Options for Separation Enhanced DME synthesis

TOWARDS CO_2 NEUTRAL INDUSTRY AND FUELS

Biomass

- Milena gasification technology → to be demonstrated in the Ambigo project
- Biorefinery concepts → mostly focused on seaweeds

Industrial Heat management

- Heat pump technology

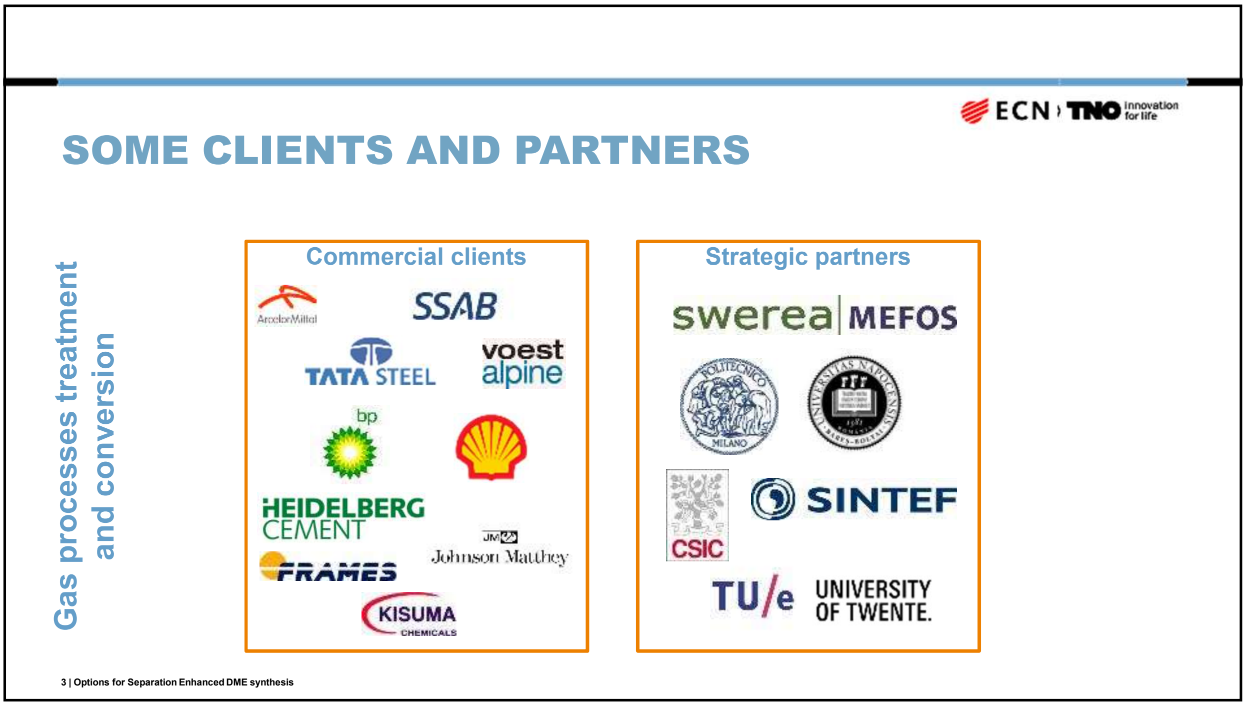
Electrification

- Electrolysis

Gas Processing, treatment and conversion

- CO_2 capture and conversion

Jaap Vente


SOME CLIENTS AND PARTNERS
Gas processes treatment and conversion
Commercial clients
ArcelorMittal
SSAB
TATA STEEL
voest alpine
bp
HEIDELBERG CEMENT
FRAMES
Johnson Matthey
KISUMA CHEMICALS
Strategic partners
