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BioMeGaFuel

Bio Methanol Production via Chemical Looping Gasification Coupled with Membrane Reactors

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Webinar:
Electrolysis and Gasification: possible synergies in energy and fuel production

March 6th, 2026

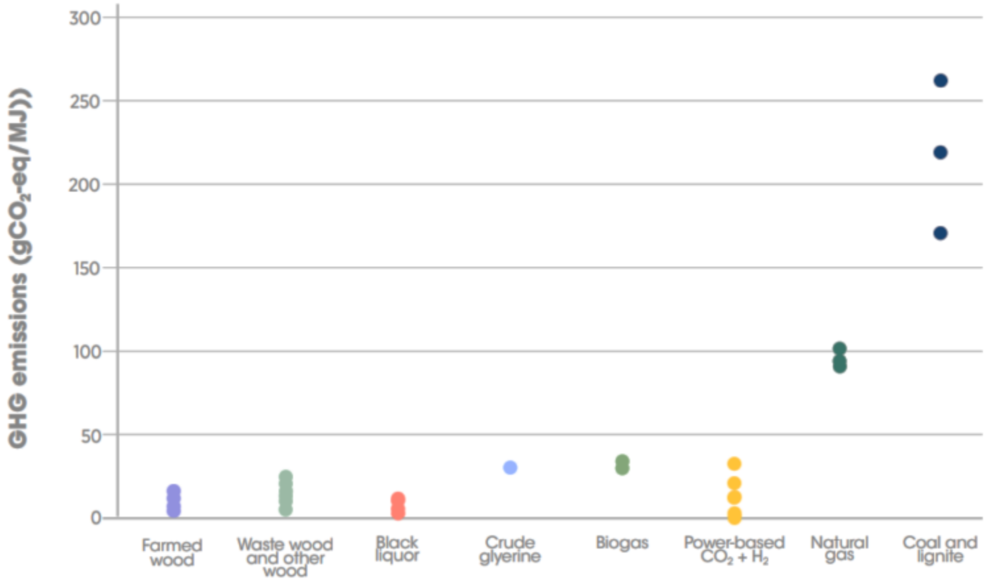
Methanol

- Besides being an important chemical commodity, methanol is a multipurpose fuel that can be used directly in internal combustion engines, blended with other fuels or for producing fuel additives.

- Methanol can be used both directly and indirectly for electricity production in fuel cells.

- In 2020, around 65% of methanol is produced by natural gas reforming, and 35% is produced by coal gasification. Only less than 1% of global methanol production is renewable methanol.

- Around 102 Mt of methanol were produced in 2020 with expectations of increasing to 500 Mt/year by 2050.
  - Correspond to releasing 1.5 Gt CO_2 per annum if solely sourced from fossil fuels.



GHG emission for methanol production from various feedstocks

Innovation Outlook: Renewable Methanol (2021), International Renewable Energy Agency (IRENA)

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BioMethanol

- While the production of biomethanol from biomass can significantly reduce the CO_2 emission, the amounts of biomass that can be generated in a sustainable way are limited.

- Currently there are several on-going/operational projects for biomethanol production from MSW, and waste wood using gasification technologies
  - the overall conversion efficiency of the gasification technologies and methanol synthesis methods is low
  - the yield of biogenic carbon in the biomethanol product is relatively low
  - these technologies are often unable to utilize low-value biogenic residues without pretreatment as feedstock, owing to their heterogenous nature and naturally high amount of contaminants

- According to IRENA, the cost of biomethanol can increase significantly from $43/ton to $660/ton by increasing the cost of biomass (from 1.5 $/GJ to 15 $/GJ) and decreasing conversion efficiency (from 70% to 50%) and while the cost of fossil-based methanol is $100-250/ton.

Innovation Outlook: Renewable Methanol (2021), International Renewable Energy Agency (IRENA)

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- To meet the increasing global demand for methanol
- To meet the net zero emission by 2050
- To reduce the cost of biomethanol to facilitate the adoption and large-scale investments.

