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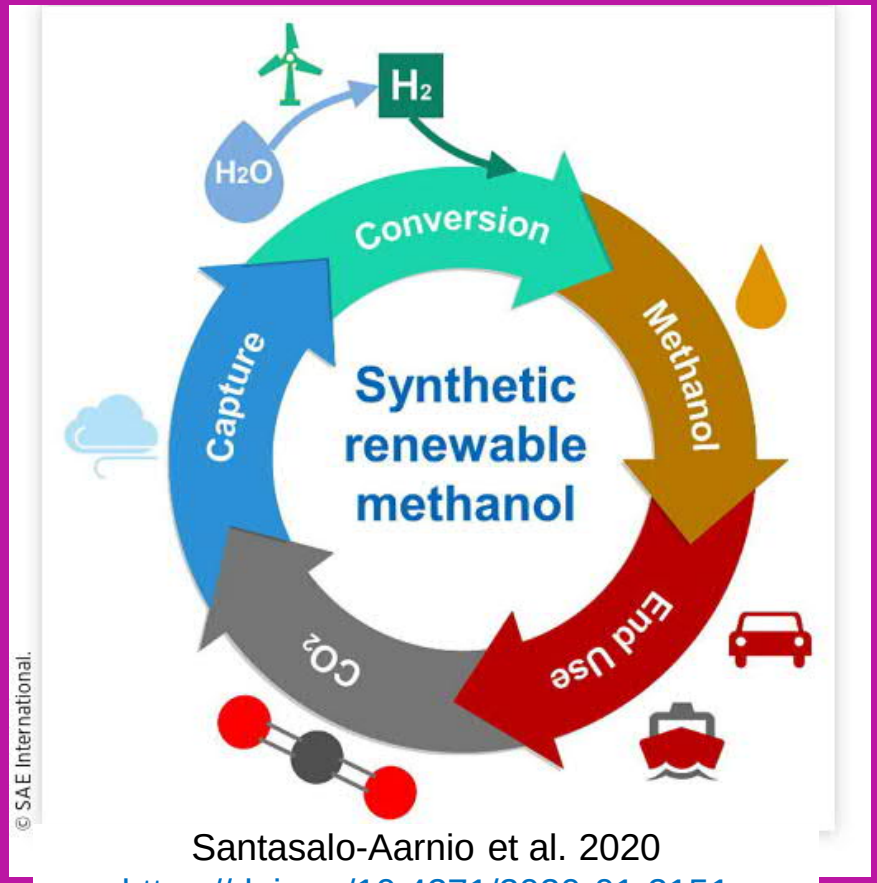
Power to Fuels

Modelling of methanol production



Santasalo-Aarnio et al. 2020
https://doi.org/10.4271/2020-01-2151

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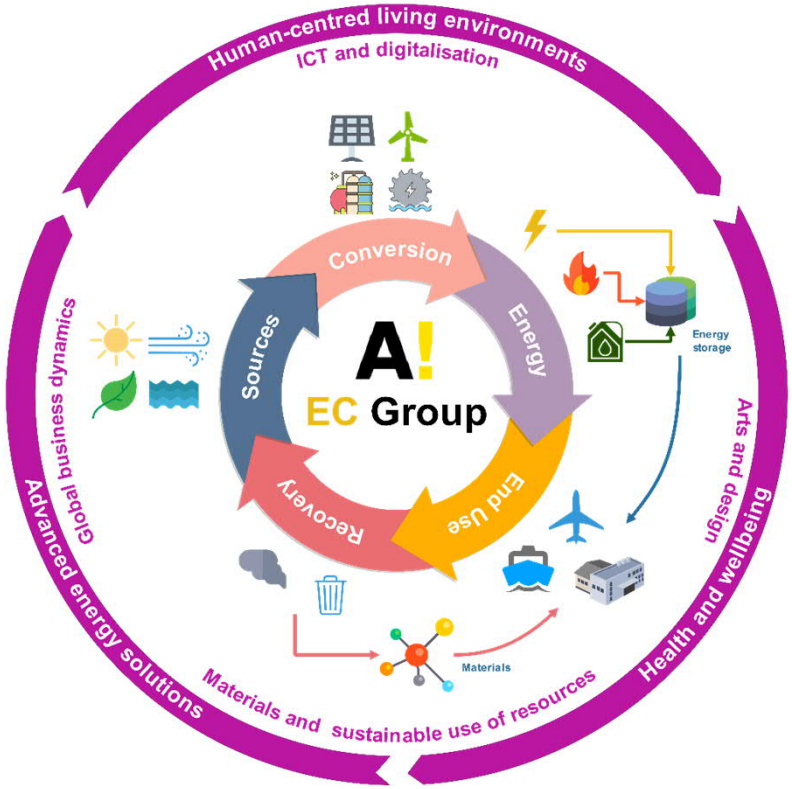
Energy Conversion
Department of Mechanical Engineering

