The case of green methanol in South Africa

Zama Duma

Building a Green Methanol Corridor in South Africa
30 November 2023

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

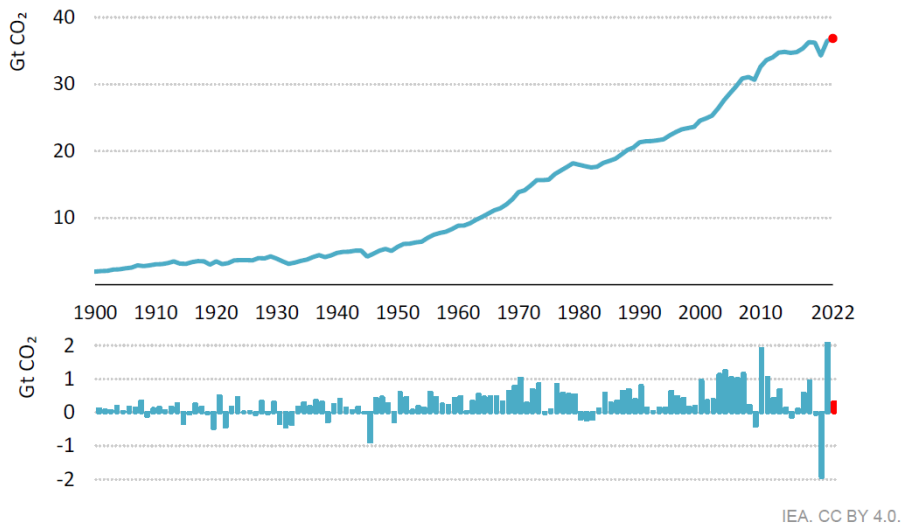
CSIR
Touching lives through innovation

Outline

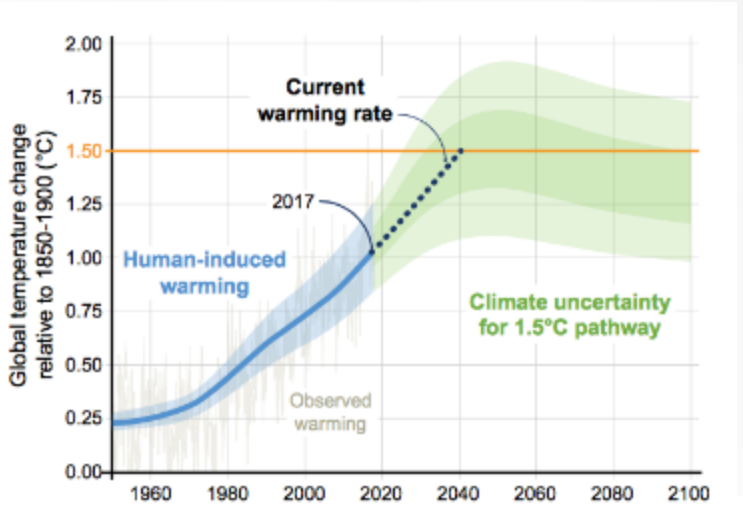
- Background
- Green methanol
  - Justification
  - Demand, supply and applications
  - Demonstrations
  - Status quo and trade statistics in South Africa
  - Early-stage trials at the CSIR
- Biogenic and Anthropogenic CCU
- Conclusions and recommendations
- Acknowledgements

Background

- An increase in **industrialisation** has culminated in unprecedented economic growth as well an increase in **greenhouse gas (GHG) emissions** from **fossil fuel combustion** and **cement production**;
- Greenhouse gases emissions (CO_2, CH_4, NO_x and H_2O) have sparked **global warming**, ocean acidification and **climate change**;
- **Carbon dioxide (CO_2)** is the most prominent greenhouse gas, technologies are required for its **capture**, **utilisation** and **storage (CCUS)**.



Global annual CO_2 emissions (IEA, 2023)



Anthropogenic warming compared to pre-industrial levels (NASA, 2023)

CSIR
Touching lives through innovation

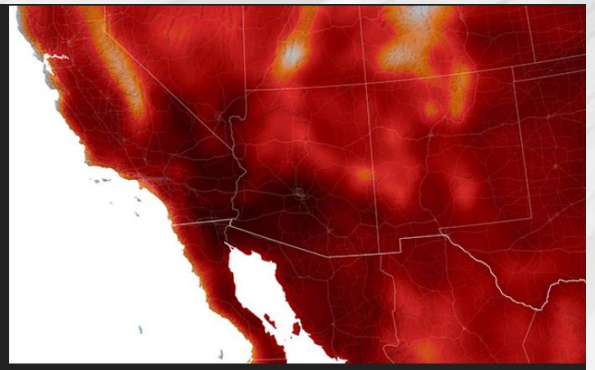
Background

Extreme Events Are Increasing in Frequency

The number of record high temperature events in the United States has been increasing, while the number of record low temperature events has been decreasing, since 1950. The U.S. has also witnessed increasing numbers of intense rainfall events.[12] Image credit: Régine Fabri, CC BY-SA 4.0, via Wikimedia Commons

