# Lignocellulosic biomass in advanced biofuels production – unlocking the potential

**Alexander Reznichenko**

# Outline

- Introducing VTT
- Why lignocellulosic biomass?
- Catalytic upgrading
- Slurry hydroprocessing
- Summary

# Sustainable growth with research and development

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|---|---|---|
| employees | customers | operating income |

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# Why lignocellulosic biomass?

- Estimated to replace 300+Mt/a of crude oil
- Finland alone produces 25+ Mt/a of forestry side streams from primary and secondary sources
- Currently used mostly in energy production
- Still Less expensive than eFuels -?

Sources Neste: 2021: plant-based-waste-and-residues-biofuel-geeking-out-over-lignocellulose
Hassan et. Al, https://doi.org/10.1007/s10163-018-0787-5

# VTT thermal conversion platform

Wastes

Forest Residues

Biomass

Agricultural Residues

CO2

Combustion

Gasification

Pyrolysis

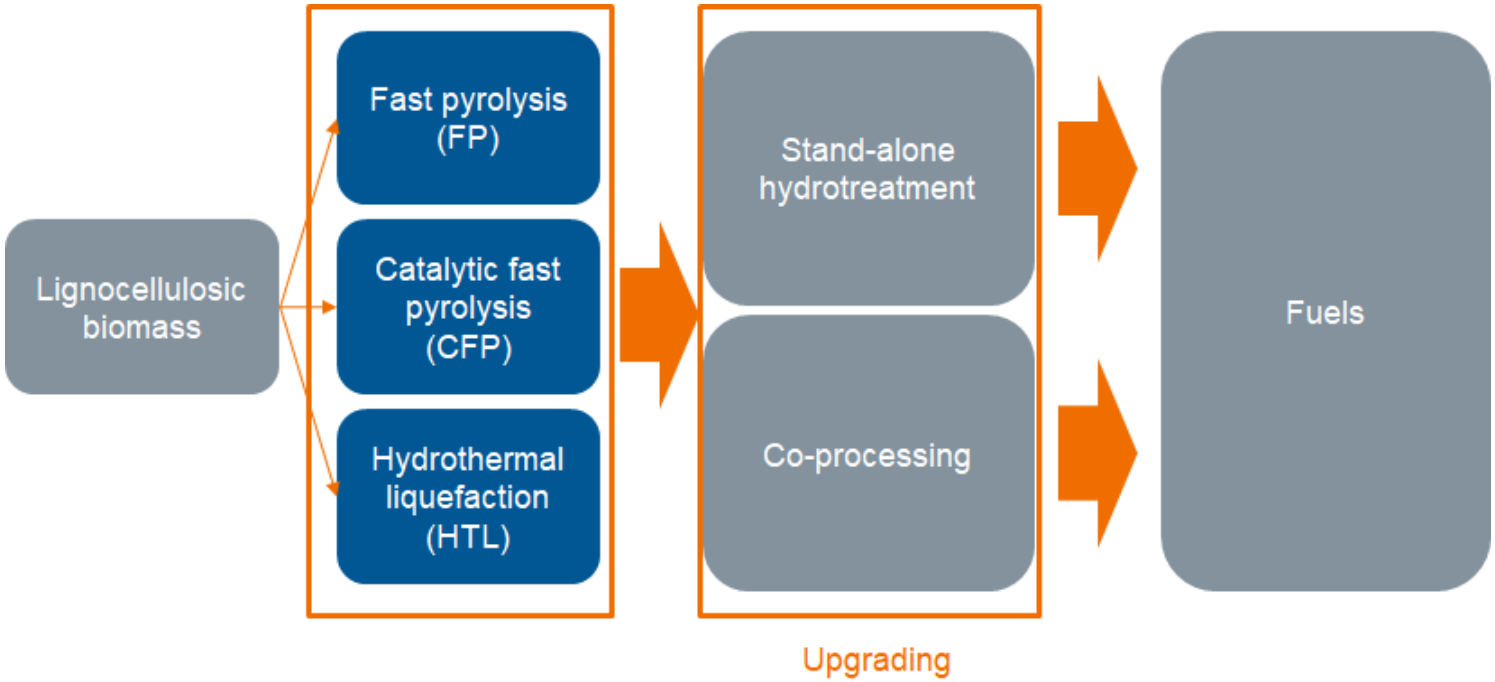
HTL, HTC

Syngas processing

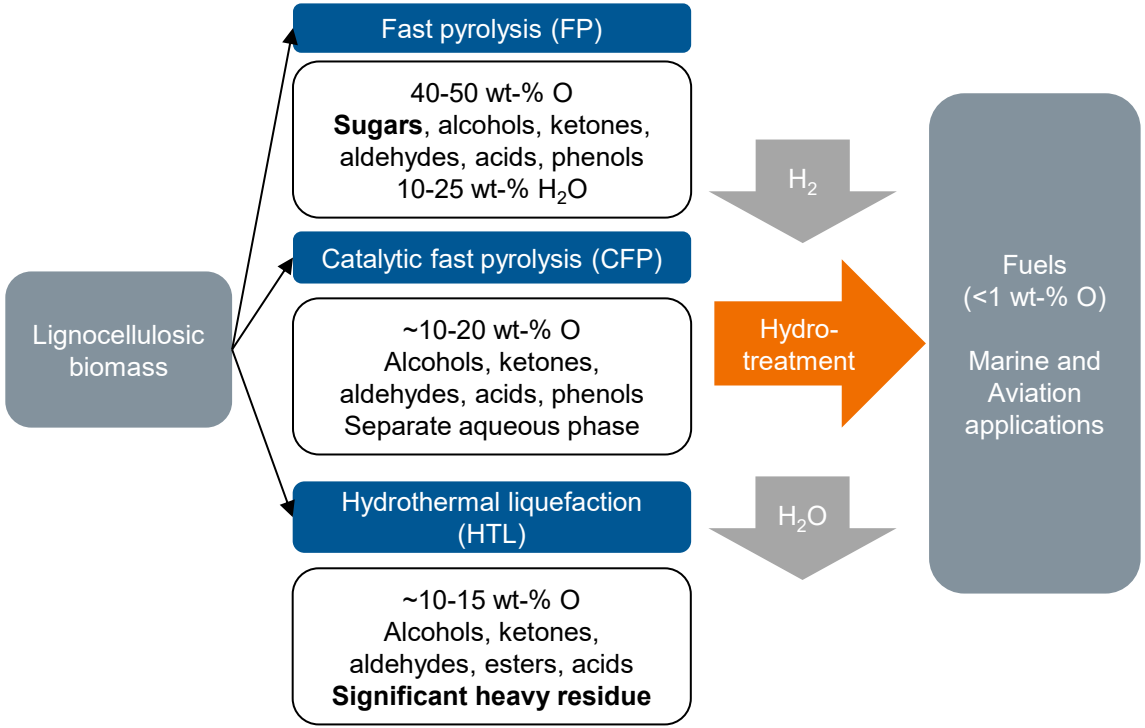
- Power
- Heat & cooling

- Gasoline
- Diesel
- Jet fuel
- Chemicals
- Recovery of inorganic materials

# Biofuels from lignocellulosic biomass via liquefaction



# Bio-oil hydrotreatment



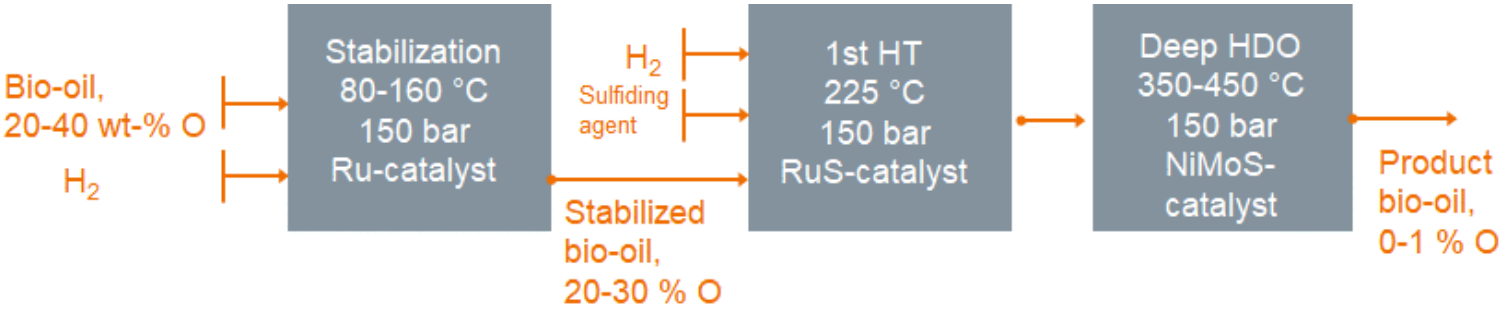

## Challenges for catalyst and process development

- Thermal instability
