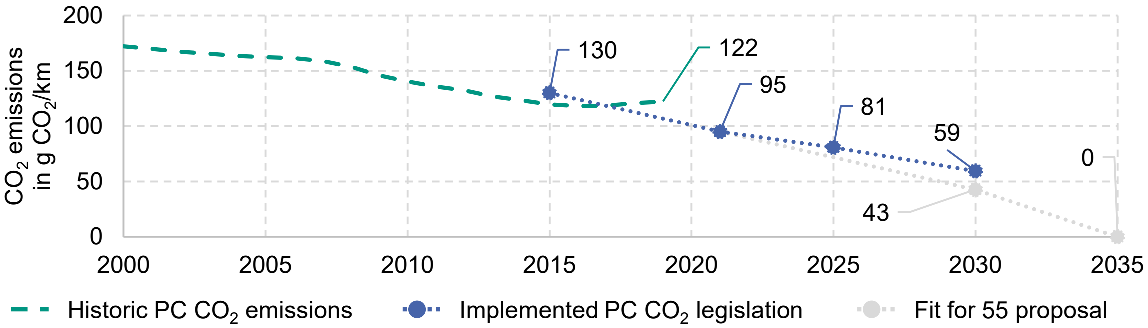
Lebenszyklusanalyse als Werkzeug für Ingenieure
Life Cycle Assessments as Tool for Engineers

Wie können wir Umweltbilanzen nutzen, um den Ingenieurbeitrag beizutragen?
Will Life Cycle Assessments affect our Engineering Toolchain?

Life Cycle Assessment as Engineering Tool
Motivation

- Target:
  Reduction of GHG
- Metrics:
  extension of TTW approach towards LCA
- Research object:
  interdependency of powertrain development and environmental impact



EUROPEAN UNION. *Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011. Regulation (EU) 2019/631*, 2019.

EUROPEAN ENVIRONMENT AGENCY (EEA). *CO2 performance of new passenger cars in Europe* [online]. 18 November 2021, 12:00 [viewed 22 April 2022]. Available from: https://www.eea.europa.eu/ims/co2-perfor-mance-of-new-passenger.

EUROPEAN COMMISSION. Communication from the Commission to the European Parliament, the Euro-pean Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal. 11 December 2019, 12:00 [viewed 9 September 2022]. Available from: https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF.

GHG = greenhouse gas, TTW = tank-to-wheel,
LCA = life cycle assessment, PC = passenger car

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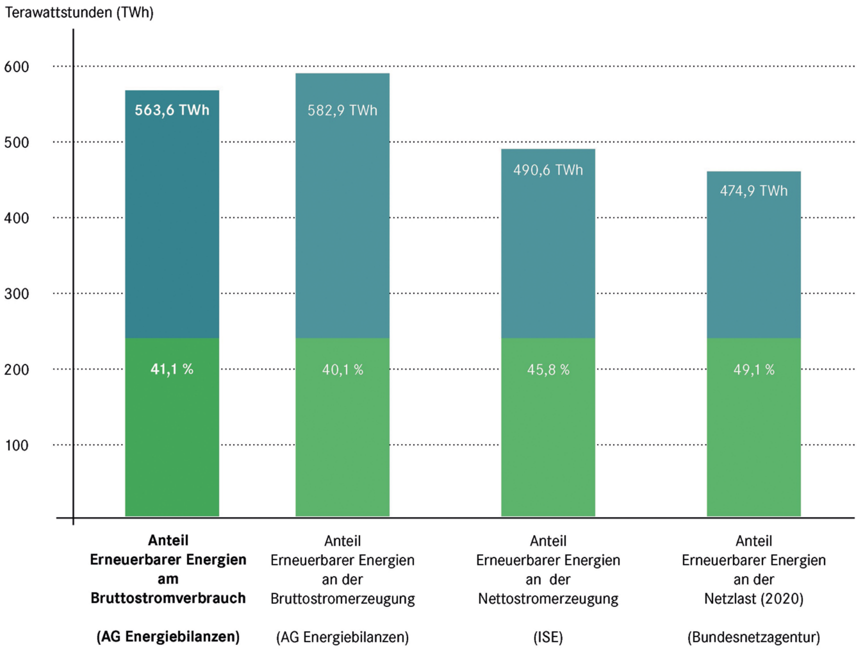
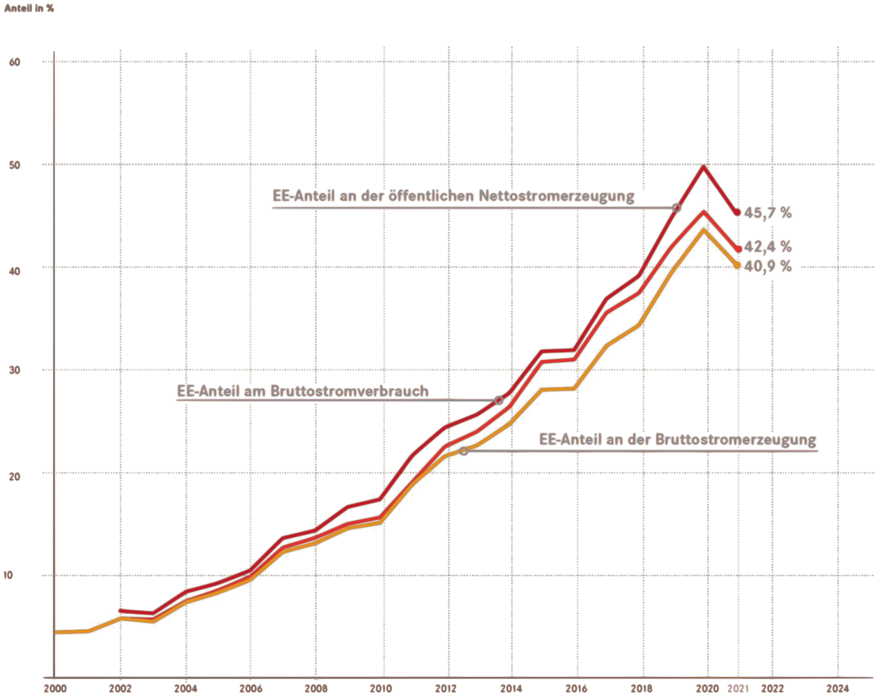
Life Cycle Assessment as Engineering Tool

- Are we really sustainable?



