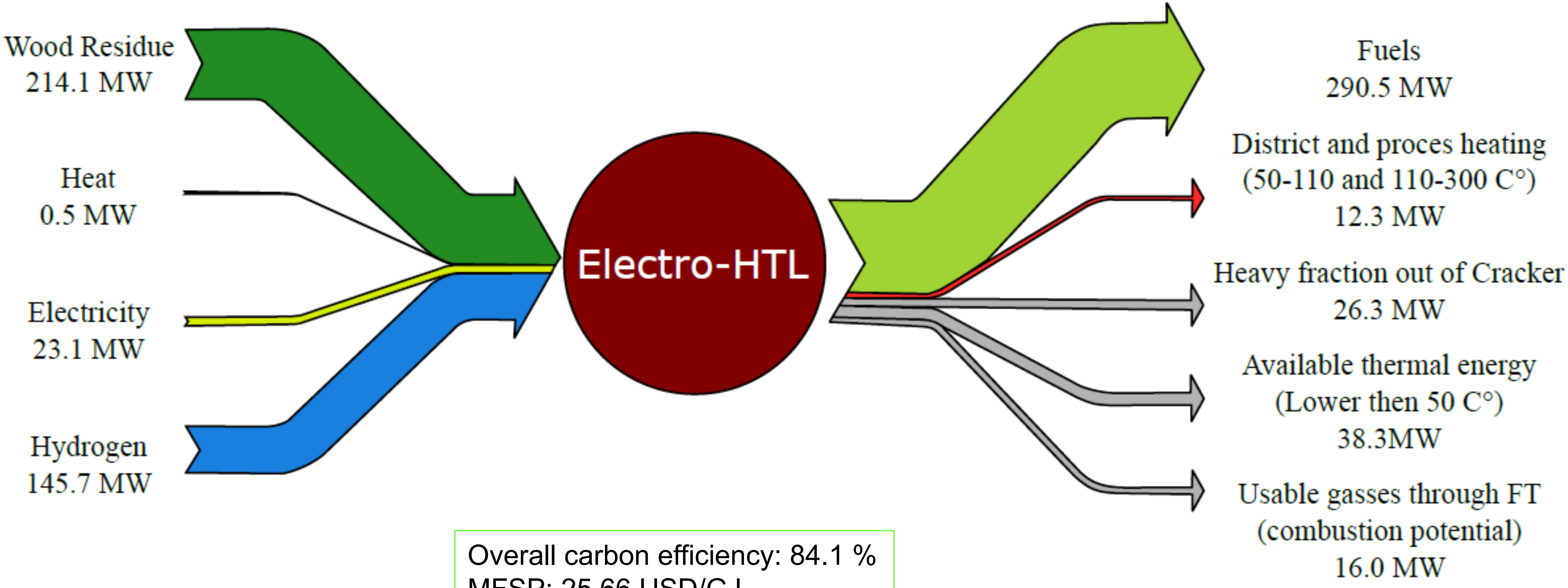


Hansen, Pedersen, Rosendahl (2018). TEA of a novel HTL implementation with electrofuels for high carbon efficiency. BioFPR (in review)

eFUEL system

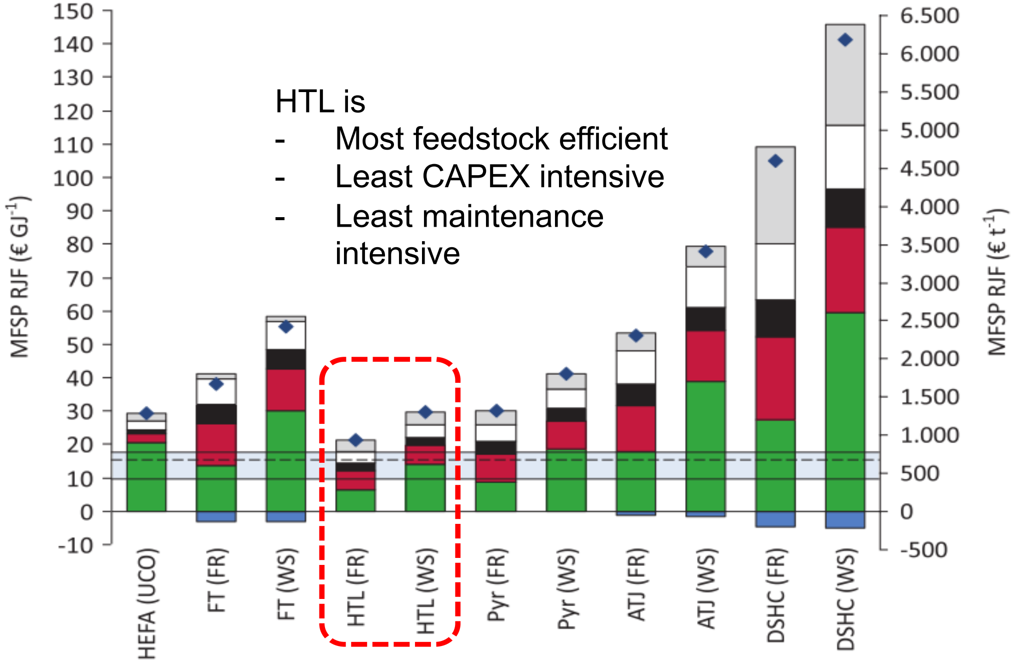


Overall energy flow



Overall carbon efficiency: 84.1 %
MFSP: 25.66 USD/GJ

Competitivenes of HTL implementations



Legend

- MFSP
- Utilities & other raw materials
- Other OPEX (incl. corporate taxes)
- Maintenance and repairs
- CAPEX
- Feedstock
- Non-hydrocarbon co-products

Top ten percentile of the fossil jet fuel in the period 2005-2014 (17.6 € GJ-1)

