Life-cycle assessment of CCU technologies

Key results of Task 1.2

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Final
Identification and analysis of promising carbon capture and utilisation technologies
coordinated by Ramboll

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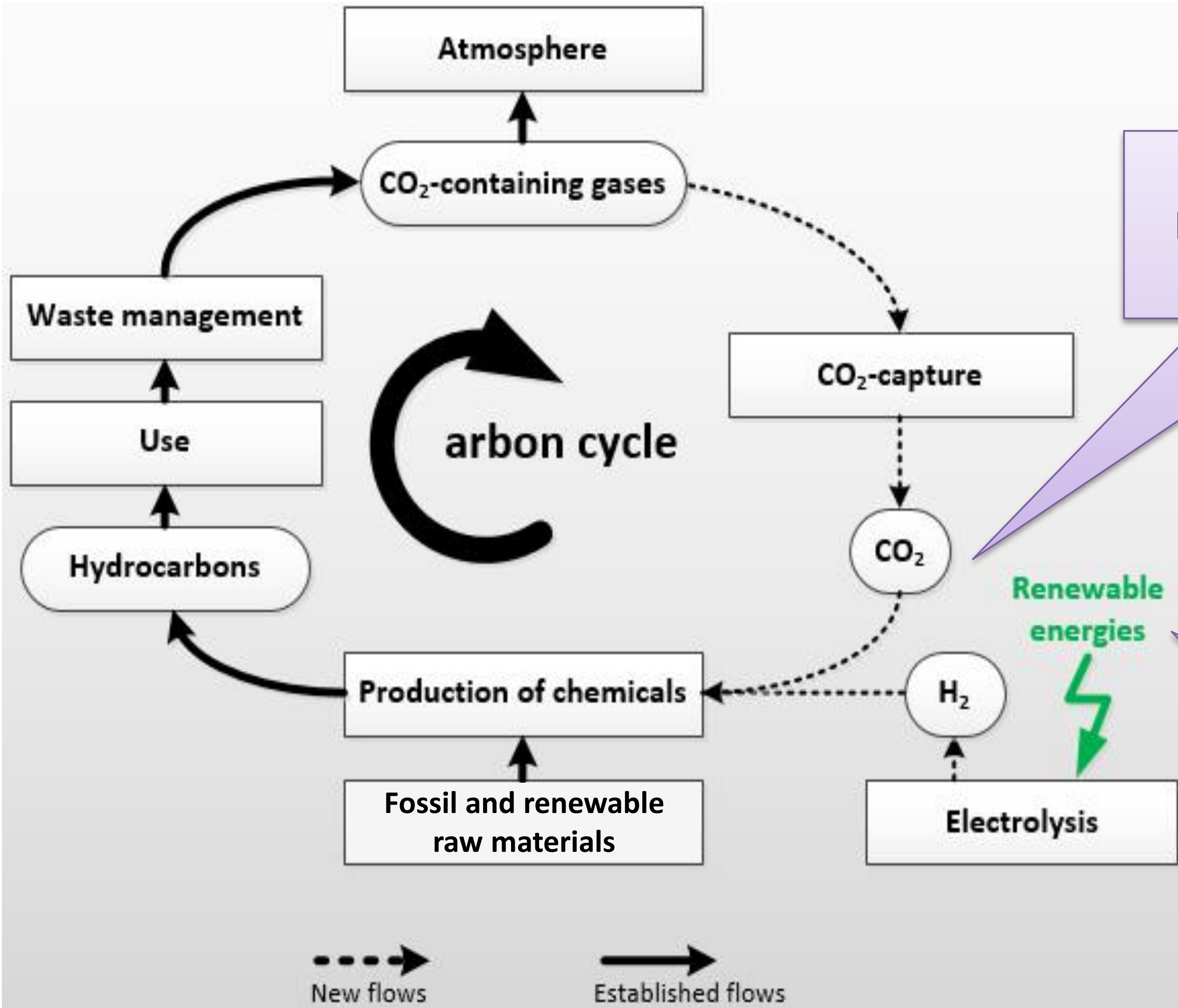
Overview

- Long-term perspective: Carbon Recycling
- CO_2 and REN availability for CCU
- LCA results

