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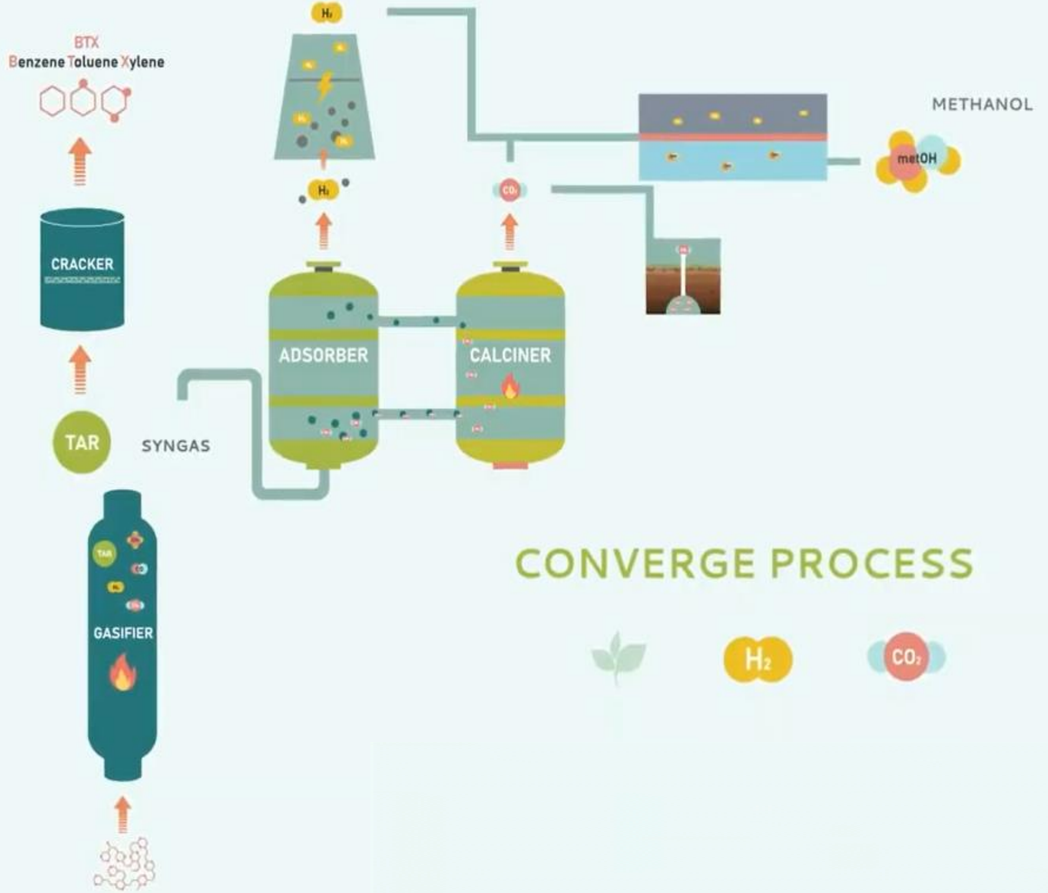

Novel catalytic tar cracking reactor for BTX co-production from indirect gasification

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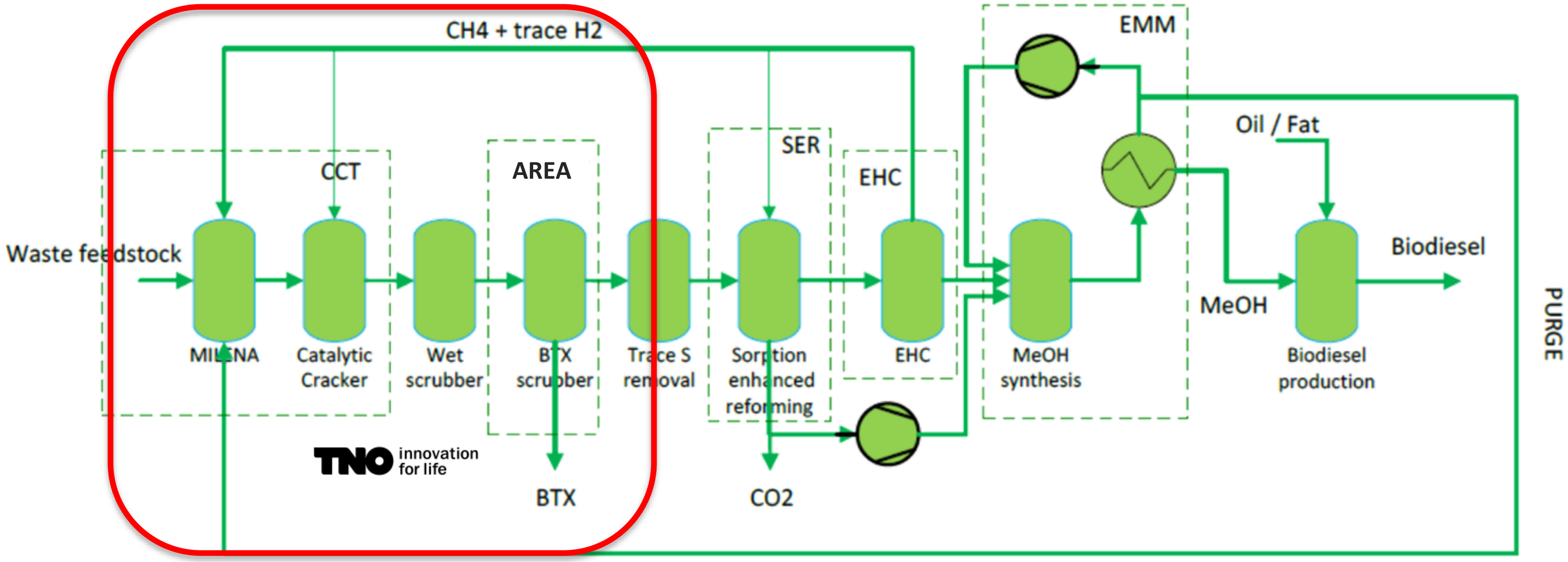
TNO Energy Transition, Biobased and Circular Technologies

WORKSHOP “Innovations in advanced biofuels production”, 18 May 2022, Petten (NL)