swerea | MEFOS
CSIC
SINTEF
TU/e
UNIVERSITY OF TWENTE.
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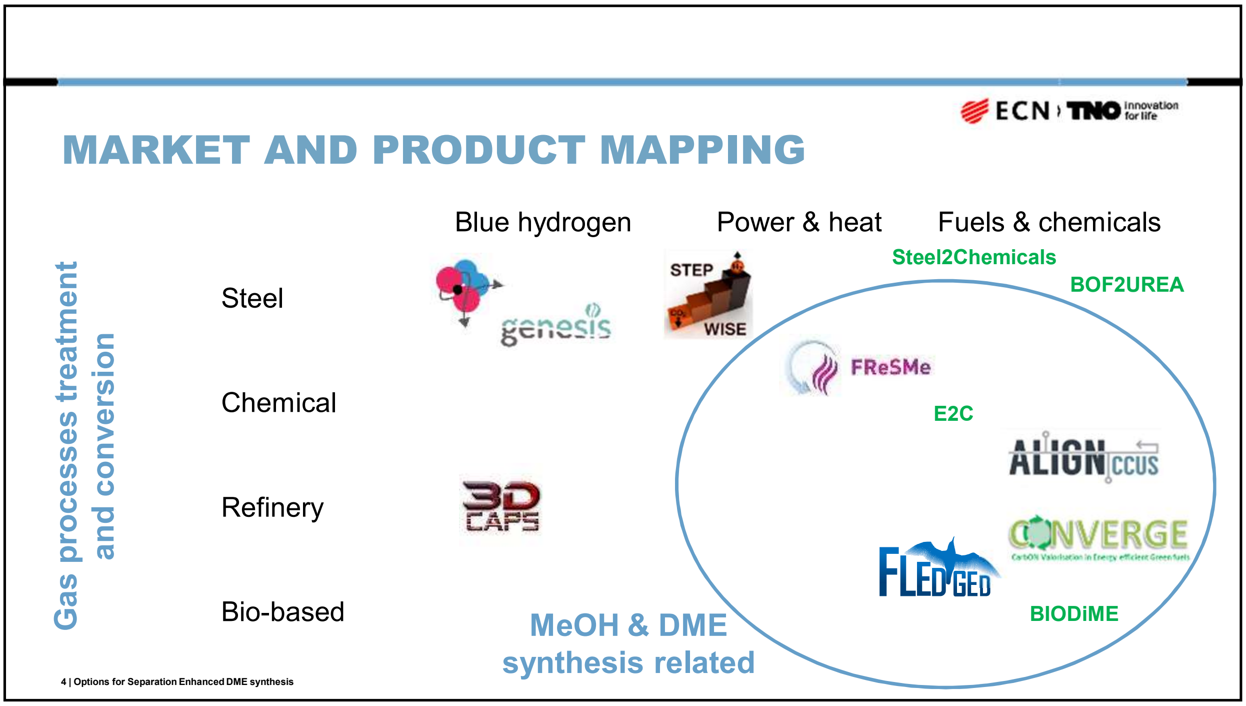
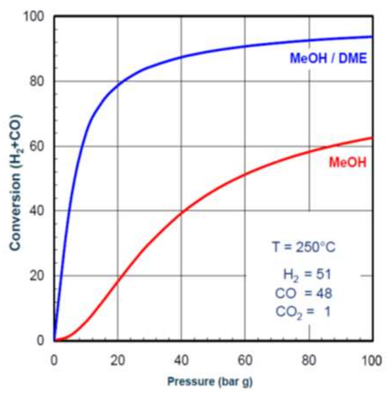

MARKET AND PRODUCT MAPPING
Gas processes treatment and conversion
Blue hydrogen
Power & heat
Fuels & chemicals
Steel
Chemical
Refinery
Bio-based
Steel2Chemicals
BOF2UREA
genesis
STEP
WISE
FReSMe
E2C
ALIGN CCUS
3D CAPS
CONVERGE
FLEDGED
BIODiME
MeOH & DME synthesis related
4 | Options for Separation Enhanced DME synthesis

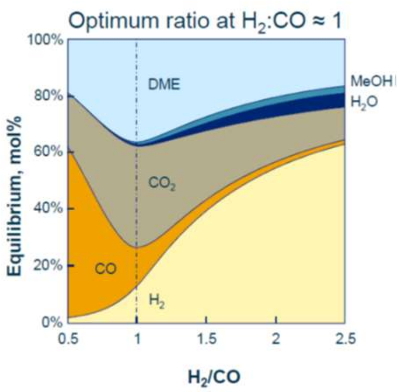
DME SYNTHESIS

- We know that:
  - DME is a wonderful fuel
  - DME is a great aerosol propellant