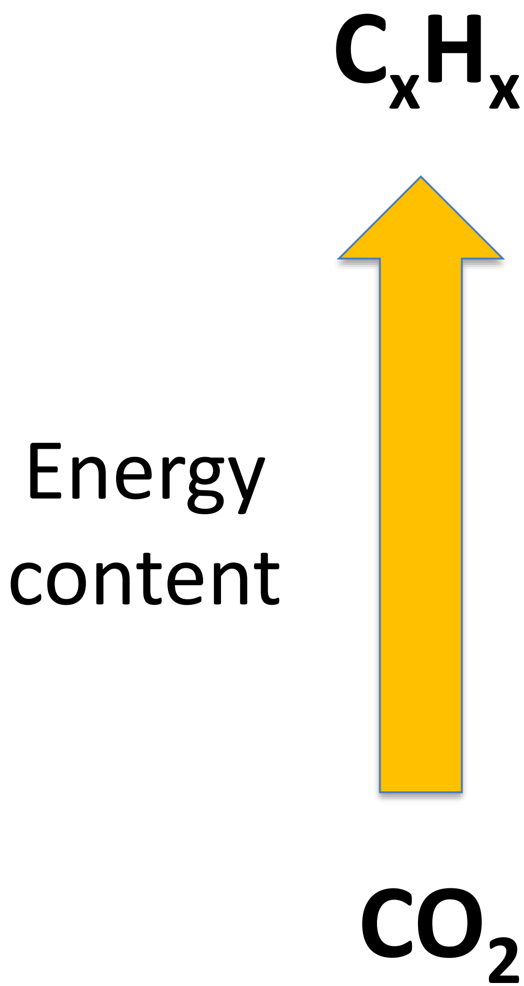
CO_2 reuse as important element of Carbon Recycling



Task:
Decoupling of Carbon and Energy supply

Challenge:
Limiting Parameter for production of hydrocarbons

CO_2 and hydrocarbons – a basic challenge

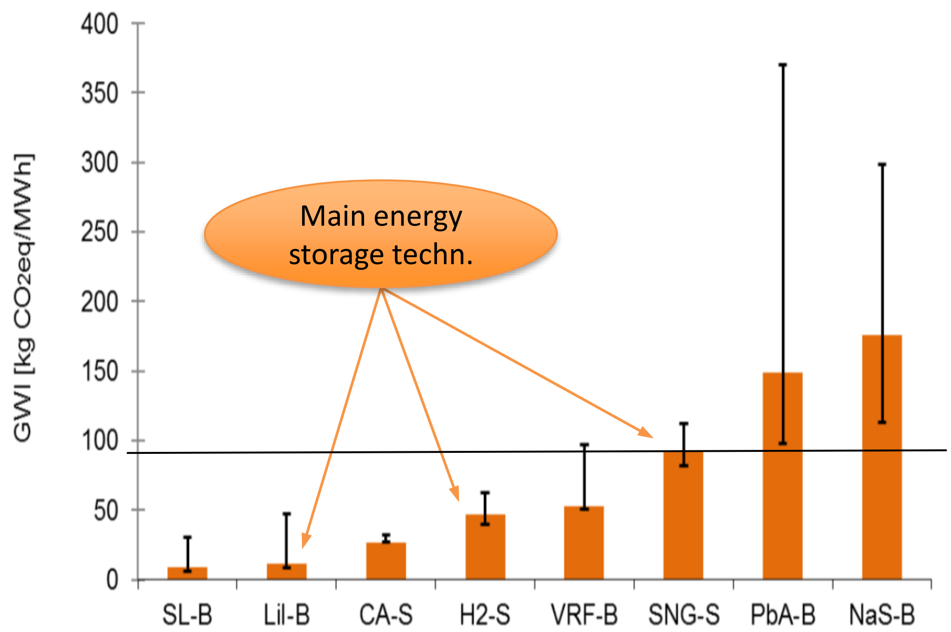


CO_2 may be used to produce hydrocarbons by

1. substituting energy rich compounds in the production chain (higher ***energy efficiency***)
   e.g. Covestro´s dream product
2. ***energy input*** (electrons, hydrogen)
   e.g. via electrolysis

CCU can combine power storage with carbon recycling

- GHG savings are higher for other power storage technologies
- CCU makes sense when **renewable carbon supply** is needed

