

Co-processing Bio-oils with VGO in a Lab-scale FCC Reactor

Experimental Insights and Challenges

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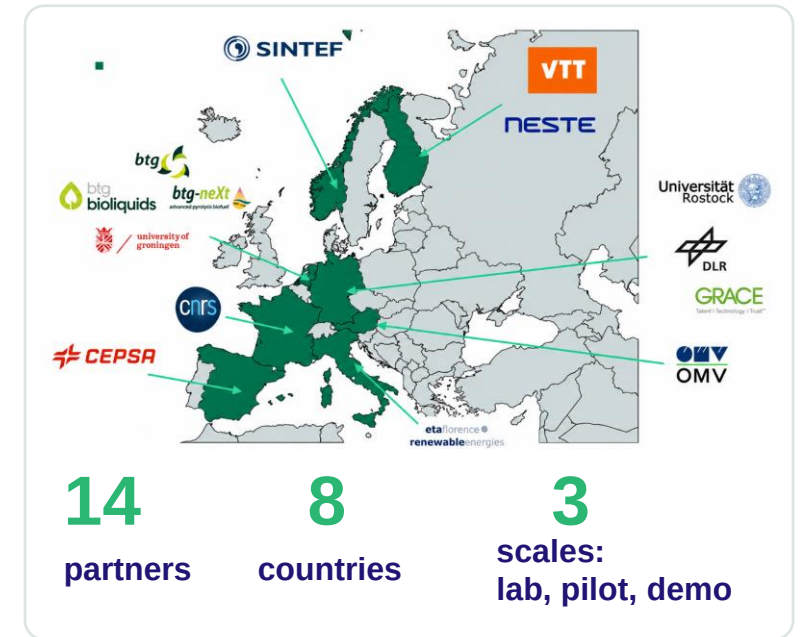
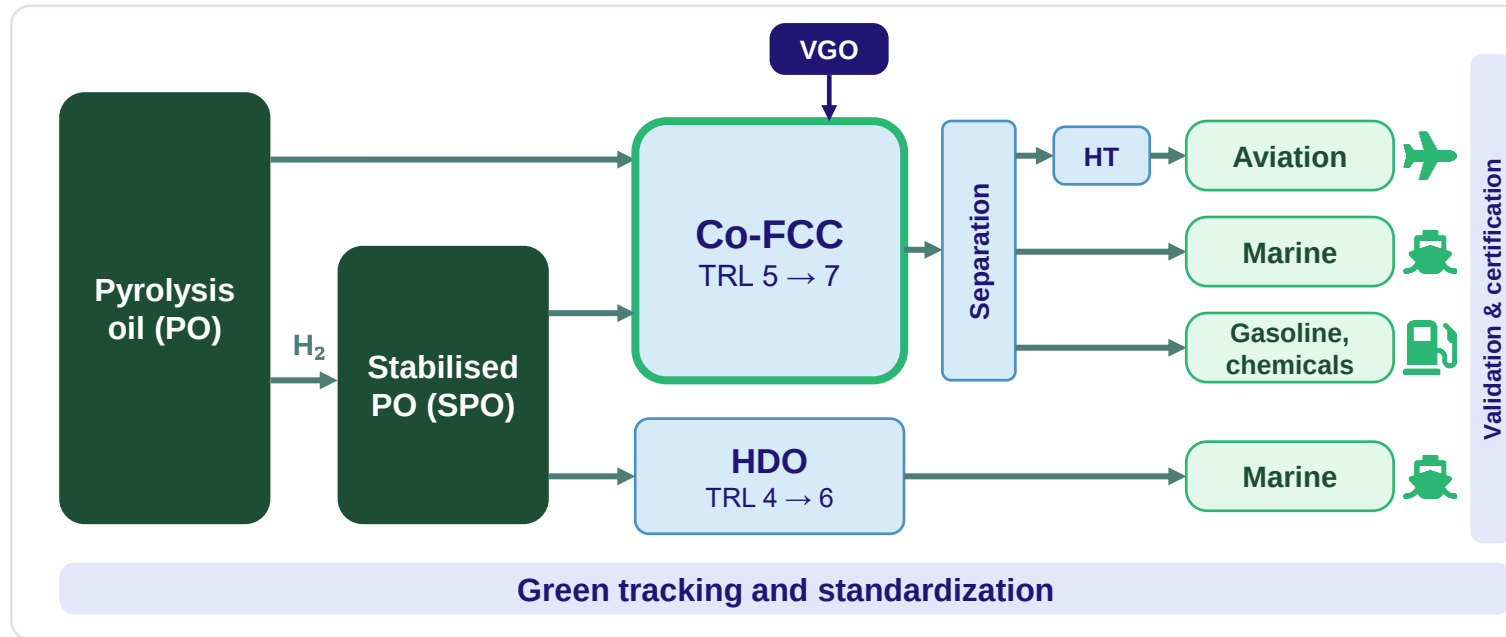


