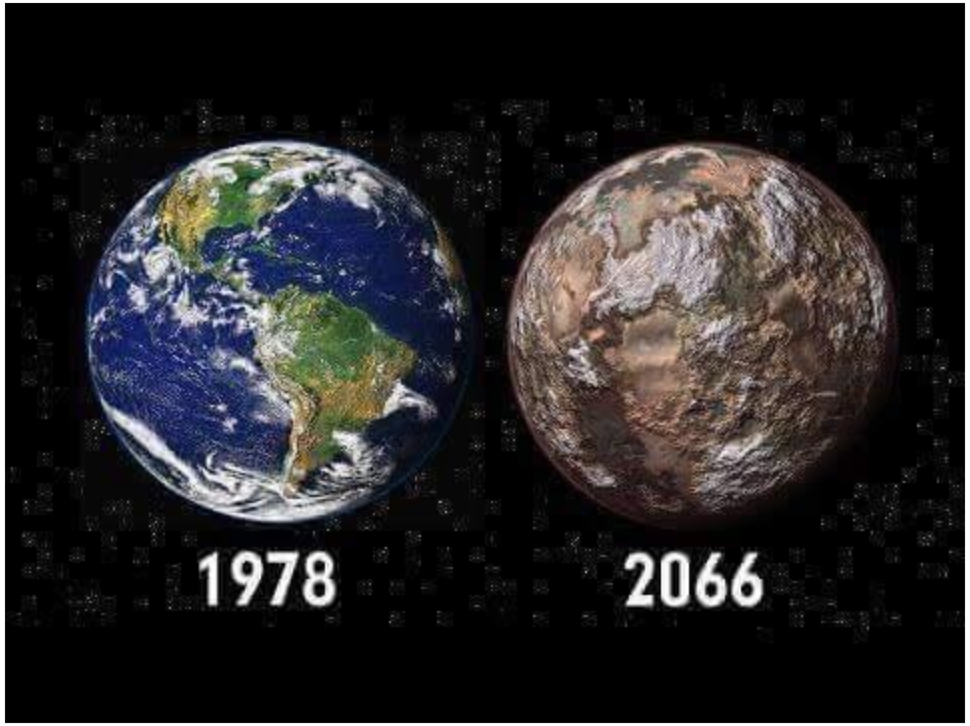
ECN › TNO innovation for life

VALORISATION OF STEEL OFF-GASES TO ENABLE ECONOMIC VIABLE CO_2 STORAGE AND UTILIZATION

Jaap Vente,
UTRECHT, 26 NOVEMBER 2019

DRIVER



The General Consensus

@Chimborazo, Ecuador
5000m above sea level

FOCUS ON THE IRON AND STEEL SECTOR

ENERGY CONTAINING RESIDUAL STREAMS

- Unique feature of current steel making processes
- Presence of diluted energy containing streams

Gas type	CO_2	CO	N_2	H_2	CH_4	LHV (MJ/Nm^3)
BFG	22	22	49	4	--	3.2
BOFG	14	57	14	3	--	7.5
COG	2	5	7	62	24	15.3

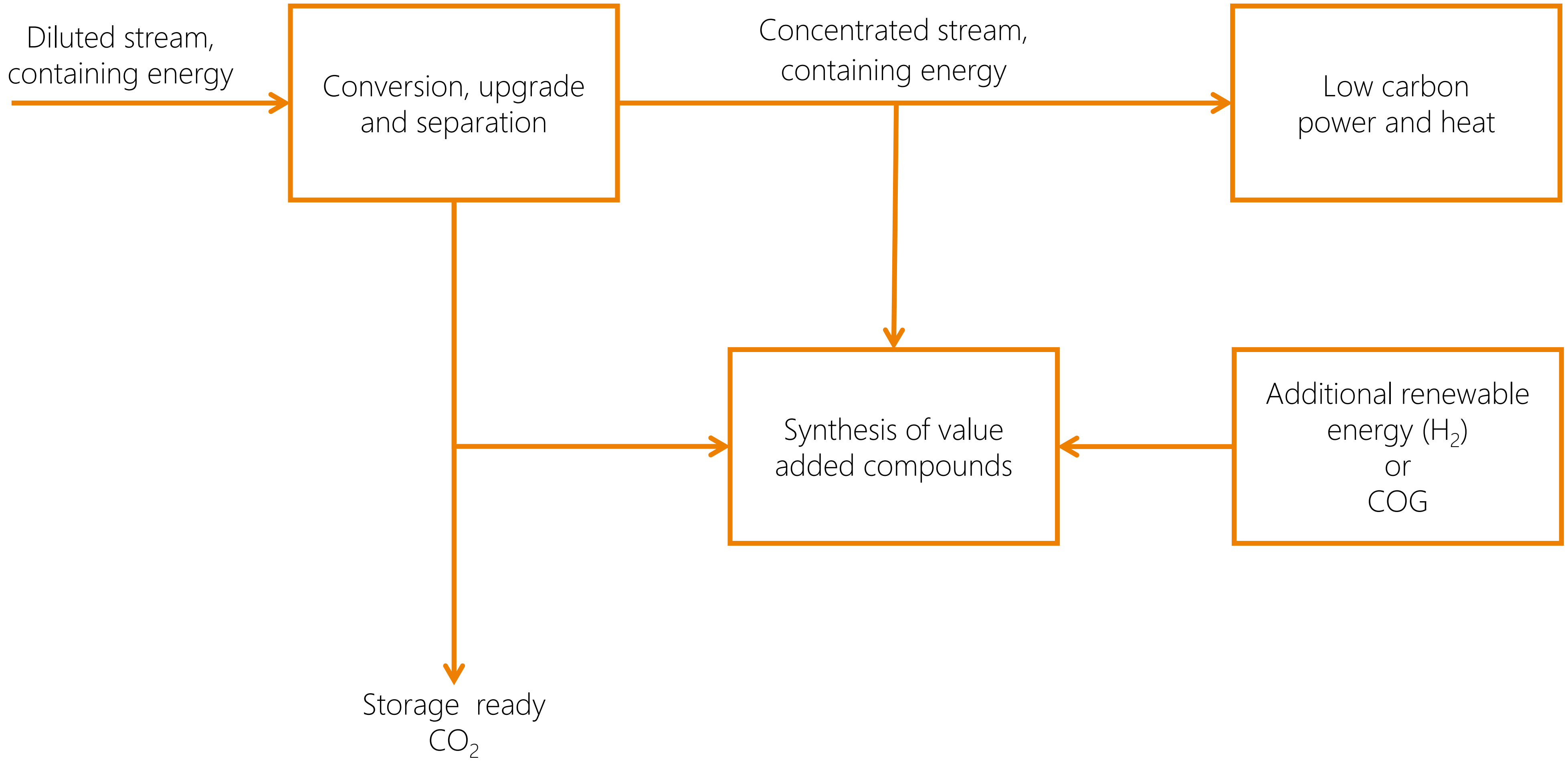
HOW TO VALORIZE THE ENERGY IN THE RESIDUAL STREAM?

