Renewables to what – insights from an environmental perspective

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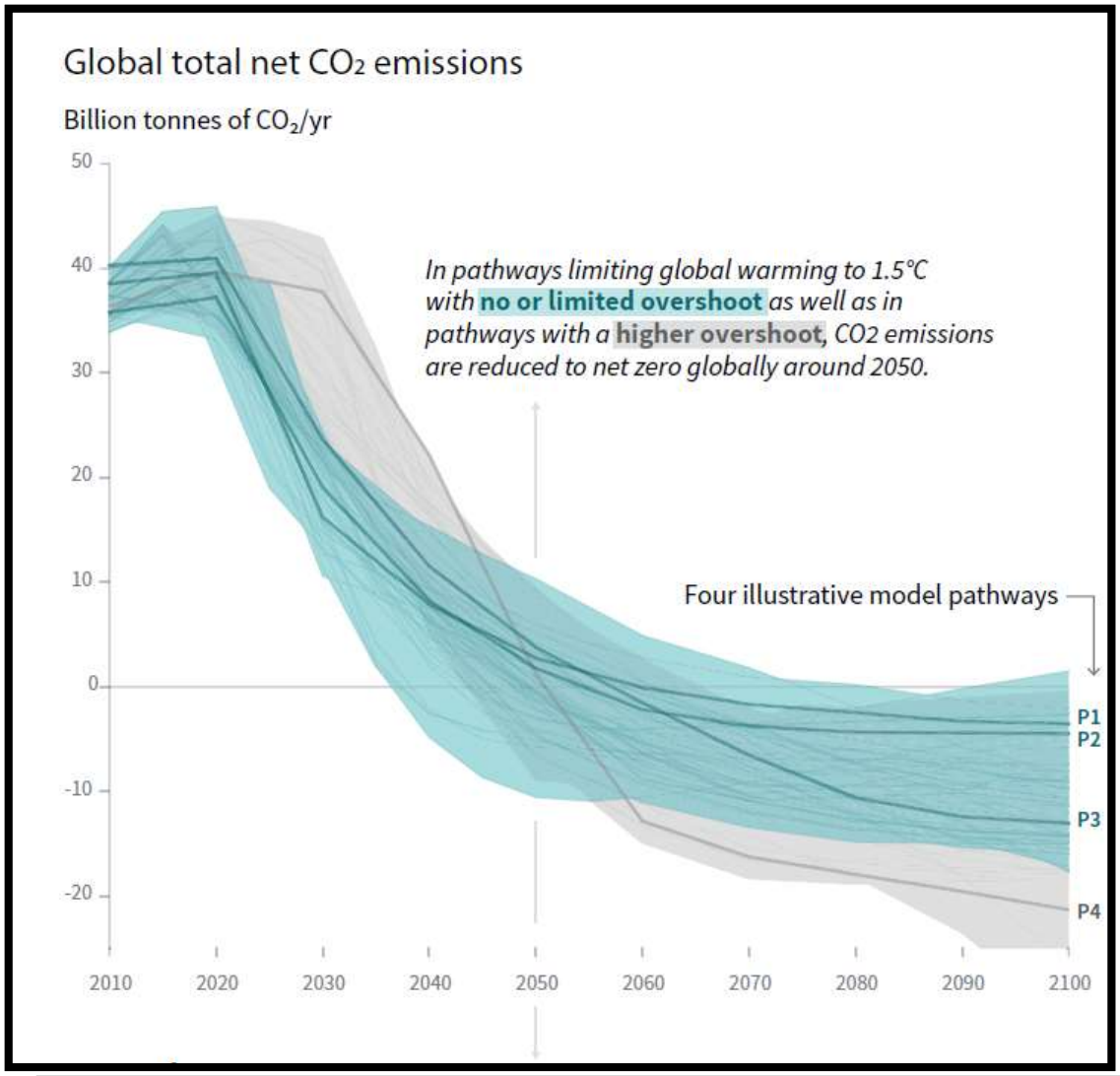
Climate change



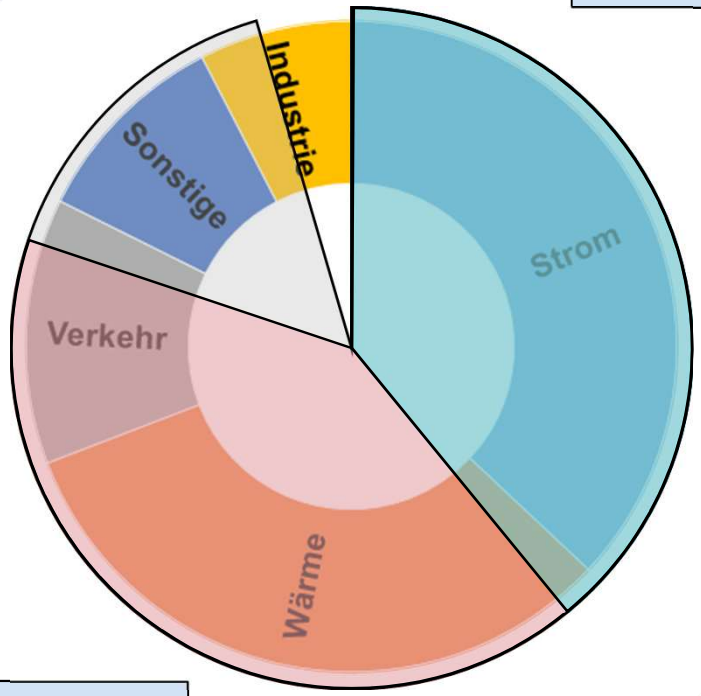
- **CO_2 emissions reach all-time high in 2018**
- **Massive reduction**
- **As of 2050 negative emissions**

Intergovernmental Panel on Climate Change (IPCC) (2018): Special Report on Global Warming of 1.5 °C

CO_2 emission goals

- **Most efforts in electricity sector**
- **Goal 2050 only with integration of renewables into other sectors**
- **Power-to-X technologies**

CO_2-eq. emissions in Germany (1990)

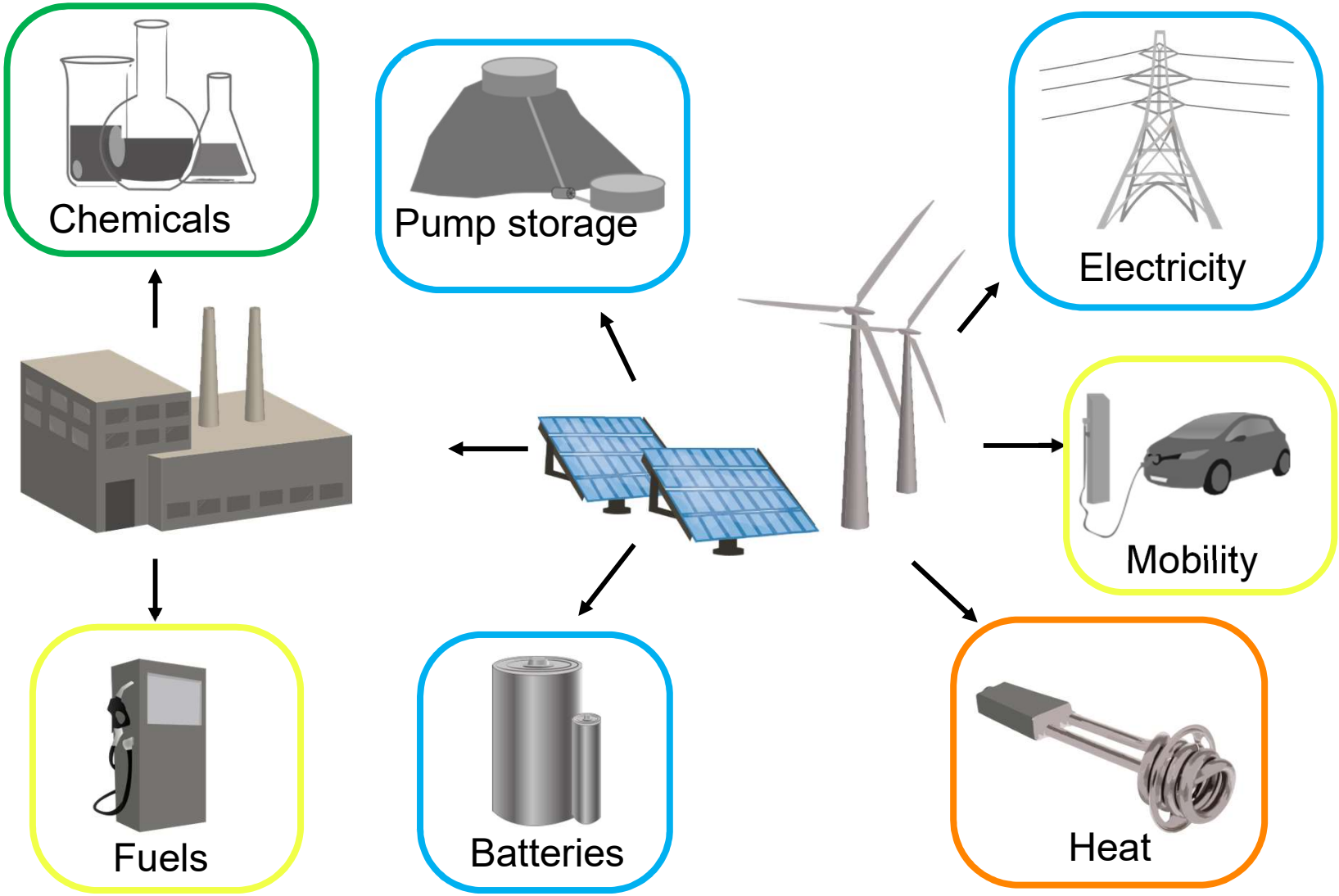


2020: 40% [1]

2050: 80-95%[1]

[1]: Merkel, 2015, Rede bei der 21. Konferenz der Vereinten Nationen zum Klimawandel

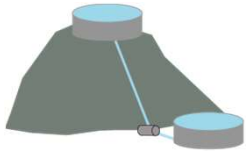
Power-to-X technologies



Power-to-X technologies

Renewable energy

to **Power**



to **Heat**

to **Mobility**

to **Chemicals**

Power-to-X technologies

Renewable energy

to **Power**

to **Heat**

to **Mobility**

to **Chemicals**

Replace conventional fossil-based processes

Highest environmental benefit?

