Hydrothermal liquefaction of biogenic waste

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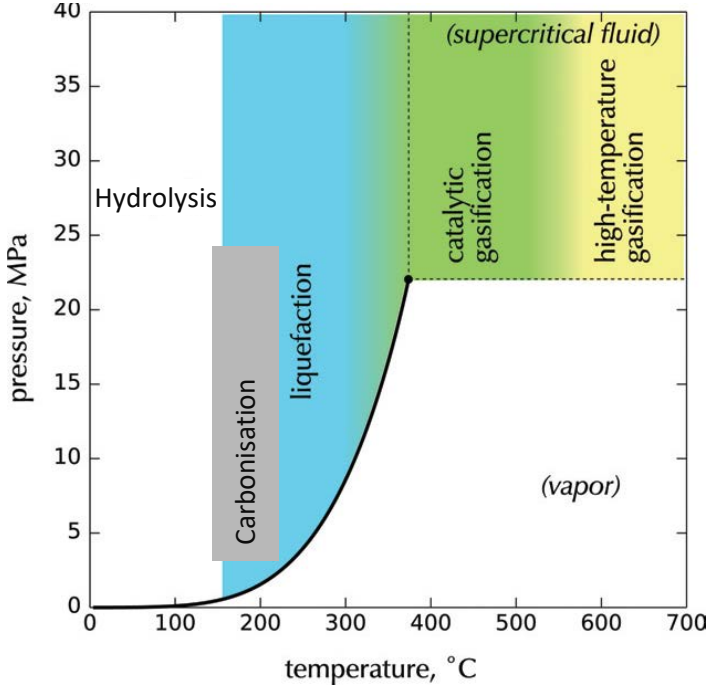
10/03/2022

DRT/LITEN/DTCH/SCPC/LRP

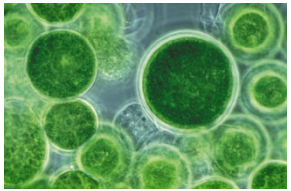
Hydrothermal Liquefaction – the basics

Hot pressurised water



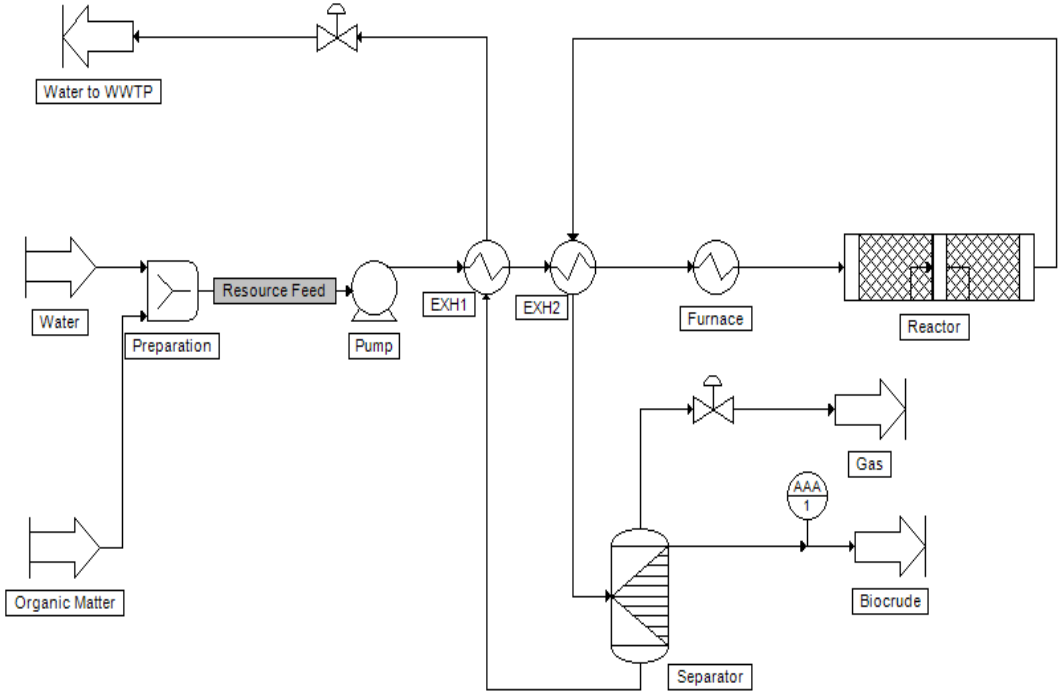
Resources: very flexible

- Dry and wet
- Wastes and culture



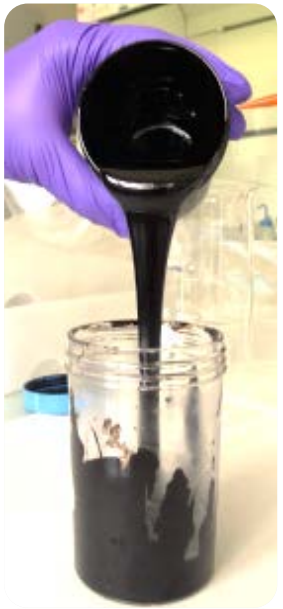
Hydrothermal Liquefaction – the basics

The process :