Research Group of Energy Conversion

Aalto University

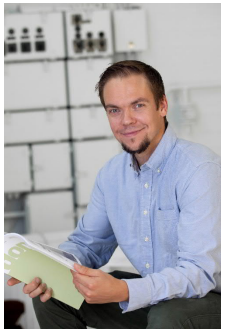
Head
Prof. Martti Larmi



https://youtu.be/mK41f24lX1k

Prof. Annukka Santasalo-Aarnio

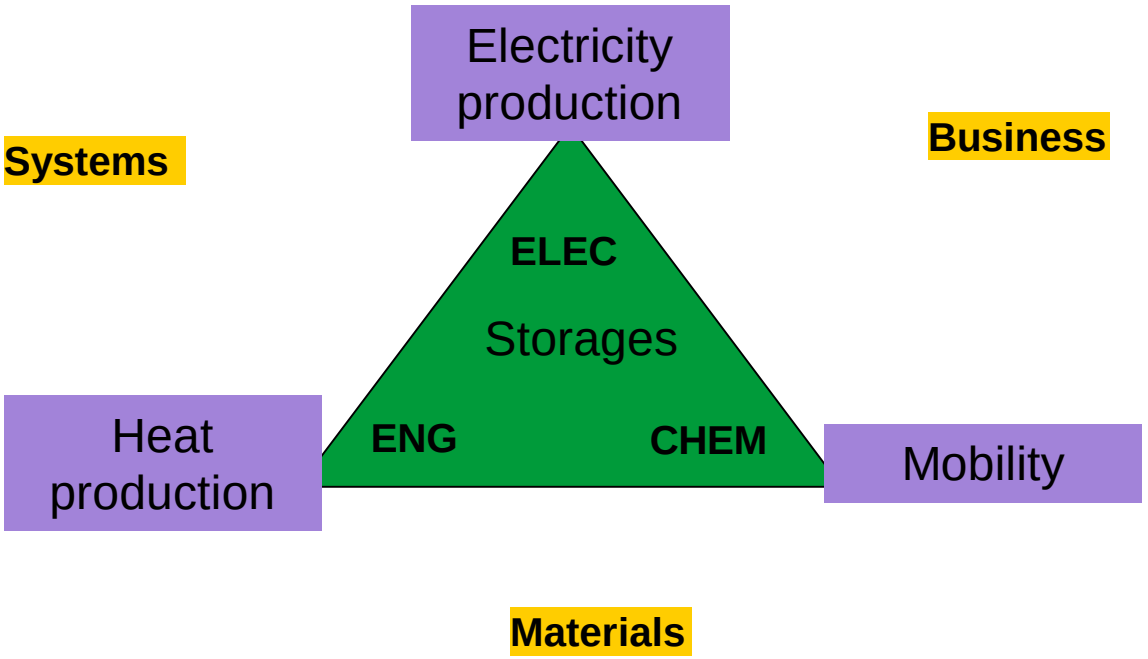
Prof. Ville Vuorinen



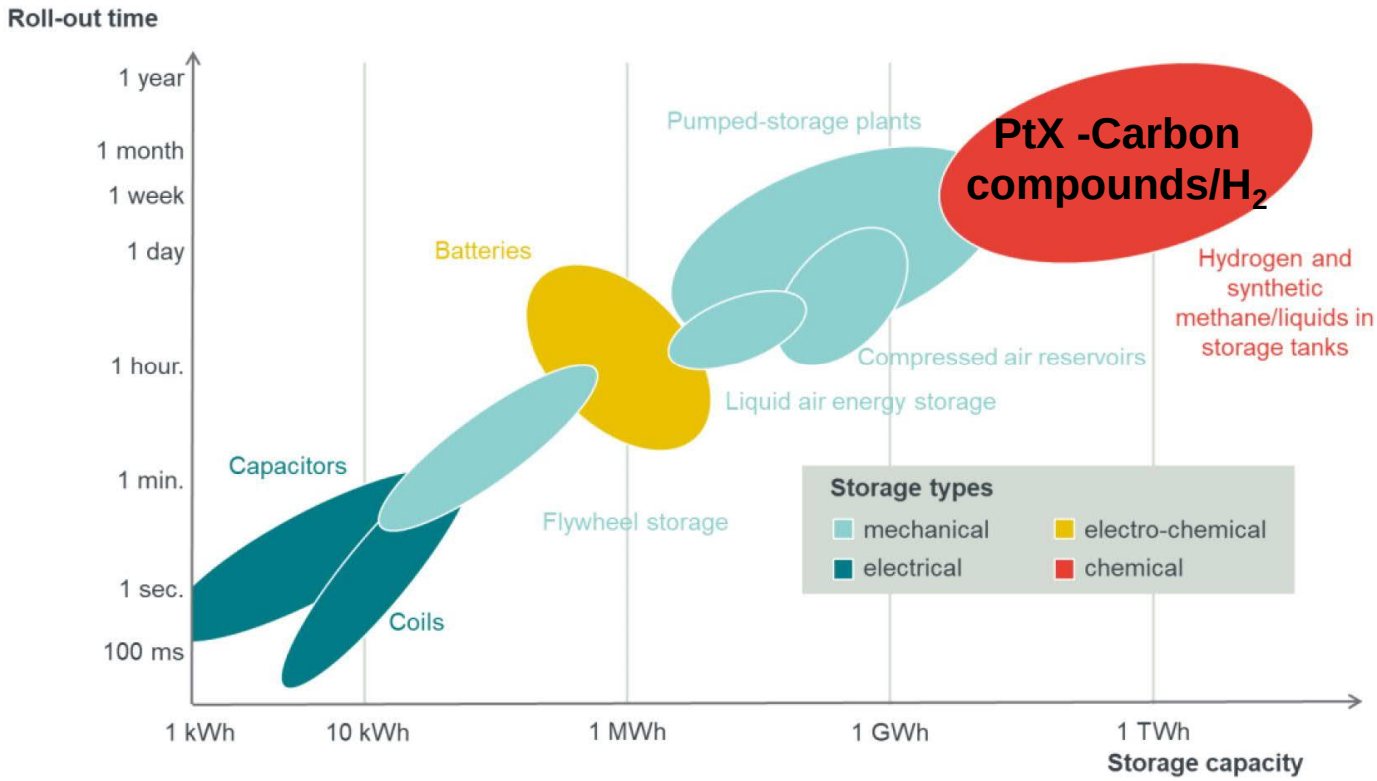
Prof. Mika Järvinen

Energy Transition

Energy Transition



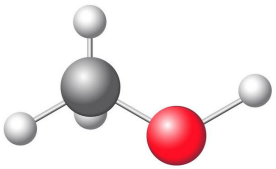
Where do we need power t X?

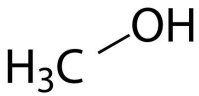


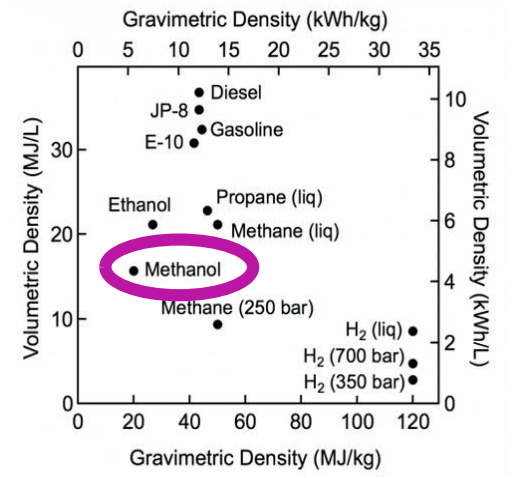
The World Energy Council Germany:
INTERNATIONAL ASPECTS OF A POWER-TO-X ROADMAP (2019)
https://www.weltenergierat.de/ptxstudie/