Quellen: Arbeitsgemeinschaft Energiebilanzen / BDEW/ Fraunhofer ISE/ Bundesnetzagentur

ENERGIEWIRTSCHAFTLICHE TAGESFRAGEN 72. Jg. 2022 Heft 4



Quellen: BDEW/ Fraunhofer ISE

Anteil der erneuerbaren Energien an der Stromversorgung und Bruttostromverbrauch – Entwicklung 2000-2021

Life Cycle Assessment as Engineering Tool

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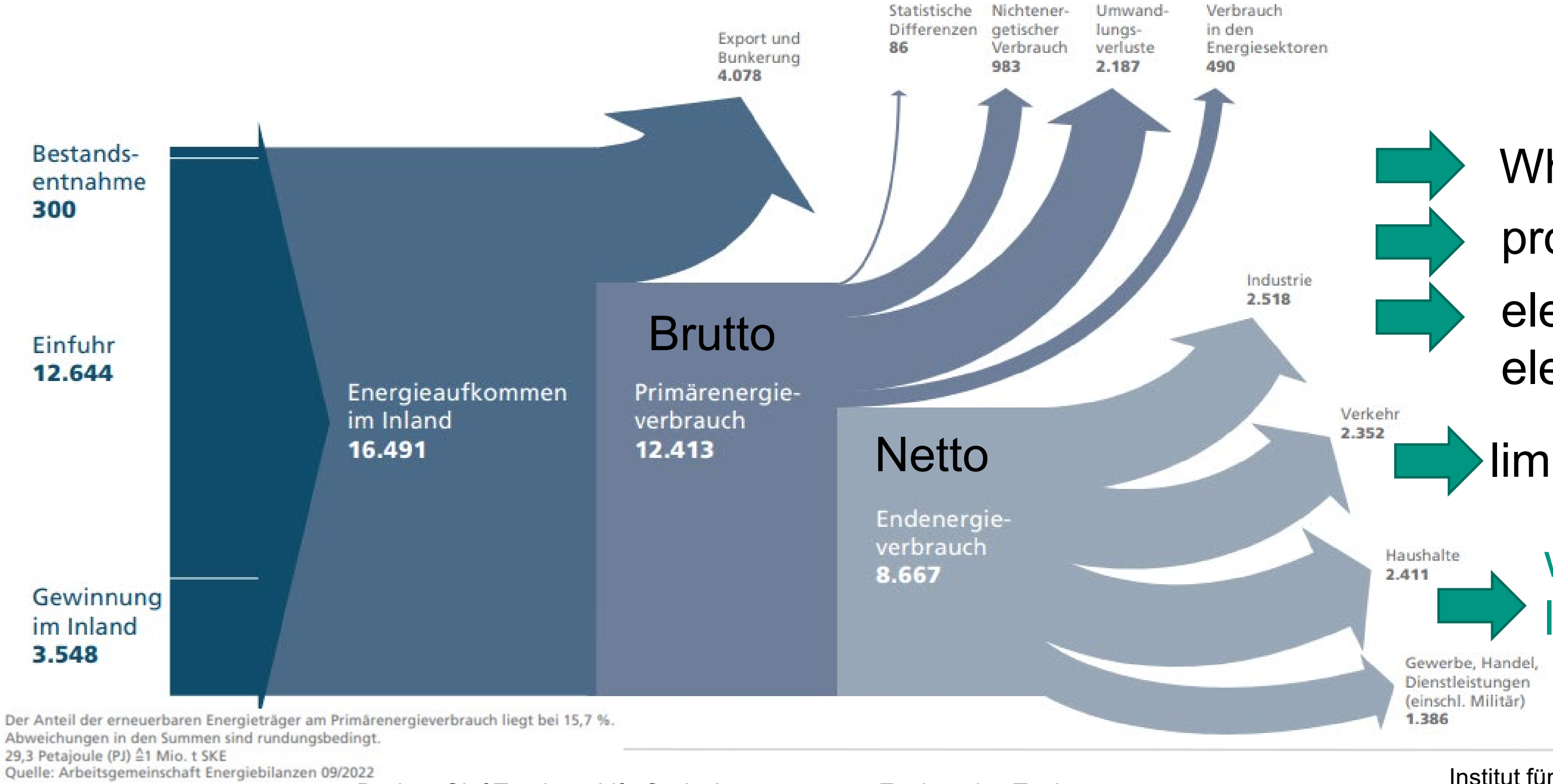
- How to get sustainable Exemplaric 2021 Energy Chart for Germany



- What is the base?
- production vs. use?
- electricity as minor element
- limited GHG-budget
- we have to us all levers

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Life Cycle Assessment as Engineering Tool
Toolchain overview

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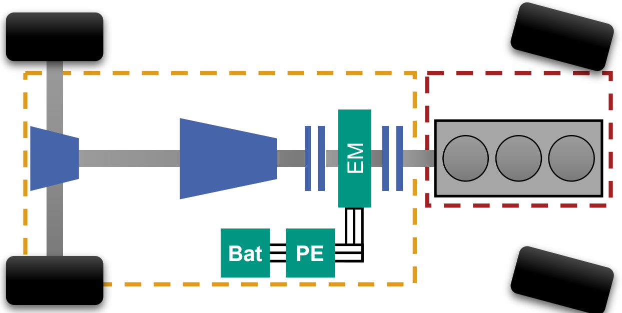
Preprocessing

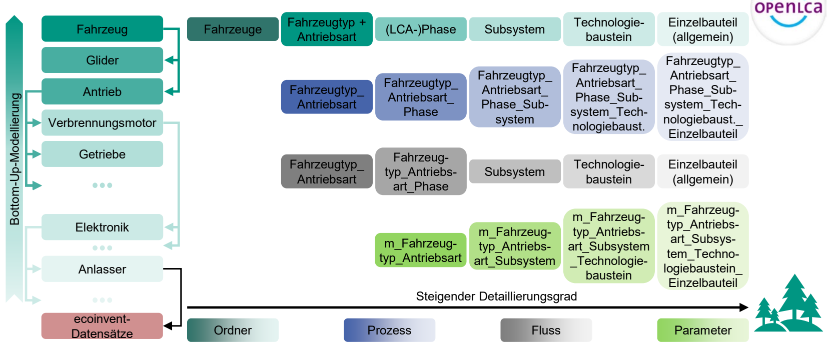
- Vehicles topology, technologies
- Production place and time
- Usage (region, time, energy carrier)
- Application (scenarios)