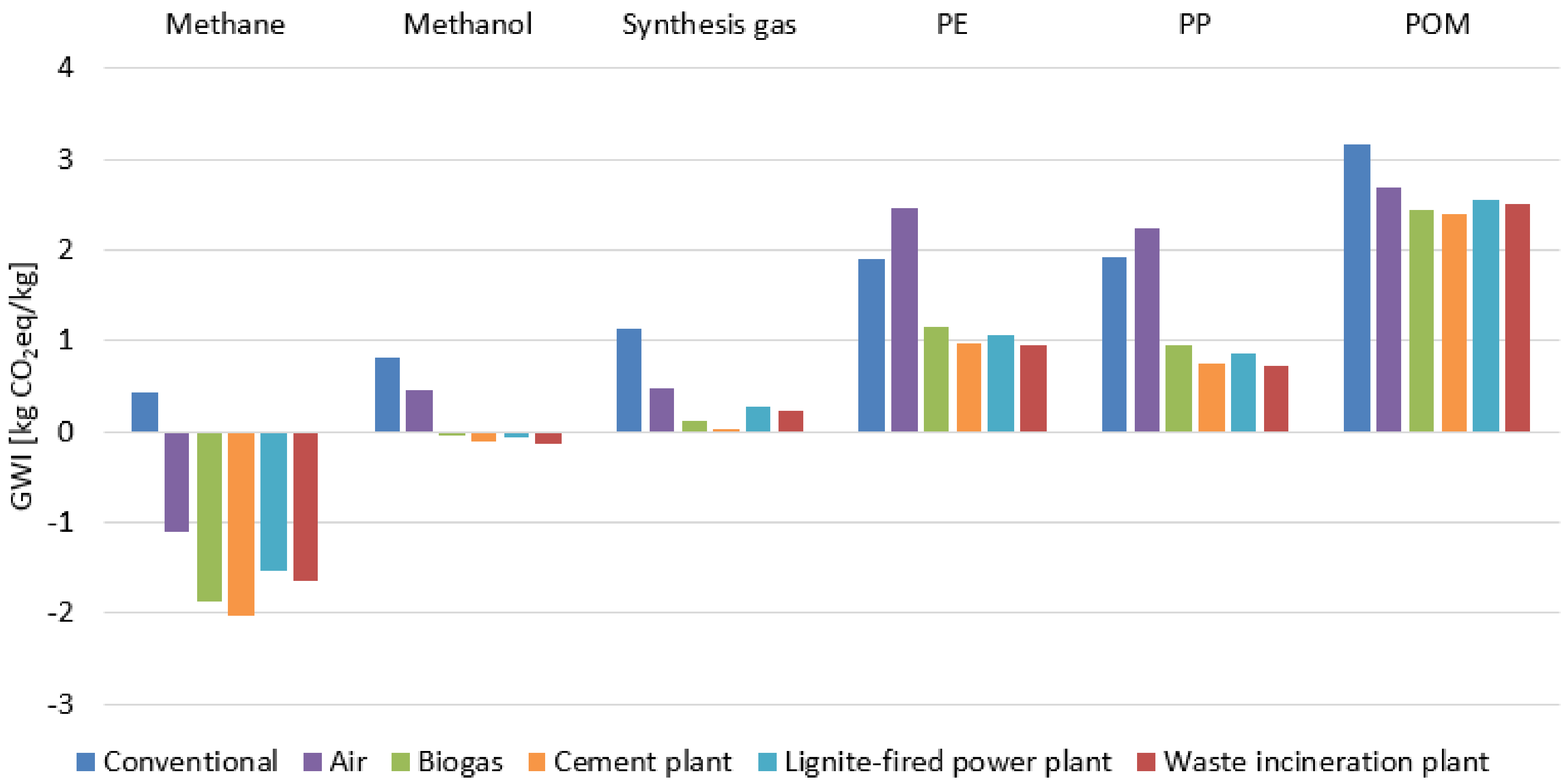


Global Warming Impact (GWI) per fed-out electricity of electrical energy storage technologies as described in (Mostert et al. 2018)
Change of global warming impact GWI per fed-out electricity for shorter and longer lifetime of electrical energy storage technologies is shown as variation to the orange columns.
SNG-S represents CCU, Lil-B= Lithium batteries, H2-S= Hydrogen storage

Goal and Scope of the LCA

- **Comparative LCA of production processes**
  - CO_2 based production process vs. conventional process
- Various CO_2 sources (biogenic, non biogenic, air)
- Process routes representative for the EU
- Indicators
  - Global Warming Impact [kgCO_2 equivalents /kg product]
  - Raw Material Input [kg raw material equivalent /kg product]
  - Cumulative Energy Demand [MJ energy equivalents /kg product]
  - Water input [kg water /kg product]
- Scenarios
  - Spatial variation (are certain transport routes for chemicals favorable?)
  - Intersectoral use (methane as transport fuel or base chemical?)
  - Energy supply (how much REN is necessary?)

