PAUL SCHERRER INSTITUT

PSI

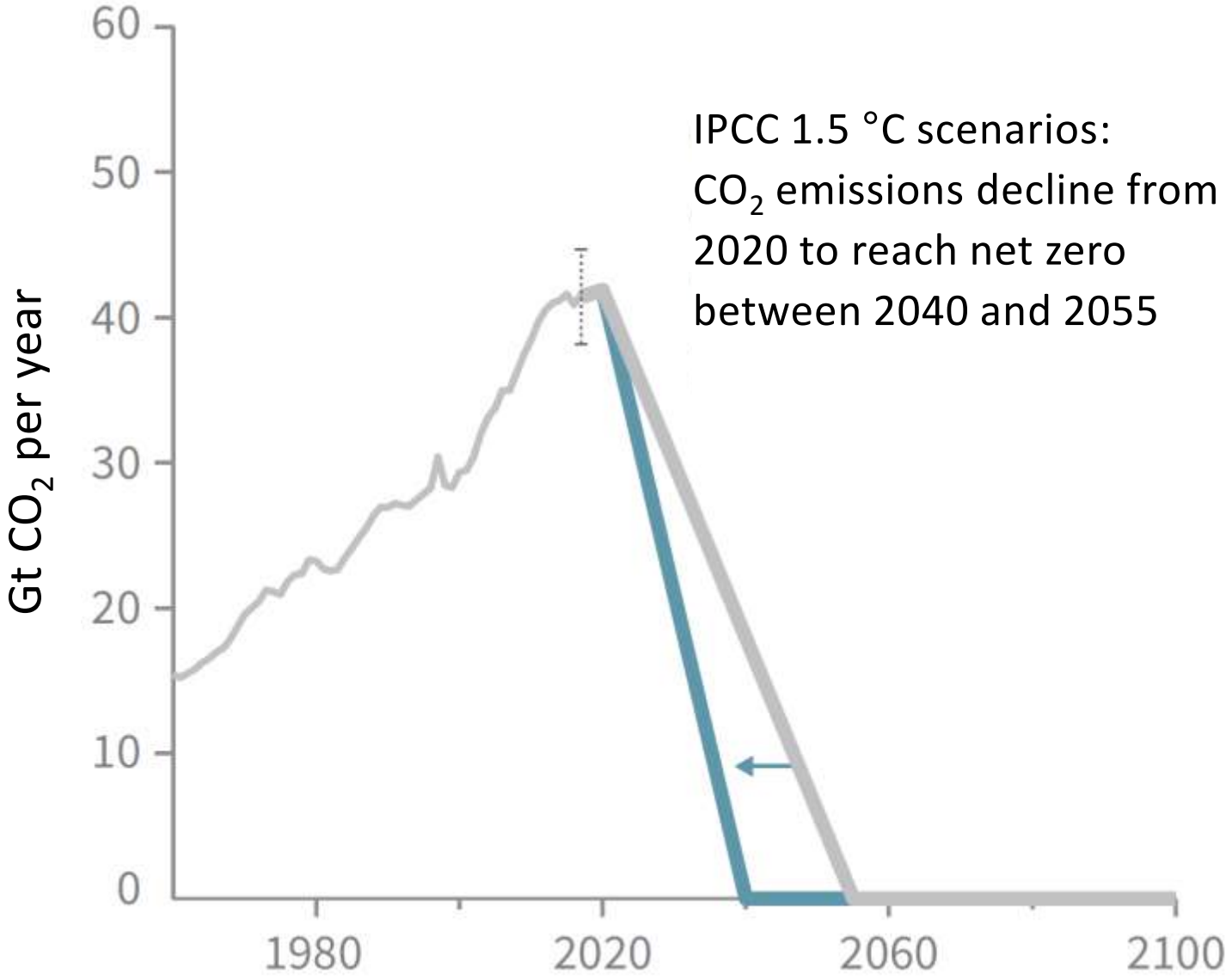
C. Bauer[1], X. Zhang[1], C. Antonini[2], M. van der Spek[2], K. Treyer[1], M. Mazzotti[2]

[1] Paul Scherrer Institut, [2] ETH Zurich

Road transport decarbonization via reforming based H_2 with CCS – a Life Cycle Assessment