Vehicle simulation



Energy demand (+ pollutants)

Modular LCA model



Postprocessing

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Life Cycle Assessment as Engineering Tool
Life cycle assessment – ISO 14040/14044

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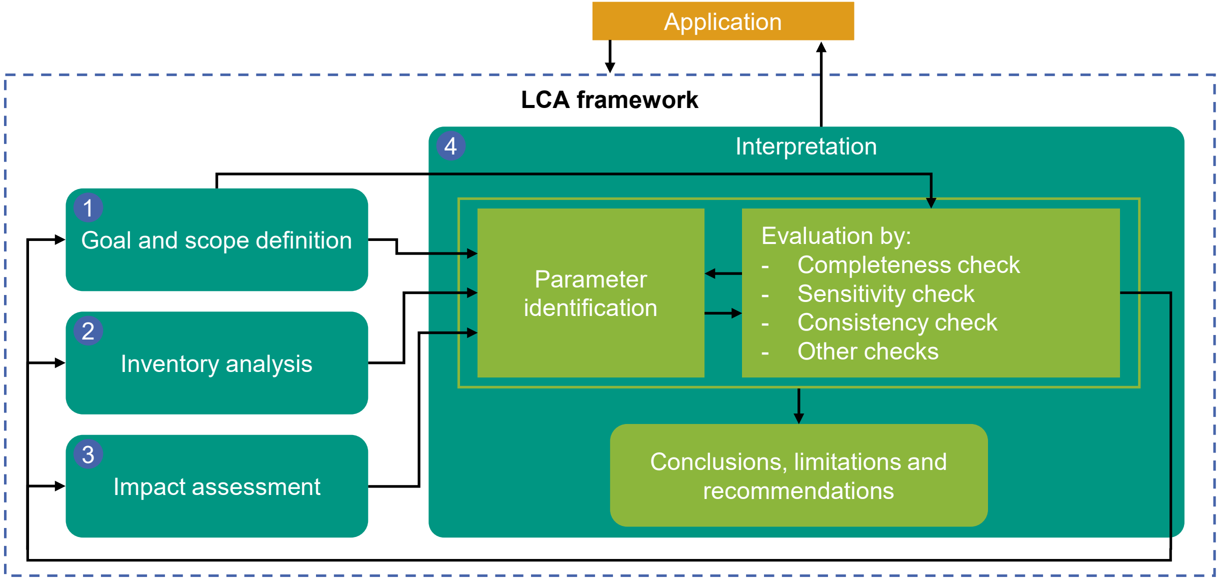
- Environmental evaluation of product life cycle impacts
- Standardized in ISO 14040/14044
- 4 phases, iterative procedure



→ Challenges: comparability (assumptions, methods, metrics), data availability, transparency

Life Cycle Assessment as Engineering Tool

System Boundaries illustrate the Risc to shift A Task instead of solving it

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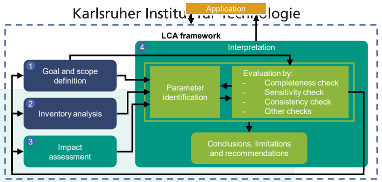
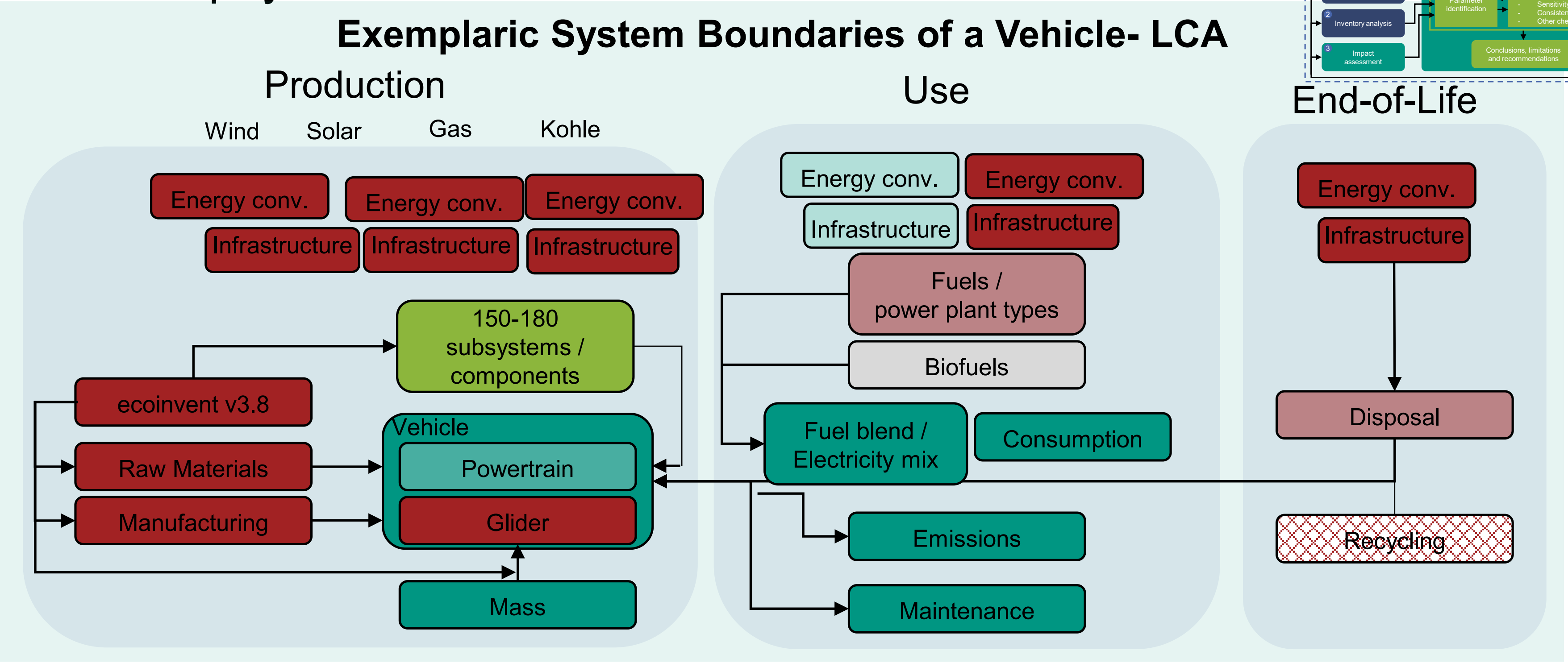
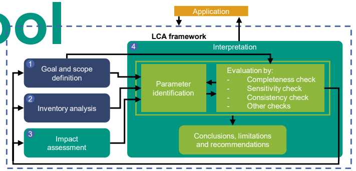