The CONVERGE project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 818135

The CONVERGE process



- Validate a state-of-the-art multi-step configuration for advanced biodiesel production from gasification
- Reduce the energy losses by 30% → increase efficiency by 12% & reduce CAPEX by 10%
- The CONVERGE technologies will be validated for more than 2000 cumulated hours at TRL5

Design and construct a CCT reactor in order to crack tar compounds to molecules < C_8 (BTX: benzene, toluene and xylenes)

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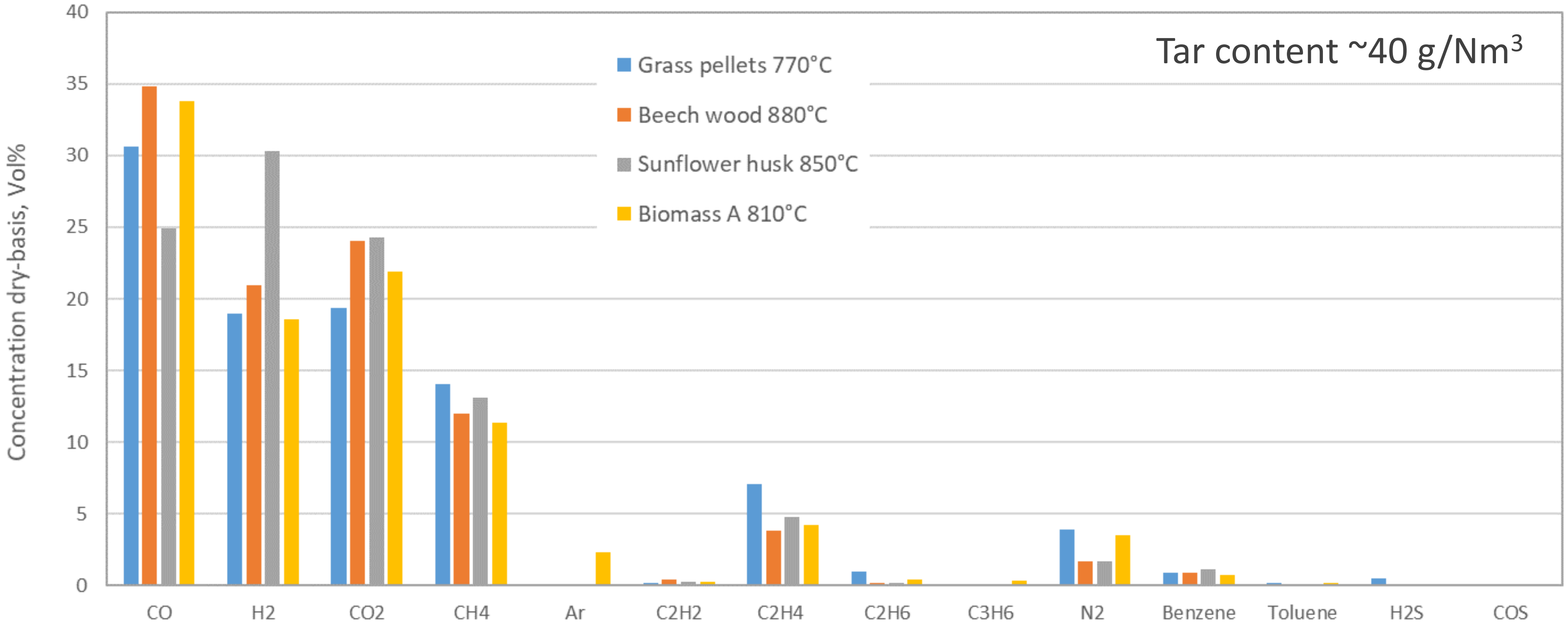
MILENA: *Indirect gasifier*
CCT *: Catalytic cracking of tar from an indirectly heated gasifier to below green C_8*
AREA: *Aromatics Recovery Apparatus*

Indirect gasification - product gas composition & tar content

- Depends on feedstock & gasification conditions (gasif. agent, temperature, bed material, carrier gas)
- Bio-BTX → valuable components serving as chemical building blocks towards renewable high performance materials (e.g. plastics), value of ~700 €/ton for fossil BTX



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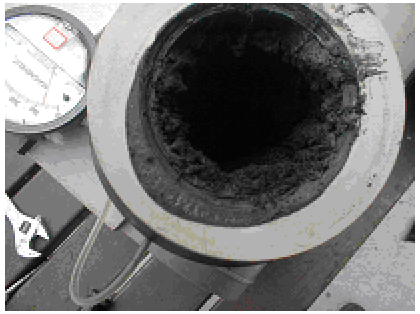
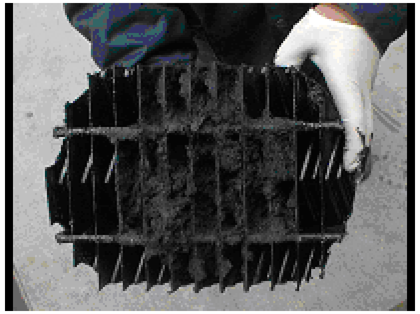
The tar problem

- "All condensable organic hydrocarbons that have higher dew points (or higher molecular weight) than benzene"