Power-to-X technologies

Extreme case for electricity:
Environmental impact = 0

Surplus power

to **Power**

to **Heat**

to **Mobility**

to **Chemicals**

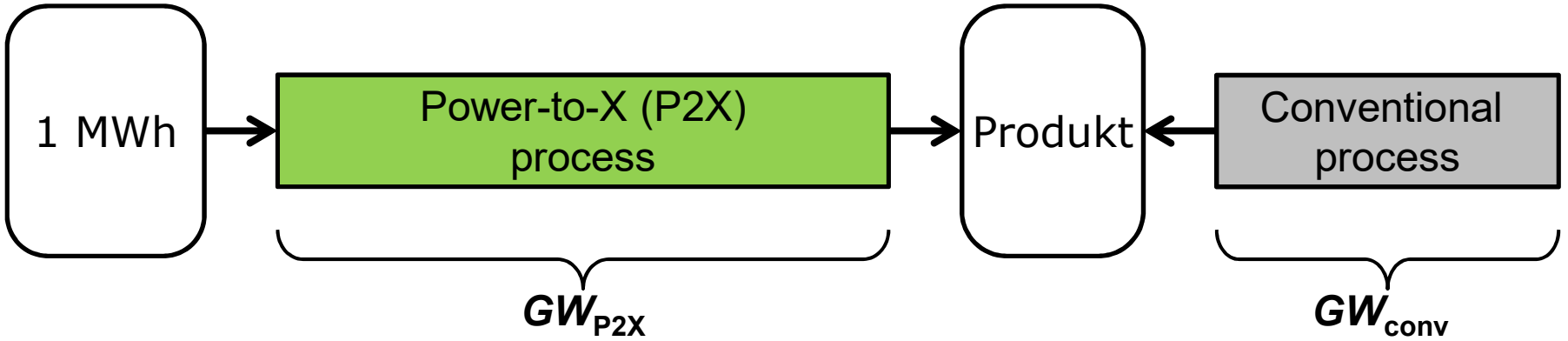
Replace conventional fossil-based processes

Highest environmental benefit?

Efficiency of Power-to-X

Which Power-to-X technology uses electricity best?

$$\text{P2X-efficiency} = \frac{\text{Reduction of } GW}{\text{per MWh used electricity}}$$



$$GW_{reduction} = GW_{conv} - GW_{P2X}$$

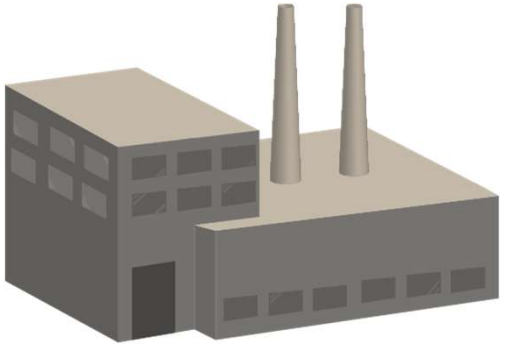
Sternberg und Bardow, *Energy Environ. Sci.*, 2015,**8**, 389-400.

