ADVANTAGES & DISADVANTAGES OF CCU FUELS FROM A LIFE CYCLE ASSESSMENT PERSPECTIVE

09.06.2022 I STEFANIE TROY

CCS, CCU, CCUS - DEFINITION

CCS – Carbon Capture and Storage is the process of capturing CO_2 before it enters the atmosphere, transporting it, and storing it for centuries or millennia.

CCU – Carbon Capture and Utilisation refers to a process whereby captured CO_2 is used as a material in another industrial process. CO_2 can either be used directly or processed into new products.

CCUS – Carbon Capture, Utilisation and Storage is used as an umbrella term for the technology routes CCS und CCU but also as a synonym for CCU.

WHY CCU?

- CCU treats CO_2 as a valuable resource. It is used as a feedstock in different applications, for example in the chemical industry or the production of fuels (i.e. methanol, DME, OME).
- The idea is to capture CO_2 from a primary production process to then re-use it in a secondary process – potentially even many times in a closed loop process. In theory this avoids the production of ‘new’ CO_2 in the secondary process, therefore opening up the potential for reducing the Global Warming Potential impact.
- A Life Cycle Assessment can test this theory by looking at the broader picture, taken into account all relevant changes to the processes.

LIFE CYCLE ASSESSMENT

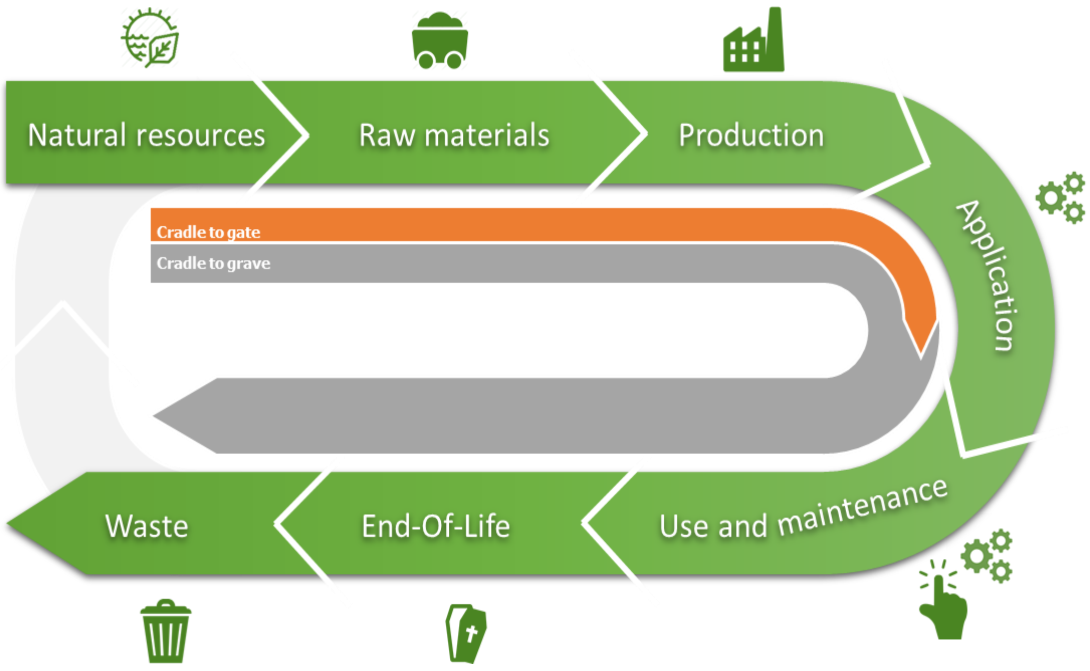
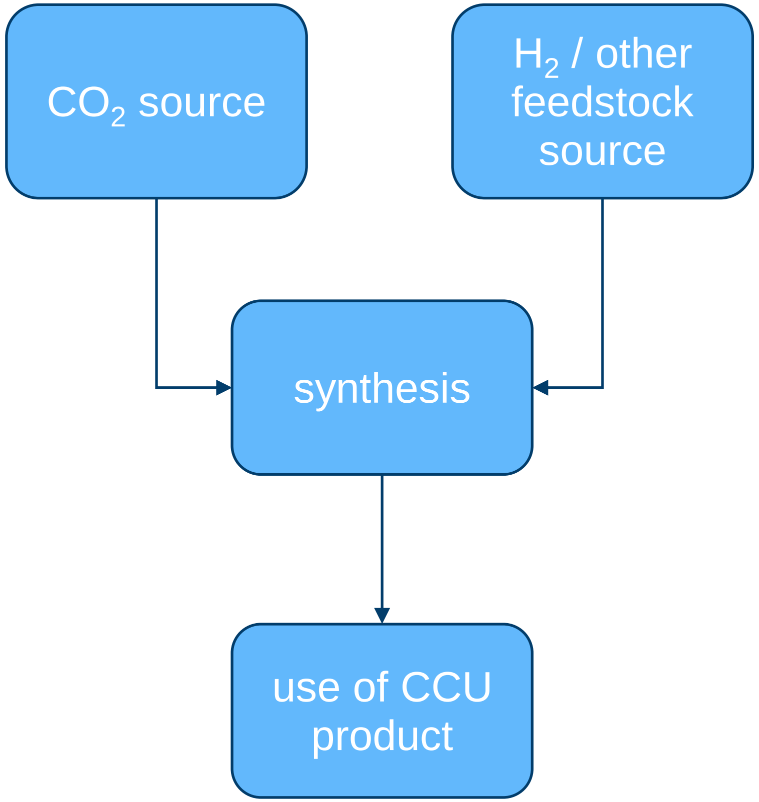


