ENHANCED CONVERSION OF CO_2 FROM BIOGAS TO DIMETHYL ETHER BY IN-SITU WATER REMOVAL

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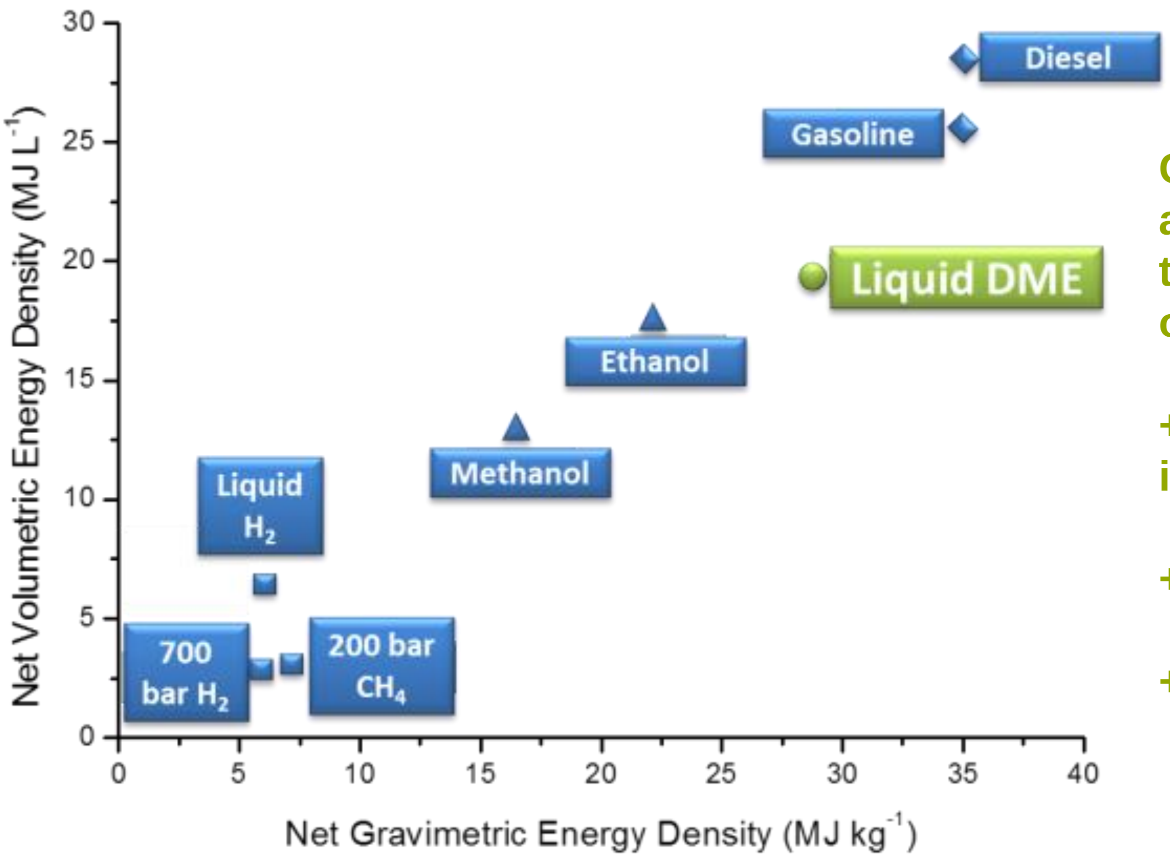
RATIONAL: WHY BIO-DME?



Concept: Instead of biomethane as a product stream, convert the biogas to green methanol or dimethylether.

+ Independence from gas infrastructure.