Results
Global Warming Impact (GWI)

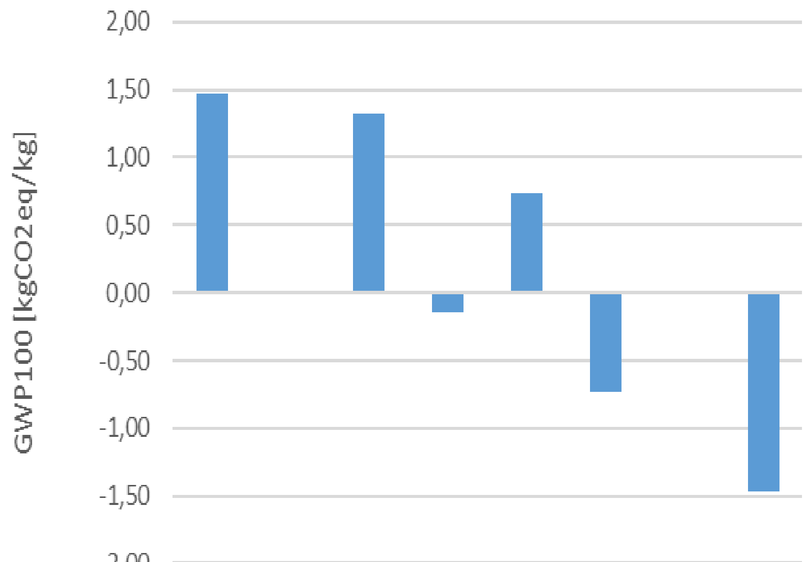


Results

No influence of varying retention time (product life time)

- The difference between the conventional and the CCU product remains the same, if both products have the same durability

- If no discrimination of products is assumed there will always be a certain mitigation effect if CO_2 is used as input together with renewable power

