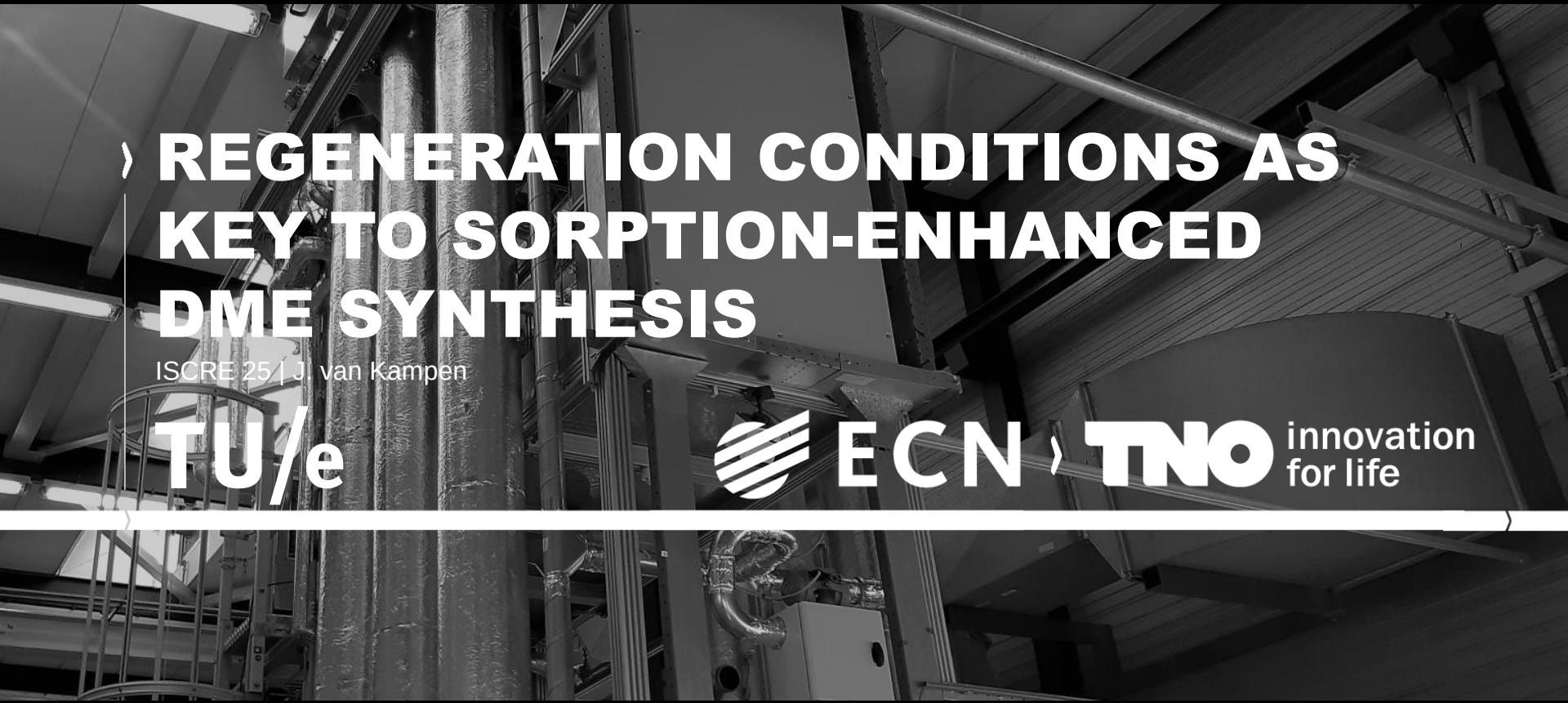

# REGENERATION CONDITIONS AS KEY TO SORPTION-ENHANCED DME SYNTHESIS

ISCRE 25 | J. van Kampen

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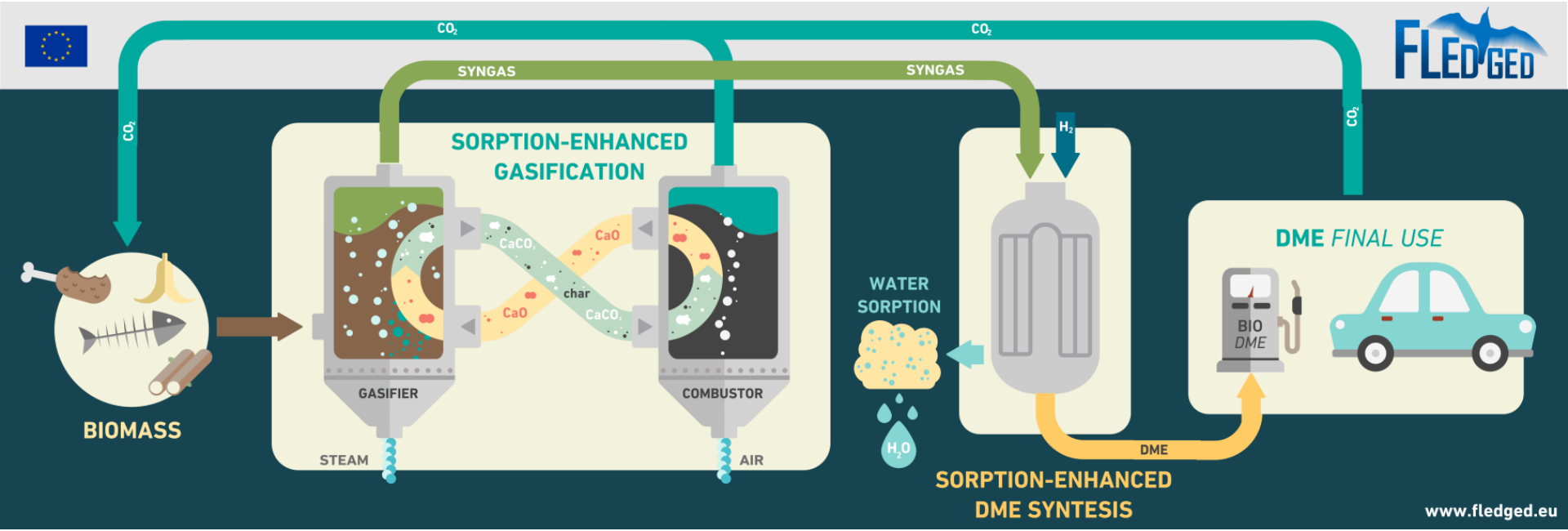
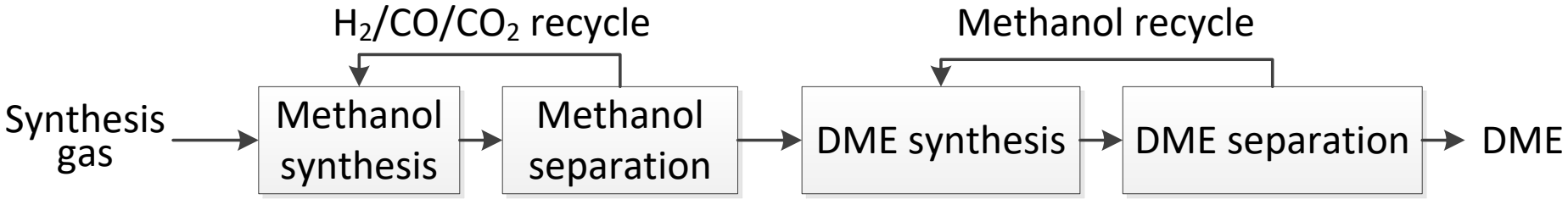

CO2
CO2
SYNGAS
SYNGAS
CO2
H2
FLEDGED
SORPTION-ENHANCED
GASIFICATION
CaCO3
CaO
char
CaO
CaCO3
BIOMASS
GASIFIER
COMBUSTOR