- BFG – Blast Furnace Gas
- BOFG – Basic Oxygen Furnace gas
- COG – Cokes Oven gas

see IEAGHG report on Iron&Steel,
http://www.ieaghg.org/docs/General_Docs/Reports/2013-04.pdf

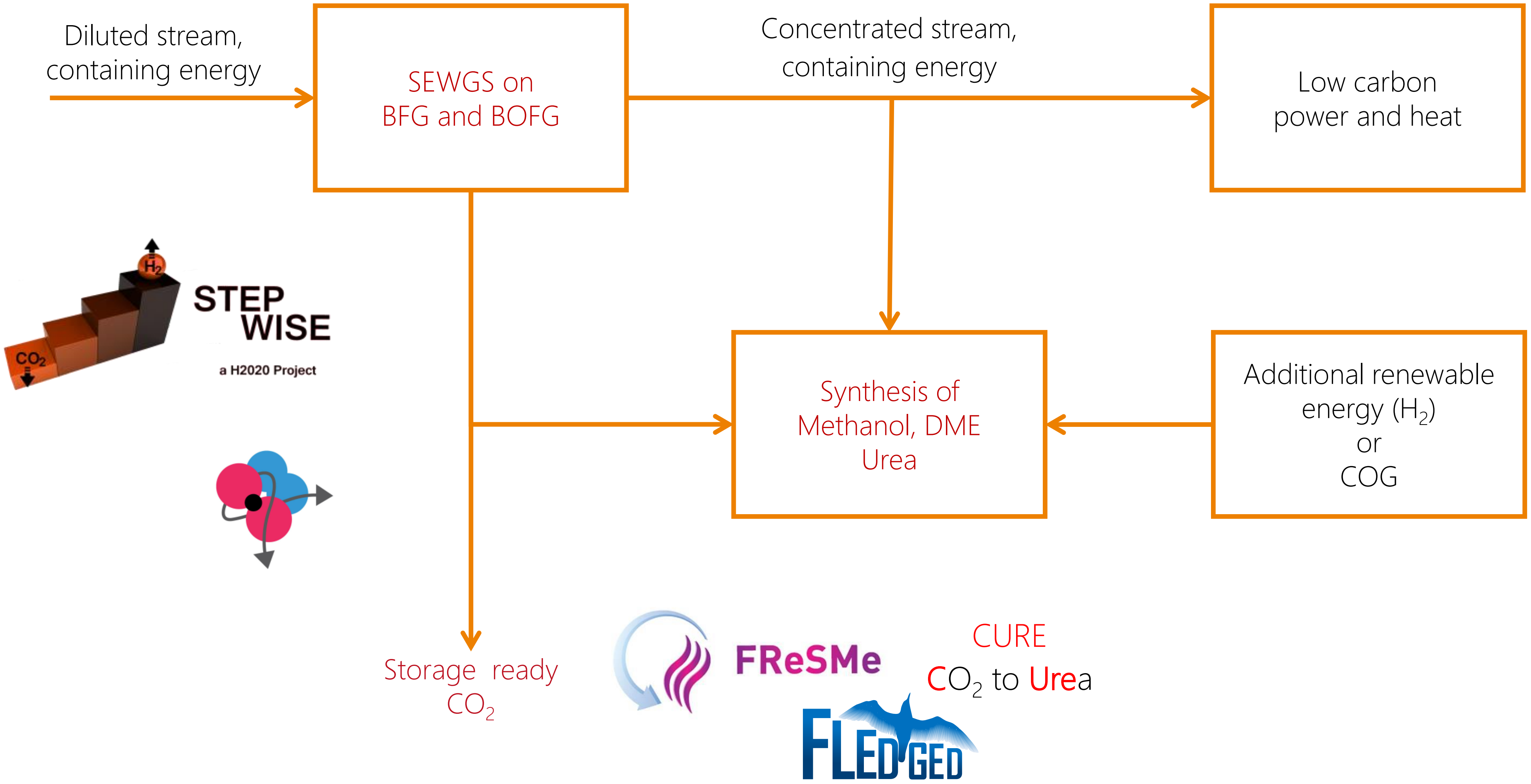
BASE CASE

CCUS APPROACH



SELECTION OF VALUE ADDED COMPOUNDS

CCUS APPROACH



SEWGS AS KEY ENABLING TECHNOLOGY

Private support
&
Public support + framework

cato

$cato_2$

SIXTH FRAMEWORK PROGRAMME

HORIZON 2020

SEWGS

CAP TECH
EOS – LT Consortium

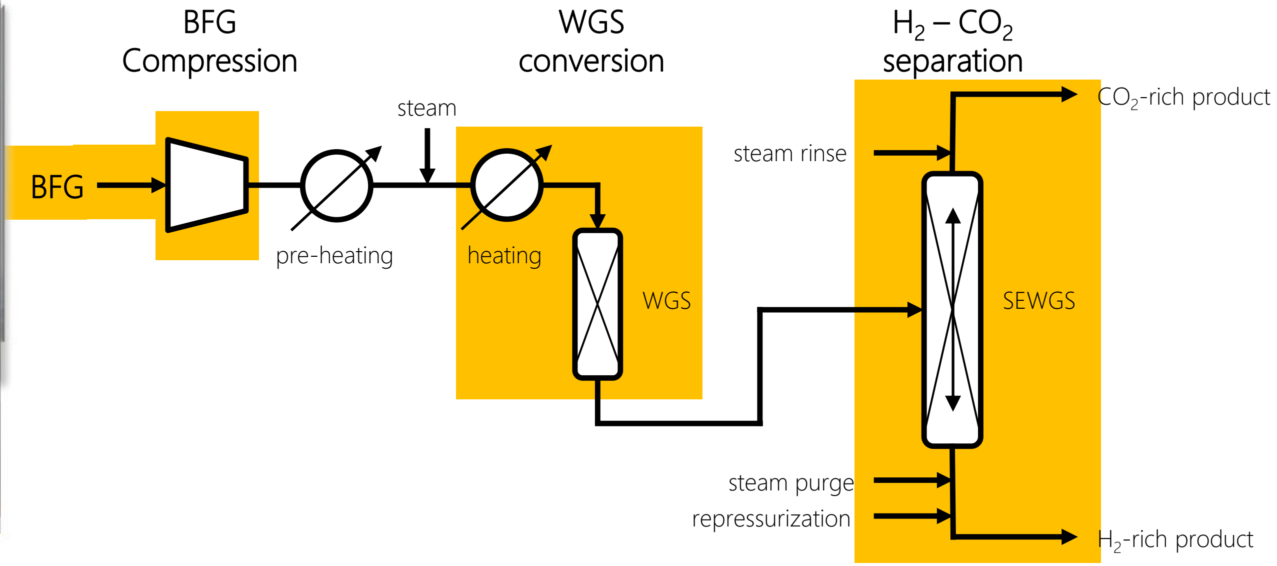
Accelerating CCS Technologies

SenterNovem

Rijksdienst voor Ondernemend Nederland

CURRENT STATUS: LULEÅ SWEDEN

