PAUL SCHERRER INSTITUT

PSI

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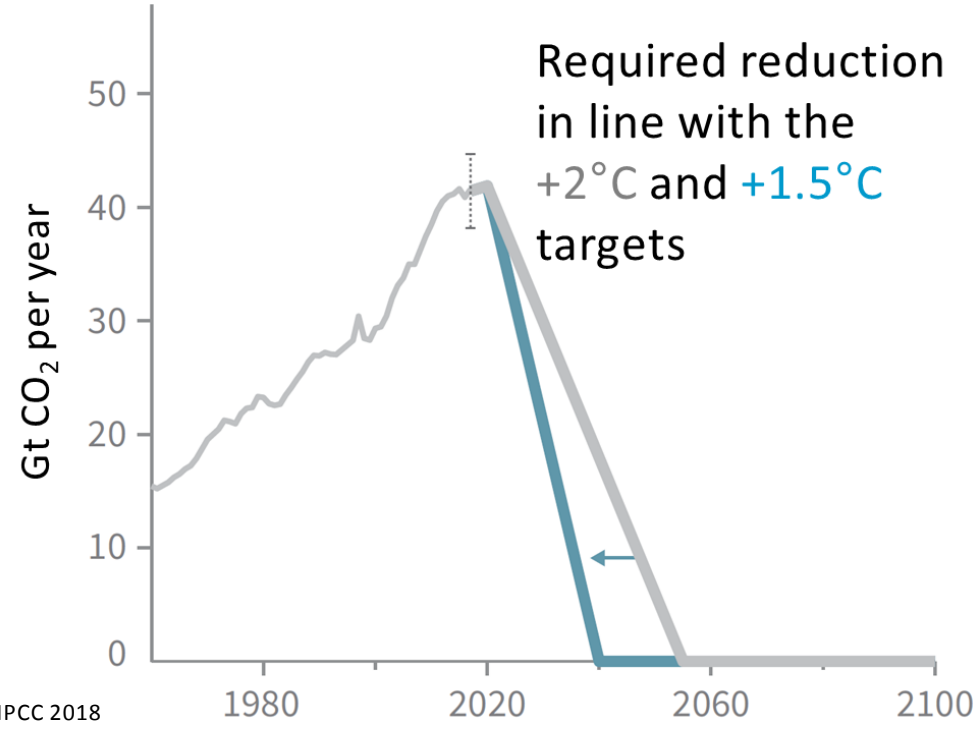
Carbon Capture and Storage and its role in sustainable transport – the life cycle perspective

Eco-mobility 2020, November 19, 2020

Sustainable transport

1. Climate change

Global net CO_2 emission pathways



IPCC 2018

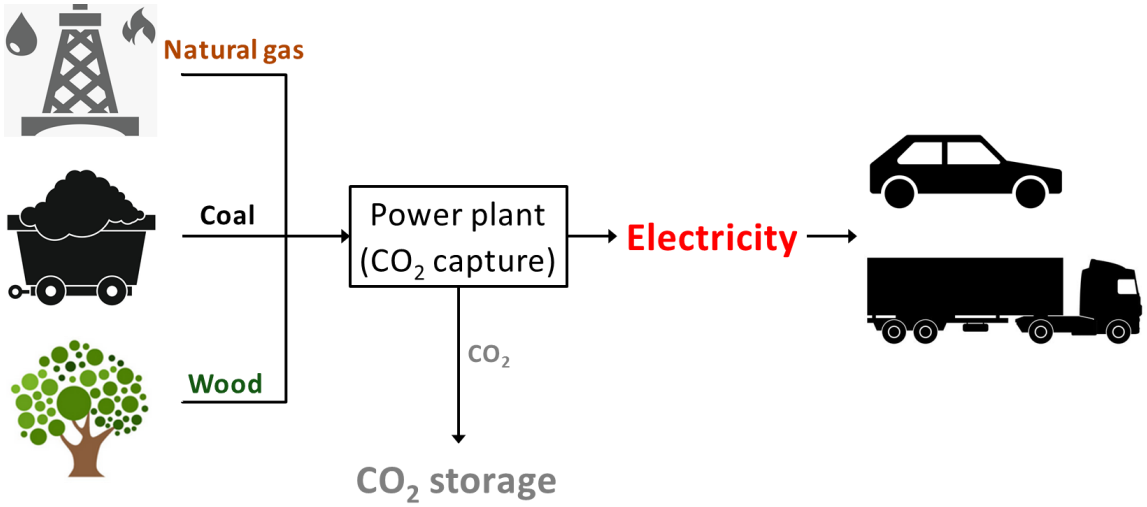
2. Local/regional air pollution

New Delhi, 2019 – © ABC news

© picture alliance / Michael Weber / Eibner-Pressefoto

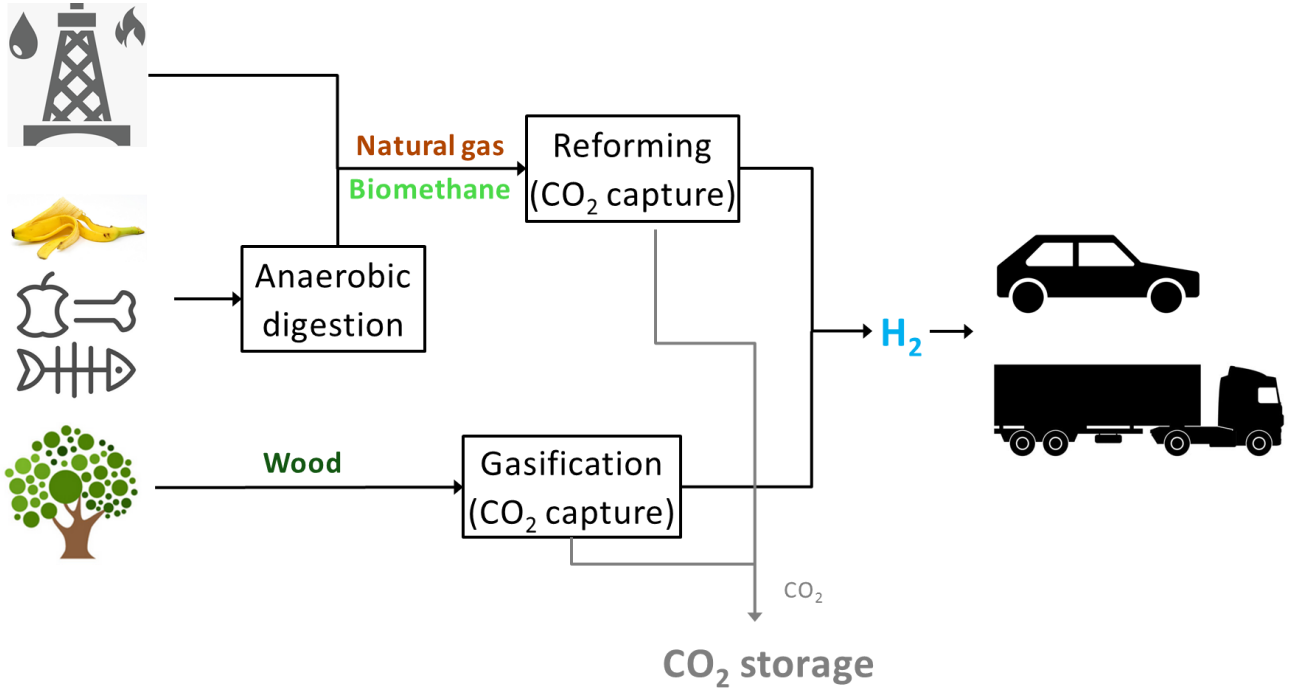
Carbon Capture and Storage (CCS) – relevance for mobility