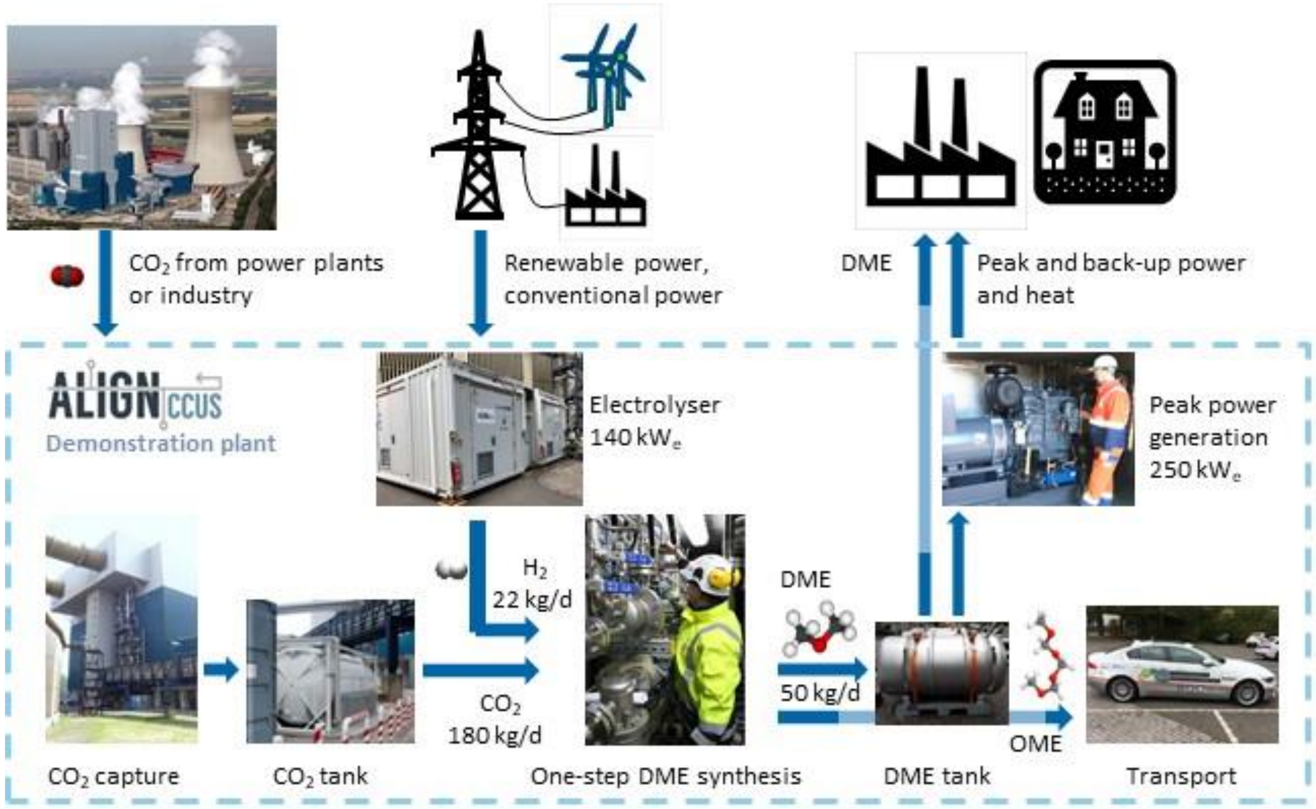
Fig.: Principle of cradle-to-gate and cradle-to-grave system