- But it is not a natural resource
- So how can it be synthesized in the most efficient way

THERMODYNAMICS DIRECT CONVERSION



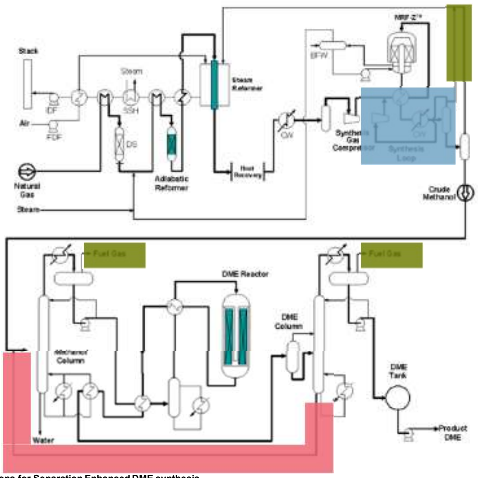


- Conversion from CO and H_2 is limited
- Excess oxygen can be bound to carbon and to hydrogen

$$3H_2 + 3CO \leftrightarrow C_2H_6O + CO_2$$
$$4H_2 + 2CO \leftrightarrow C_2H_6O + H_2O$$

E. Sorensen Haldor Topsoe, DME7

THERMODYNAMIC LIMITATIONS



- MeOH route
- Thermodynamic limitations result in:

Syngas recycle in methanol part

Methanol recycle in DME synthesis

Avoidable fuel gas production

CO_2 SENSITIVITY

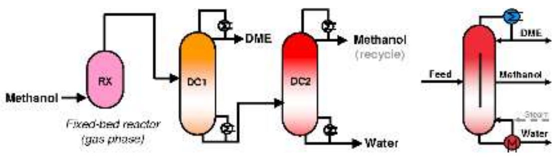
- Preparation for future applications
- Carbon efficiency is expected to become leading
- CO_2 conversion requires the formation of H_2O as the byproduct
- How to push the DME formation reaction to form H_2O
- Catalyst won’t help

Bill Clinton famously captured the essence of process intensification in 1992

SEPARATION ENHANCEMENT FOR MEOH / DME

- MeOH to DME

- Separation on boiling point
- Reactive distillation in a divided wall column



- H_2 for the reduction of CO_2 to CO (RWGS)
- Syngas conversion to MeOH
  or directly DME

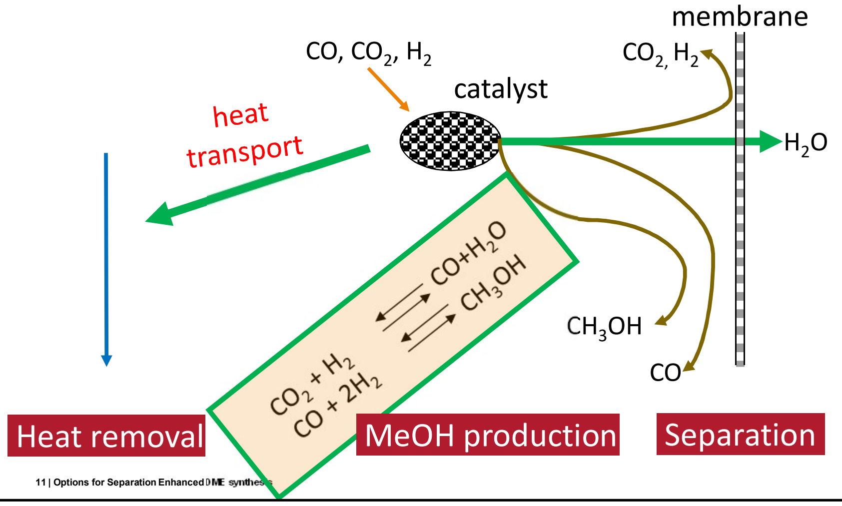
- Remove H_2O from reaction mixture
  Membranes or Sorbents