July 2023 hottest month on record as heatwaves scorch Earth

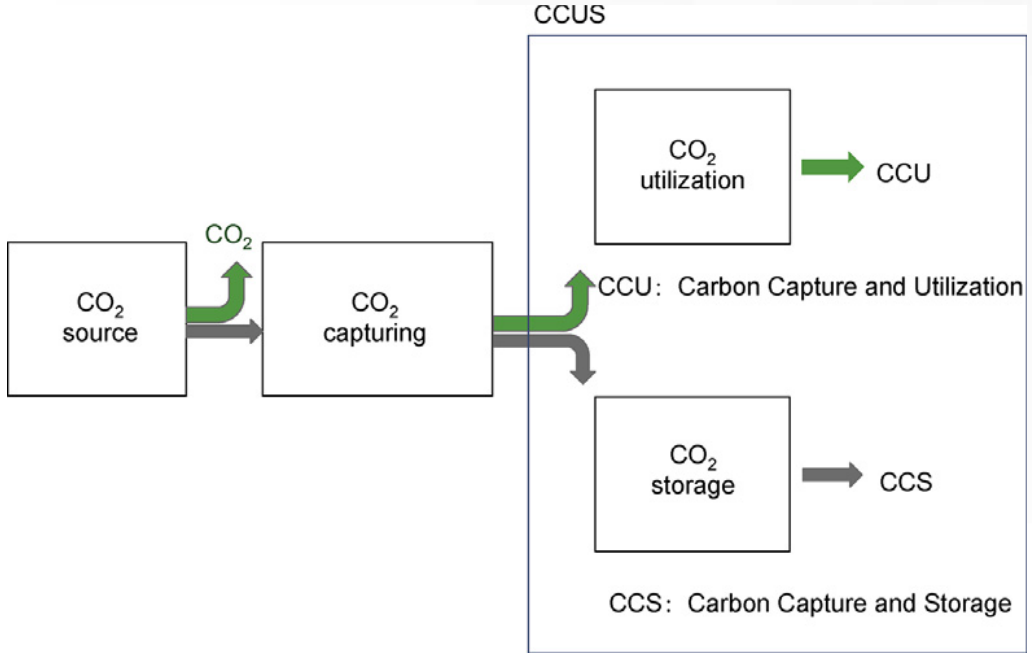
Global average temperature for July confirmed to be highest on record of any month, says Copernicus Climate Change Service.



Source: NASA (2023), Al Jazeera (2023)

Carbon capture, utilisation and storage

- Carbon Capture and Utilisation (CCU) is a viable alternative for the abatement of CO_2 emissions
- Sustainable conversion of anthropogenic carbon emission to value-added chemicals
- Paradigm shift to view CO_2 as a valuable resource i.e., **CO_2-to-methanol (Green methanol)**
- Promises to form closed, circular carbon cycle



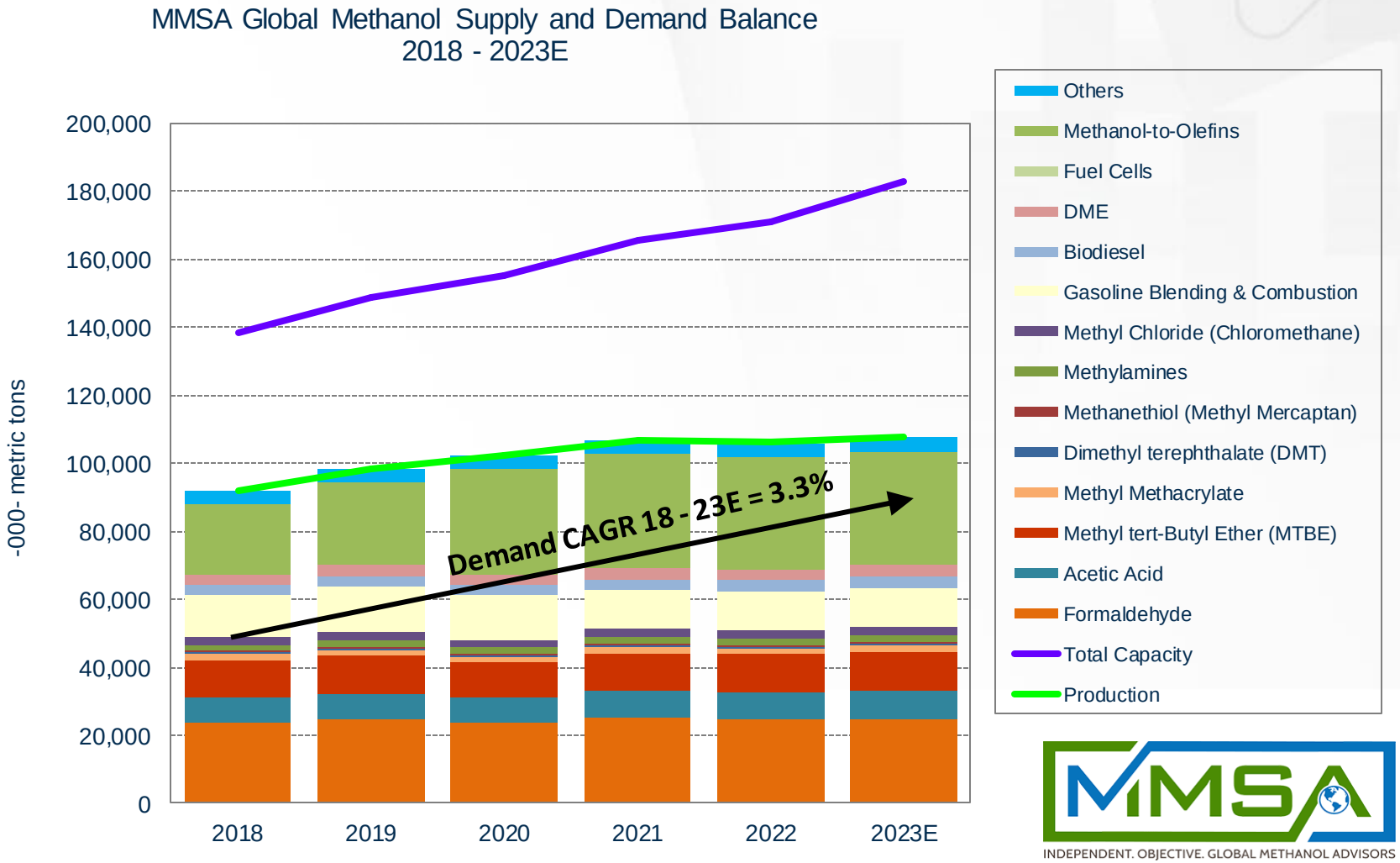
Alper *et al* (2017); Rodin *et al* (2020)

CSIR
Touching lives through innovation

Why CO_2 conversion to green Methanol?

