Catalytic hydropyrolysis for sustainable aviation fuel

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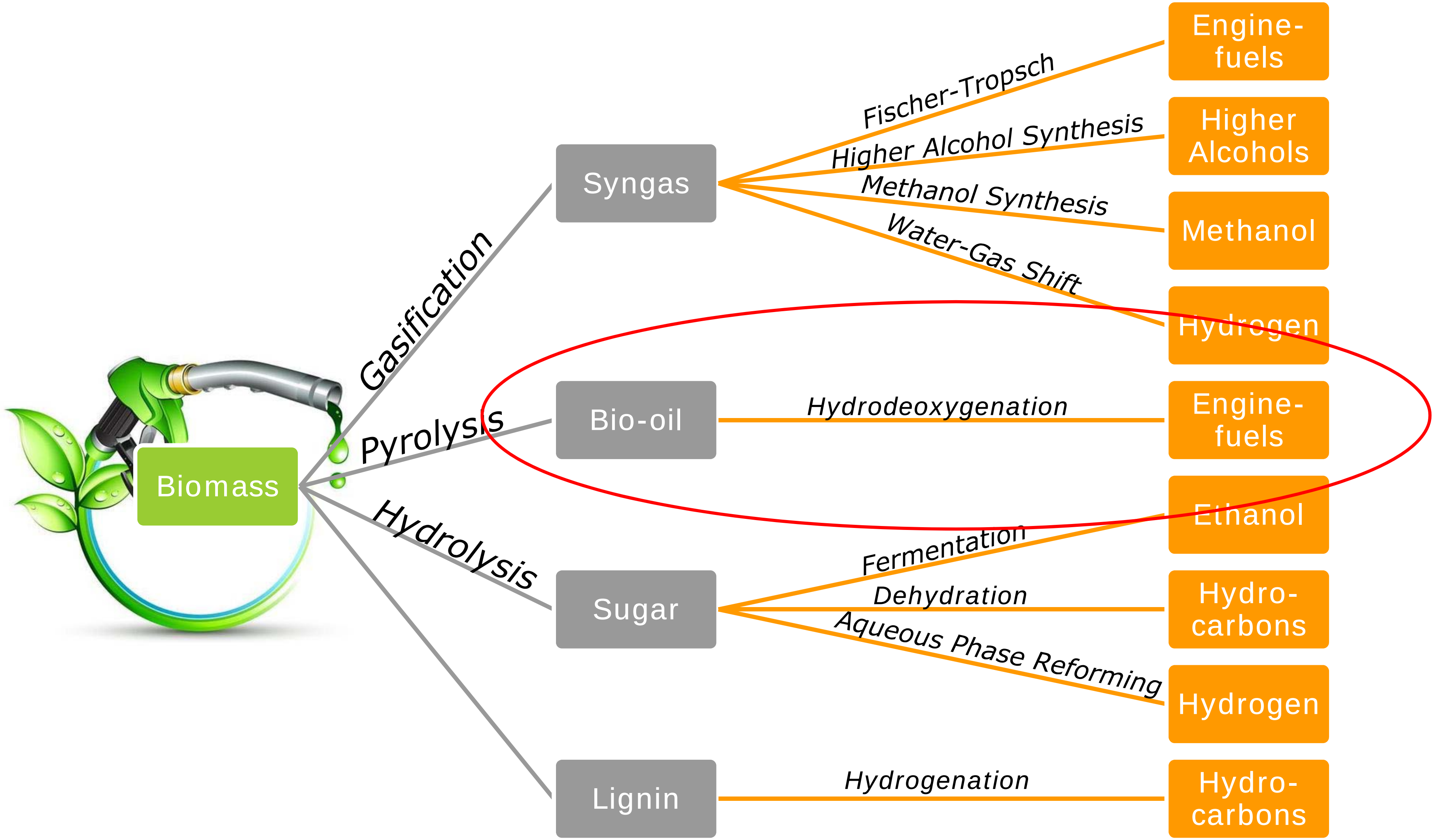
Sustainable carbon based fuels

- Generally accepted that carbon based fuels will be needed at least in the short to medium time frame

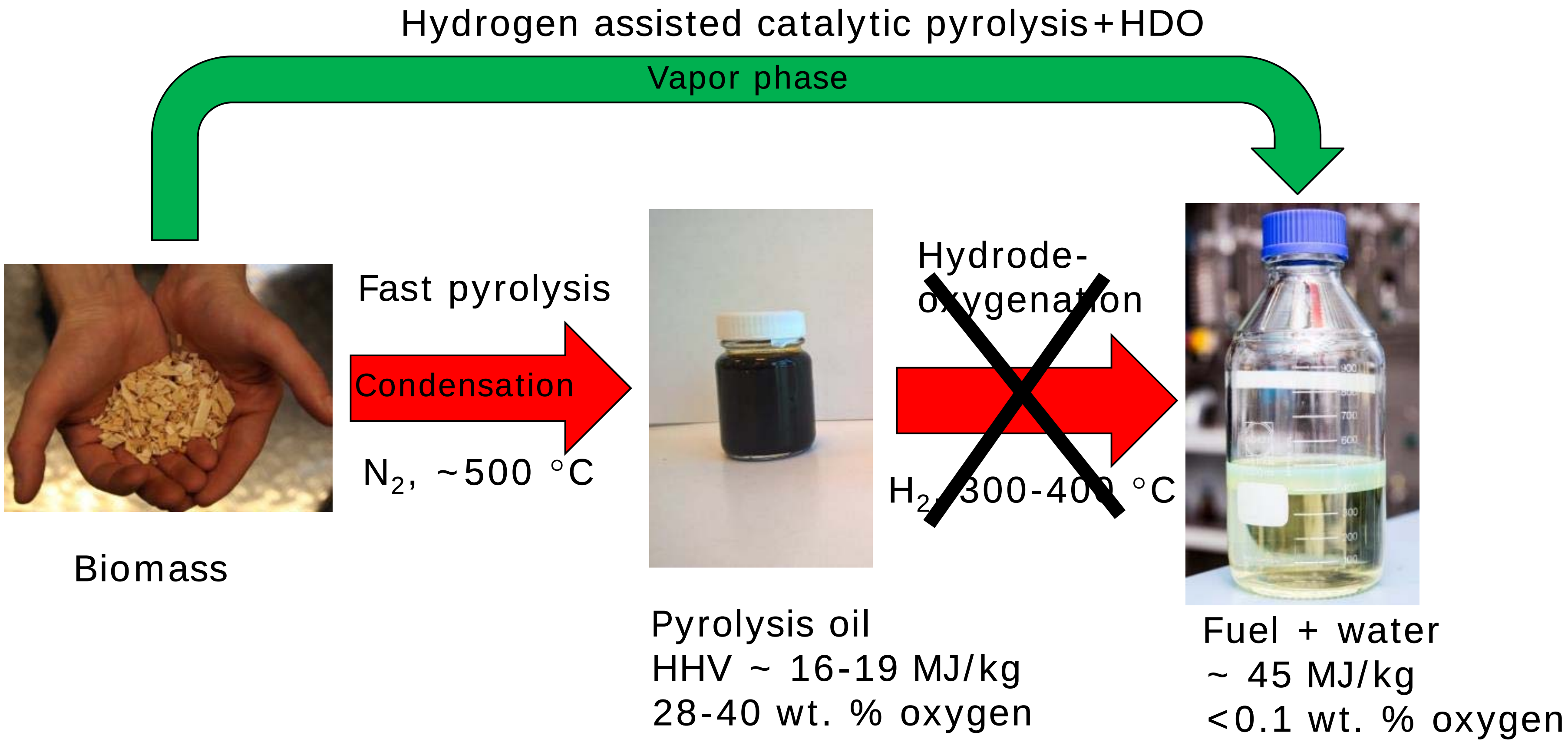
- Sustainable carbon sources:
  - CO_2 from point sources (power plants, cement, biogas etc.)
  - Biomass