- Goal and Scope Definition
  - Determination of scope and system boundaries
- Life Cycle Inventory
  - Data collection, modeling & analysis
- Impact Assessment
  - Analysis of inputs and outputs and their environmental effects
- Interpretation
  - Draw conclusions

Functional Unit: quantified description of the performance requirements that the product system fulfils. Examples: 1l diesel, 1 car, 1 km driven, 1kWh.

LCA EXAMPLE: THE ALIGN-CCUS PROJECT





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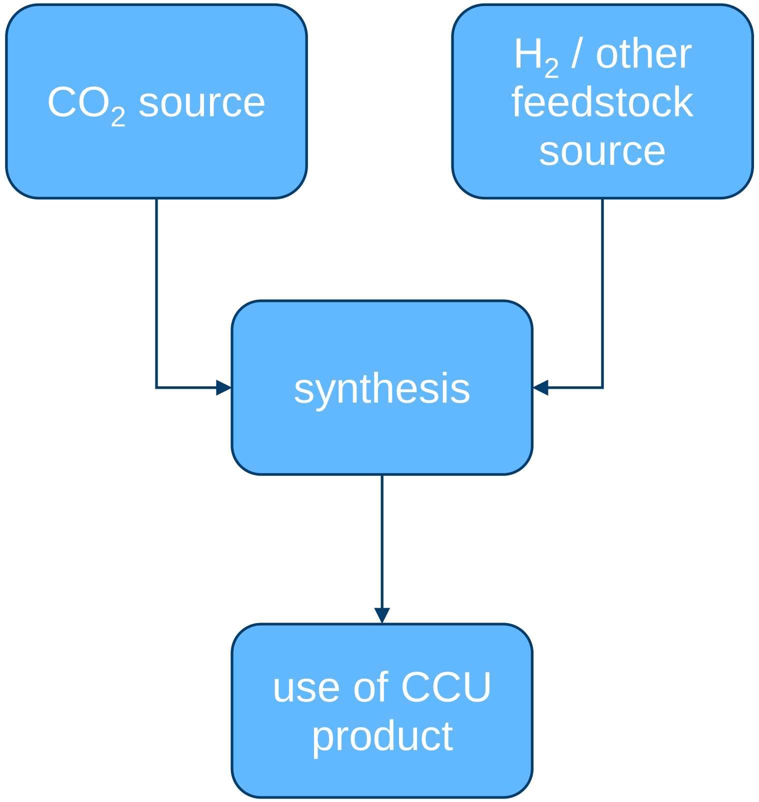
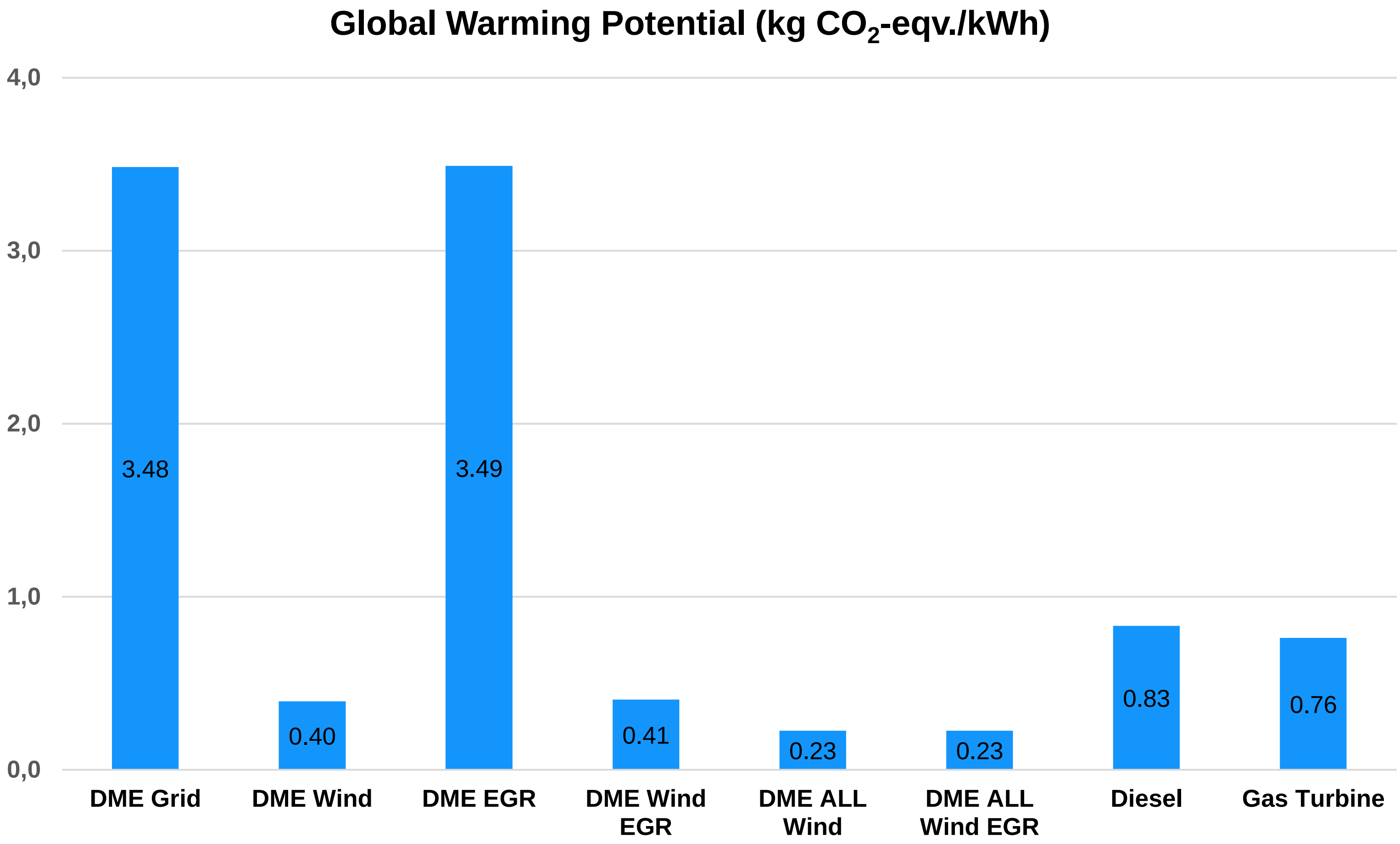