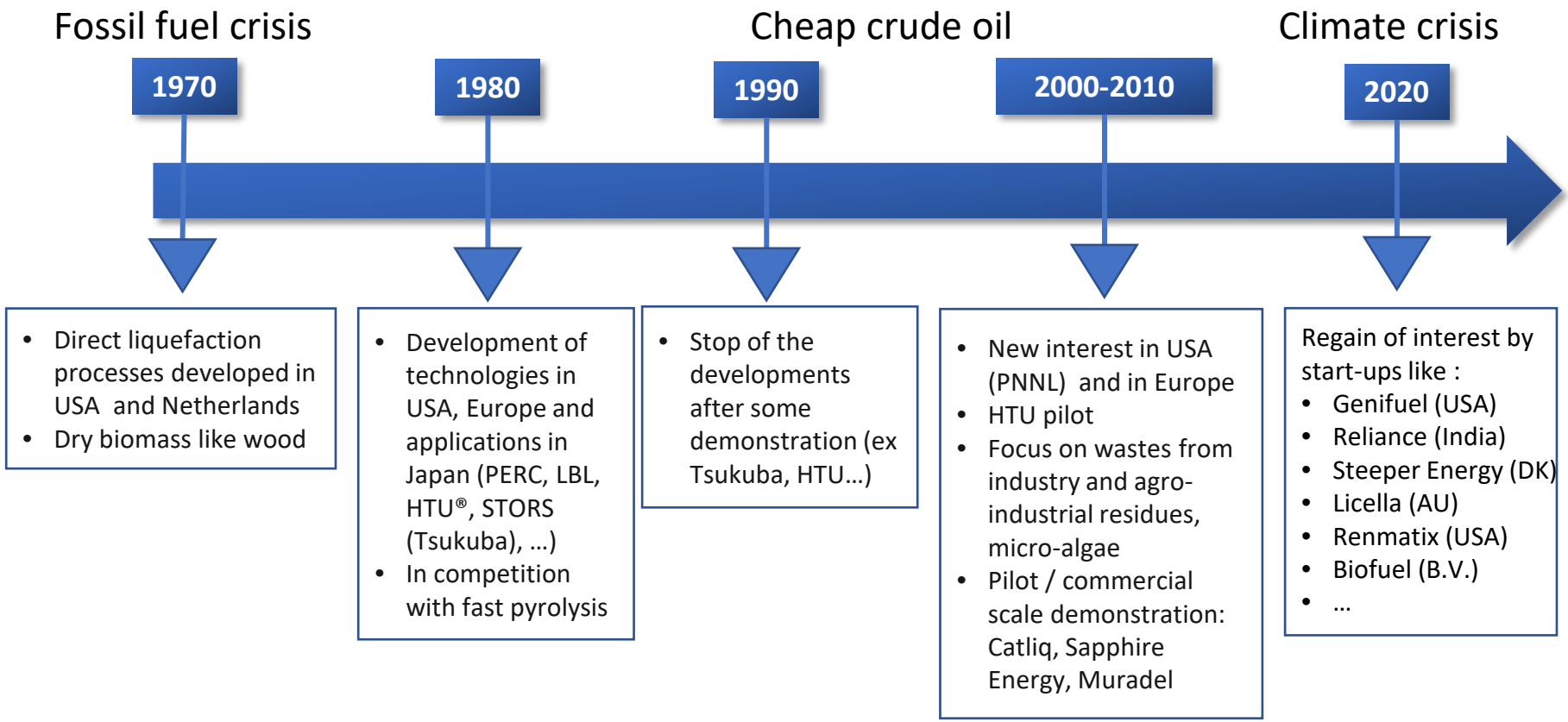


Products:

- Black viscous oil



Hydrothermal Liquefaction - History



Presentation

Resources
- Composition

Hydrothermal transformation
- Equipment
- Chemistry
- Kinetics

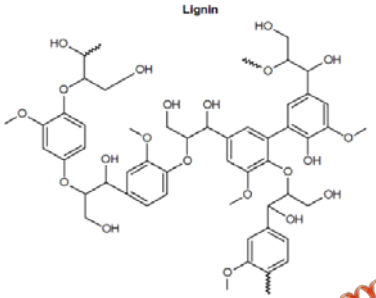
Products
- Yields
- Characterisation

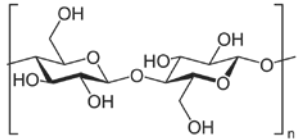
Wastes and economics

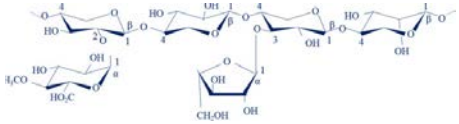
Characterisation resources

Chemical composition

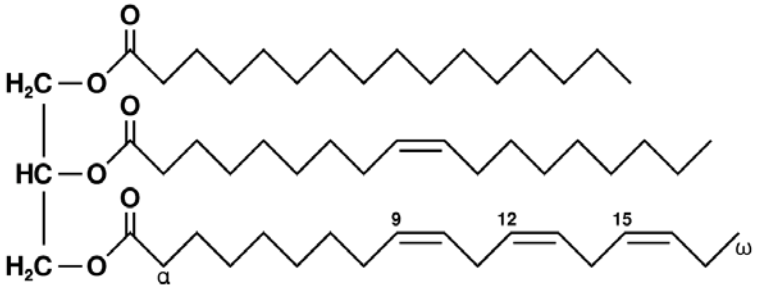
- Fibres
  - Lignin
  - Cellulose
  - Hemicellulose
- Proteins (amino acids)
- Lipids
- Extractives
  - Sugars
  - Tannins (phenolics)
  - Acids
  - Pigments
  - …
- Inorganics