TCCS-10, June 18, 2019

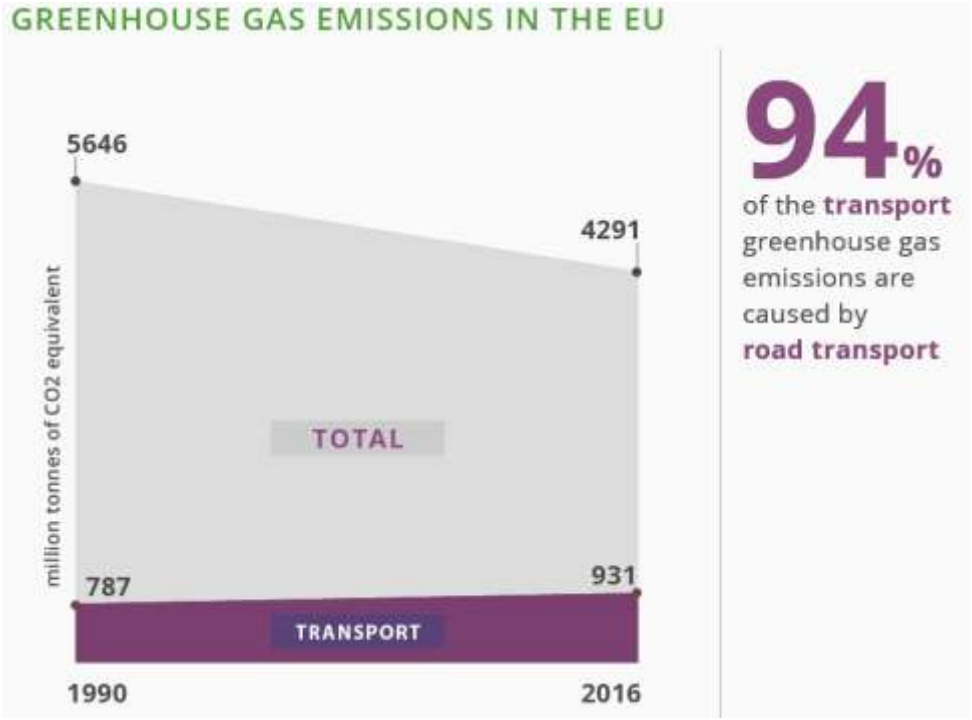
Road transport decarbonization: Why?



IPCC 1.5 °C scenarios:
CO_2 emissions decline from 2020 to reach net zero between 2040 and 2055

Source: IPCC 2018, Special Report: Global Warming of 1.5 ºC

GHG emissions from road transport in Europe



Source: https://www.consilium.europa.eu/en/infographics/greenhouse-gas-emissions/