→ Blocking and plugging of pipes

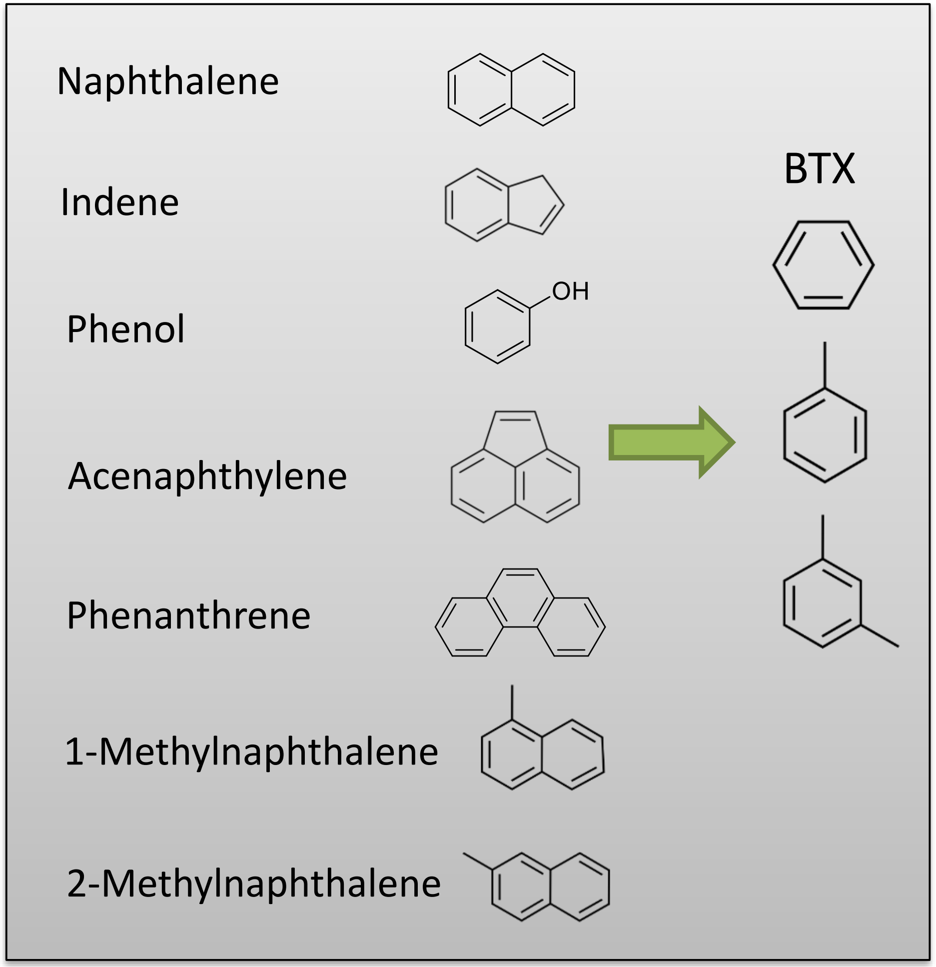
→ Coke formation

→ Condensing on the surface of filters, pumps, and heat exchangers

→ Corroding the surface of the pipes

→ Reduce the gasification efficiency

→ Increase in the process cost



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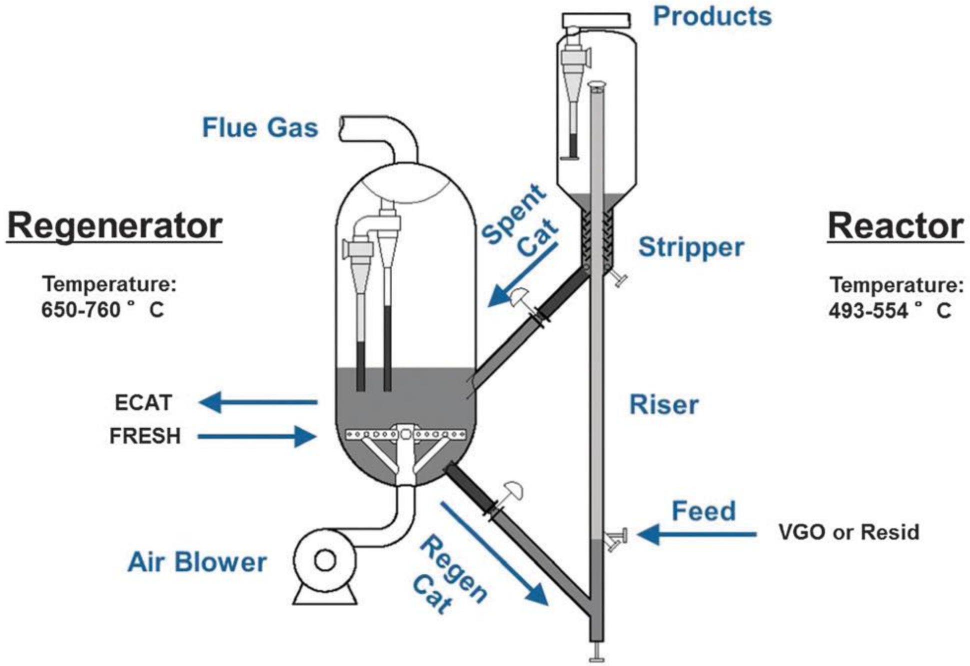
CCT reactor design considerations

- CCT reactor initial design considered monolith beds or fluidized reactors in order to handle dust / particles
- Not possible to operate in pressurized conditions
- FCC type reactor:
  - Catalyst regeneration
  - Heat transfer though the catalyst from the regeneration to the cracking zone
  - No need for inlet gas nozzles that would be clogged by the dust

Suitable catalysts
- Strong resistance to attrition, for fluidized conditions
- Easy regeneration
- High availability of commercial catalysts



FCC (Fluid Catalytic Cracking) reactor[1]