- CO_2 source
  - impact on production of primary product: efficiency, scaling, changes to process, transport, storage…
- H_2 / other feedstock source
  - fuel sector: H_2 = energy!!!, depending on CCU product (i.e. chemical industry) other intermediates, transport, storage,…
- synthesis
  - synthesis unit, energy demand, Co-products (i.e. steam), waste, transport, storage,…
- Use of CCU product
  - advantages or disadvantages compared to original product? i.e. fuel sector: efficiency changes, different emissions, different handling (i.e. temperature for phase changes,…),…

RESULTS OF ALIGN-CCUS – DME FOR PEAK POWER



Grid: electricity supply from German electricity grid

Wind: electrolyser supplied with wind power

ALL Wind: complete synthesis route supplied with wind power

EGR: Exhaust Gas Recirculation to improve engine performance

Diesel: diesel powered engine as peak power generator as benchmark

Gas Turbine: electricity production using a gas turbine as benchmark

[1]Troy, S., Zapp, P., Kuckshinrichs, W., Peters, R., Weiske, S., Moser, P., Stahl, K., Life Cycle Assessment for Full Chain CCU Demonstration in the Align-CCUS Project –Dimethyl Ether and Polyoxymethylen Dimethyl Ethers Production from CO_2 and its Usages in the Mobility and Electricity Sectors (April 7, 2021). Proceedings of the 15th Greenhouse Gas Control Technologies Conference 15-18 March 2021,