1. Methanol is one of the Top 5 global chemicals – green chemical
2. Energy carrier for maritime industry
3. Export pathway for hydrogen
4. Synthetic fuel feedstock (Methanol-to-Olefins; Biodiesel; etc.)
5. MeOH fuel cells
6. Cooking applications

Methanol supply, demand and applications



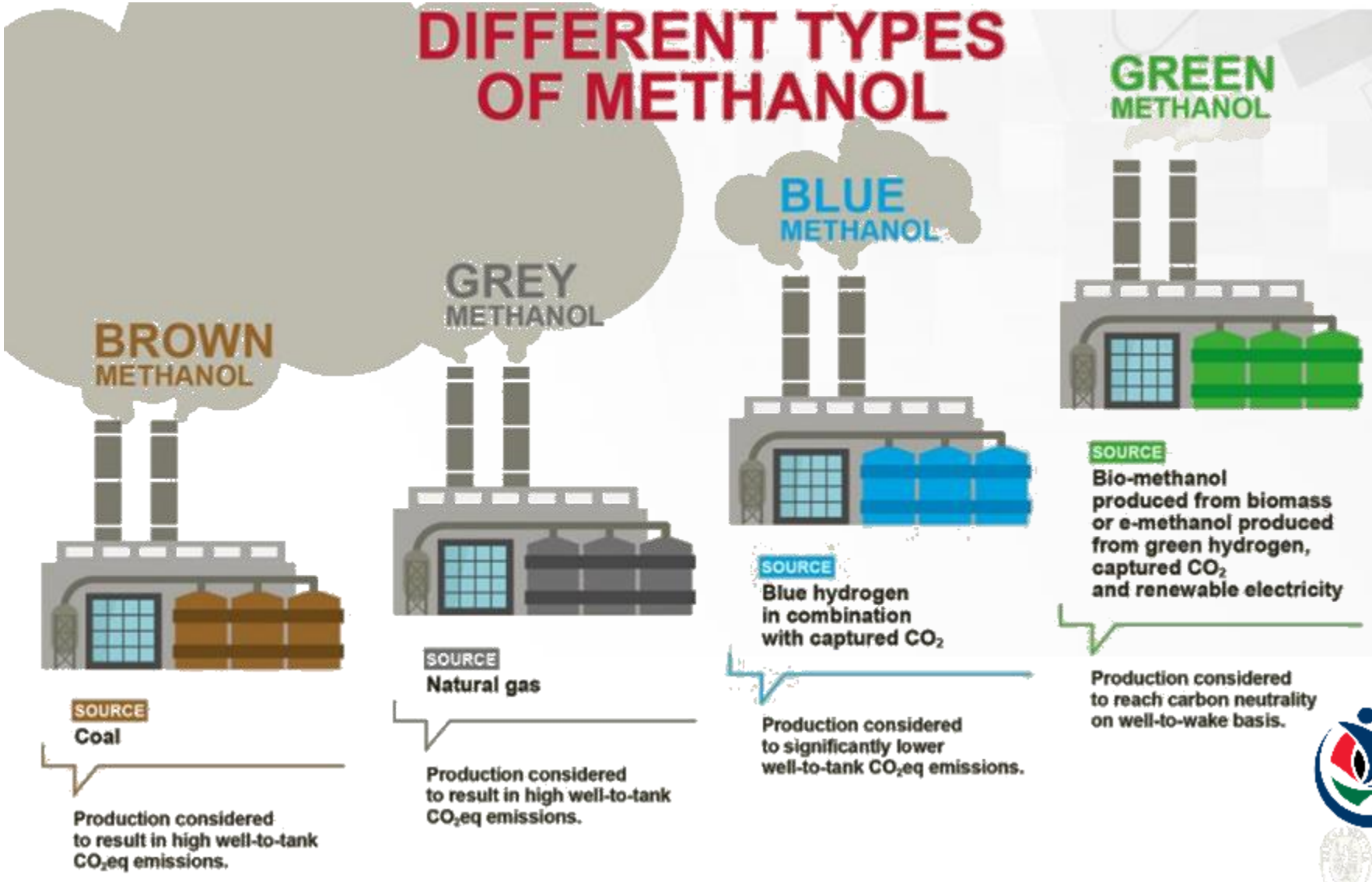
On average 110 million metric tons produced annually