- Catalyst coking
- Catalyst poisoning
- Catalyst cost

# Stepwise processing of bio-oils

- Fast deactivation & plug formation in the reactor tackled by hydroprocessing the bio-oil in multiple fixed-bed reactors

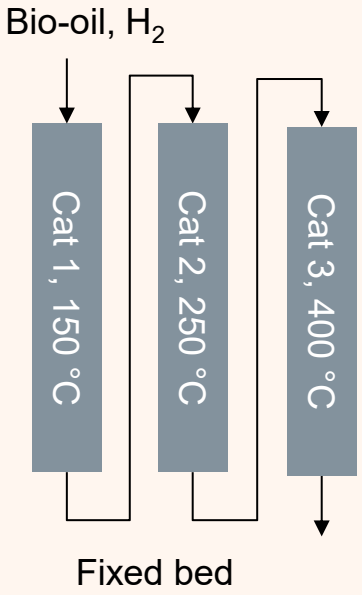
- **Problems**: expensive catalysts, deactivation during 1st stabilising hydrogenation step, due to sulphur and coke formation
  - Longest successful run at VTT with FPBO: ~ 70 hrs



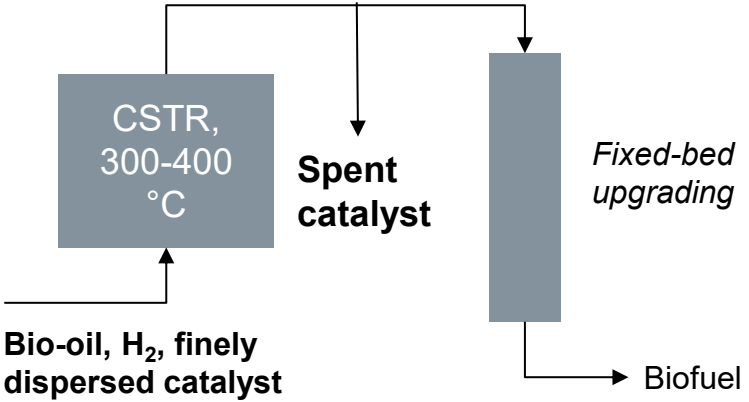

Zacher, A. H. *et al.* (2019) 'Technology advancements in hydroprocessing of bio-oils', *Biomass and Bioenergy*. Pergamon, 125, pp. 151–168. doi: 10.1016/J.BIOMBIOE.2019.04.015.