STEAM
AIR
WATER
SORPTION
H2O
DME FINAL USE
BIO
DME
DME
SORPTION-ENHANCED
DME SYNTESIS
www.fledged.eu

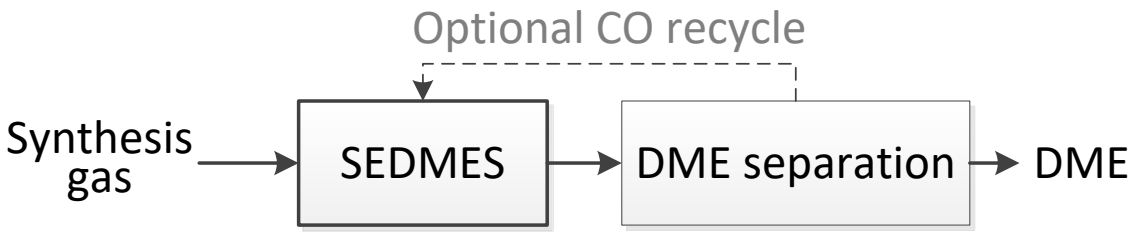
# CONVENTIONAL DME SYNTHESIS

- Methanol synthesis: $CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O$
- Methanol dehydration: $2\ CH_3OH \rightleftharpoons CH_3OCH_3 + H_2O$
- Reverse water-gas shift: $H_2 + CO_2 \rightleftharpoons CO + H_2O$