➢ It is necessary to develop **efficient processes** for the conversion of **low-value biogenic residues and waste** to **biomethanol**

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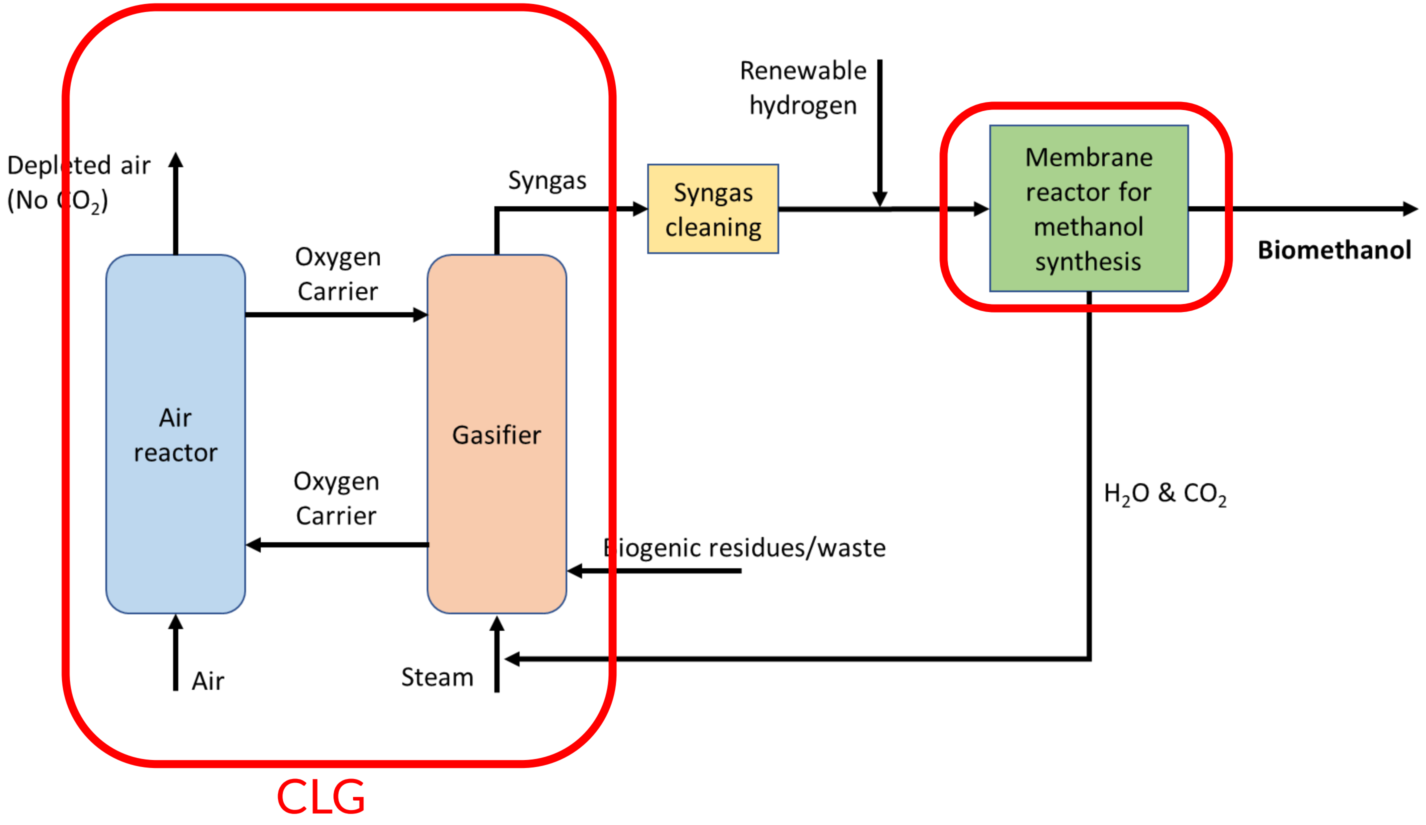
Bio-MeGaFuel idea:

biomethanol production via chemical looping gasification (CLG) coupled with membrane reactors