Power-to-X

1 MWh

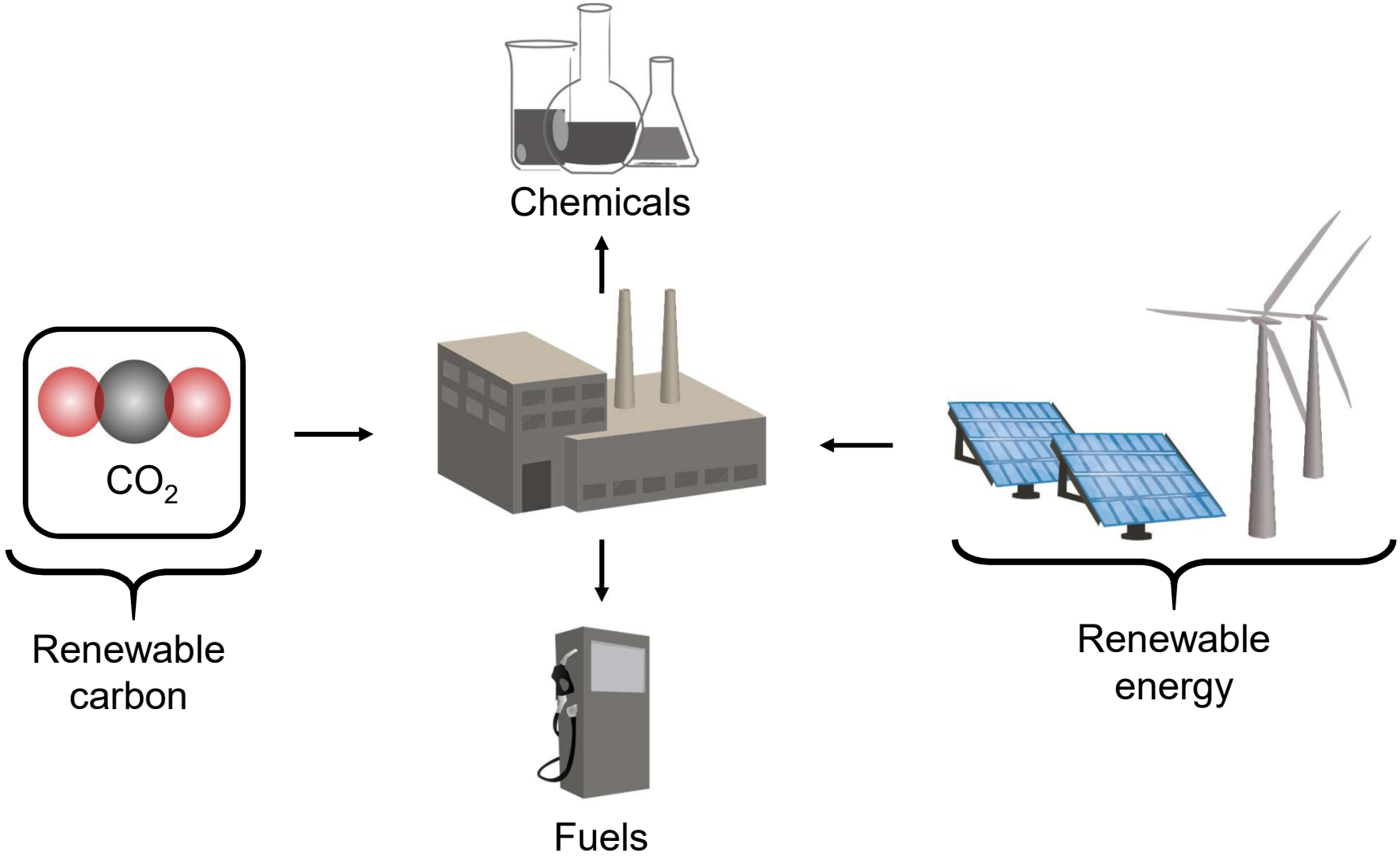
Surplus

power

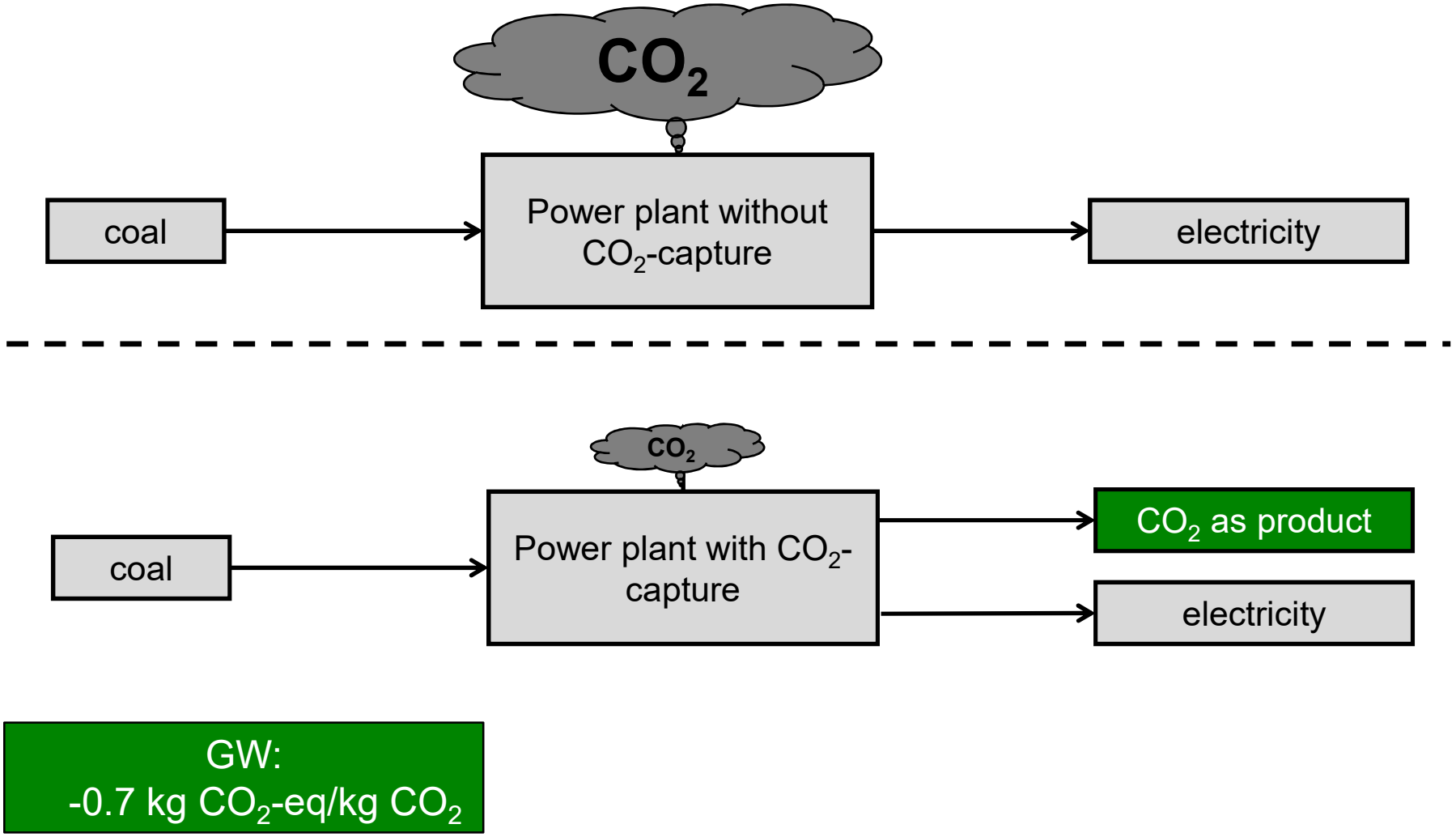


to **Chemicals**

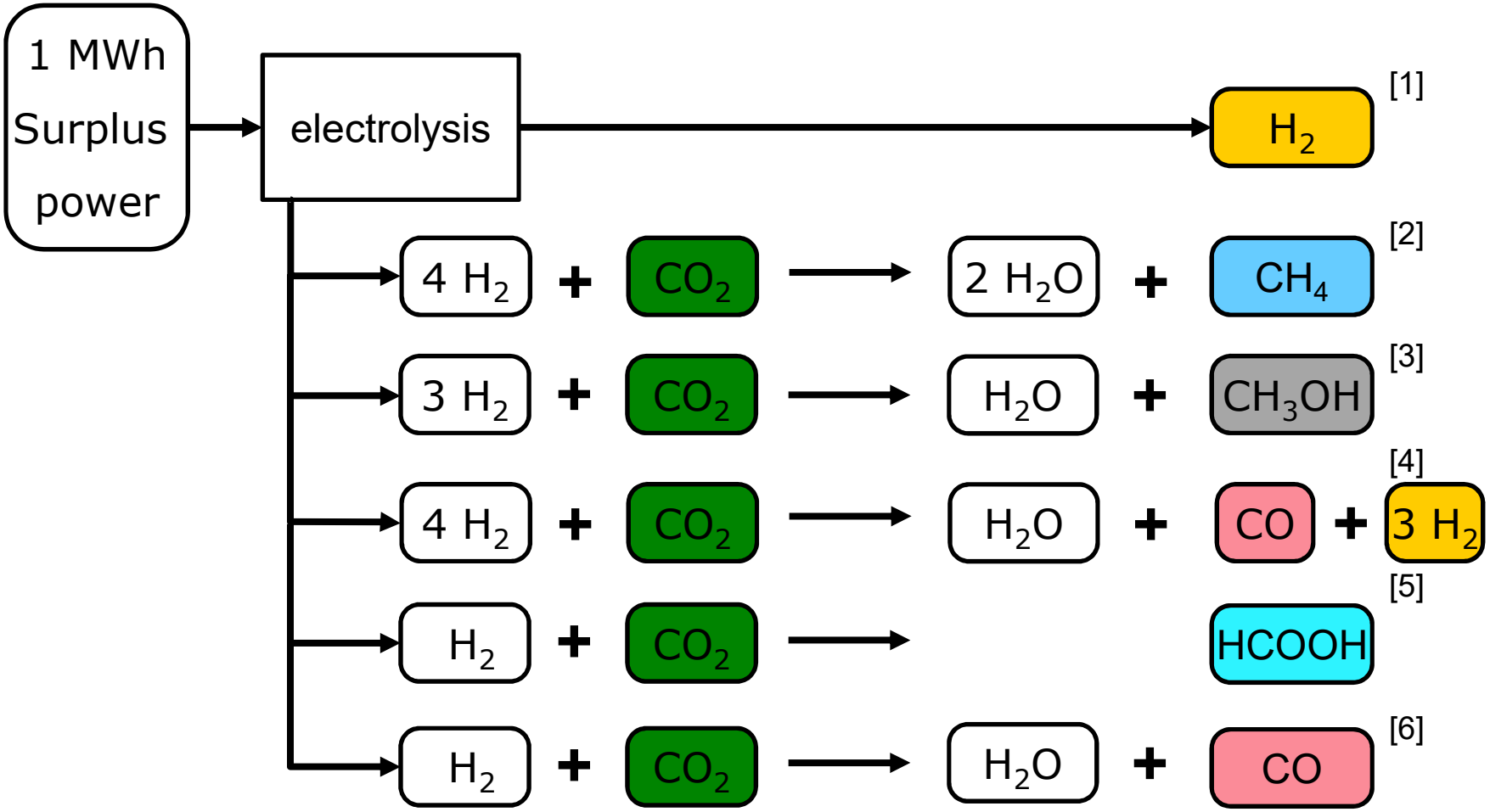
Utilization of CO_2



GW of the CO_2-supply



Power-to-Chemicals



[1] Schüth, *Chem. Ing. Tech.*, 2011, **83**, 1984–1993.
[2] Müller, Müller, Teichmann, Arlt, *Chem. Ing. Tech.*, **83**, 2011.
[3] Rhiko-Struckmann, Peschel, Hanke-Rauschenbach, Sundmacher, *Ind. Eng. Chem. Res.*, 2010, **49**, 11073–11078.
[4] CO_2RRECT (033RC1006B) 2014.
[5] Jens, Nowakowski, Scheffczyk, Leonhard and Bardow, 2016, *Green Chem.*, 2016,**18**, 5621-5629
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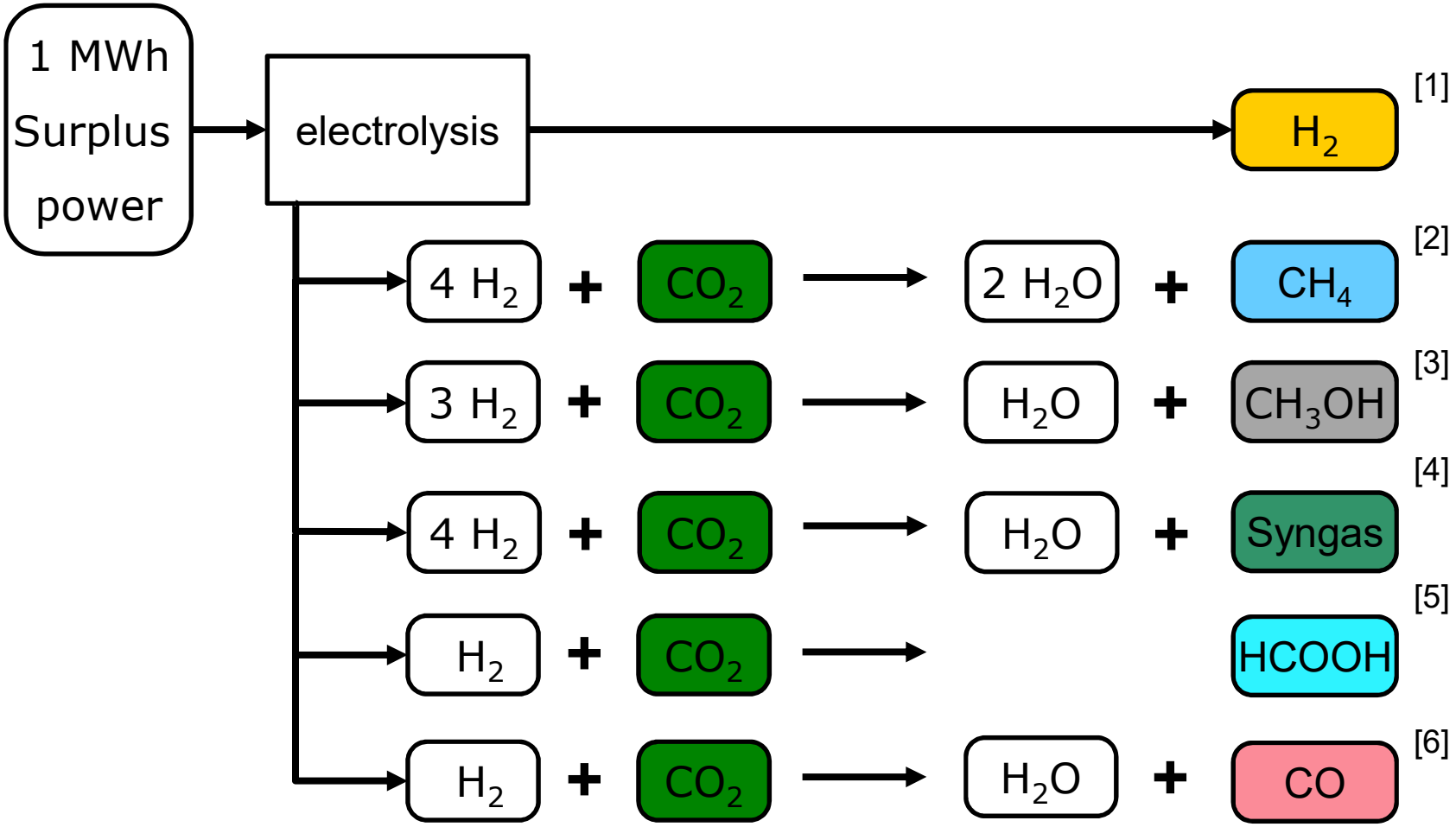
Power-to-Chemicals