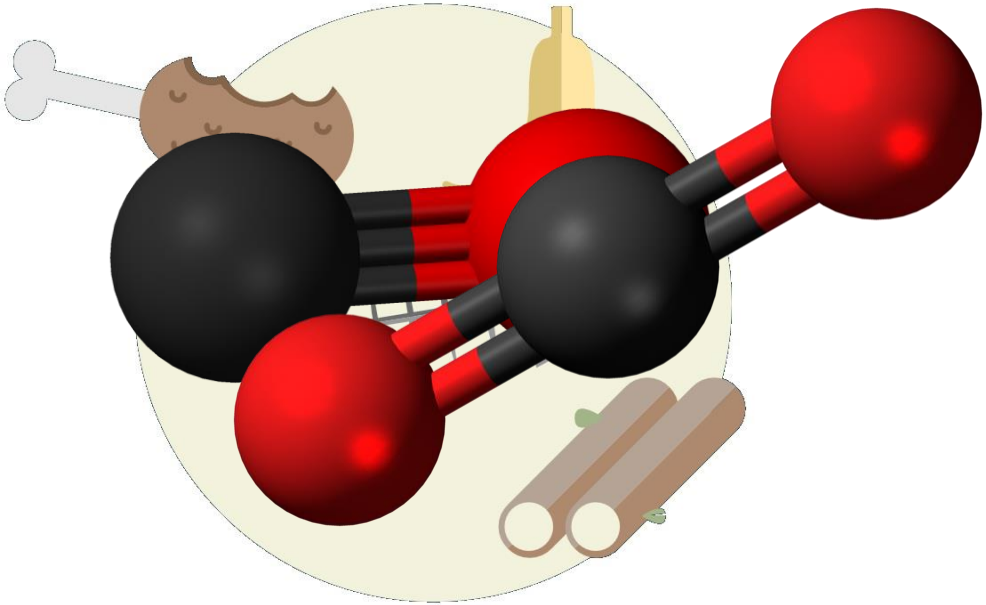


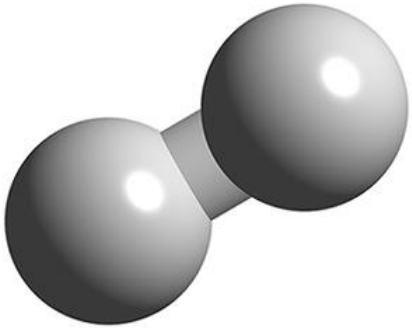
# SORPTION-ENHANCED DME SYNTHESIS (SEDMES)

- Direct DME: $2\,CO_2 + 6\,H_2 \rightarrow CH_3OCH_3 + 3\,H_2O$
- Direct DME: $2\,CO + 4\,H_2 \rightarrow CH_3OCH_3 + H_2O$
- Adsorption: $H_2O\,(g) \rightarrow H_2O\,(ads)$