STEPWISE PILOT LAY-OUT



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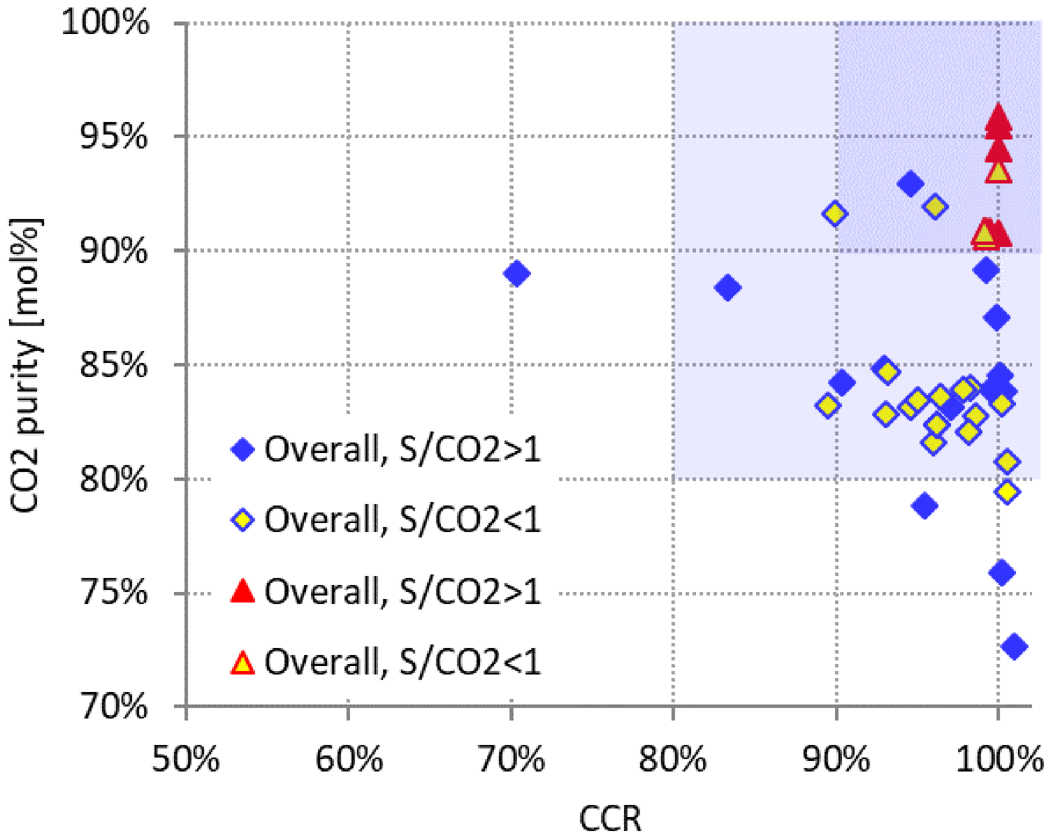
CAPTURING PERFORMANCE

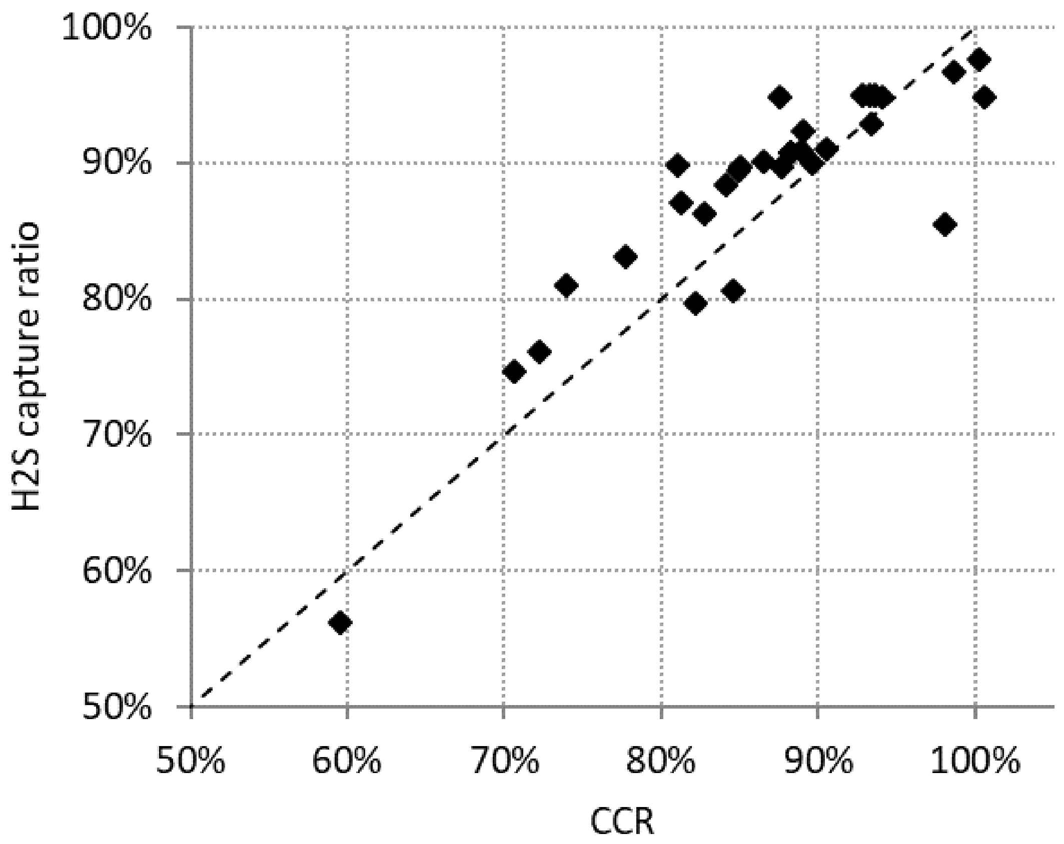
- Cyclic performance mapping
  - Carbon Capture Ratio
  - CO_2 purity
  - Rinse & Purge steam usage per CO_2 avoided
- 1st campaign results
  - Mapping
- 2nd campaign
  - Optimization
- In total 5000 cycles



EFFECTIVE SULPHUR REMOVAL

- Reversible sorption of H_2S
  - No influence on CCR, purity, steam
  - High CCR = high SCR
  - Simultaneous sulphur and carbon removal
  - H_2S ends up in CO_2 product
  - H_2S slip prior to breakthrough < 1 ppm,wet