Biofuels



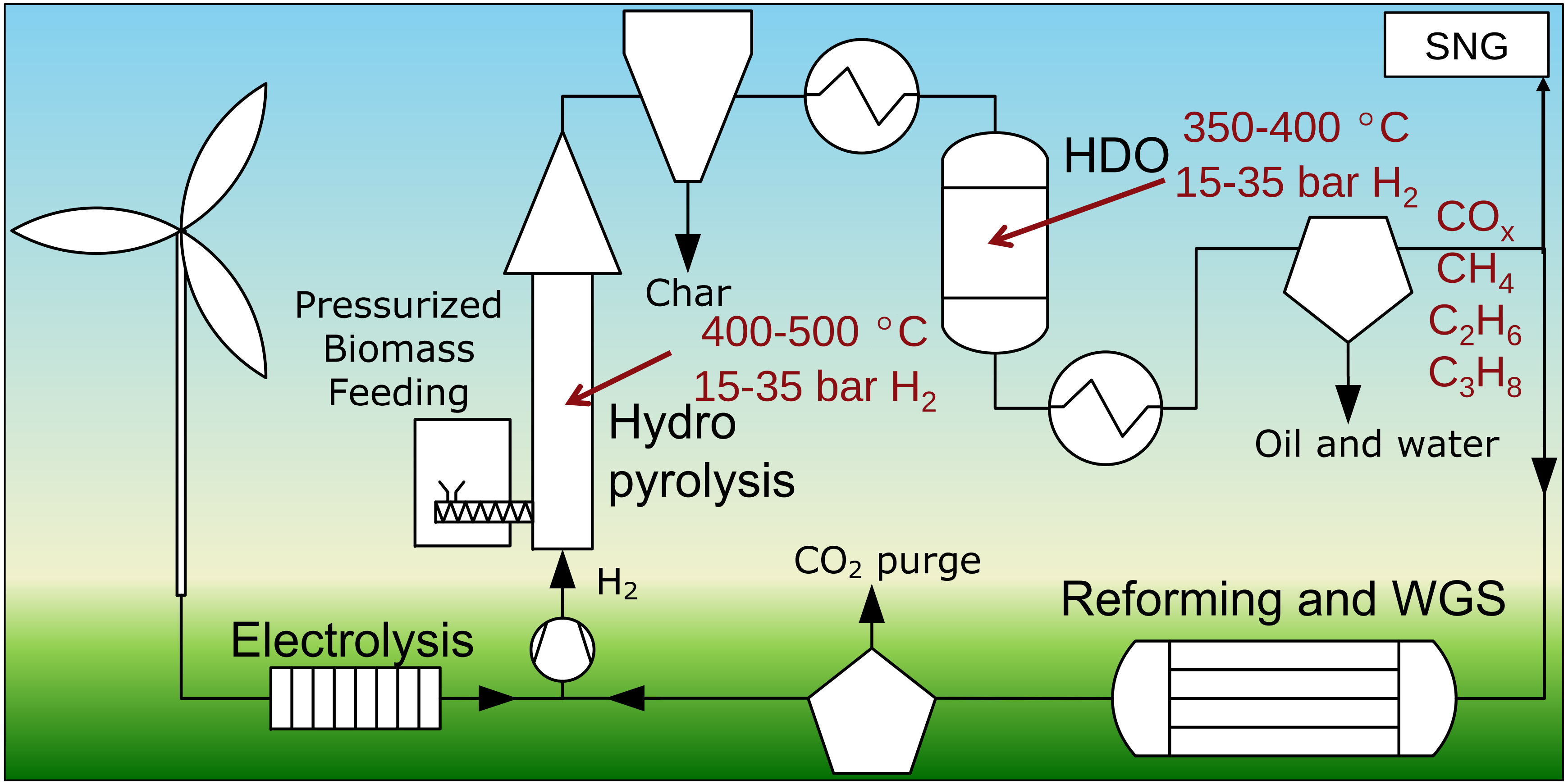
Biomass
Gasification
Pyrolysis
Hydrolysis
Syngas
Bio-oil
Sugar
Lignin
Fischer-Tropsch
Higher Alcohol Synthesis
Methanol Synthesis
Water-Gas Shift
Hydrodeoxygenation
Fermentation
Dehydration
Aqueous Phase Reforming
Hydrogenation
Engine-fuels
Higher Alcohols
Methanol
Hydrogen
Engine-fuels
Ethanol
Hydro-carbons
Hydrogen
Hydro-carbons