+ Larger potential for transport

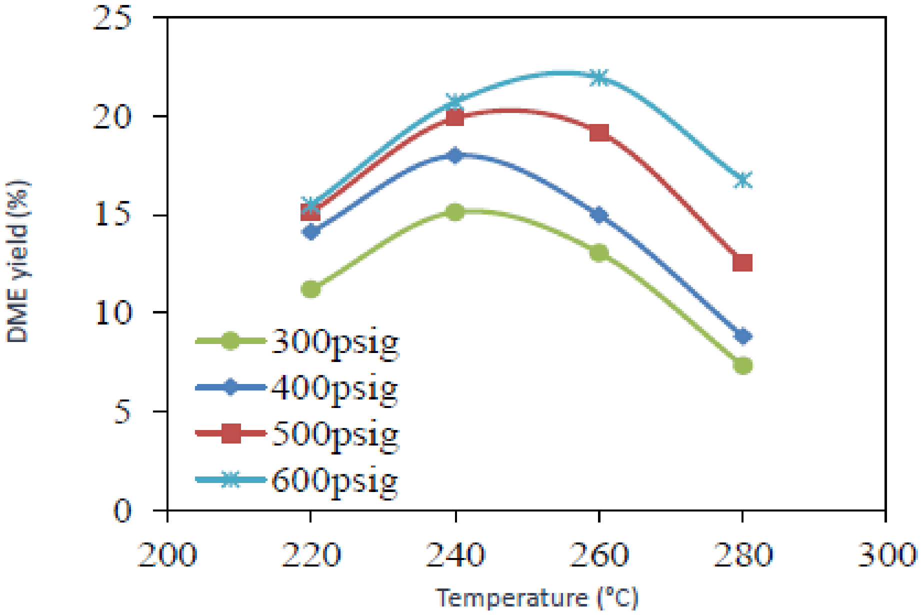
+ Higher product value

DME PRODUCTION

(1) $CO_2 + 3\ H_2 = CH_3OH + H_2O$
(2) $2\ CH_3OH = CH_3OCH_3 + H_2O$

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

Typical conversion conditions:
T ~ 250 C, P ~ 50 bar



- Effect of pressure
- Trade-off between kinetics and thermodynamics

DME PRODUCTION

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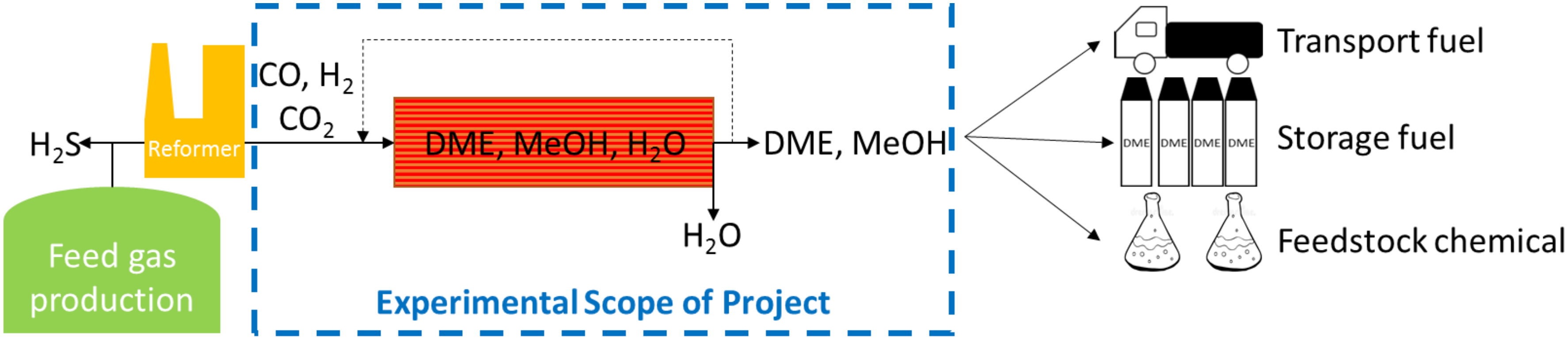
Typical conversion conditions:
T ~ 250 C, P ~ 50 bar

- Shift equilibrium towards DME (Le Chatelier principle):
  - High pressure
  - Water removal

