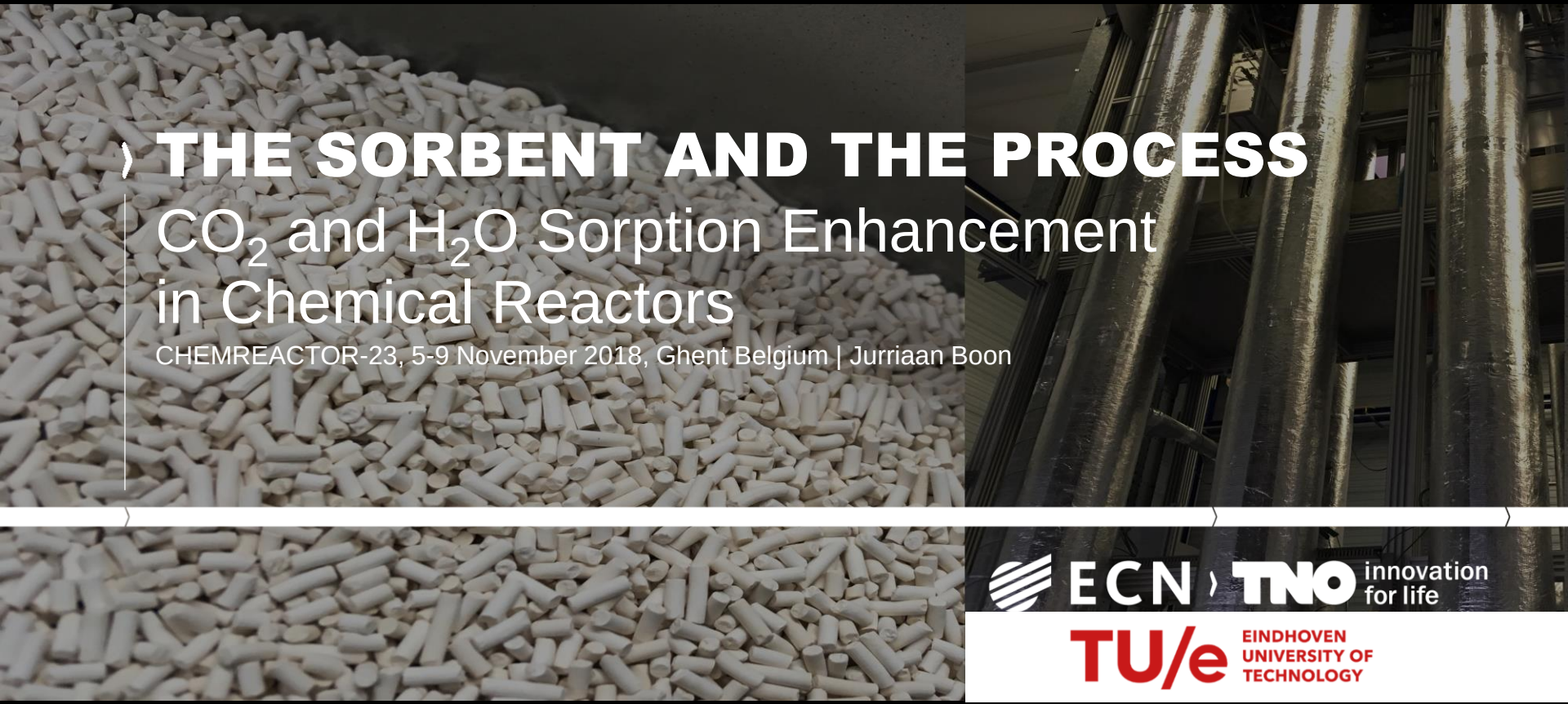

THE SORBENT AND THE PROCESS

CO_2 and H_2O Sorption Enhancement in Chemical Reactors

CHEMREACTOR-23, 5-9 November 2018, Ghent Belgium | Jurriaan Boon

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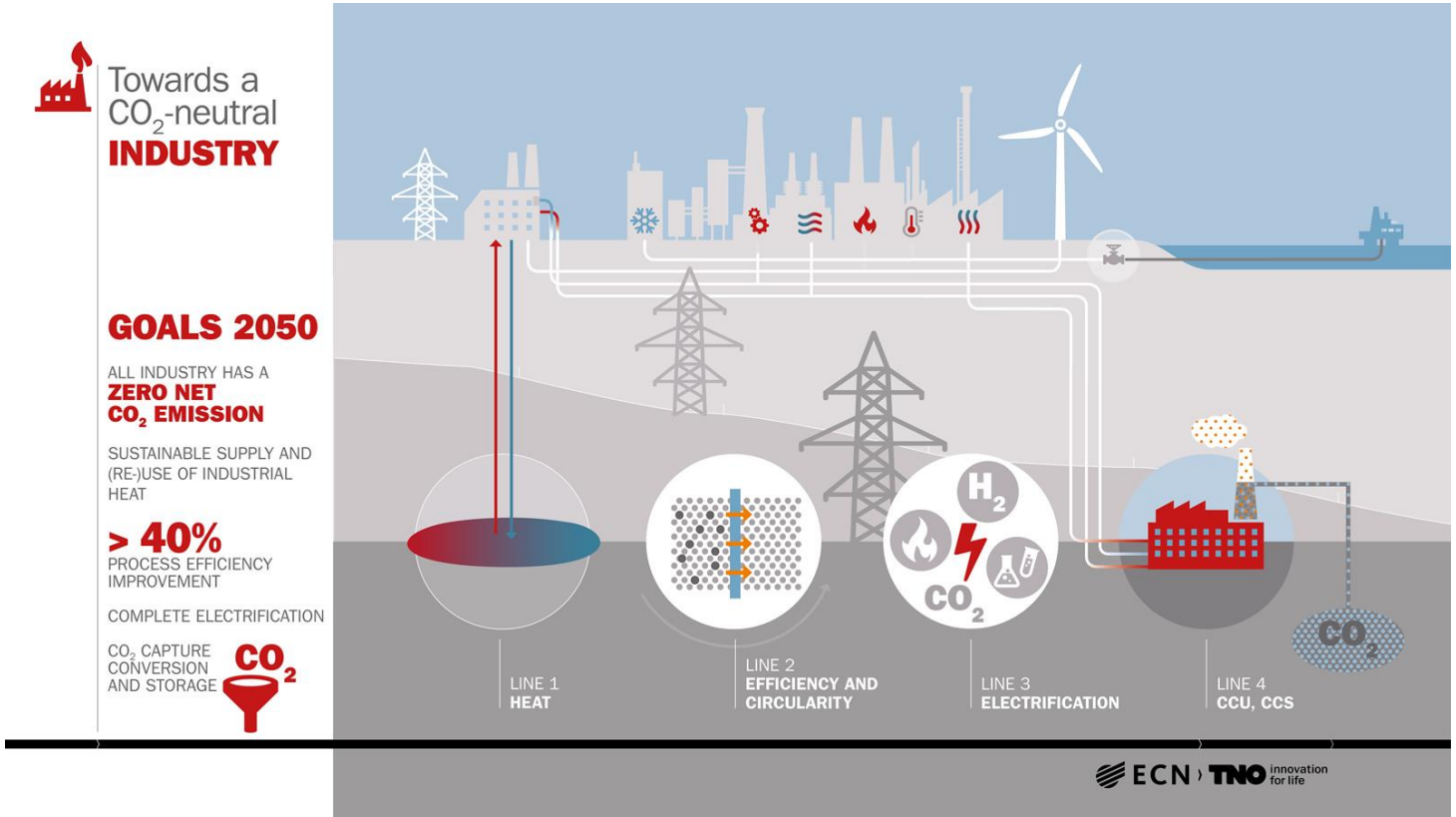
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

ECN PART OF TNO ROADMAP INDUSTRY



SORPTION-ENHANCED REACTIONS FOR CCS AND CCU

- Water-gas shift

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

- Sorption-enhanced water-gas shift (SEWGS)

$$CO_2 + * \rightarrow CO_2 *$$
$$CO + H_2O \rightarrow H_2 \left(+ CO_2\right)$$

- Reverse water-gas shift

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

- Sorption-enhanced reverse water-gas shift

$$H_2O + * \rightarrow H_2O *$$
$$CO_2 + H_2 \rightarrow CO \left(+ H_2O\right)$$