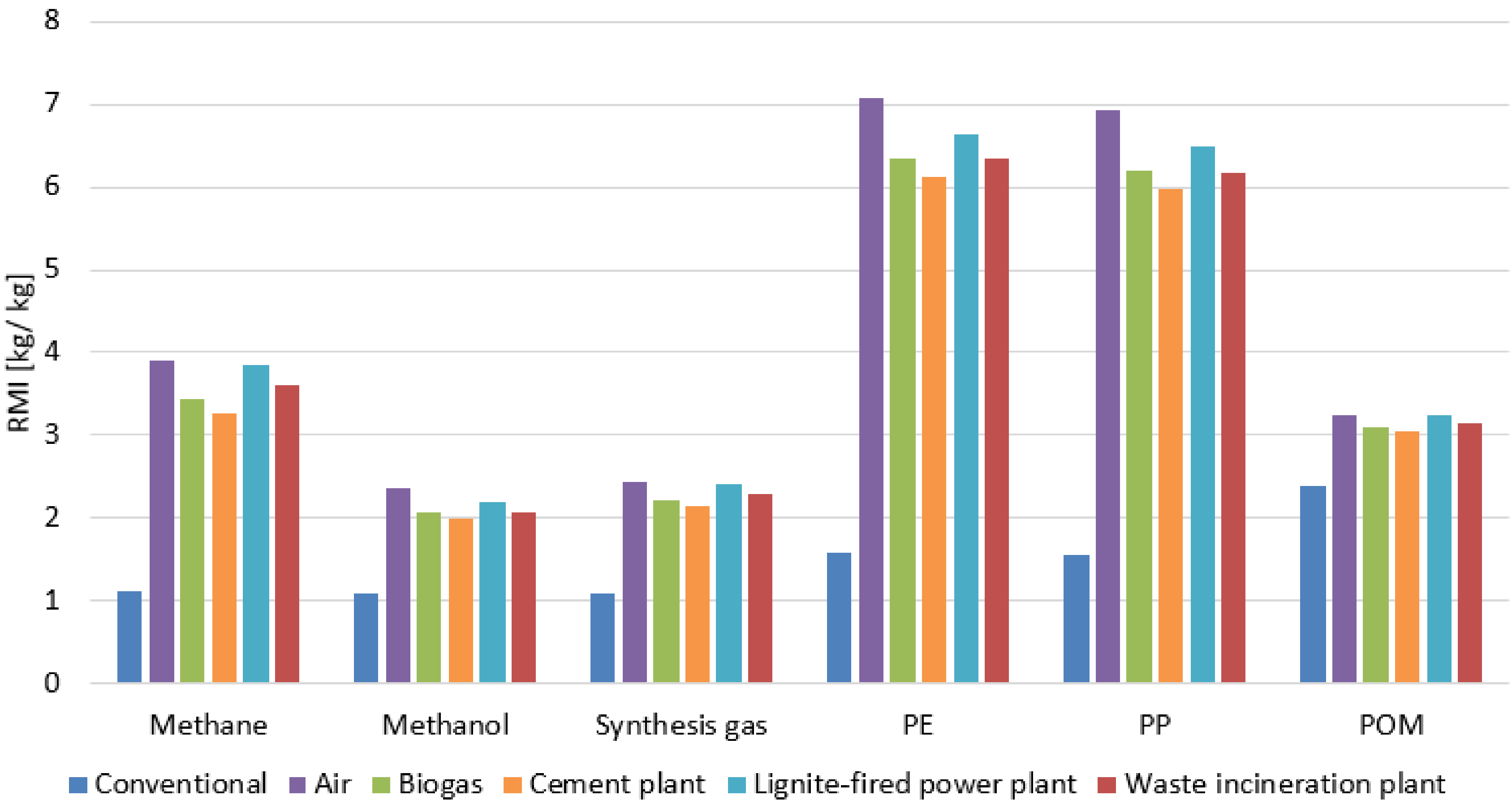


	Conv. POM (RT 0)	CCU POM (RT 0)	Conv. POM (RT 10)	CCU POM (RT 10)	Conv. POM (RT 50)	CCU POM (RT 50)	Conv. POM (RT 100)	CCU POM (RT 100)
GWP 100 [1 kg Product]	1,47	0,00	1,32	-0,15	0,73	-0,73	0,00	-1,47

GWP100 values for conventional and CCU POM assuming different retention times based on the ILCD Handbook (2010, p. 226) based on a carbon input of 1,47 kg CO_2 per kg POM

Results

Raw Material Input (RMI)



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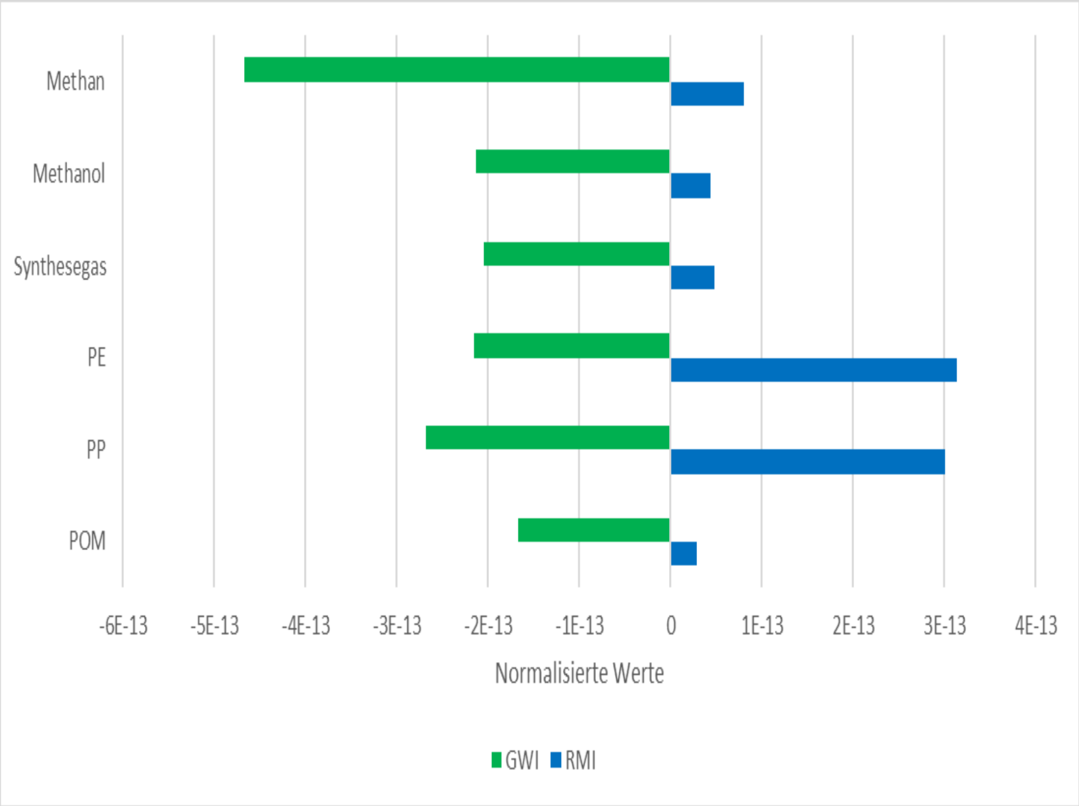
Weighting the trade-off
Normalization of differences by EU reference values