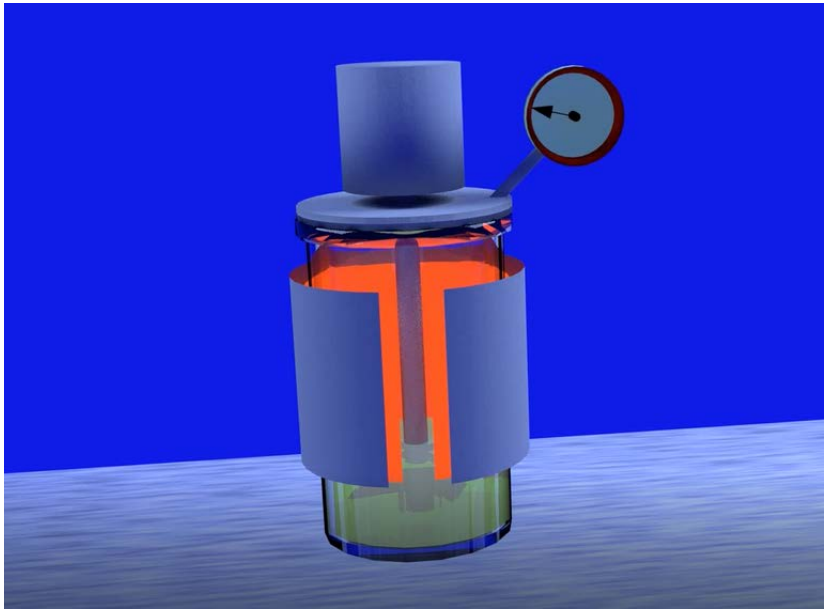


Amino acids



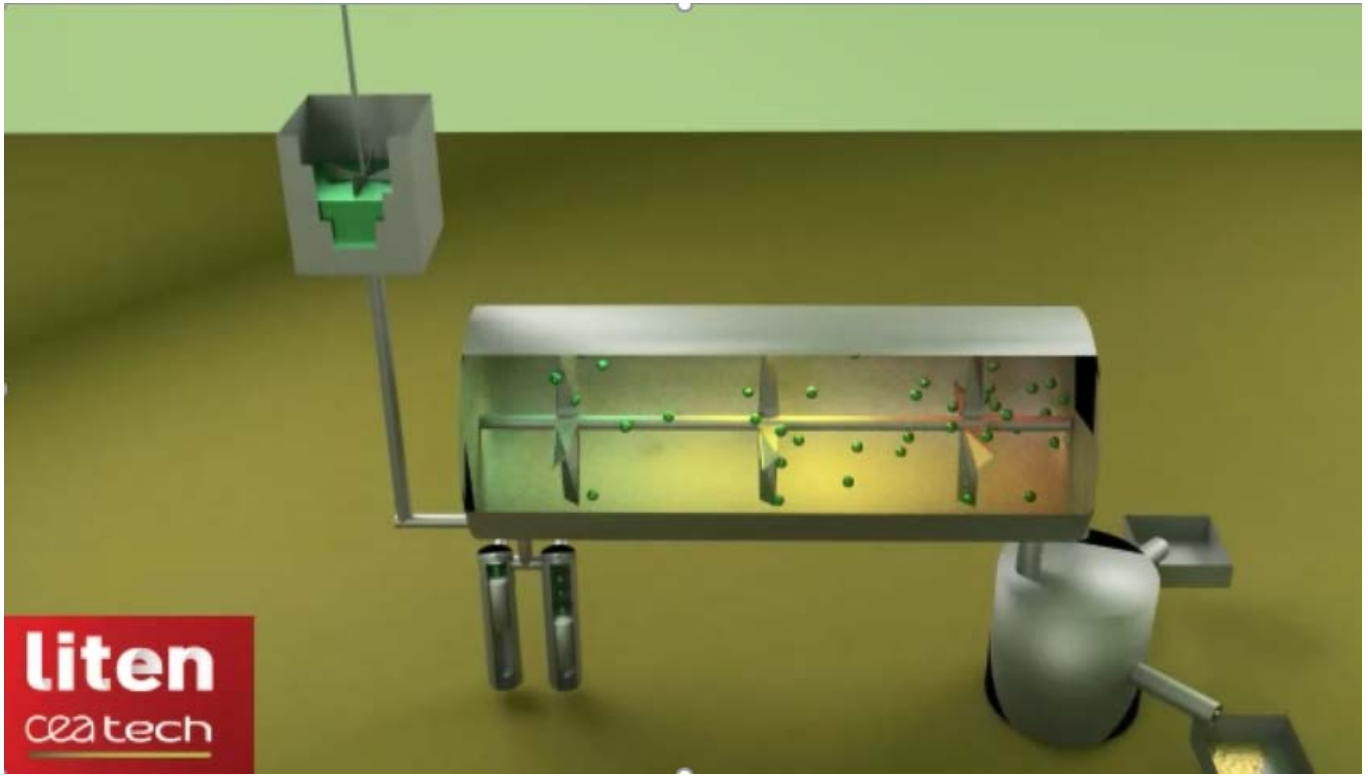
Hydrothermal Liquefaction – the process

Batch in the laboratory



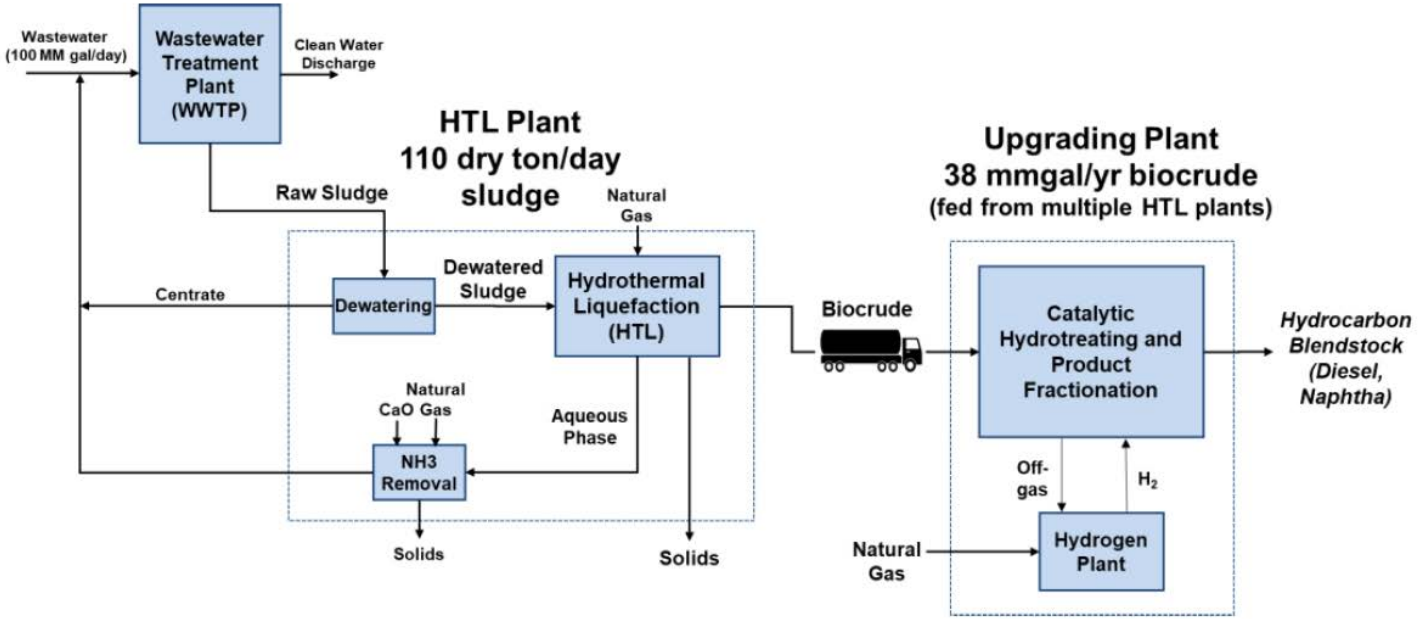
Hydrothermal Liquefaction – the process

Continuous in the laboratory



Hydrothermal Liquefaction – the process

Industrially



L. Snowden-Swan et al., PNNL - 29882

Products

HTL Reactor → Mixture

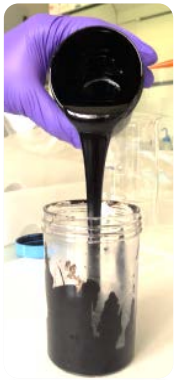
- Process water

- Gas

CO_2 with traces of CH_4, H_2, CO, …

- Biocrude
  - Bio-oil