Source: The Methanol Institute

MMSA
INDEPENDENT. OBJECTIVE. GLOBAL METHANOL ADVISORS

CSIR
Touching lives through innovation

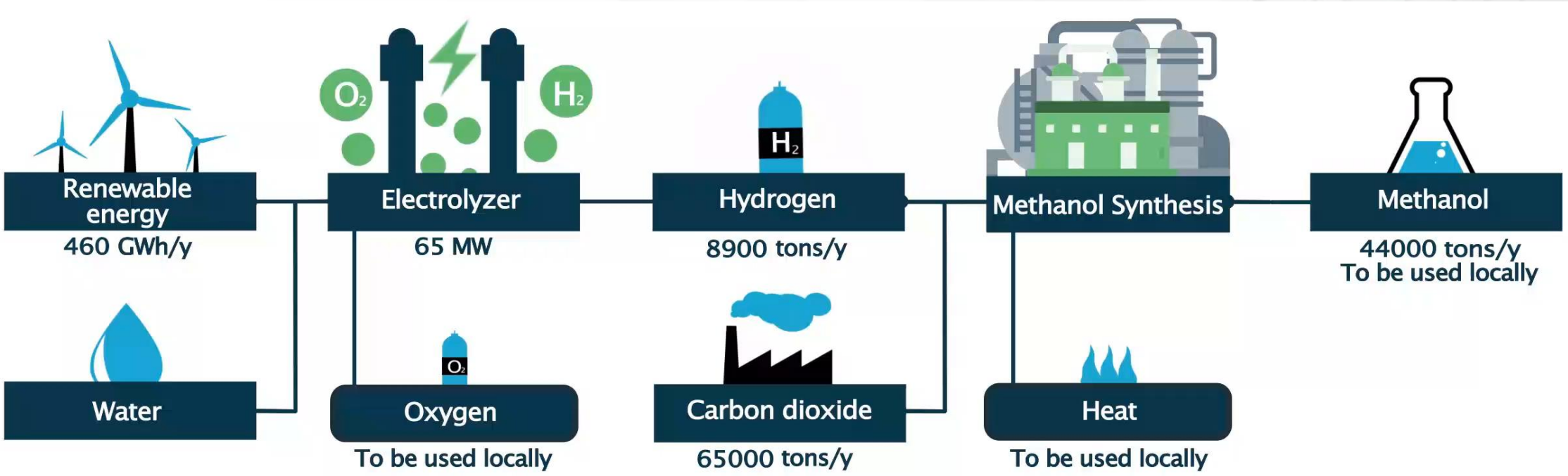
Different types of Methanol



Source: Bureau Veritas

CSIR
Touching lives through Innovation

Why CO_2 conversion to green Methanol?



Source:

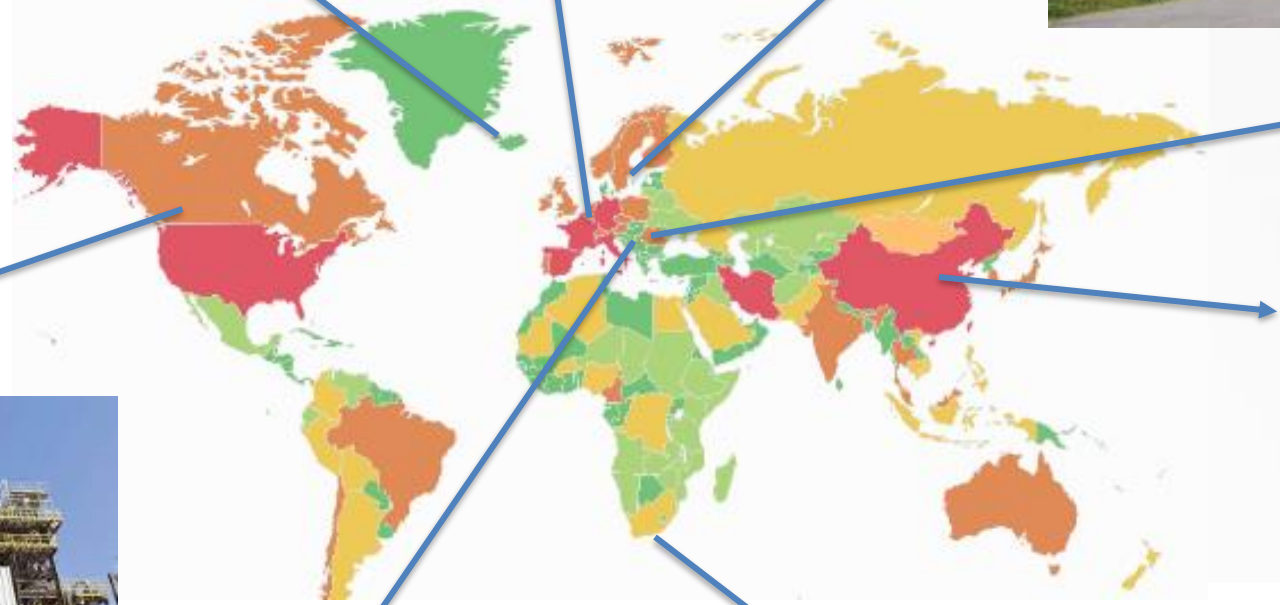
CO_2 to green MeOH demonstrations in the world

Carbon Recycling international (CRI) methanol production plant (Iceland)

BioMCN – The Netherlands (from biogas)

Chemrec – Sweden (from forest waste)

EU funded MefCO_2 project brings together 9 partners throughout Europe



Enerkem Canada (from municipal solid waste)

Shunli commercial plant, China (110,000 tones/year of methanol commissioned in late 2022)