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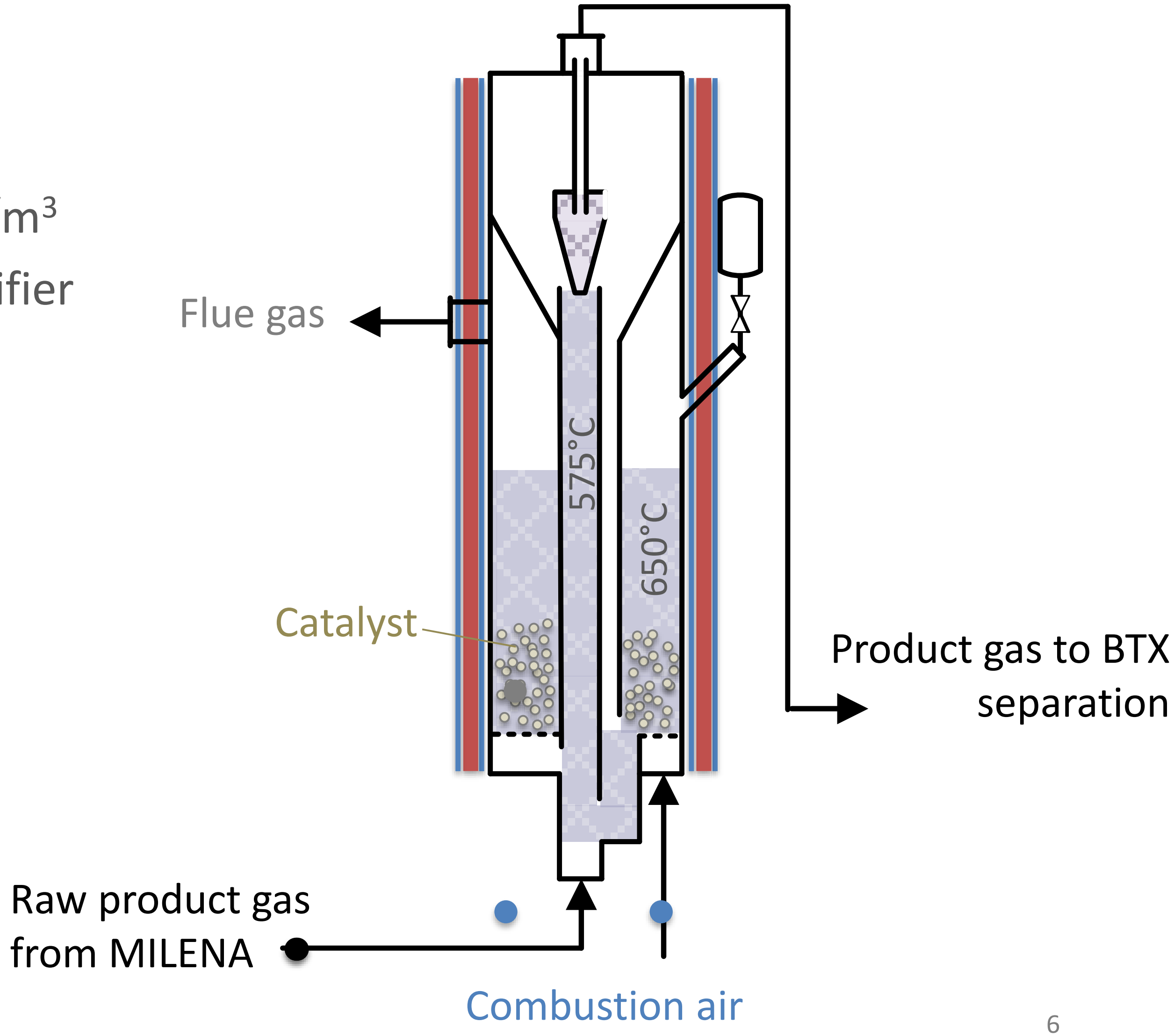
[1]*Vogt, Eelco & Weckhuysen, Bert. (2015), Chemical Society reviews.*

CCT reactor design assumptions

- Fluidized dual bed reactor (FCC type)
- Integrated design: riser cracking reactor & regeneration BFB reactor
- Catalyst particle size: 80µm, solid density: 1600 kg/m^3
- Directly fed with raw product gas from MILENA gasifier

Process conditions:

- Residence time in riser: 2 seconds
- Residence time in settling chamber: ~2 seconds
- Catalyst to dry gas mass ratio: 10
- Recirculation flows were based on assumptions for coke formation



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CCT reactor construction phase

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Problems along the way

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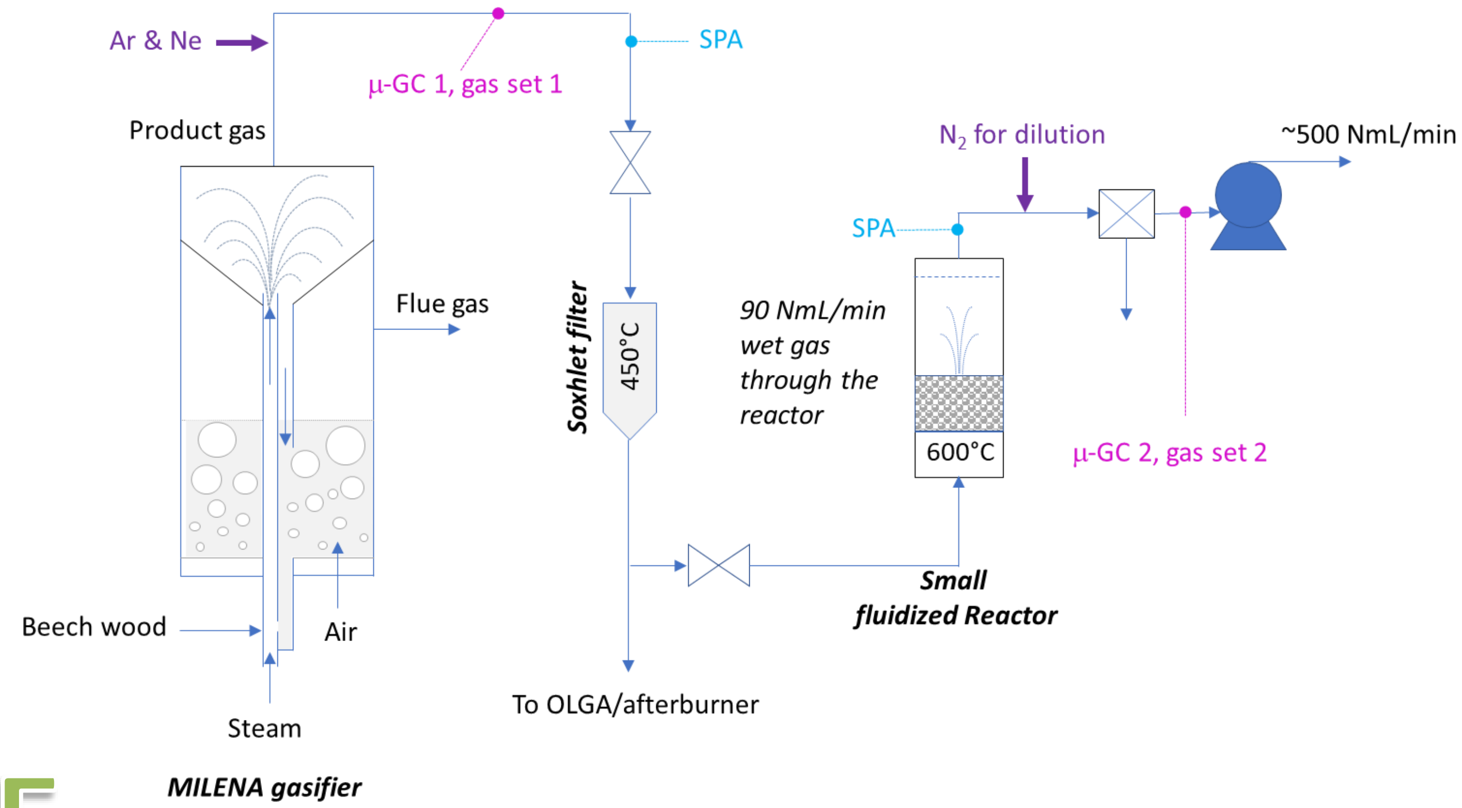
Biomass tar cracking - preliminary tests