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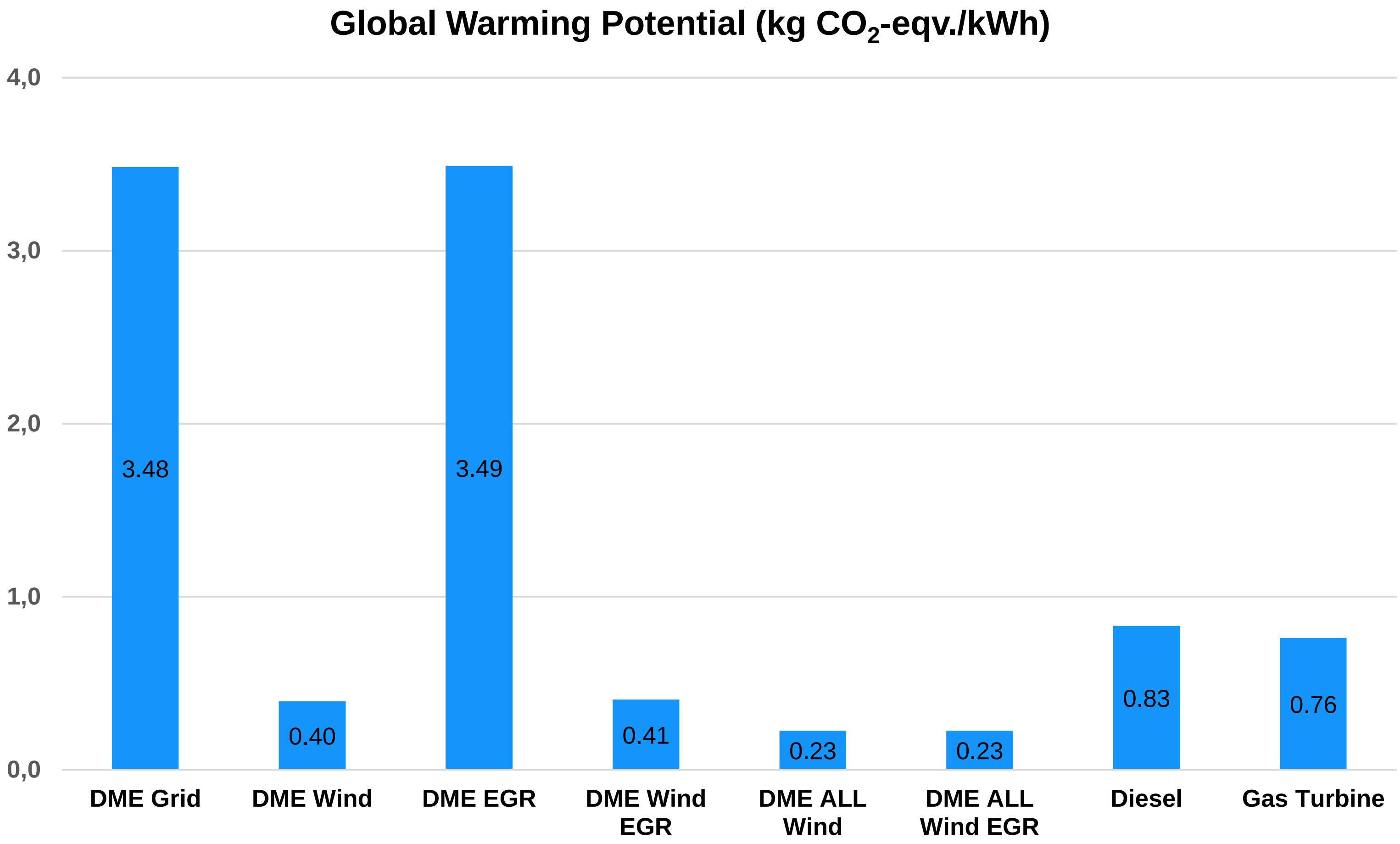

- DME-powered peak electricity using grid electricity for synthesis has an impact 4 times as high as a diesel-powered engine.
- Using wind power for all synthesis processes can enable an impact of 230 g CO_2-eqv./kWh peak electricity.
- Electricity source is defining factor.