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REFOLUTION

Refinery integration, scale-up and certification for aviation and marine biofuels



Challenge

Unlock advanced biofuel production in existing European refineries

Collaboration

The full value chain in one industry–research consortium

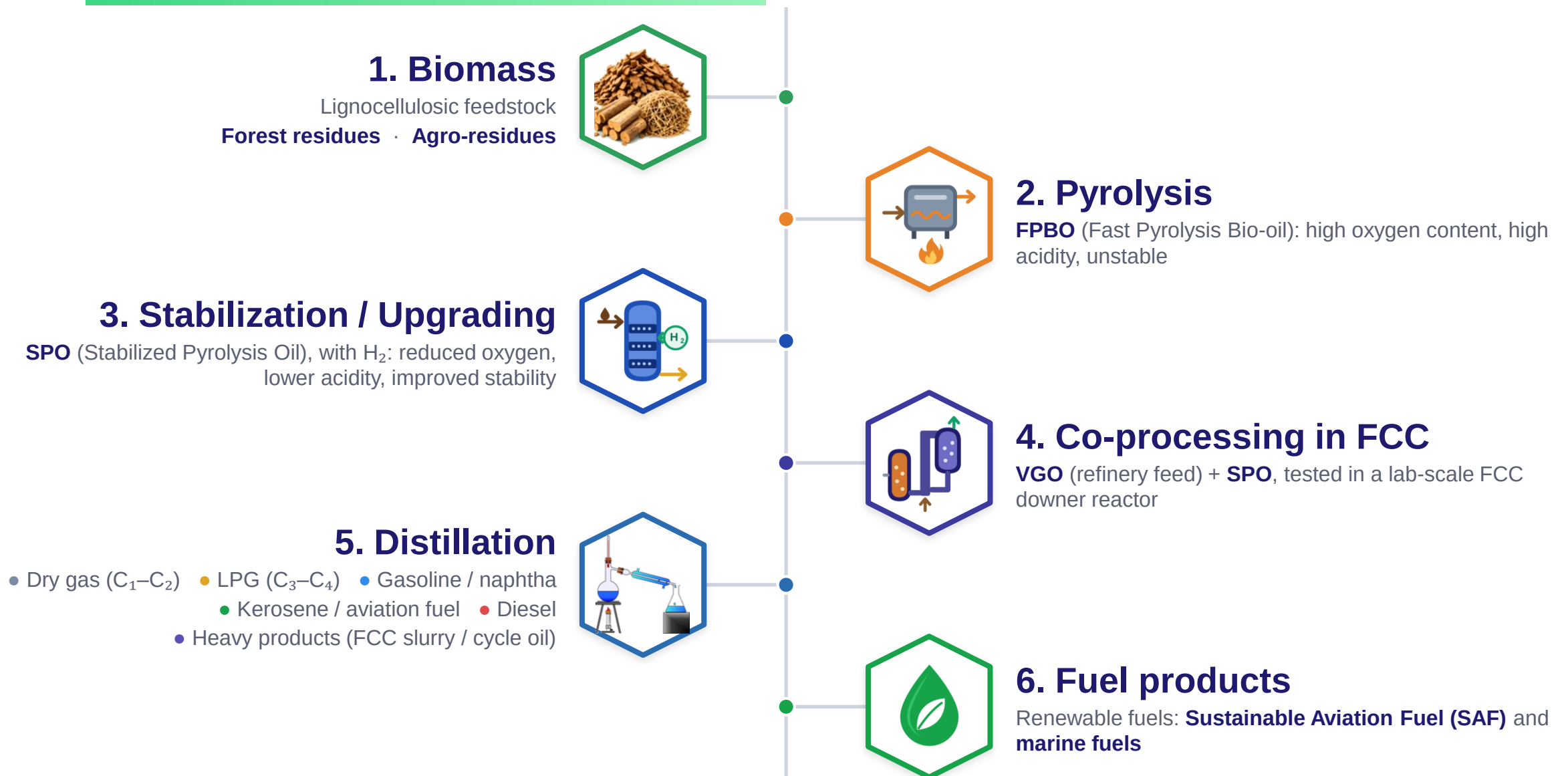
Impact

Cost-effective, sustainable biofuels and faster market uptake

University of Groningen role

Co-processing pyrolysis oils with VGO in a **lab-scale FCC downer**: conversion, product distribution, operating conditions and catalysts