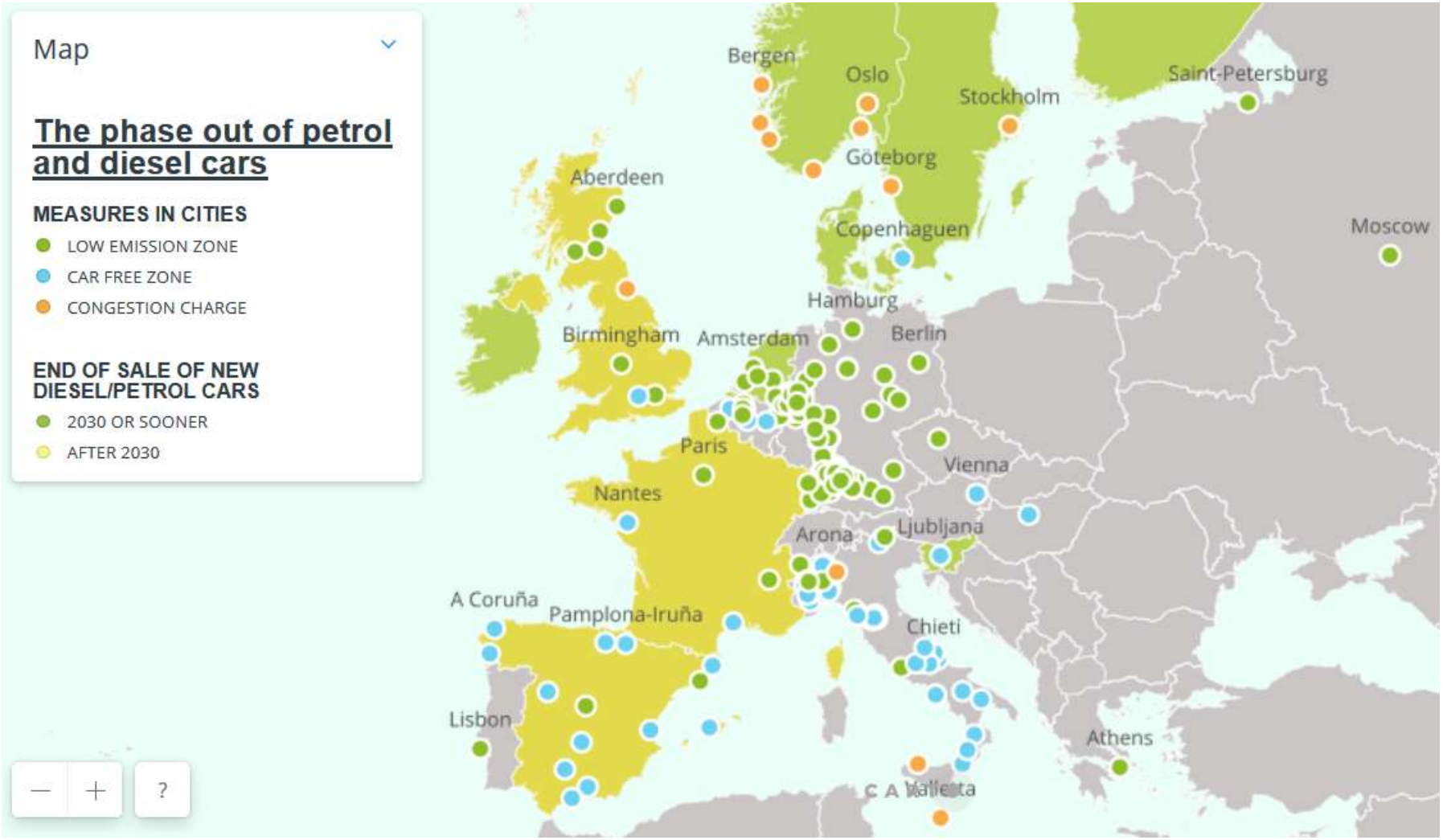
Secondary benefit: air quality


New Delhi, 2019 – © ABC news


Bejing, 2019 – © Quartz

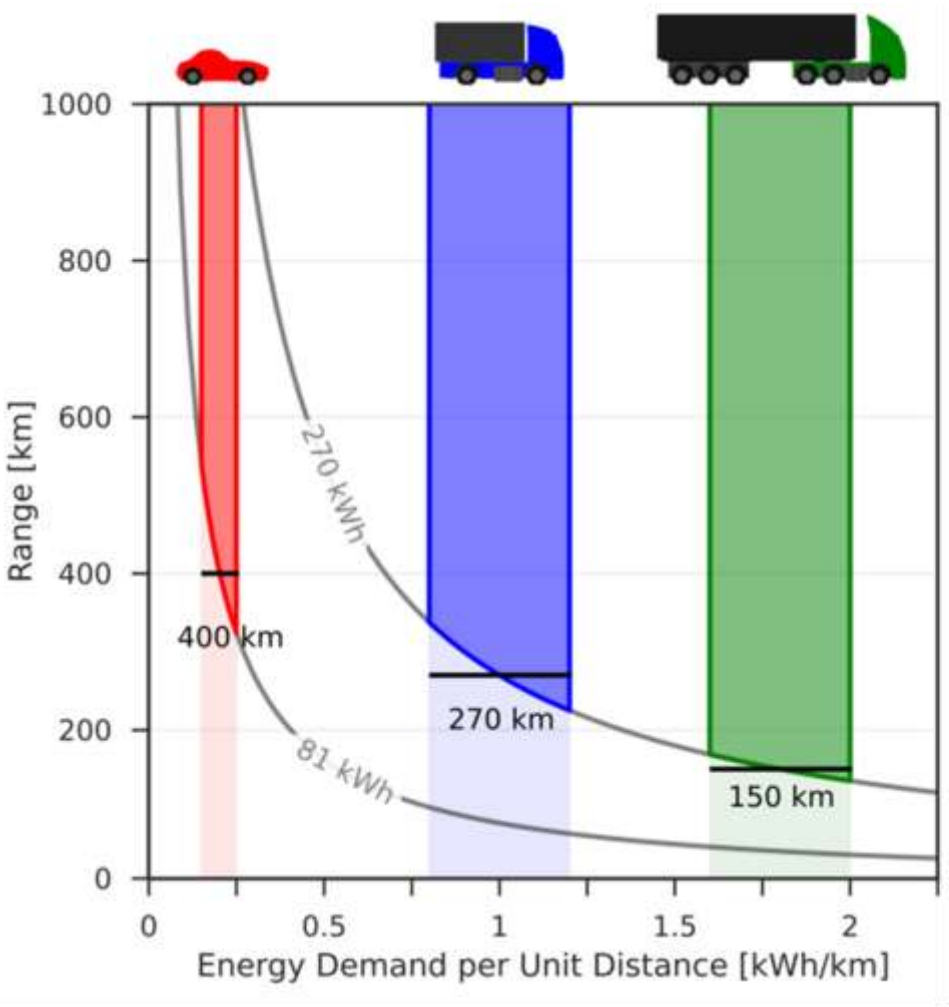
Hamburg, 2019 – © picture alliance/Daniel Bockwoldt/dpa