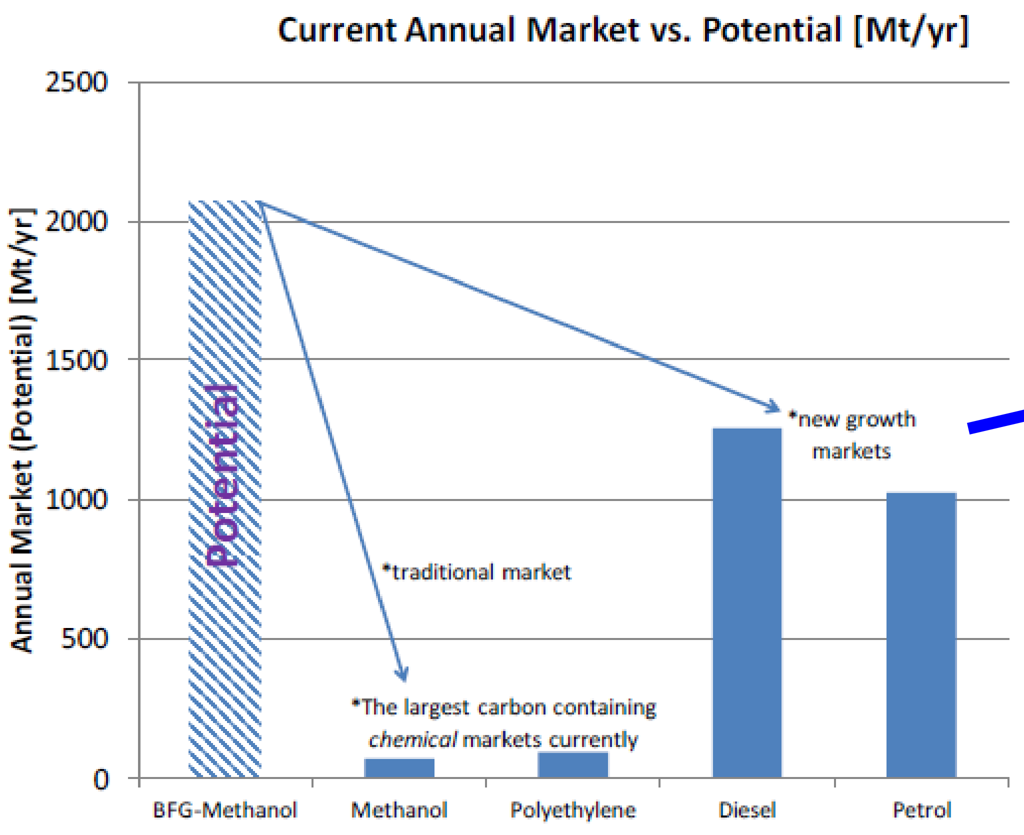
Aiming for a FoaK 100 kton CO_2 per year capture plant within 5 years