1. CCS in power generation



«Low-carbon» electricity from coal, NG, or biomass power plants with CCS, used in Battery Electric Vehicles

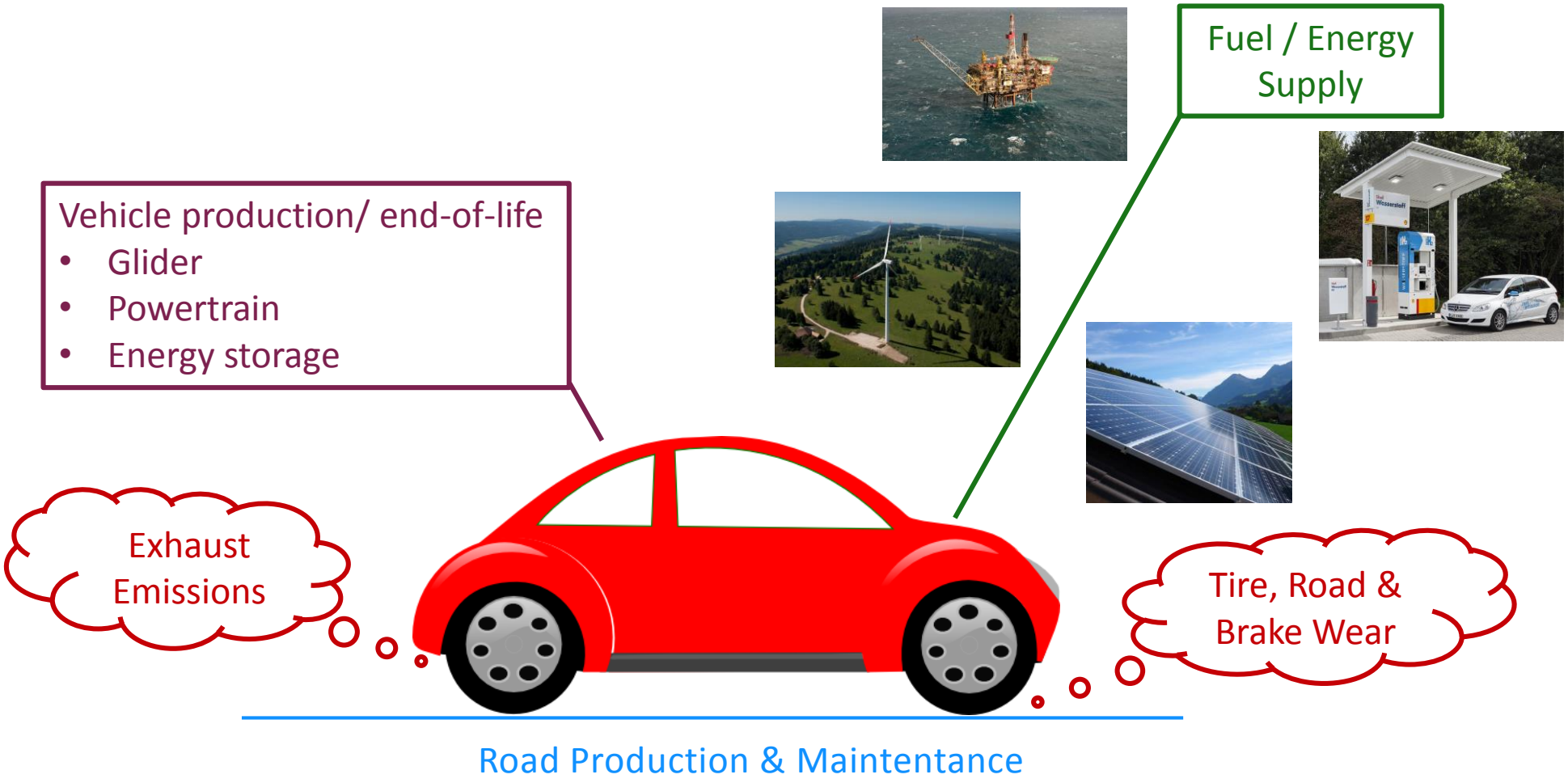
2. CCS in hydrogen production



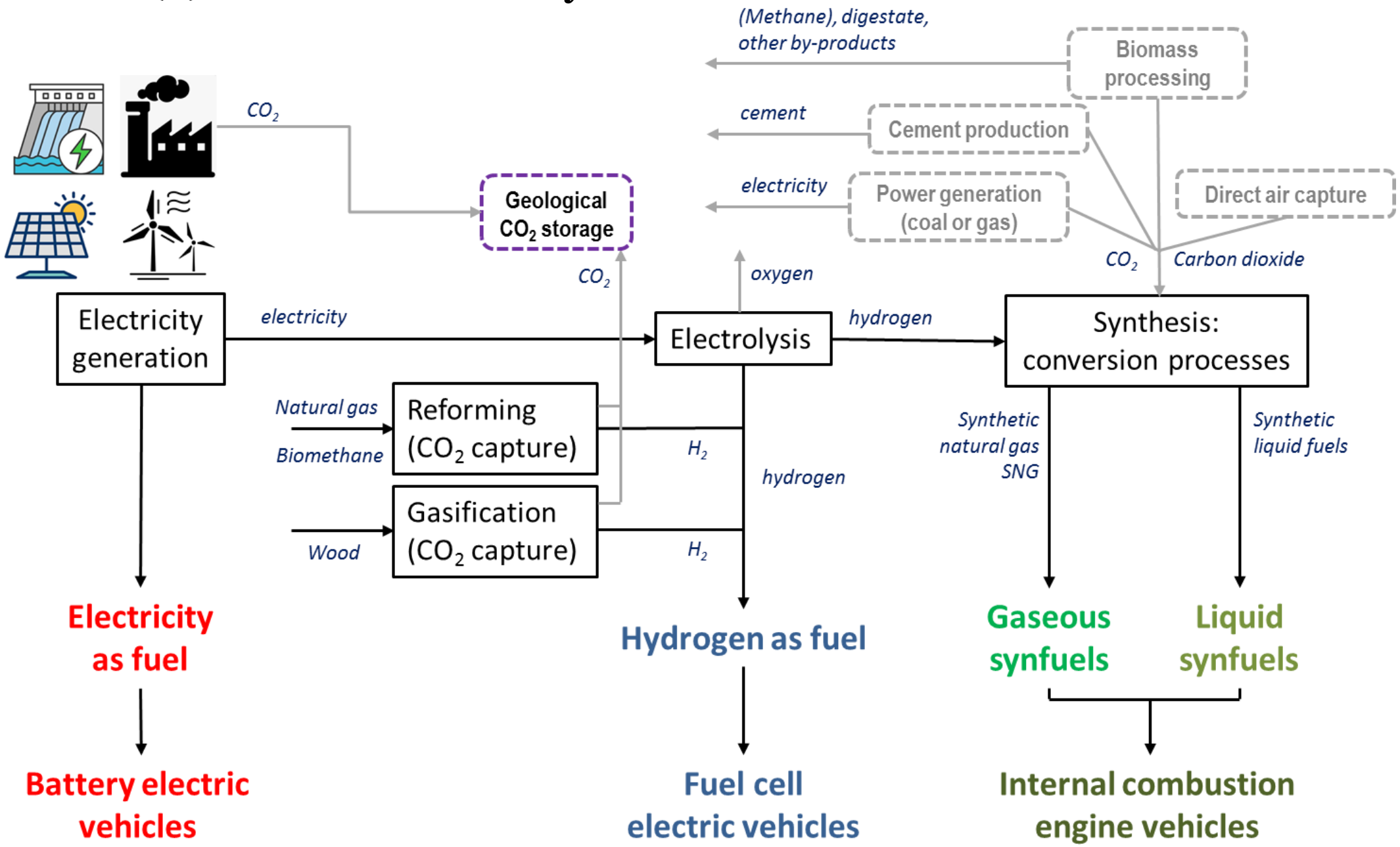
«Low-carbon» hydrogen from natural gas or biomass with CCS, used in Fuel Cell Electric Vehicles