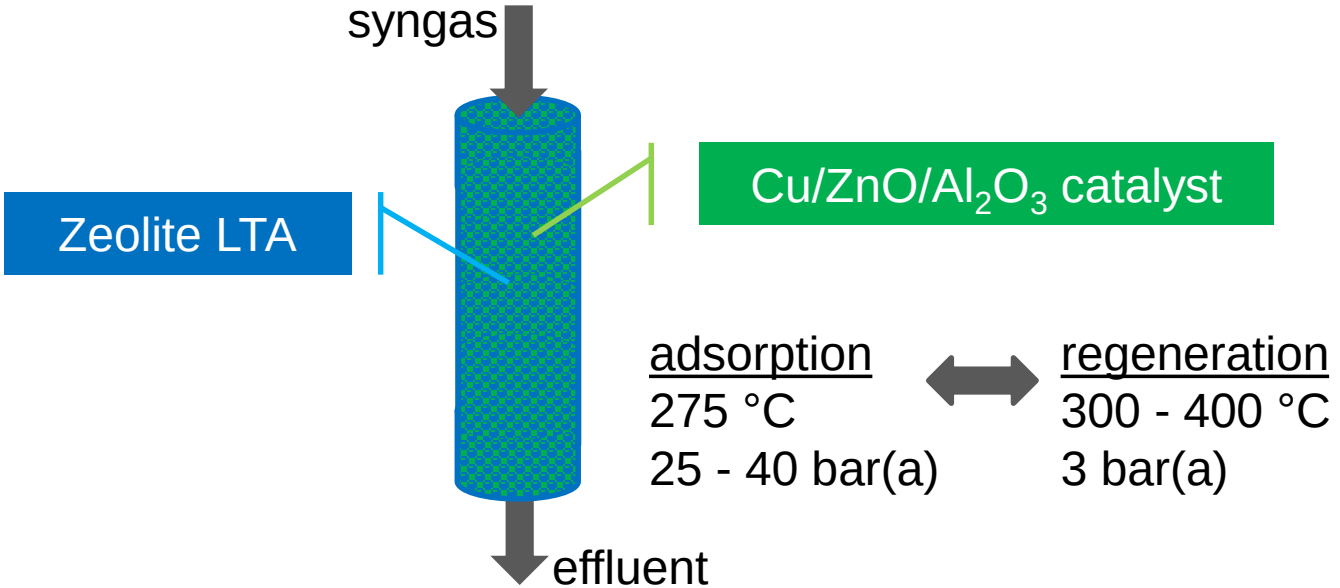


# FEED FLEXIBILITY

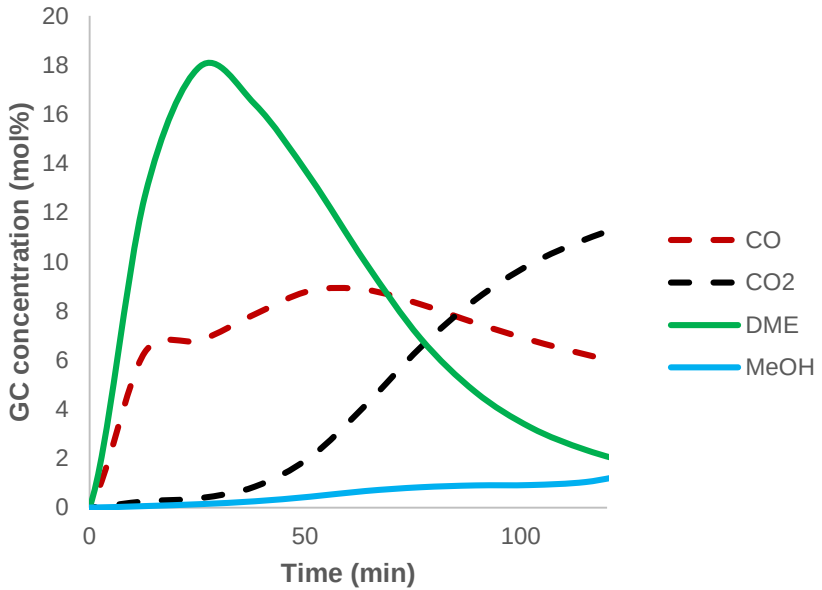




# EXPERIMENTAL: SEDMES

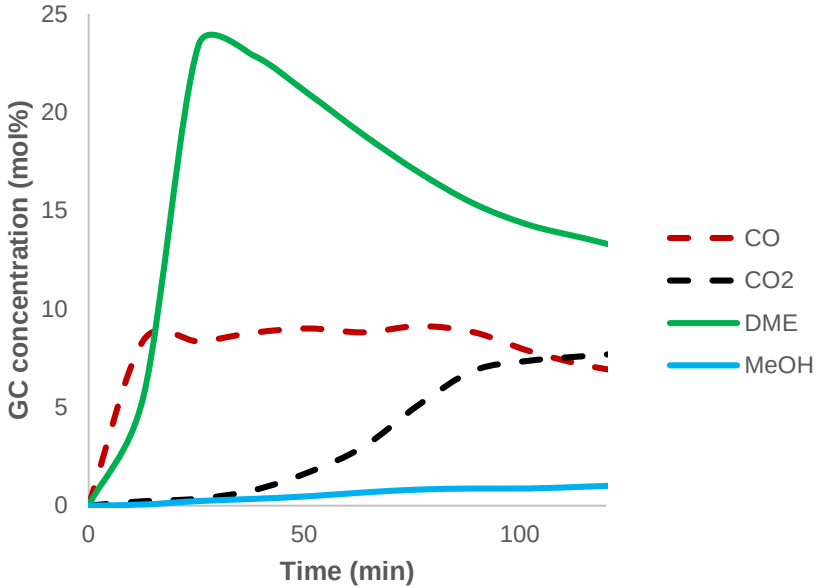


# FEED FLEXIBILITY




- $CO_2$ feed
- M = ($[H_2]$-$[CO_2]$)/($[CO]$+$[CO_2]$) = 2
- 275 °C & 40 bar(a)
- Regeneration 400 °C

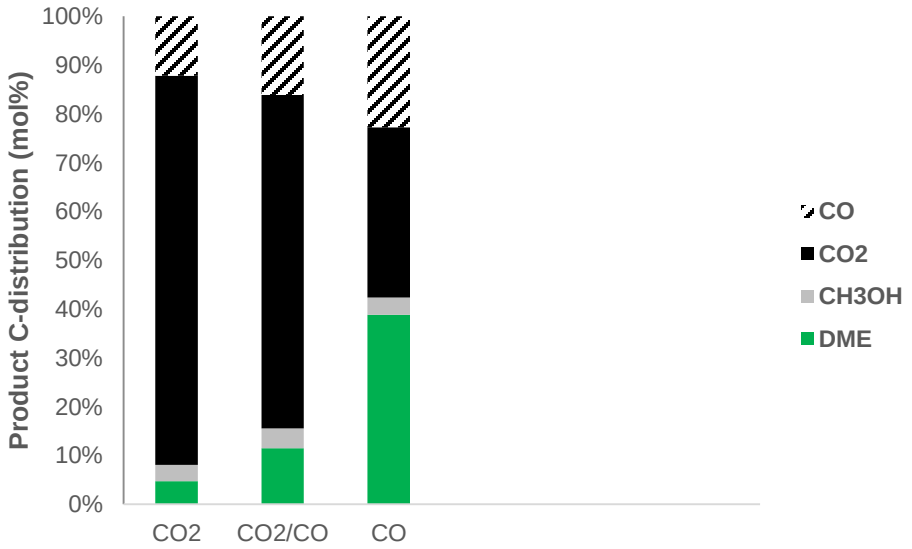
# FEED FLEXIBILITY




- CO feed
- M = ([$H_2$]-[$CO_2$])/([CO]+[$CO_2$]) = 2
- 275 °C & 40 bar(a)
- Regeneration 400 °C