METHANOL: FUEL FOR SHIPPING

METHANOL POTENTIAL: CO_2-BASED

- Annual global CO_2-production in steel industry vs. current annual markets



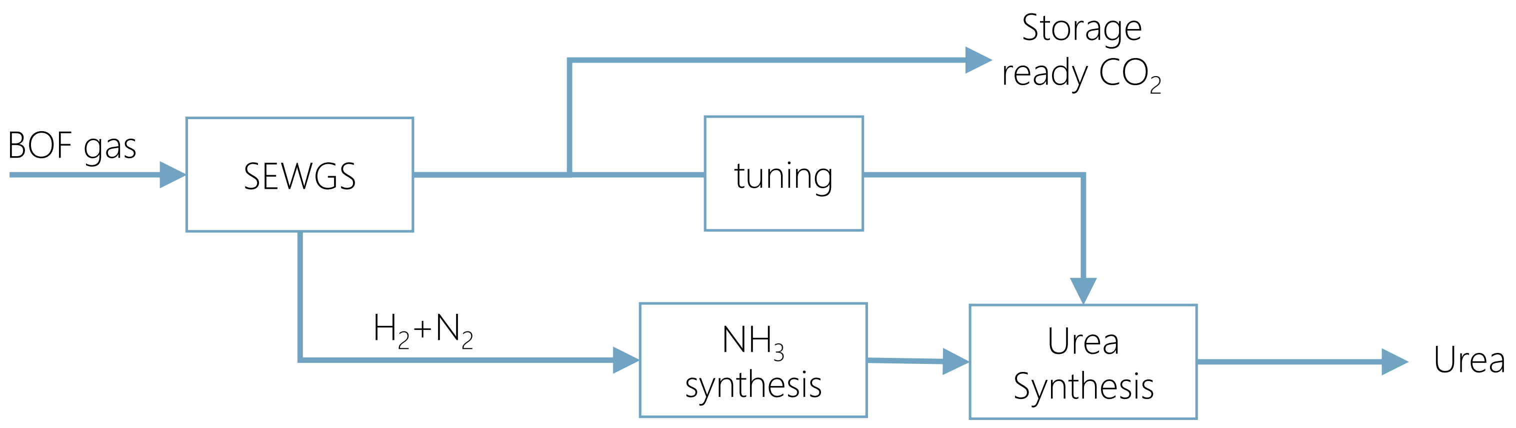
Methanol fuel market as growth market

Demonstration @ 1 ton MeOH/day is about to start

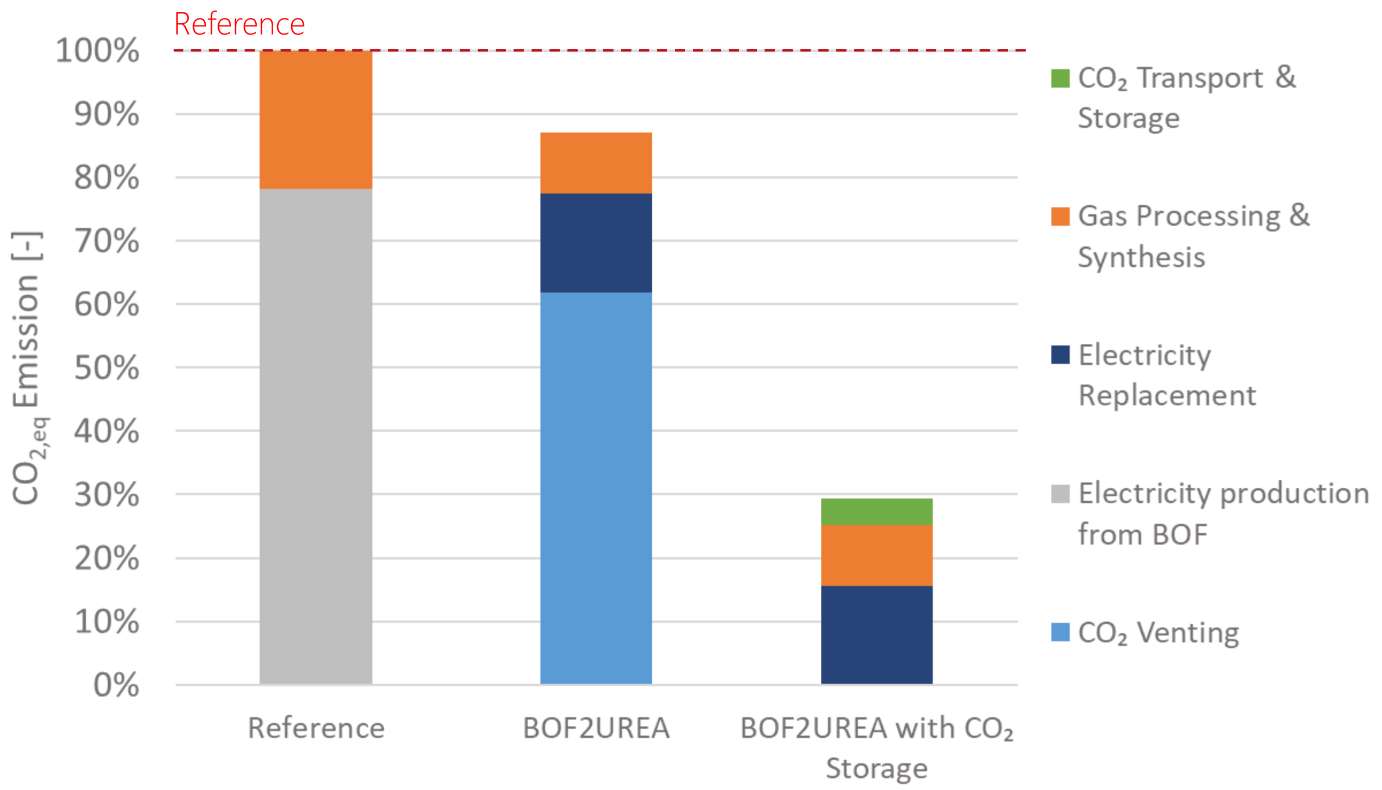
A POSITIVE BUSINESS CASE: UREA PRODUCTION

UREA PRODUCTION FROM BOFG

- ~55% of globally produced H_2 is used for NH_3
- Residual gases in the steel industry contain N_2
- After STEPWISE technology
  - N_2 goes with the H_2
  - Treated BOF gas has the right H_2/N_2 ratio for ammonia synthesis



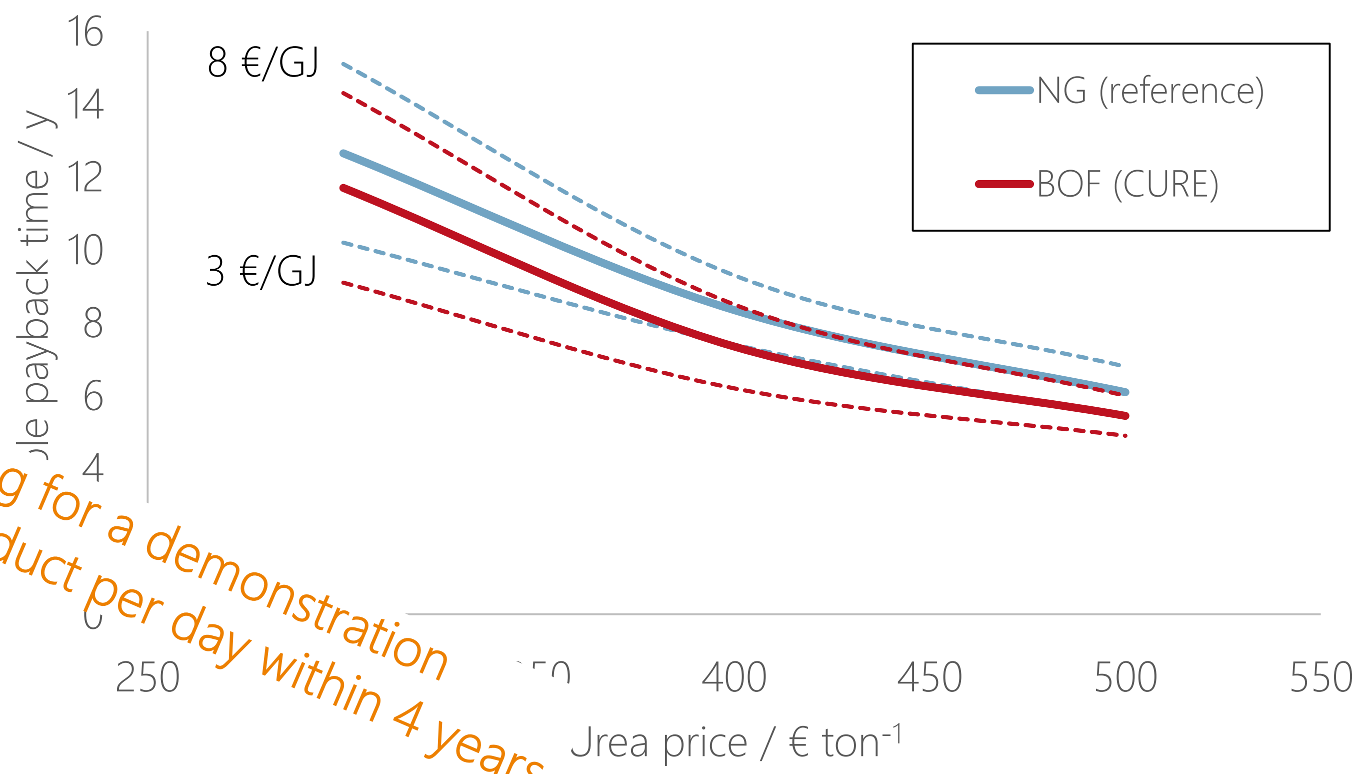
LIFE CYCLE ANALYSIS



- Global Warming Potential (GWP) reduction of ~13% without CO_2 Storage.
- 70% $CO_{2,eq}$ avoided if deployed with storage and transport.
- Electricity consumption is the primary source of remaining $CO_{2,eq}$.