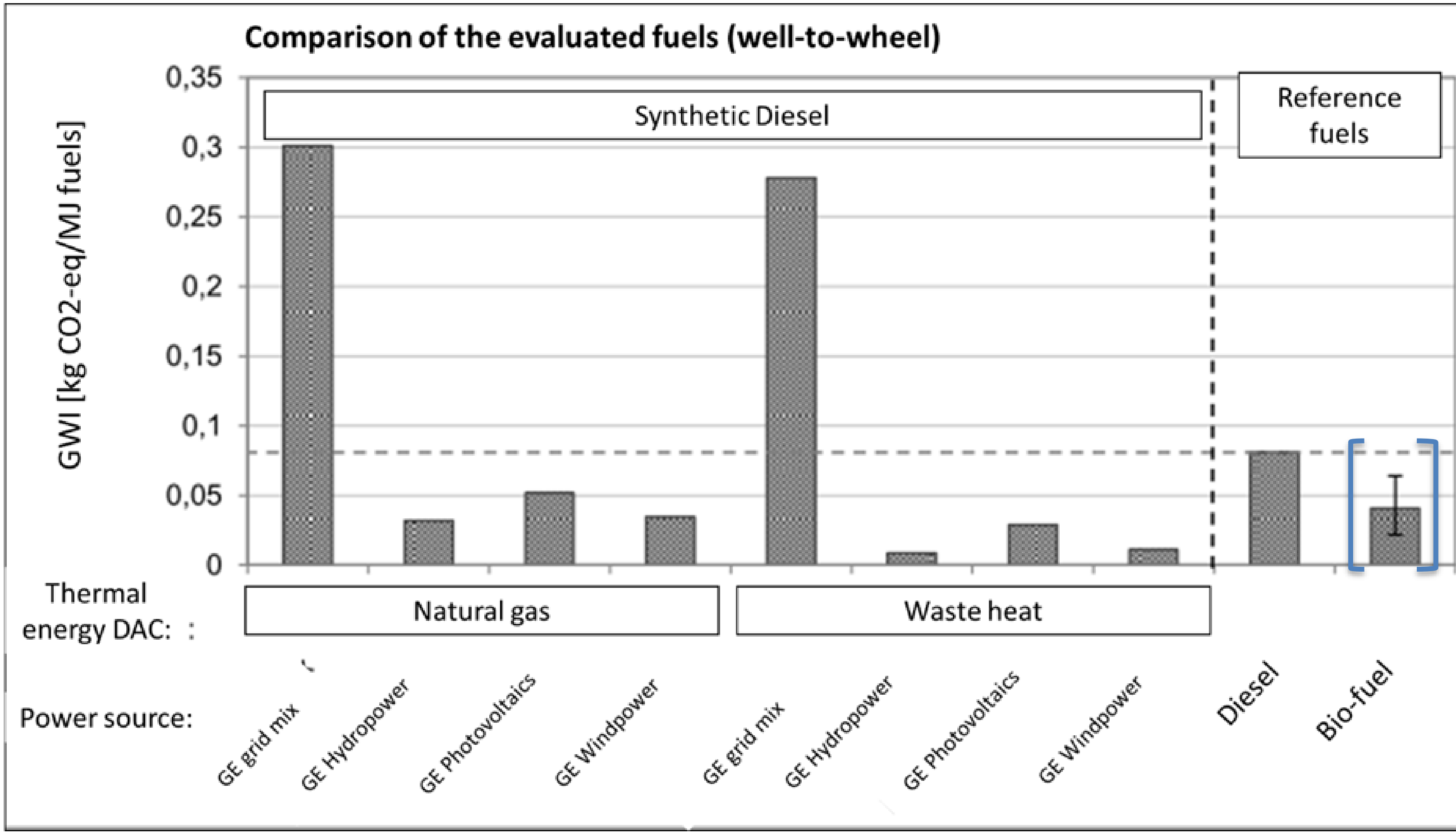
$$Normalized\ value = \frac{\Delta GWI\ or\ \Delta RMI}{reference\ value}$$

- The CO_2 savings are relative higher than the increased raw material requirements for methane, methanol, synthesis gas and POM
- The studied routes of PE and PP production (MtO methanol to olefins) would be less advisable