Biomass to green fuels



Mortensen et al., Appl. Catal. A 407 (2011) 1-19

Proposed catalytic hydropyrolysis process



Hydropyrolysis processes

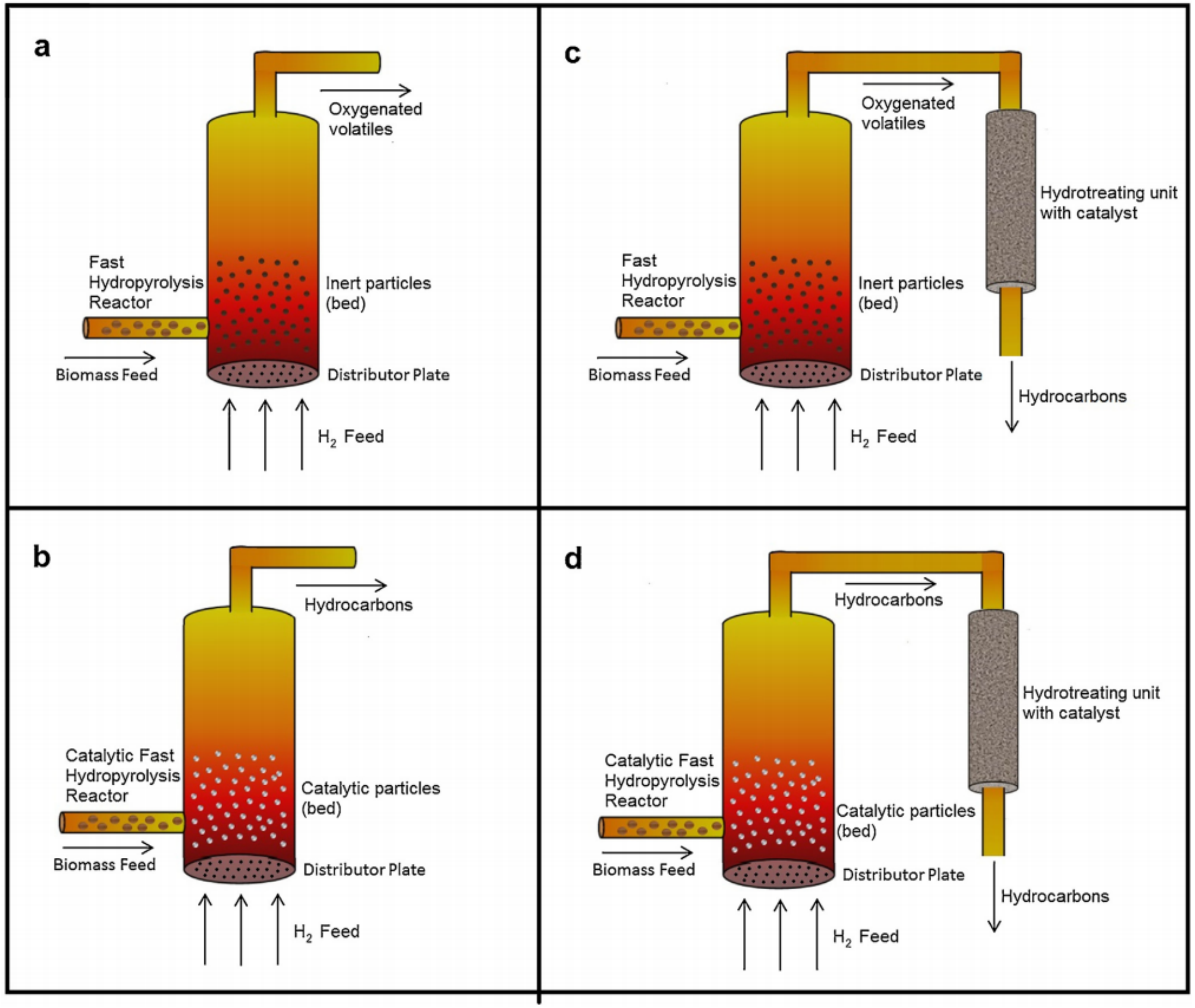
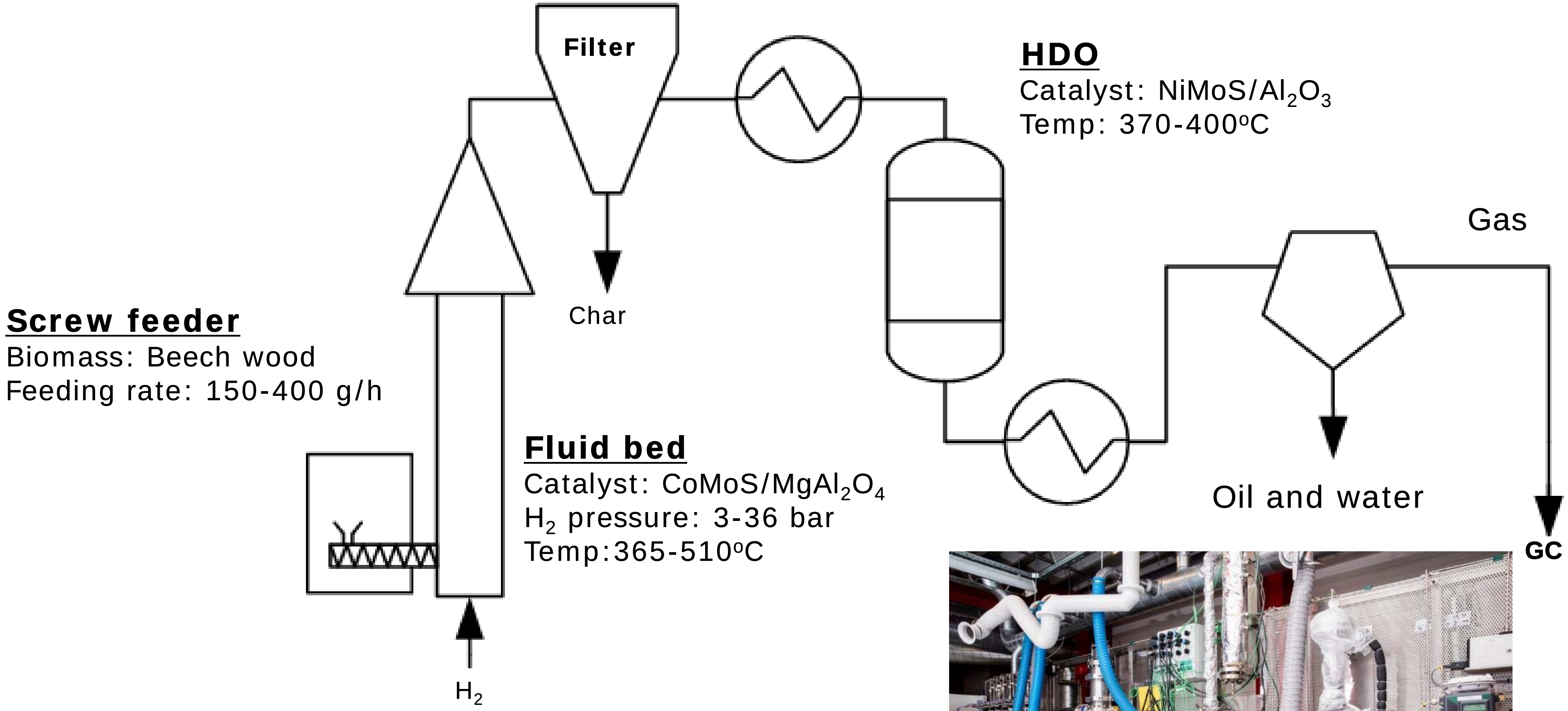