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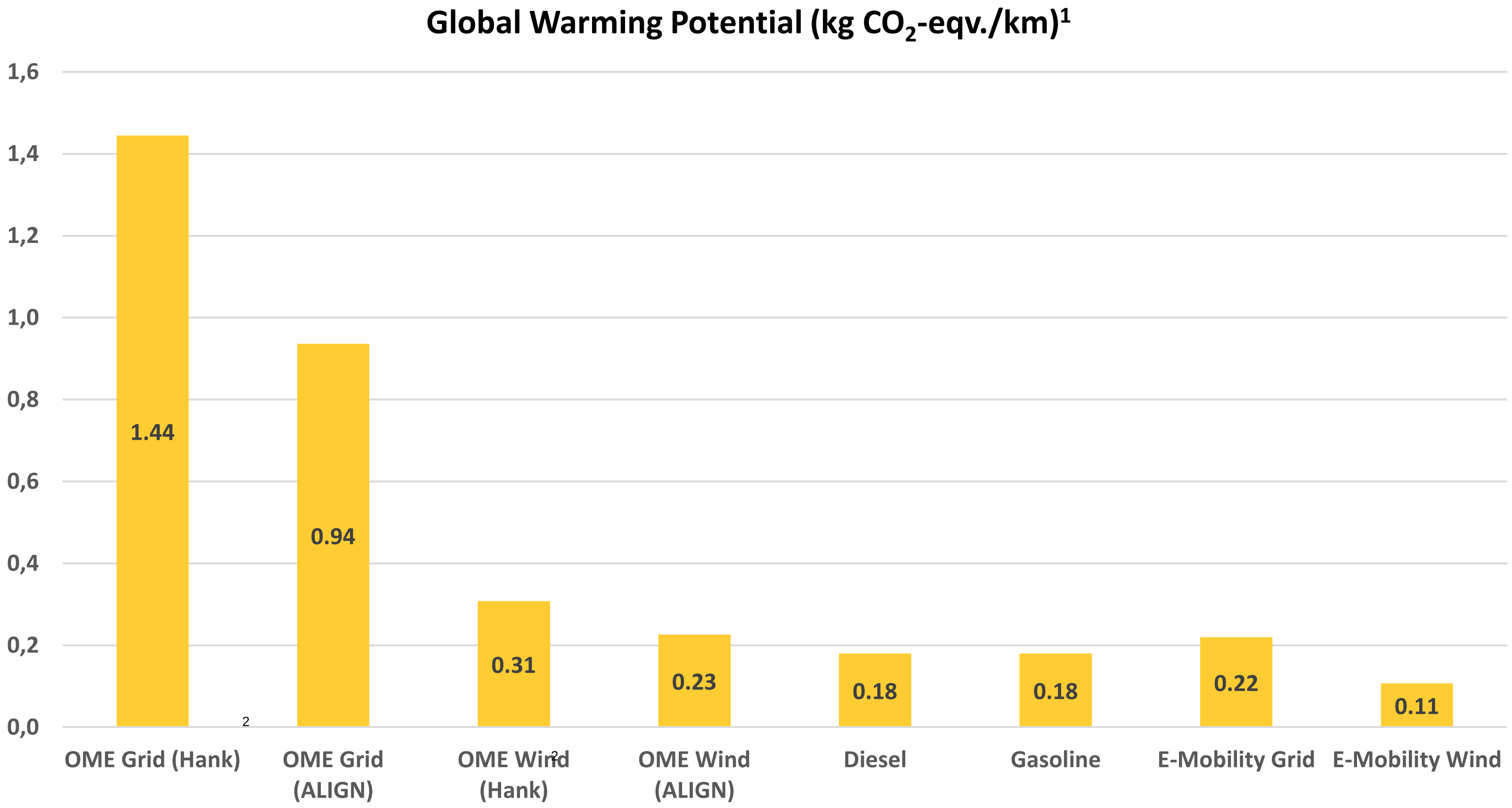
RESULTS OF ALIGN-CCUS – $OME_{3\text{-}5}$ FOR MOBILITY



Grid: electrolyser for synthesis uses German grid electricity

Wind: electrolyser for synthesis uses wind power

Hank: inventory data based on publication by Hank et al.

