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Four-Year Experience in Co-Processing Fast Pyrolysis Bio-Oil in an Industrial Fluid Catalytic Cracker

tcbiomass, Denver (USA)

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Agenda

Four-Year Experience in Co-Processing Fast Pyrolysis Bio-Oil in an Industrial Fluid Catalytic Cracker

- Refinery development over time
- Biocrudes and thermochemical oils as feedstock to refinery
- From laboratory to full scale commercial production
- Commercial implementation and experiences
- Take home message from a researcher working in a refinery

Conventional crude oil refining - the oil island museum



Petroleum refinery development over time

The oil island



Operation: 1895-1927 (only during spring/summer/fall)

Capacity: 238 m³ per year

Main product: High-quality kerosene for smoke-free lighting

VAROPreemraff Lysekil



Operation: 1975-

Capacity: 12 million m³ per year

Products: Conventional as well as renewable; LPG, naphtha, gasoline, kerosene, diesel, marine fuels

Biocrudes and thermochemical oils as feedstock to refinery

Evaluation and processing of emerging thermochemical oils



Biocrudes and thermochemical oils as feedstock to refinery

Evaluation and processing of emerging thermochemical oils

- At what points can renewable feeds be introduced into the refinery?
- Do they blend well with existing refinery streams?
- Does the refinery processing end up in saleable products (yield, quality, specification)?
- Is there a need for new reactors, catalyst guard beds, or catalysts?
- Who supplies and licenses the relevant technology?
- When is it possible to carry out modifications to the refinery?
- Are the overall impacts on the refinery understood?
- Is there a need for demonstration trials?
- Can access to representative test volumes be arranged?



Pyrocell Fast Pyrolysis oil plant

Ownership

- Pyrocell is jointly owned by Setra and VAROPreem.
- www.setragroup.com & www.varopreem.com

Feedstock

- The residual product sawdust from Pine (Pinus Sylvestris)

Production

- Annual target quantity 25,000 tons, continuous operation
- 12 Employees incl. Management , shift work 24/7

Products

- FPBO: Certified according to ISCC EU & Plus, sold to refinery.
- Steam: Used for drying of sawdust, excess steam sold to sawmill.
- Fly ash/sand mix

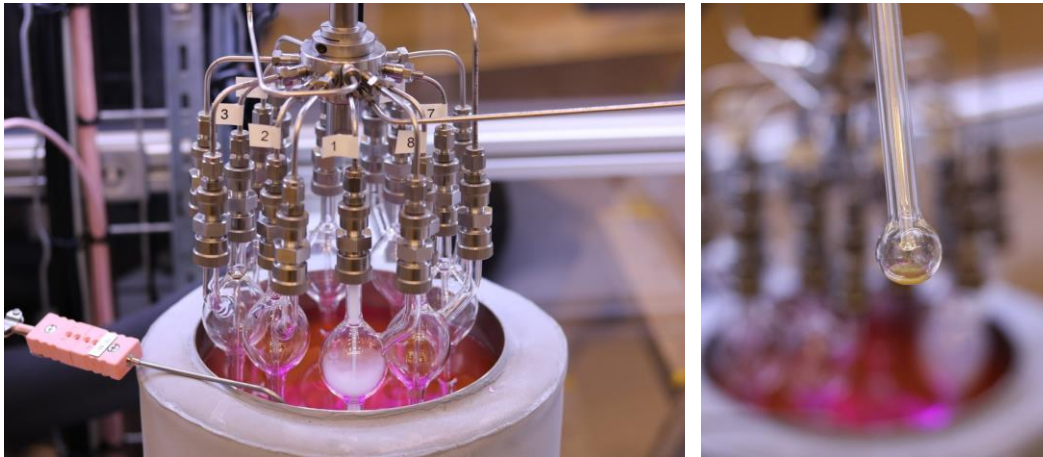
Uniqueness

- Integrated sawdust flow with sawmill
- Integrated steam flow with heating plant & sawmill
- Integrated supply chain - rail transport from Gävle to refinery

From laboratory to commercial production

Research testing in laboratory; grams

- Micro Activity Test (MAT)
- Advanced Cracking Evaluation (ACE)
- Micro Down Flow Unit