Project approach: From biomass to renewable fuels



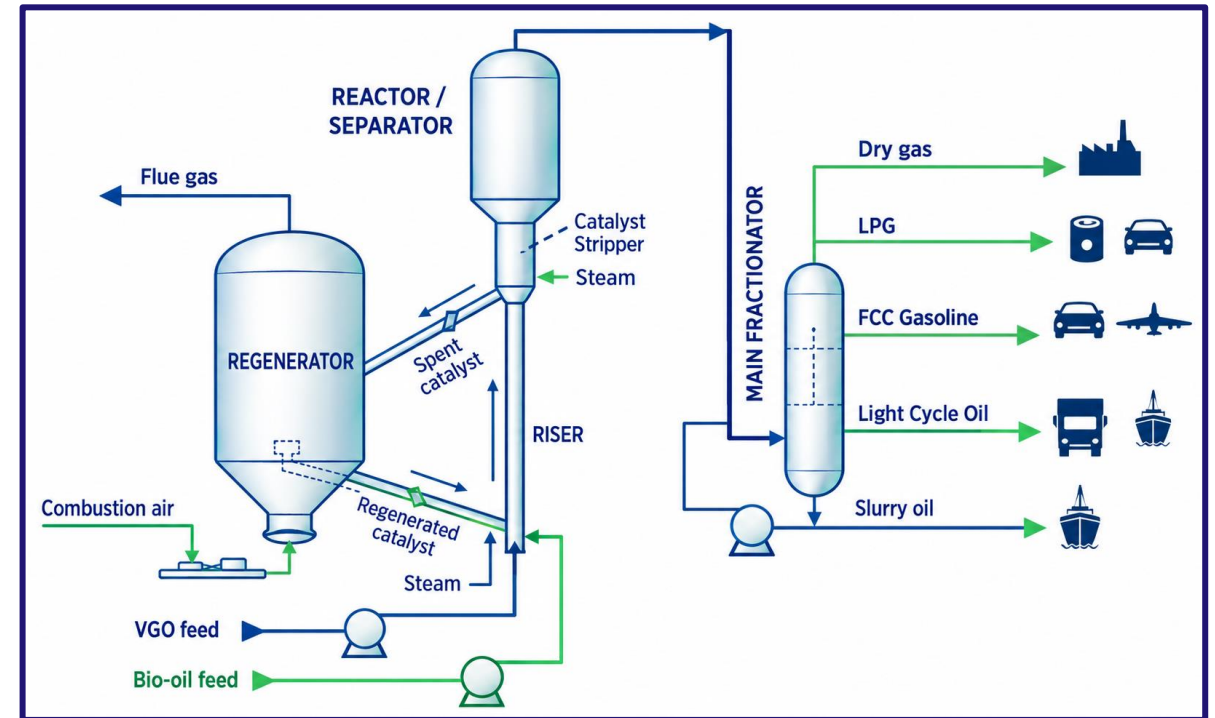
Why co-process renewable feedstocks in a refinery?

Why co-processing?

- Leverage existing refinery infrastructure
- Lower capital requirements
- Integrate renewable carbon into conventional fuel streams
- Produce drop-in fuel blendstocks

Why FCC?

- A flexible catalytic conversion platform
- Handles complex/heavy feedstocks
- Converts them into valuable fuel-range products
- No external H_2 required for the cracking step



Schematic representation of a conventional FCCU and its main process streams.