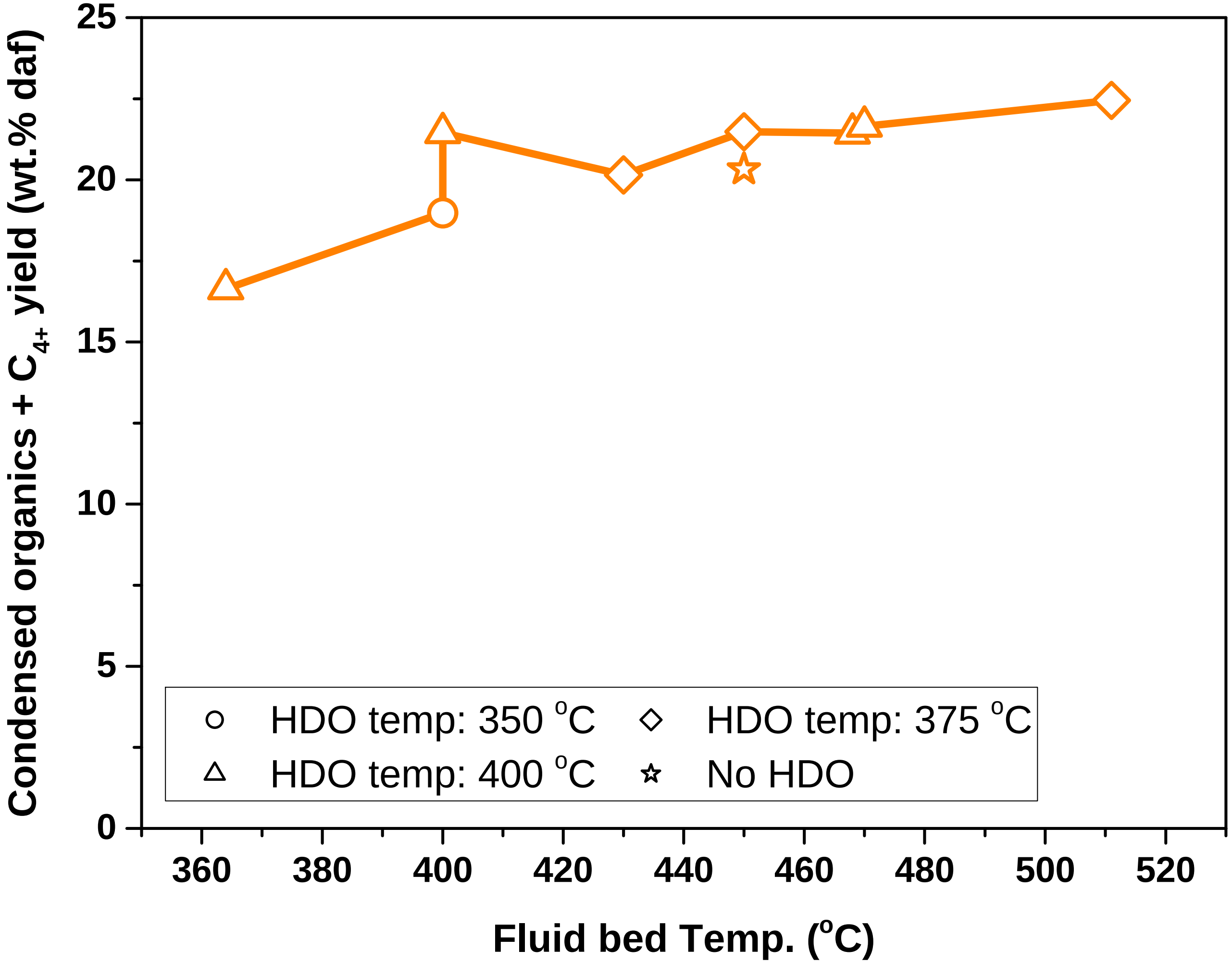
Fig: Resende, *Catal. Today* 2016

- b) RTI (Dayton et al. *Energ. Fuels*, 2013)
- c) Phillips 66 (Zhang et al. *Green Chem.* 2017)
- c) H_2Bioil – Purdue University (Agrawal and Singh, *AIChE J.* 2009)
- d) IH^2 – GTI/Shell (Marker et al. *Environ. Prog. Sus. Energ.* 2012)