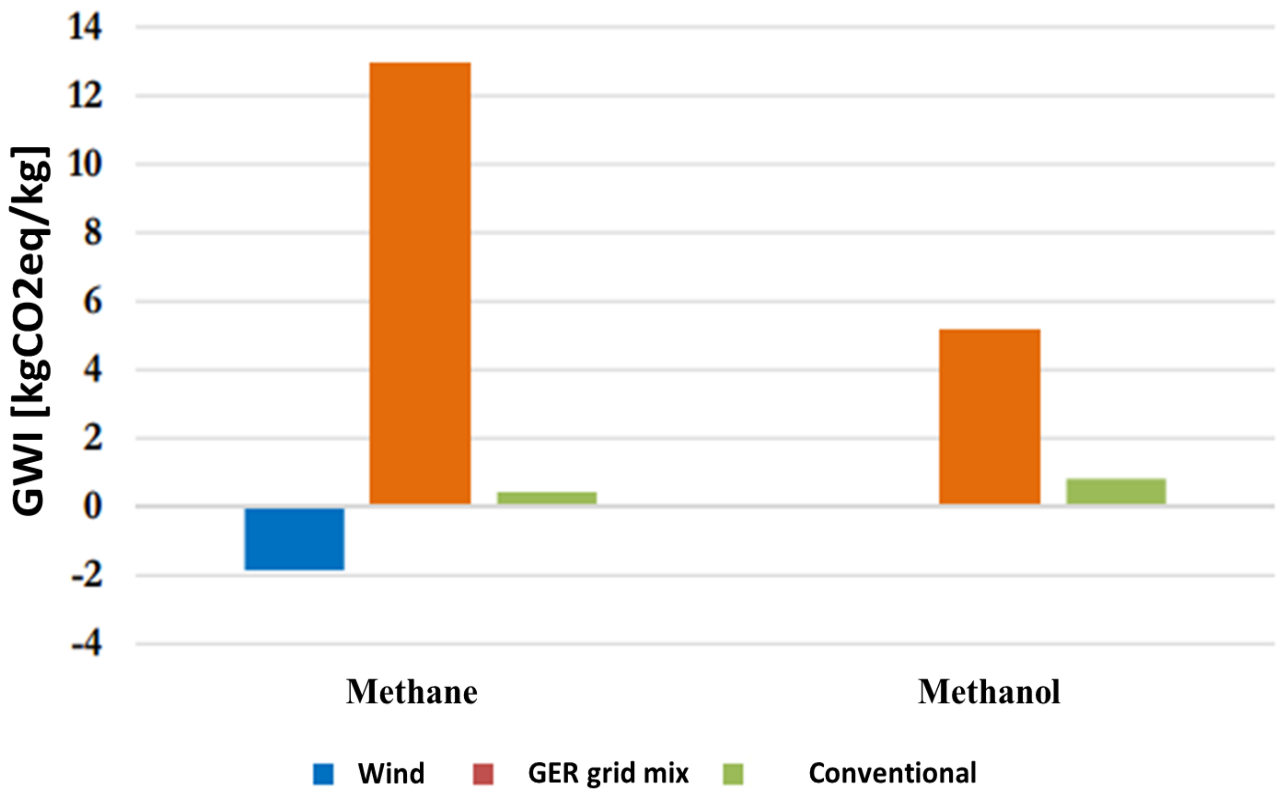
Normalized reductions (minus) and increases (plus) of environmental pressures through substitution of CO_2-based for fossil-based basic chemicals and polymers for the European Union using data from Eurostat: GWI: 4.4*10^12 kg CO2eq in 2015 (Eurostat 2017), RMI: 9.7*10^12 kg in 2015 (Eurostat 2018)

Results of available LCA data
GWI of synthetic diesel from air capture vs. diesel



based on Universität Stuttgart (2015). GE = German, DAC = Direct air capture; * do not consider iLUC

Results
Energy supply scenarios



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- Supplying CCU from grid mix would increase GHG emissions dramatically
- Breakeven with conventional requires 86% REN power input minimum (German case)