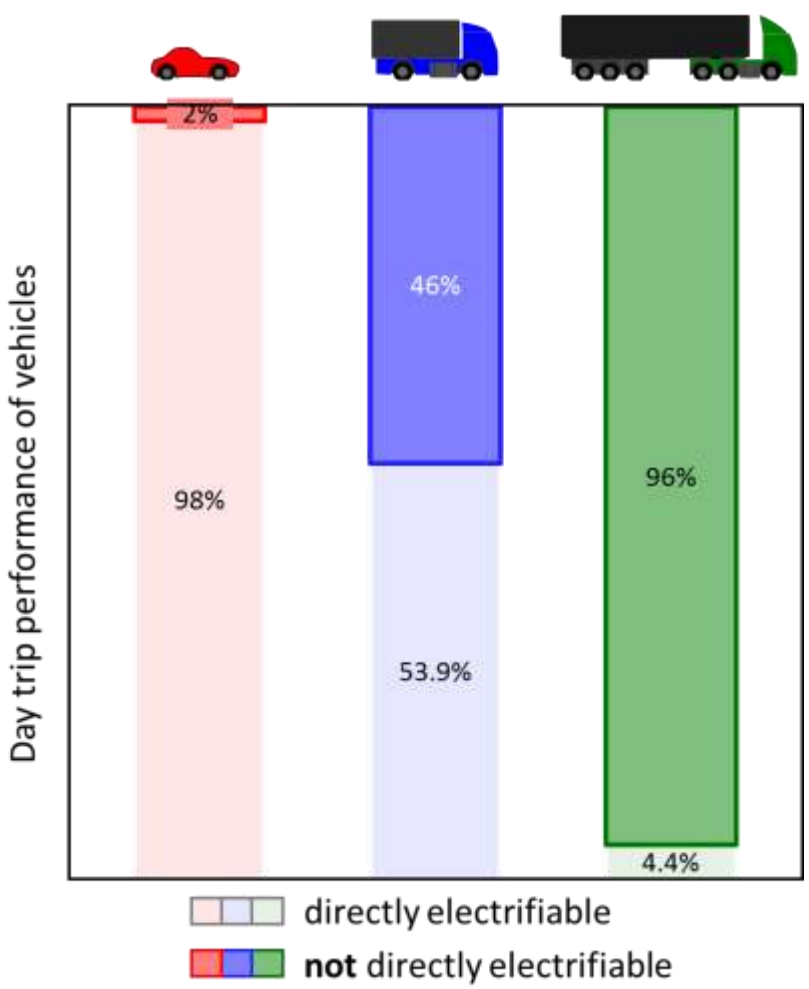
Actions taken or announced in Europe



https://www.greenpeace.org/international/act/clean-air-now/

Potential for direct electrification





The potential for direct electrification of heavy-duty transport today is small

Sources:
Federal Statistics Office and Federal Office for Spatial Development, "Mobility and Transport Microcensus," Passenger mobility statistics, 2010.
M. Held, et al. (2018) "Future mobility demand estimation based on sociodemographic information: A data-driven approach using machine learning algorithms," Swiss Transp. Res. Conf., 2018.

What is Life Cycle Assessment (LCA) of a vehicle?

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 («burdens»)

