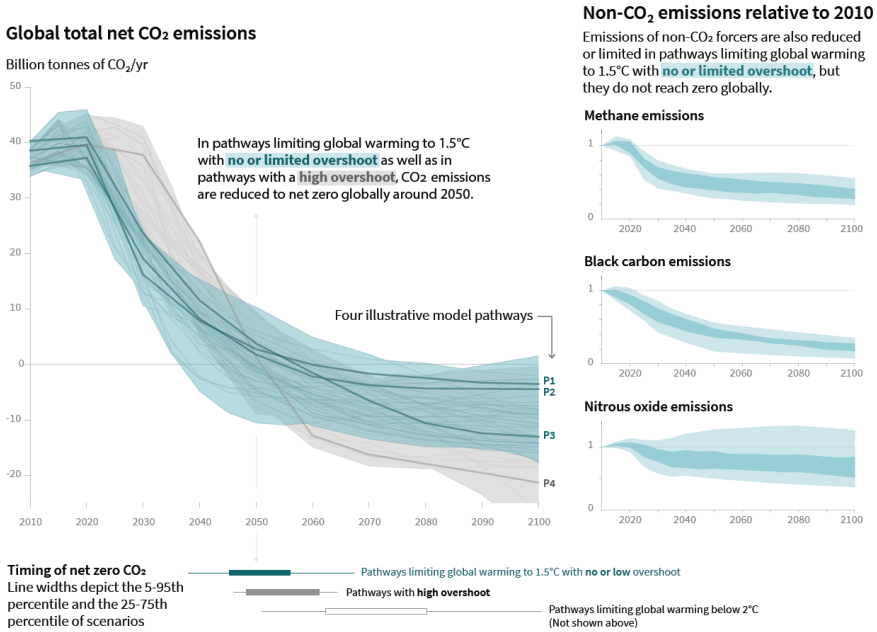
MAXIMISING CARBON EFFICIENCY THROUGH STEAM SEPARATION ENHANCEMENT

ECCE 12 | J. van Kampen

ECN › TNO innovation for life

CO_2 EMISSION REDUCTION!



IPCC, 2018

- CCS (up to 1218 $GtCO_2$ until 2100)
- Fuels, chemicals, materials: CO_2 & energy
- CCS & CCUS & CCU – joint development
- Investing in technology relevant today, equally relevant in 2050
- Where possible, let CCU enable CCS

CO_2 AND H_2 TO PRODUCTS

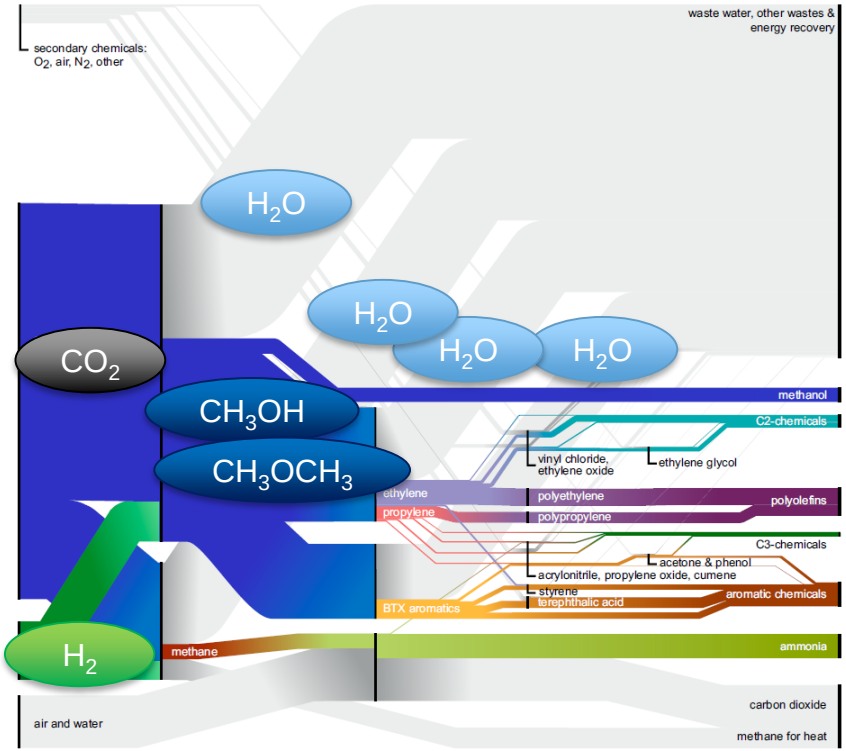
- Mass flows within the chemical industry (2030)