Pyrolysis oil stabilization

Renewable oils for co-processing



Vegetable oils



Waste & cooking oils



Animal fats

This work



Lignocellulosic bio-oils

Biomass-derived pyrolysis oils



Non-food feedstock

Made from abundant forest and agricultural residues



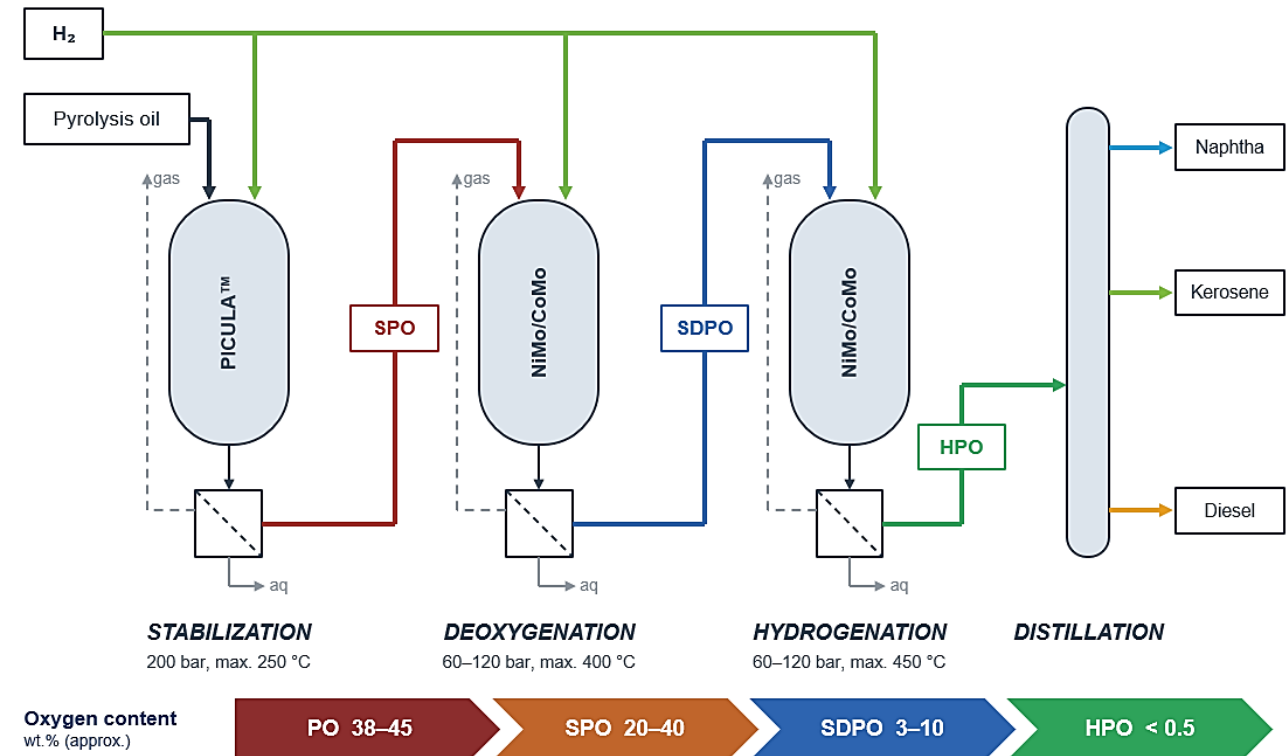
High oxygen content

Acidic, unstable and harder to process than fossil oils



Stabilisation needed

Before integration into conventional refinery processes



Existing FCC Setups for Bio-oil Co-processing: Capabilities and Limitations

Setup	Reactor configuration	Main strength	Key limitation for our question
MAT Micro-activity test	Fixed bed · batch · lab scale	+ Simple and standardised; widely used to rank catalysts	– Contact, temperature and coke profiles differ from industrial FCC
ACE Advanced Cracking Evaluation	Fixed fluidised bed · batch · lab scale	+ Fast, automated; used with model bio-oil compounds + VGO	– Batch; stable feeding of real bio-oil depends on the model
MicroDowner MDU, ITQ Valencia	Continuous downflow transport reactor · lab	+ Short contact (0.3–2 s); matches DCR yields; used for bio-oil + VGO	– Short tests with grams of feed: little product for upgrading
DCR Davison Circulating Riser	Circulating riser + regenerator · pilot	+ Closest to commercial FCC; used for pyrolysis oil + VGO	– ~1.35 kg/h feed; complex and costly to operate

Research need: An accessible lab-scale platform for controlled bio-oil/VGO co-feeding, short-contact-time cracking, and flexible operating conditions, bridging catalyst screening and pilot-scale FCC testing.