  - Char

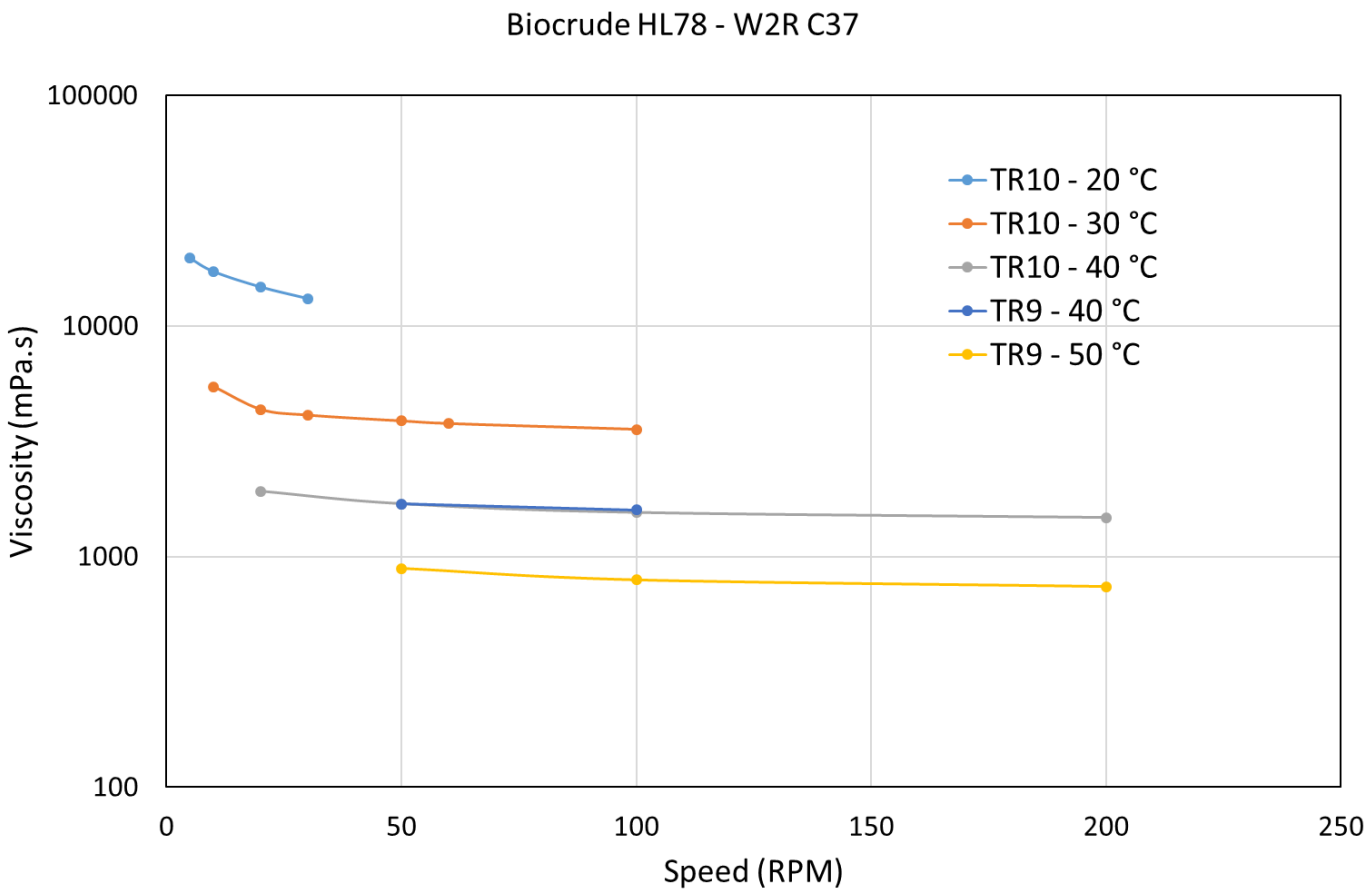
Solvent separation
Distillation



Products - Viscosity

Viscosity Biocrude

- Non Newtonian fluid
- Strong temperature dependency



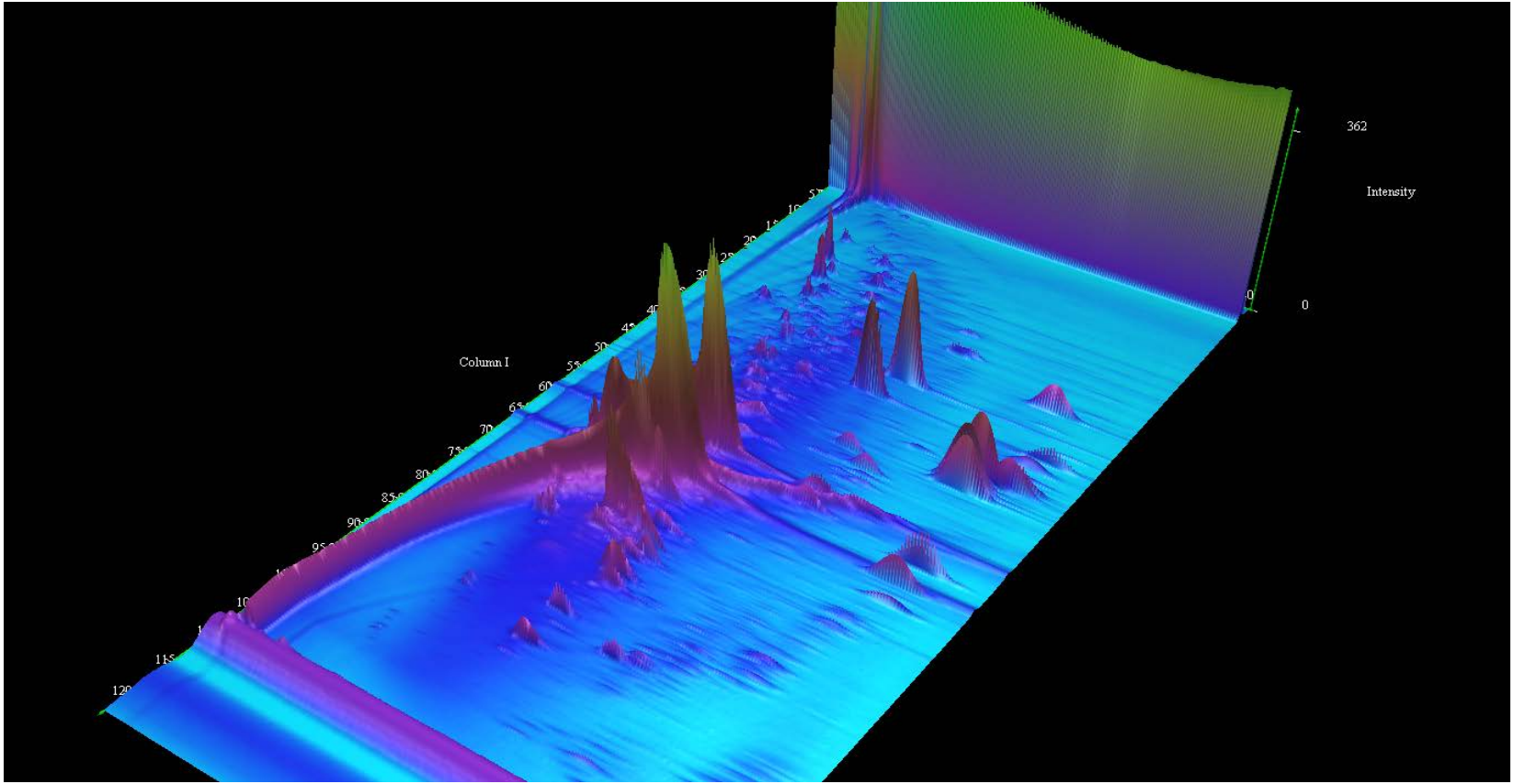
Products – Fuel properties

Chemical properties of biocrude and bio-oils

- Low inorganics content < 1 %
- Acidity 90-150 mg KOH/g oil
- Iodine value 100-150 g I_2/100 g oil
- Density between 900 and 1100 kg/m^3
- Heating value (32-37 MJ/kg)
- Oxygen content <10 %
- Sulphur and Nitrogen content variable