The life cycle perspective: Life Cycle Assessment (LCA)

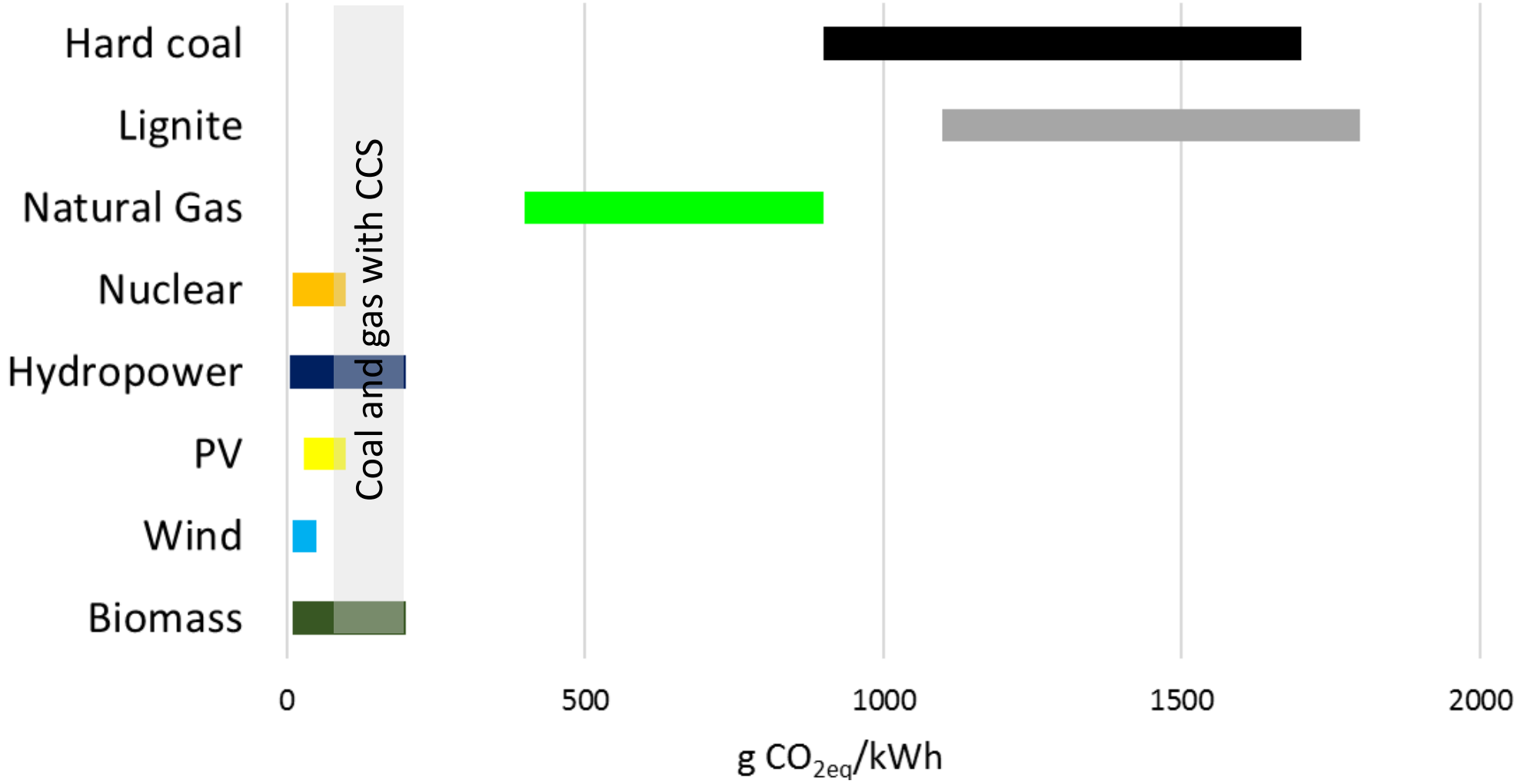
LCA quantifies the **total environmental burdens** of all relevant environmental exchanges over a products' lifetime: **production, use, end-of-life**; and groups these into environmental impact categories



«Clean» (?) fuels for mobility?