- Holistic physical View



Life Cycle Assessment as Engineering Tool

LCA modeling – Modeling approach



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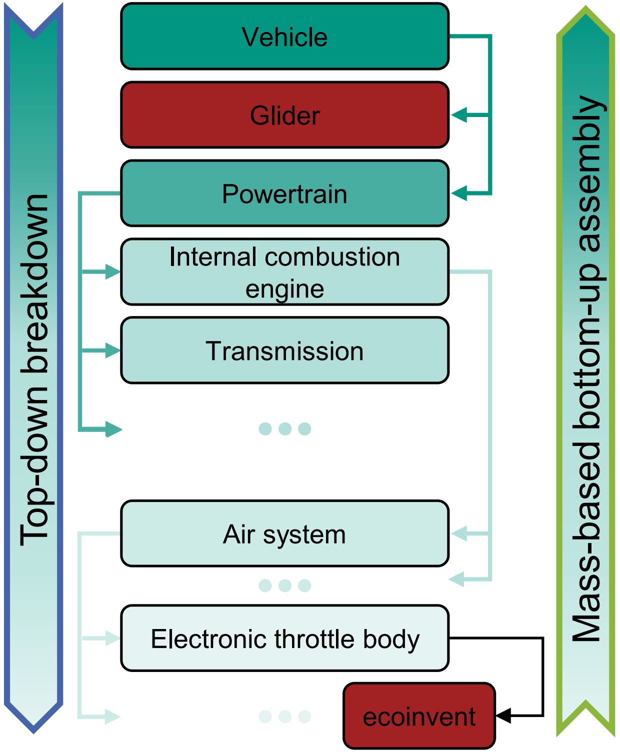
- Multilevel top-down bottom-up modeling
  - Vehicle = powertrain + glider („rest")
  - $m_{Glider} = m_{Vehicle} - m_{Powertrain} - m_{Driver} - m_{Tank}$

- Vehicles with three hybridization degrees

Powertrain	ICEV-g MT	MHEV-g P1-MT	FHEV-g P2-DCT
Reference vehicle	Ford Focus		
Transmission	6-speed MT		7-speed DCT
EM power	2 kW	11.5 kW (48 V)[1]	30 kW (400 V)[2, 3]
HV battery	-	0.384 kWh[4]	2 kWh[4]

[1]Data from a manufacturer of belt integrated starter generators
[2]NORDELÖF et al., 2018. A scalable life cycle inventory of an electrical automotive traction machine—Part I: design and composition [online]. The International Journal of Life Cycle Assessment, 23(1), 55-69. ISSN 0948-3349. Available from: doi:10.1007/s11367-017-1308-9
[3]NORDELÖF et al., 2018. A scalable life cycle inventory of an electrical automotive traction machine—Part II: manufacturing processes [online]. The International Journal of Life Cycle Assessment, 23(2), 295-313. ISSN 0948-3349. Verfügbar unter: doi:10.1007/s11367-017-1309-8
[4]ELLINGSEN et al., 2013. Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack [online]. Journal of Industrial Ecology, 18(1), 113-124. ISSN 10881980. Verfügbar unter: doi:10.1111/jiec.12072



Life Cycle Assessment as Engineering Tool

Production and use emissions of a gasoline and a diesel vehicle

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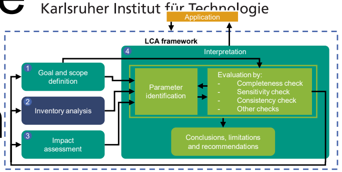
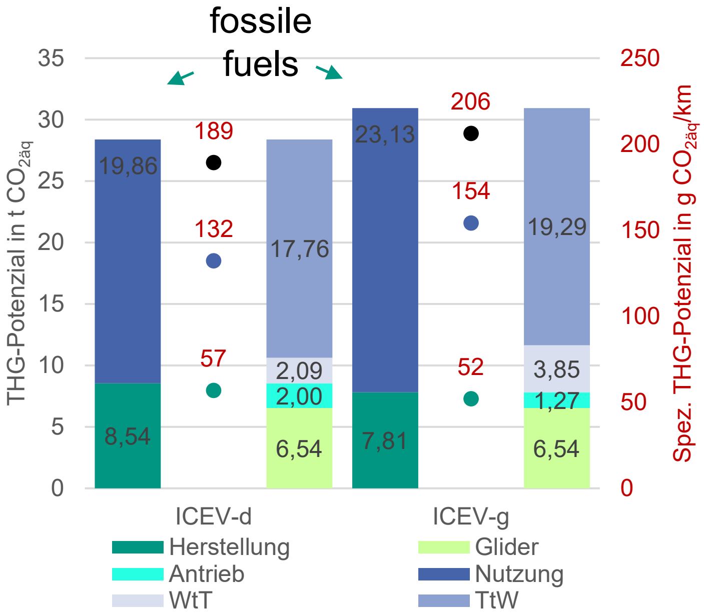
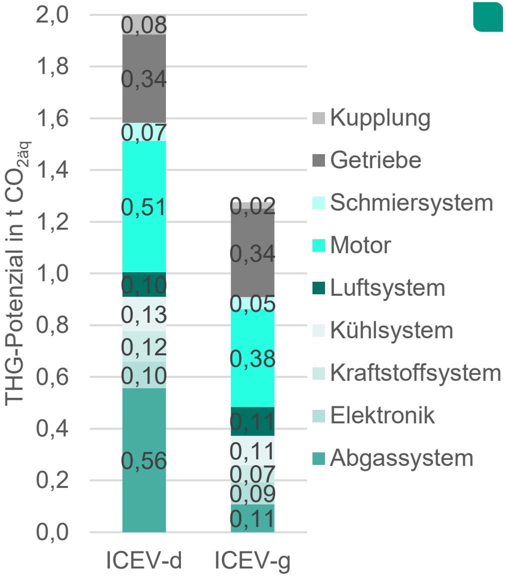