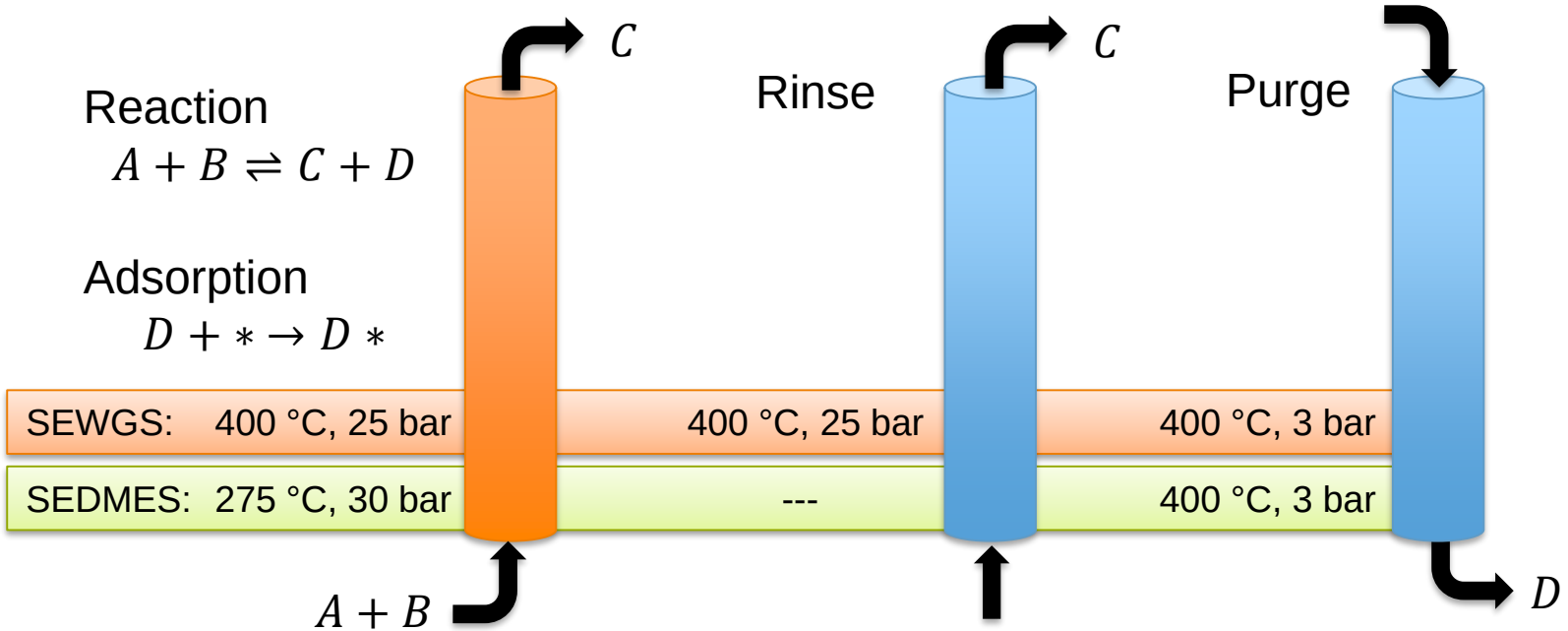
- Sorption-enhanced DME synthesis (SEDMES)

$$H_2O + * \rightarrow H_2O *$$
$$2CO_2 + 6H_2 \rightarrow CH_3OCH_3 \left(+ 3H_2O\right)$$

Carbon Capture & Storage

Carbon Capture & Utilisation

SORPTION-ENHANCED REACTIONS
ADSORPTION AND REGENERATION



PRECOMBUSTION CO_2 CAPTURE: SORPTION-ENHANCED WATER-GAS SHIFT – SEWGS

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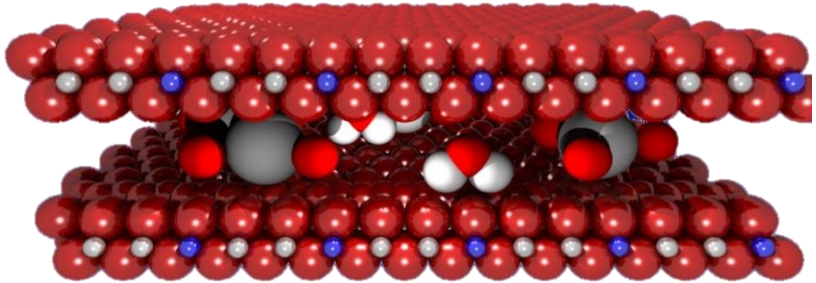
SEWGS: HYDROTALCITE PARTICLE