BUSINESS CASE

- Comparable economics for natural gas based and BOF-gas based urea
- Urea pays for capture technology, storage ready CO_2 as side product



Aiming for a demonstration @ 3 ton product per day within 4 years

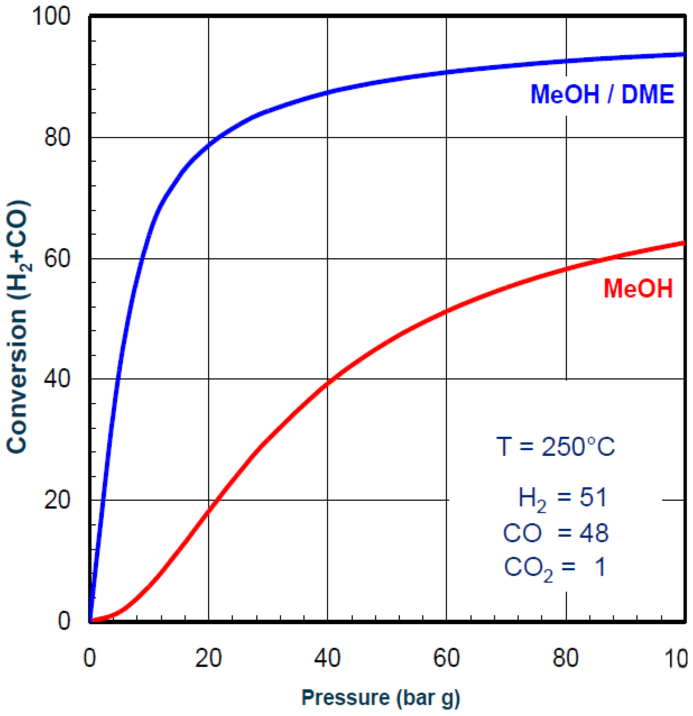
DME: THE ADVANCED FUEL FROM RENEWABLE RESOURCES

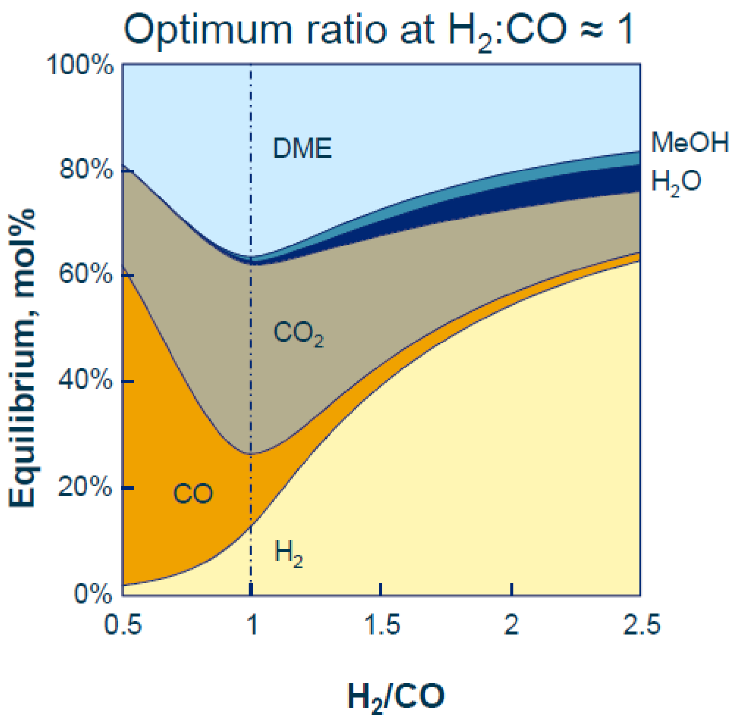
THERMODYNAMIC LIMITATIONS

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

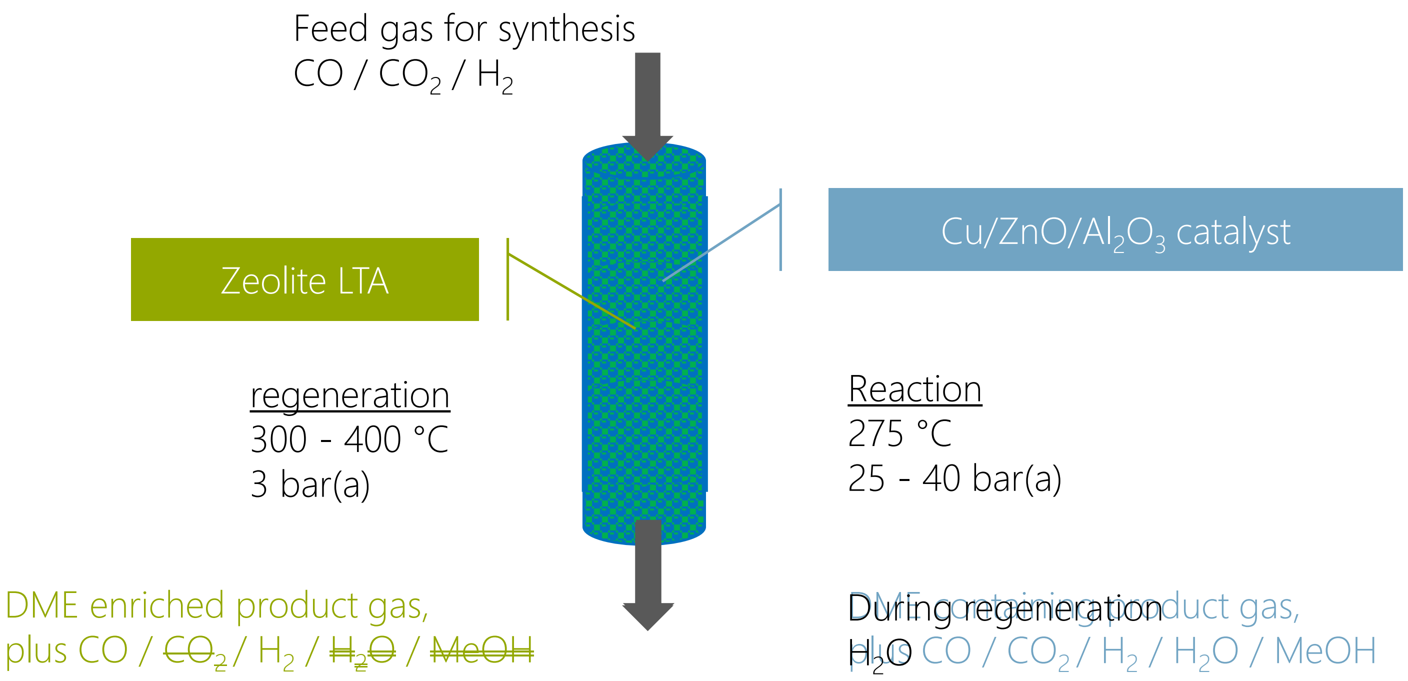
$$3H_2 + 3CO \leftrightarrow C_2H_6O + CO_2$$
$$4H_2 + 2CO \leftrightarrow C_2H_6O + H_2O$$

- Conversion from CO_2 and H_2 is minimal
- Challenge: Excess oxygen must be bound to hydrogen