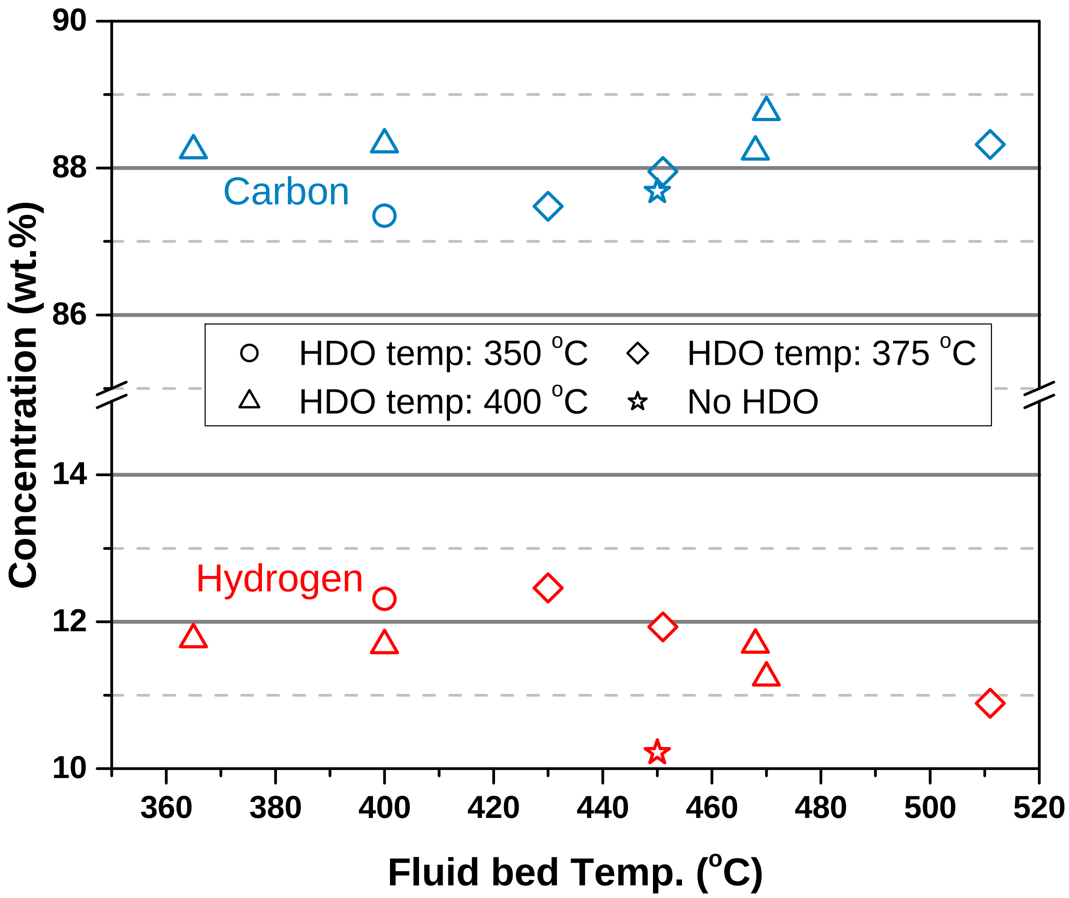
Setup at DTU Chemical Engineering



Hydropyrolysis of beech wood (25 bar)
- Yield of oil as function of temperature

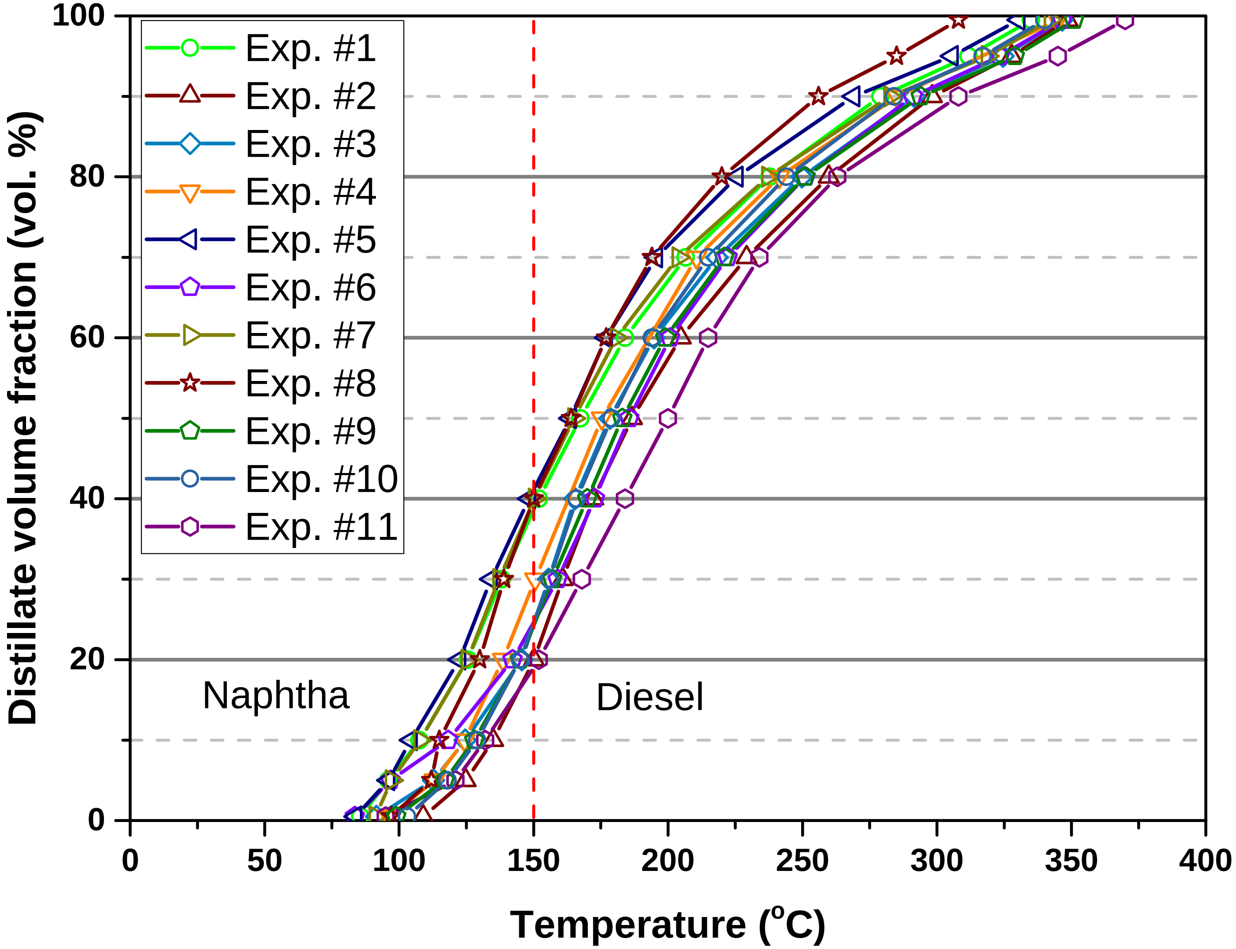


Oil analysis
- Oil composition

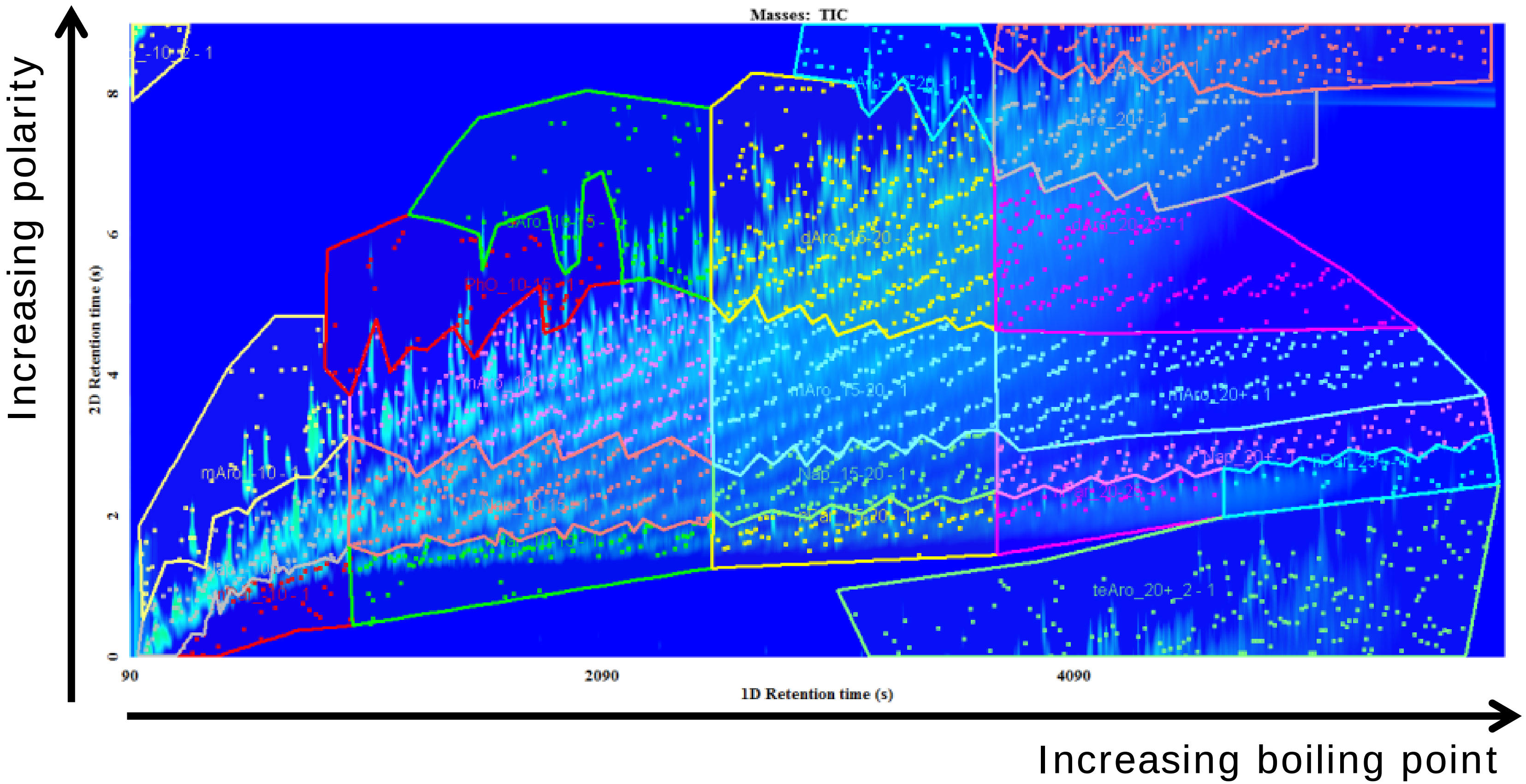


Oxygen <0.1 wt.%
Nitrogen: 0.6 - 24 ppm
Sulphur : 0.06-0.3 wt.%

Oil analysis
- Simulated distillation

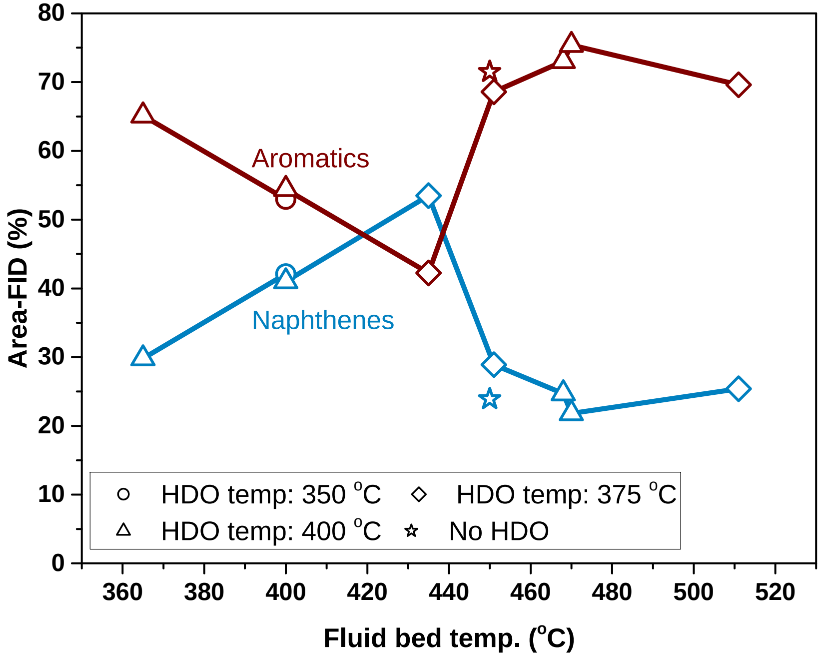


Oil analysis