Advantages:

- Flexible toward feedstocks and can utilize various biogenic residues and wastes
- Higher conversion efficiency compared to conventional gasification and methanol synthesis methods, leading to lower production costs and maximum biogenic conversion to biomethanol.
- Reducing the number of downstream units, with the possibility of heat and power integration, provides significant potential for cost and energy demand reduction.
- Produce biomethanol with near zero emissions (significant emission reduction).
- The process is less energy intensive and is self-sufficient in terms of heat.



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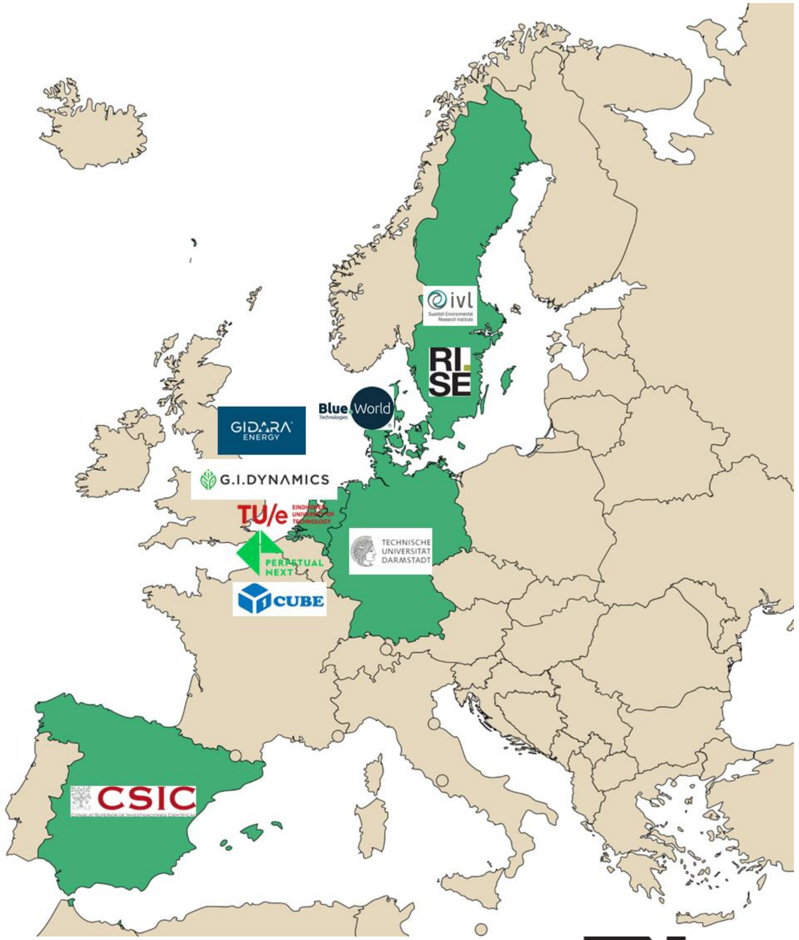
Bio-MeGaFuel Consortium

Duration: 48 months

Start date: September 2024

Budget: Approximately 3.8 Million Euros (Funded by EU)

	Participant organisation name	Country
1	RISE RESEARCH INSTITUTE OF SWEDEN	Sweden
2	GIDARA ENERGY	Netherlands
3	G.I. Dynamics (Affiliated to GID)	Netherlands
4	TECHNISCHE UNIVERSITÄT DARMSTADT	Germany
5	EINDHOVEN UNIVERSITY OF TECHNOLOGY	Netherlands
6	SPANISH NATIONAL RESEARCH COUNCIL	Spain
7	IVL SWEDISH ENVIRONMENTAL RESEARCH INSTITUTE	Sweden
8	PERPETUAL NEXT BIOCARBON	Netherlands
9	1CUBE	Netherlands
10	BLUE WORLD TECHNOLOGY	Denmark