- 6 commercial FCC catalysts have been tested in small scale fluidized reactor
- 80 ml catalyst, T = 600°C, GHSV = 220h^{-1}, 1h run time
- Analysis: semi-online micro-GC and SPA (Solid Phase Adsorption)

Beech wood gasification @760°C



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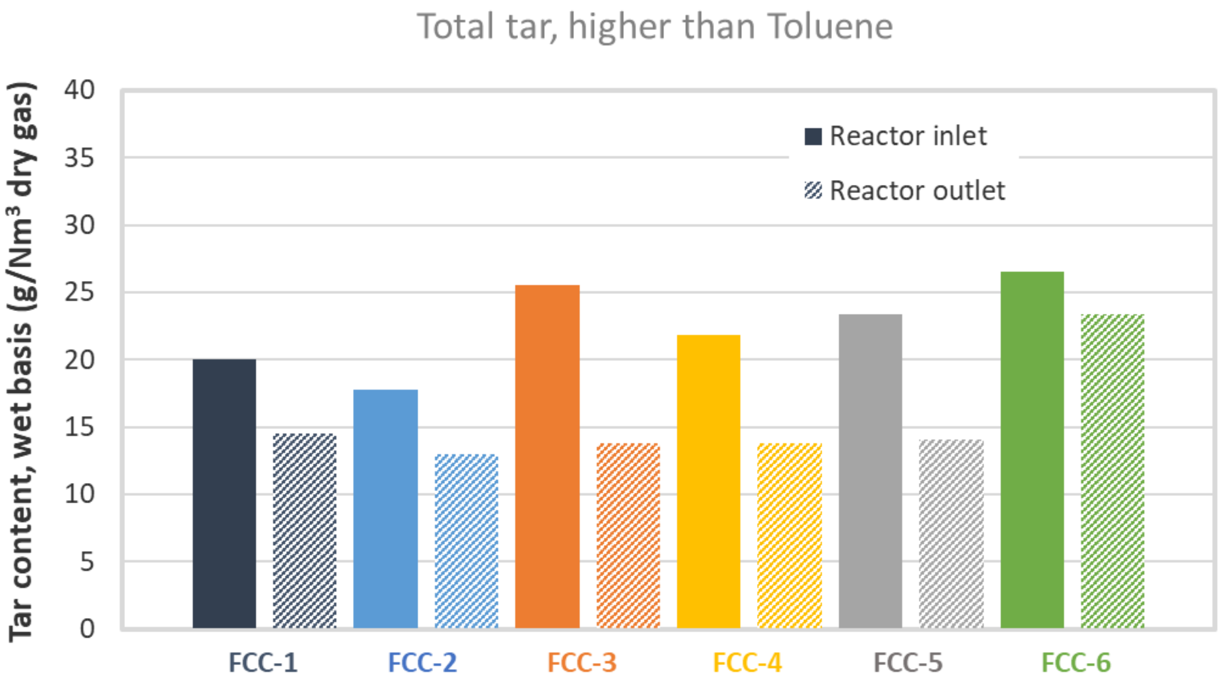
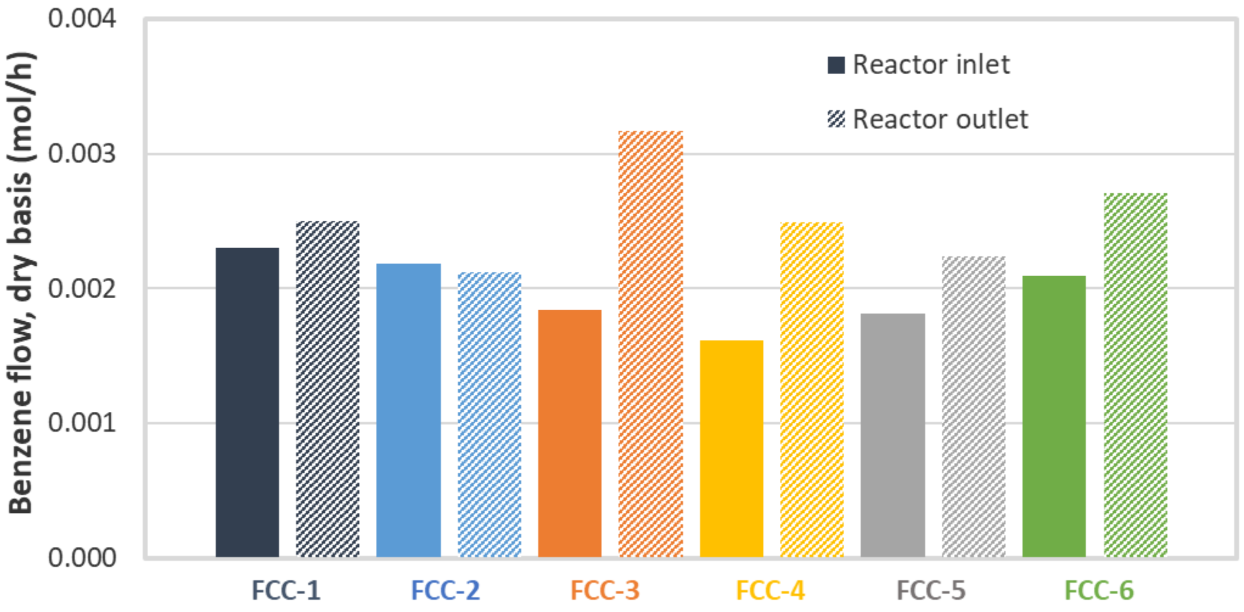
Preliminary tests results