- GCxGC-MS/FID

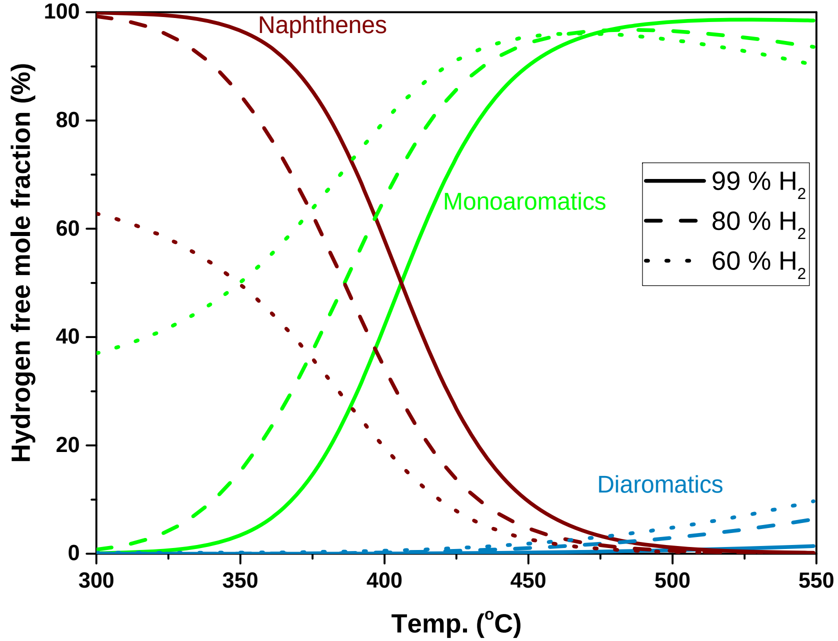


Oil analysis
- Aromatics

Measured concentration

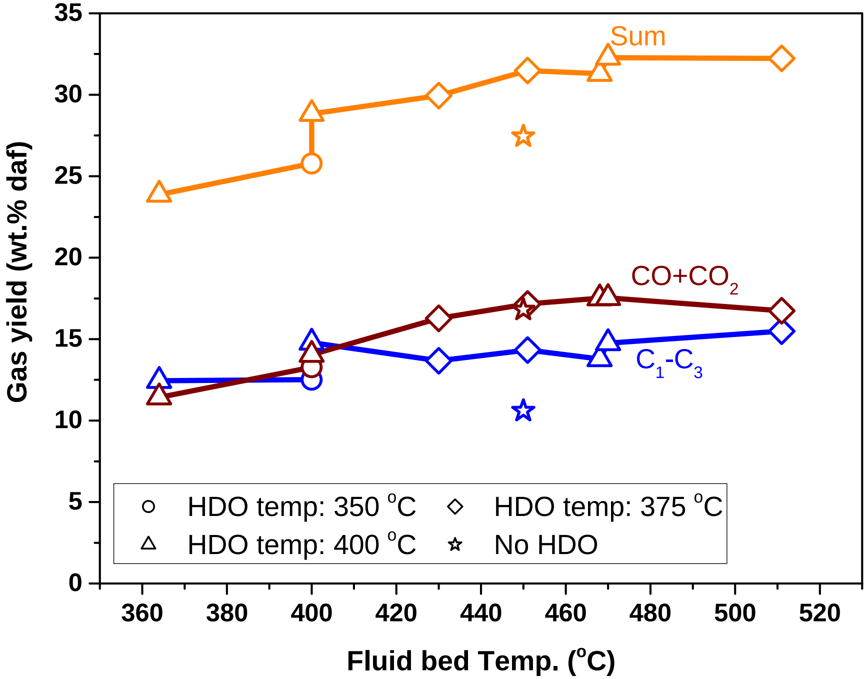


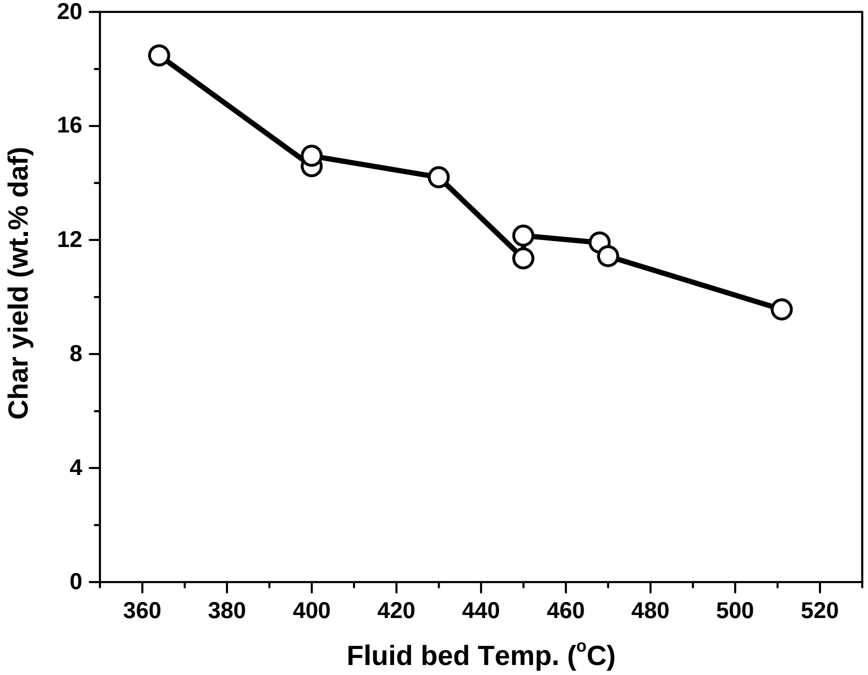
Concentration at equilibrium



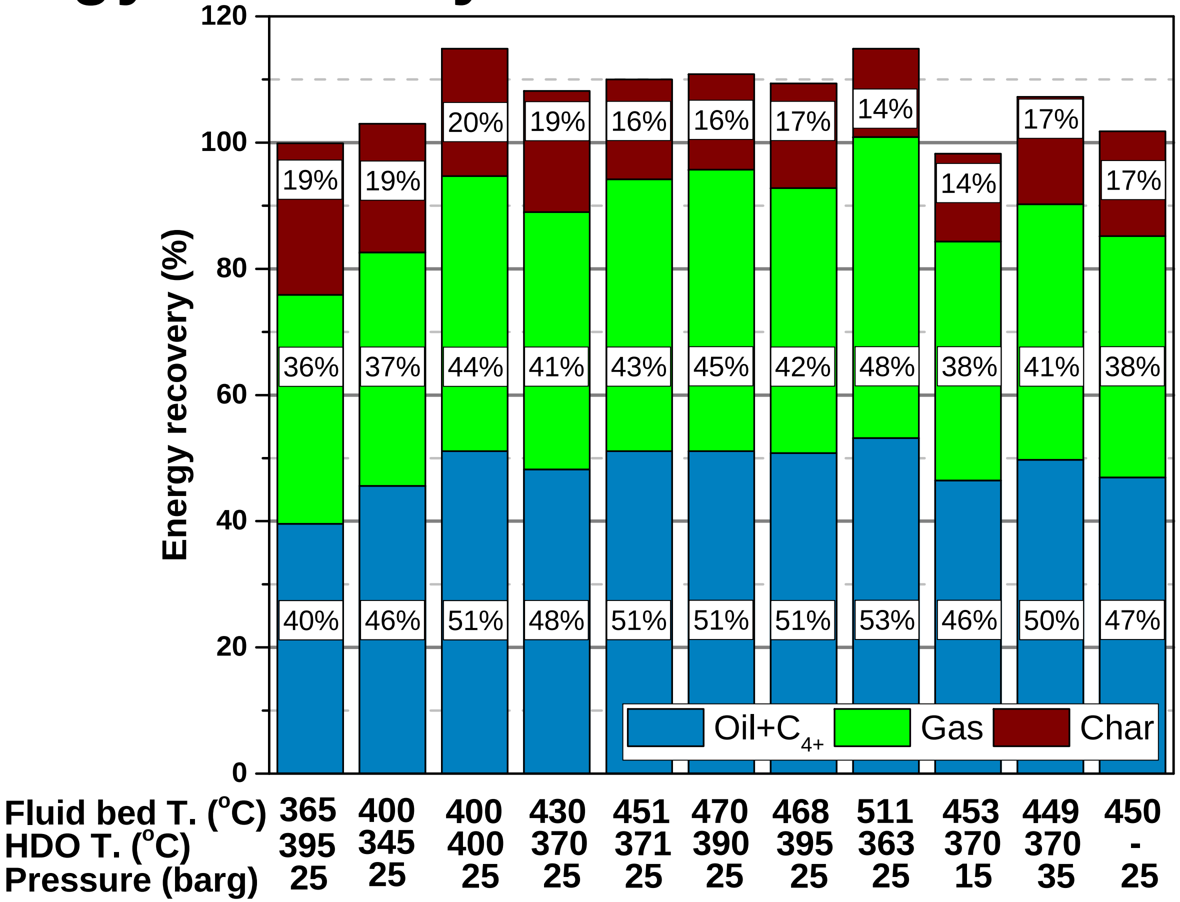
The concentration of aromatics is controlled by kinetics at low temperature and equilibrium at high temperature

Hydropyrolysis of beech wood
- Yield of gas and char as function of temperature