Fuel Production

Vehicle production/ end-of-life
- Glider
- Powertrain
- Energy storage

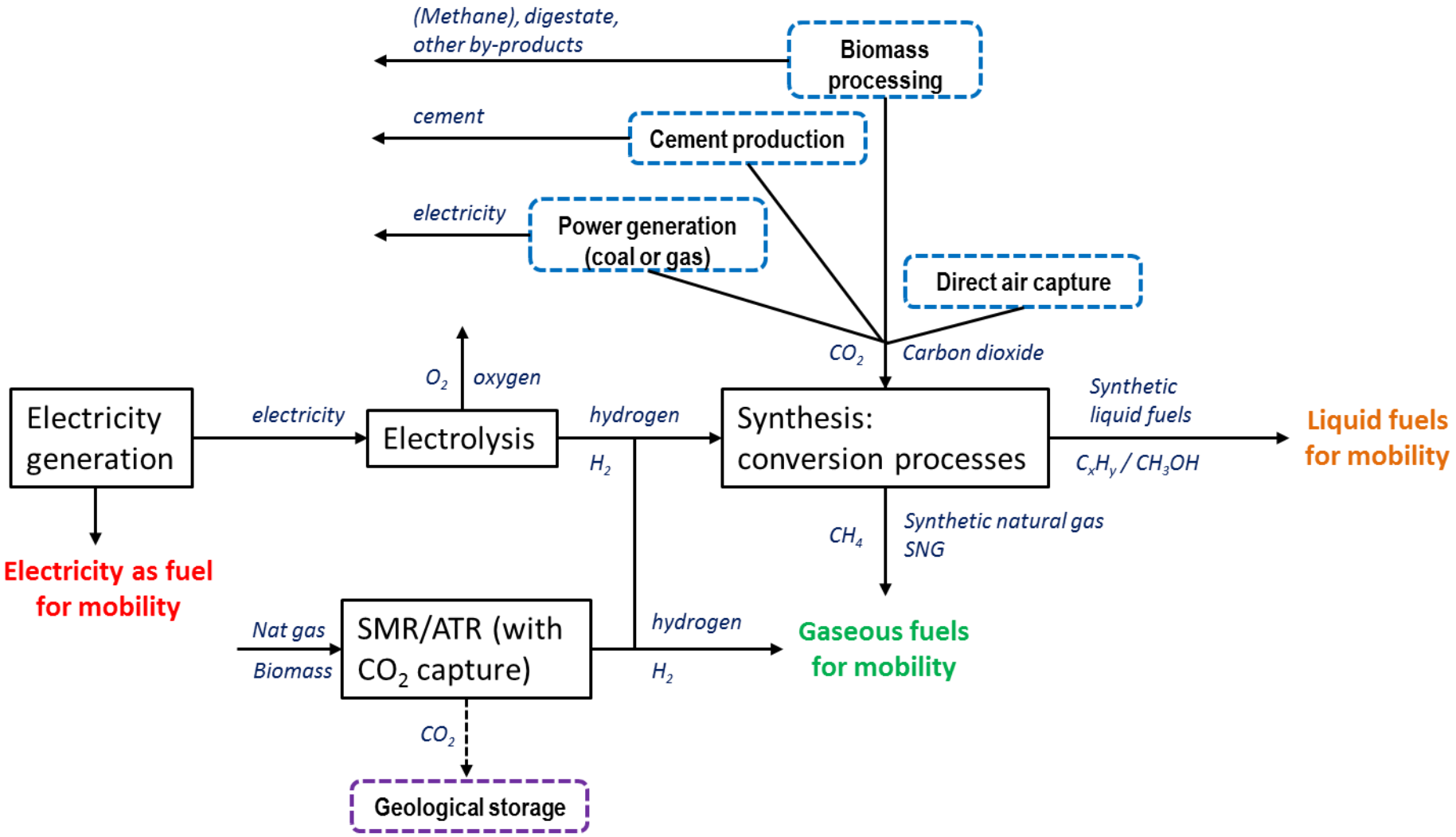
Exhaust Emissions

Tire, Road & Brake Wear

Road Production & Maintentance

Background inventories: ecoinvent LCA database

Potential clean (?) transportation fuels



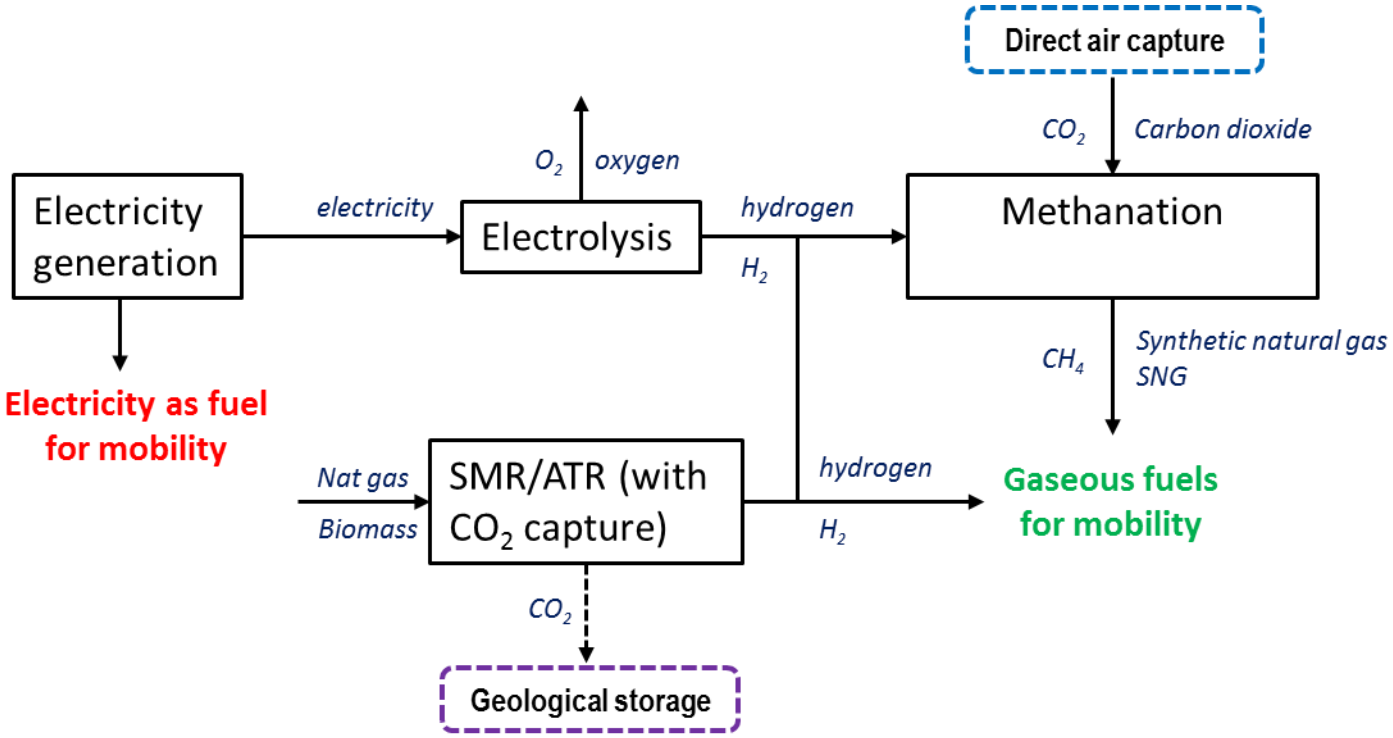
Potential clean (?) transportation fuels

Here: focus on:

a) Direct use of electricity

b) Hydrogen from electrolysis and natural gas reforming (with CCS)

c) Synthetic natural gas (with direct air capture of CO_2)



LCA: goal & scope

Reference systems:

- Lorry, diesel, mid-size (28t) [impacts per tonne-km]
- Passenger vehicles, diesel, mid-size [impacts per km]

Temporal scope:

- current lorries
- current & mid-term future passenger vehicles

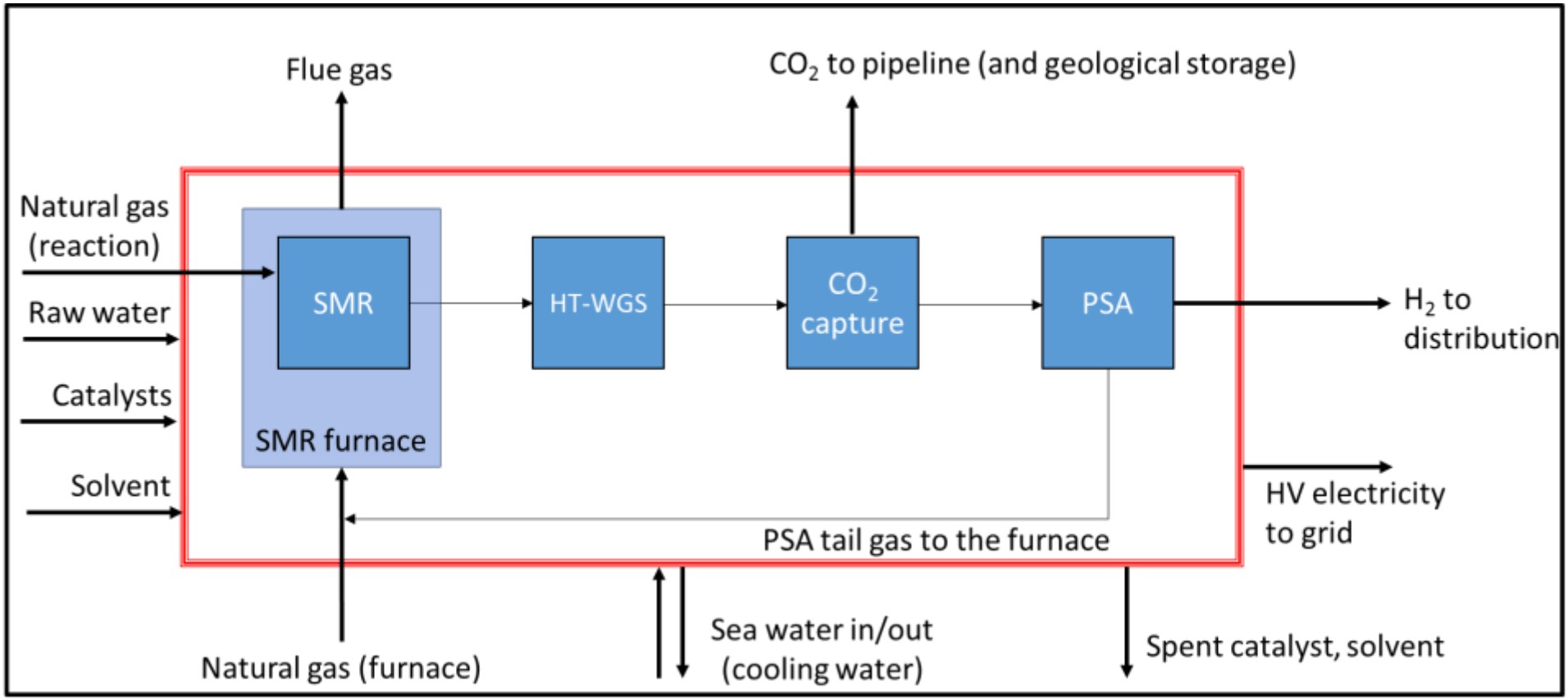
Geographical scope: Europe

Evaluation of average conditions: attributional LCA

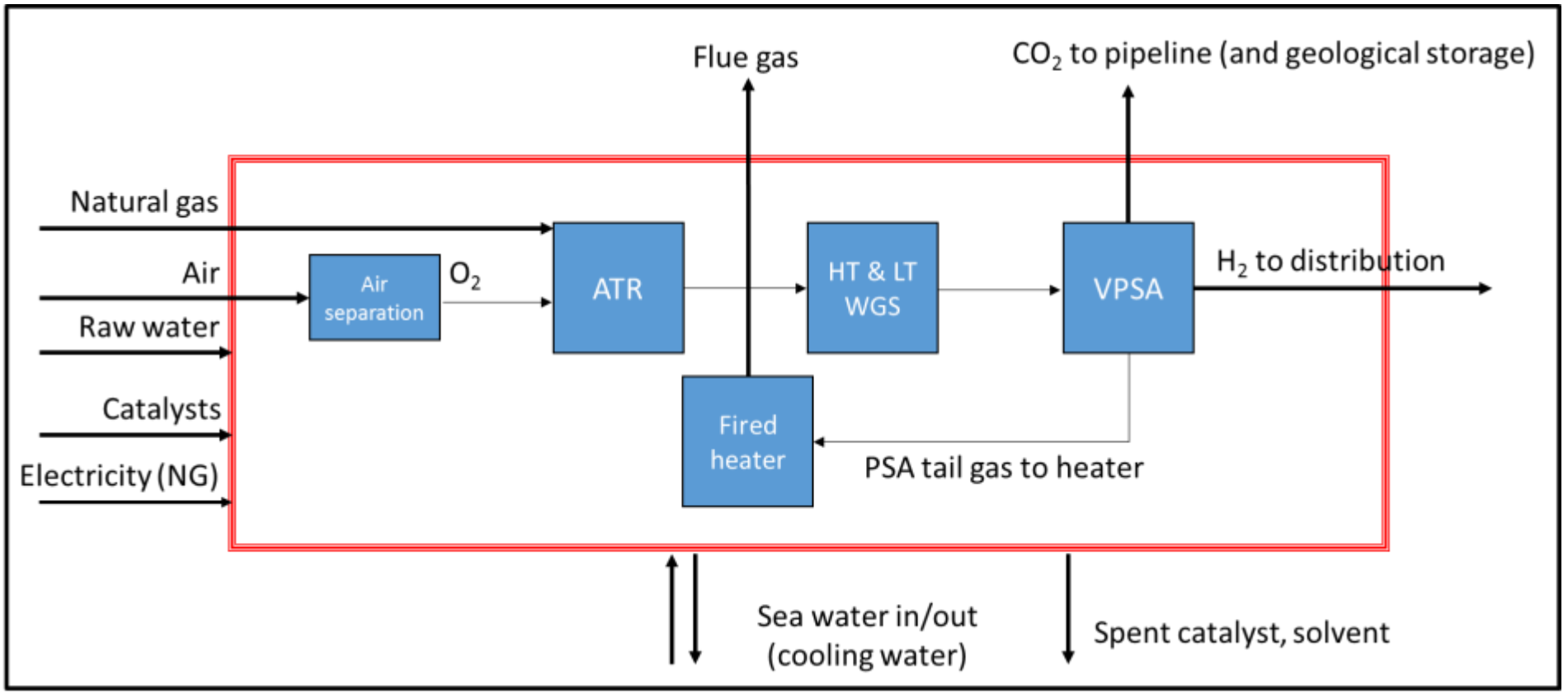