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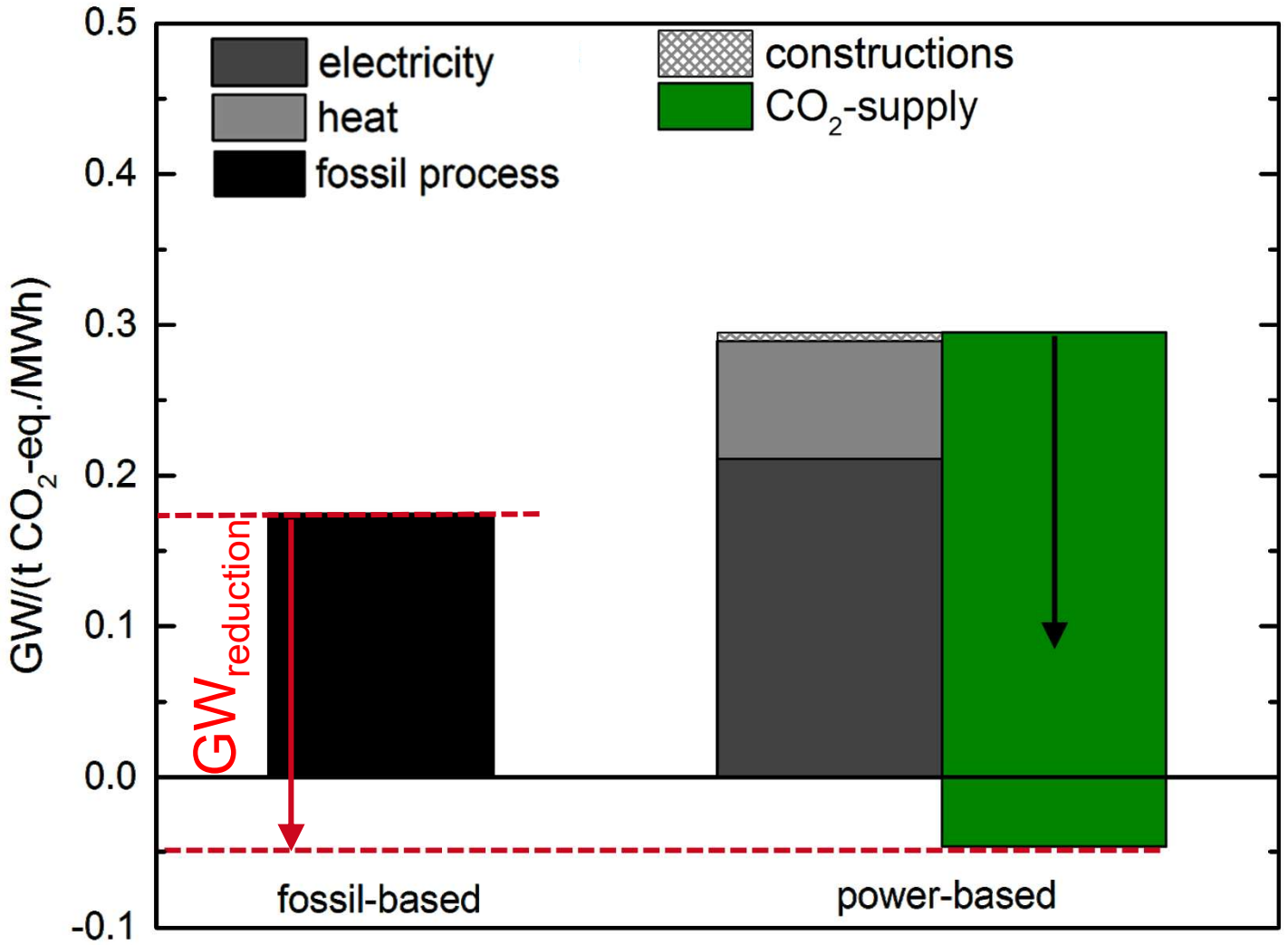
Fossil vs. power-based CO

$$GW_{reduction} = GW_{conv} - GW_{P2X}$$



Power-to-Chemicals

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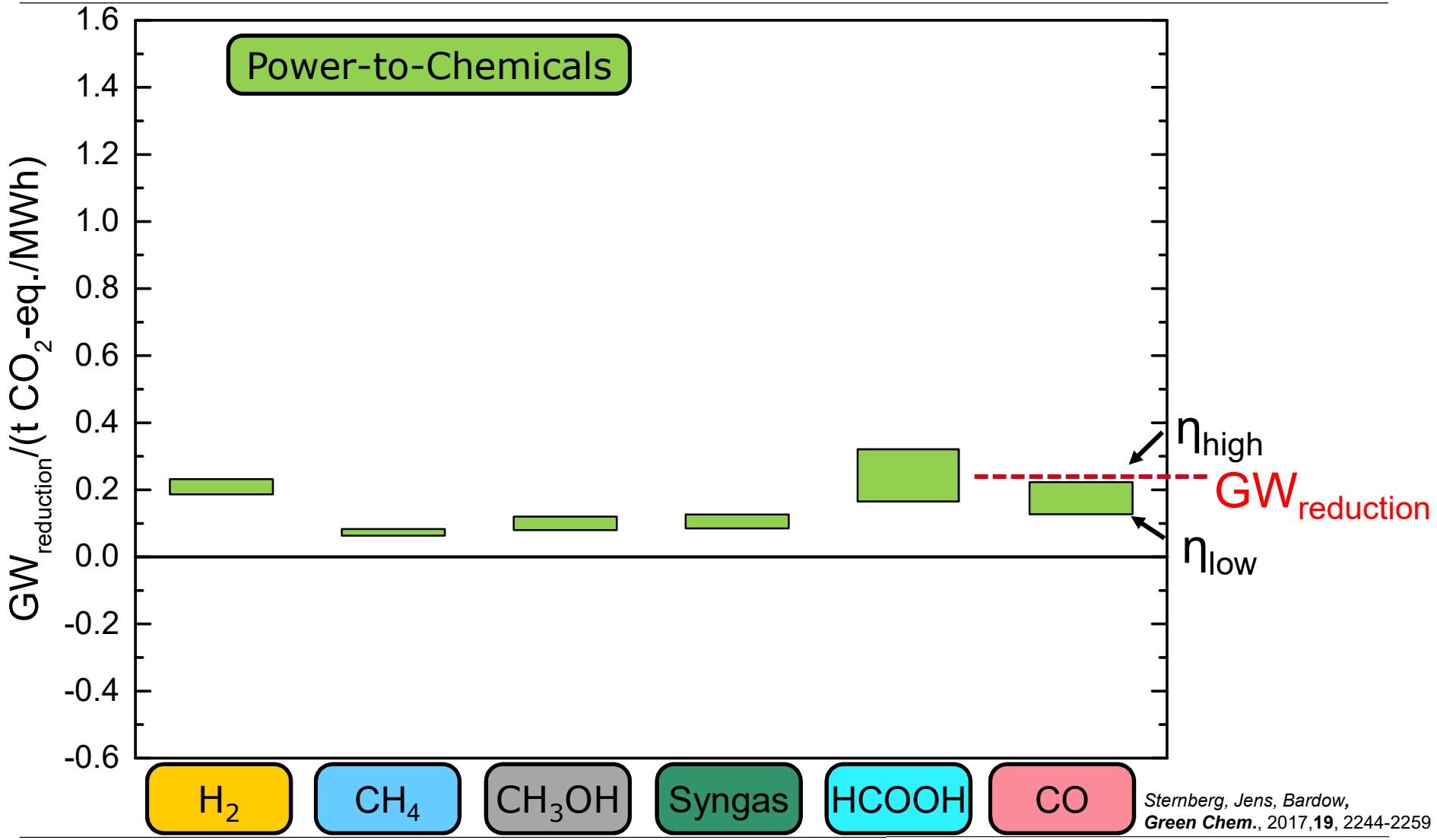