Methanol: a clean-burning multipurpose fuel

Methanol





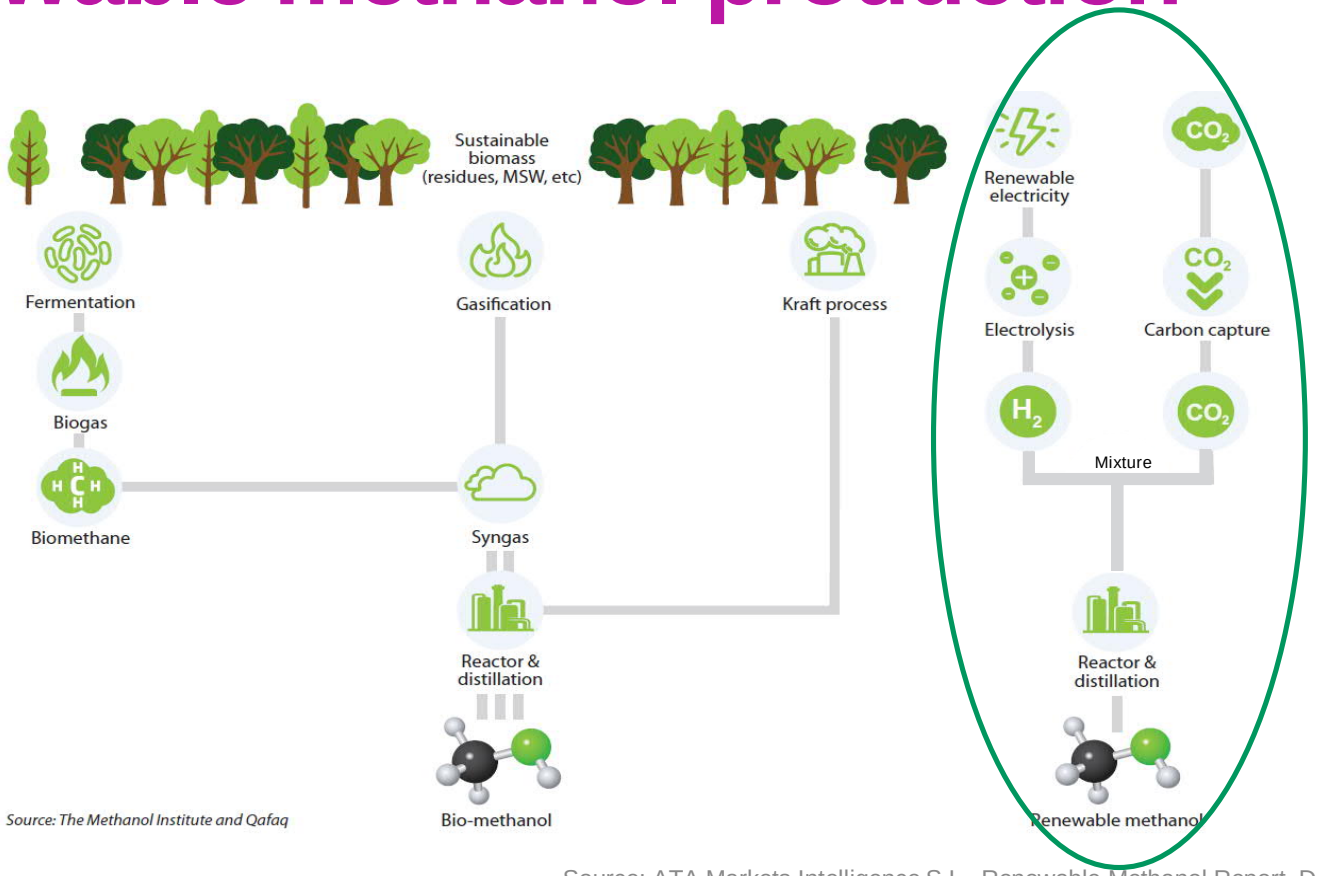


Comparison of specific energy (energy per mass or gravimetric density) and energy density (energy per volume or volumetric density) for several fuels based on lower heating values.

Emission reductions when compared to heavy fuel oil

Sources: Methanex, Investor Presentation, Macrh 2019
ATA Markets Intelligence S.L., Renewable Methanol Report, December 2018

Renewable methanol production



Source: ATA Markets Intelligence S.L., Renewable Methanol Report, December 2018

Full system modelling Aspen Plus

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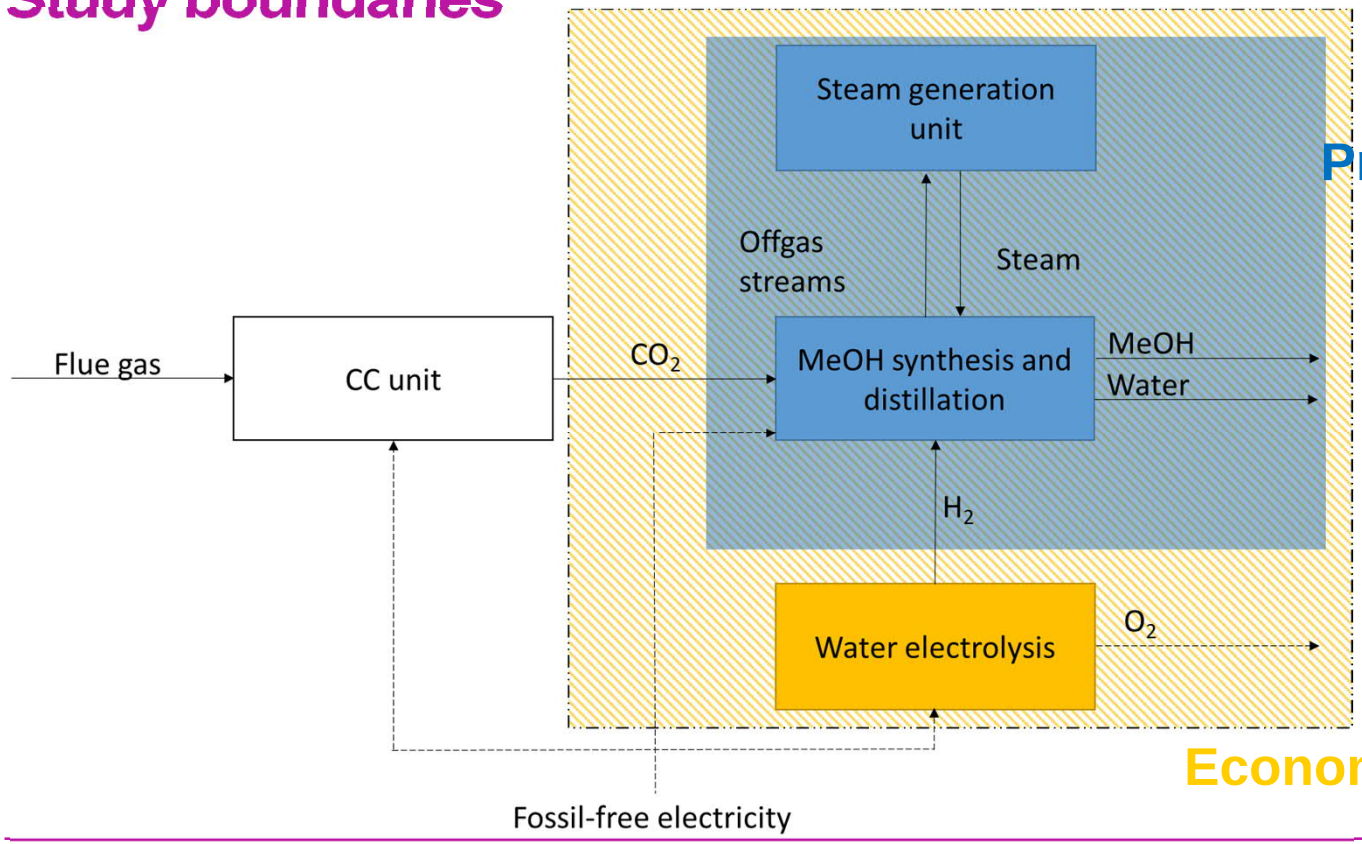
Methanol plant