FOCUS

Kiss et. al. Chem. Eng. Trans,., 35, 91, 2013

MEMBRANE ASSISTED METHANOL SYNTHESIS

MEOH SYNTHESIS



Results obtained

- 50% increase of CO_2 conversion
- Resulting from a reduced P_{H2O}
- Even with low selectivities

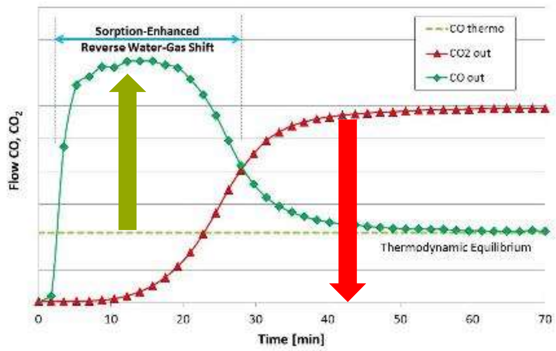
- Status:
  Scaling up to TRL5 in a gasified biomass setting

ALIGN CCUS

ECN › TNO innovation for life

REVERSE WATER-GAS SHIFT COMAX – PROOF-OF-PRINCIPLE

WGS cat + zeolite sorbent
Feed: 80% H_2, 20% CO_2, 1bar, 300°C



- Enhancement based on steam sorption
- Low P → high selectivity
- High P → Larger more complex hydrocarbons
- Status: development of catalysts with an increased selectivity at higher pressures

FLEDGED

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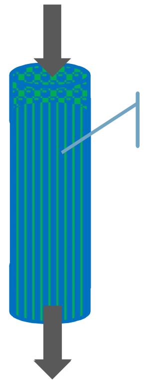
SORPTION ENHANCED DIRECT DME SYNTHESIS SEDMES

Feed gas for synthesis
CO / CO_2 / H_2



Cu/ZnO/Al_2O_3 catalyst

Reaction
275 °C
25 - 40 bar(a)

DME containing product gas,
plus CO / CO_2 / H_2 / H_2O / MeOH

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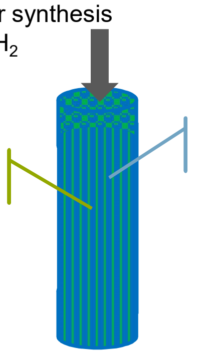
SORPTION ENHANCED DIRECT DME SYNTHESIS SEDMES

Feed gas for synthesis
CO / CO_2 / H_2

Zeolite LTA



Cu/ZnO/Al_2O_3 catalyst

regeneration
300 - 400 °C
3 bar(a)

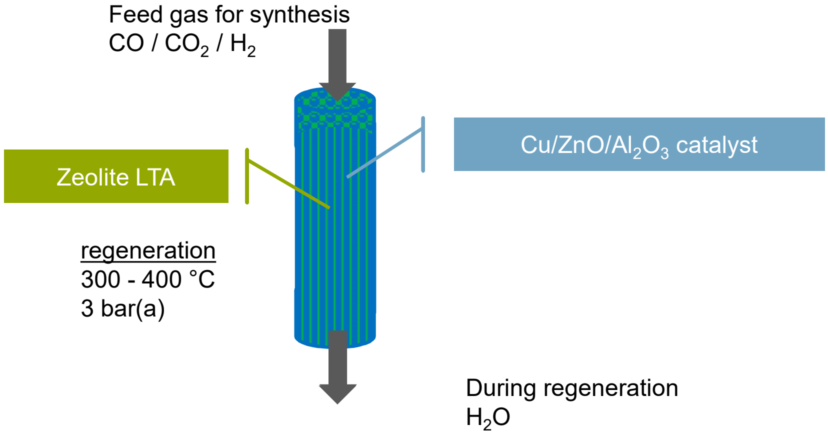
Reaction
275 °C
25 - 40 bar(a)