Average fossil jet fuel price 2014 (15.1 € GJ-1)

Bottom ten percentile of the fossil jet fuel in the period 2005-2014 (9.4 € GJ-1)

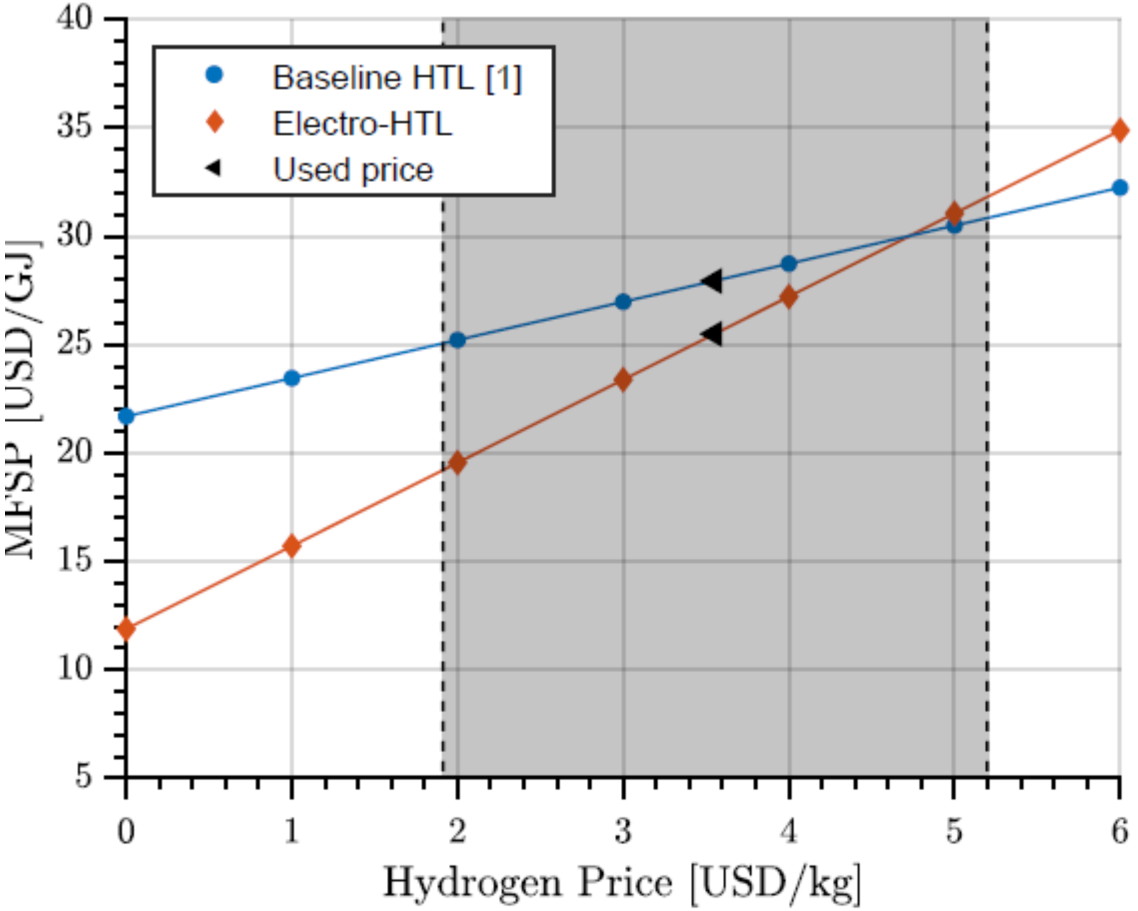
Abbreviations

HEFA = Hydroprocessed Esters and Fatty Acids
FT = Fischer-Tropsch
HTL = Hydrothermal Liquefaction
Pyr = Pyrolysis
ATJ = Alcohol-to-Jet
DSHC = Direct Sugars to Hydrocarbons

UCO = Used cooking oil
FR = Forestry residues
WS = Wheat straw

De Jong (2015), BIOFPR

Copernicus Institute of Sustainable Development, Utrecht University



Commercialisation of HTL

steeper ENERGY
The Renewable Oil Company ™

Denmark/Canada

Hydrofaction™ process

Wood

4,000 L/day

10,000 ton/y

Tires, algae

168 L/h

nifuel

HTP™ process

Sewage sludge

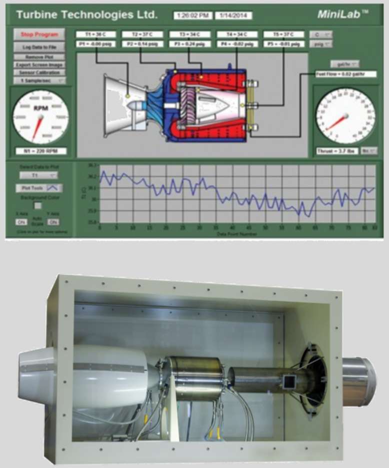
AAU BIOMASS TO VALIDATED FUEL PLATFORM
WWW.BIOMASS.AAU.DK

ANALYSIS

Biomass pretreatment

Take-home messages

- HTL is currently making its way into demonstration scale
- Cost- and resource effective production of sustainable fuels from diverse feedstocks
- Can be operated as RED II-compliant biofuel plant or effective BioCCS
- Provides interesting opportunities for renewable electricity integration and BioCCU
- Effective technology for circular economy – valorization of organic waste fractions as well as inorganic (eg phosphorous)



End use validation – jet or ICE engine platform

Renewable oil well

Existing & adapted infrastructure

THANK YOU FOR YOUR ATTENTION

Acknowledgements:

steeper ENERGY
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ENSYSTRA
HyFlexFuel
4refinery
NEXTGEN roadfuels

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