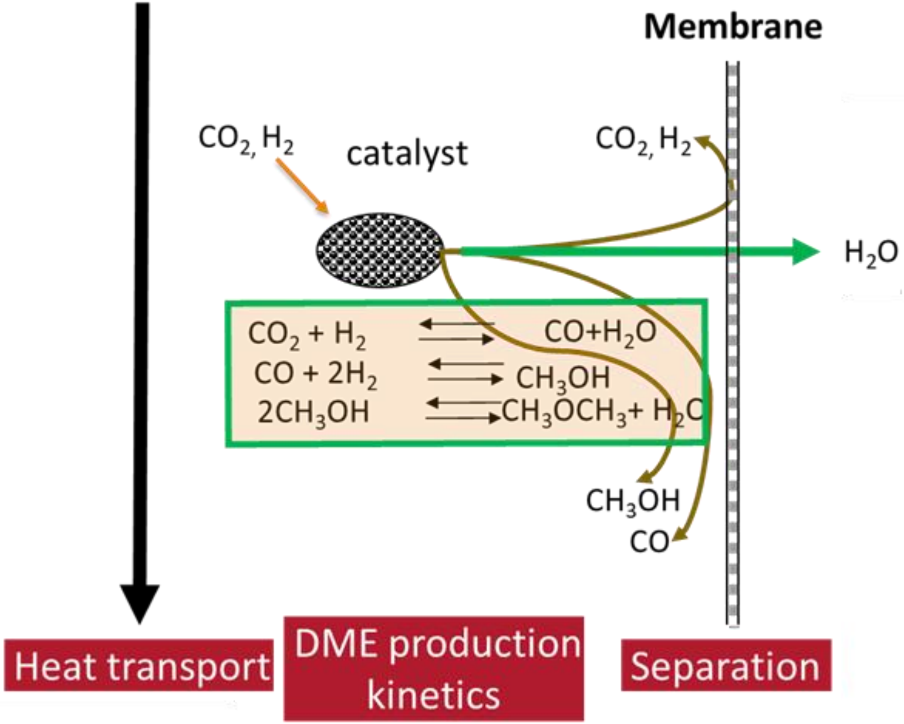
Ref: GTI's ARPA-E REFUEL Project

IN-SITU CONVERSION FOR ENHANCED DME PRODUCTION



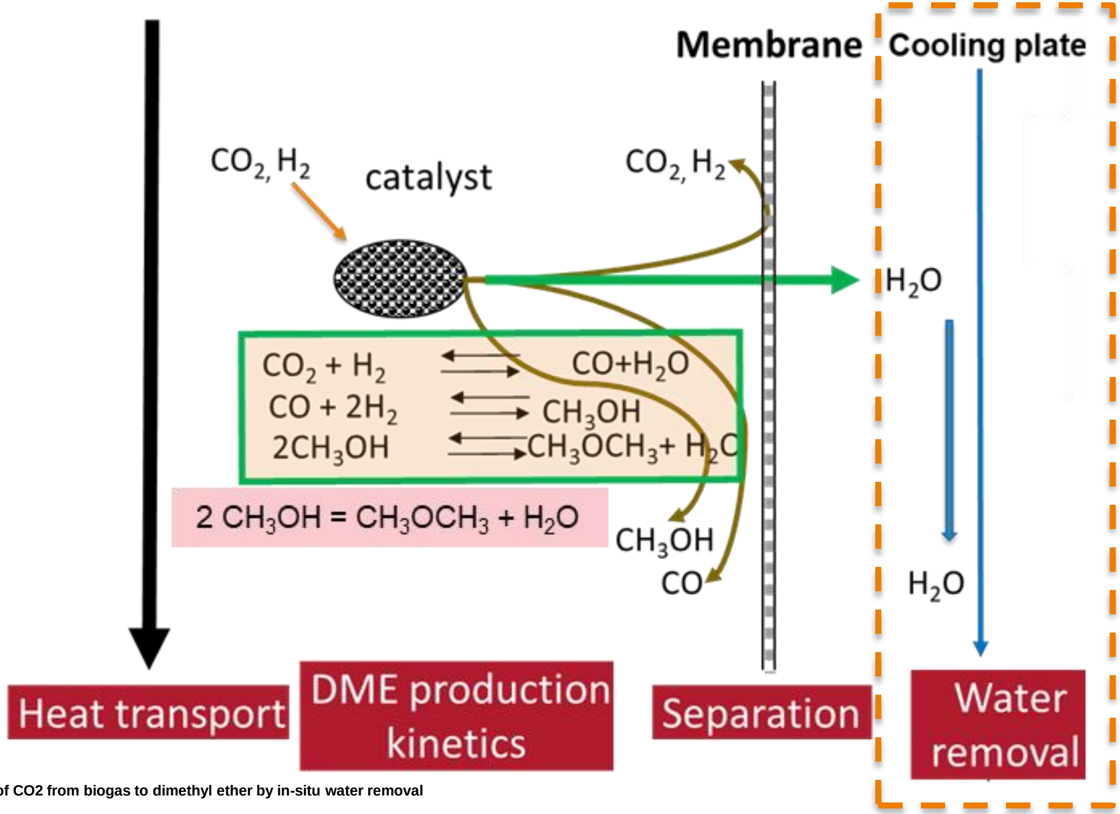
New process concept to produce DME from CO_2 rich gasses such as biogas