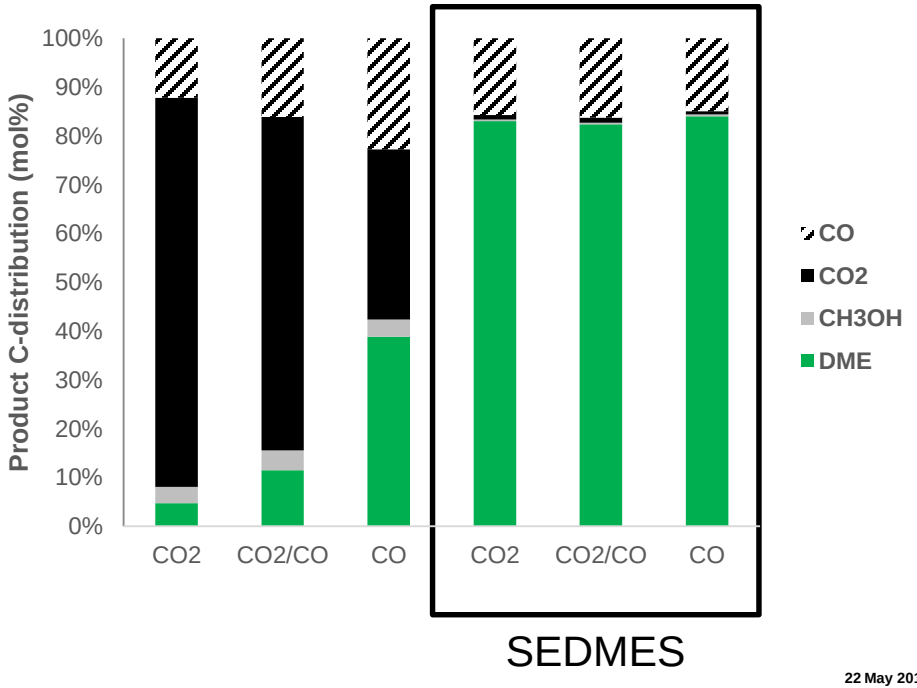
# FEED FLEXIBILITY

- Direct DME synthesis
- 275 °C & 40 bar(a)
- Thermodynamic equilibrium



# FEED FLEXIBILITY

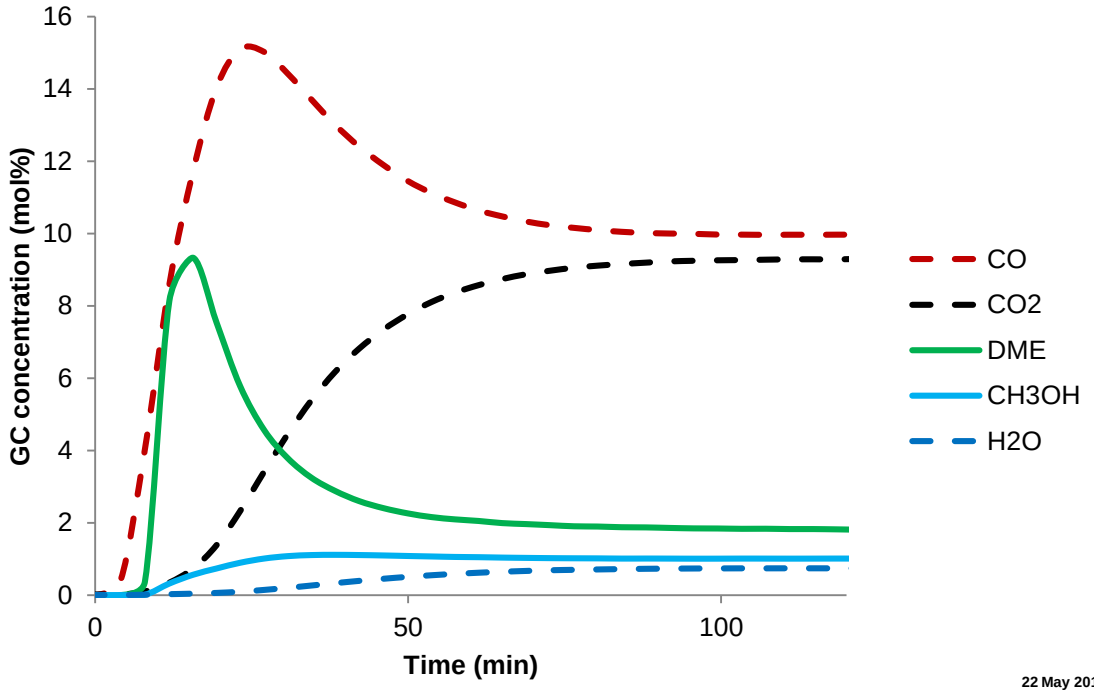
- Sorption-enhanced DME synthesis
- 275 °C & 40 bar(a)
- Experimental results



# REGENERATION CONDITIONS

- Catalyst & sorbent regeneration at **300 °C**

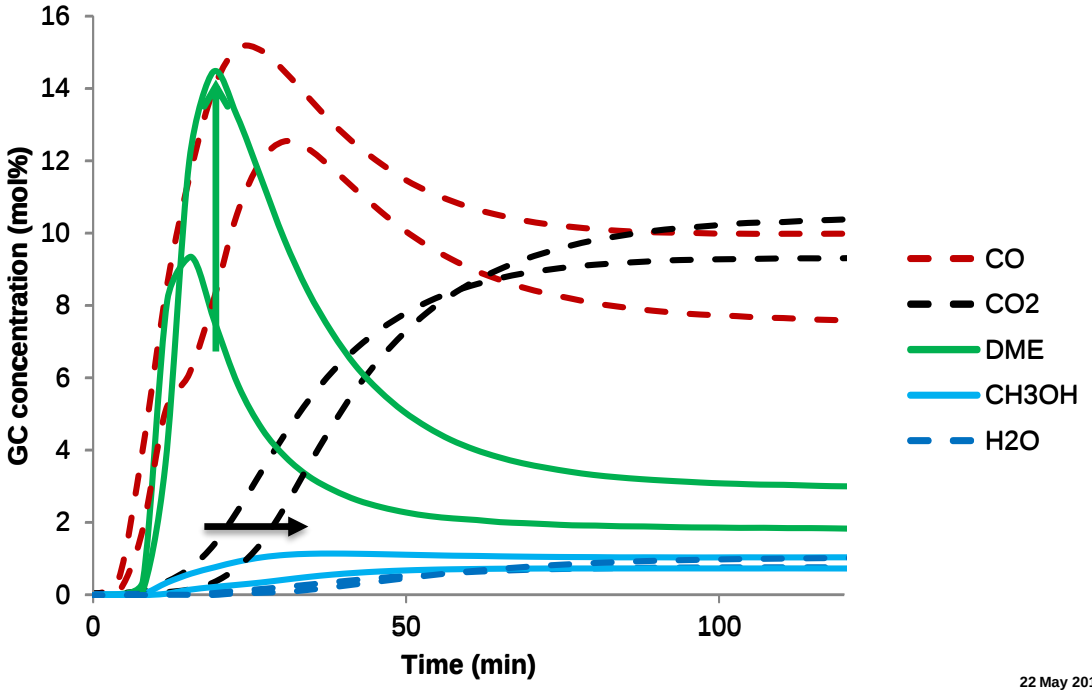
- $CO_2$:CO = 1:2
- M = ([$H_2$]-[$CO_2$])/([CO]+[$CO_2$]) = 2
- 275 °C & 25 bar(a)