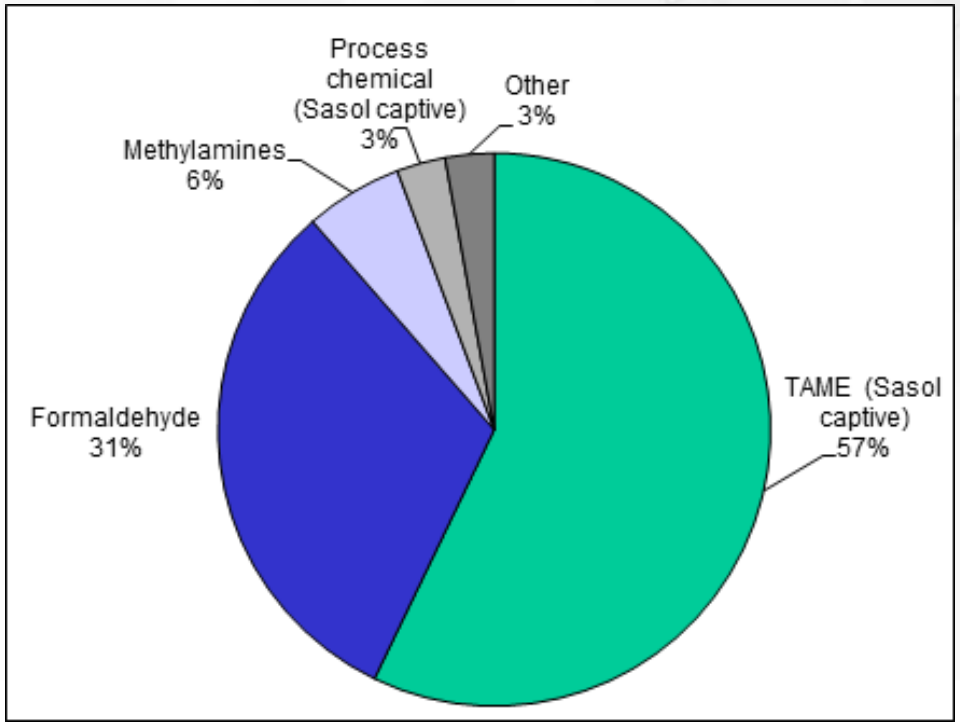
Belgium: North CCU-Hub Roadmap

Lab-scale demonstration (CSIR)

Methanol in South Africa

- A total of 140 000 tons of methanol is consumed per annum in South Africa
- SASOL is sole producer of methanol (Grey, from natural gas)
- Sasol consumes 60% of the methanol they produce

User	Area	Consumption of Methanol (Metric tons per annum) 2019
Formaldehyde Producers	-	**44 000**
Wood Chemicals	Piet Retief	40 500
Resinkem	Umbogintwini	3 500
TAME Producer	**-**	**80 000**
Sasol	Sasolburg	80 000
Captive as process chemical	-	**4 000**
Sasol	Secunda	4 000
Methylamine Producer	-	**8 000**
African Amines	Newcastle	8 000
Other identified users (including paint strippers, fuel & heating)		**4 000**
Total		**140 000**

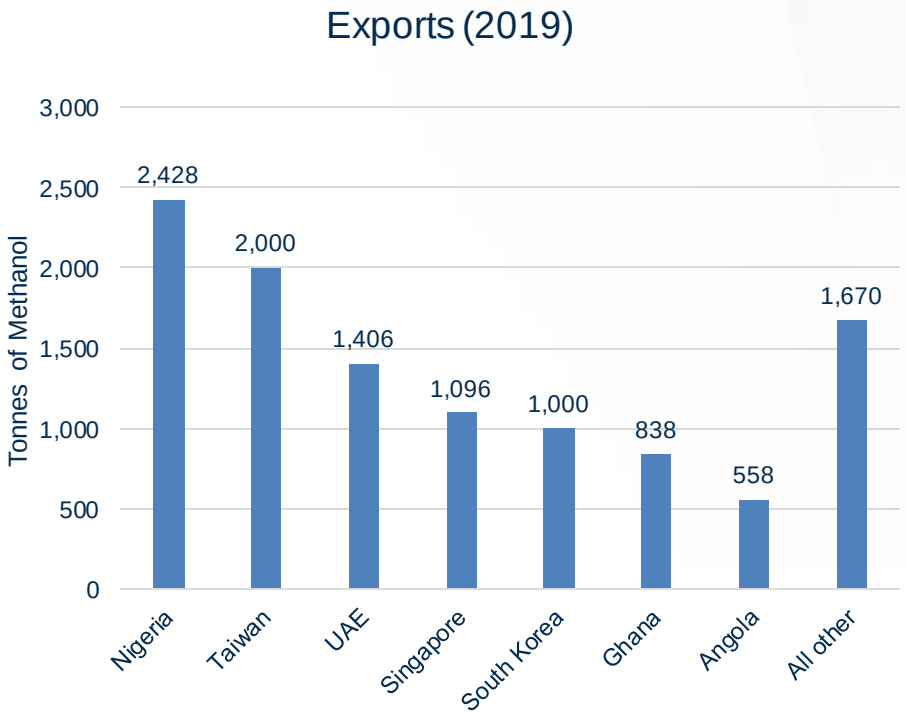


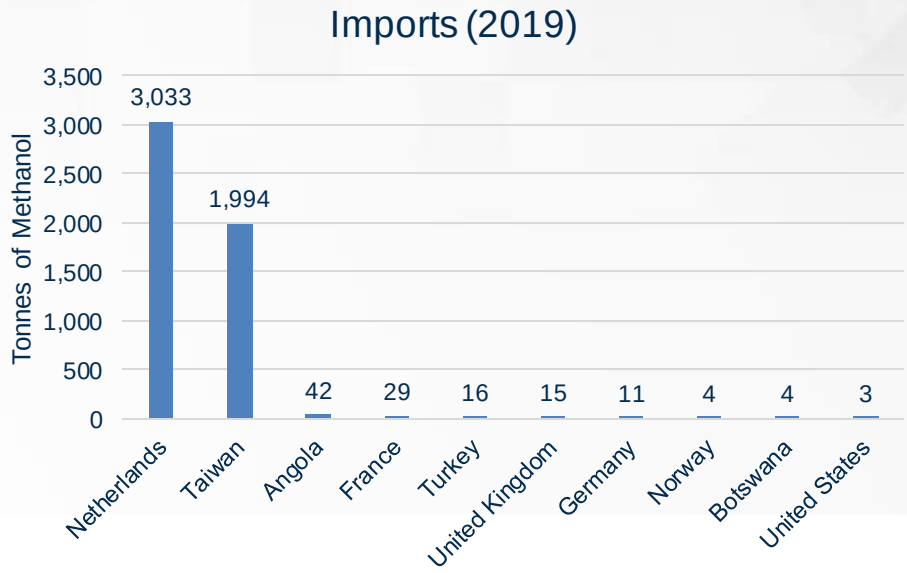
Source: SARS, CSIR Market Study

CSIR
Touching lives through innovation

Trade statistics

- About 11 000 tons exported in 2019 worth 65 million Rand
- Imports of 5 000 tons amounted to 26 million Rand
- Methanol traded amounts to 11,5% of domestic production (140 000 tons)