ON-GOING WORK ON METHANOL PRODUCTION

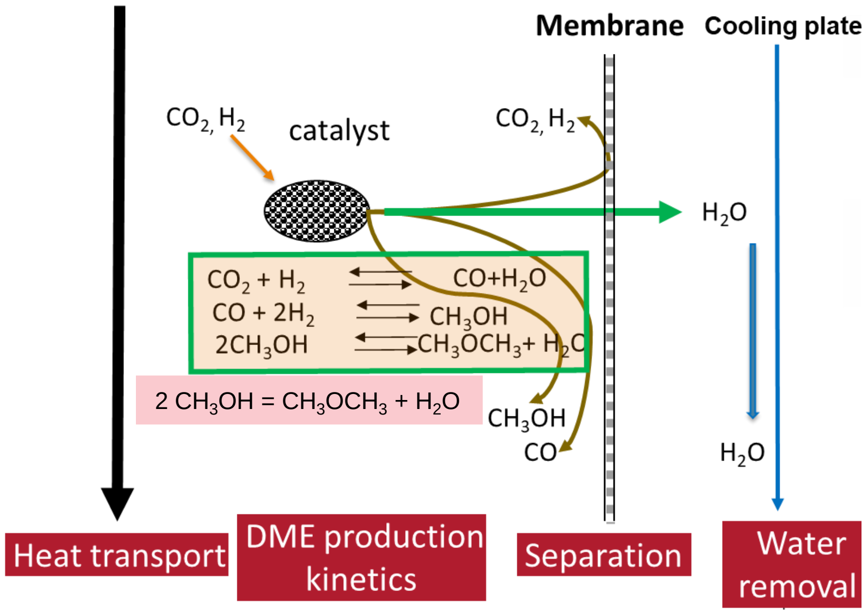


+ 50% CO_2 conversion

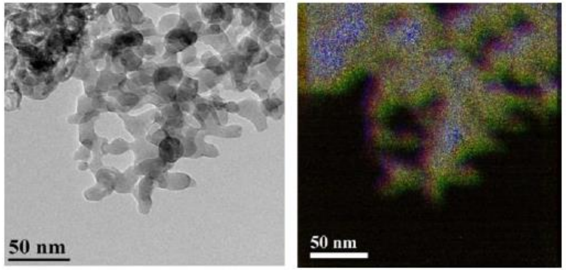
REACTOR CONCEPT



REACTOR CONCEPT



Existing bi-functional catalysts for DME production



Colors represent:
Cu - yellow
Zn - blue
Al - green
O - red

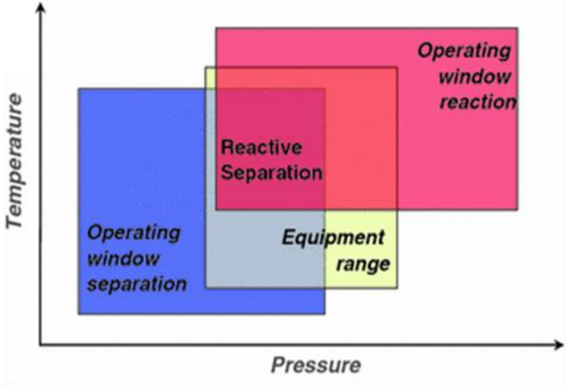
Catalyst Properties

- Methanol synthesis: $CuO/ZnO/Al_2O_3$
- DME synthesis: H-ZSM-5
- BET surface area 132 m^2/g
- Particle size 10-30 nm