- LCA of combustion vehicles using fossile fuels for 150.000km





- Emissions of production and use of
  - Compact Car Vehicles:
    - ICEV-d = Diesel-car
    - ICEV-g = gasoline-car
  - Use = Well-to-Tank + Tank-to-Wheel

➡ Neither vehicle production nor the energy carrier can be ignored

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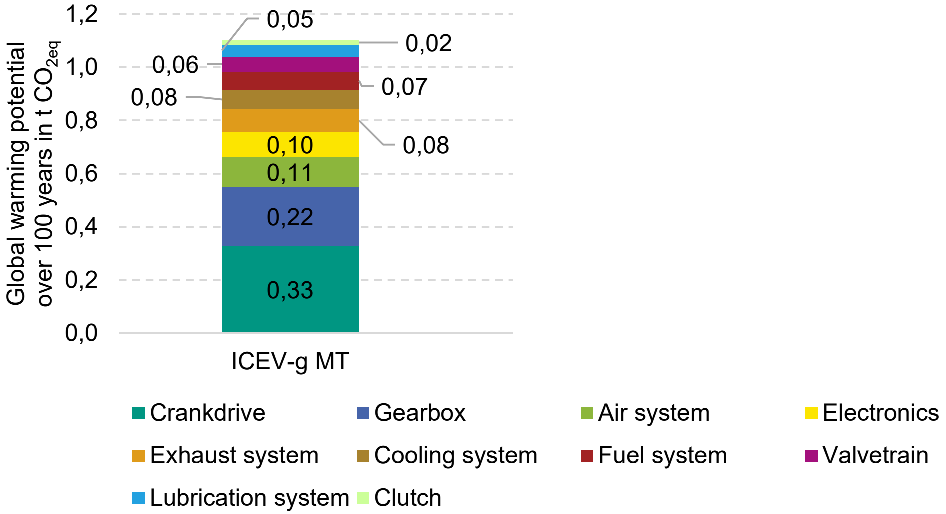
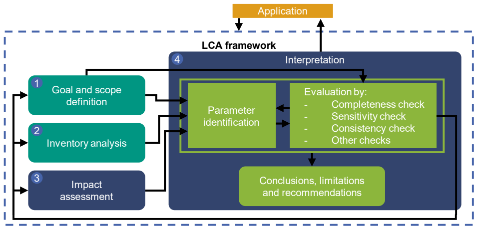
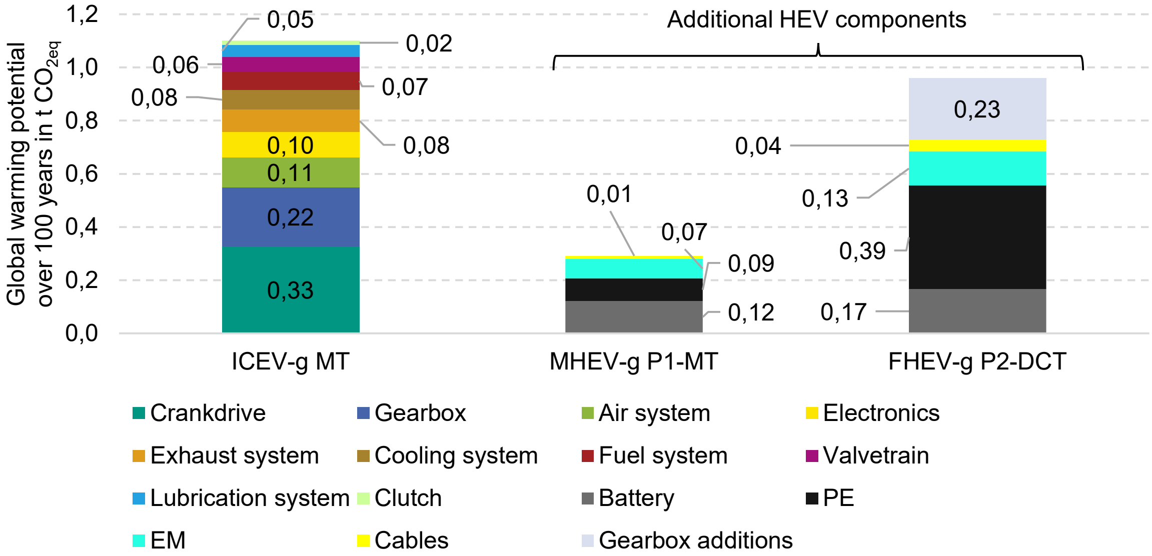
Life Cycle Assessment as Engineering Tool
Life cycle GWP100 – Breakdown