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Technology development activities

Activity	Bio-MeGaFuel TRL	Verification
CLG of low-value waste and biogenic residues to produce syngas	5	Gasification of 50-70 tons of low-value biogenic residues and waste in a 1 MW unit with: • >100 h autothermal CLG operation , • mixing using CO_2 and steam as the fluidizing and gasification agent, • 80% gasifier cold gas efficiency, • 98% carbon conversion in gasifier, • <10% of reactive ash species released in air reactor.
Methanol synthesis from syngas using a membrane reactor	5	Production of 3 kg/day of biomethanol with a double yield of methanol production from syngas compared to packed beds and with in-situ CO_2 separation.

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Chemical looping gasification

Oxygen carrier (OC):

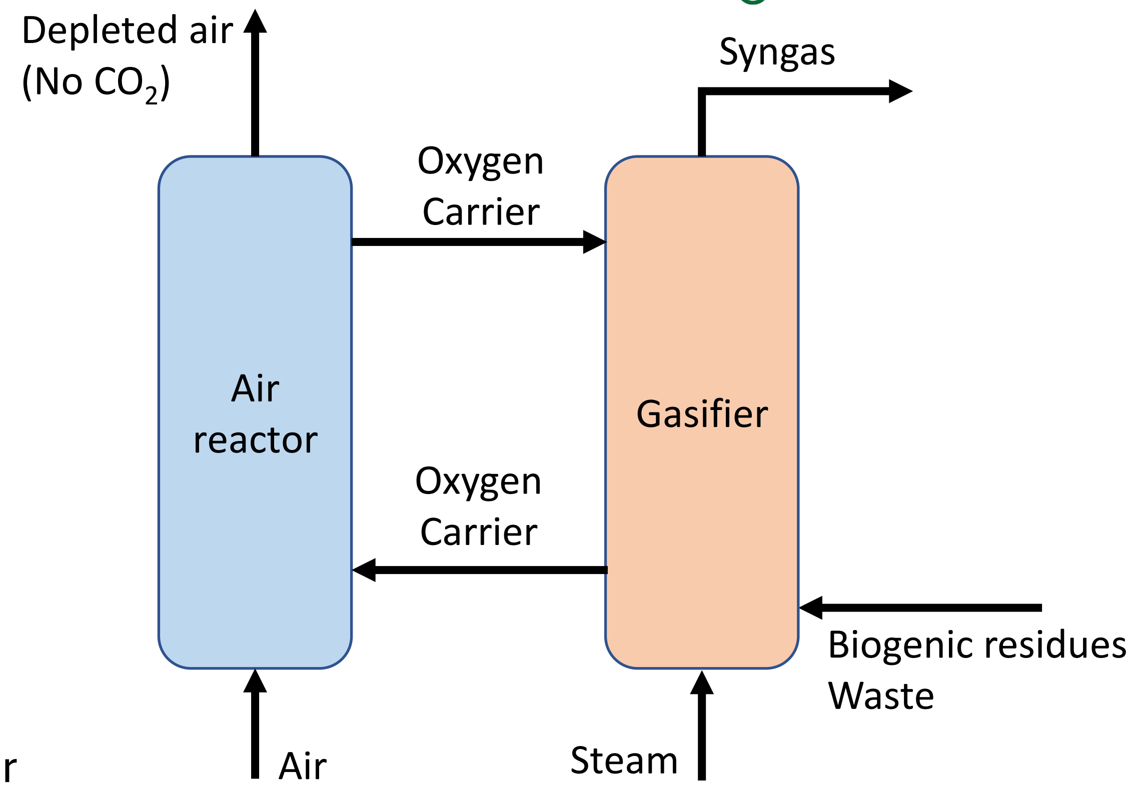
$$Me_xO_{y-1} + \frac{1}{2}O_2 \leftrightarrow Me_xO_y \qquad (\Delta H < 0)$$