Ref: GTI's ARPA-E REFUEL Project

REACTOR CONCEPT

› Choice of system conditions (P, T) is dependent on a several competing factors



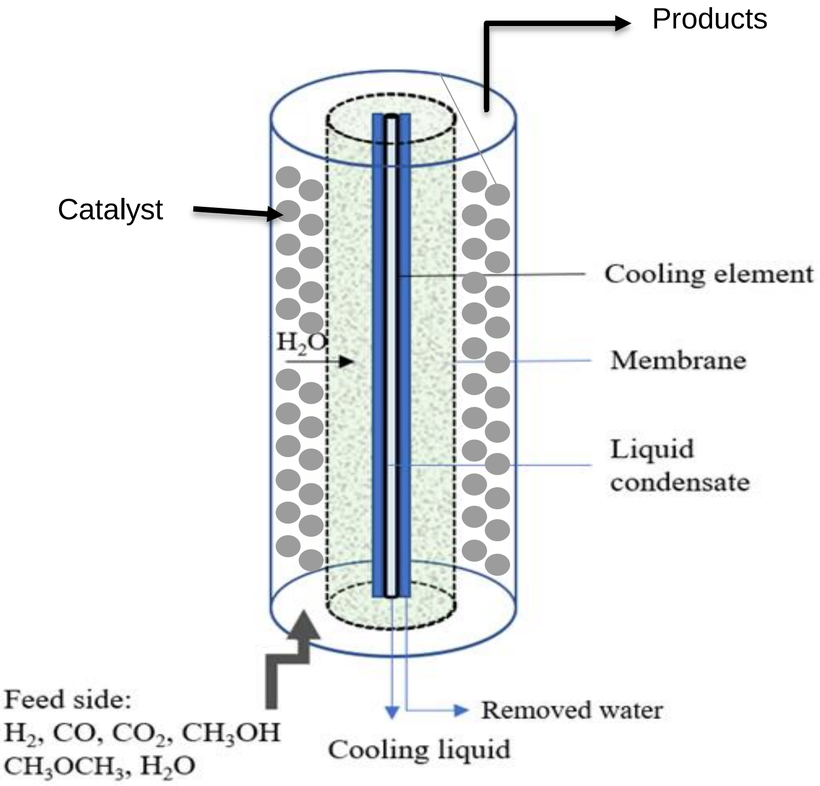
System design: T,P

Membrane selection

Transport (Heat and Mass)