Development towards deployment

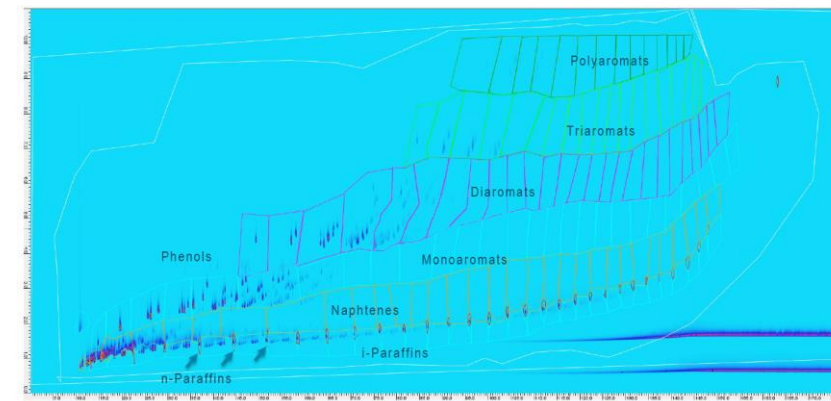
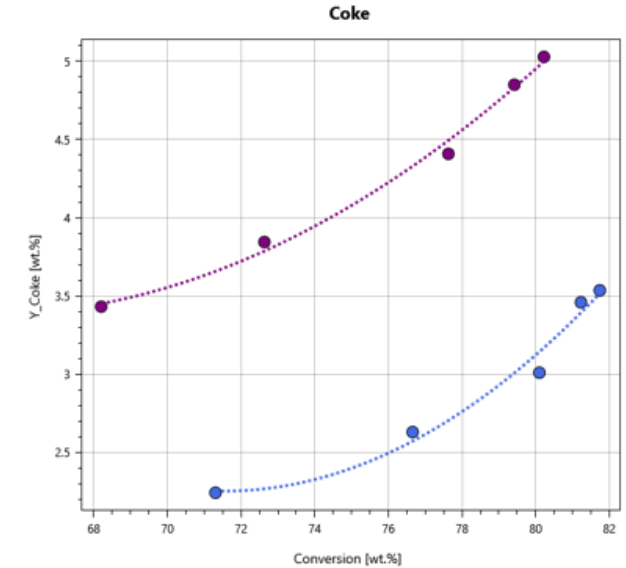
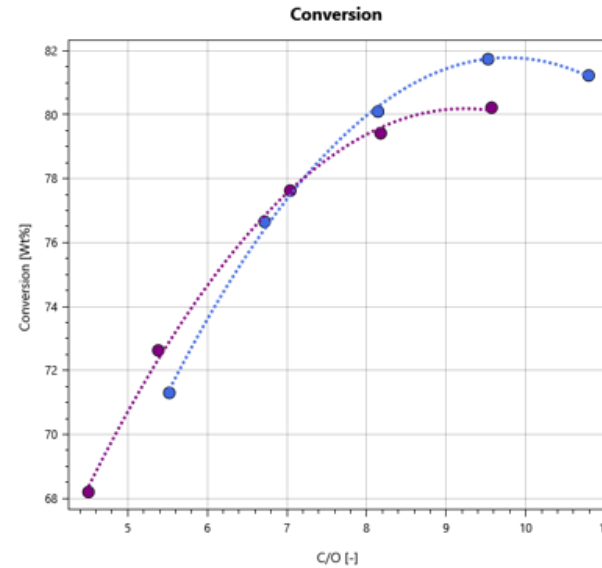
- Continuous pilots; kg
- Industrial demonstrations; >200 ton
- Commercial production; ton/h



Lab – Pilot – Industrial plant

Laboratory testing – small volumes (g) in an isolated test unit

- Feeding immiscible feedstocks
 - Mass balance
 - GC-Simdist analysis
 - Conversion vs cat/oil
 - Yield vs Cat/Oil and Conversion
 - Dry gas, LPG, Gasoline, LCO, HCO, Coke
 - H₂, CO, CO₂
 - RON/MON
 - PIONA – Paraffins, Isoparaffins, Olefins, Naphthenes, Aromatics
- General understanding of how the thermochemical oil will behave **in the FCC reactor, but not necessarily how it will affect the refinery**



Commercial implementation and experiences

VAROPreem industrial co-processing

- Demonstration trials in 2021 with temporary equipment.
- Continuous operation between 2022-2026 (with some interruptions).



Commercial implementation and experiences

Transport logistics from Pyrocell to Lysekil refinery

- Production storage tank at Pyrocell, long term storage at VAROPreem terminal, iso-containers in circulation, small volumes, transport across Sweden by train and truck.

Storage at refinery and injection to the FCC

- Unloading from truck to dedicated storage tanks and fed through dedicated nozzle.
- More than 30,000 ton of fast pyrolysis bio-oil co-processed.
- Separate injection through a dedicated nozzle.
- 1-2 ton per h, equivalent to 0.5-2.0% of total FCC feed.