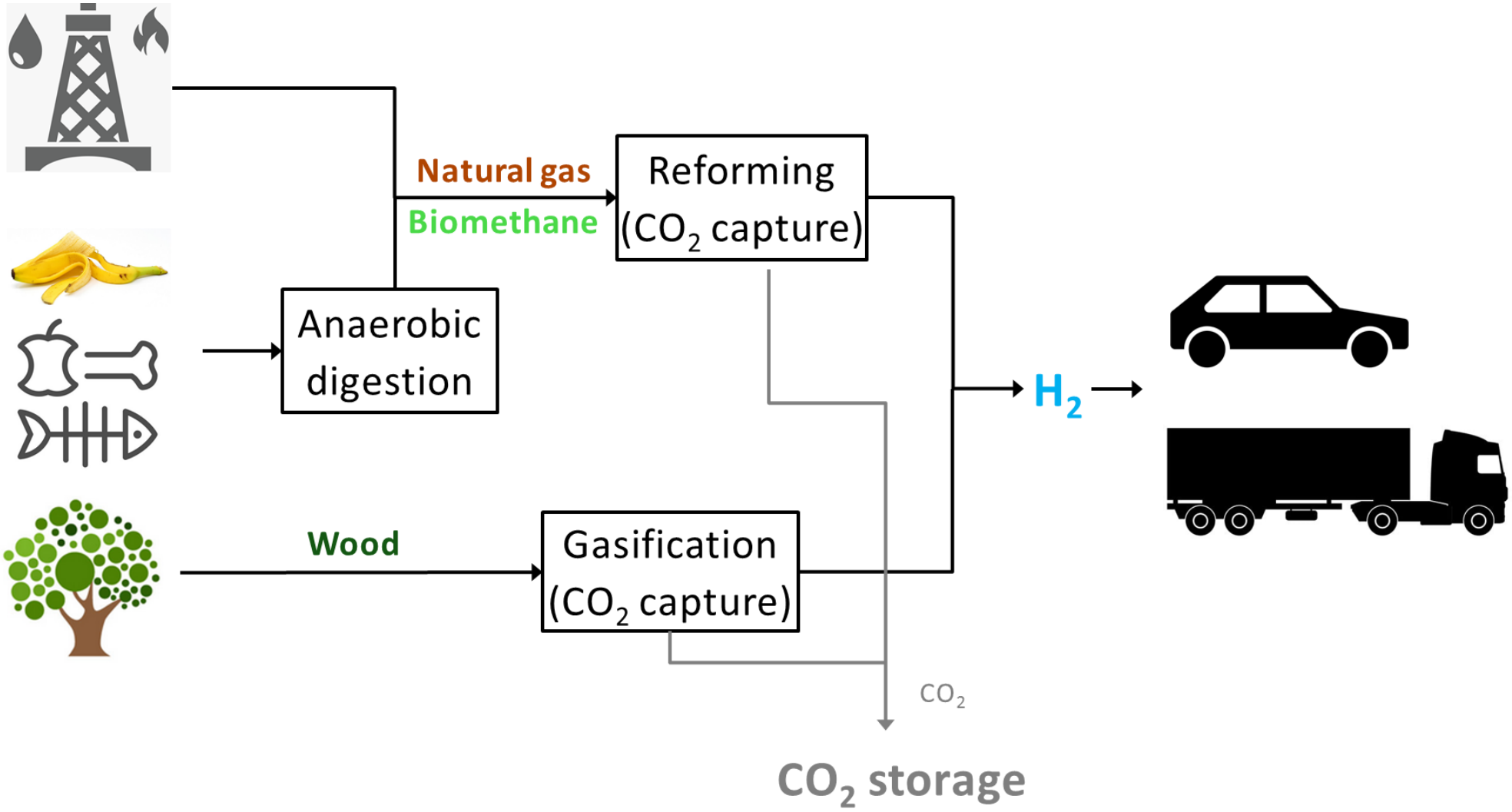


Electricity generation (with CCS) – GHG emissions



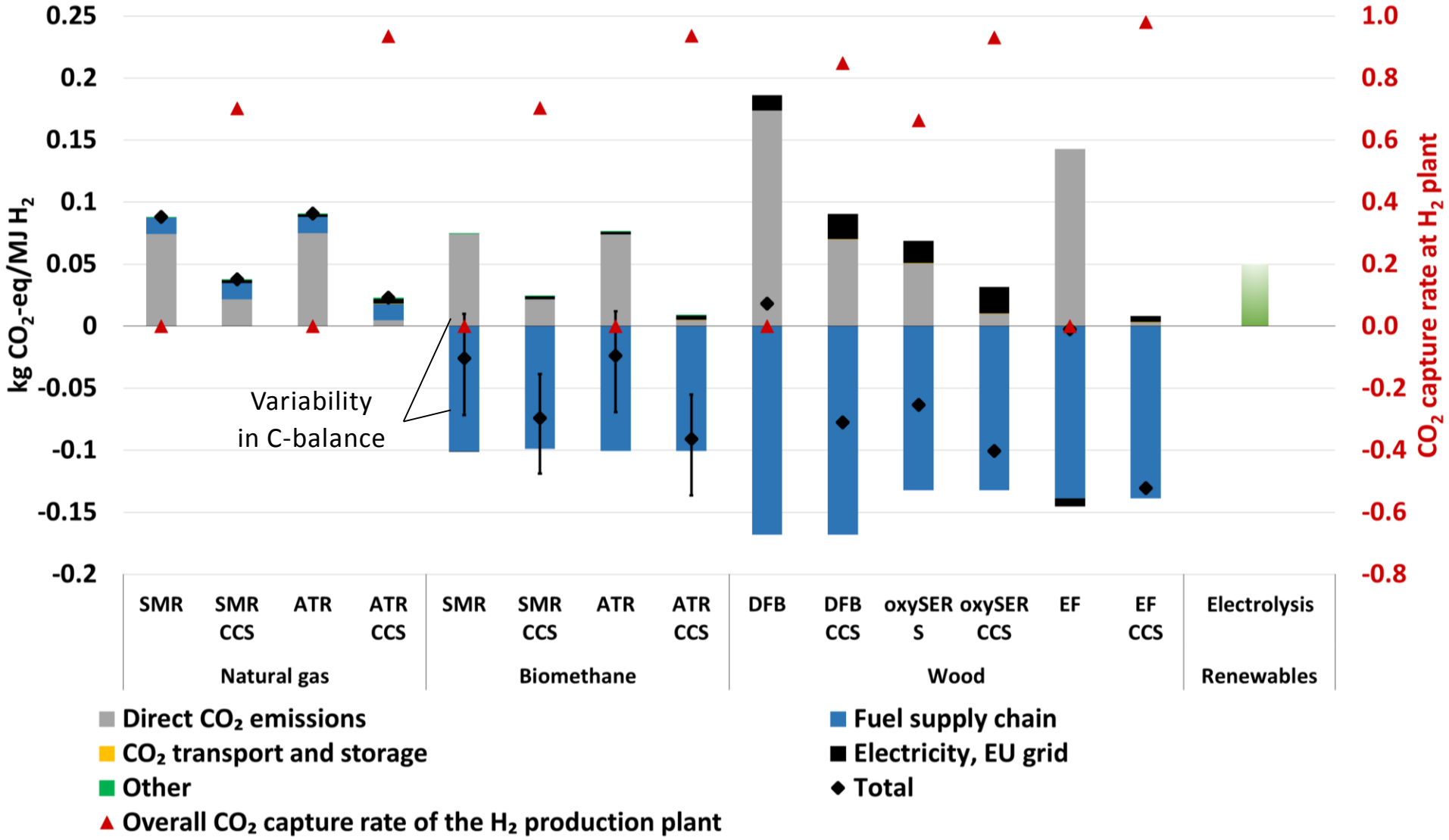
- CCS can reduce GHG emissions of fossil power (almost) to the level of renewables and nuclear power
- CCS for biomass power (BECCS) allows for negative GHG emissions