- Hydrotalcite, a layered double hydroxide mineral

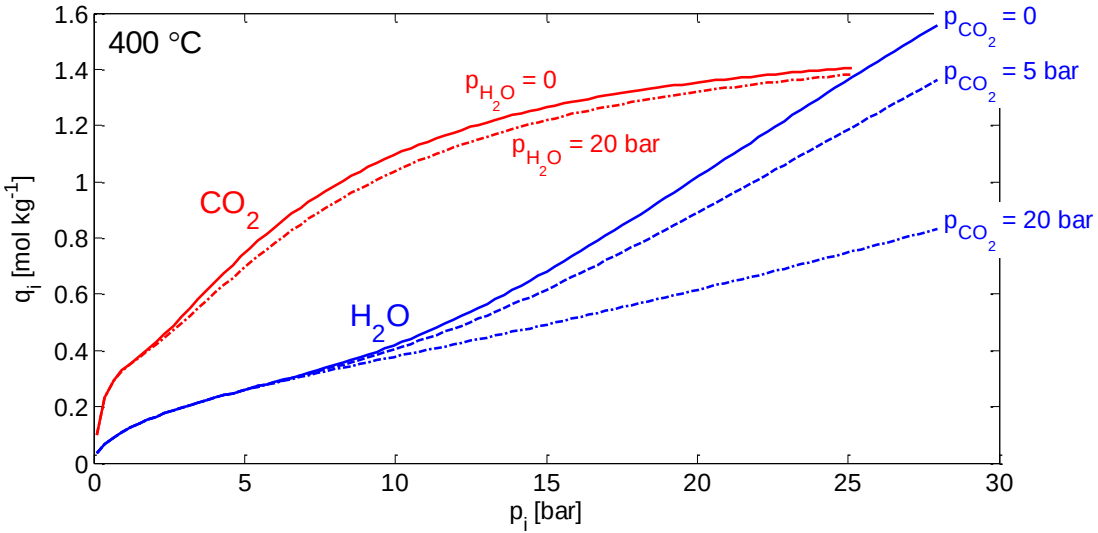
$Mg_6Al_2(OH)_{16}CO_3.4H_2O$

(varying Mg:Al ratio)



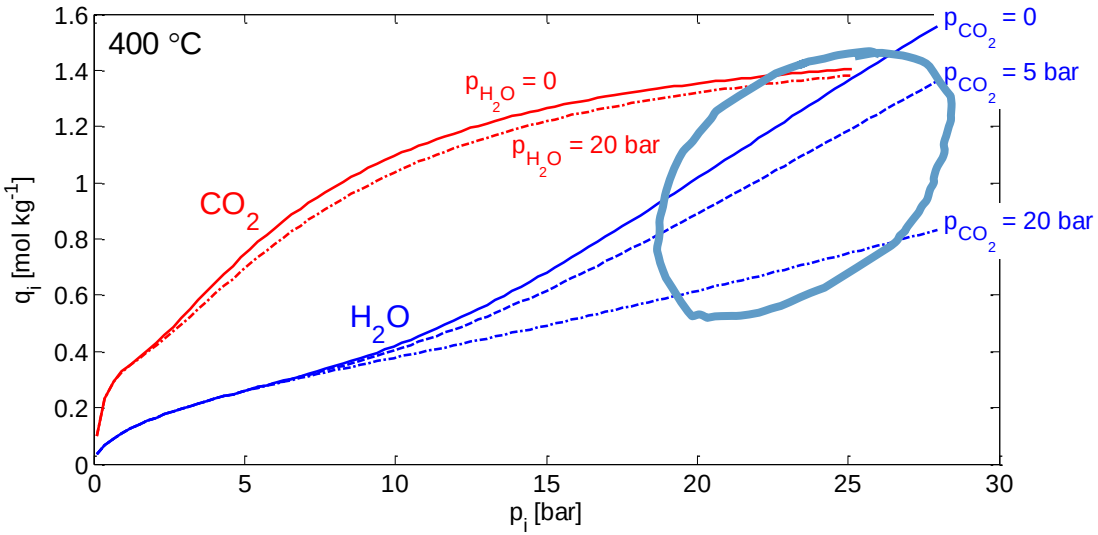
- Under reaction conditions: disordered mixed metal oxide
  - Adsorbs and releases CO_2, H_2O; catalytically active for WGS
  - Capacities around 1 mol/kg, for CO_2 **and H_2O**
  - Stable under high temperatures, high $p(H_2O)$

SEWGS: ISOTHERM



Boon et al. Chem Eng J 248 (2014) 406-414
Boon et al. Chem Eng Sci 122 (2015) 219-231
Boon et al. Adv Chem Eng 51 (2017) 207-260