Fast pyrolysis bio-oil stability over time

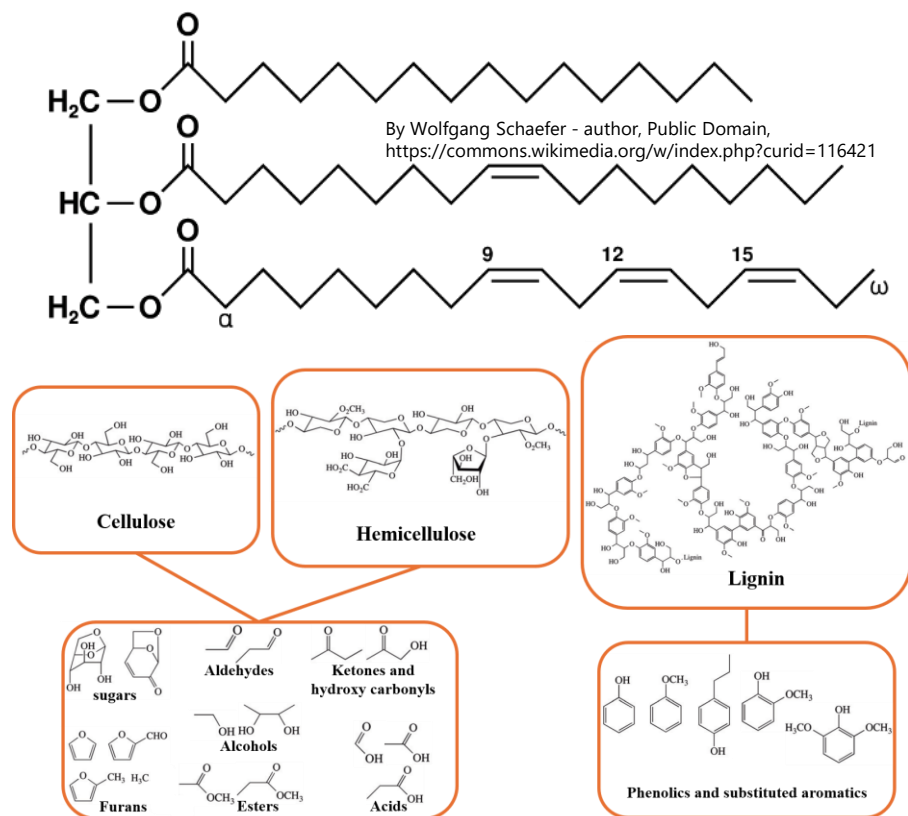
- Storing in lower quality steel drums caused corrosion, significant metal leaching and generation of gas, with H_2 levels up to as high as 70% and also C1-C6 hydrocarbons and CO_2 .
- Gas formed more rapidly at increasing temperatures (25, 40 and 80 °C).



Commercial implementation and experiences

Refinery integration effects – appear immediately or after longer time

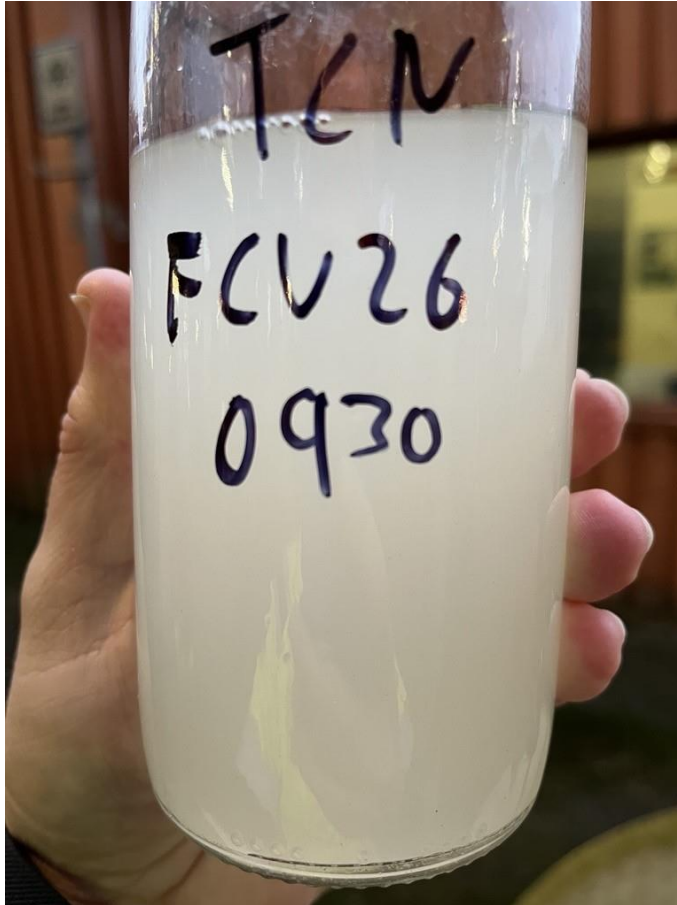
- Reduced dust emissions.
- Increased load on wastewater treatment (phenolics).
- Increased caustic consumption.
- Shorter catalyst lifetime in downstream processes.
- Oxygenate species, the oxygen chemistry in feedstock and its conversion is important. E.g., acetone, phenolics.
- Positive effect on coke and heat balance – depends on co-feed properties.
- How much renewable carbon in the products?