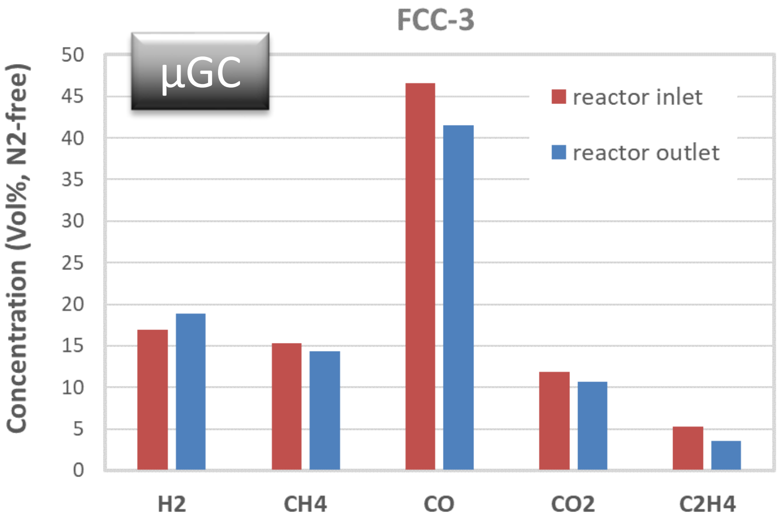
- All catalysts clearly promote benzene & toluene formation
- **FCC-3** shows the highest tar conversion (40 mol%) and selectivity (70 mol% benzene & 100 mol% toluene increase)

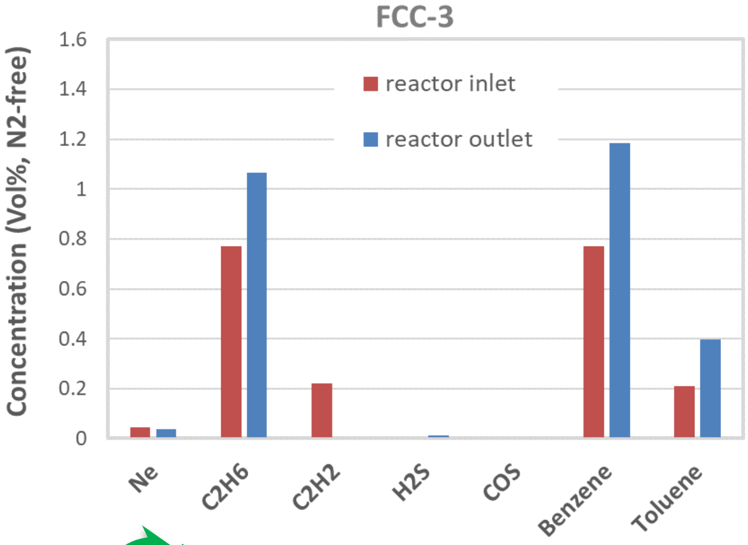
➡ Improved matrix activity (due to higher alumina content within the matrix)