# Catalytic slurry hydroprocessing

# Slurry hydroprocessing of bio-oil




- Bio-oil stabilization
  - Removal of unstable oxygen compounds
  - Adjustment of physical and chemical properties for further upgrading
- Continuous catalyst removal and replacement
- Recirculation and/or recovery of catalyst

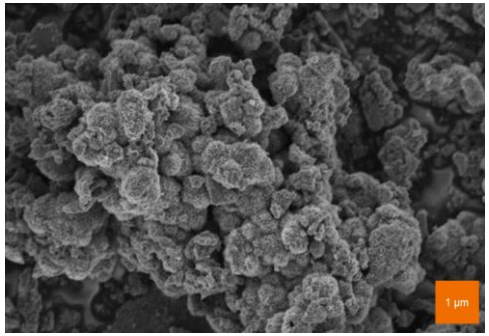



Funded by the European Union

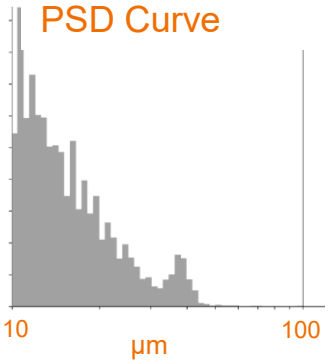
# Slurry hydrotreatment catalyst

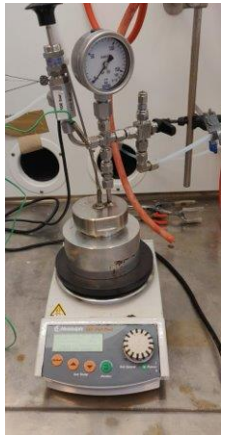
**Desired:**

- High activity and selectivity
- Easy separation & recirculation
  - Regeneration
  - Metal recovery
- **Low cost incindence**




236 $m^2/g$

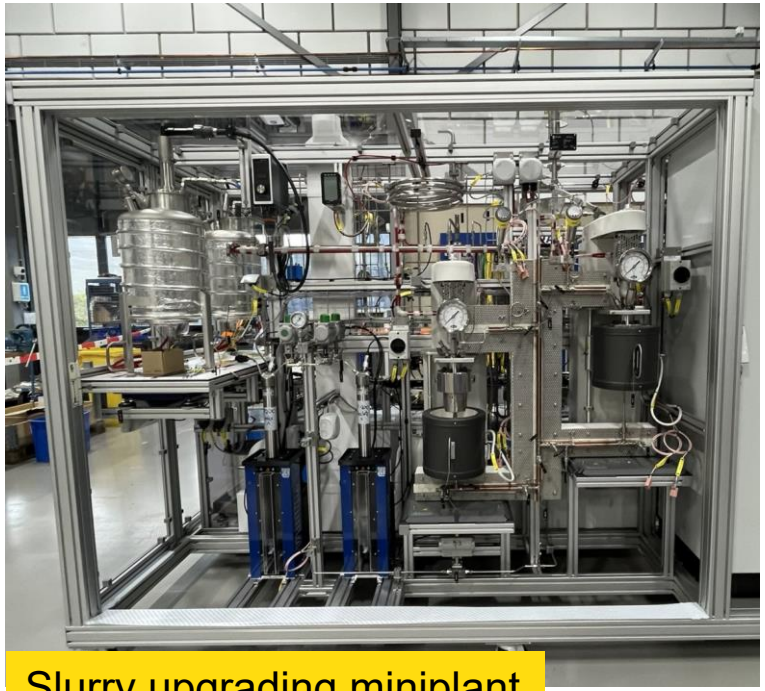


**1 g/batch** **40 g/batch**

- Hydrothermally precipitated unsupported **MoS abd CoMoS**
- Repeatable, scalable and robust
- Good activity in tests with isoegenol and real pyrolysis bio-oils