Source: SARS, CSIR Market Study

Trade statistics

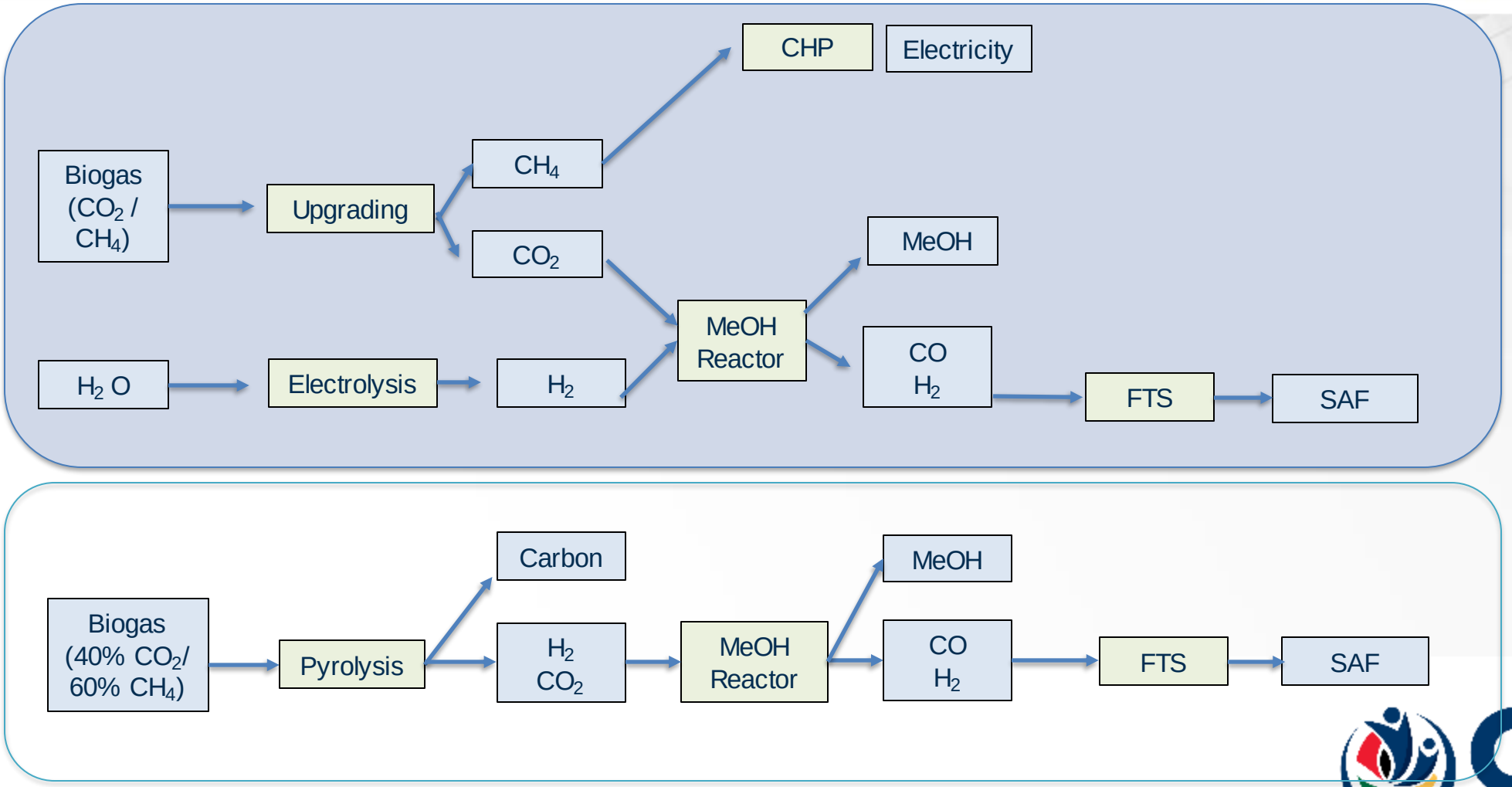
- Noticeable decrease in methanol trade:
- African Explosives and Chemical Industries (AECI) methanol plant with 20 000 tons/y closed down in late 1990s
- Commensurate with state economy?

Source: SARS, CSIR Market Study

Techno-economic studies of the methanol project

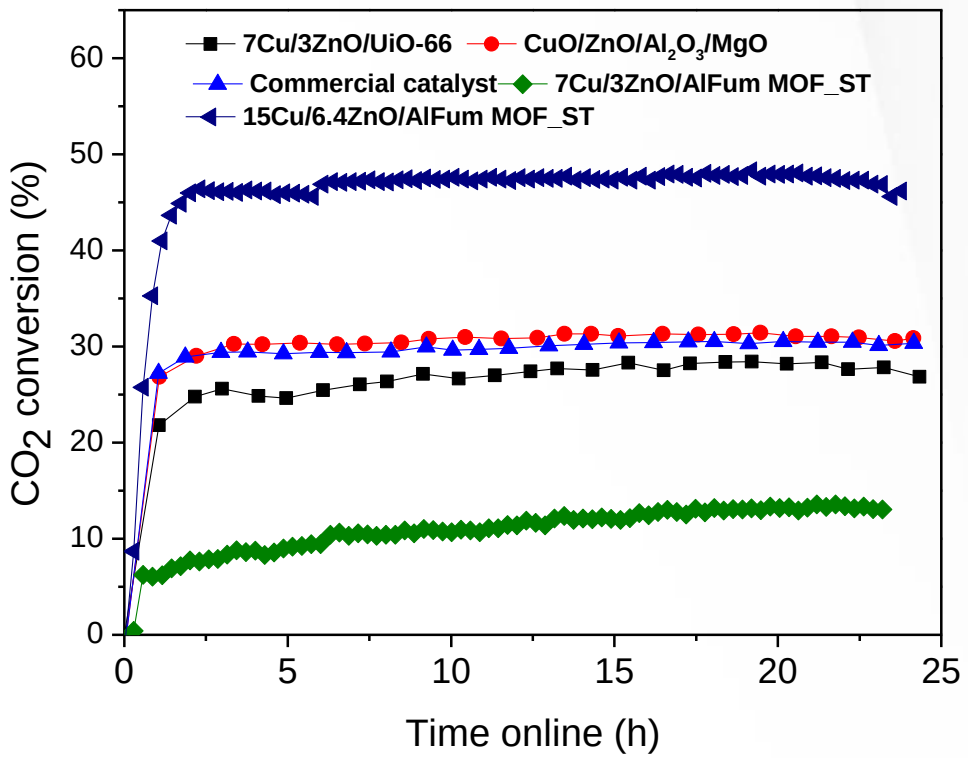
- **Catalytic conversion of CO_2 to methanol Model assumptions**
- Methanol plant capacity: 8500 kg/hr
- Three plants in system (CO_2 capture, H_2 production, methanol production).
- A 20-year equipment depreciation
- Methanol price = 450 euros/ton
- Catalyst cost = 95 240 euros/ton
- CO_2 and H_2 conversion = 90%