Hydrogen production (with CCS)



Antonini, C., Treyer, K., Moioli, E., Bauer, C., Mazzotti, M. (submitted) **Hydrogen from wood gasification with CCS – a techno-environmental analysis of production and use as transport fuel**. Sustainable Energy & Fuels, in review,
https://chemrxiv.org/articles/preprint/Hydrogen_from_Wood_Gasification_with_CCS_-_a_Technoenvironmental_Analysis_of_Production_and_Use_as_Transport_Fuel/13213553/1

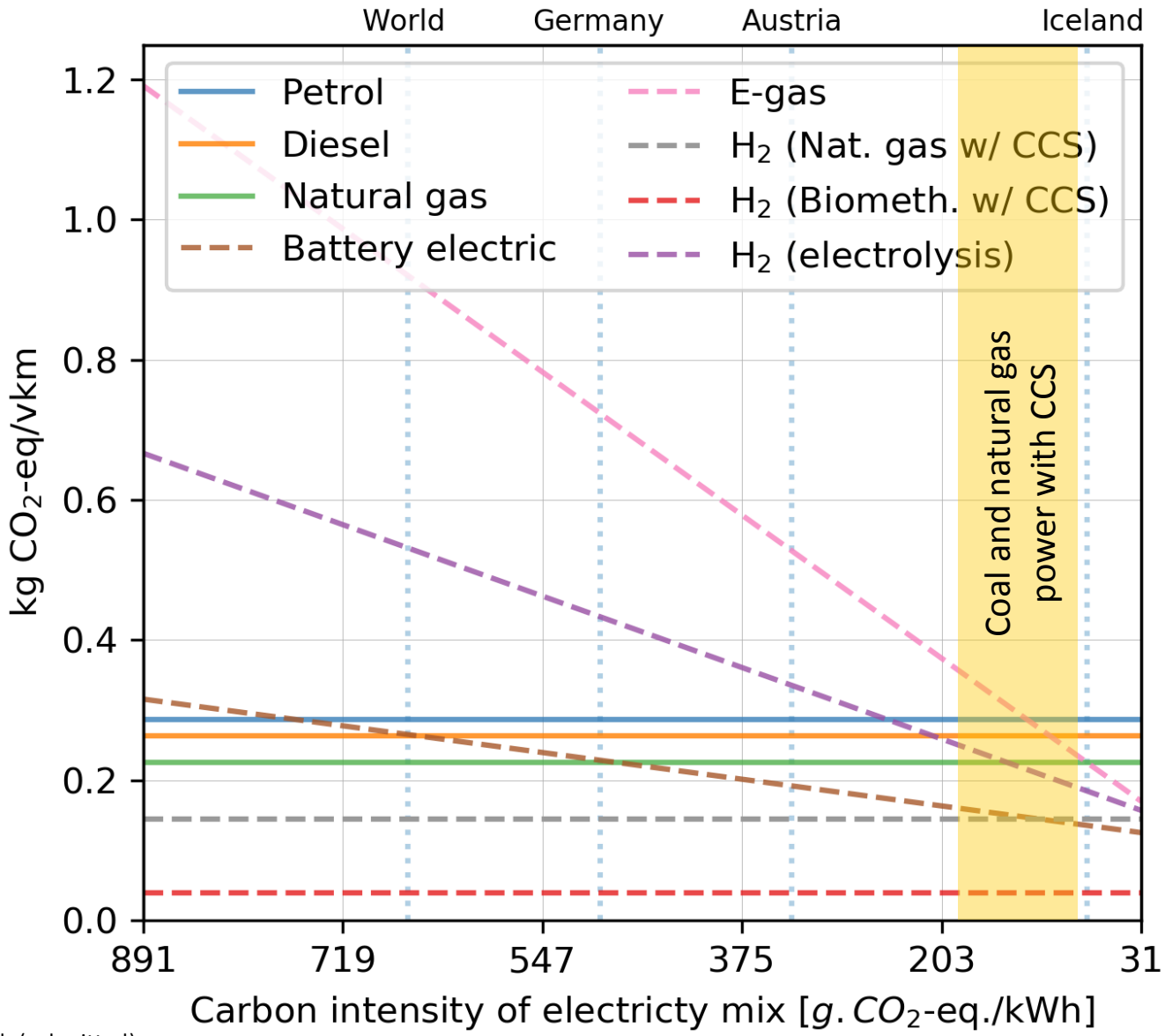
Hydrogen production (with CCS) – GHG emissions



Antonini et al.
(submitted)