Me_xO_y: Metal (such as Fe, Mn, Cu or Ni) oxides

particles in the range of 100–500 μm

OC can be:

- natural ores such as ilmenite
- industrial waste materials such steel slag convertor and cupper slag
- Synthetic material such as pervoskites



Depleted air
(No CO_2)

Syngas

Oxygen Carrier

Air reactor

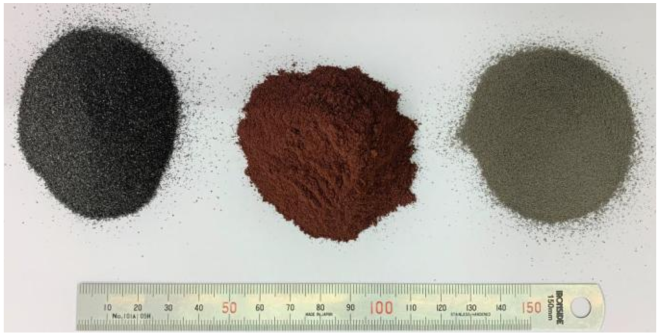
Gasifier

Oxygen Carrier

Biogenic residues
Waste

Air

Steam



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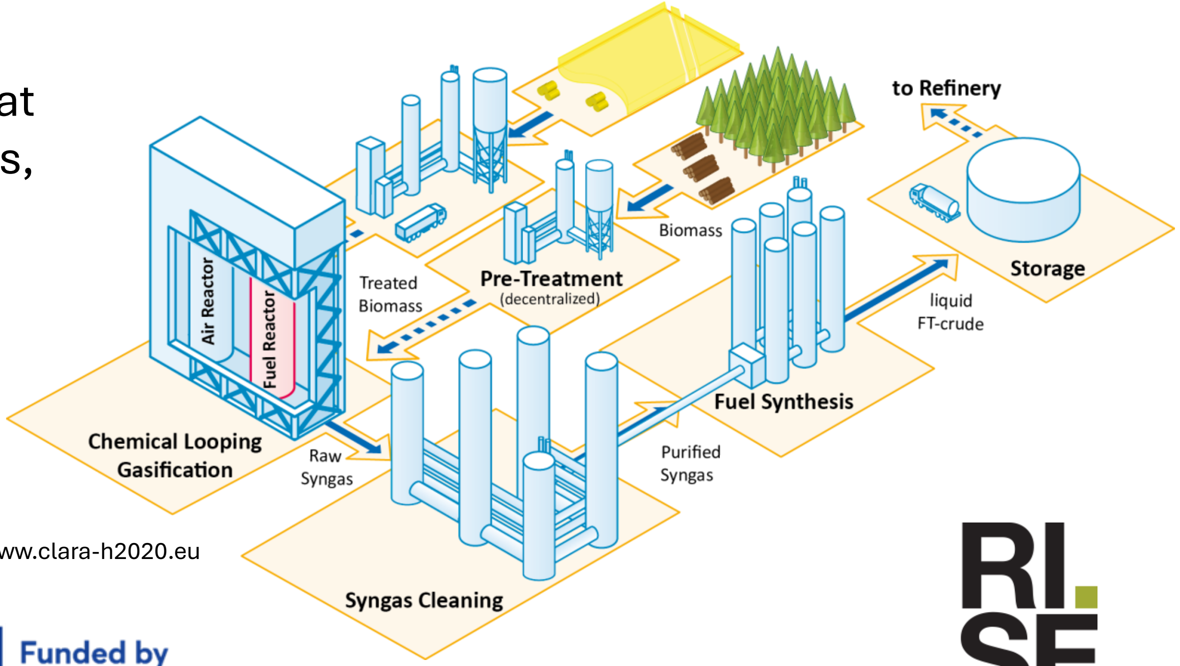
Chemical looping gasification