Products Composition

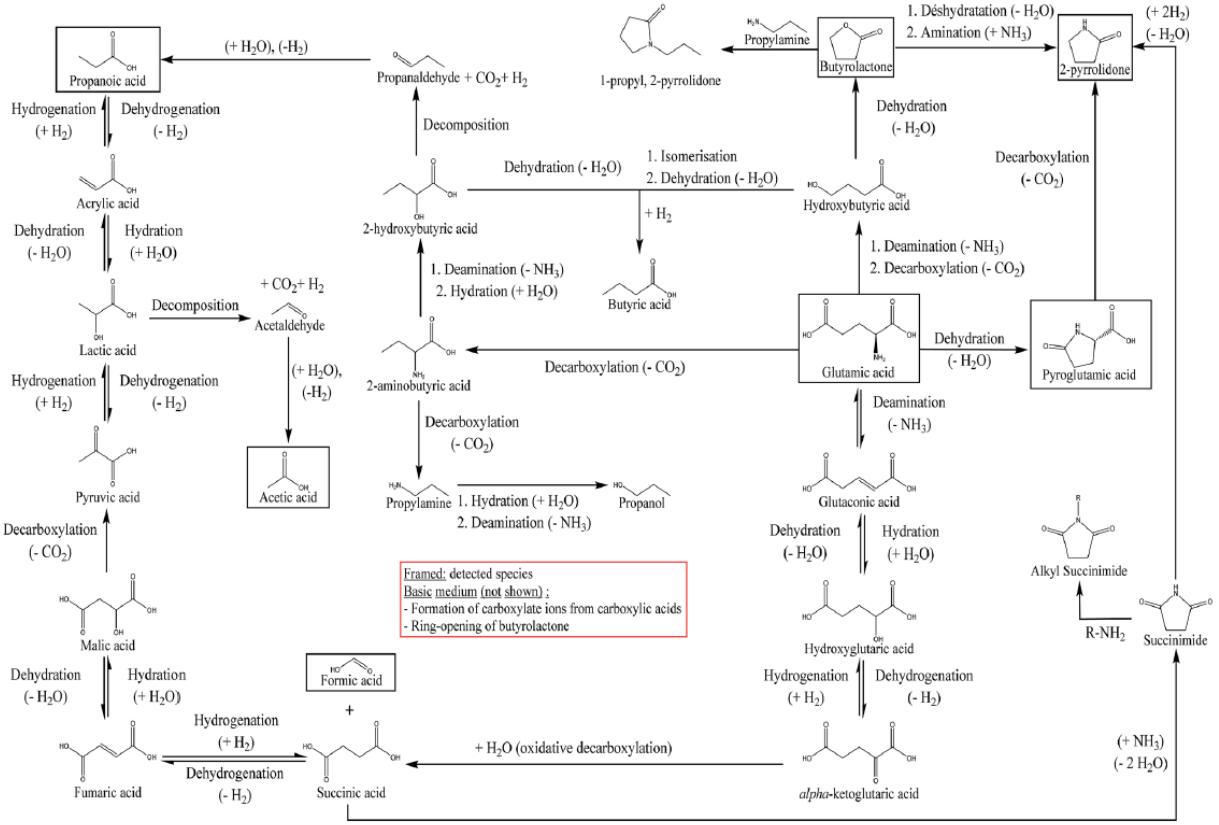
Chromatography



Chemistry – Reaction Mechanisms

From the detail …

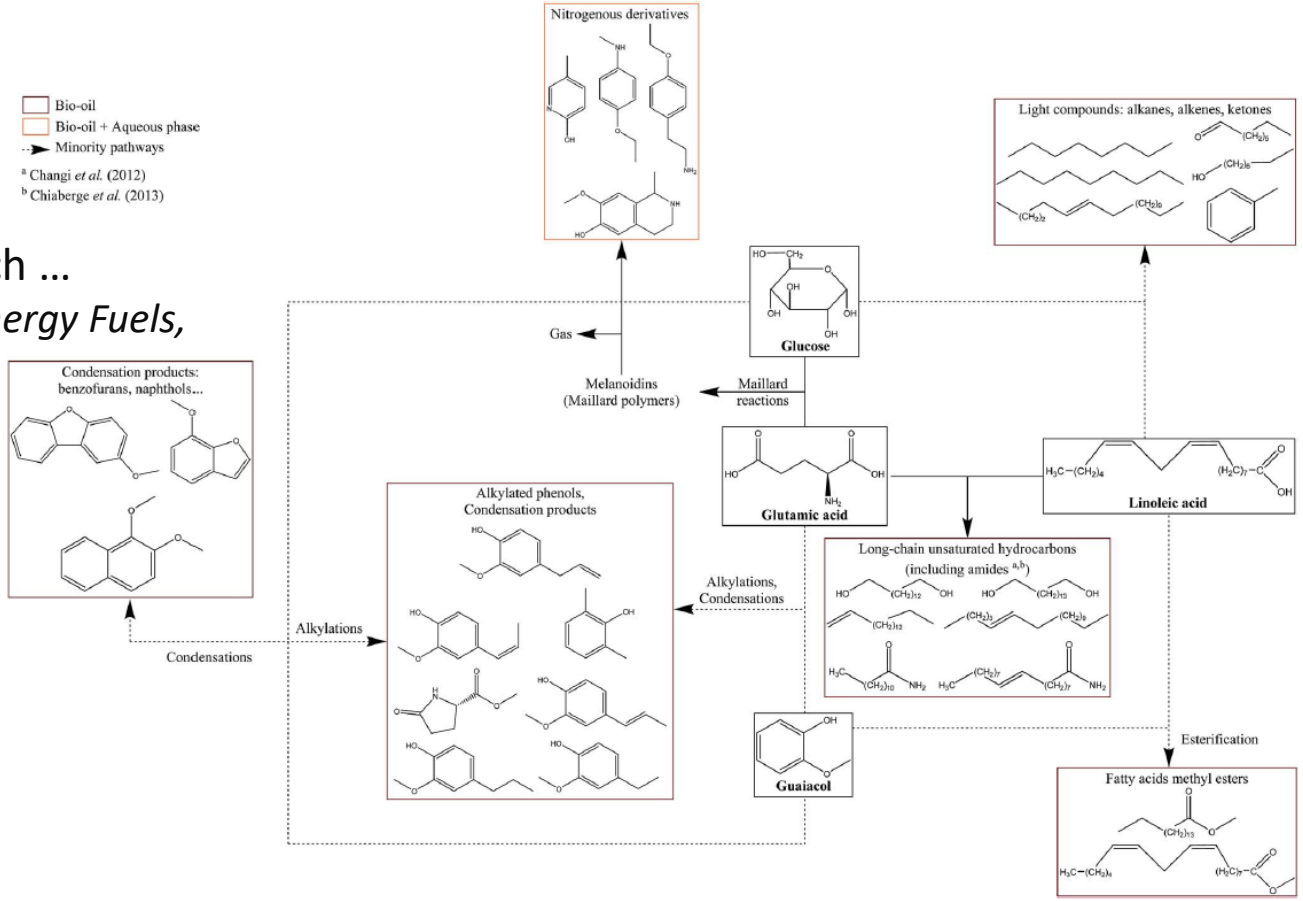
A. Kruse and A Gawlik, Ind. Eng. Chem. Res. ***2003,*** *42, 267-279*