Biogenic CCU to methanol at CSIR

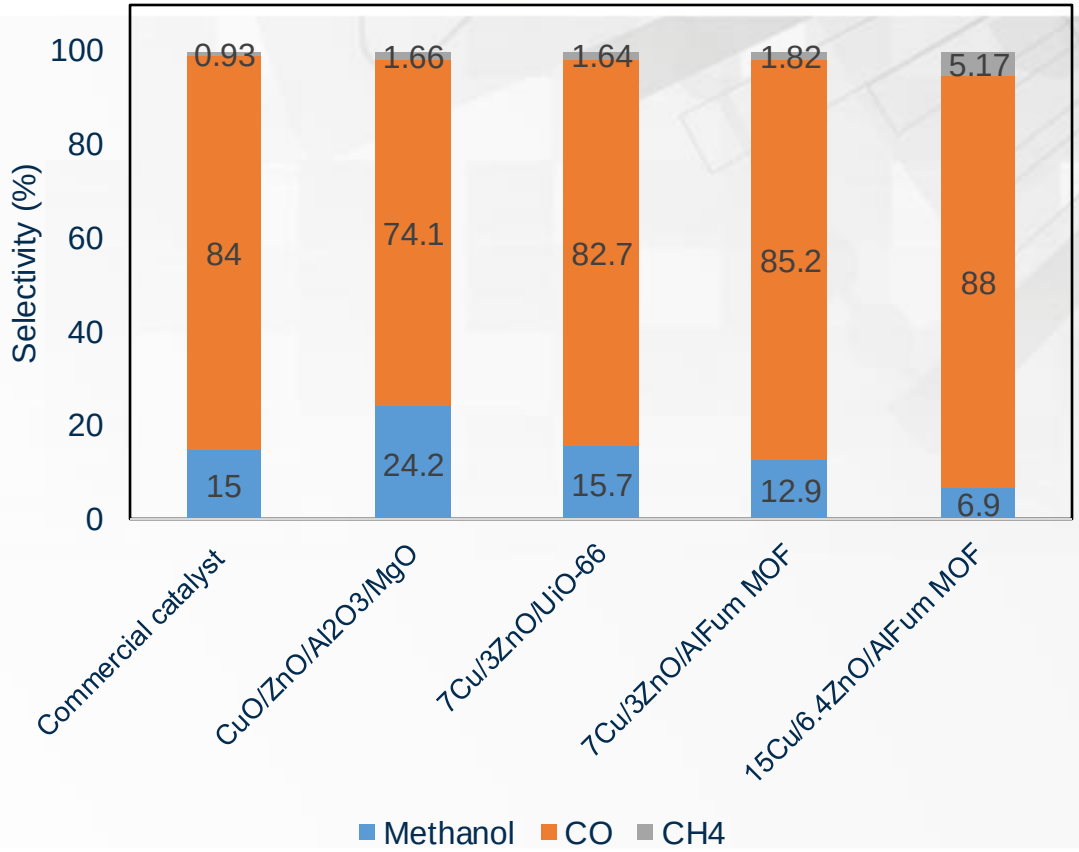


CSIR
Touching lives through innovation

CO_2 valorisation to green methanol



CO_2 conversions. T = 230 ° C; P = 50 bar; $Q_{v,0}$ = 40 ml.min^{-1}; GHSV = 10 000 h^{-1}; H_2/CO_2 = 3:1; 24 hours.