- No Nitrogen Dilution Compared to Air Gasification
  → Higher calorific value of the syngas, and less CAPEX and OPEX for syngas cleaning.
  → The produced CO_2 in the syngas is concentrated, meaning that CO_2 can be removed with low energy penalty

- No Need for Pure Oxygen
  → No ASU → Less energy penalty and CAPEX, and higher energy efficient

- The oxygen carrier promotes uniform heat distribution and reduces local hotspots, enhancing overall reaction stability.



CLARA H2020 “CHEMICAL LOOPING GASIFICATION FOR SUSTAINABLE PRODUCTION OF BIOFUEL”, www.clara-h2020.eu

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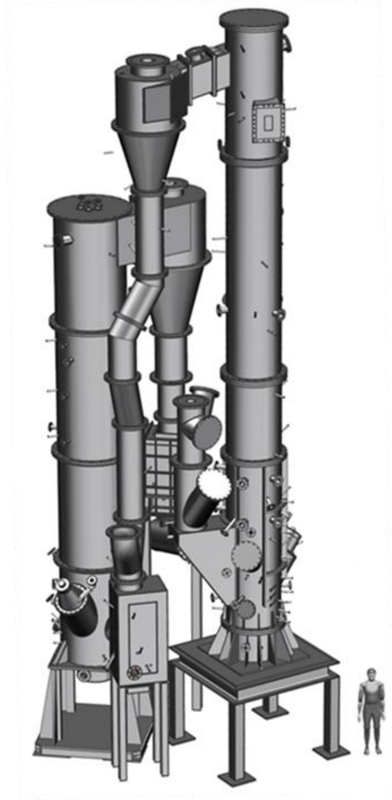
Chemical looping gasification

- Improved Syngas Quality
  - CLG typically produces syngas with a higher H_2/CO ratio,
    - desirable for: Fischer–Tropsch synthesis, Methanol production, Hydrogen generation, etc.
  - Lower Tar and Pollutant Formation
    - The presence of oxygen carriers promotes tar cracking and reforming reactions → Lower tar content and reduced sulfur and nitrogen pollutants
    - This simplifies downstream gas cleaning systems and lowers operational costs.

- Autothermal Operation
  - The process is self-sustaining in heat balance:
    - The oxidation of the metal oxide (in the air reactor) generates heat.
    - That heat is transferred to the fuel reactor (endothermic), maintaining desired temperatures without external fuel combustion.


1 MW unit at TU Darmstadt

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Chemical looping gasification

- Higher Carbon Conversion, syngas yield and Fuel Flexibility
    - CLG provides a more controlled oxidation environment, improving:
        - Carbon conversion efficiency (less unreacted char)
        - Syngas yield (less unreacted char and tar)
        - Fuel flexibility, allowing the use of difficult biomass, or waste-derived fuels as feedstock

Technology	Gasifying Agent	Cold Gas Efficiency (CGE)	Carbon Conversion	Overall Energy Efficiency
Air Gasification	Air	55–70%	85–95%	50–60%
Steam Gasification	Steam	60–75%	85–98%	55–65%
Oxygen Gasification	O_2	70–80%	95–99%	60–70%
Chemical Looping Gasification (CLG)	Metal oxide + Steam	**80–90%**	**98–100%**	**70–85%**