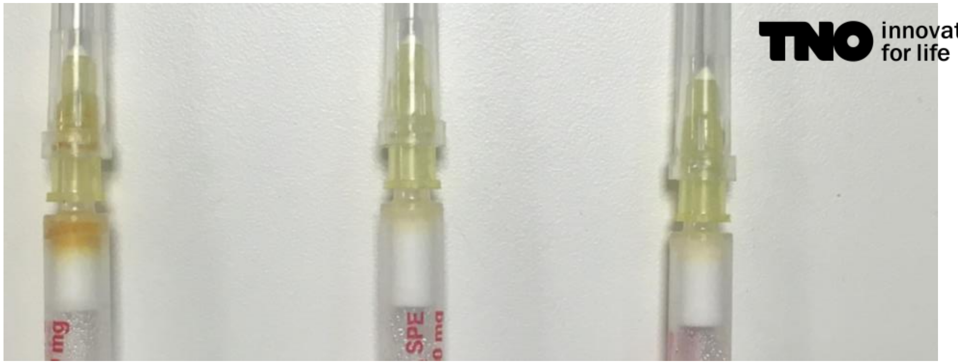




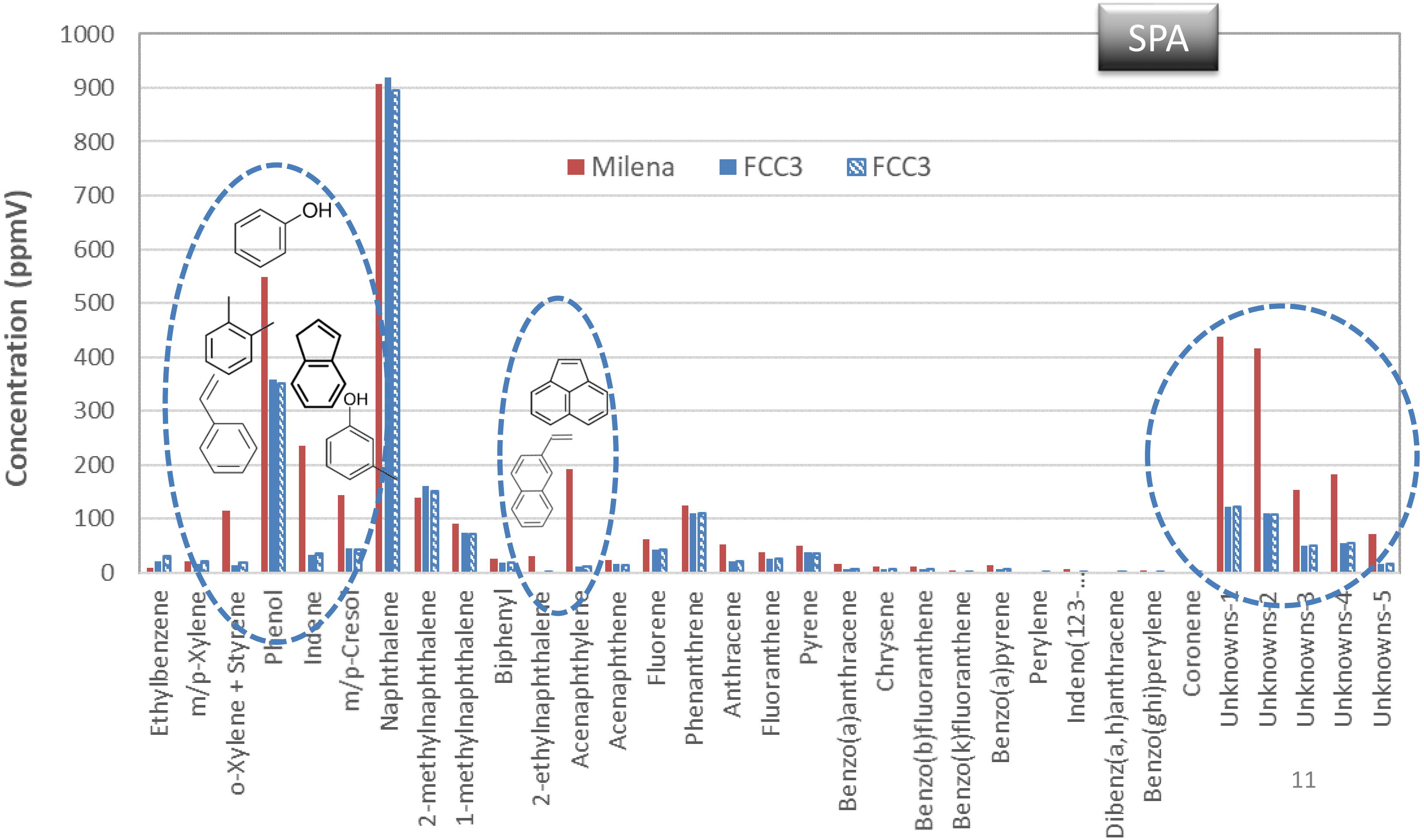
Preliminary tests results: FCC-3







Reactor inlet Reactor outlet



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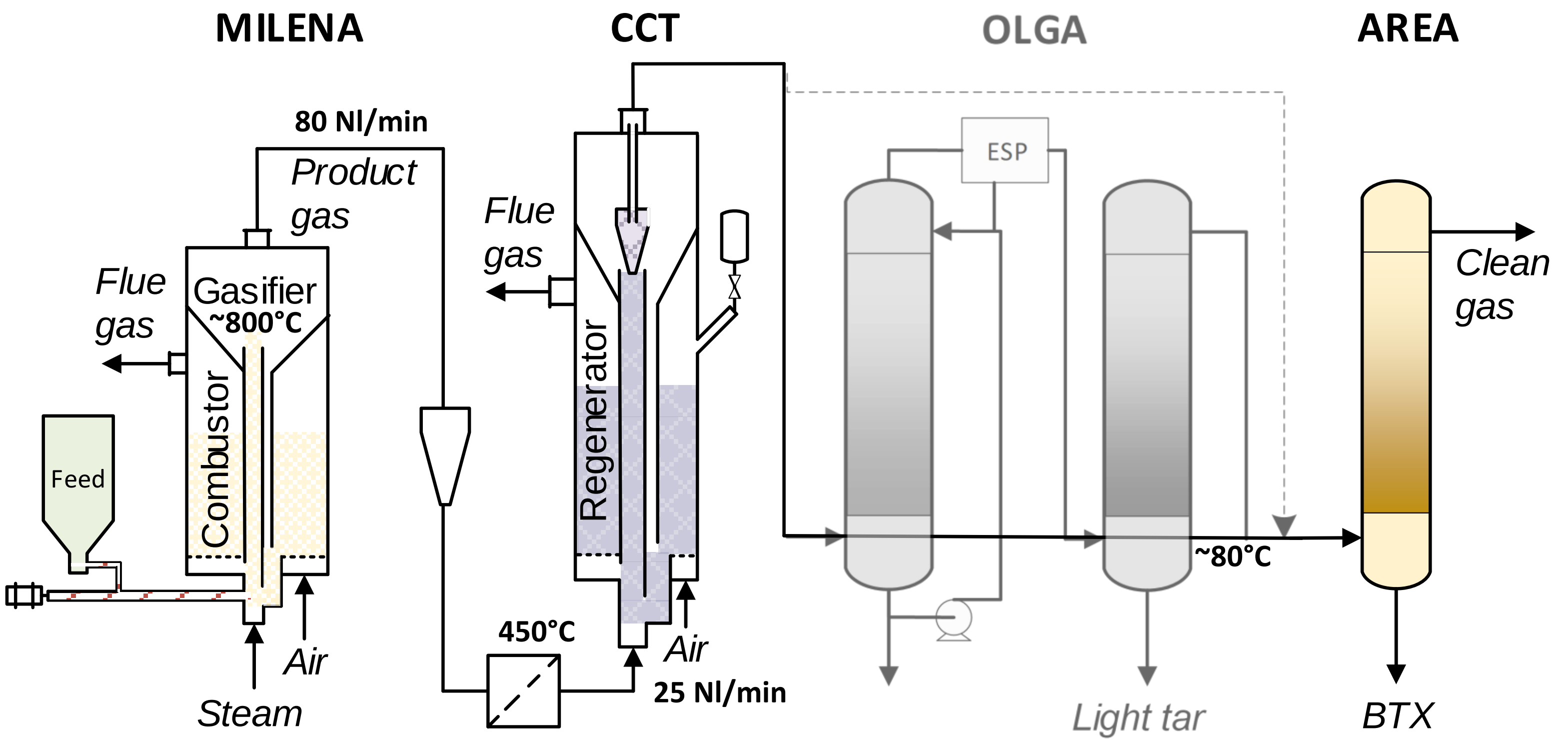
CCT reactor & line-up PFD