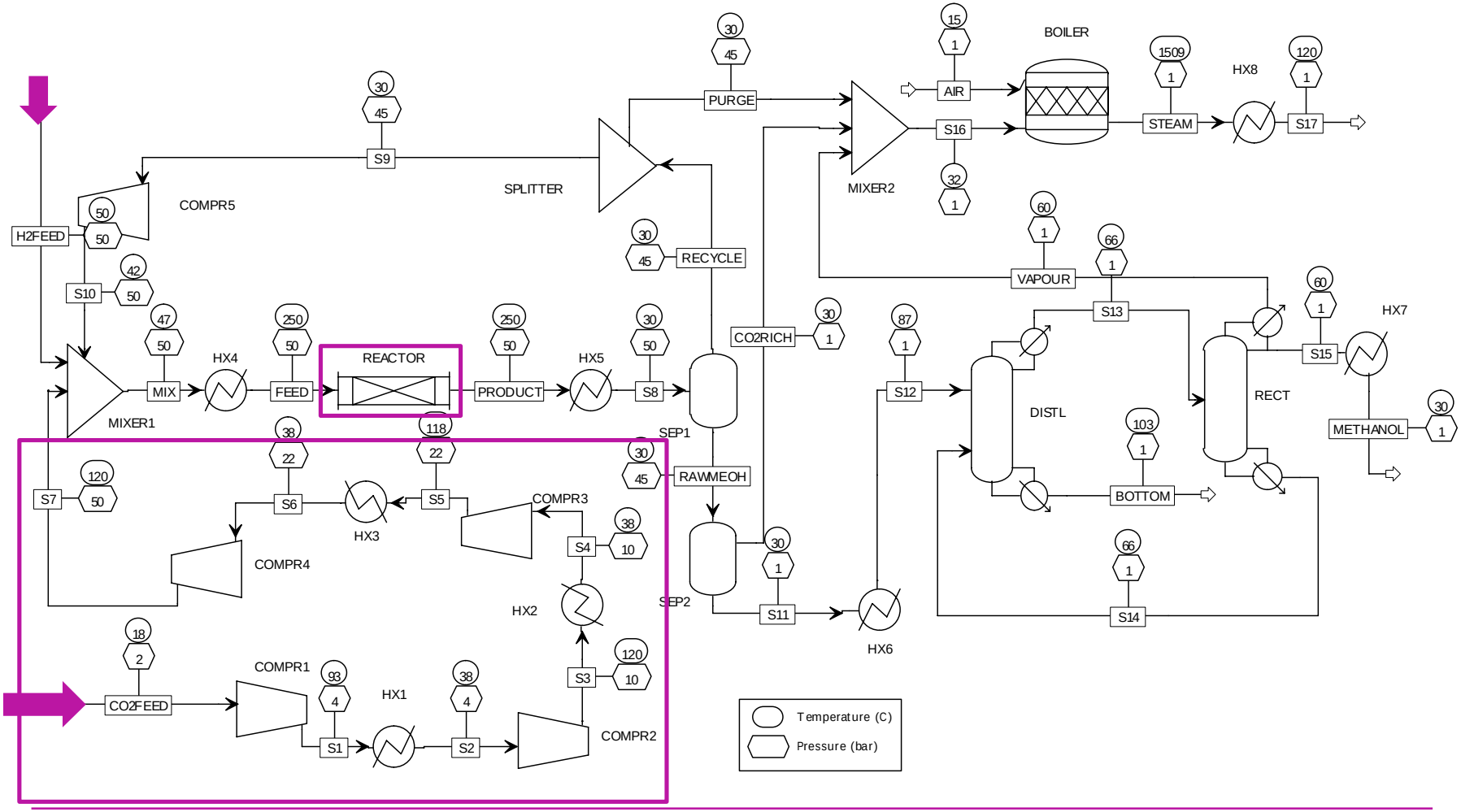
Study boundaries



Process simulation

Economic feasibility

Nyári *et al.* 2020 J. CO_2 utilization, https://doi.org/10.1016/j.jcou.2020.101166