Sternberg, Jens, Bardow, ***Green Chem.***, 2017,**19**, 2244-2259

Power-to-Chemicals

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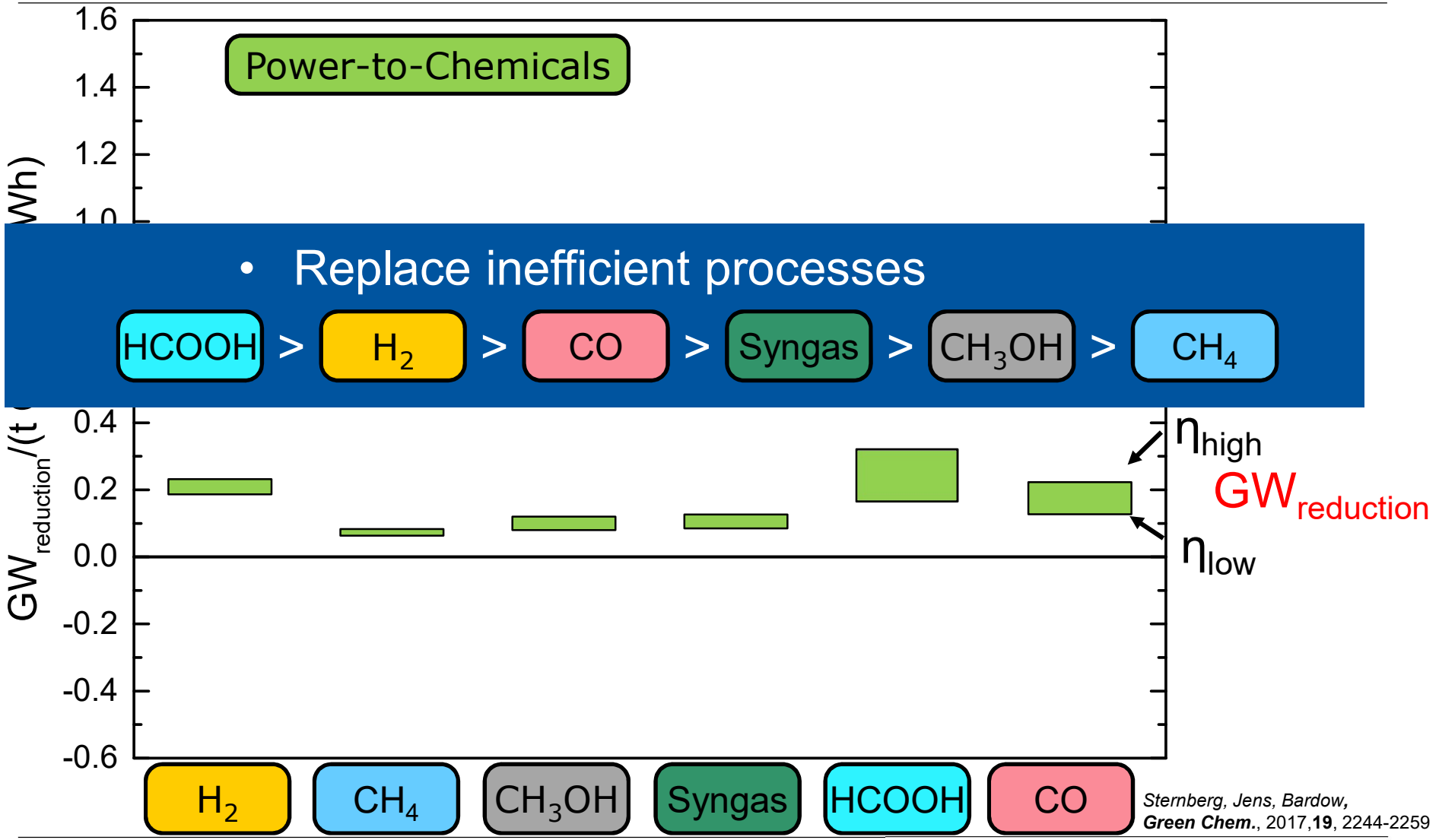

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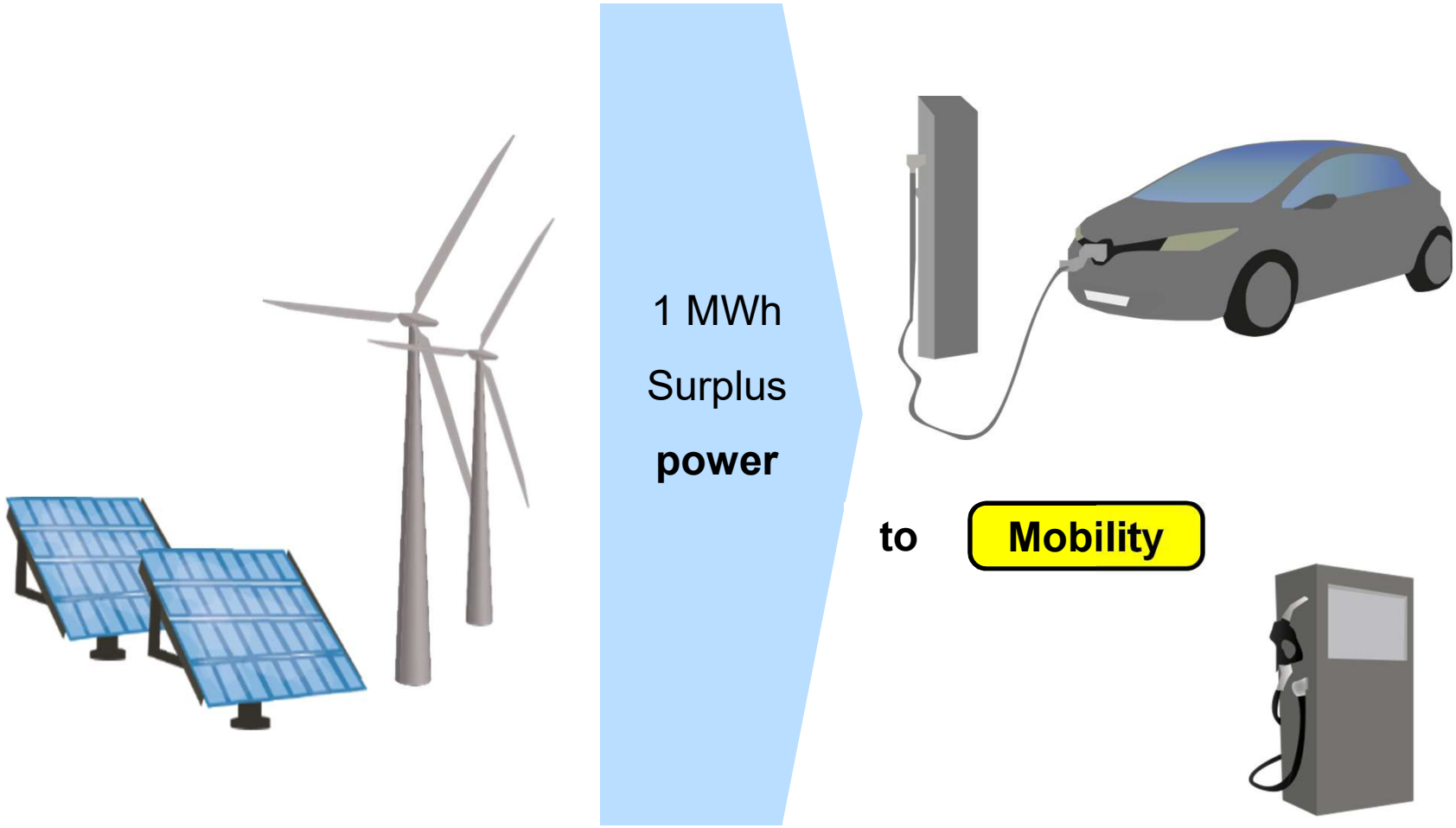
Power-to-Mobility



Power-to-Mobility

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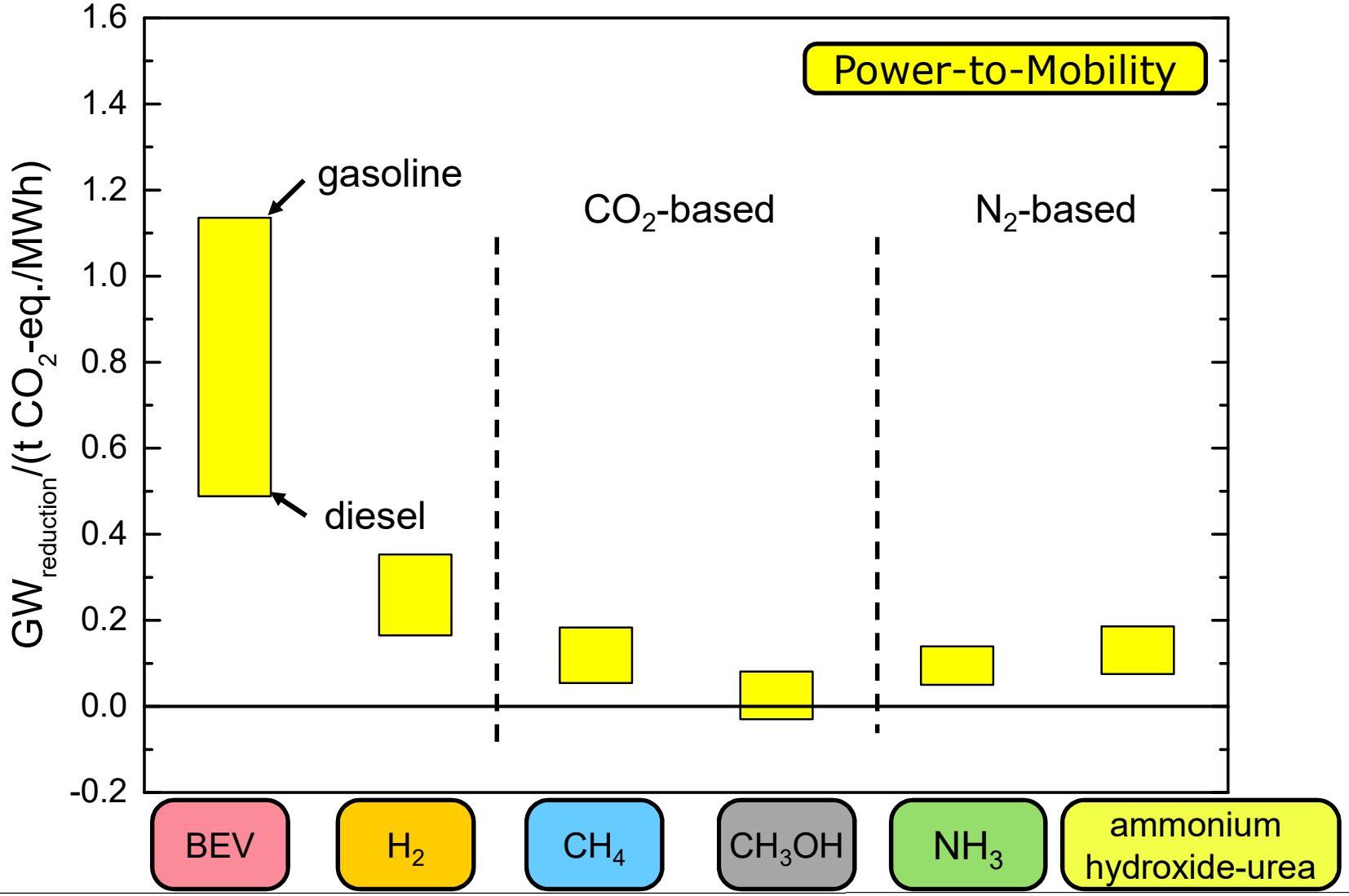