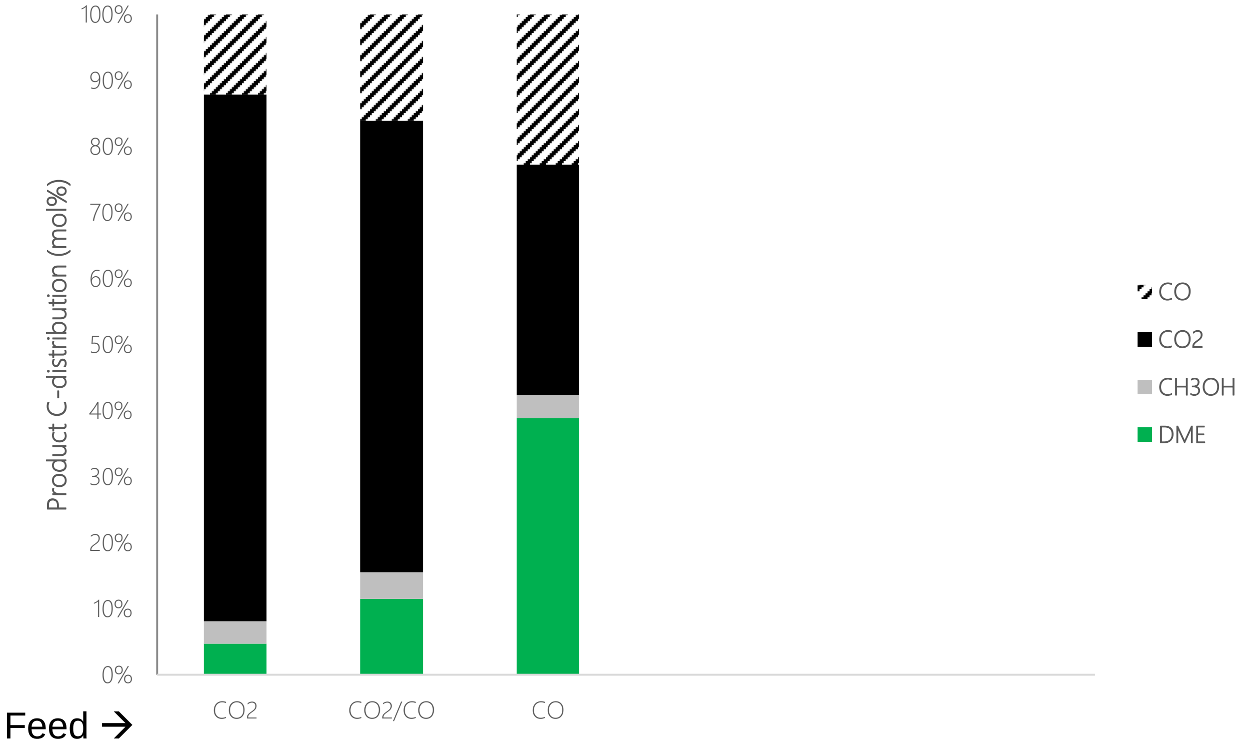


SORPTION ENHANCED DIRECT DME SYNTHESIS



FEED FLEXIBILITY

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



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

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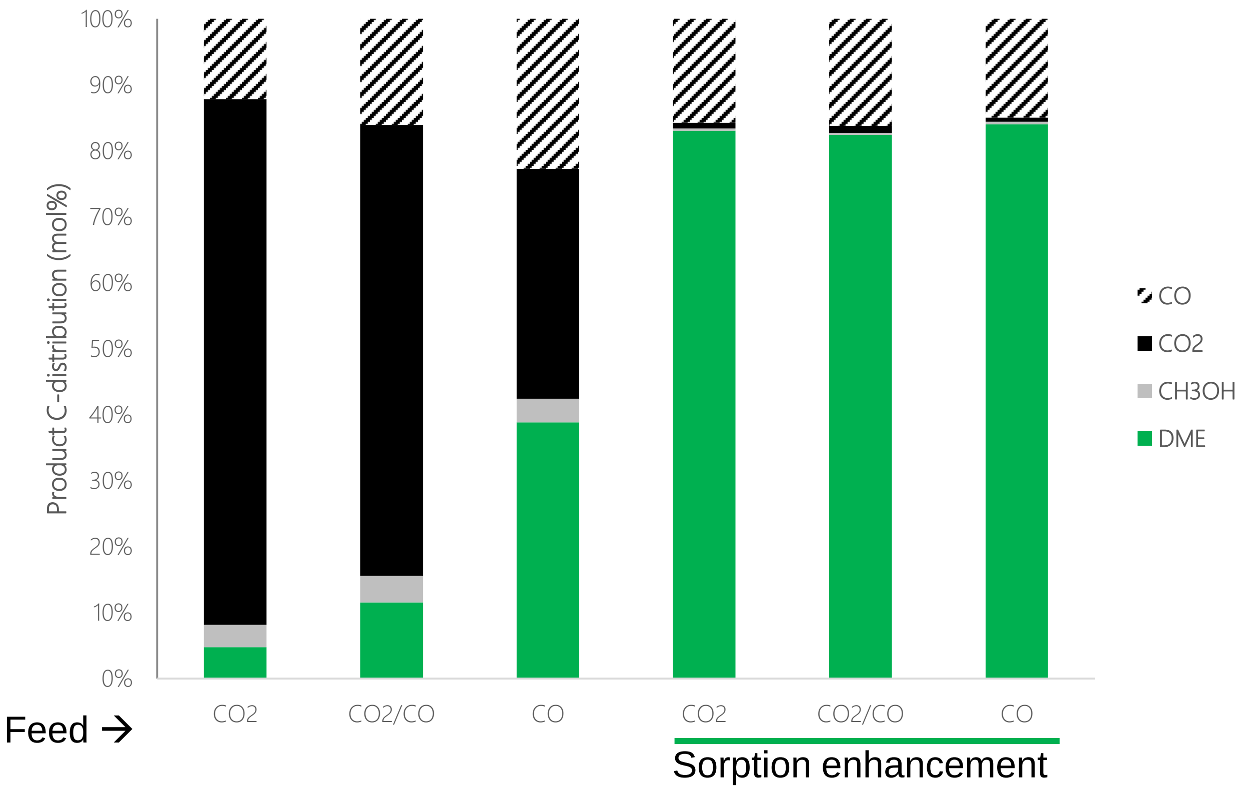
FEED FLEXIBILITY