Data sources: mainly literature & HBEFA database (for vehicle emissions)

Background life cycle inventory:
ecoinvent v3.4, allocation, «cut-off by classification»

SMR with CCS («SMR + MDEA»)



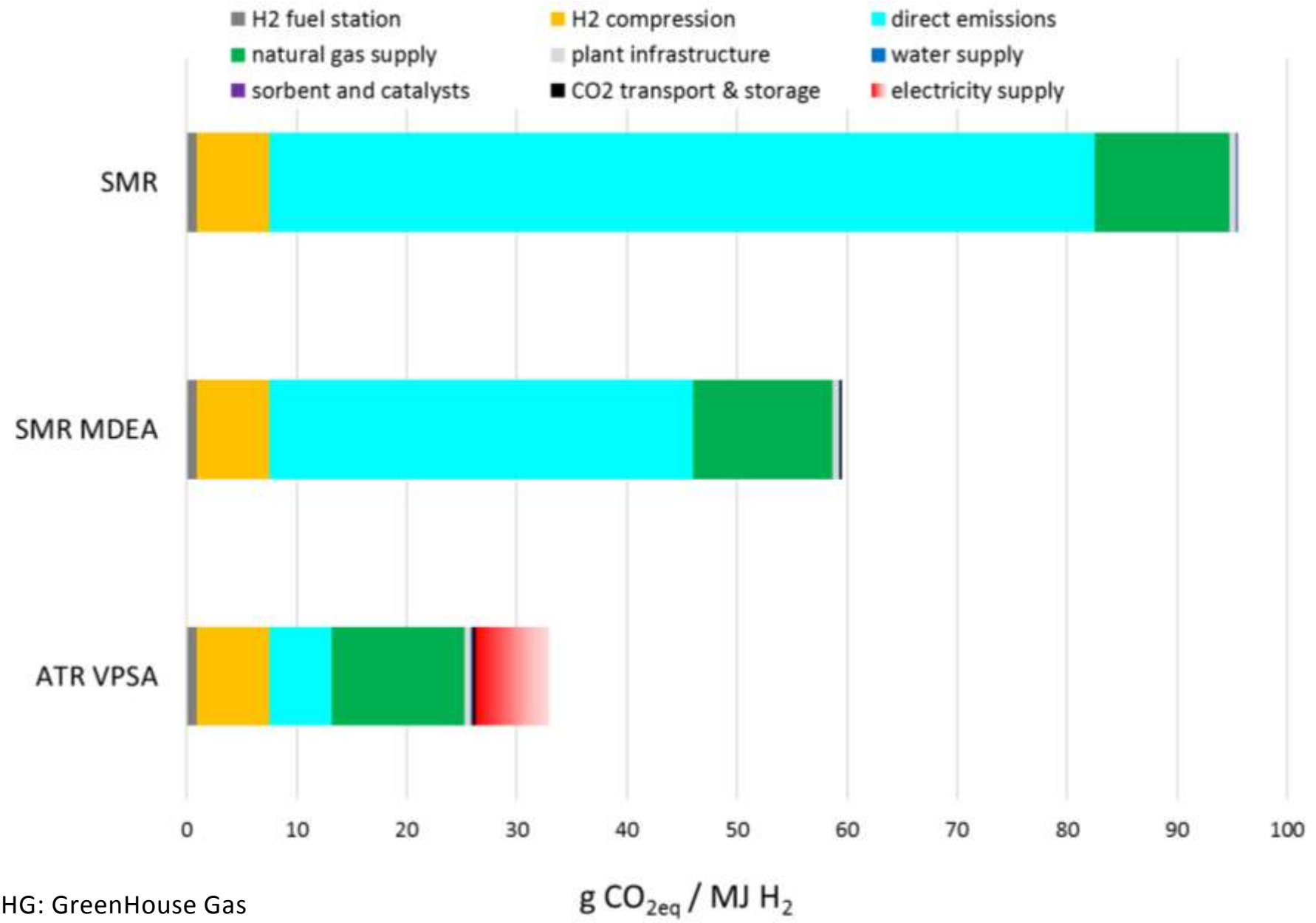
ATR with CCS («ATR + VPSA»)