SEWGS: ISOTHERM

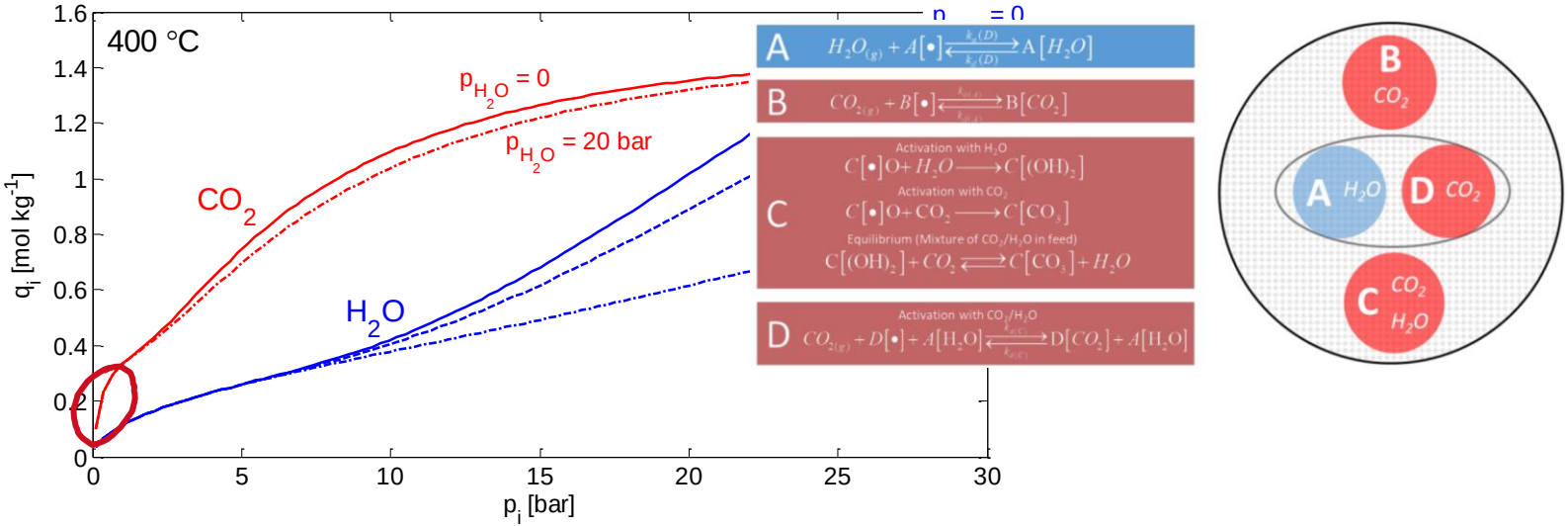


Adsorptive rinse
(high partial pressure steam)

→ enhanced efficiency

Boon et al. Chem Eng J 248 (2014) 406-414
Boon et al. Chem Eng Sci 122 (2015) 219-231
Boon et al. Adv Chem Eng 51 (2017) 207-260

SEWGS: ISOTHERM



Coenen et al. Chem Eng J 293 (2016) 9-23
Coenen et al. Chem Eng J 314 (2017) 554-569
Boon et al. Adv Chem Eng 51 (2017) 207-260

Multiple sites
including CO_2-H_2O exchange site

→ regeneration behaviour

SEWGS: PROCESS SCALE-UP

3.8 × 200 cm

3.8 × 600 cm

30 × 900 cm

TOWARDS CIRCULAR CARBON: SORPTION-ENHANCED DME SYNTHESIS – SEDMES

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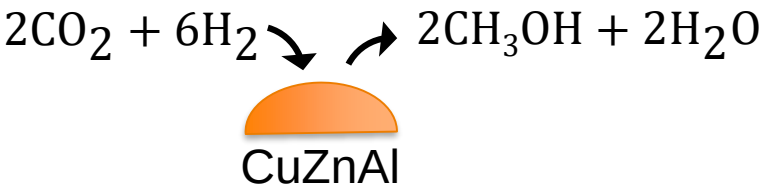
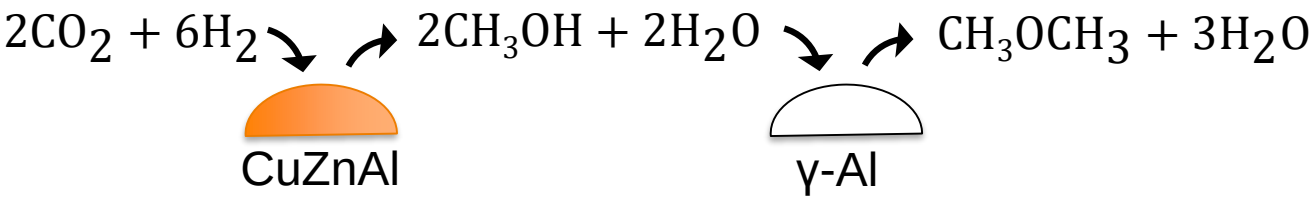
SEDMES: CATALYST AND ADSORBENT

