POWER UPGRADE OF BIOGAS TO BIOMETHANOL OR BIOMETHANE

TOPSOE

World Biogas Summit
15-16 June 2022 Birmingham, U.K.

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16 June 2022

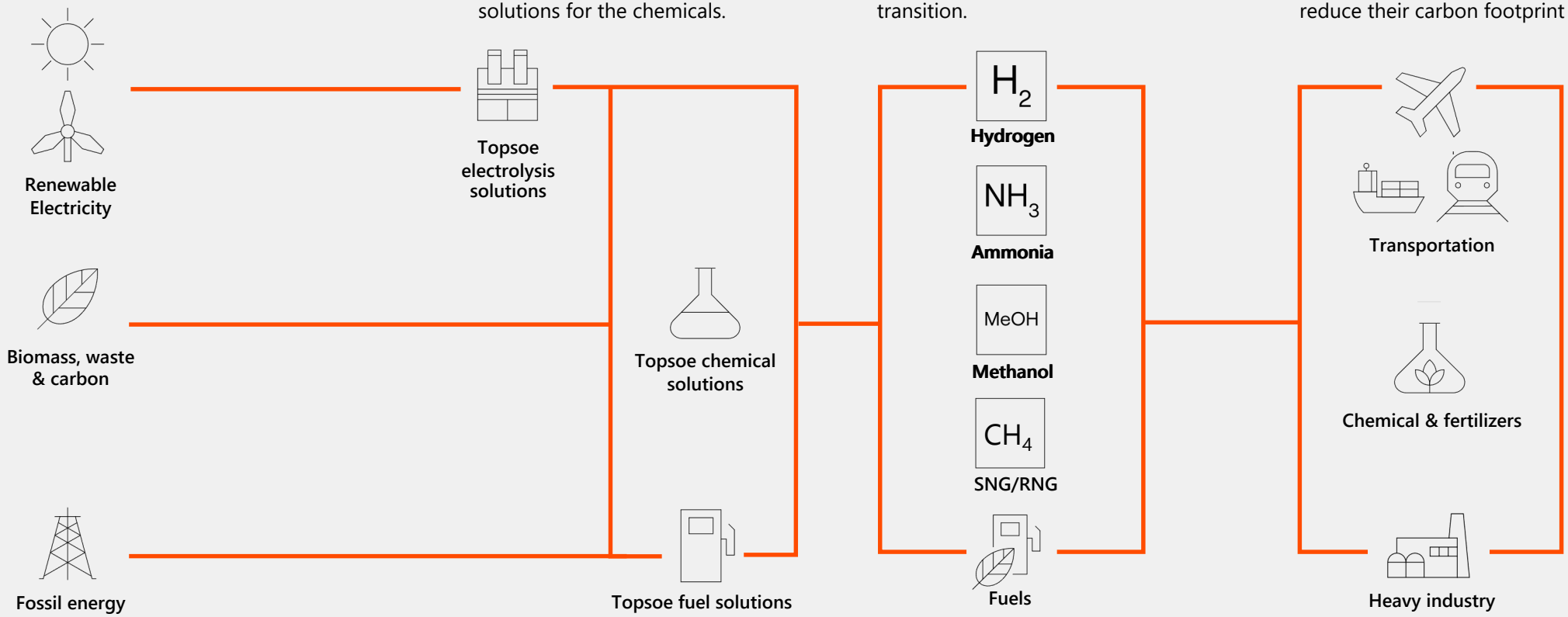
TOPSOE SOLUTIONS ACCELERATE THE ENERGY TRANSITION

ENERGY SOURCES
Fuels and chemicals can be produced from various ways of both renewable and fossil feedstocks.

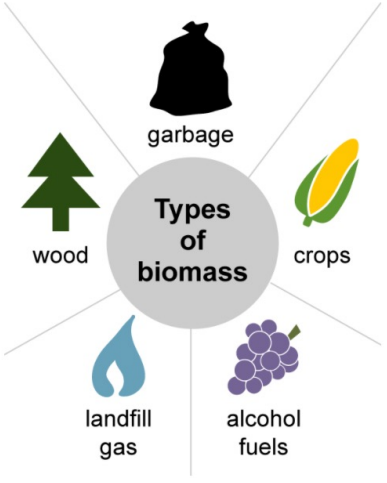
SOLUTIONS
Topsoe helps customers on their decarbonization journey through advanced energy solutions, such as Power-to-X, renewable fuels and blue solutions for the chemicals.