SMR: Steam Methane Reforming; ATR: Autothermal Reforming; DFB: Dual Fluidised Bed; SER: Sorption Enhanced Reforming; EF: Entrained Flow

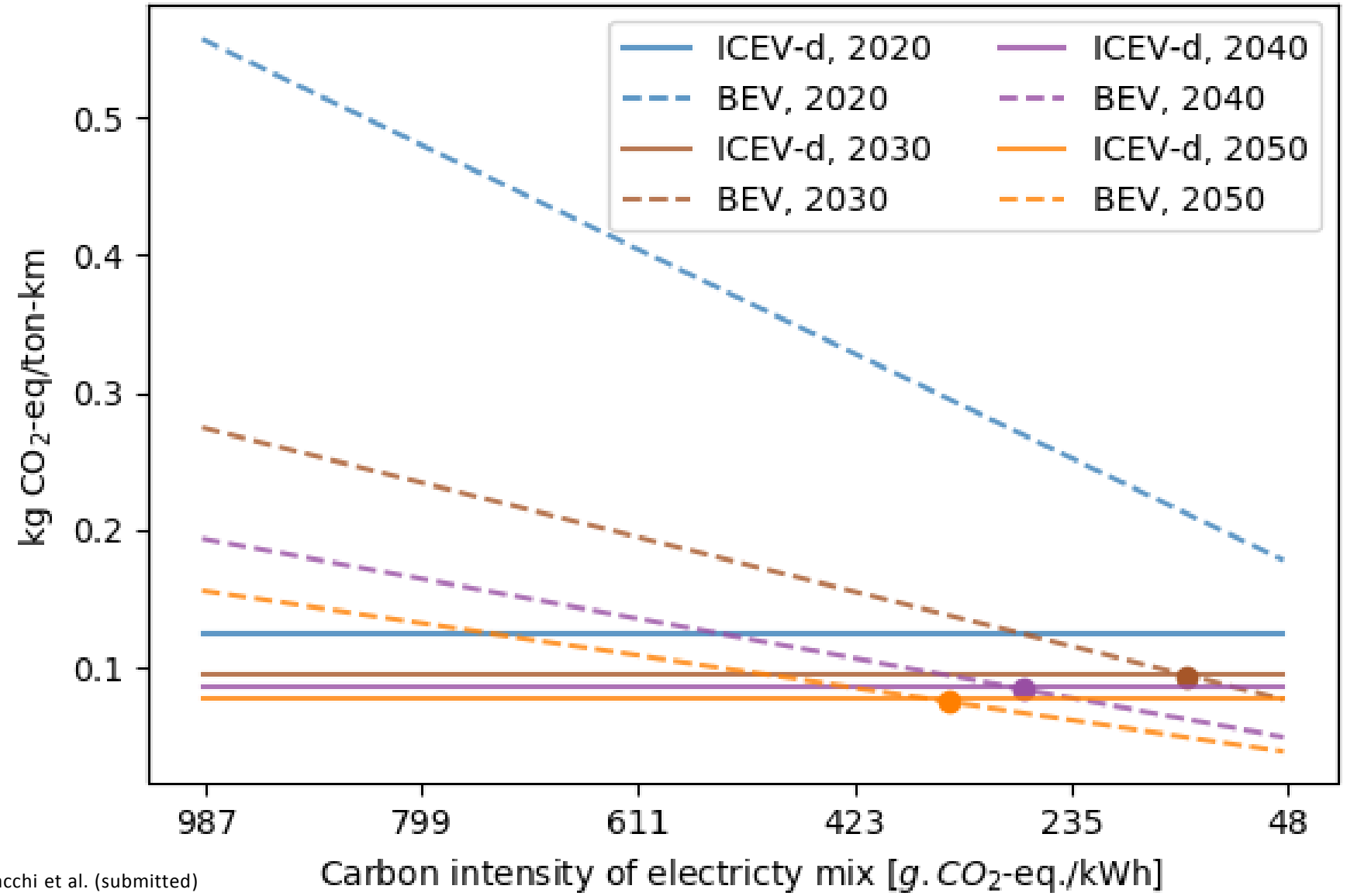
Passenger vehicles – GHG emissions



- FCEV with H_2 from natural gas with CCS show very good GHG performance
  - ✓ Equal to H_2 from electrolysis with very low-C electricity
  - ✓ Similar to BEV with low-C electricity
- FCEV with H_2 from biomethane with CCS almost allow for climate-neutral transport
- BEV with CCS-electricity similar to NG-H_2-CCS FCEV re GHG emissions
- Synthetic e-fuels suffer from a low energy efficiency in the fuel production chain

Sacchi et al. (submitted)

Trucks – GHG emissions BEV vs ICEV-diesel (40t vehicle, 800km range)