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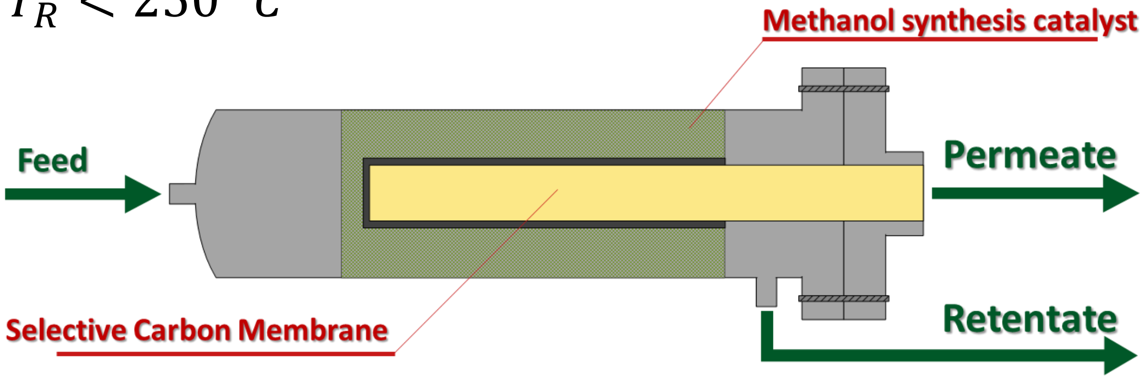
Methanol synthesis via membrane reactors

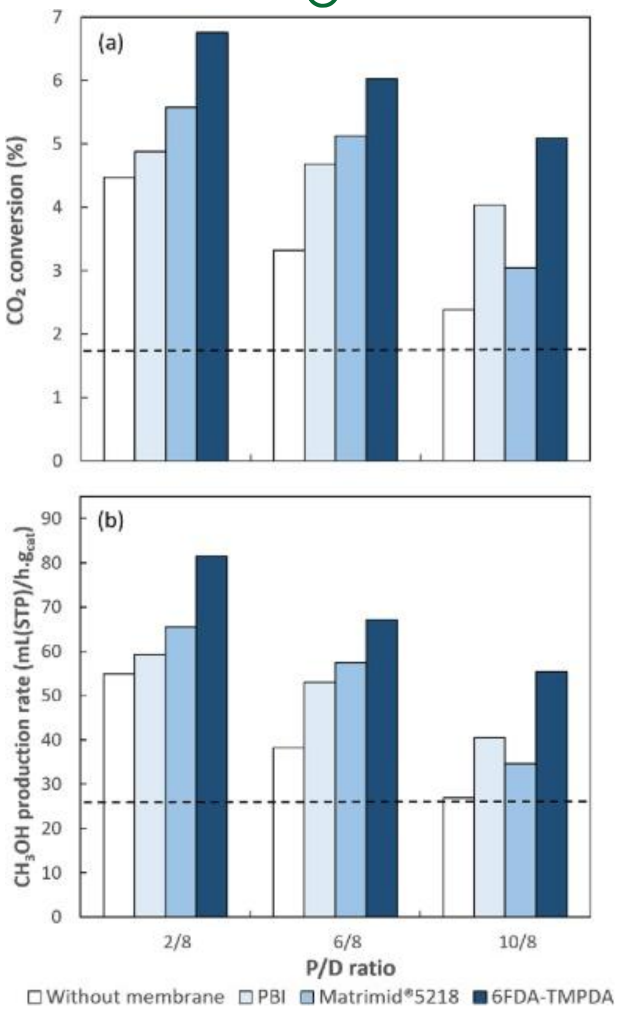
The methanol synthesis is an equilibrium system:

$$CO + 2\,H_2 \Leftrightarrow CH_3OH \qquad \Delta H = -90.7 \;\; kJ/mol$$
$$CO_2 + H_2 \Leftrightarrow CO + H_2O \qquad \Delta H = 41.19 \;\; kJ/mol$$
$$CO_2 + 3\,H_2 \Leftrightarrow CH_3OH + H_2O \qquad \Delta H = -49.51 \;\; kJ/mol$$

Commercial $Cu/ZnO/Al_2O_3$ catalyst

$$P_R < 40\ bar$$
$$T_R < 250\ °C$$





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Thank you for your attention

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