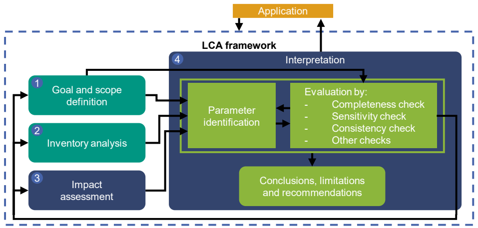




Life Cycle Assessment as Engineering Tool

Life cycle GWP100 – Breakdown

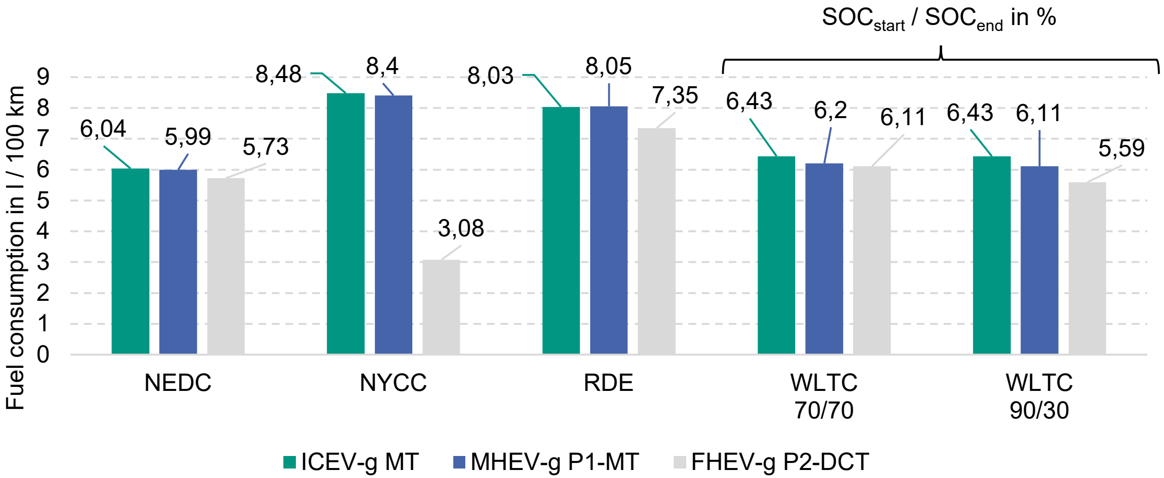


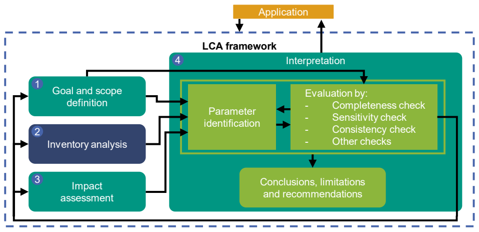


→ Full hybridization ≈ twice as much CO_{2eq} as conventional powertrain

Life Cycle Assessment as Engineering Tool

Fuel consumption using CM with no modification





→ **Strongest hybridization improved consumption by up to ca. 8 % without specific system optimization**

→ **Here vehicle models just as engineering example**

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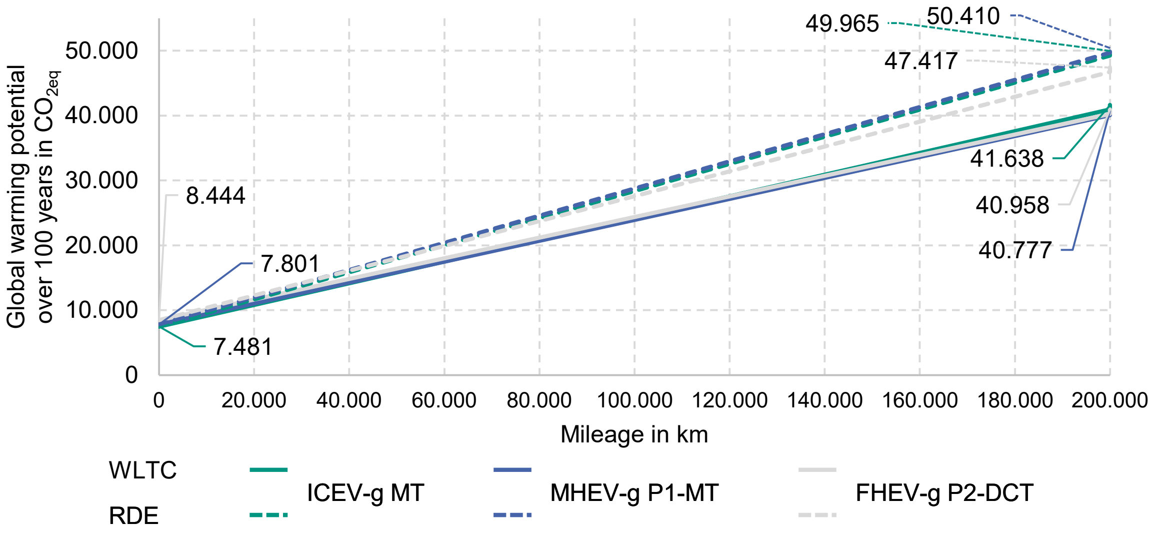
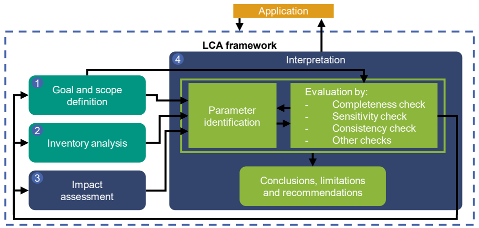
Life Cycle Assessment as Engineering Tool
Life Cycle GWP100 – Mileage as fuctional Unit





Fuel: E5

WLTC, 200,000 km

→ Strongest hybridization not necessarily CO_{2eq}-optimal over life

→ Depending on application, MHEV-g slightly better

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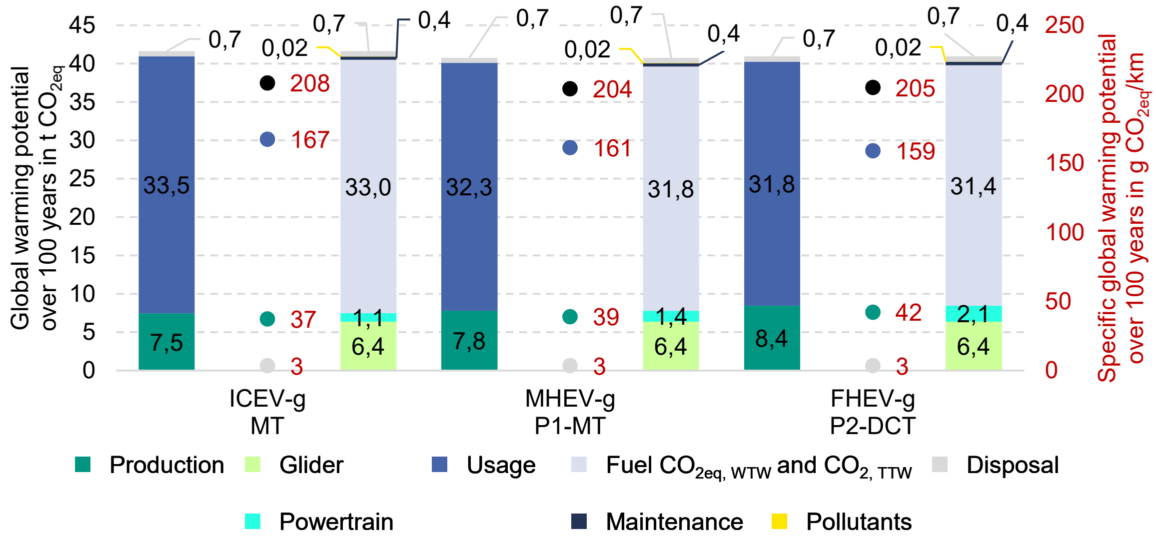
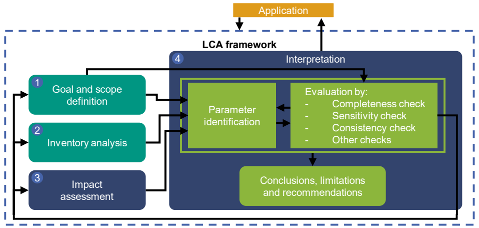
Life Cycle Assessment as Engineering Tool