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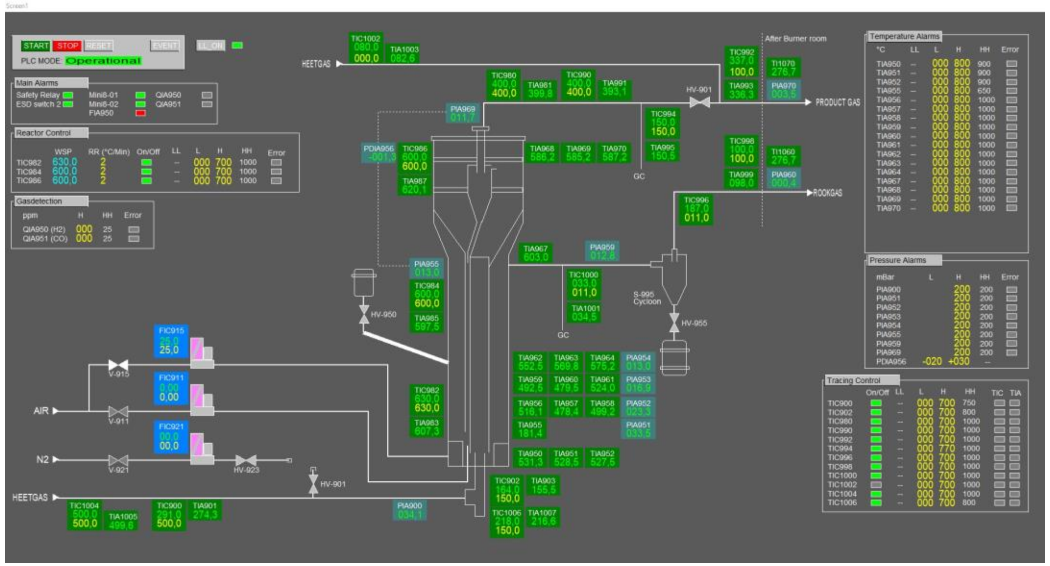
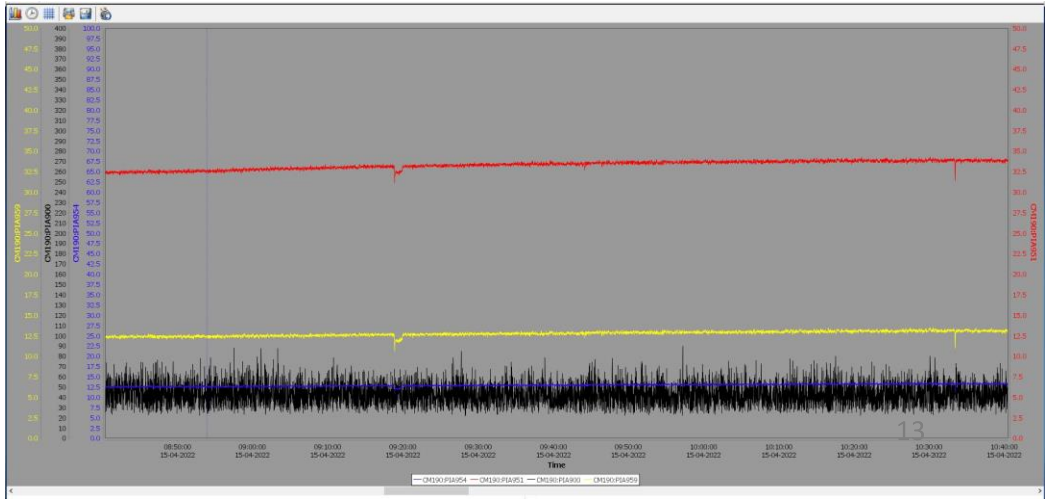
Hot commissioning and functional test

- Hydrodynamic test done (inert material)
  - Low gas exchange (< 1%) between regenerator and riser reactor
  - Acceptable pressure drop, somewhat higher than foreseen because of additional filters and long piping
  - Minor fouling of piping to CCT reactor, because of broken trace heating
- Functional test done (inert material)
  - Successful connection of two CFB reactors, no deviations in MILENA operation required
  - No significant changes in gas composition after CCT reactor when inert bed material is used in CCT
- Test campaigns **on-going**
  - Optimizing reaction conditions and complete line-up
  - Optimizing the catalyst for this process





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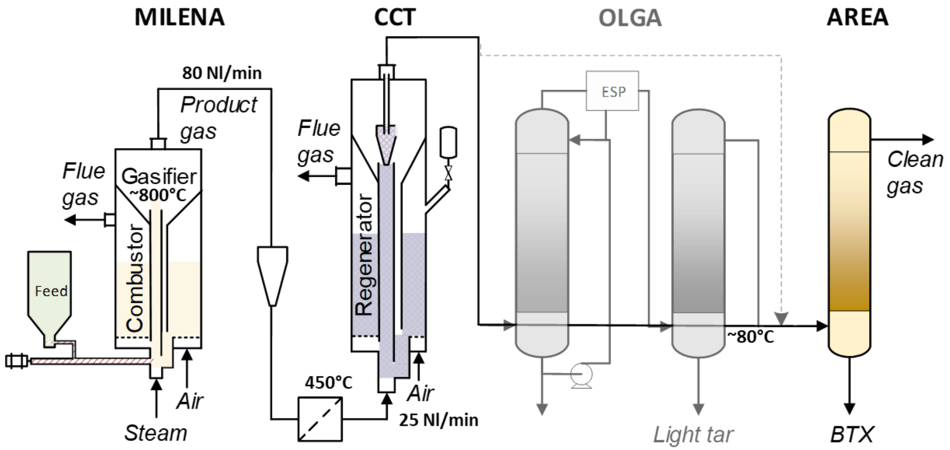
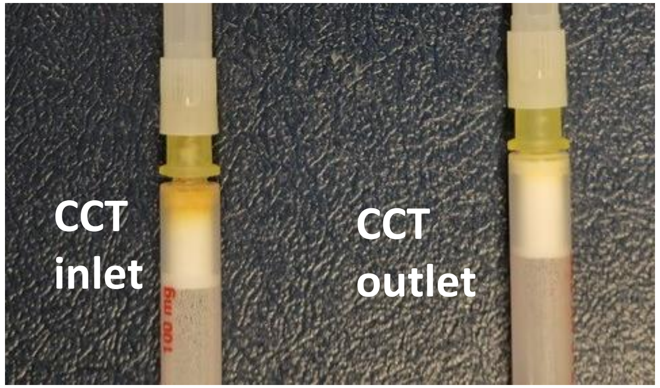
Current status and next steps

- First test functional test including the whole line-up was successfully completed





- The first BTX sample was collected with the CCT in operation!
- Optimizing reaction conditions includes:
  - Reducing the gasification temperature
  - Increasing the regeneration temperature of the CCT
  - Decrease the workload in the gasifier
  - Increase the steam flow (on-going)
  - Increasing the riser / cracking temperature of CCT (scheduled)

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TNO innovation for life

Thank you!

This work was made possible by the contributions of:
Christiaan van der Meijden, Herman Bodenstaff, Edwin Brouwer, Theo Kroon, Tom Nijbacker, Gerard de Jong, Marco Geusebroek, Arnold Toonen, Ben van Egmont, Dennis Slort

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