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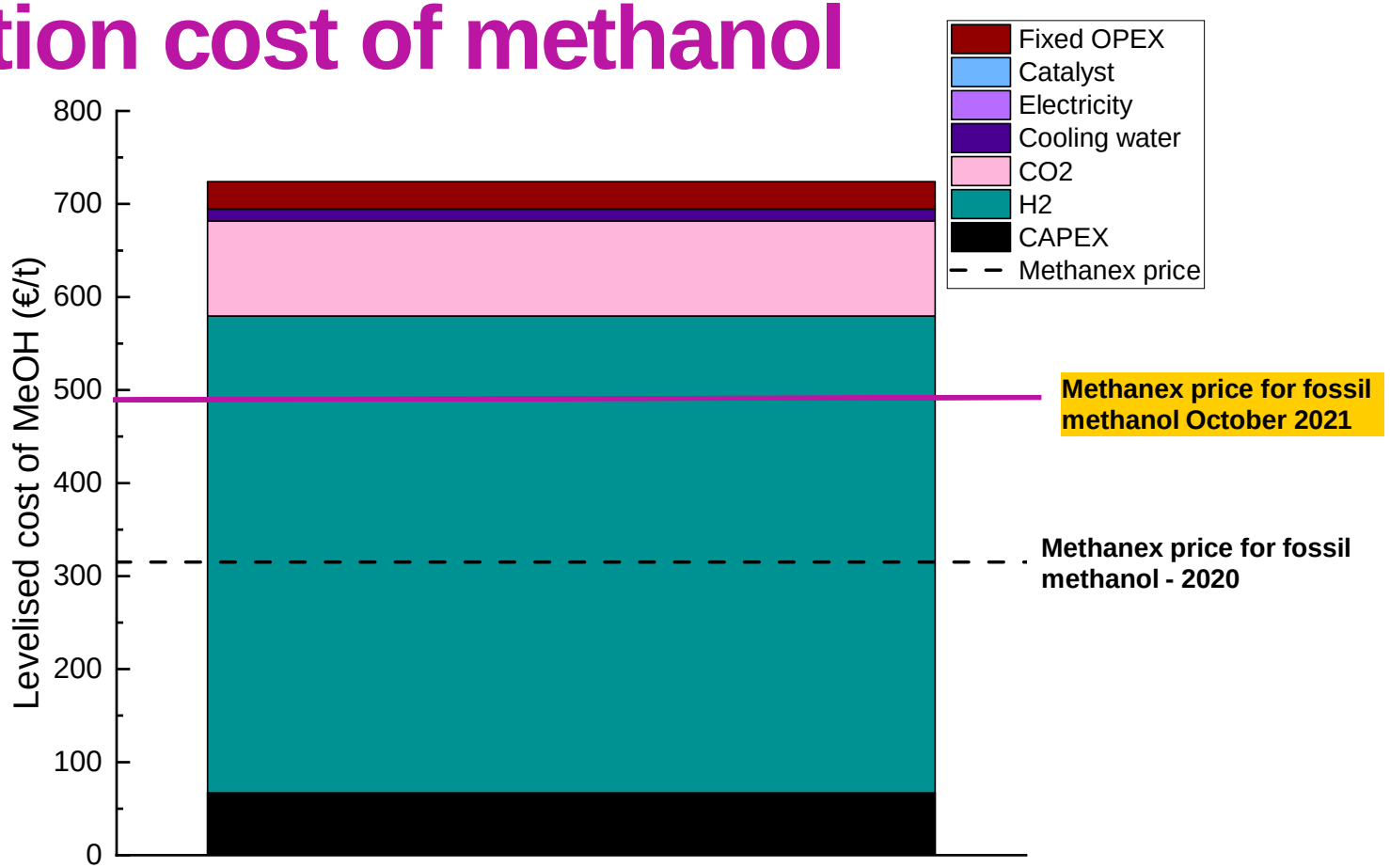
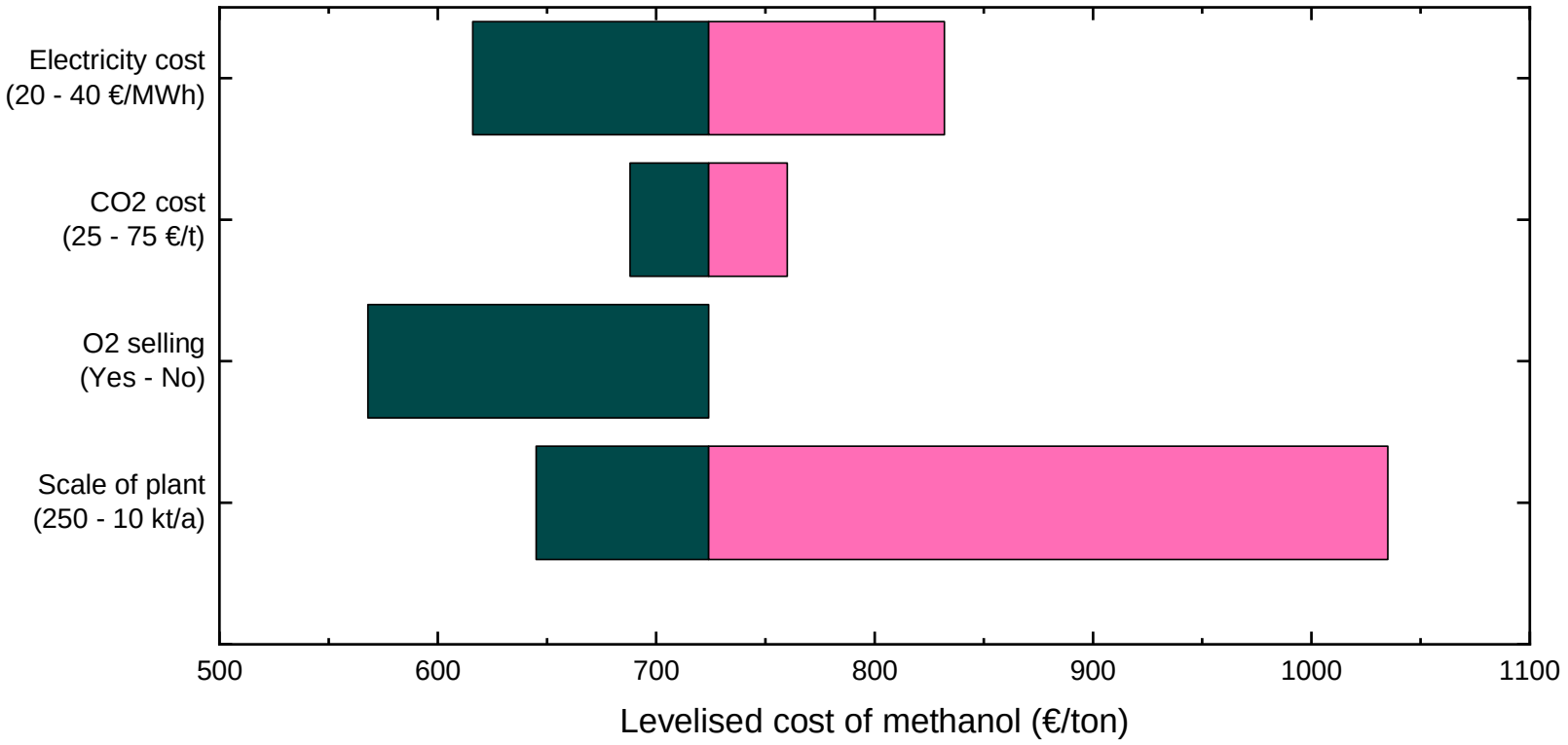
Nyári *et al.* 2020 J. CO_2 utilization,
https://doi.org/10.1016/j.jcou.2020.101166

Production cost of methanol



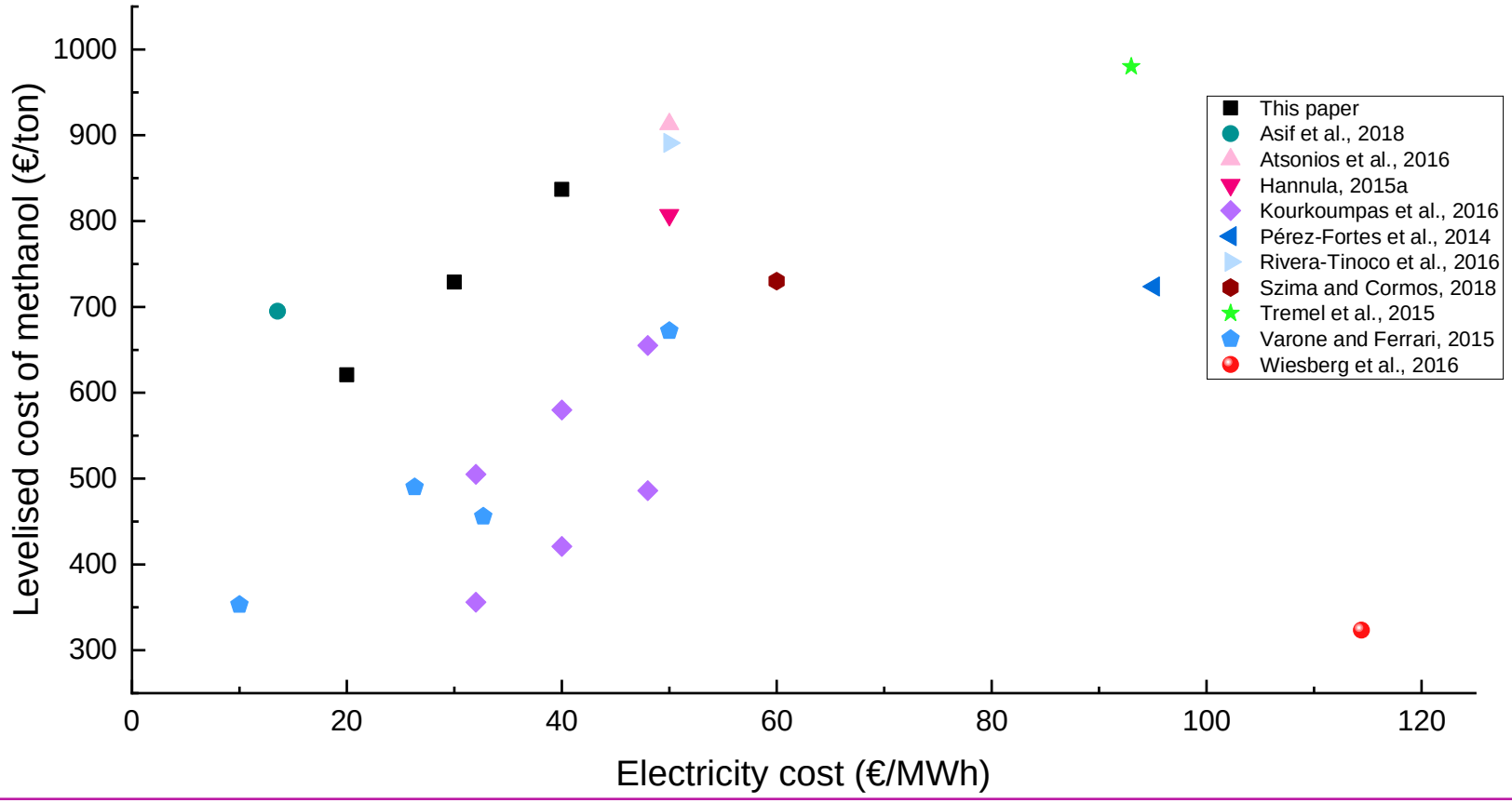
Nyári *et al.* 2020 J. CO_2 utilization, https://doi.org/10.1016/j.jcou.2020.101166