DME enriched product gas,
plus CO / ~~CO_2~~ / H_2 / ~~H_2O~~ / ~~MeOH~~

Jaap Vente

ECN TNO innovation for life

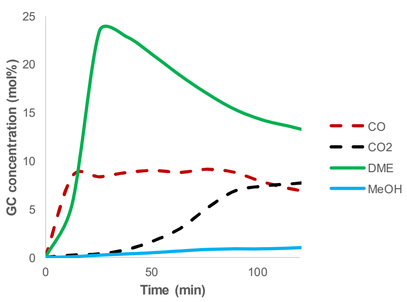
SORPTION ENHANCED DIRECT DME SYNTHESIS SEDMES



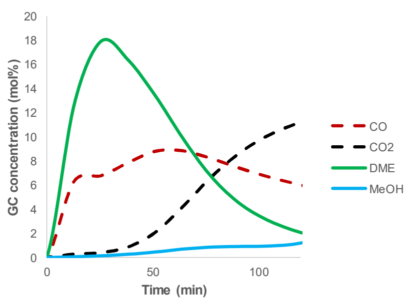
ECN TNO innovation for life

SEDMES FEED FLEXIBILITY (1)

- Stoichiometry factor $M = \frac{([H_2]-[CO_2])}{([CO]+[CO_2])} = 2$



H_2 / CO as feed

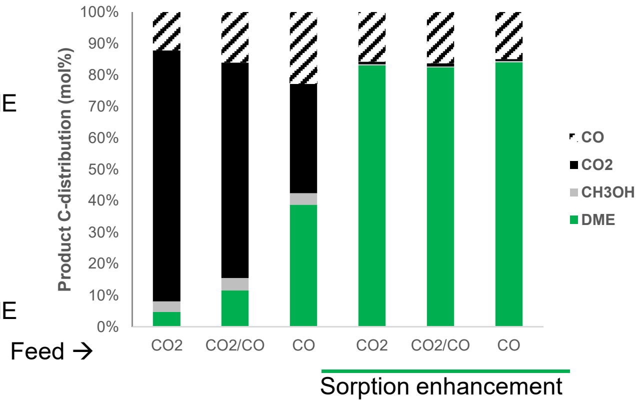


H_2 / CO_2 as feed

SEDMES
FEED FLEXIBILITY (2)

- Direct DME synthesis
- 275 °C & 40 bar(a)
- Thermodynamic equilibrium
- Carbon is found in CO / CO_2 / MeOH / DME

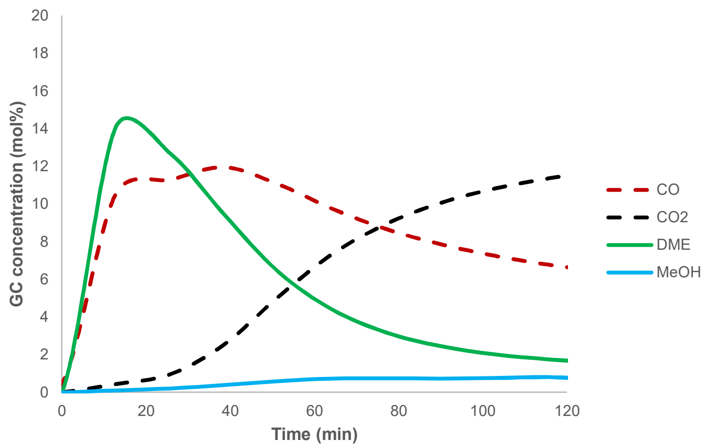
- Sorption-enhanced DME synthesis
- 275 °C & 40 bar(a)
- Experimental results
- Carbon is found in CO / ~~CO_2 / MeOH /~~ DME