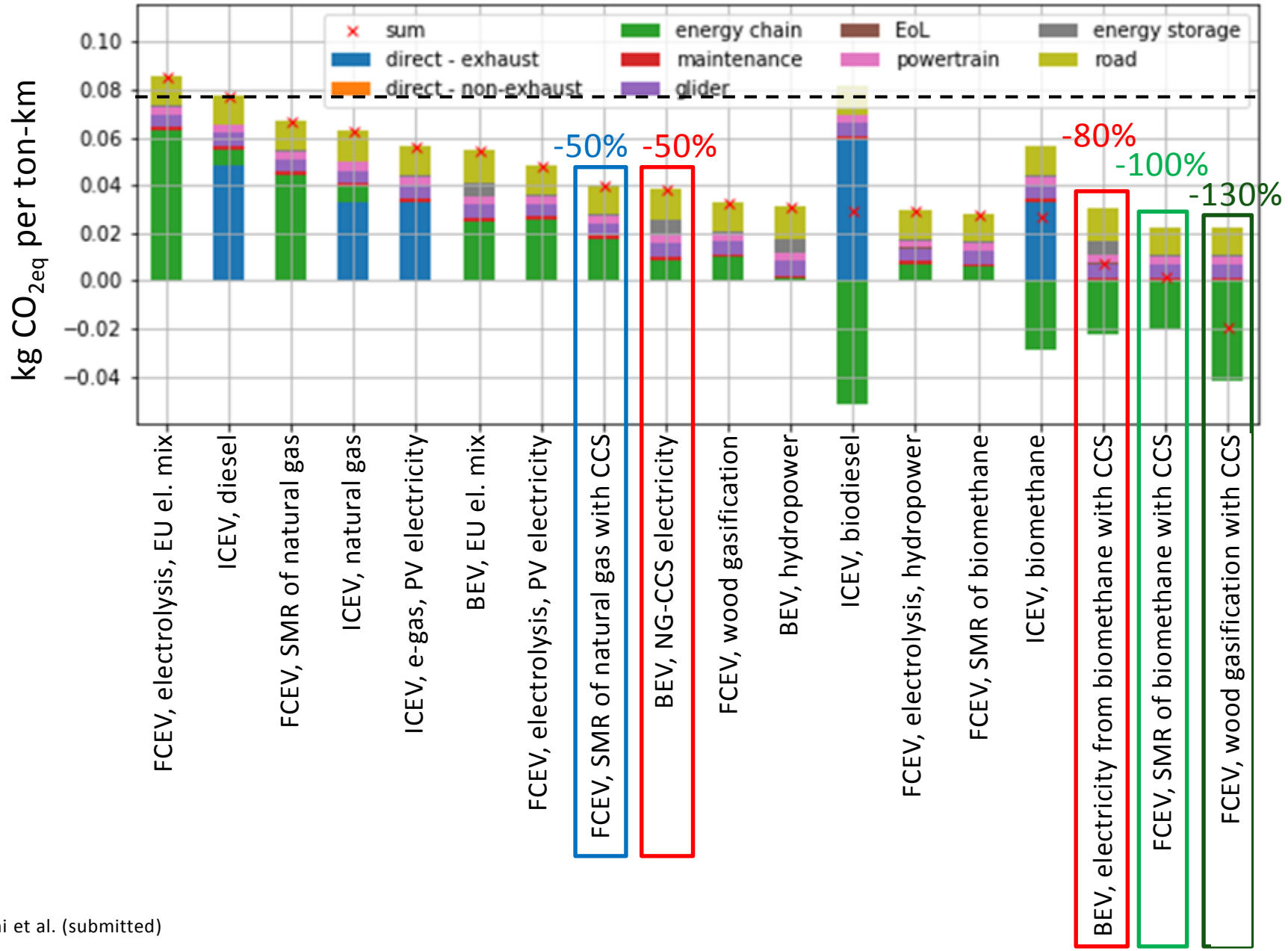


- Large BEV trucks limited by battery technology today
  - ✓ Only short ranges possible
  - ✓ Negative impact on environmental performance
- Doubling of specific battery storage capacity by 2050 expected
  - ✓ Larger ranges possible
  - ✓ Better environmental performance
- Still substantial amounts of low-C electricity required

Sacchi et al. (submitted)

FCEV trucks – better low-carbon option today

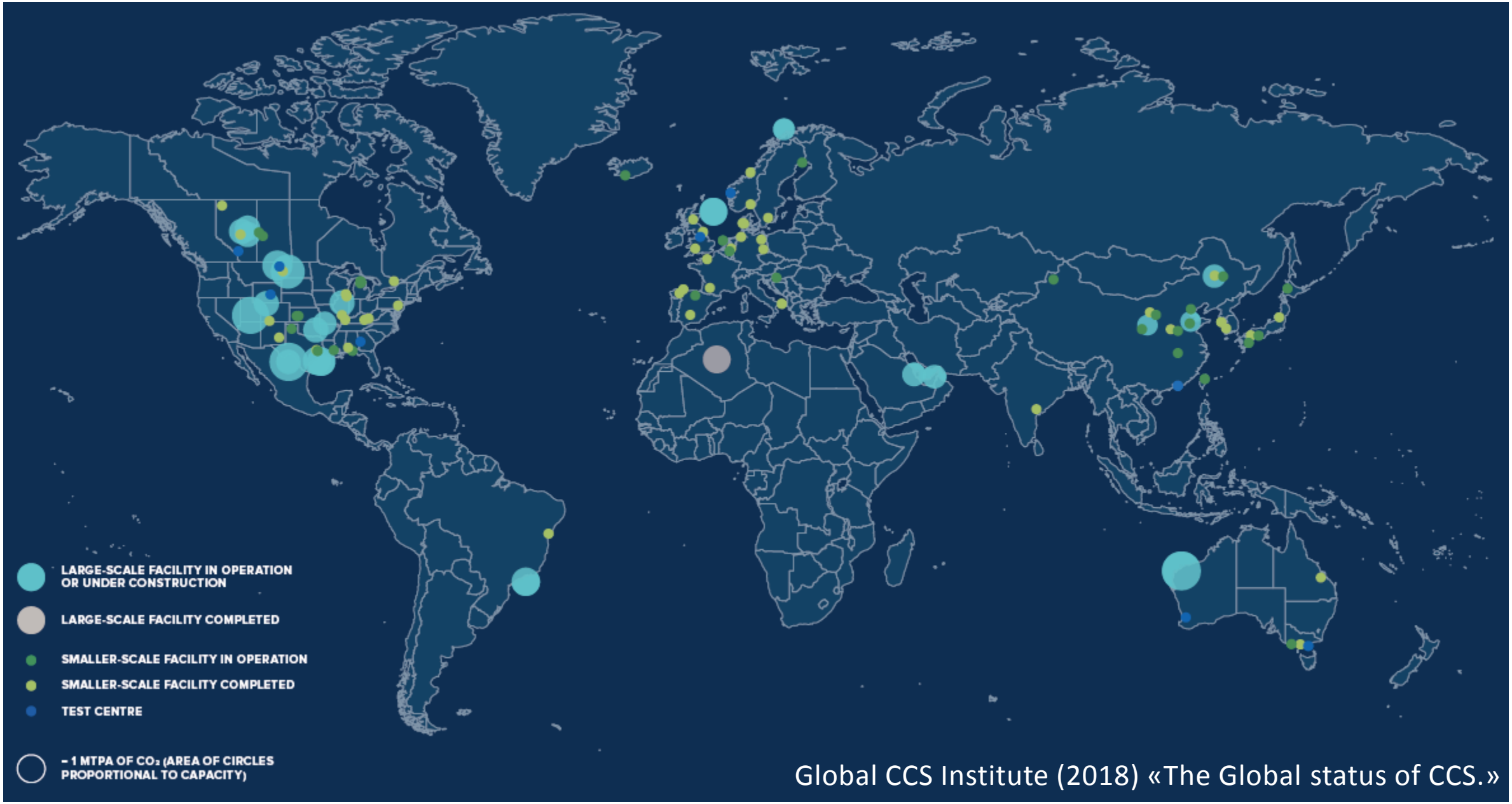
Trucks – GHG emissions (40t vehicle, year 2050, 800km range)



- FCEV with H_2 from SMR+CCS and
  BEV with fossil power + CCS
  reduce GHG emissions by 50%
- Biomass CCS-fuels (electricity and H_2) allow for much largest reductions of GHG emissions
- Sustainable biomass is a limited resource with competing use options

Sacchi et al. (submitted)

Geological CO_2 storage – dream or reality?