# REGENERATION CONDITIONS

- Catalyst & sorbent regeneration at **400 °C**

- $CO_2$:CO = 1:2
- M = ([$H_2$]-[$CO_2$])/([CO]+[$CO_2$]) = 2
- 275 °C & 25 bar(a)



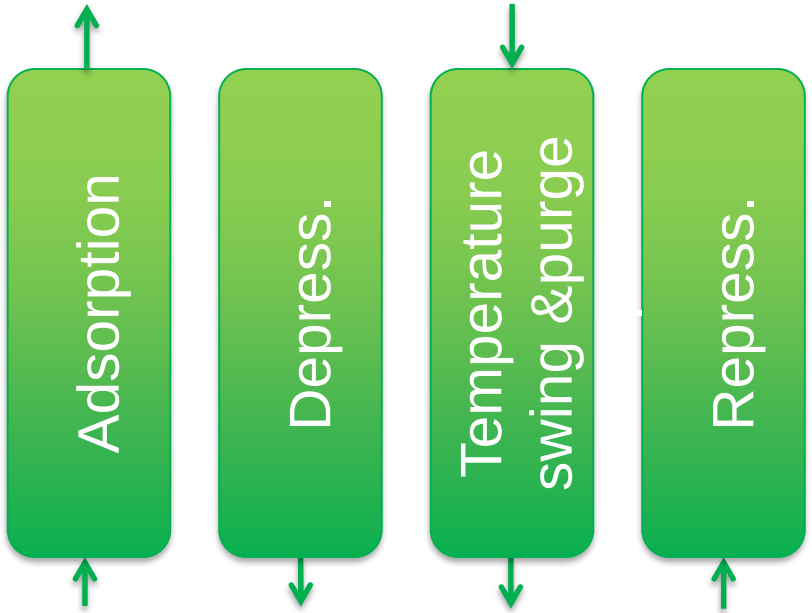
# SUB CONCLUSION

- Regeneration
  - Temperature swing required
  1. Increased adsorption capacity
  2. Increased steady state DME yield