Bottlenecks of economic viability



Nyári *et al.* 2020 J. CO_2 utilization,
https://doi.org/10.1016/j.jcou.2020.101166

Comparison to other LCOMeOH studies



Nyári *et al.* 2020 J. CO_2 utilization,
https://doi.org/10.1016/j.jcou.2020.101166

Reactor modelling
Computational Fluid Dynamics (CFD)

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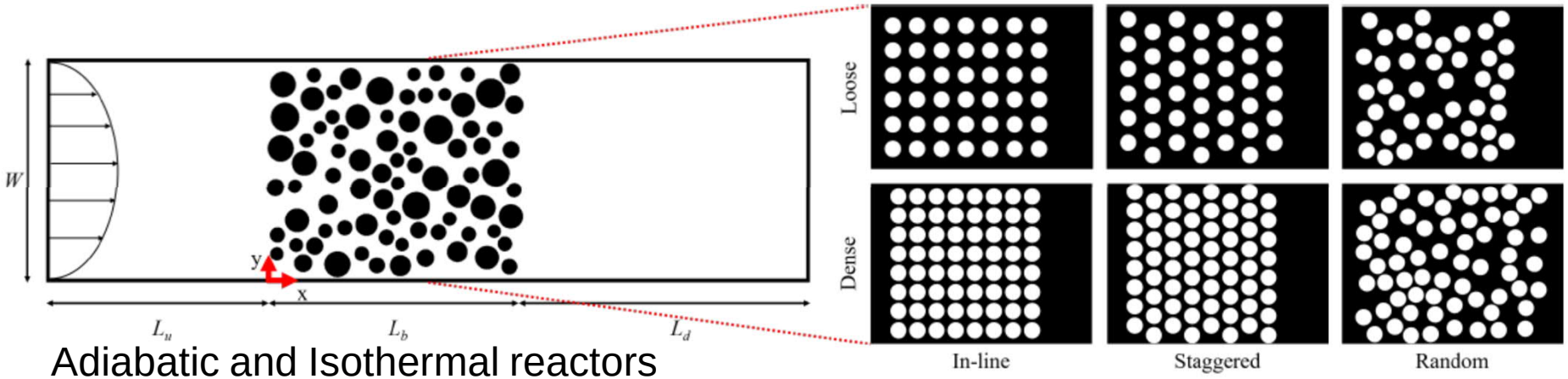
Computational Fluid Dynamics

CFD modelling of multi-tubular and milli-scale reactors.

P2X ENABLE

Aim and objectives

Development of intensified cost-effective methanol synthesis process starting from H_2 and CO_2 using modular milli-scale reactor design.



Adiabatic and Isothermal reactors

Software:
OpenFOAM

Izbassarov *et al* (2021)
https://doi.org/10.1016/j.ijhydene.2021.02.031

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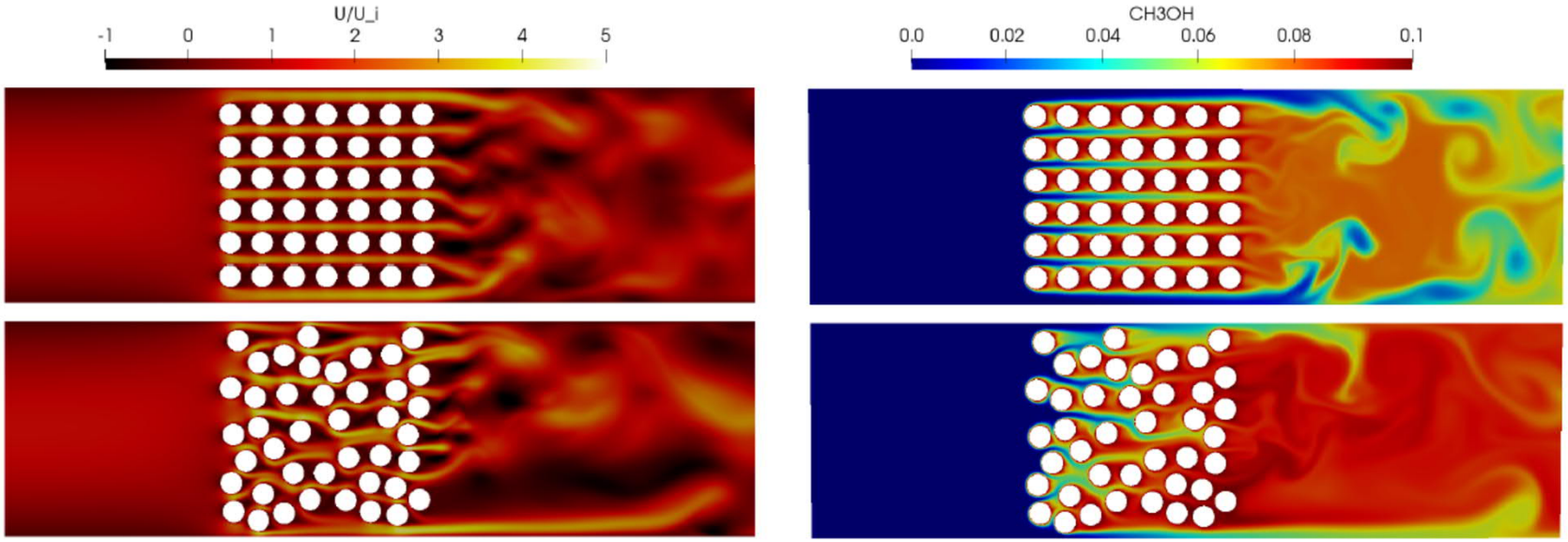
2D Fixed-bed Reactor