# Successful proof of concept in pilot scale: 70 hours of continuous operation

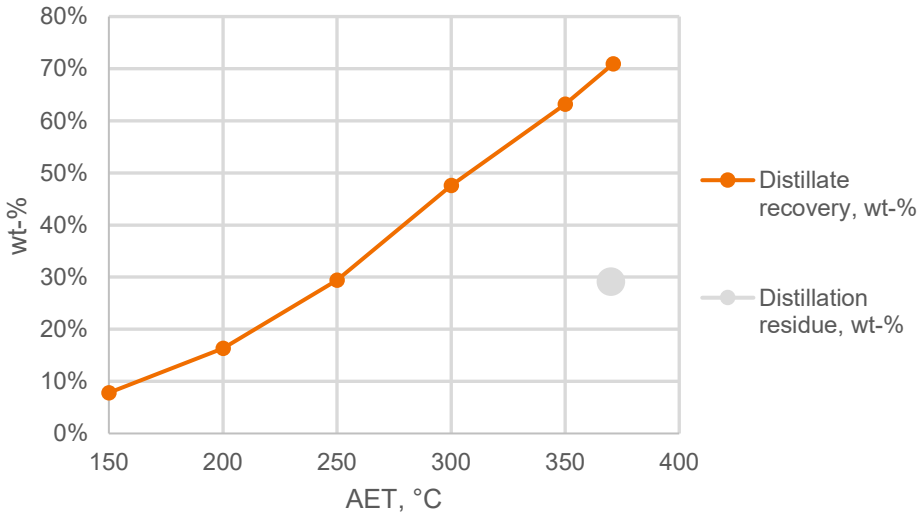


Slurry upgrading miniplant

| | |
|---|---|
| **Equipment** | 2 L CSTR |
| **Residence time** | 1.5 h |
| **Catalyst loading** | 1500 wt-ppm Mo in bio-oil |
| **H2-to-bio-oil** | 1127 NL $H_2$/ L bio-oil |

| Temperature | Pressure, bar | Hydrogen consumption g/kg bio-oil | Degree of deoxygenation |
|---|---|---|---|
| 350 °C | 140 | 30.1 | 49.0% |
| 380 °C | 75 | 36.8 | 54.9% |
| 380 °C | 140 | 35.7 | 56.6% |
| 410 °C | 140 | 45.5 | 58.1% |

# Distillation of slurry-hydrotreated product




| Diesel-range total | |
|---|---|
| wt-% | 63% |
| Composition | |
| C, wt-% | 74% |
| H, wt-% | 10% |
| O, wt-% | 16% |


- Batch distillation of heavy oil fraction produced at 380 °C, 140 bar, VTT catalyst

# Upgrading of slurry hydrotreated product in fixed-bed reactor

- Parallel testing of max. 4 **heterogenous catalysts** in tubular fixed-bed Hastelloy reactors under trickle-bed conditions
- **Continuous 24/7** operation in once through mode
- High temperature (**450 °C**) and pressure (**180 bar**) possible