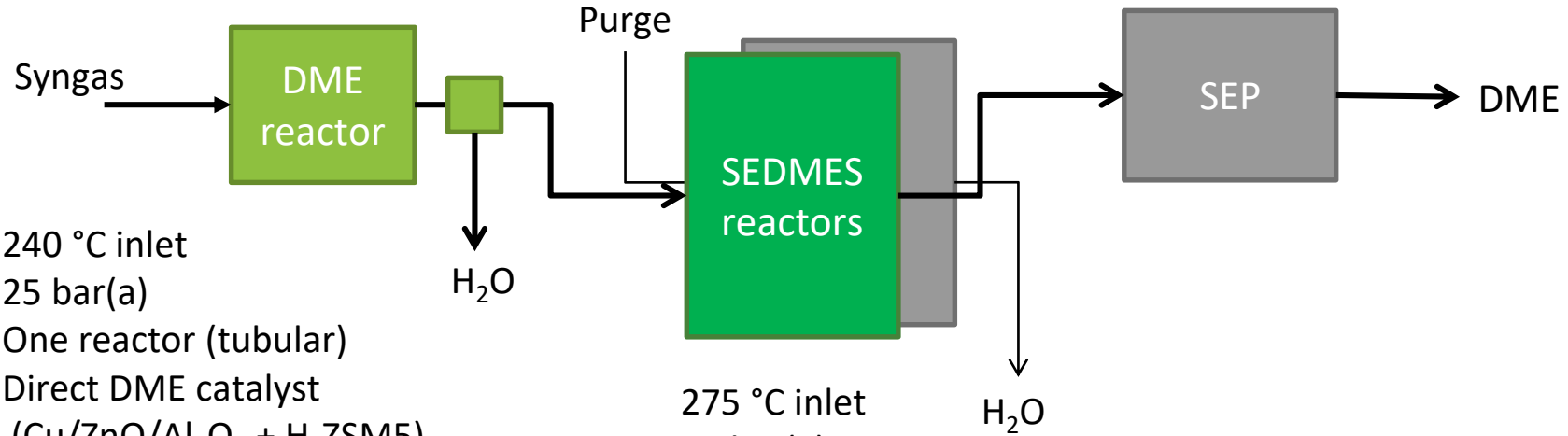
# SEDMES TPSA CYCLE

- Example: 4-step TPSA cycle design

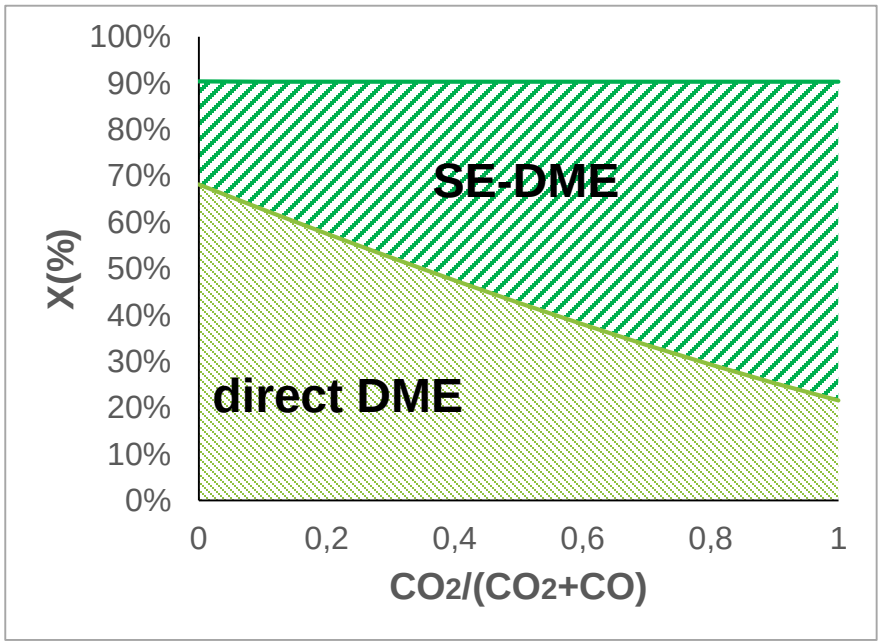
1. Adsorption
2. Depressurisation (blowdown)
3. Temperature swing & purge
4. Repressurisation



# PROCESS CONSIDERATIONS



# PROCESS CONSIDERATIONS




- 90% overall DME yield
- → ~90% overall conversion

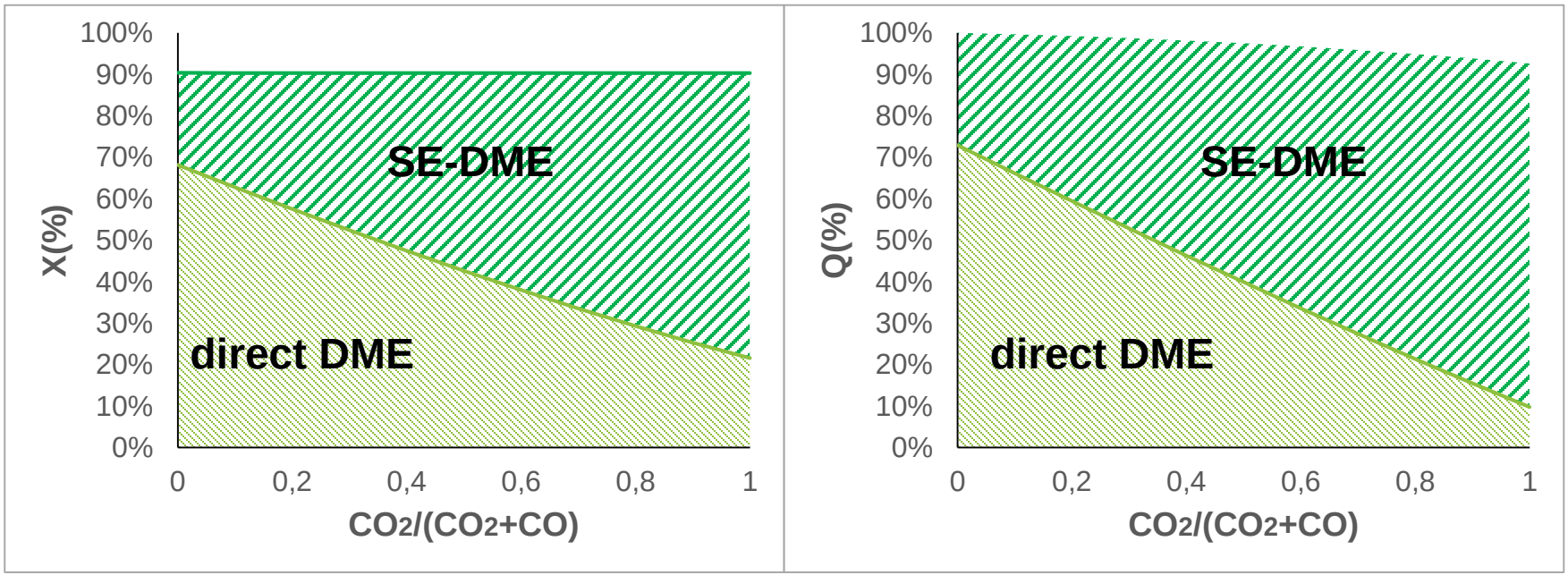
# SORPTION-ENHANCED DME SYNTHESIS (SEDMES)

- Direct DME: $2\,CO_2 + 6\,H_2 \rightarrow CH_3OCH_3 + 3\,H_2O$
- Direct DME: $2CO + 4\,H_2 \rightarrow CH_3OCH_3 + H_2O$
- Adsorption: $H_2O\ (g) \rightarrow H_2O\ (ads)$

# SORPTION-ENHANCED DME SYNTHESIS (SEDMES)

- Direct DME: $2\,CO_2 + 6\,H_2 \rightarrow CH_3OCH_3 + 3\,H_2O$ -122 kJ/mol
- Direct DME: $2\,CO + 4\,H_2 \rightarrow CH_3OCH_3 + H_2O$ -204 kJ/mol
- Adsorption: $H_2O\,(g) \rightarrow H_2O\,(ads)$ -45 kJ/mol