Nejadmoghadam, E. PhD Thesis, Chalmers (2024)

Visual example of downstream the FCC reactor during co-processing

Naphtha before Merox



Naphtha after Merox

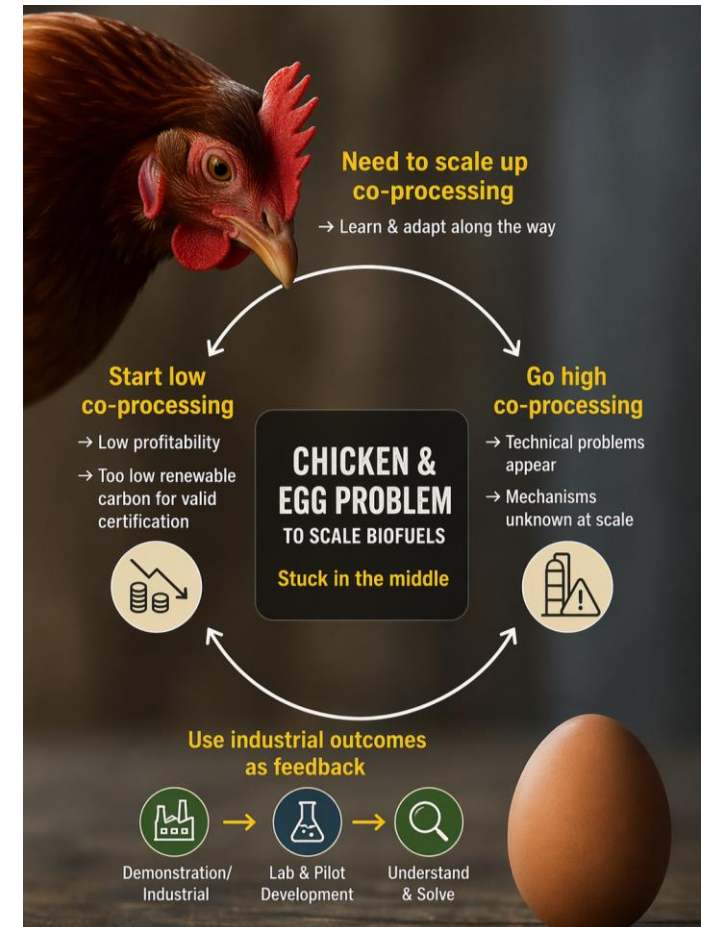


Simple way forward to increase renewable fuels from thermochemical oils?

- New “problems” arise with renewables at large scale implementation which go undetected in lab and pilot testing.
- Understand the mechanism behind it to use proper mitigation strategy.
- How do researchers and technology developers know what to target?
- Use demonstration and industrial outcome as feedback to lab and pilot developments to avoid repetitive research syndrome.

Challenge to advance large scale renewable co-processing:

- A refinery starts with low % co-processing to learn and adapt, new investment/installations may be necessary if it was not as easy as the lab and pilot trials suggested.
- Higher co-processing ratios may be hindered during this period.
- Too low content of renewable carbon in products for accurate determination to be valid under the certifications.
- This will be a strong hinder for scale-up and need to be addressed!



Take home message from a refinery R&D Manager

General considerations

Biocrude FCC co-processing is a start, and further development is needed for refinery drop-in feedstock at scale

FCC co-processing is feasible today at low co-processing and to realize the potential further upstream pretreatment is required; Refinery integration demands stable, upgraded intermediates. FCC reactor itself is not the main limitation.

Scale-up depends on partners, licensors, and FOAK support

Commercialization requires technology providers with proven pathways and government-backed FOAK demonstrations - startups cannot finance scale-up alone.