$$CO_2 + 3H_2 \leftrightarrow CH_3OH + H_2O$$

$$2CO_2 + 6H_2 \leftrightarrow CH_3OCH_3 + 3H_2O$$

- DME as Simple, Available, Sustainable, Low-Emission, Infrastructure Compatible Fuel
  https://www.aboutdme.org/

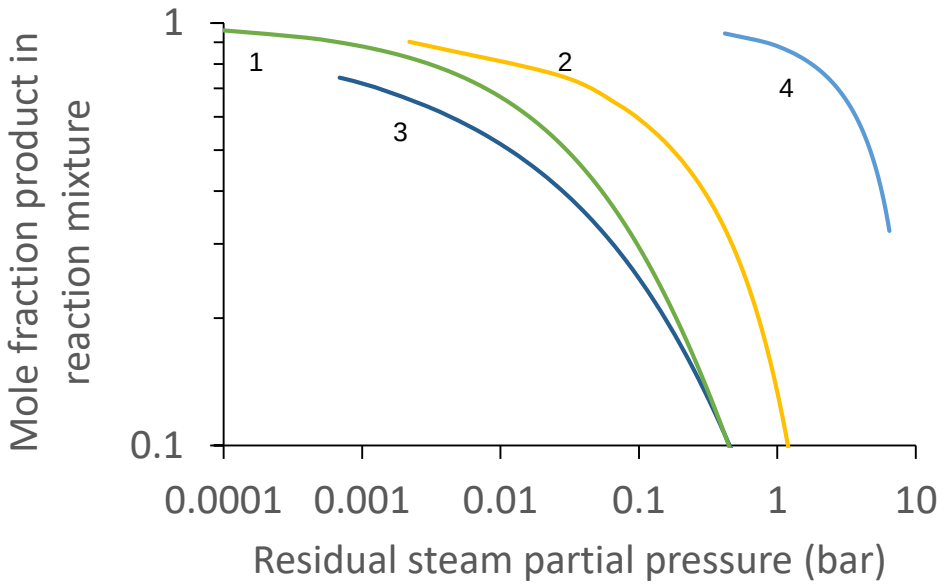
IDA
International DME Association
DME: 21st Century Energy



Kätelhön et al. (2019). *Proceedings of the National Academy of Sciences*, *116*(23), 11187-11194.

DIRECT SYNTHESIS FROM CO_2

- Steam separation enhancement: process intensification for CO_2 utilisation
- Reactions from CO_2:
  - Reverse water-gas shift
  - DME synthesis
  - Methanol synthesis
  - Methanation
- Reducing the steam partial pressure in situ
  - Adsorbents
  - Membranes



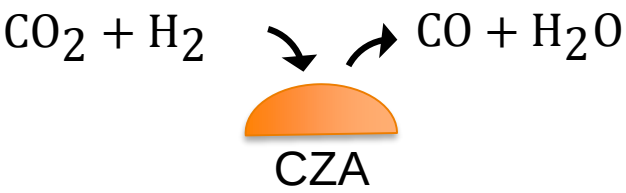
van Kampen et al. (2019) *Chemical Engineering Journal*. https://doi.org/10.1016/j.cej.2019.06.031

SEPARATION ENHANCEMENT: ADSORBENTS

REVERSE WATER-GAS SHIFT

Reverse water-gas shift (WGS)

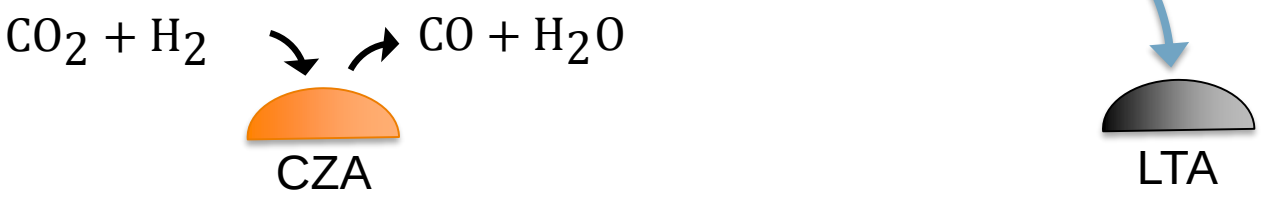
$$H_2 + CO_2 \rightleftharpoons CO + H_2O$$