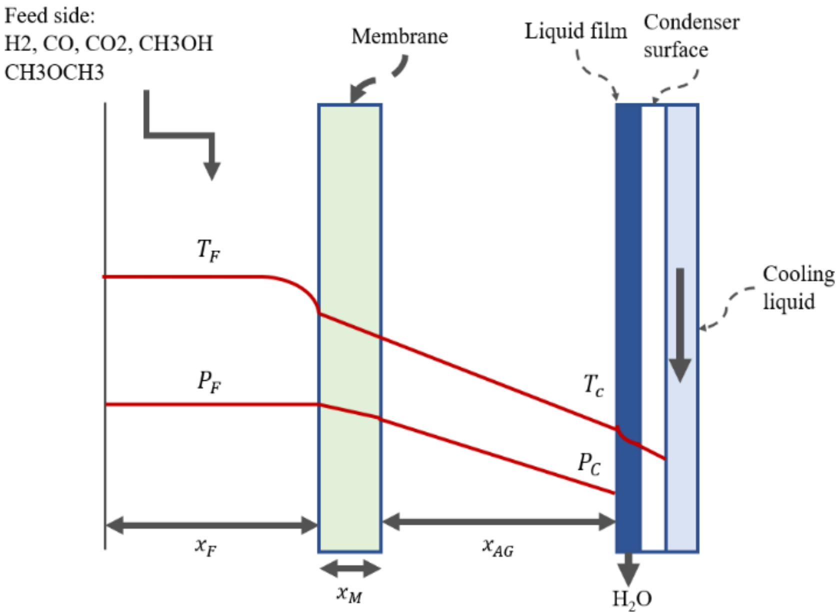
Reaction kinetics

REACTOR CONCEPT



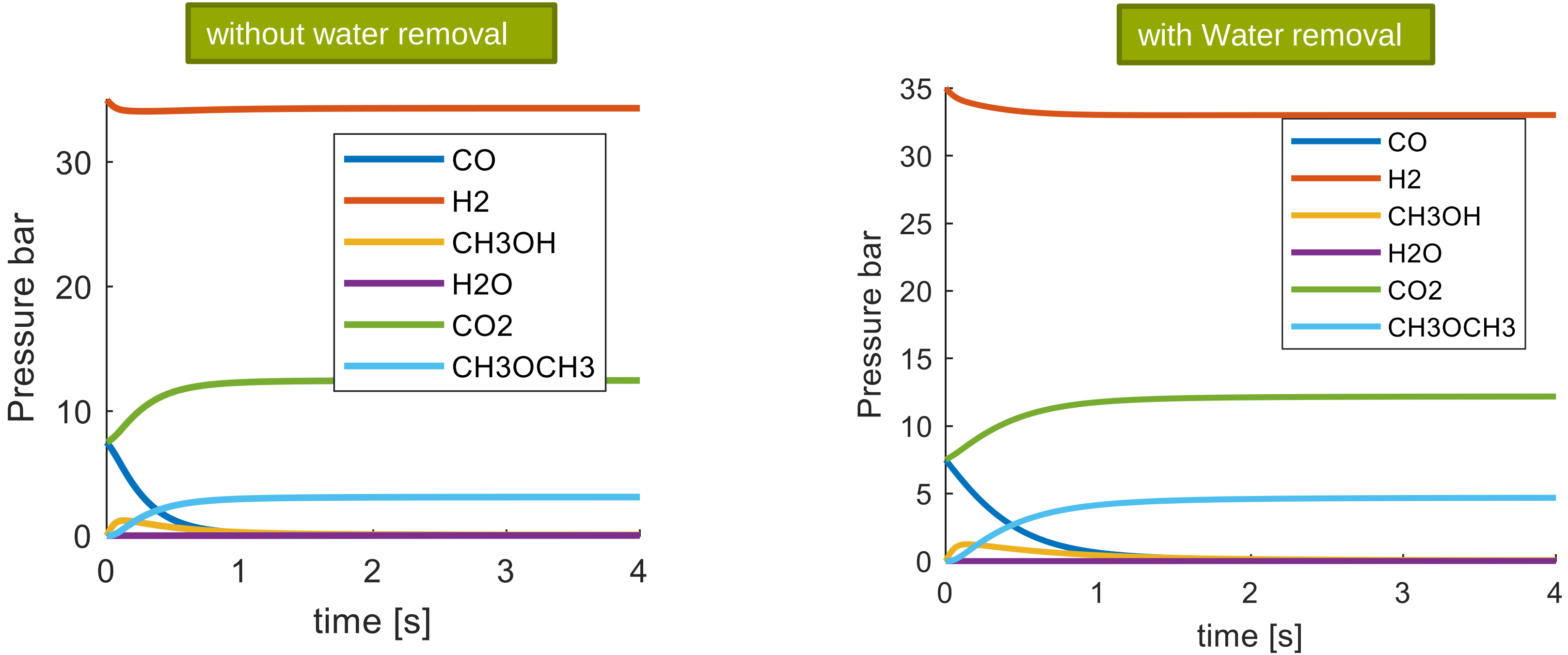
REACTOR MODEL DESCRIPTION

Mass transfer model

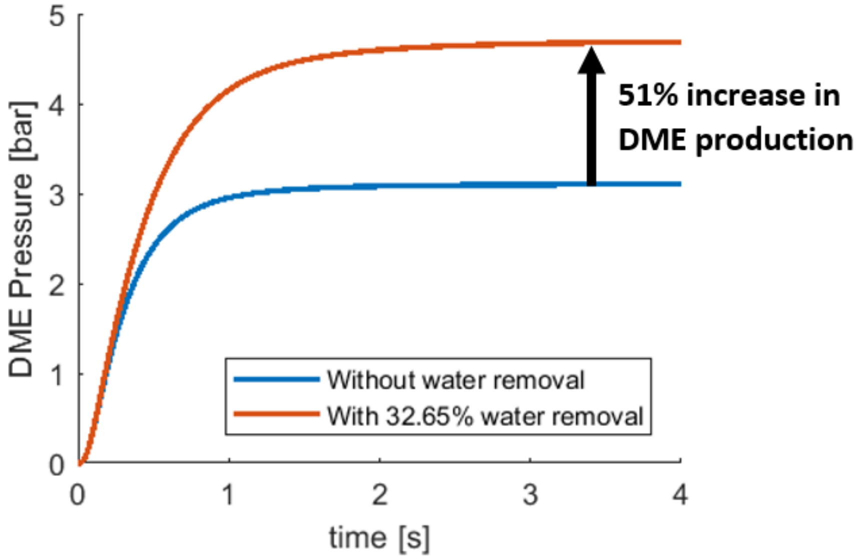