P2X ENABLE



Adiabatic reactor

$T_i = 523K, p_i = 5MPa, Re = 100, SV = 6\,m^3/kg_{cat}\,h$

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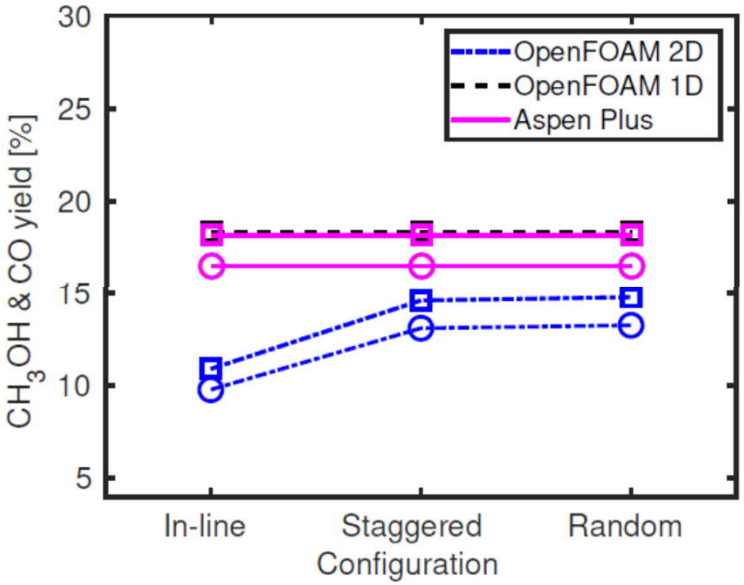
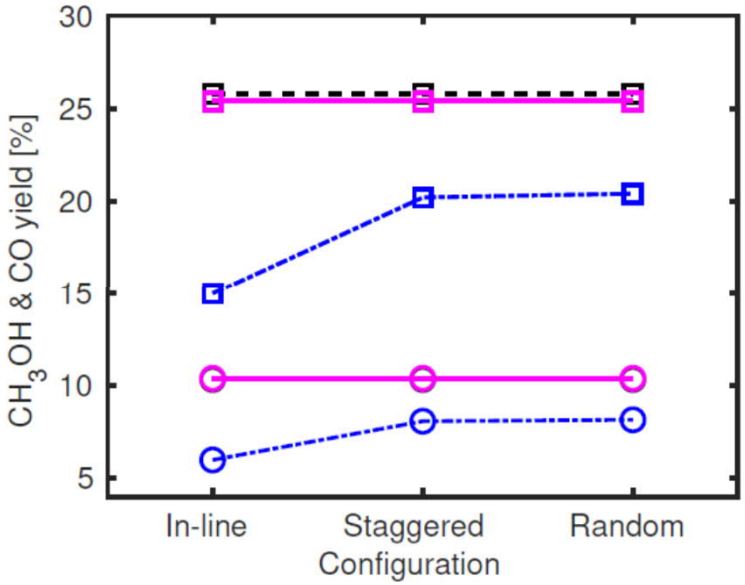
Izbassarov *et al* (2021)
https://doi.org/10.1016/j.ijhydene.2021.02.031