CHEMICALS AND FUELS
For our customers, the output is more efficient processes or renewable feedstocks, that significantly can lower the carbon footprint, and thereby supporting them in their energy transition.

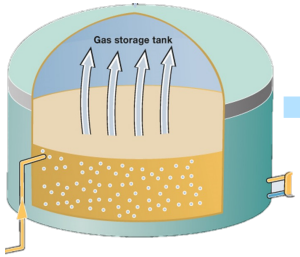
UTILIZATION
The societal benefits of these end-products come, among other things, in the shape of a cleaner transportation sector and hard-to abate sectors such as steel, cement, and mining, who can reduce their carbon footprint



BIOGAS OPTIONS



Other biomass applications



~40-45% CO_2

~55-60% CH_4

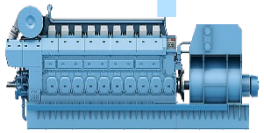
Biogas to methanol

Methanol

$CO_2 + H_2 \rightarrow CH_4$

CO_2 vent

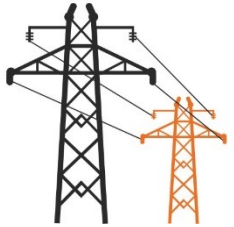
CO_2



CBG / LBG

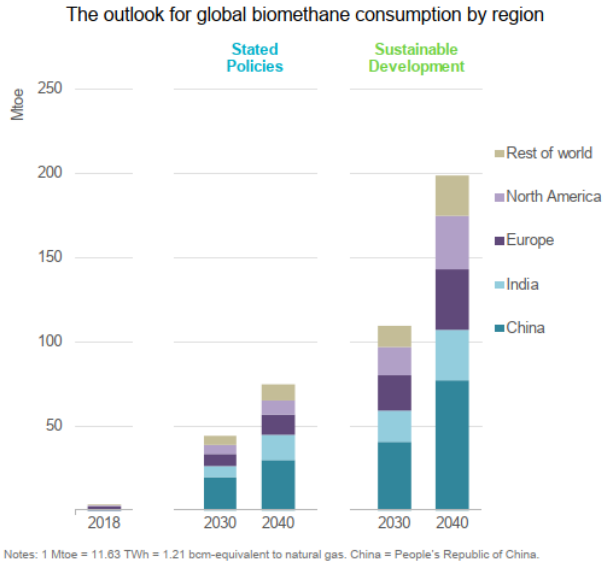
Gas grid

Energy grid



BIOMETHANE AND BIOMETHANOL OUTLOOKS

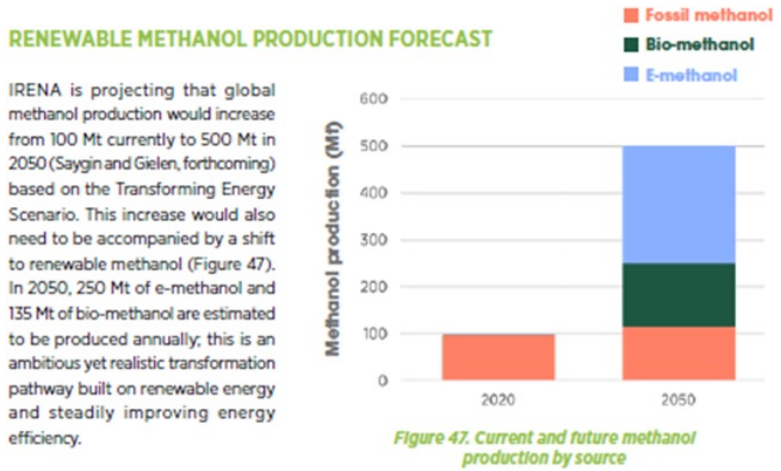
- **Biomethane: Fuel and feed for green chemicals**
- Around 90% of biomethane currently comes from biogas upgrading.
- Europe – REpowerEU aims at 30 billion m^3 biomethane by 2030.



IEA (2020) – Outlook for biogas and Biomethane: Prospects for organic growth. All rights reserved