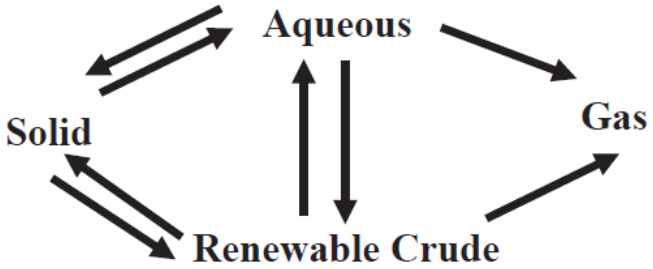
Chemistry – Reaction Mechanisms

… to a more global approach …

M. Déniel et al., Sustainable Energy Fuels, 2017, 1, 555



Chemistry – Reaction Mechanisms

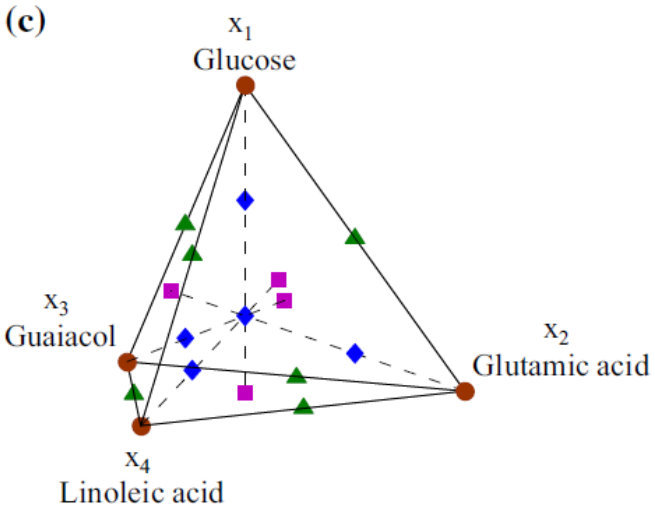


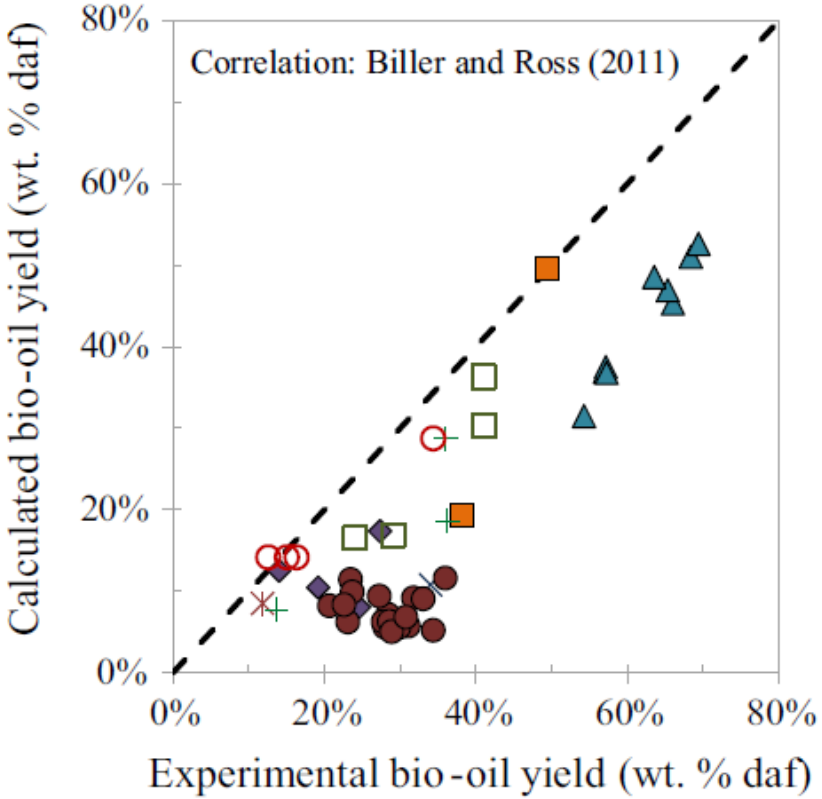
… to even more simple

R. Obeid et al., Chemical Engineering Journal 389 (2020) 124397