SORPTION ENHANCED RWGS

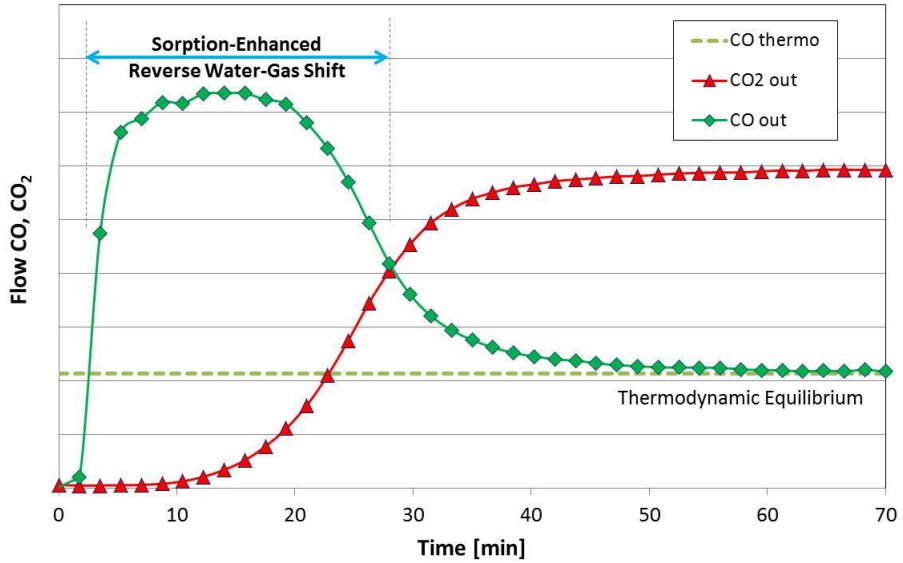
Reverse water-gas shift (WGS)