# PROCESS CONSIDERATIONS



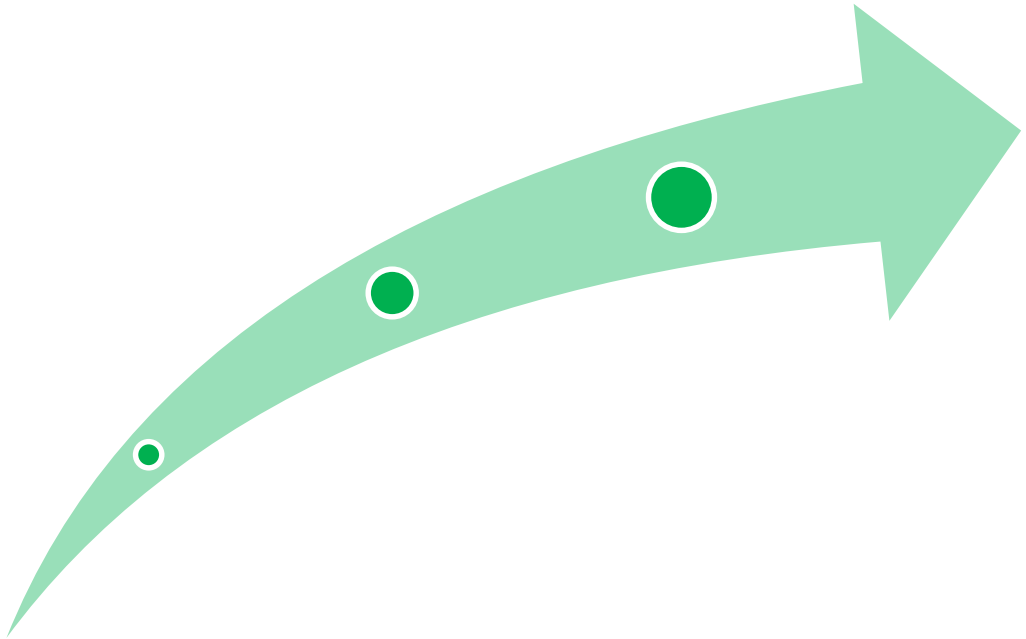
# CONCLUSION

- Sorption-enhanced DME synthesis (SEDMES):
  - Proof-of-concept
  - High DME yield pre steam breakthrough
  - Feed flexibility → $CO_2$ utilisation
  - Temperature swing regeneration to 400 °C
    - Improves DME yield pre and post steam breakthrough
    - Adsorbent capacity increases

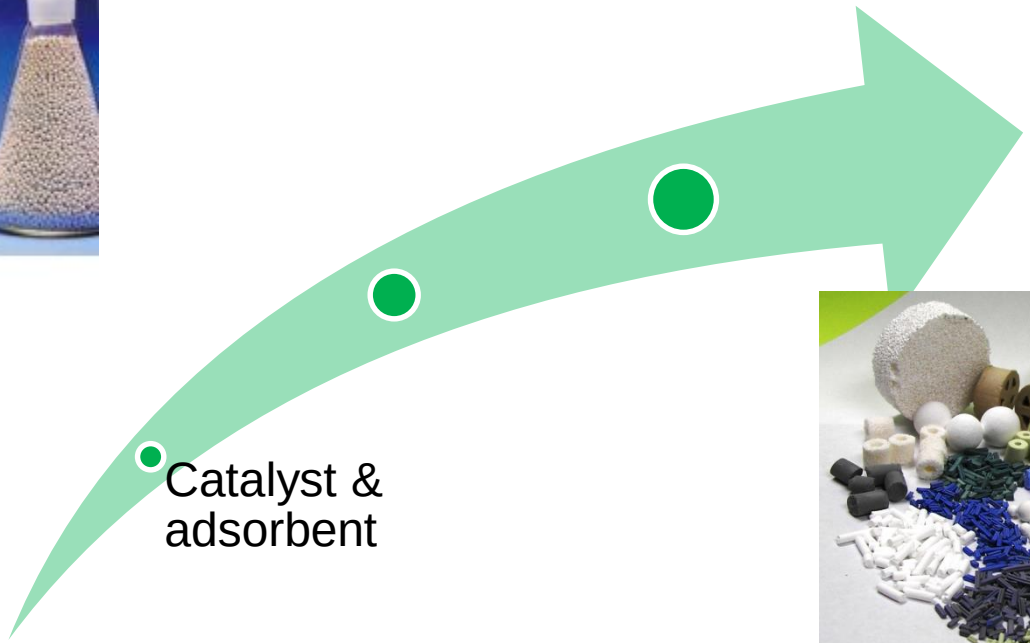
# OUTLOOK

- Sorption-enhanced DME synthesis (SEDMES):
  - Regeneration
    - TSA vs PSA
  - Heat management
    - Heat mitigation to direct DME reactor
    - Adiabatic or non-adiabatic operation
    - Integration of temperature swing regeneration

# OUTLOOK



# OUTLOOK




# OUTLOOK



Catalyst & adsorbent

Small scale reactor

# OUTLOOK



Pilot scale production: 3 kg /hr

Small scale reactor

Catalyst & adsorbent

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# FLEDGED

*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727600.*

# THANK YOU FOR YOUR ATTENTION

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