Life cycle GWP100 – Breakdown





Fuel: E5

WLTC, 200,000 km

→ Usage = dominant phase (77 % to 80 %)

→ Glider = main production share (up to 85 %) → segment important

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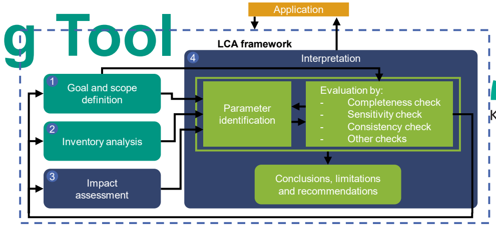
Life Cycle Assessment as Engineering Tool
Overall impact categories



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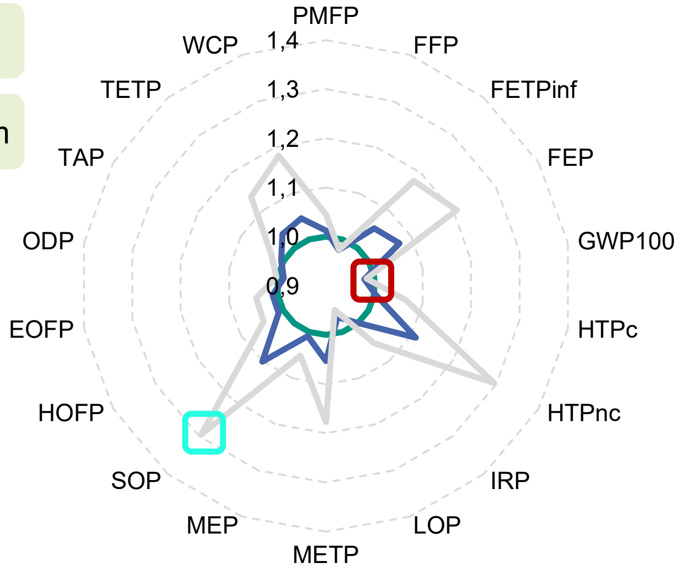
Fuel: E5

WLTC, 200,000 km

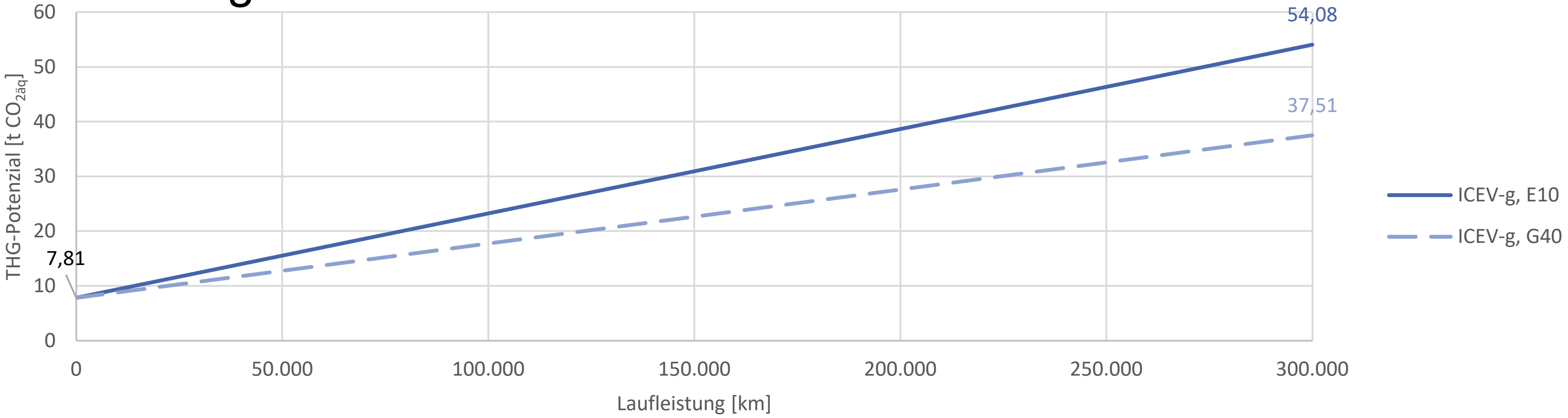


PMFP	Fine particulate matter formation
FFP	Fossil resource scarcity
FETPinf	Freshwater ecotoxicity
FEP	Freshwater eutrophication
GWP100	**Global warming**
HTPc	Human carcinogenic toxicity
HTPnc	Human non-carcinogenic toxicity
IRP	Ionizing radiation
LOP	Land use
METP	Marine ecotoxicity
MEP	Marine eutrophication
SOP	**Mineral resource scarcity**
HOFP	Ozone formation, human health
EOFP	Ozone formation, terrestrial ecosystems
ODP	Stratospheric ozone depletion
TAP	Terrestrial acidification
TETP	Terrestrial ecotoxicity
WCP	Water consumption

→ Despite beneficial GWP100, hybridization might cause harm in other impact categories, e.g., mineral resource scarcity (+ 30 %)

Vehicle-LCA using reFuels als E10 gasoline replacement

- Variation of gasoline fuel



➡ MtG-gasoline baed on biogenic waste stores CO_2 from air, is energetic self-supplying and delivers additional waste heat (CO_2-negative insides of system limits).

➡ EN 228-Blend G40 using 30% biowaste-MtG-gasoline shows significant CO_2-reduction in use phase.