Correlations

- Design of experiments
- Fit equations on experiments

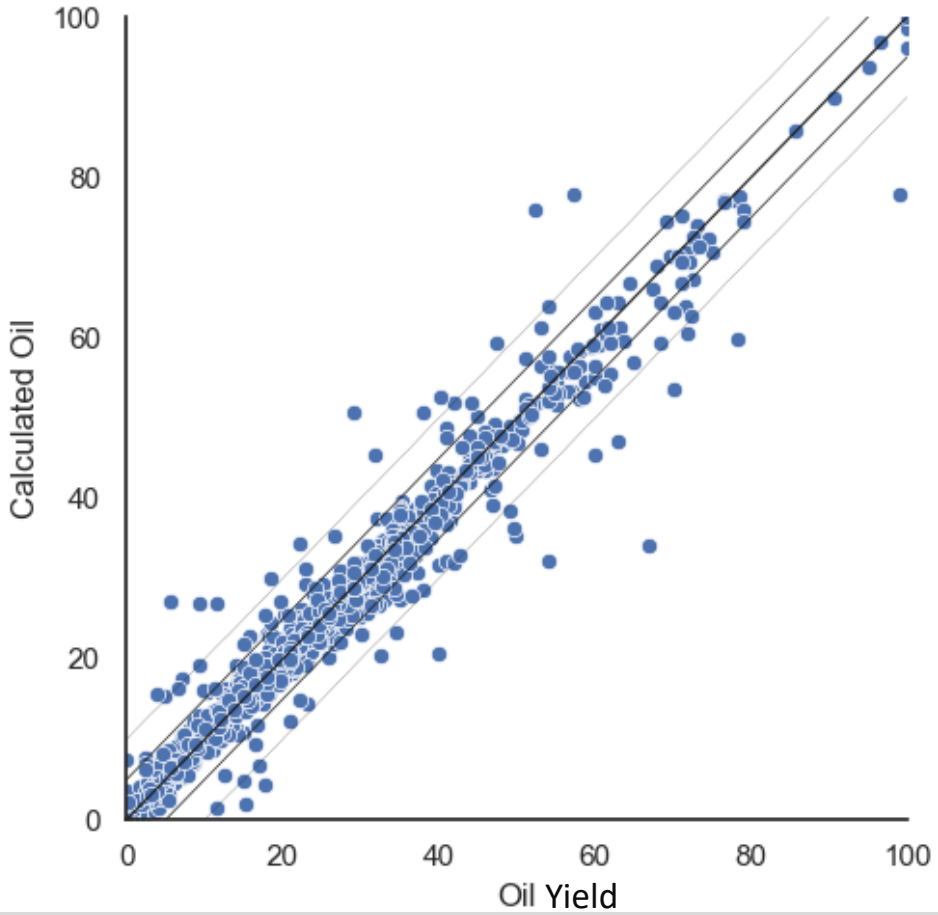




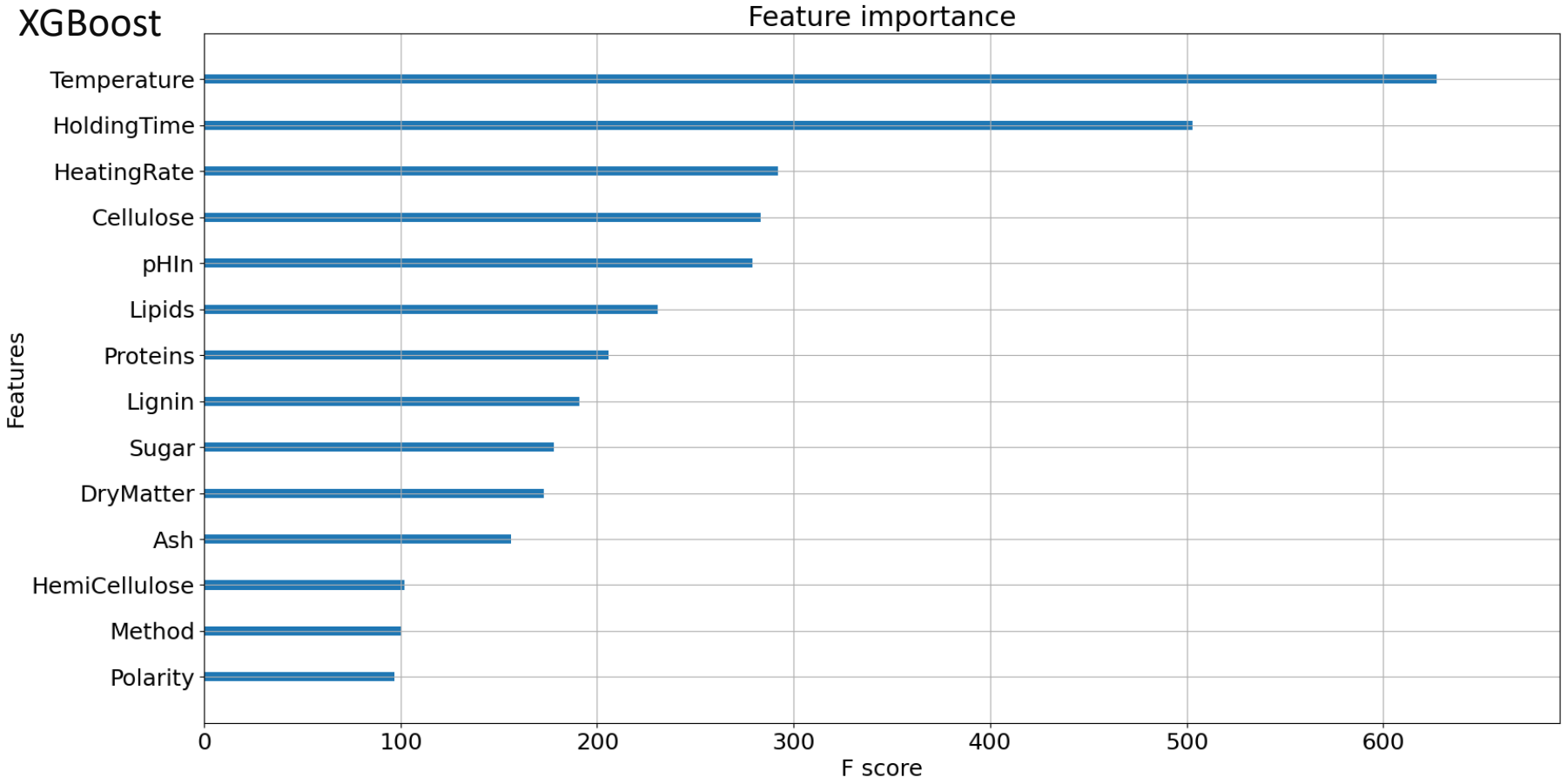
Déniel et al., Waste Biomass Valor, 7, 2016, DOI 10.1007/s12649-016-9726-7

Chemistry – ML Modelling

eXtreme Gradient Booster
(dataset 1377 experiments)