- Catalyst



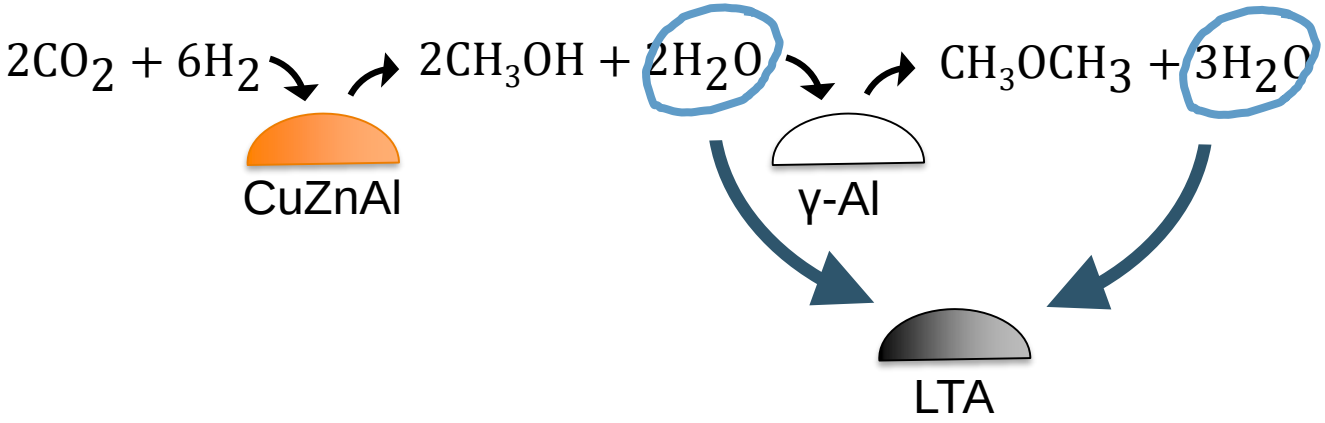
SEDMES: CATALYST AND ADSORBENT

- Catalyst

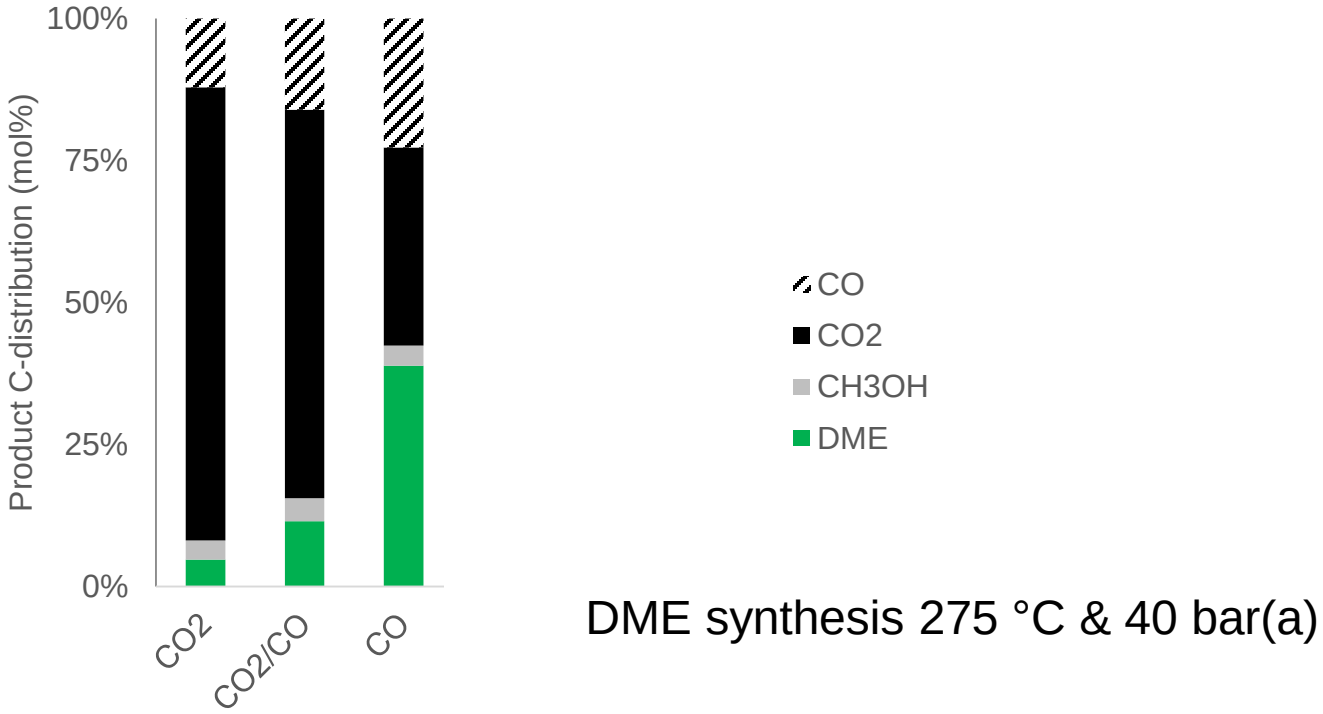


SEDMES: CATALYST AND ADSORBENT

- Catalyst
- Adsorbent

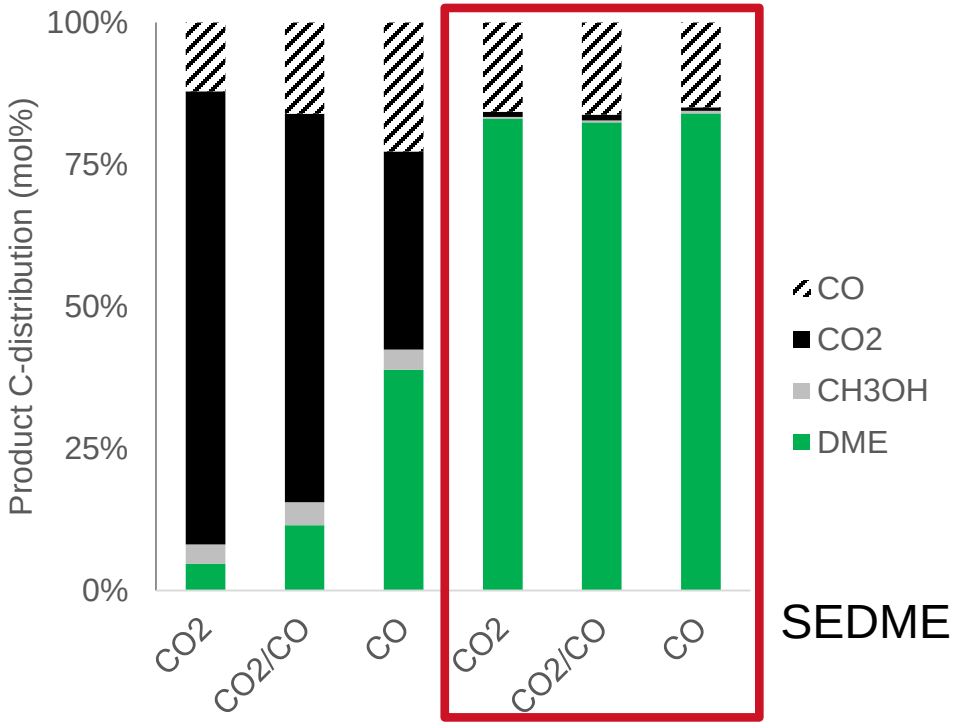


SEDMES: DME YIELD IMPROVEMENT



DME synthesis 275 °C & 40 bar(a)