$$H_2 + CO_2 \rightleftharpoons CO + H_2O$$



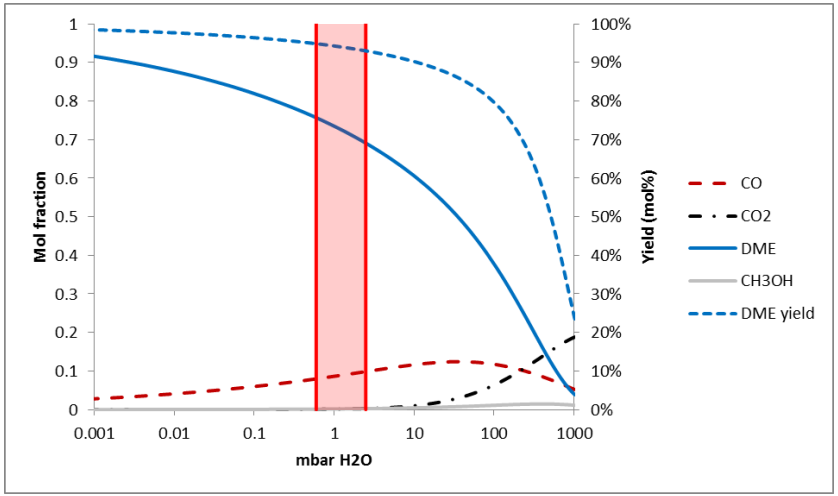
SORPTION ENHANCED RWGS

>98% selectivity to CO



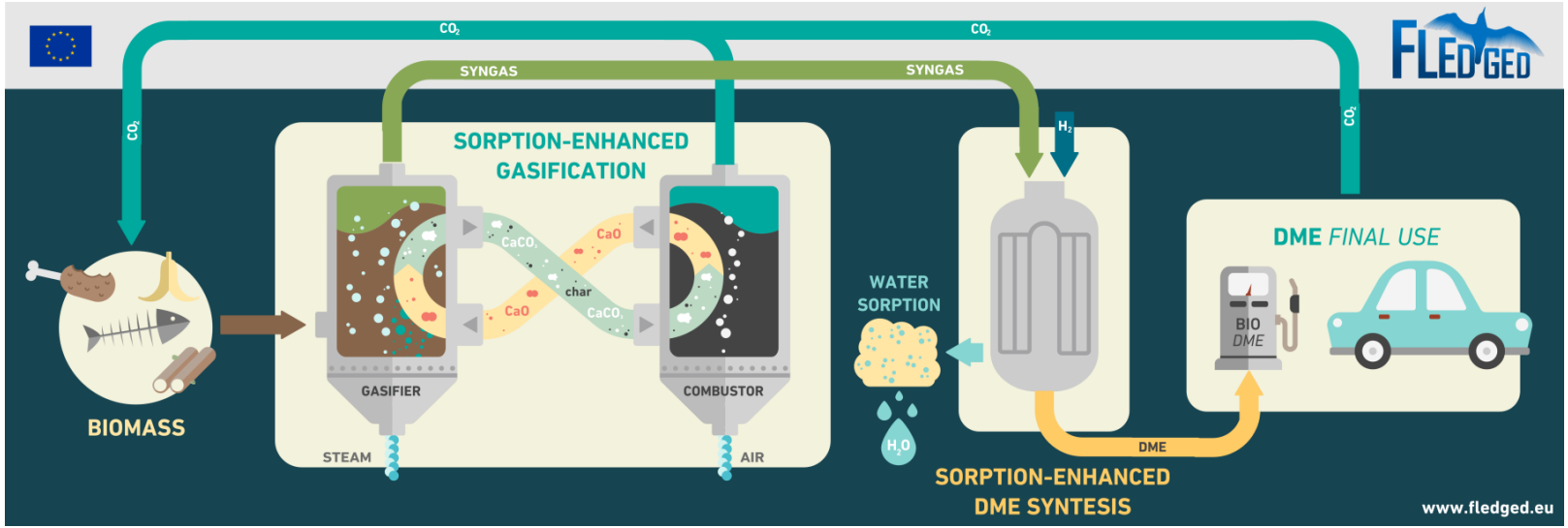
SORPTION ENHANCED DME SYNTHESIS

- Equilibrium model with in situ water removal
- Stoichiometric feed (CO_2), 275 °C, 25 bar(a)
- Target
  - 90% DME yield
  - Small residual CO_2 concentration