Move beyond repetitive R&D - focus on deployment

Further basic studies on feedstocks or policy scenarios do not advance commercialization; effort must shift to pretreatment solutions, engineering design, and value-chain integration.

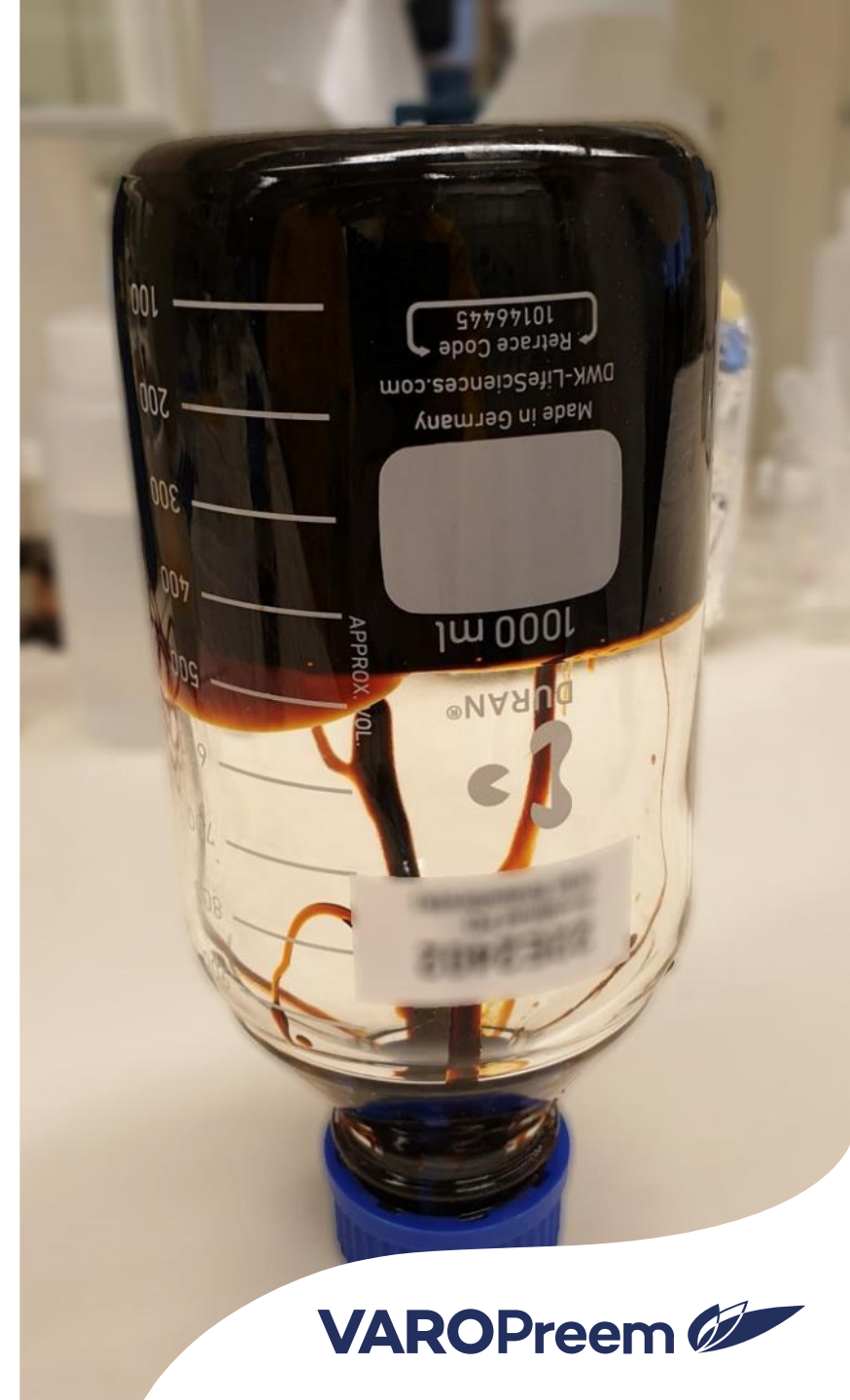
The pathway A→B→C is essential for real projects

A: Biomass liquefaction → B: Pretreatment → C: Refinery drop-in and conversion to saleable products.

Each step must be demonstrated with representative volumes to de-risk investment.

Success requires realistic timelines & robust engineering

Startups systematically underestimate time and complexity. Mature refinery environments demand long-cycle reliability, and on-spec product delivery.



Acknowledgements

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