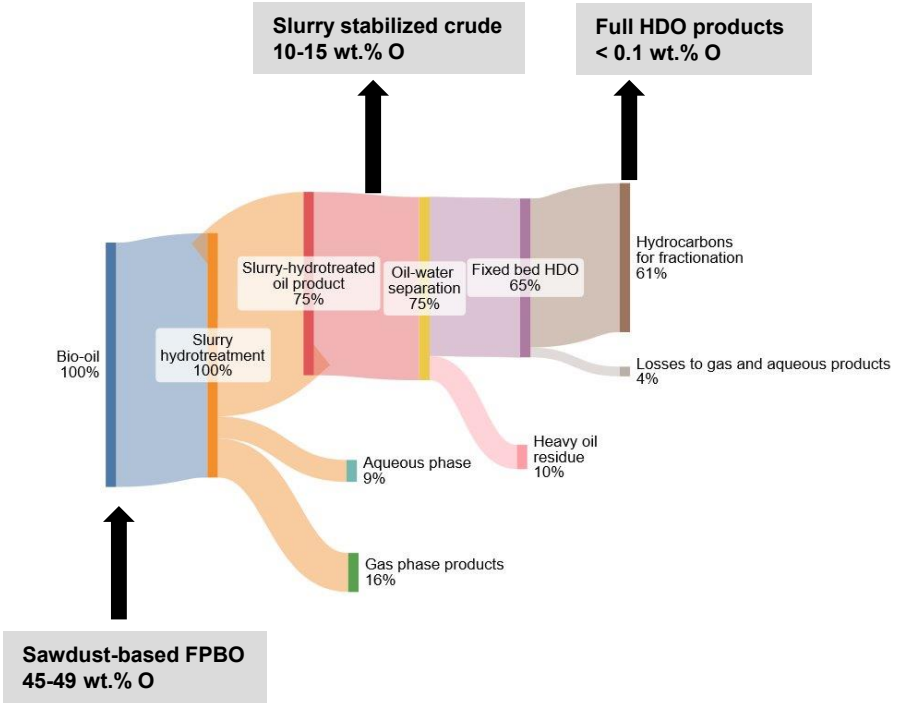
4-folded high-throughput hydrotreatment unit

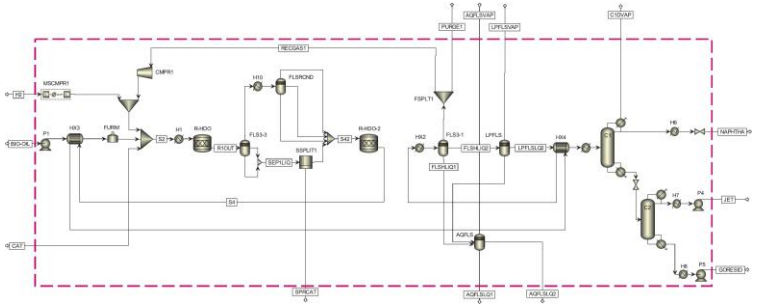
TOS ↓

| T(°C) | P (bar) | LHSV (1/h) | C (wt-%, dry) | H (wt-%, dry) | O (wt-%, dry, diff.) | Degree of deoxygenation, % | Density at 40°C, g/ml |
|---|---|---|---|---|---|---|---|
| Feed | | | 77.0% | 8.8% | **14.1%** | | 0.98 |
| 360 | 80 | 0.5 | 85.8% | 12.5% | **1.6%** | **88%** | 0.87 |
| 360 | 80 | 0.25 | 85.9% | 11.8% | **2.2%** | **85%** | 0.87 |

Longest runs @VTT ~120 h, no operational issues

# Carbon balance & process economics



- 400 FPBO kt/a unit modelled
- 150 kt/a blendstock production
- Total production costs **1800 Eur/t**

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CaSH

Viertiö et. Al 10.32040/2242-122X.T425
Tuppurainen et. al 10.1016/j.ces.2025.122567

# VTT capabilities in upgrading of challenging feedstocks

We help our clients and partners:

- Evaluate new feedstocks
- Develop new upgrading paths
- Produce fuels samples for application tests

VTT aims to bridge the gap between available & difficult feedstocks and advanced biofuels

- Standalone
- Co-processing

**Slurry upgrading**

**Fixed bed upgrading**

**Analytics & Separation**

# Summary

# Upgrading of bio-oils is challenging yet possible

# Robust catalytic paths open new value chains from lignobiomass to fuels

- Slurry hydroprocessing is a good alternative enabling continuous addition/ removal of the catalyst
- Promising results achieved with unsupported Mo catalysts developed at VTT
- 4+ Successful piloting trials with VTT catalysts producing ~ 150 l of stabilized and partly deoxygenated bio-oils
- Further upgrading to middle distillate fuel components low oxygen using conventional fixed bed reactors
- Preliminary TEA looks promising, a lot of work ahead

# Thank you!

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VTT

# beyond

## the obvious

Thank you!

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