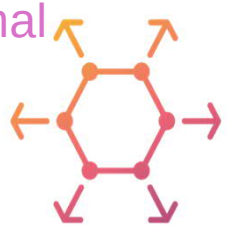
2D Fixed-bed Reactor



Adiabatic



Isothermal

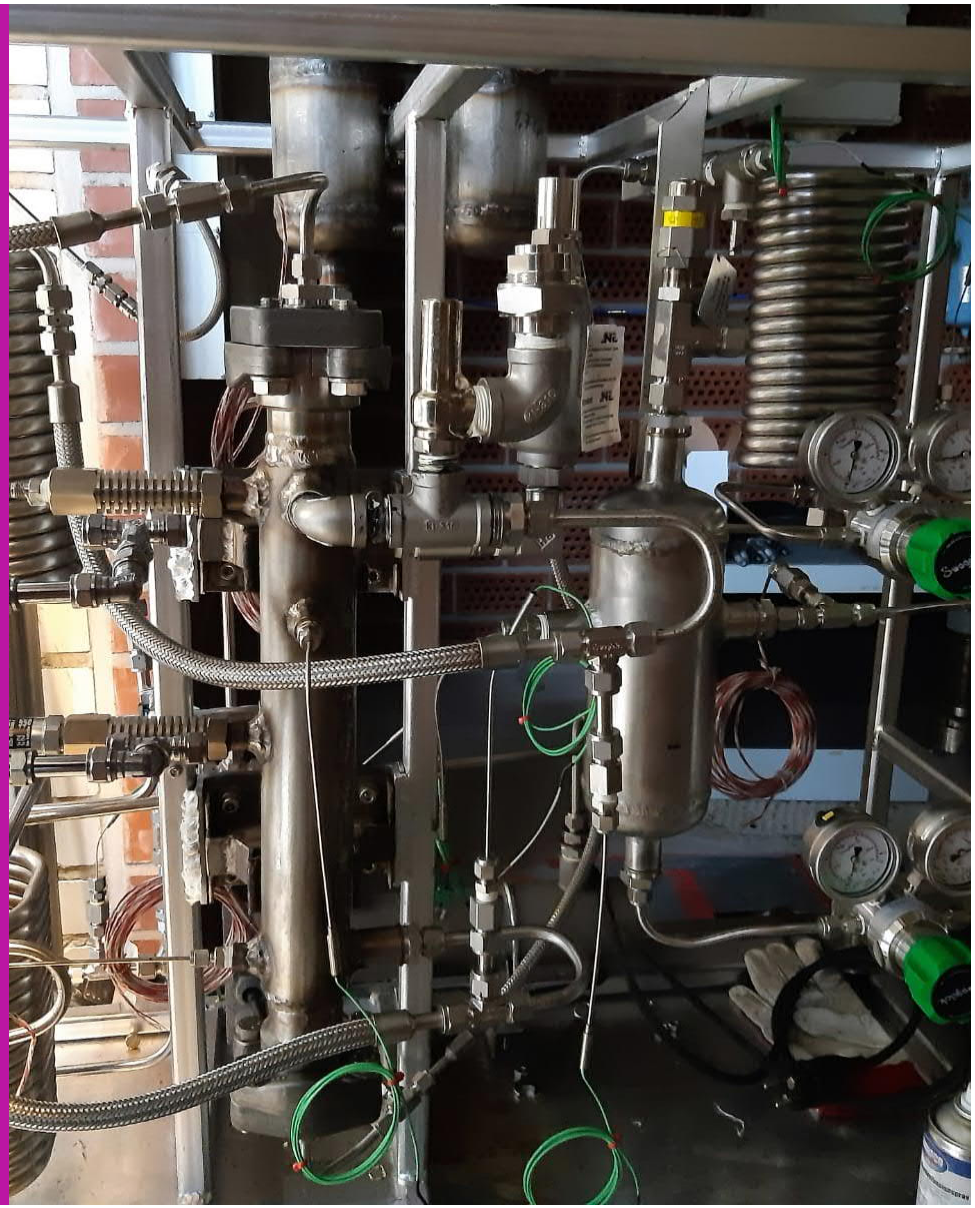


P2X ENABLE

Izbassarov *et al* (2021)
https://doi.org/10.1016/j.ijhydene.2021.02.031

Experimental studies

Lab-scale methanol synthesis reactor



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Experimental reactor system

Methanol synthesis from CO_2 and H_2

Process conditions

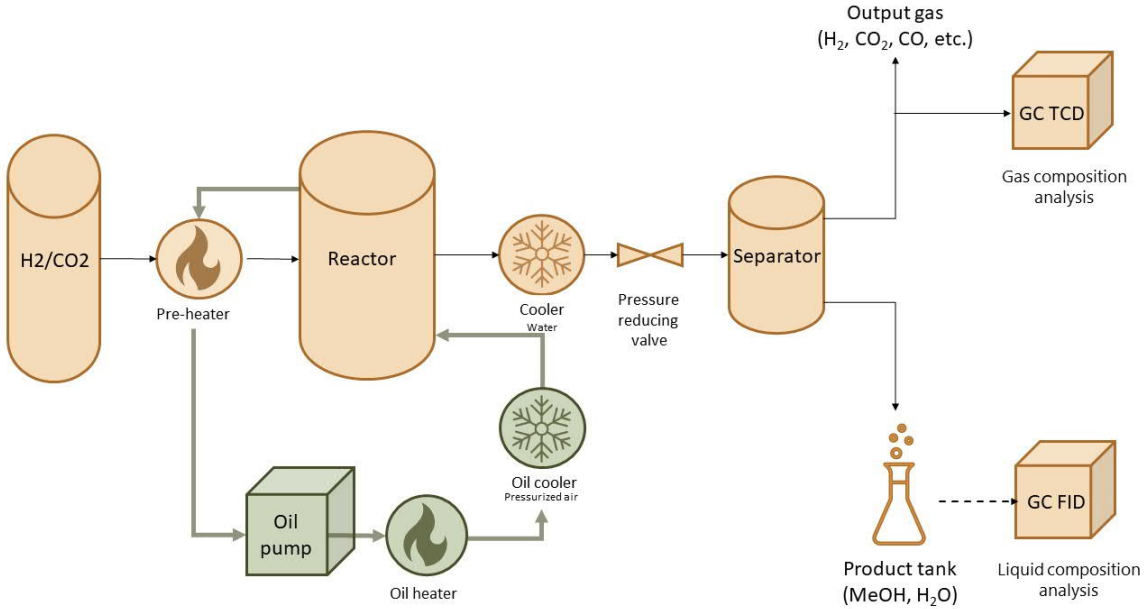
T: 200 – 250 °C

p: 30 – 50 bar

Commercial

Cu-based catalyst

Optimized with modelling



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Reactor Details

Height: 50 cm

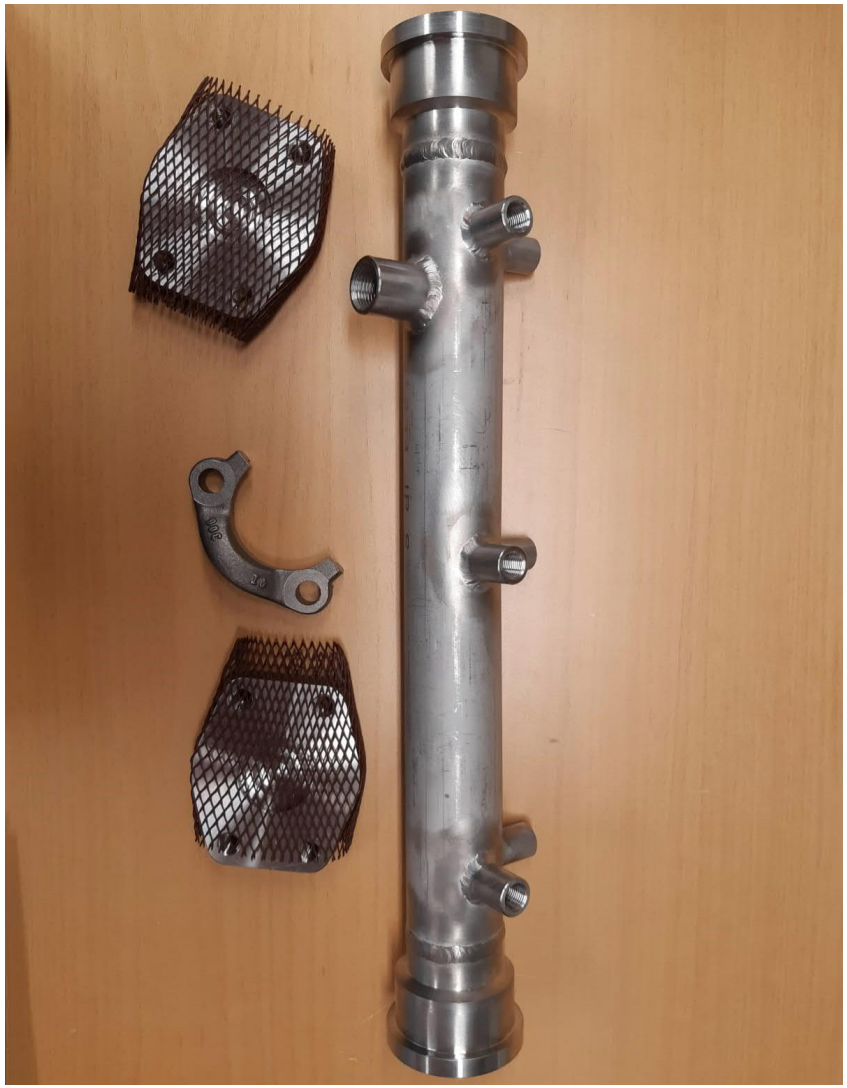
Inner diameter: 3,8 cm

(Volume: 0.567 L)

Integrated oil cooling channels on the outside

3 places for temperature sensors

3 places for pressure sensors



Research topics

- Different catalyst materials
- Different catalyst packings
- Different feed gas compositions (e.g. CCU product gases)
- Validation of simulation results (Aspen Plus& OpenFoam simulation)
- The effect of operating conditions in modified cases

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Conclusion

Methanol is a versatile chemical compound that can be implemented into the current fuel infrastructure

Technically viable to synthesise from CO_2 and H_2

Price of H_2 is significant contributor to high methanol production cost

Efficiency improvements needed