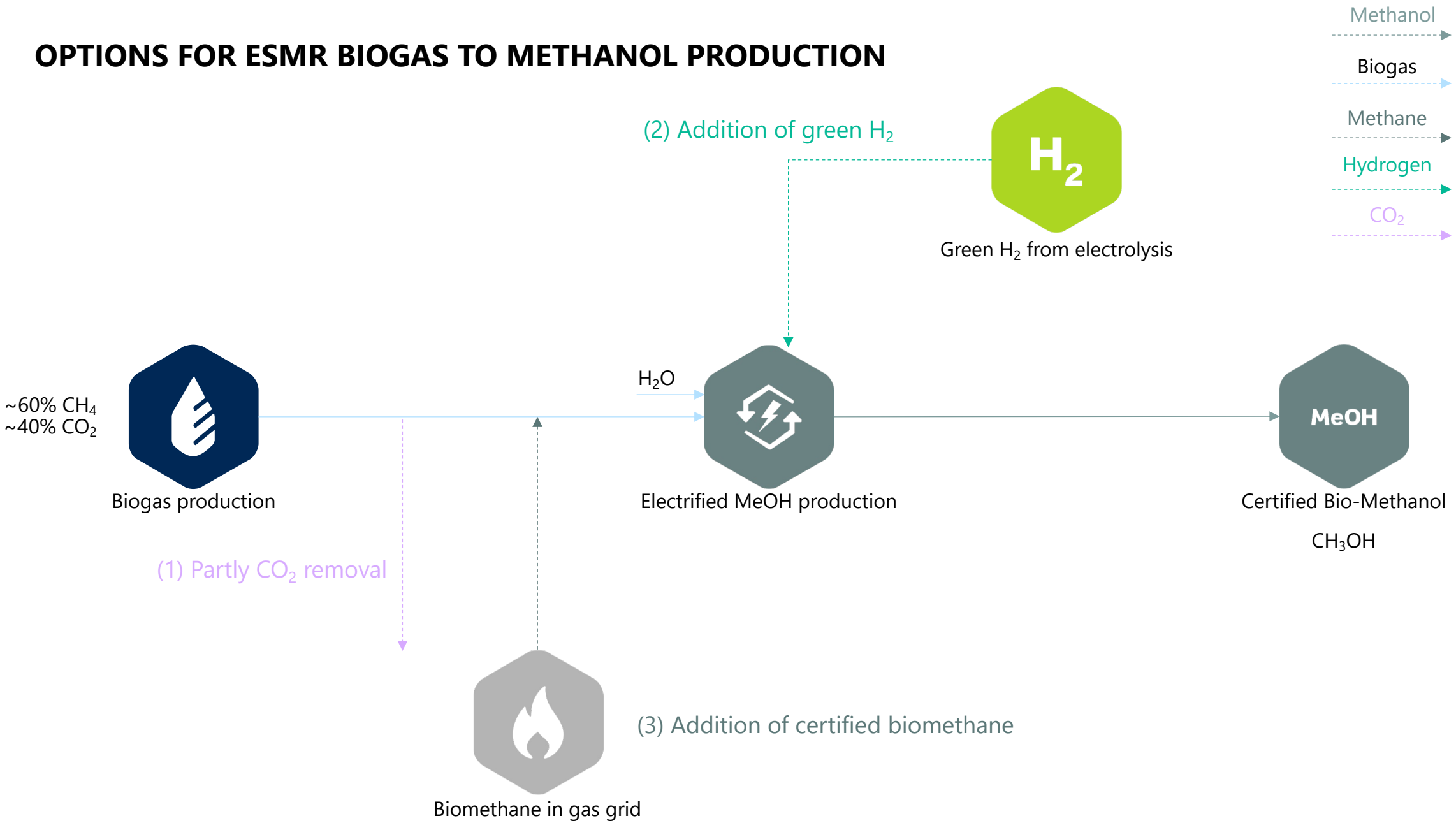
Bio-methanol: Bulk chemical

- Current global market is ~100 million ton/yr and growing at ~3% / yr
- Prices of "grey" methanol varies with gas price in the range 300-800 USD / ton, currently in the high end.



IRENA AND METHANOL INSTITUTE (2021), *Innovation Outlook : Renewable Methanol*, International Renewable Energy Agency, Abu Dhabi.