Lab-scale FCC unit for bio-oil co-processing

1 Controlled catalyst circulation

Screw feeders set the catalyst feed rate, spent catalyst returns pneumatically to the regenerator

2 Flexible co-feeding

VGO and bio-oil fed separately, bio-oil injection height can be varied to study feed-catalyst contact

3 Downer configuration

Pre-heated FCC catalyst flows downward through a 1.3 m long, 8 mm ID reactor, 100 g/h feed-rate

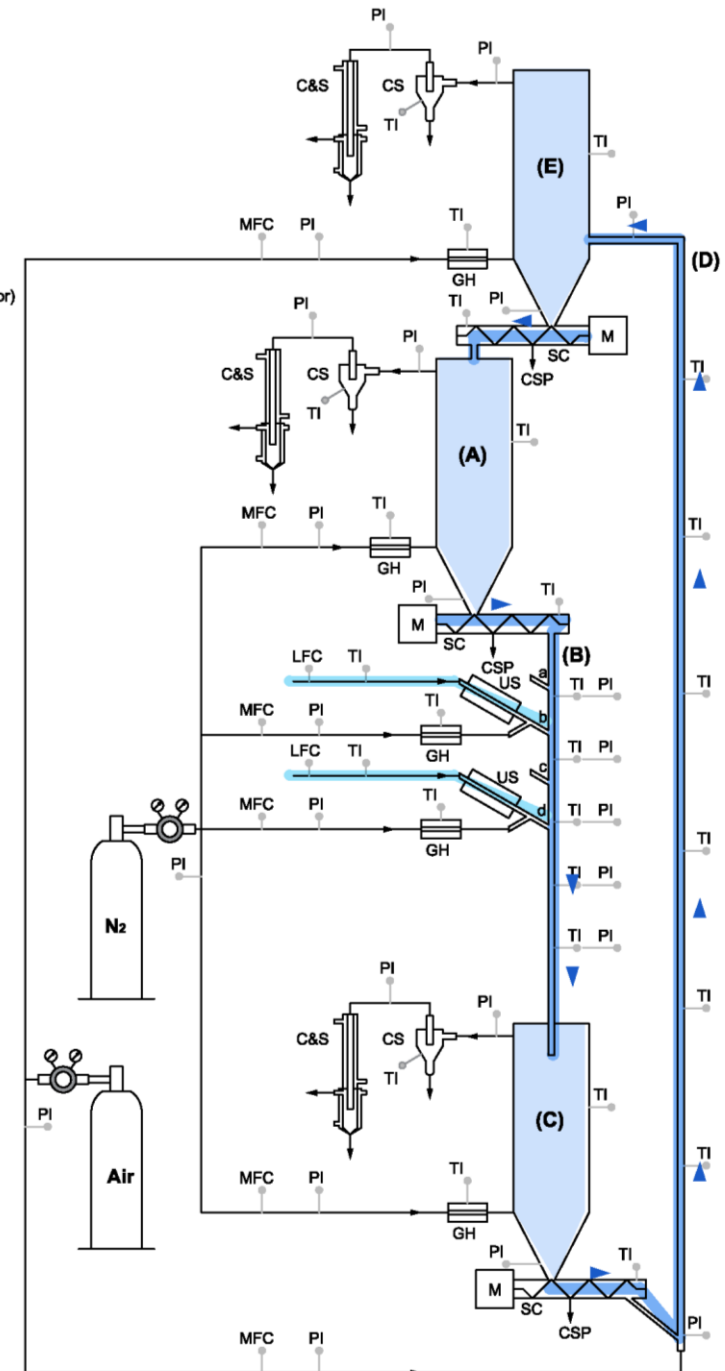
4 Designed for experimental flexibility

Three fluidized beds (buffer, stripper, regenerator), continuous operation with adjustable conditions