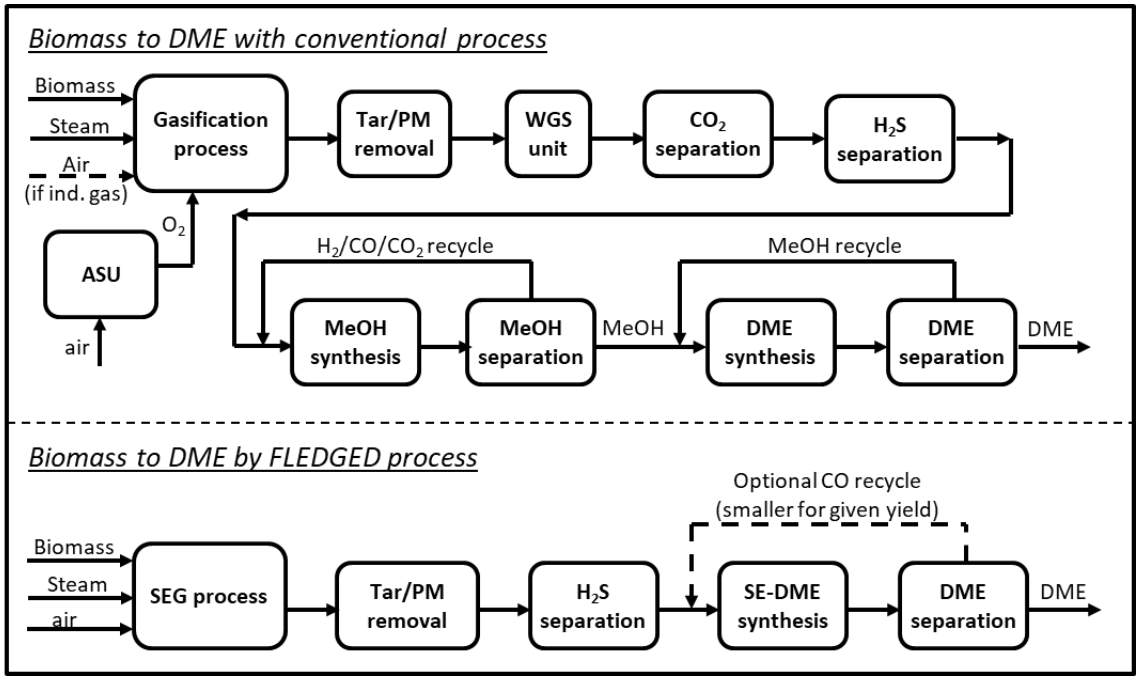


THE FLEDGED PROJECT

- The ***FLEDGED*** project will deliver a process for ***Bio-based Dimethyl Ether (DME)*** production from **biomass** gasification, validated in ***industrially relevant*** environment (TRL5).



FLEDGED: BIOMASS TO DME



www.fledged.eu/

https://youtu.be/JEn39Zi_aCg

EU INTERREG E2C PROJECT

Interreg 2 Seas Mers Zeeën
European Regional Development Fund
EUROPEAN UNION

e2C

Electrons to High Value Chemical Products

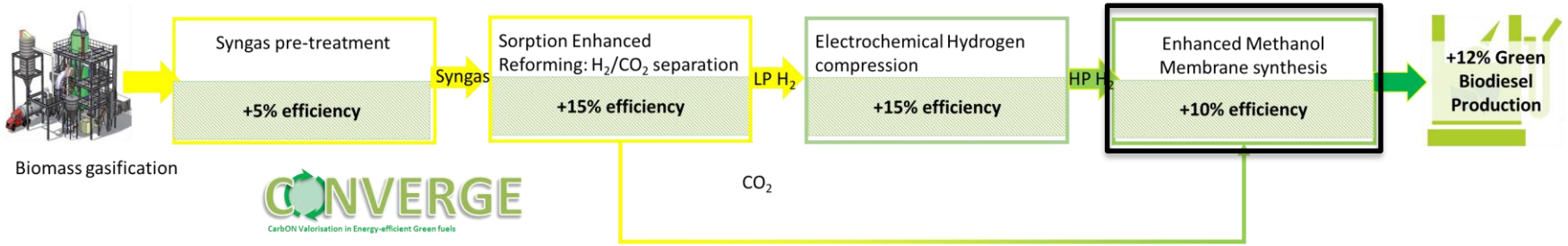
International open innovation platform, open to additional industrial partners during and after the project

http://www.voltachem.com/E2C

SEPARATION ENHANCEMENT: MEMBRANES

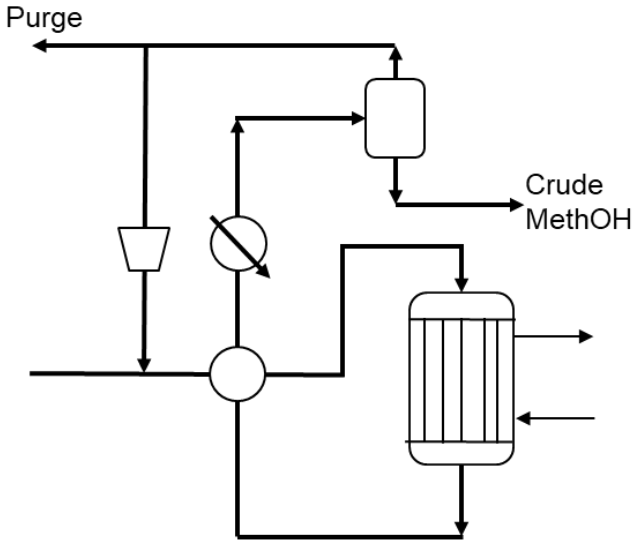
THE CONVERGE PROJECT

- The ***CONVERGE*** **project will validate an innovative process (TRL5)** which will **increase the biodiesel production by 12%** per secondary biomass unit used and **reduce the CAPEX by 10%.**