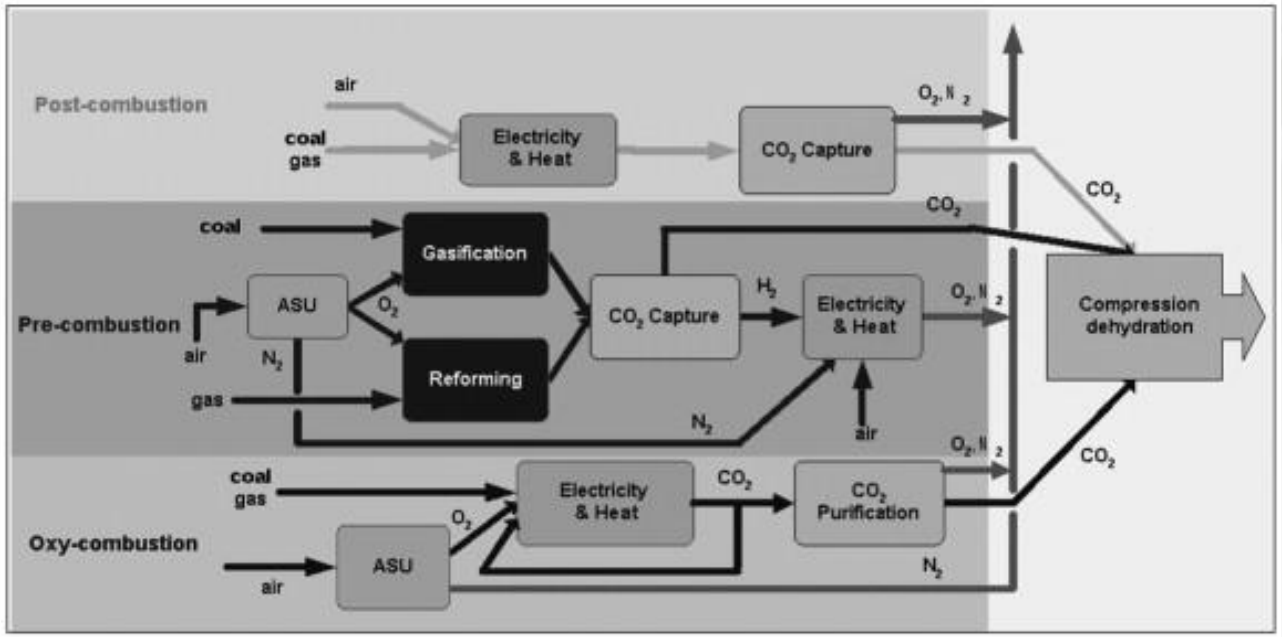
- CO_2 conversions range from 10-46% under industrially relevant catalytic evaluation conditions
- Catalysts exhibit high selectivity towards CO due to endothermic competing RWGS reaction
- Methane formation also observed due to the Sabatier reaction

CSIR Touching lives through innovation

Duma *et al*, Catalysts 2022, 12, 1104; Duma *et al*, Catalysts 2022, 12, **401**

Anthropogenic CCU vs. Biogenic CCU

- Capture of CO_2 from fossil fuel-based power plants.
- Pre-, post- and oxy-fuel combustion capture.
- Post-combustion: Capture of CO_2 from flue gas
- Pre-combustion: Capture of CO_2 from syngas after reforming or gasification
- Oxy-combustion: Combustion in O_2 reach conditions (Separation from H_2O)
- Benefits: **Abatement of CO_2 emissions**
- Limitations: **Decreased plant efficiency due regeneration of CO_2 sorbents, increased operational and electricity costs; low partial pressures of CO_2 in streams (5-15%)**



Kanniche *et al.* (2020); Madejski *et al.* (2022)

CSIR
Touching lives through innovation

Biogenic CCU vs. Anthropogenic CCU

- Relatively concentrated streams of biogenic CO_2 (Compared to 15-20% in Cement and Steel production processes)

Biogas upgrading (Up to 40% v/v CO_2)

- Anaerobic digestion or thermal treatment of biomass
- Gaseous fuel: 60% biomethane and 40% CO_2

Bioethanol production (Up to 100% v/v CO_2)

- CO_2 from liquid fermentation (Wine and beer brewing Food and Beverage industries)
- CO_2 recycled for carbonation and protection of liquor from O_2

Biomass combustion (Up to 8% v/v CO_2)

- CO_2 from solid biofuels
- Small concentration of CO_2, economically infeasible

Rodin *et al.* (2020); Enebe *et al.* (2023)

Conclusions and Recommendations

- In South Africa “Grey” methanol is currently produced at scale
- South Africa is a net exporter of methanol (2019)
- Direct CO_2 hydrogenation to green methanol is viable for scale-up
- Waste, anthropogenic and **biogenic** CO_2 will be the carbon sources
- Methanol will be one of the important **green chemicals**
- **Catalyst development** and optimization is highly relevant
- Reliable supply of **gigatons of low-carbon hydrogen** is mandatory

Acknowledgements

HySA Infrastructure
Hydrogen South Africa

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

CSIR
Touching lives through innovation

NWU®

AHK
Deutsche Industrie- und Handels-kammer für das südliche Afrika
Southern African-German Chamber of Commerce and Industry

CSIR
Touching lives through innovation

References

The Methanol Institute, https://www.methanol.org/, accessed in November 2023.

Different types of methanol, https://marine-offshore.bureauveritas.com/insight/infographics/different-types-methanol, accessed in November 2023.

North-C-Methanol, North CCU Hub, https://northccuhub.eu/north-c-methanol/, accessed in November 2023.

Masukume, M. Market Study on methanol in South Africa, 2019.

Duma, Z. G., et al. (2022). "Thermocatalytic Hydrogenation of CO2 to Methanol Using Cu-ZnO Bimetallic Catalysts Supported on Metal-Organic Frameworks." Catalysts **12**(4): 401.

Duma, Z. G., et al. (2022). "Towards High CO2 Conversions Using Cu/Zn Catalysts Supported on Aluminum Fumarate Metal-Organic Framework for Methanol Synthesis." Catalysts **12**(10): 1104.

Enebe, N. L., et al. (2023). "Biogas and Syngas Production from Sewage Sludge: A Sustainable Source of Energy Generation." Methane **2**(2): 192-217.

Rodin, V., et al. (2020). "Assessing the potential of carbon dioxide valorisation in Europe with focus on biogenic CO2." Journal of CO2 Utilization **41**: 101219.

Alper, E. and O. Yuksel Orhan (2017). "CO2 utilization: Developments in conversion processes." Petroleum **3**(1): 109-126

https://climate.nasa.gov/news/2878/a-degree-of-concern-why-global-temperatures-matter/ accessed in August 2023

https://www.aljazeera.com/news/2023/8/8/july-2023-hottest-month-on-record-as-heatwaves-scorch-earth accessed in August 2023

https://climate.nasa.gov/evidence/ accessed in August 2023

Thank you