(A) catalyst buffer
(B) downer
(C) stripper
(D) riser
(E) catalyst regenerator

GH (gas heater)
LFC (liquid flow controller)
MFC (mass flow controller)
US (ultrasonic spray)
PI (pressure indicator)
TI (temperature indicator)
SC (screw conveyor)
CSP (catalyst sampling point)
CS (cyclone separator)
C&S (condenser and separator)

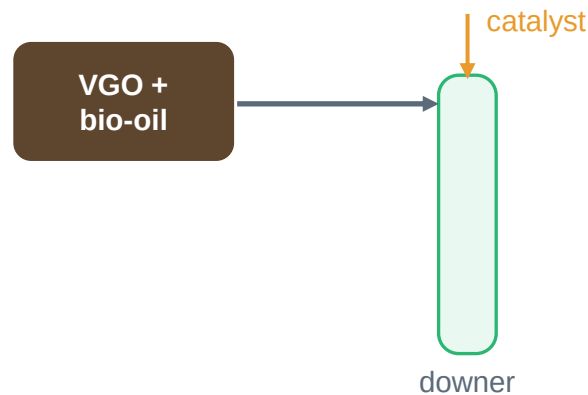
Flow paths
Catalyst circulation
 $E > A > B > C > D > E$
Liquid feed
(VGO / bio-oil) into B



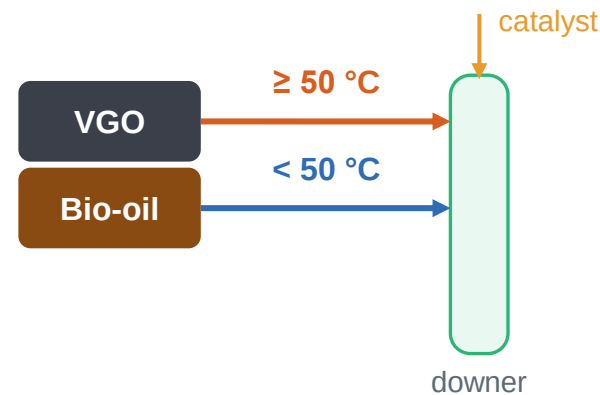
Built for co-processing: flexible bio-oil feeding

Two feeding modes

A Premixed blend



B Separate feeds



Why separate feeding? The feed-temperature constraint

VGO needs $\geq 50\text{ }^{\circ}\text{C}$ to stay pumpable (waxy at lower temperature)

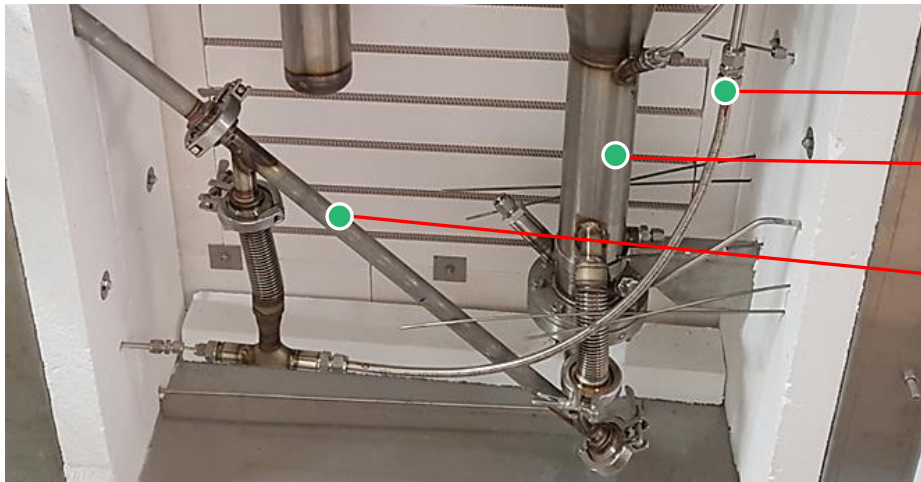
Bio-oil kept $< 50\text{ }^{\circ}\text{C}$ to limit polymerization, coking and line plugging

→ A shared feed line cannot satisfy both, separate lines give independent control

What the unit offers

- ✓ Co-feeding of petroleum streams with different types of bio-oil
- ✓ A dedicated pump per feed: HPLC pump for VGO, syringe pump for bio-oil
- ✓ Tunable CTO, temperature and contact time
- ✓ Steady co-feeding runs of up to ~3-4 hr in once-through mode
- ✓ Enough product to distil, hydrotreat