Hydropyrolysis of beech wood - Energy recovery



Energy added in the form of H_2: 0.26-0.34 MJ/MJ biomass

Energy integration with SNG and renewable wind and solar power

Tuong-Van Nguyen & Lasse Røngaard Clausen, Energy Conversion and Management, 171 (2018) 1617–1638

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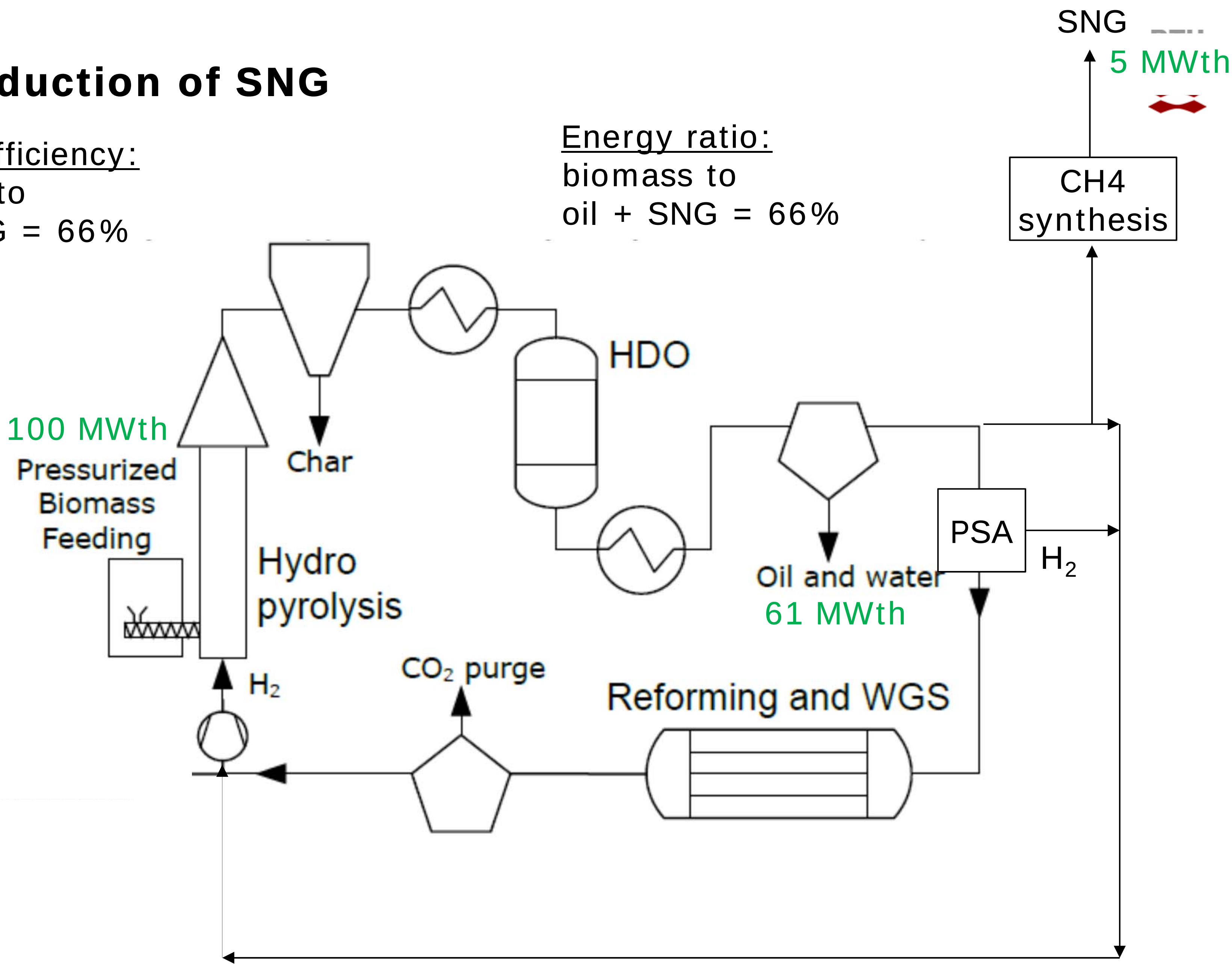
Department of Chemical and Biochemical Engineering