Global CCS Institute (2018) «The Global status of CCS.»

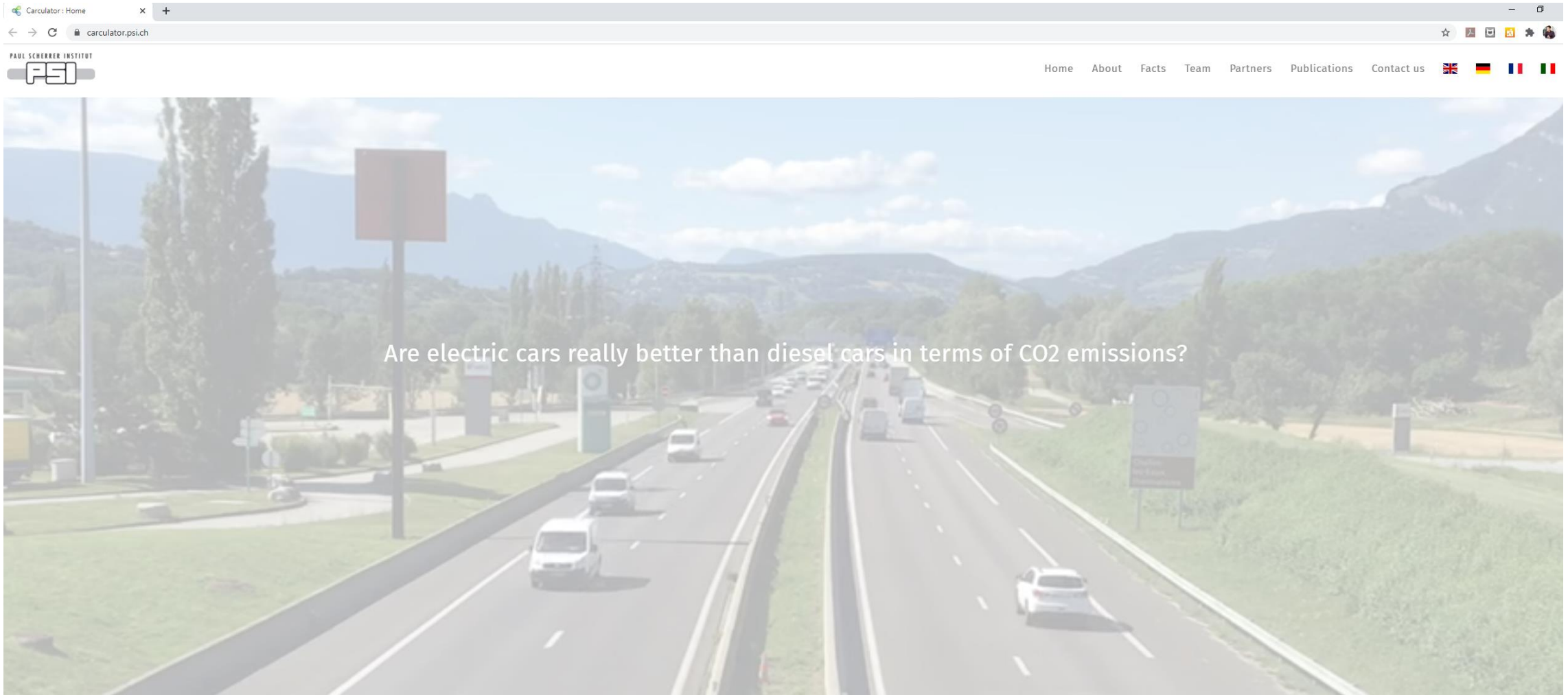

Northern Lights
Project
Menu
Northern Lights
A European CO_2 transport and storage network
Latest News October 20, 2020
Preparing the onshore facilities for the Northern Lights project
https://northernlightsccs.com/en

Take home messages – CCS for clean transport

- Carbon-neutral mobility/energy systems/economies have to build upon all low-carbon technologies: electrification, hydrogen, syn-fuels, CCS
- Fossil electricity with CCS as well as hydrogen from natural gas with CCS and from biomass can be considered as «low-carbon» or «zero-carbon» fuels
  (similar to electrolysis with low-carbon electricity)
- BECCS and hydrogen from biomass with CCS removes CO_2 from the atmosphere
  (limited biomass resources need to be taken into account)
- Low-carbon natural gas and biomass-based H_2 does not depend on expansion of renewable electricity generation
- In general, H_2-FCEV trucks perform better regarding GHG emissions than H_2-FCEV passenger cars and are closer to large-scale market penetration
- Policy measures are required supporting low-carbon technologies,
  including the establishment of a European CO_2 and H_2 infrastructure

LCA web-tool

https://carculator.psi.ch



Further information

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- Antonini, C., Treyer, K., Moioli, E., Bauer, C., Mazzotti, M. (submitted) **Hydrogen from wood gasification with CCS - a techno-environmental analysis of production and use as transport fuel.** Sustainable Energy & Fuels, in review, https://chemrxiv.org/articles/preprint/Hydrogen_from_Wood_Gasification_with_CCS_-_a_Technoenvironmental_Analysis_of_Production_and_Use_as_Transport_Fuel/13213553/1.
- Sacchi, R., Bauer, C., Cox, B., Mutel, C. (submitted) **carculator: an open-source tool for prospective environmental and economic life cycle assessment of vehicles. When, Where and How can battery-electric vehicles help reduce greenhouse gas emissions?** Renewable and Sustainable Energy Reviews, in review, https://www.psi.ch/en/media/57994/download
- Sacchi, R., Bauer, C., Cox, B. (submitted) **Does size matter? The influence of size, load factor, range autonomy and application type on the Life Cycle Assessment of current and future trucks.** Environmental Science and Technology, in review.
- Zhang, X., Bauer, C., Mutel, C. and Volkart, K. (2017) **Life Cycle Assessment of Power-to-Gas: Approaches, system variations and their environmental implications.** Applied Energy, https://doi.org/10.1016/j.apenergy.2016.12.098

Wir schaffen Wissen – heute für morgen

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ELEGANCY
SCCERs mobility, HaE, SoE, biosweet

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