Experimental unit overview



Riser

Stripper

Screw feeder

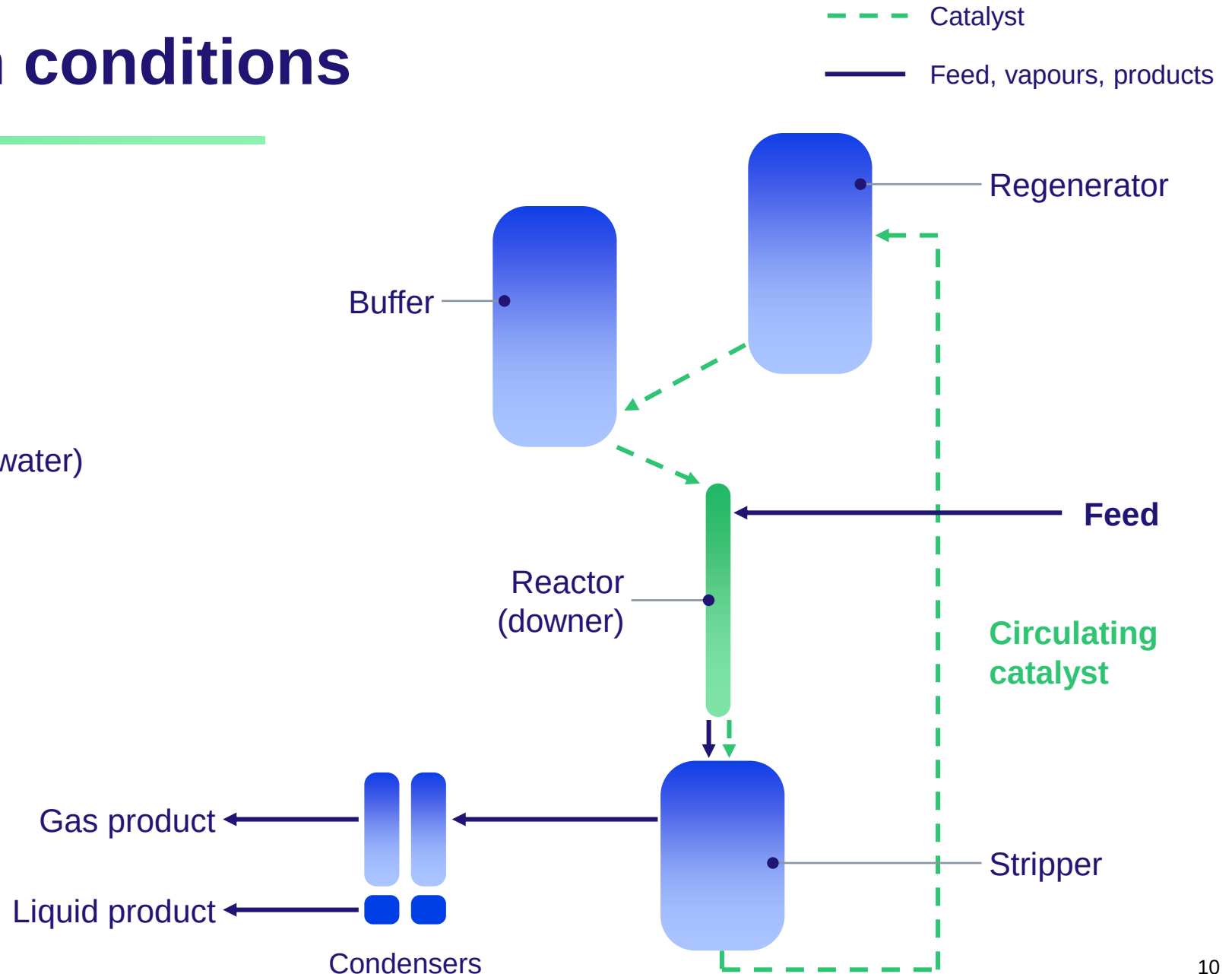
Bottom oven



Enclosure of the unit

Typical operation conditions

Feed: HVGO, SPO, HPO
Catalyst: FCC E-CAT
VGO storage & line Temp= 100°C
Catalyst Temp = 650-750 °C
Reaction Temp = 480-550 °C
Stripper Temp = 500-550 °C
Stripping agent= Steam + N₂
1st condenser Temp = 15-20 °C (tap water)
2nd condenser Temp = -20 °C



Co-processing is technically feasible

10 wt.%

SPO co-feed

90 wt.%

VGO fraction

Why this matters

Stable co-feeding of 10 wt.% SPO with VGO has already been demonstrated in the unit.