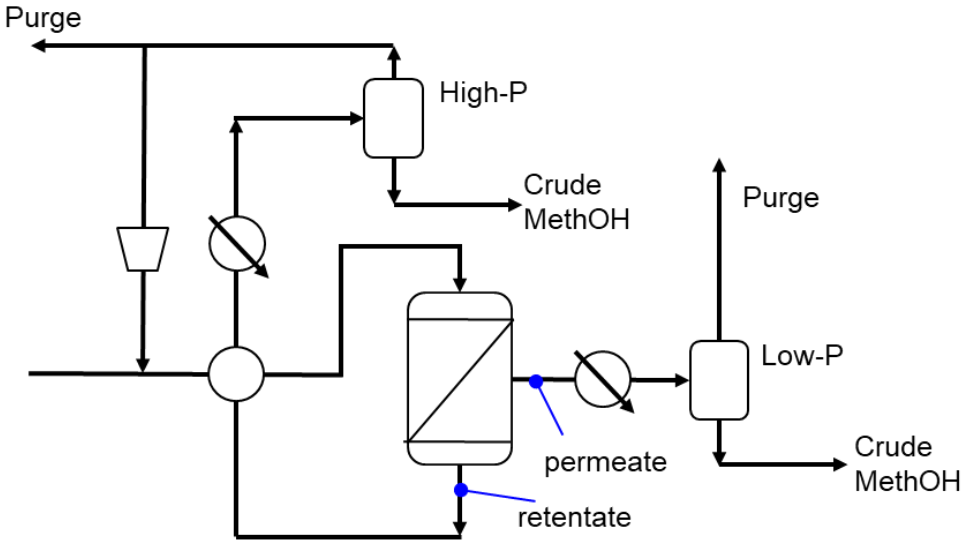


ENHANCED METHANOL MEMBRANE SYNTHESIS

conventional

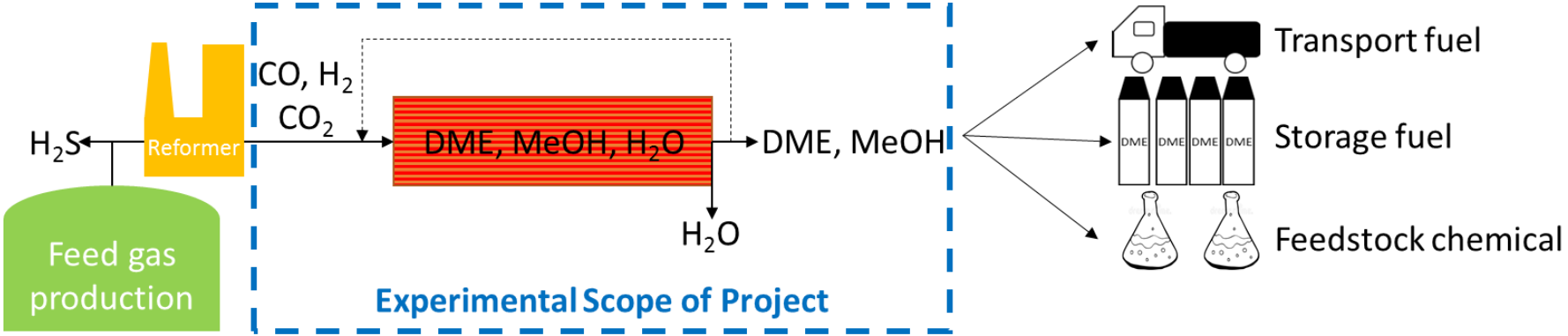


membrane assisted

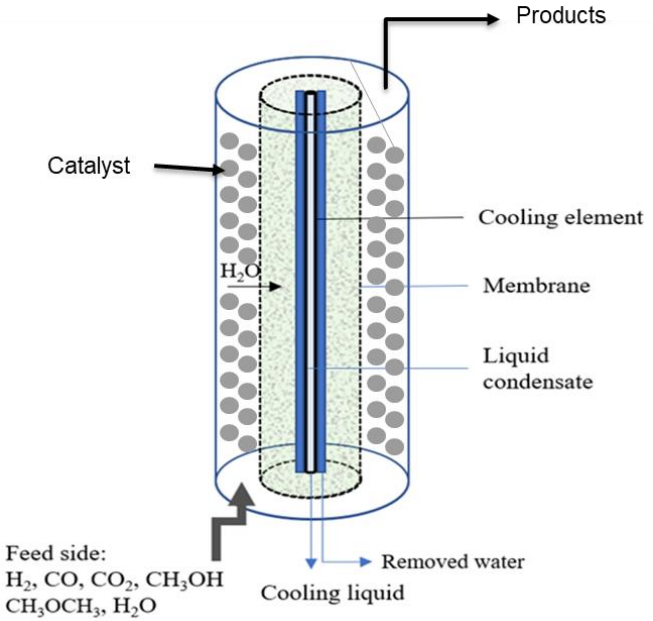


BIODIME

- New process concept to produce DME from CO_2 rich gasses such as biogas

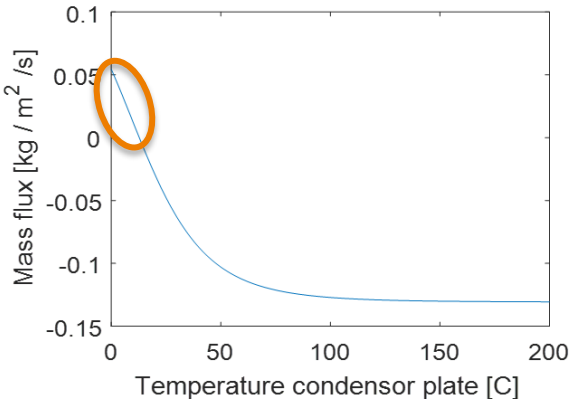


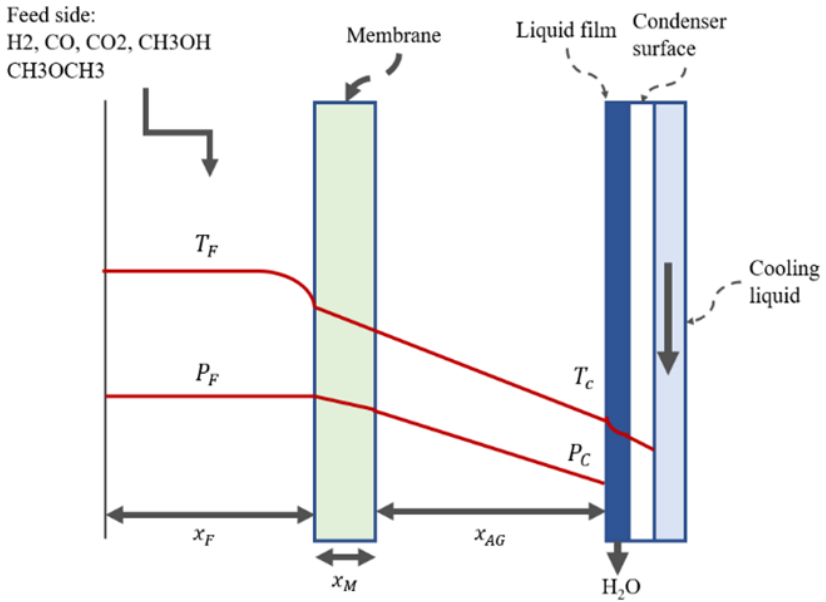
PERMEATION ENHANCED DME SYNTHESIS: REACTOR CONCEPT



REACTOR MODEL

- Mass transfer model with reactor kinetics for estimation of DME production
- 50% increase in single-pass DME yield





EXPERIMENTAL MEMBRANE REACTOR SETUP

SEPARATION ENHANCED PROCESSES FOR THE UTILISATION OF CO_2

- Steam separation enhancement promising process intensification for CO_2 utilisation
- Complex interplay of catalysis and separation
- In situ steam removal to be addressed case specifically (not only theoretically)
- Adsorbents
  - Sorption enhanced reverse water-gas shift
  - Sorption enhanced dimethyl ether synthesis
- Membranes
  - Enhanced methanol membrane synthesis
  - Permeation enhanced dimethyl ether synthesis

ACKNOWLEDGEDMENTS

- ECN part of TNO
  - Biomass & Energy Efficiency, Petten, The Netherlands
  - Sustainable Process & Energy Systems, Delft, The Netherlands

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CONVERGE
CarbON Valorisation in Energy-efficient Green fuels

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ALIGN CCUS

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THANK YOU FOR YOUR ATTENTION
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