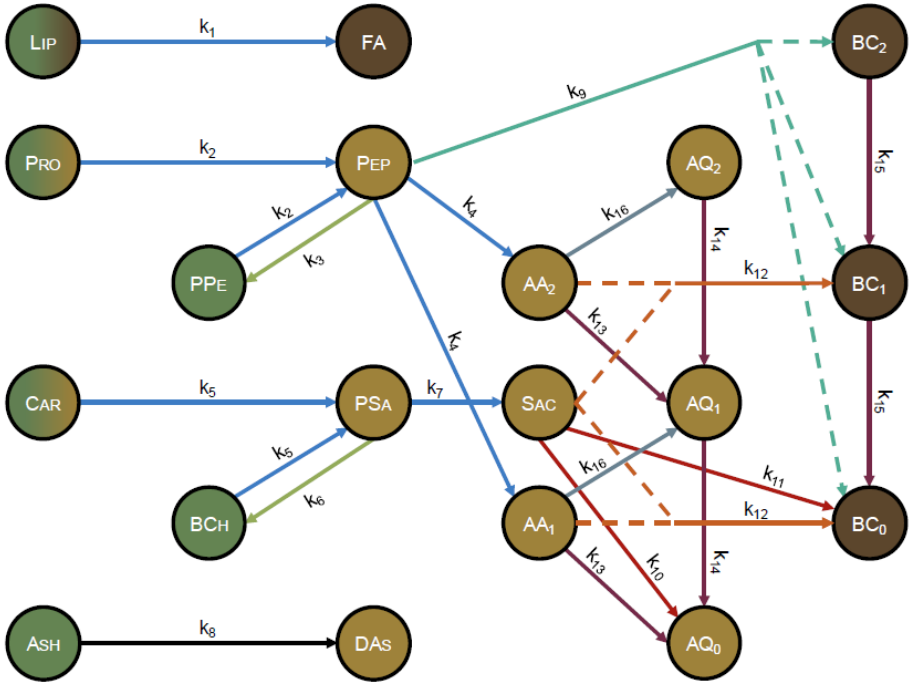


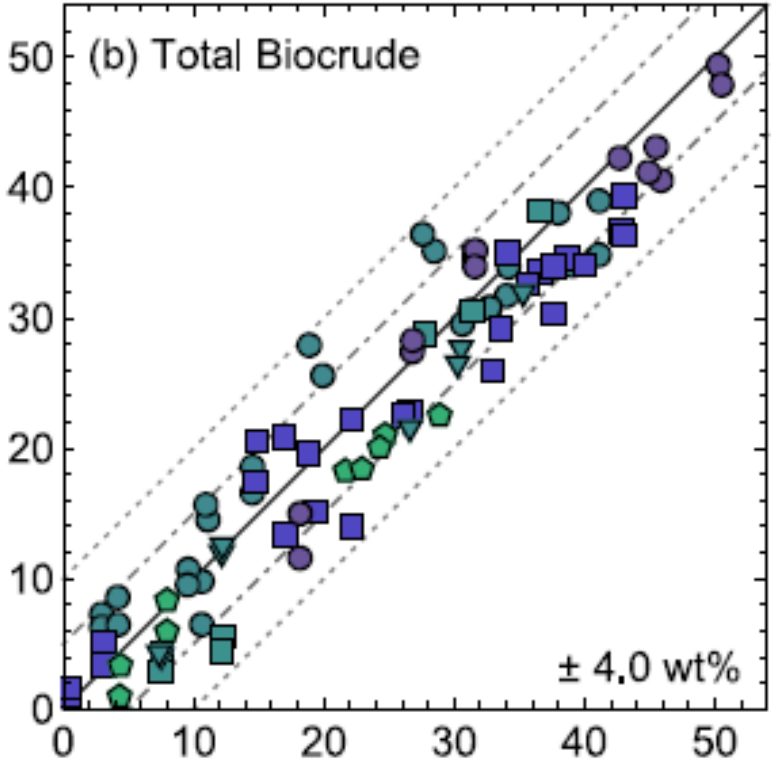
Chemistry – ML Modelling



Some propositions

D.C. Hietala and P.E. Savage , Chemical Engineering Journal 407 (202





Wastes

Water phase

- Rich in organics and inorganics
- Require treatment before discharge
  - Recycle in HTL process
  - Recycle in algae pond
  - Hydrothermal treatment (catalytic, supercritical)

10-30 g Carbon/L

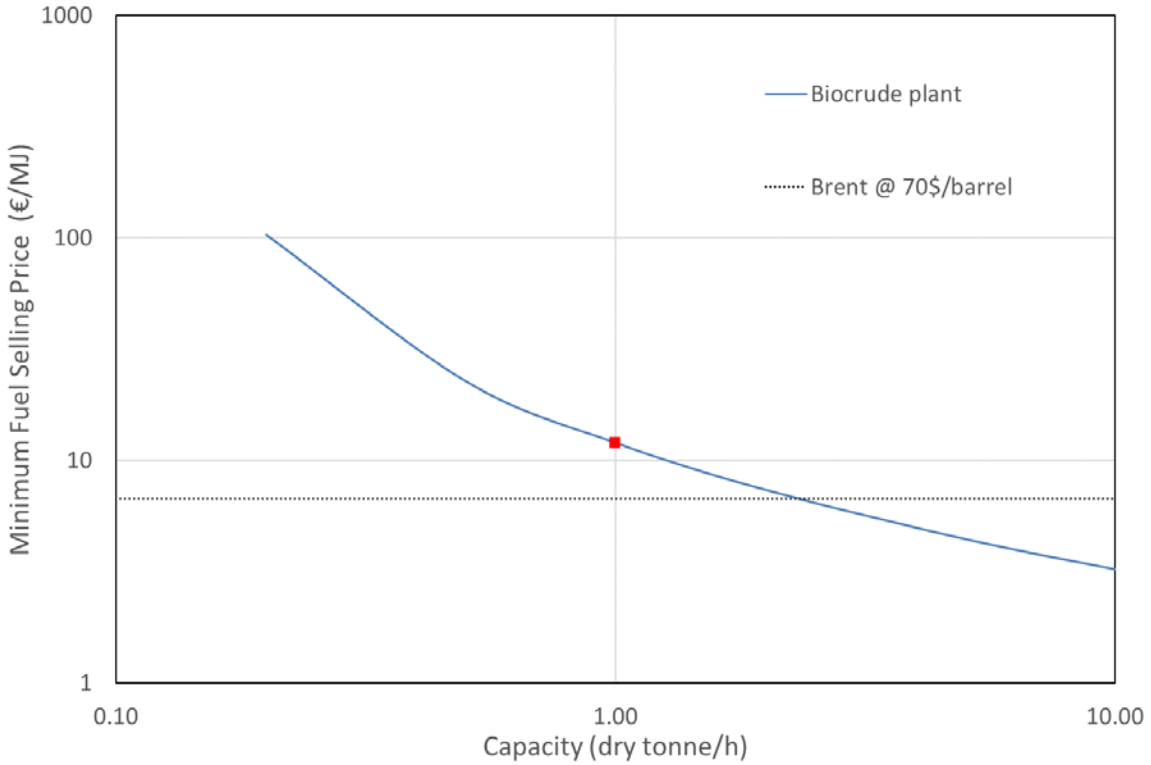
Hydrochar

- Fuel
- Material applications

Economics

Costs (1 t dm/h)

- CAPEX 6-10 M€



Expensive but feasible

- Free resources
- Gate fee makes it possible
- Uncertainty markets

G. Haarlemmer et al., Detritus / Volume 03 - 2018 / pages 84-92
L. Snowden-Swan et al., Report PNNL - 29882

Conclusions and lookout

Interesting conversion technology

- Flexible in the resource
- Low temperature -> Not too energy intensive
- Economics delicate

Future work

- The chemistry and its kinetics
- Upgrading of the HTL Liquids
- Demonstrate

THANK YOU FOR YOUR ATTENTION

March 10, 2022