Power-to-Mobility

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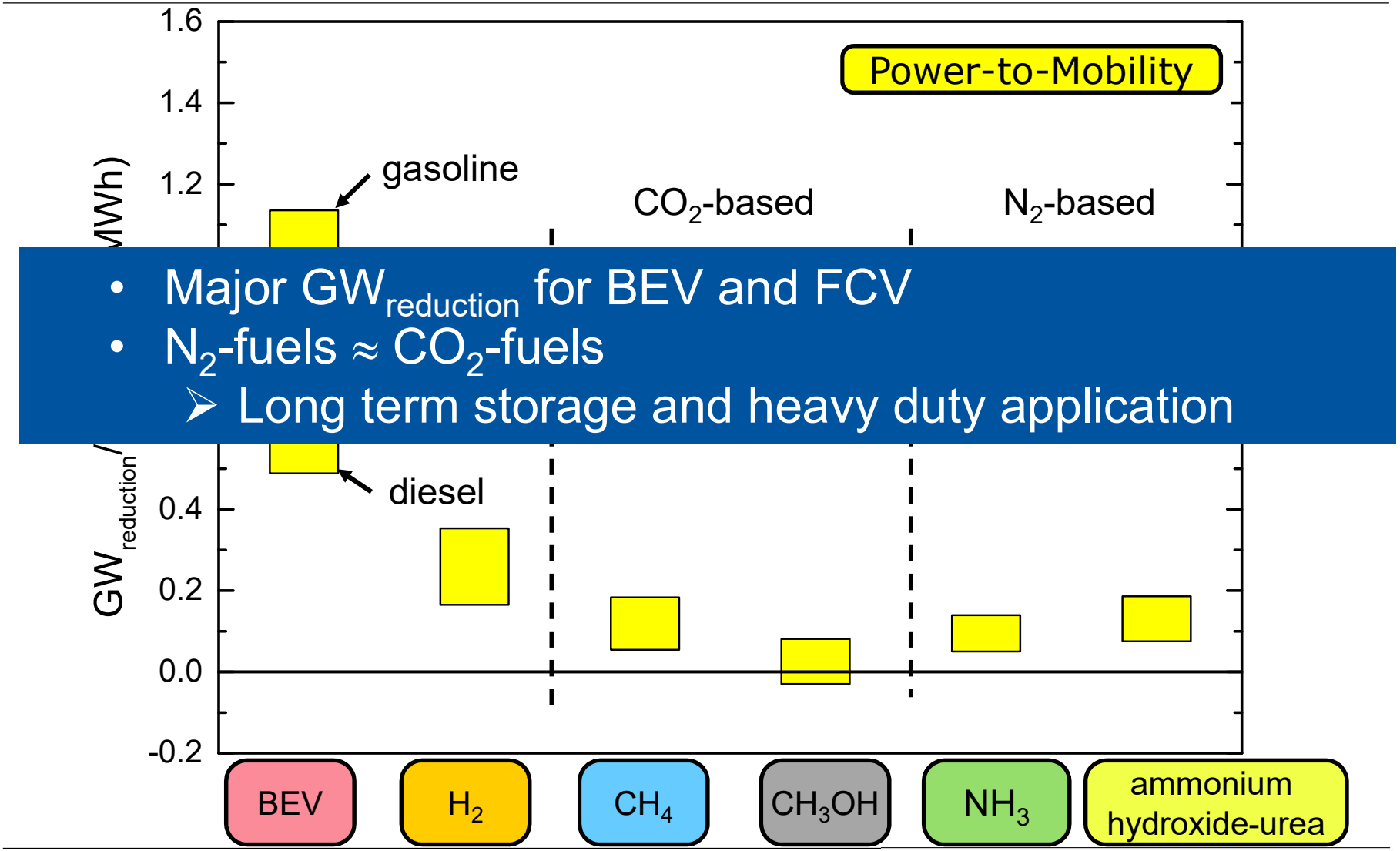
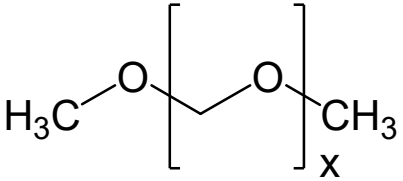


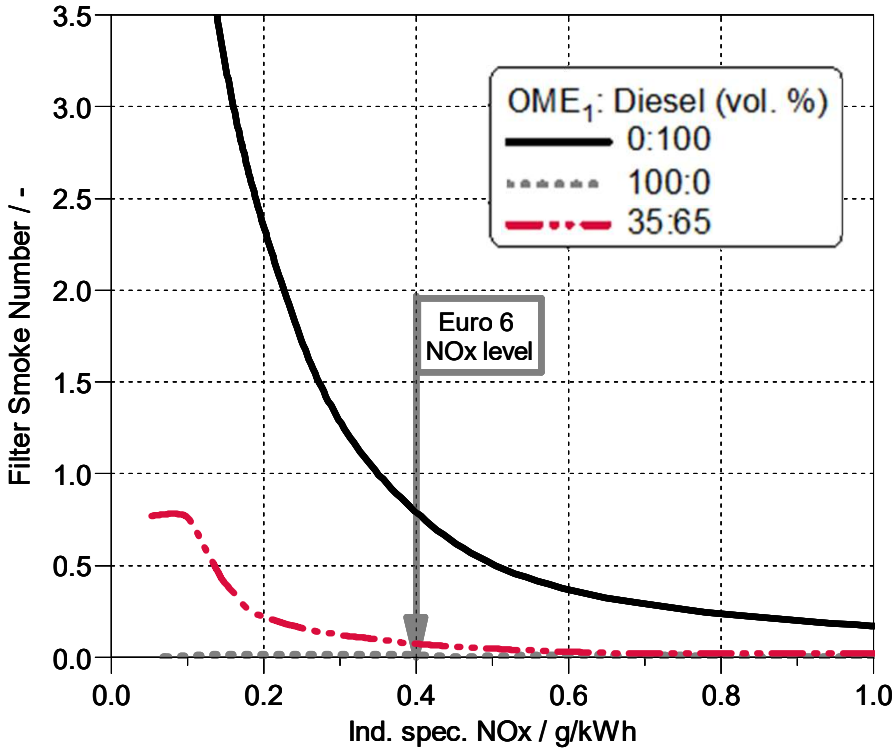
- Major $GW_{reduction}$ for BEV and FCV
- N_2-fuels ≈ CO_2-fuels
  - ➢ Long term storage and heavy duty application

Decarbonization is not all – Novel CO_2-based fuels: Oxymethylene ether (OMEx)

Oxymethylene ether

OME_x (1; 3 < x < 6)