➡ EN 228- kompatible G85 Blend as significant step in direction CO_2-nutrality.

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Vehicle LCA using reFuels als Diesel replacement

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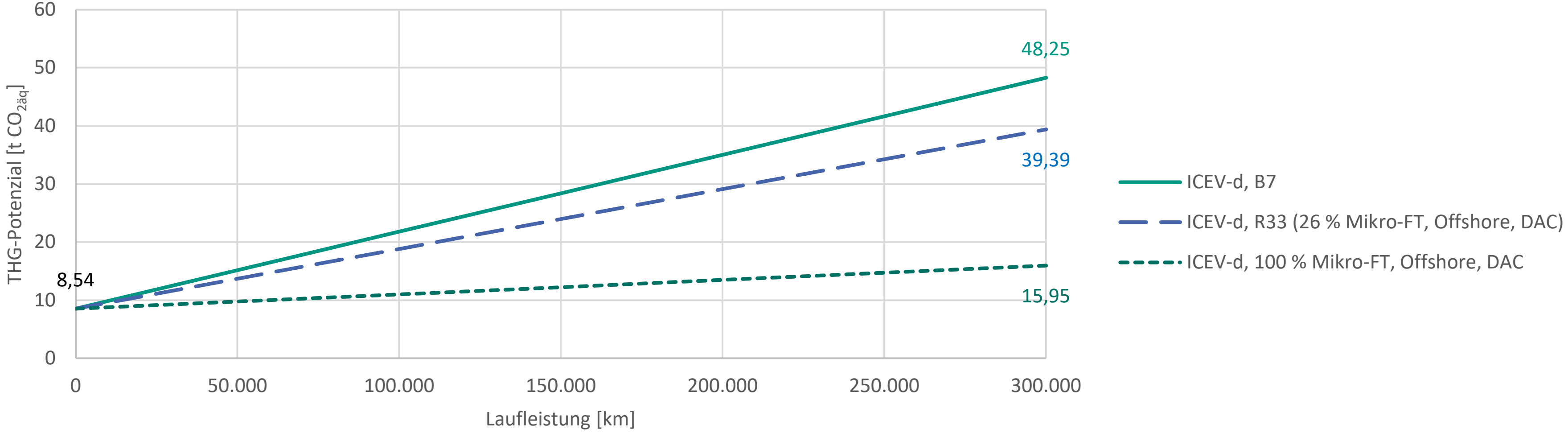
Diesel Fuel Variation



- Even as drop-in component (R33) a 22% CO_2-reduction in use phase
- ~82 % CO_2-reduction by E-Fuel –Diesel in existing fleet using offshore wind electricity.
- CO_2-reductions potential increases w availability of enrgy by regen. sources → pref. locations
- Import of intermediates (Fischer-Tropsch-crude and methanol) in existing refinaries

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Life Cycle Assessment as Engineering Tool

Life Cycle Assessment of Fuel Synthesis – Global Warming Potential

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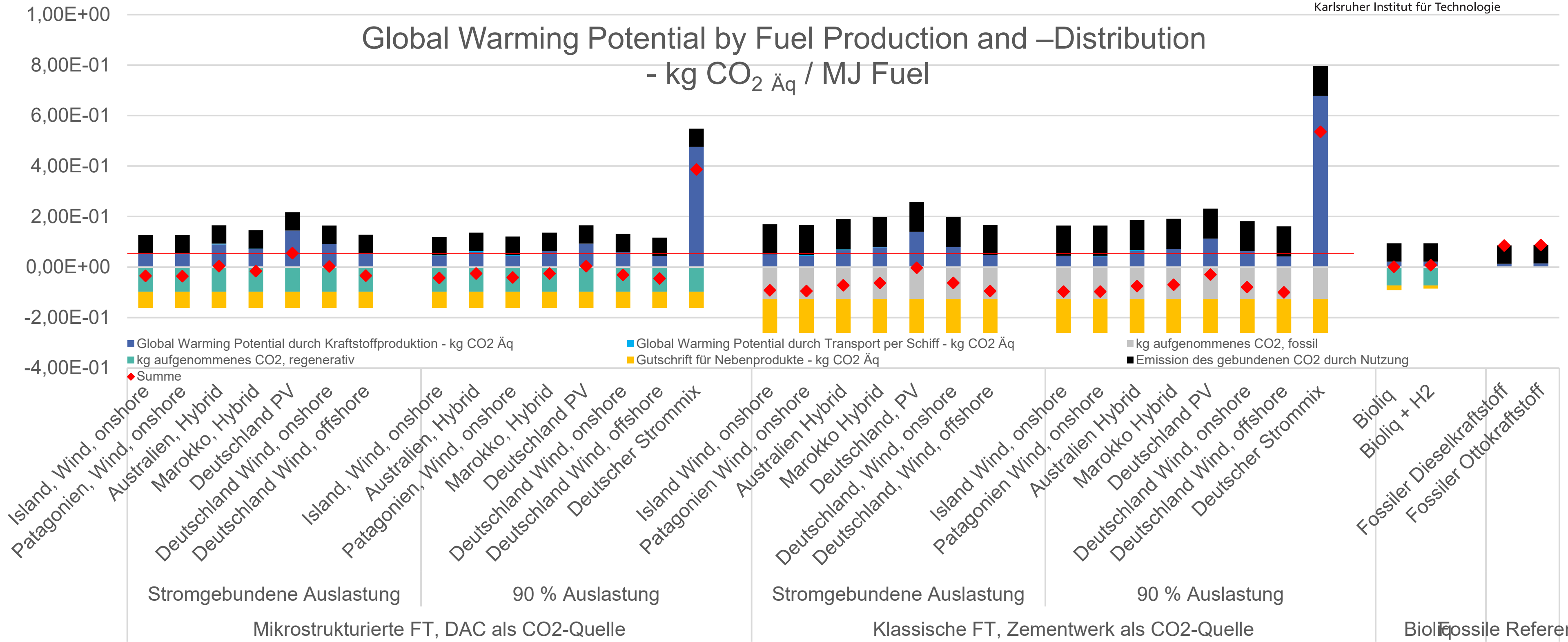

→Fuels and intermediates (Methanol, FT-Crude) @ preferred locations are transported in existing infrastructure


Thank you for your attention