Co-production of SNG

Energy efficiency:
biomass to
oil + SNG = 66%

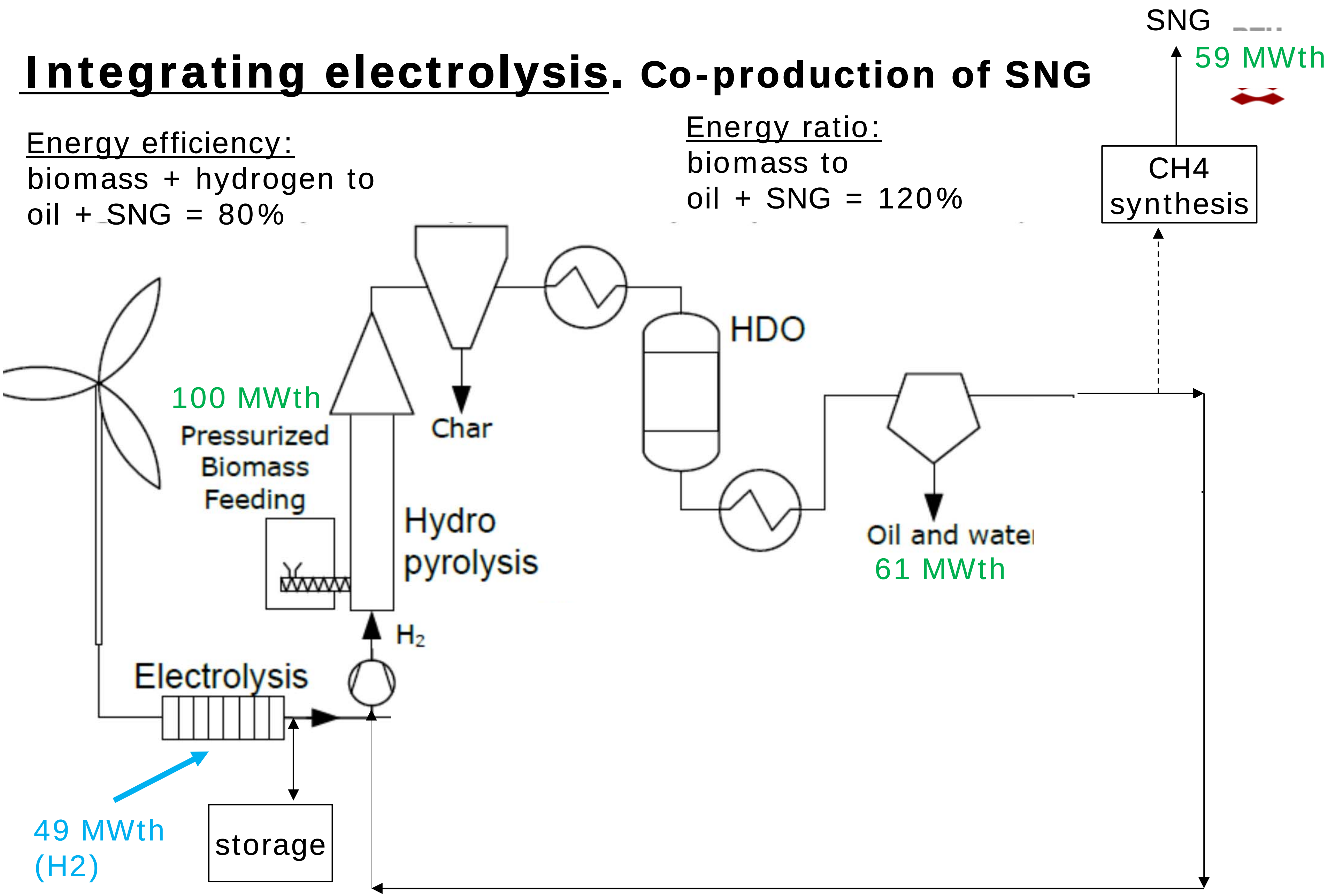
Energy ratio:
biomass to
oil + SNG = 66%



Integrating electrolysis. Co-production of SNG

Energy efficiency:
biomass + hydrogen to
oil + SNG = 80%

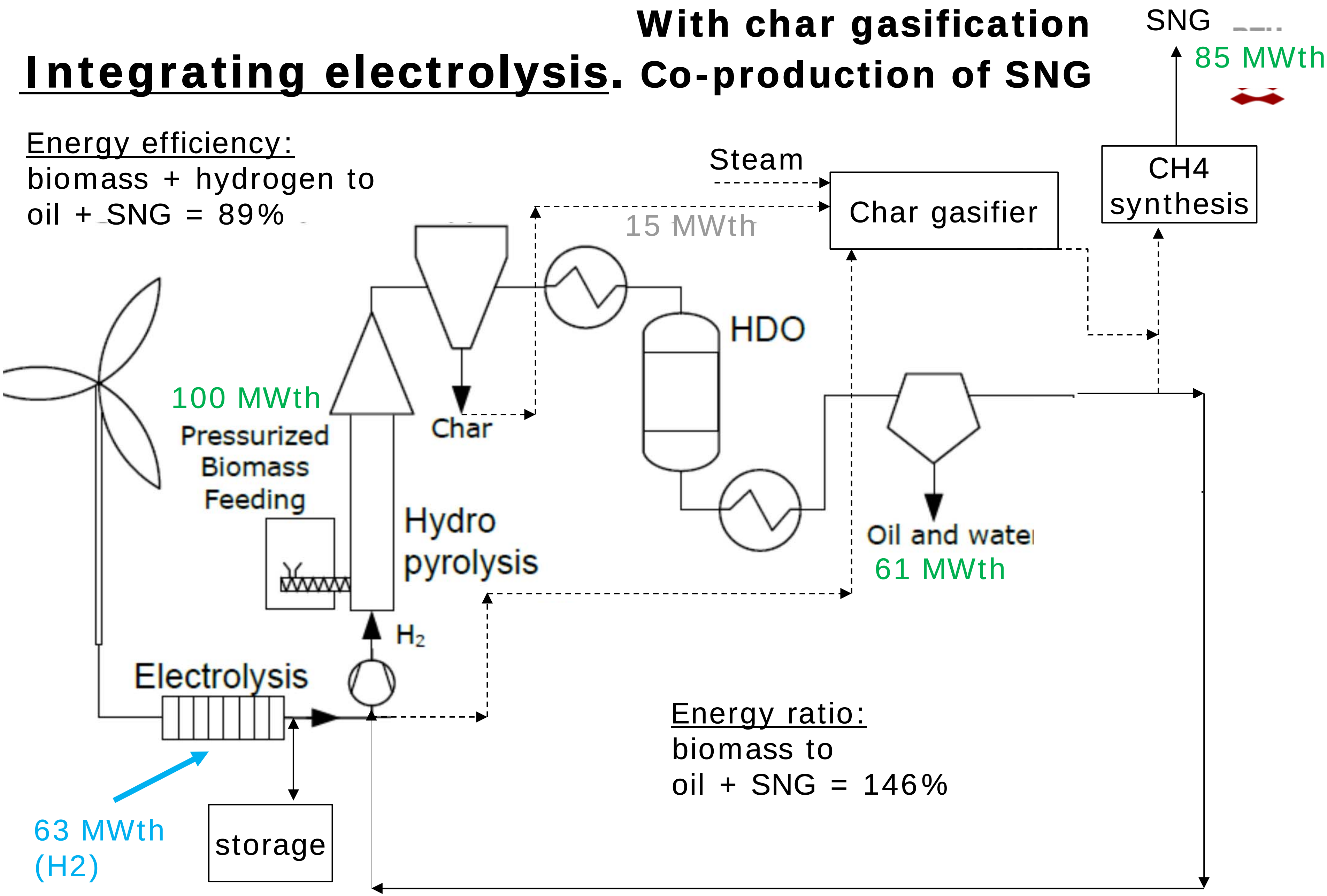
Energy ratio:
biomass to
oil + SNG = 120%



With char gasification

Integrating electrolysis. Co-production of SNG

Energy efficiency:
biomass + hydrogen to
oil + SNG = 89%



Energy ratio:
biomass to
oil + SNG = 146%

Summary

- Catalytic hydropyrolysis efficiently converts biomass into oxygen-free HC fuels with a significant fraction in the aviation fuel BP range
- Co-production of natural gas
- Up to 25 wt. % oil yield ~60 % energy recovery in the oil
- Light gases can be used to generate the required H_2 and some SNG: Total energy efficiency of 66 %
- When coupled with electrolysis to produce the required H_2:
  - Total energy efficiency of 80 % (energy ratio of 120 %)
- Exploiting also the char and coupled with electrolysis:
  - Total energy efficiency of 89 % (energy ratio of 146 %)

Thank you for your attention

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