Theoretical potential for GHG savings by CCU methanol in the EU

Highest GWI reduction

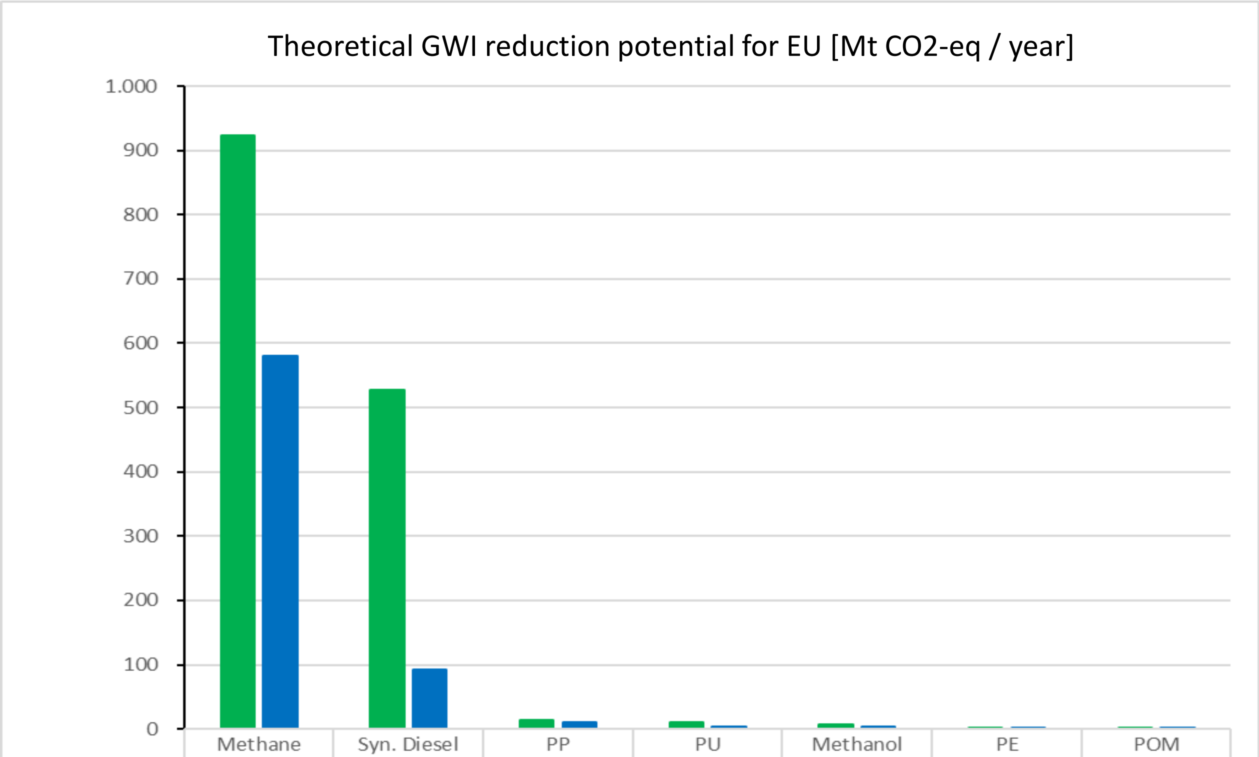
Substitution-Scenario	Share of EU Demand	Methanol [Mt/a]	GWI Reduction [Mt/a]	Required REN-electrical energy for production acc. to LCA-Inventory [TWh/a]	Share of EU GWI (Eurostat 2018)
Domestic EU production	15%	1,21	1,13	14,3	0,03%
Half EU market	50%	4,02	3,78	47,6	0,09%
Imports to EU	85%	6,83	6,42	81,0	0,15%
Full EU market	100%	8,04	7,56	95,3	0,17%

Lowest GWI reduction

Substitution-Scenario	Share of EU Demand	Methanol [Mt/a]	GWI Reduction [Mt/a]	Required REN-electrical energy for production acc. to LCA-Inventory [TWh/a]	Share of EU GWI (Eurostat 2018)
Domestic EU production	15%	1,21	0,44	14,3	0,01%
Half EU market	50%	4,02	1,46	47,7	0,03%
Imports to EU	85%	6,83	2,48	81,1	0,06%
Full EU market	100%	8,04	2,91	95,4	0,07%

- REN based CCU could contribute only minor share to overall mitigation but would require high REN supply
  → **CCU is for C recycling not for solving the climate issue**

Theoretical potential for GHG savings
for evaluated CCU processes in the EU



	Methane	Syn. Diesel	PP	PU	Methanol	PE	POM
Best Case	922,4	526,6	13,4	9,8	7,6	2,8	0,2
Worst Case	580,7	92,0	10,9	4,2	2,9	2,2	0,1

- Available **renewable energy will be the limiting parameter** for production

Conclusions

Long term perspective

- CCU essential for carbon (re-)sourcing of the chemical industry (→ circular economy)
- Energy and carbon sources will have to be separated

Global warming mitigation

- For hydrogenic routes mitigation only if power supply comes from renewable sources
- Then substantial REN input required for large scale production
- Mitigation effect by substitution independent from durability of products for given product mix (→ input of CO_2 decisive for given retention times)

Trade-off with material and energy requirements for infrastructure

- Higher raw material requirements and cumulative energy demand than conventional routes
- Trade-off GWI vs. RMI may be acceptable for certain routes

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Many thanks for your attention !

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Further reading:

Life Cycle Costing (LCC), Cradle2Gate

Economic assessment of CO2-based methane, methanol and polyoxymethylene production
Wieland Hoppe, Stefan Bringezu and Nadine Wachter
DOI: 10.1016/j.jcou.2018.06.019

Detailed LCA, Cradle2Gate

Life Cycle Assessment of Carbon Dioxide-Based Production of Methane and Methanol and derived Polymers
Wieland Hoppe, Nils Thonemann and Stefan Bringezu
DOI: 10.1111/jiec.12583