The question is less whether co-feeding is possible and more how to control severity and product selectivity.

Feeds and catalyst



Stabilised Pyrolysis Oil
(SPO)



VGO



FCC Ecat

Key variables

- Reaction temperature
- Cat to oil ratio (CTO)
- Bio-oil blending ratio
- Catalyst type / formulation

What we evaluate

- Product distribution
- Gas / liquid / coke formation
- Catalyst performance

Beyond this example: a systematic co-feeding programme



Pyrolysis liquid

Hydrotreated and stabilized pyrolysis oils of different upgrading levels



Catalysts

Different FCC catalysts and formulations



Temperatures

Different reaction temperatures



Cat-to-oil ratio

A range of CTO values

Reference for every case: VGO-only runs at the same conditions, so the effect of the Pyrolysis liquid can be isolated

Results from this ongoing study are not presented here. detailed findings will be reported in future publications.

Co-processing challenges and how we address them

1. Thermal instability of bio-oil: feed-line clogging

→ Cooled feed line

2. Viscosity, water and poor miscibility with VGO

→ Feed preheating, blend-stability tests (Turbiscan), separate feeding

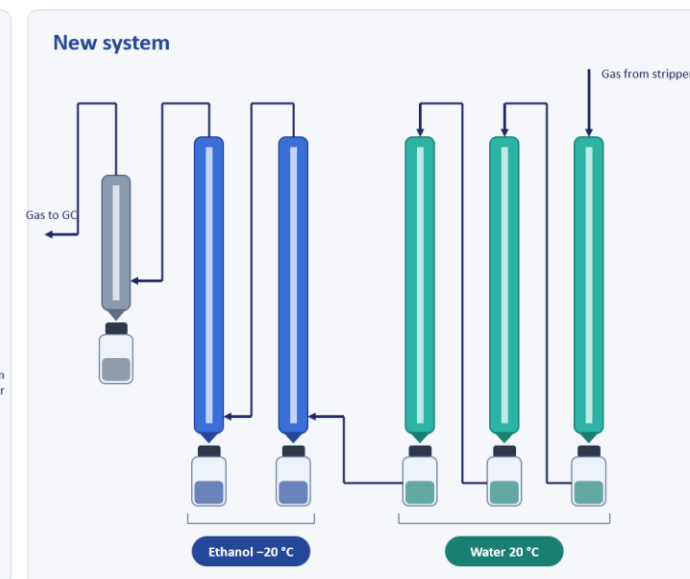
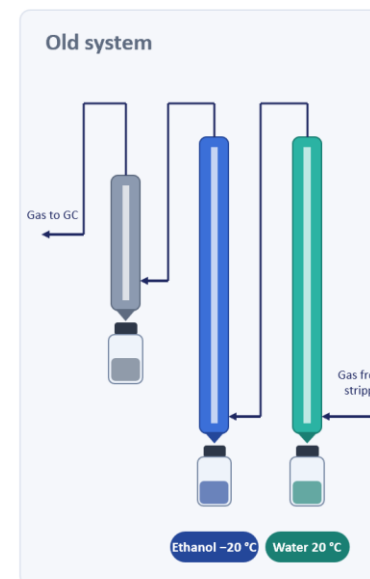
3. Oxygen leaves as water, CO/CO₂ and fine aerosols

→ Larger condenser with electrostatic precipitator, steam stripping

4. Catalyst circulation and entrainment

→ Optimised screw angle and feeding, extra N₂ line

5. C₄ quantification in gas phase



Conclusions

Research gap. Co-FCC lacks a simple lab tool: batch MAT/ACE tests are less-representative, pilot risers are costly.

Built for co-processing. Premixed or separate feeding at selectable height, hours of steady operation, enough product for upgrading.

VGO benchmark. In line with literature trends.

Co-feeding. HPO and SPO co-fed

Next. Higher co-feed ratios, Unit in circulation mode





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