SEDMES: DME YIELD IMPROVEMENT



SEDMES 275 °C & 40 bar(a)

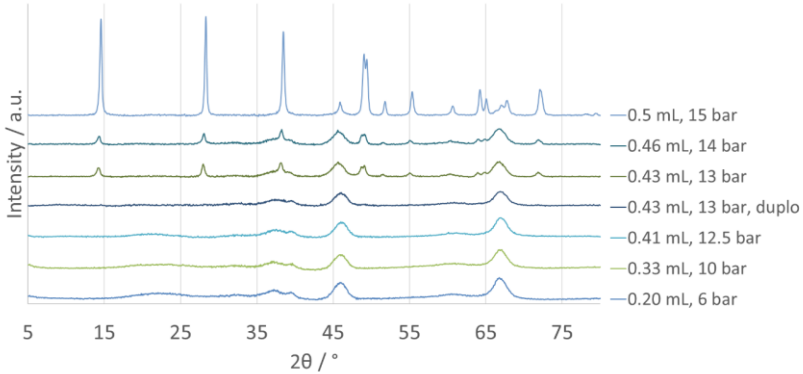
SEDMES: REGENERATION CONDITIONS

- TPSA regeneration (heating to 400 °C, depressurisation to 3 bar(a))
  - Improved water adsorption (lower water slip level)
  - Improved catalytic activity