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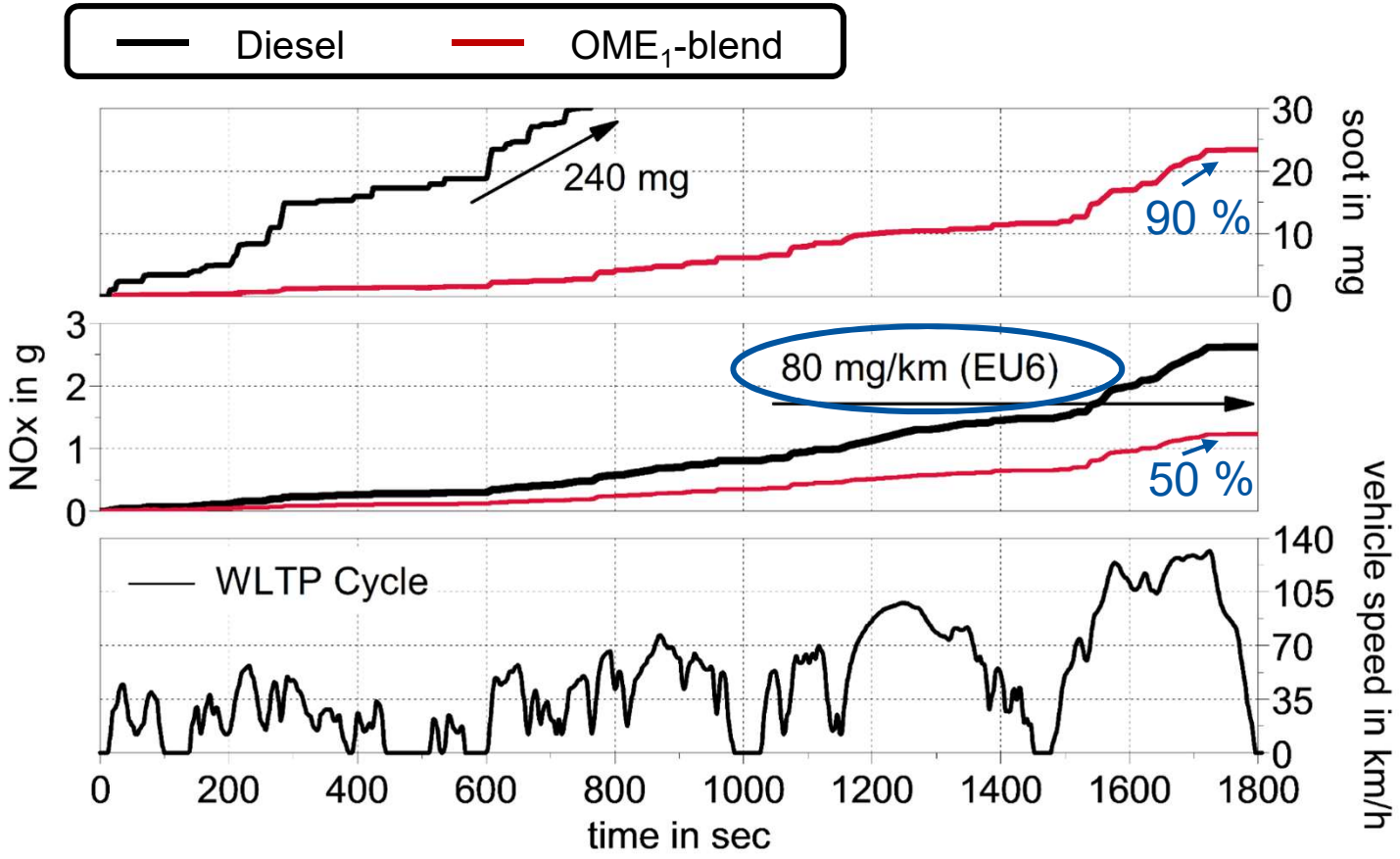
Engine tests and Cycle simulations - Cumulative soot and NOx raw emissions



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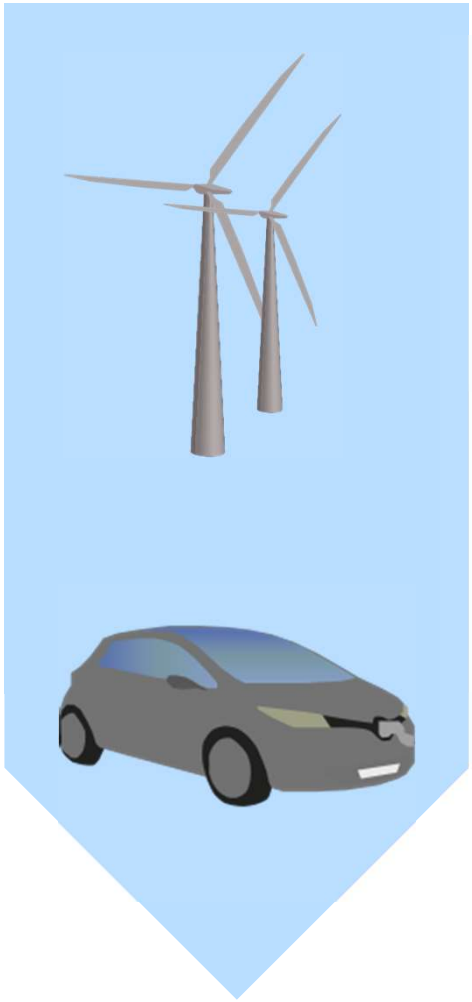
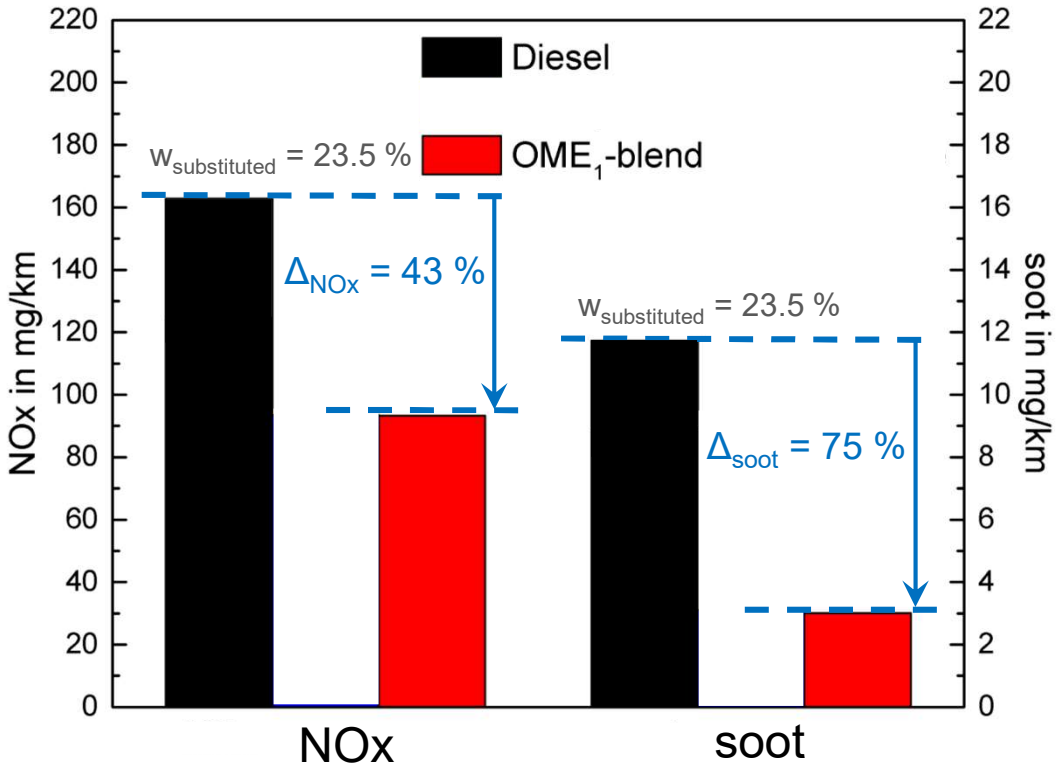
NOx and soot emissions from wind-to-wheel





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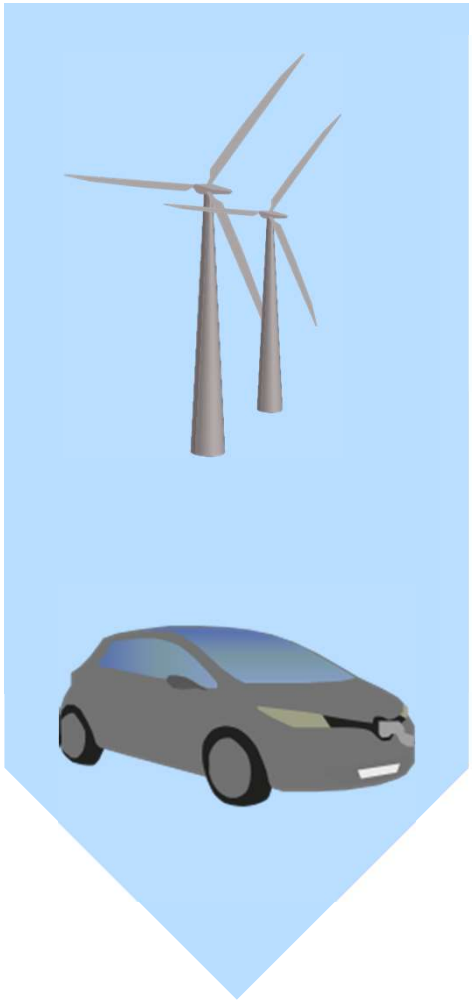

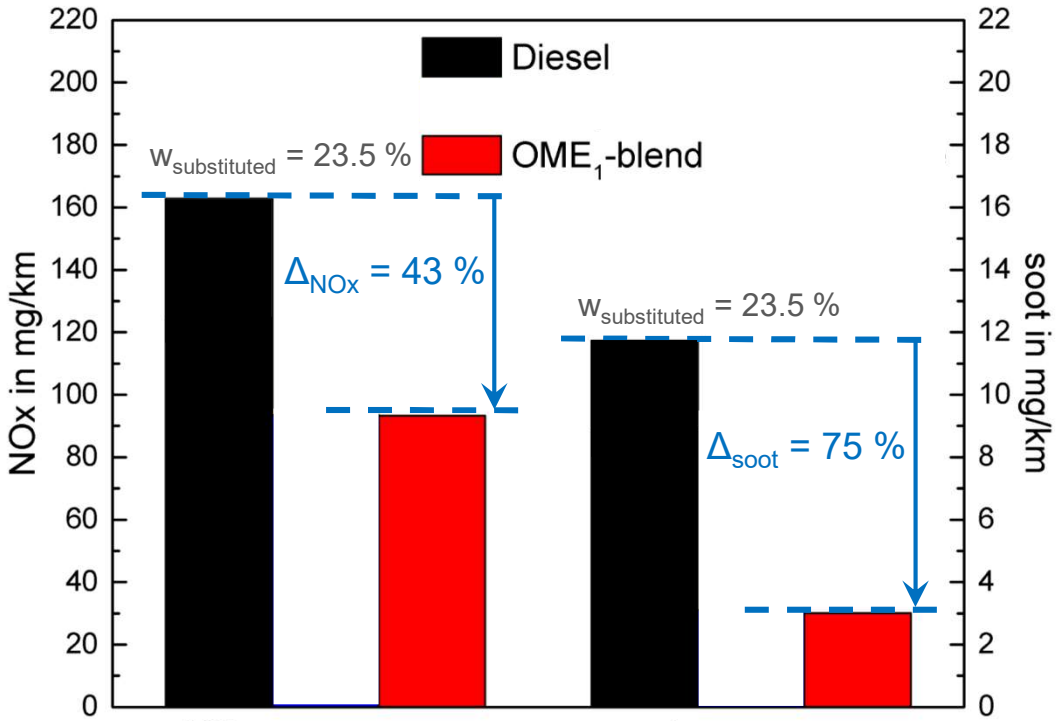

- OME_1 disproportionately reduces NOx and soot emissions

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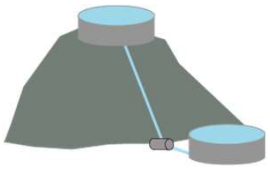
Power-to-X

1 MWh
Surplus
power

to **Power**



to **Heat**

to **Mobility**

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Power to What?