Mass transfer model with reactor kinetics for estimation of DME production

MODELLING RESULTS



MODELLING RESULTS

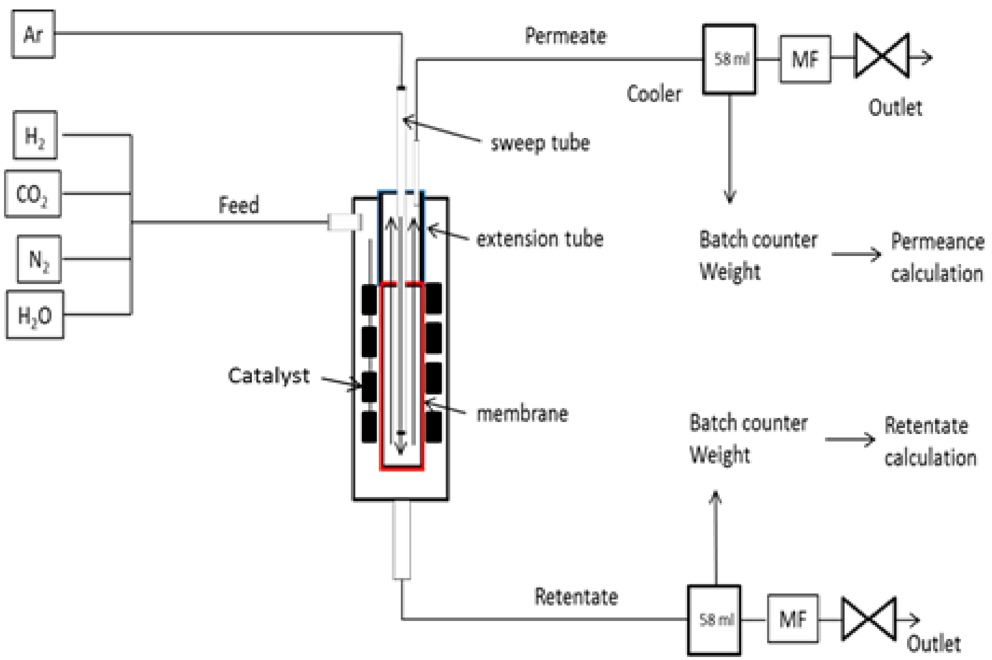


EXPERIMENTAL WORK

ECN › TNO innovation for life

EXPERIMENTAL SETUP

PERFORMANCE MEASUREMENT SETUP



Conditions:

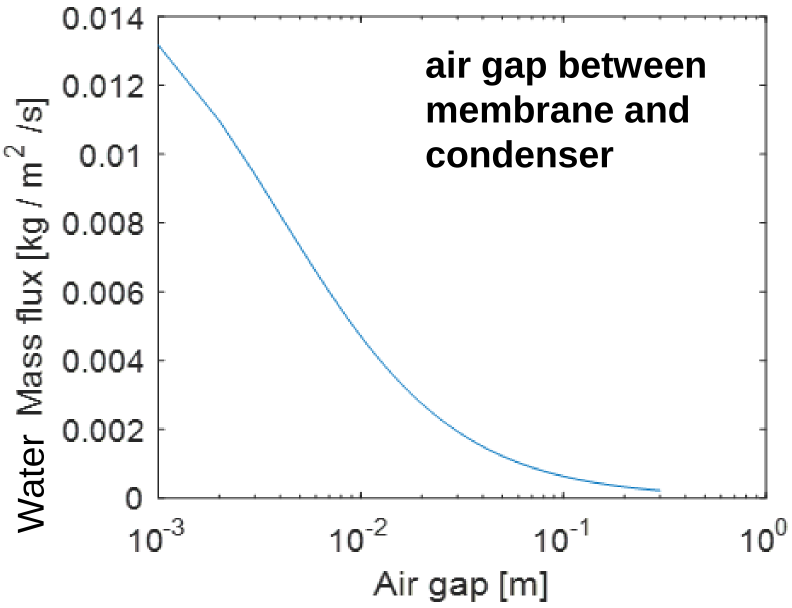
T = 220 ^{0}C; P = 25 bar

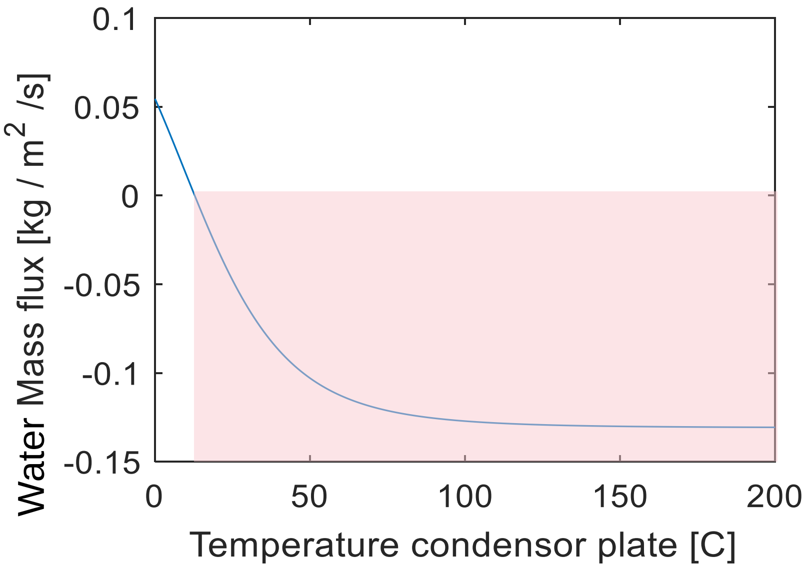
Flux results:

- 1-2.10^{-5} mol/m^2.h.Pa for H_2
- 2.10^{-4} mol/m^2.h.Pa for H_2O

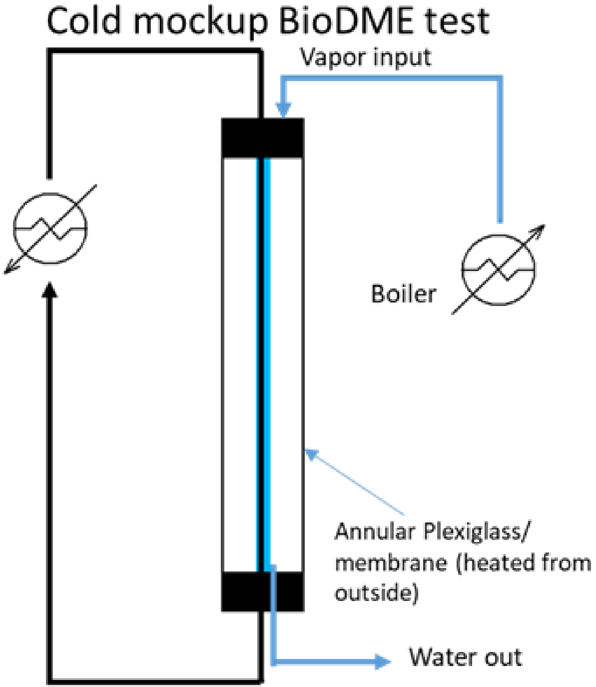
Gas	Quantity in L_n/min	Max g/h
Hydrogen (H_2)	20	107
Nitrogen (N_2)	20	1500
Carbon dioxide (CO_2)	10	1179
Carbon monoxide (CO)	2	150
Water (H_2O)	3	144
Methanol (CH_3OH)	1.7	144
Sweep Ar or He	20 (or 15)	2140 (or 160)

OPTIMIZATION FOR WATER REMOVAL BASED ON CRITICAL PARAMETERS





PRACTICAL TESTS: MEMBRANE/ CONDENSER FIT



And thin film movement along the majority of length of condenser

CONCLUSIONS

- Model estimates an increase of up to 51% in the production of DME
- Condenser Temperature and air gap are critical parameters for system design.
- Membrane characterization show selectivity of H_2O to H_2 of up to 16
- In-situ condenser configuration practically tested for dimensions of reactor.

THANK YOU FOR YOUR ATTENTION

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