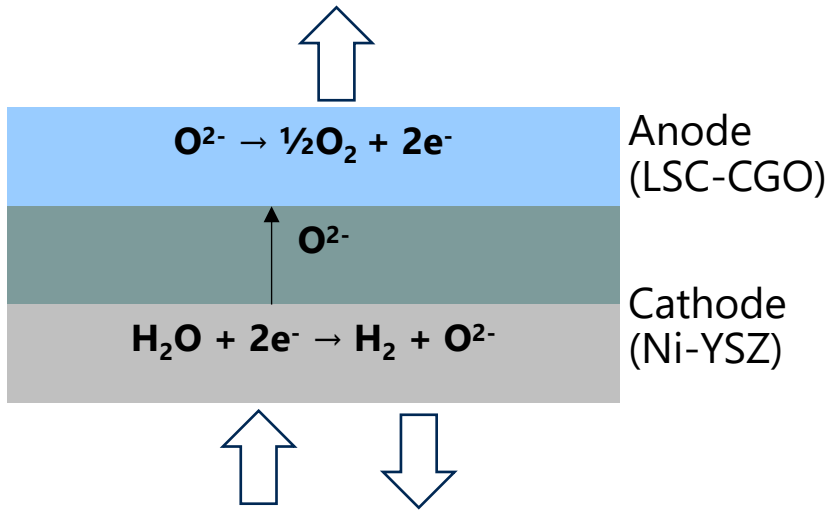
OPTIONS FOR ESMR BIOGAS TO METHANOL PRODUCTION



HIGH T SOEC MOST ENERGY EFFICIENT ELECTROLYZER

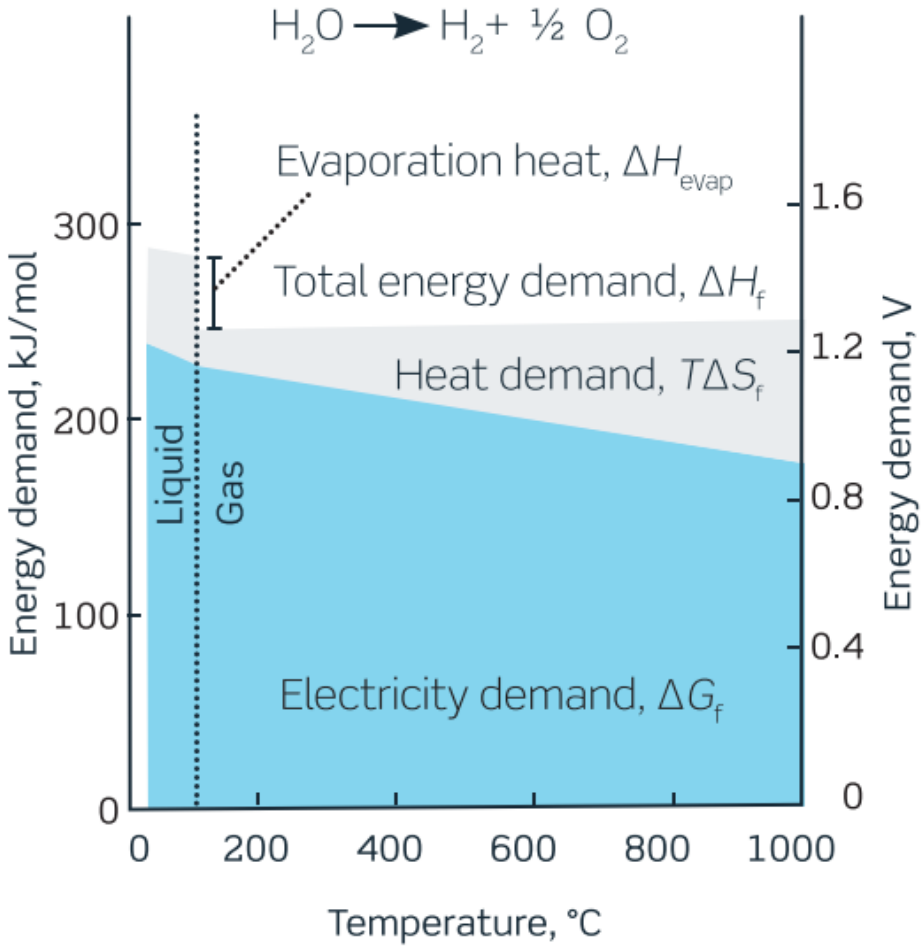
SPECIALLY WELL SUITED FOR INTEGRATION WITH HEAT GENERATING PROCESSES

SOEC electrolysis



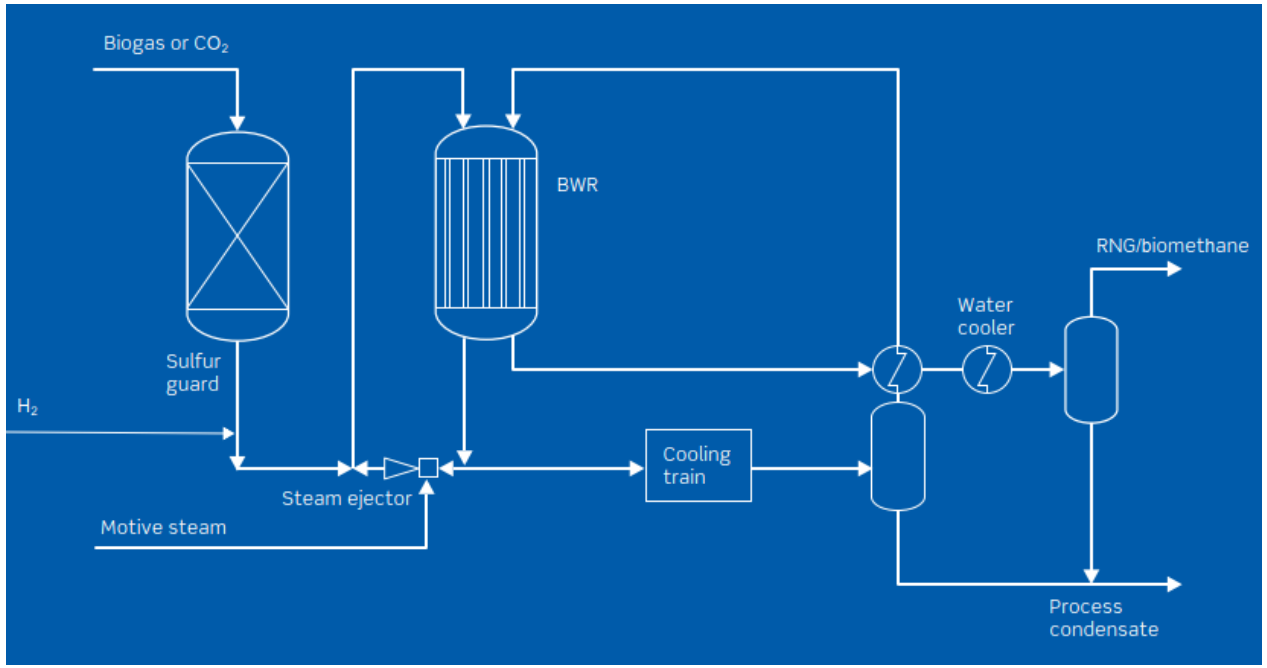
Stack power consumption

3.1 kWh/Nm^3 H_2



BIOGAS OR BIOCO2 METHANATION
HYDROGEN SUPPLEMENT FROM ELECTROLYSIS

- Carbon source: Biogas mixture or pure CO_2
- Hydrogen addition to achieve: $H_2/CO_2 = 4$
- Isothermal reactor by TREMP™ design
- Integrate with SOEC to achieve an unmatched system efficiency.



ENERGY CONSUMPTIONS AND EFFICIENCIES – INDICATIVE NUMBERS

POWER UPGRADE OF A BIOGAS OF 60% CH4 / 40% CO2

		Energy input per LHV output		Energy efficiencies	
		BG Gas LHV input	Total Power input	Energy Efficiency to product	District heat output (+/- 50%)
		MW / MW	MW / MW	%	%
Methanol via eSMR	**Partial CO2 vent**	**0,97**	**0,52**	**67%**	**~10 %**