Align: inventory data based on ALIGN-CCUS project data

Diesel: diesel powered car

Gasoline: gasoline powered car

E-Mobility Grid: battery powered car using German grid electricity

E-Mobility Wind: battery powered car using wind power

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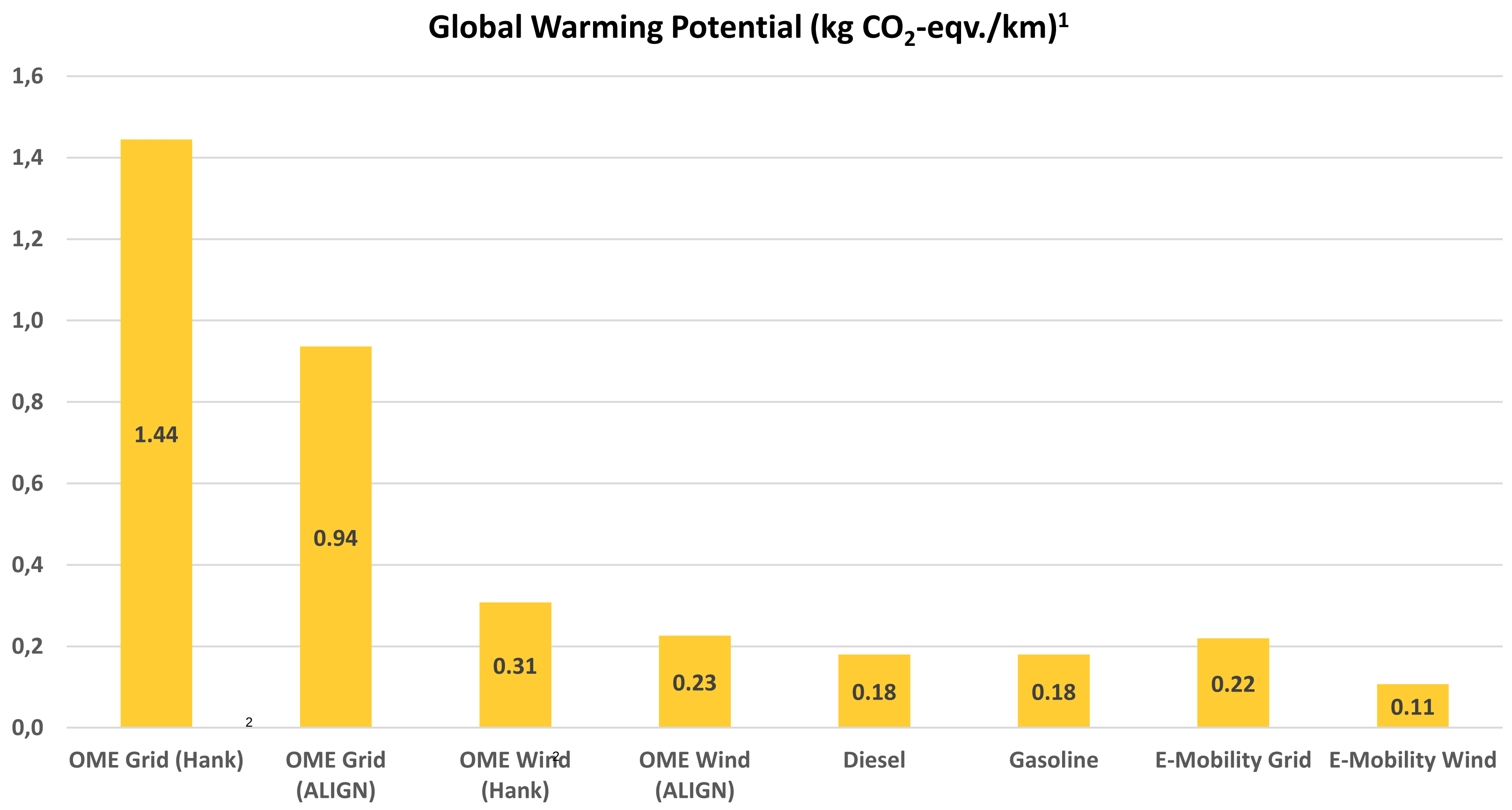

- $OME_{3\text{-}5}$ mobility is very energy intensive. Even if using wind power for electricity supply of synthesis, GWP impact remains higher than benchmark technologies.
- High pressure steam demand raises impact even further.

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SENSITIVE PARAMETERS

Electricity source

- The electricity demand for the investigated CCU application is high: approx. 5.5 kWh per 1 kWh peak power or approx. 1.25 kWh (and an additional 0.32 kWh high pressure steam) per 1 km driven mobility with $OME_{3\text{-}5}$.
- Highest impact due to hydrogen supply.
- Choice of electricity source is crucial, only systems with near 100% renewable energy usage enable GWP reduction scenarios.
- Optimization and efficiency increase by using excess steam within the system or in other applications can improve the overall results.

Further parameters

- There is a potential for soot and NOx reduction at the engine when using $OME_{3\text{-}5}$ or DME, depending on engine optimization measures. This can lead to improvements in other impact categories like Particulate Matter Formation or Photochemical Ozone Creation Potential.
- Efficiency is key at every element of the process chain. Therefore, the exact application and implementation hugely influences the overall results.

THANK YOU FOR YOUR ATTENTION