PRESSURE

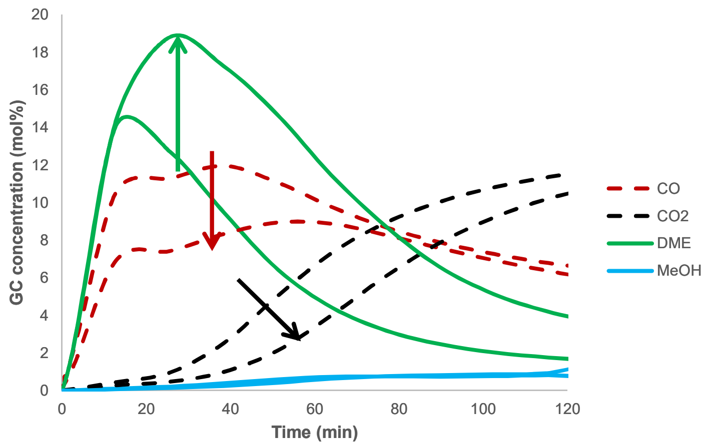
- Reactive adsorption at **25 bar(a)**

- CO_2:CO = 2:1
- $M = \frac{([H_2]-[CO_2])}{([CO]+[CO_2])} = 2$
- 275 °C



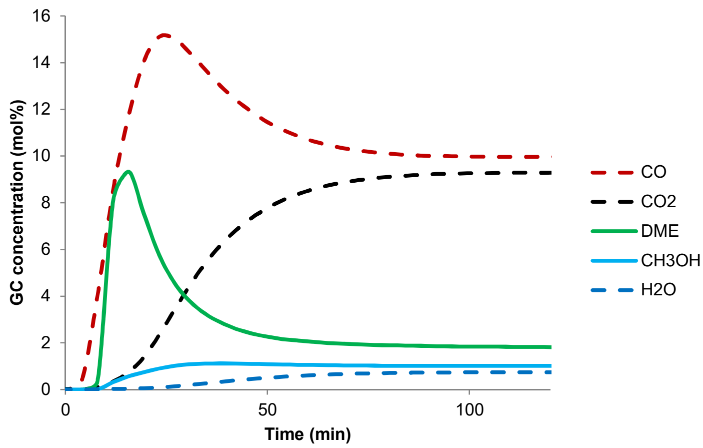
PRESSURE

- Reactive adsorption at **40 bar(a)**
- CO_2:CO = 2:1
- $M = \frac{([H_2]-[CO_2])}{([CO]+[CO_2])} = 2$
- 275 °C



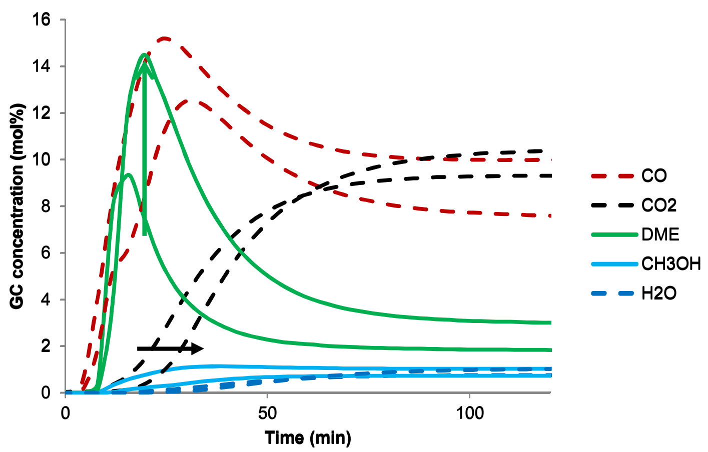
REGERATION CONDITIONS

- Catalyst & sorbent regeneration at **300 °C**
- CO_2:CO = 1:2
- $M = \frac{([H_2]-[CO_2])}{([CO]+[CO_2])} = 2$
- 275 °C & 25 bar(a)



REGERATION CONDITIONS

- Catalyst & sorbent regeneration at **400 °C**
- CO_2:CO = 1:2
- $M = \frac{([H_2]-[CO_2])}{([CO]+[CO_2])} = 2$
- 275 °C & 25 bar(a)



STATUS SEDMES

Achievement

- DME yield can be boosted dramatically
- CO_2 is not an inert but can be converted as well
- Regeneration is key maximum performance

Upcoming actions

- Heat management
- TRL5 testing in multicolumn set up

ACKNOWLEDGMENTS

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- The E2C project has received funding from the Interreg 2Seas program

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