- 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

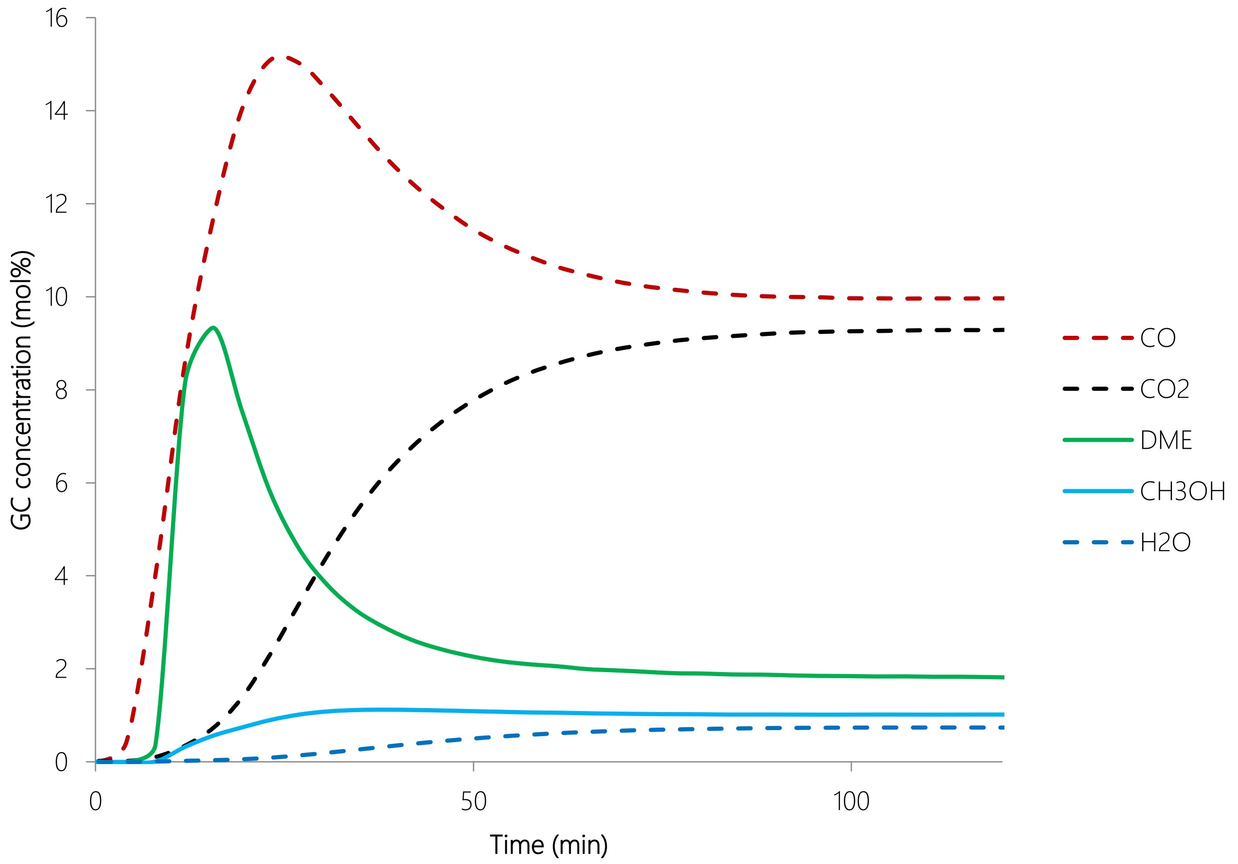


$$M = \frac{([H_2] - [CO_2])}{([CO] + [CO_2])} = 2$$

REGENERATION 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)

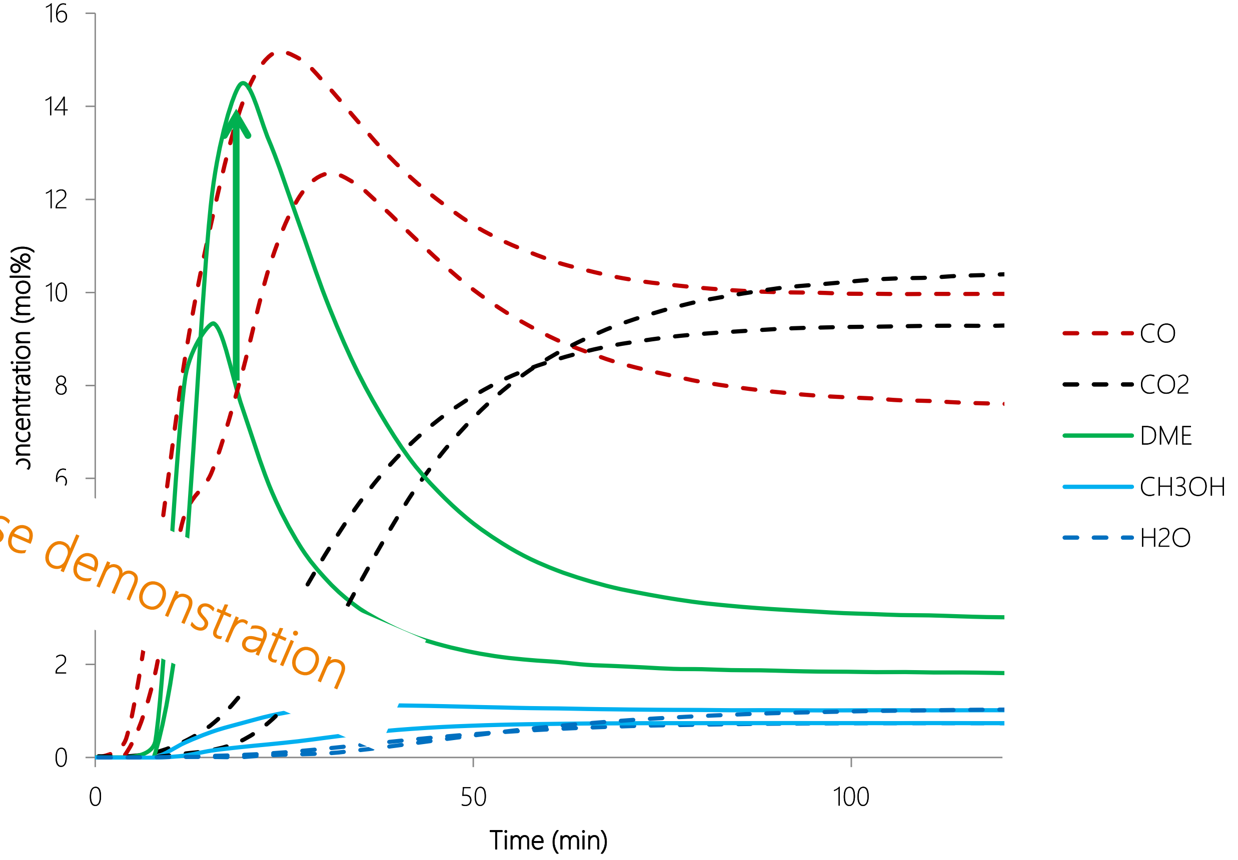


REGENERATION CONDITIONS

- Catalyst & sorbent regeneration from **300 to 400 °C**

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

- The more severe regeneration procedure increased performance



2020: TRL5 in house demonstration

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No. 640769
www.stepwise.eu
2015 – 2019

No. 727600
www.fledged.eu
2017 – 2020

No. 727504
www.fresme.eu
2017 – 2020

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https://www.sintef.no/elegancy

2017 – 2020

The CURE project has received funding from RvO under grant agreement TES 1216120

CURE CO_2 to Urea

2016

› THANK YOU FOR YOUR ATTENTION

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