	+ SOEC H2	**0,78**	**0,76**	**65%**	**~10 %**
	+ LT H2	**0,78**	**0,83**	**62%**	**~10 %**
	+ CH4	**0,97**	**0,52**	**67%**	**~10 %**
eMethanol via BG separation	**+ SOEC H2**	**-**	**1,97**	**51% ****	**~10%**
	+ LT* H2	-	2,28	44% **	~10%
methanation	**+ SOEC H2**	**-**	**1,49**	**67% ****	**~10%**
	+ LT* H2	-	1,97	51% **	~20%

* Low temperature electrolysis
** Not including unreacted CH4

OUTLOOK AND SUMMARY

- **BIOGENIC CO2 WILL BE A VALUABLE RESOURCE FOR OUR GREEN ENERGY TRANSITION SERVING THE HARD-TO-ABATE SECTORS**
- **UPGRADING BIOGAS BY RENEWABLE POWER TO METHANE OR METHANOL ARE VIABLE ROUTES**
- **TOPSOE HAS ENERGY EFFICIENT TECHNOLOGIES AVAILABLE FOR BOTH ROUTES**
- **THE NOVEL ESMR TECHNOLOGY ENABLES FULL BIOGAS CONVERSION TO METHANOL WITH HIGH ENERGY EFFICIENCY AND NO PROCESS CO2 EMISSION**
- **SOEC TECHNOLOGY ENABLES FULL BIOGAS CONVERSION TO METHANE WITH HIGH ENERGY EFFICIENCY BY USING THE HEAT OF METHANATION FOR HYDROGEN PRODUCTION**

QUESTIONS

April 28, 2022

TOPSOE