- Separate tests water-induced deactivation of γ-alumina for methanol dehydration

SEDMES: REGENERATION CONDITIONS

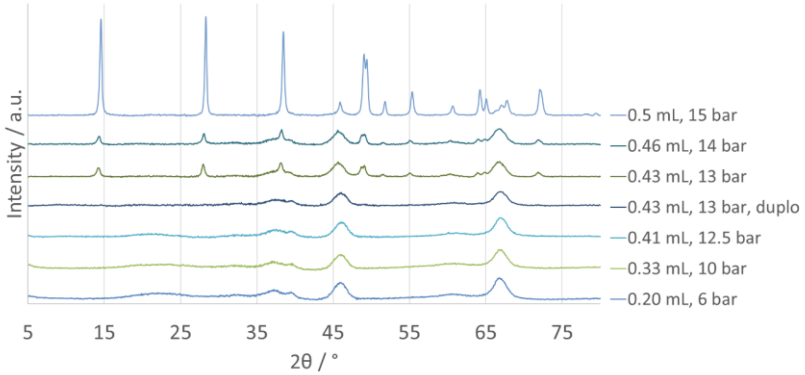
- Separate tests water-induced deactivation of γ-alumina for methanol dehydration

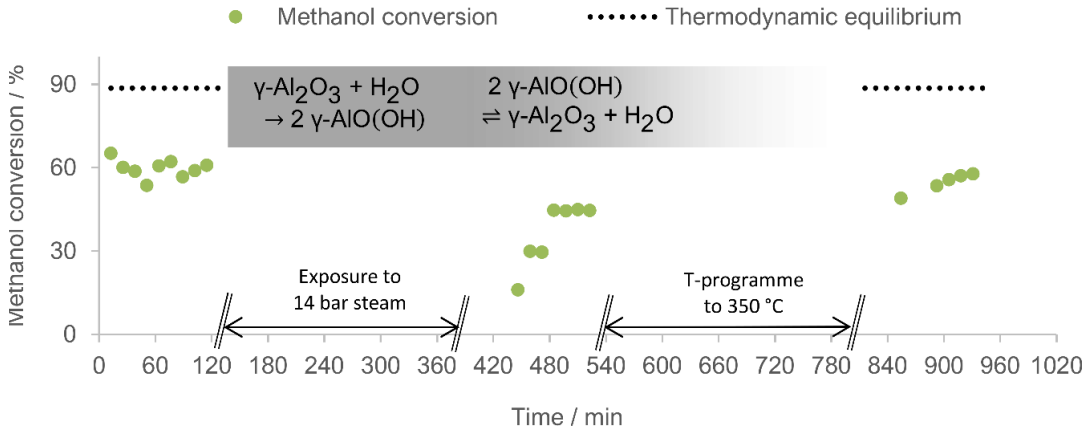


Boon et al. Cat Com 119 (2019) 22-27

SEDMES: REGENERATION CONDITIONS

- Separate tests water-induced deactivation of γ-alumina for methanol dehydration





- Reversible deactivation by γ-AlO(OH) formation

Boon et al. Cat Com 119 (2019) 22-27

SEDMES: PROCESS SCALE-UP

0.9 × 20 cm

3.8 × 200 cm

3.8 × 600 cm

THE SORBENT AND THE PROCESS
CO_2 and H_2O Sorption Enhancement

- Particle-scale phenomena for understanding sorption-enhanced processes

- SEWGS
  - Adsorptive rinse
  - CO_2-H_2O exchange site

- SEDMES
  - Adsorbent response to regeneration conditions
  - Catalyst response to regeneration conditions (reversible deactivation by H_2O)

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  Chemical Process Intensification
  Eindhoven, The Netherlands

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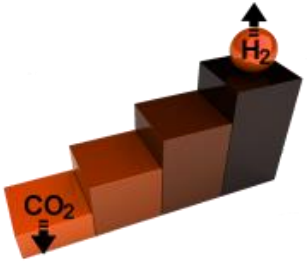

STEP WISE

a H2020 Project

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