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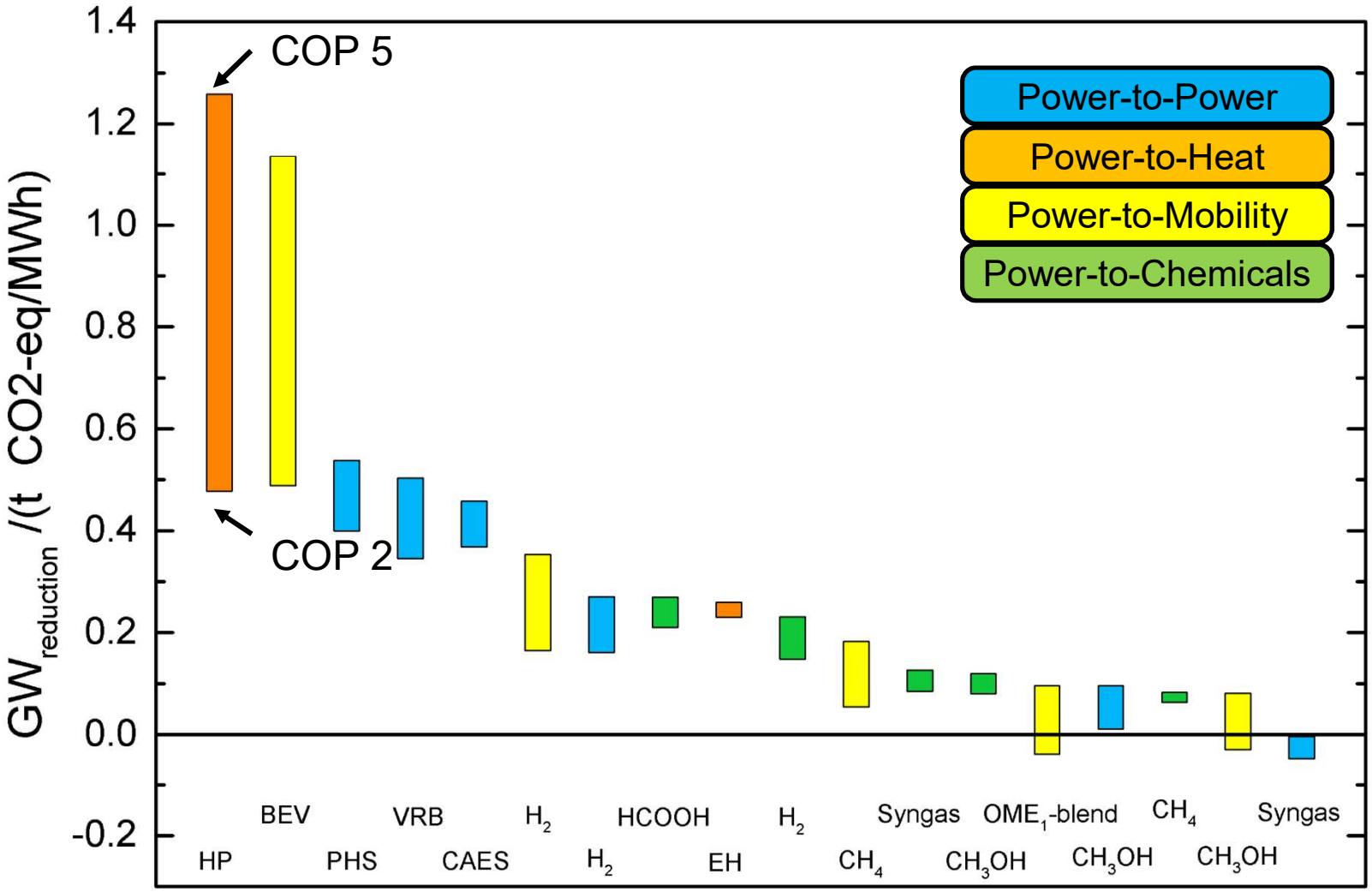

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Power to What?

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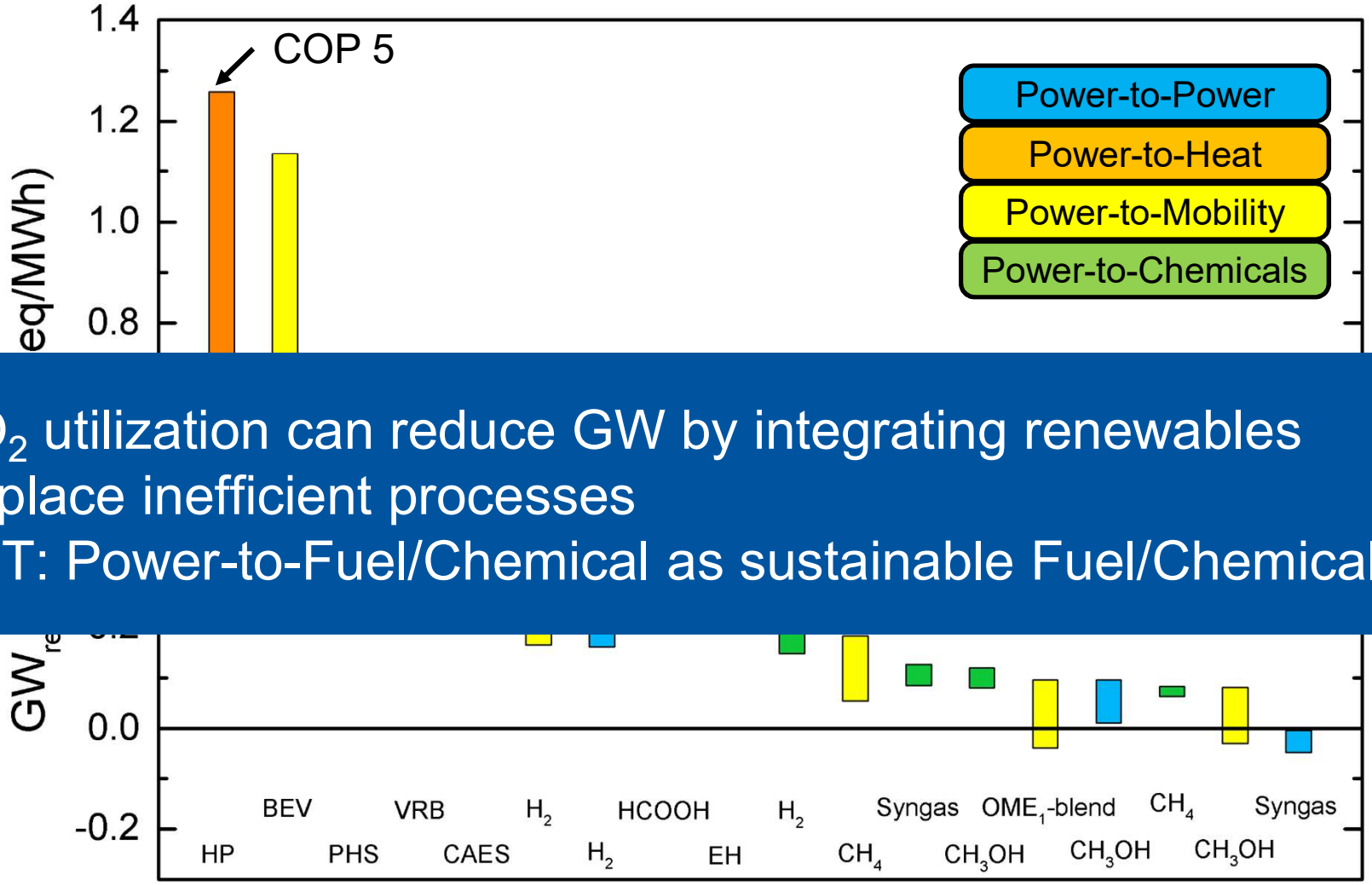

CO_2 utilization can reduce GW by integrating renewables
Replace inefficient processes
BUT: Power-to-Fuel/Chemical as sustainable Fuel/Chemical

Sternberg und Bardow, *Energy Environ. Sci.*, 2015,**8**, 389-400.

Conclusion

- Renewables provide new opportunities for the integration of renewable energies in other sectors

- Replace inefficient processes with a high environmental impact

- Power-to-Fuel/Chemical as sustainable Fuel/Chemical

- Synthetic fuels with improved properties such as the reduction of local pollutants

Thank you for your attention!

Sarah Deutz

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