Basic characteristics of SMR /ATR

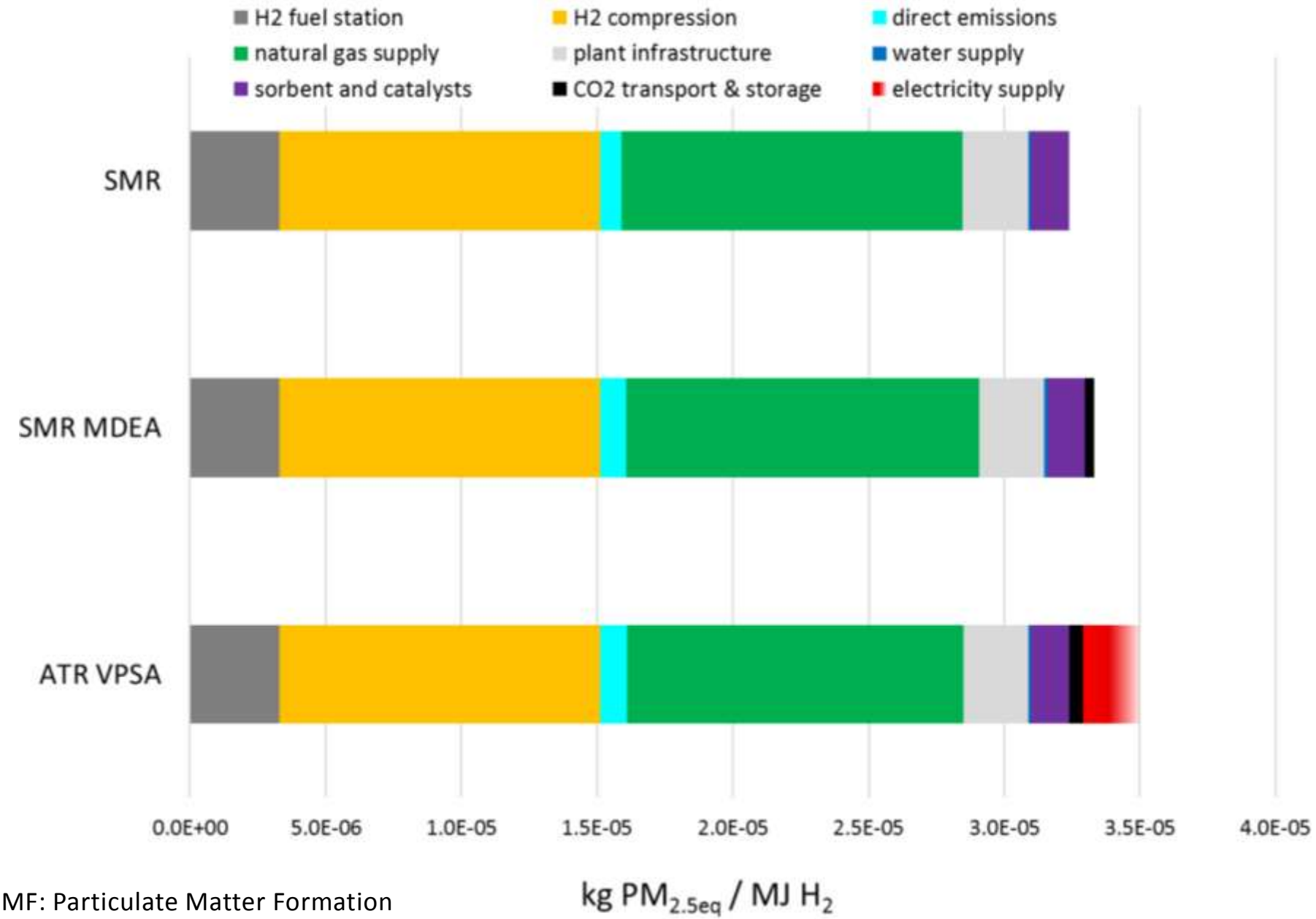
	SMR	SMR+MDEA	ATR+VPSA
H_2 production Nm^3/h	100'000	99'909	100'919
Energy in product MW	299.7	299.4	300.2
Excess power to grid MW_{el}	11.1	3.3	-17.3
Spec. **CO_2 emissions** $kg/Nm^3\ H_2$	0.81	0.42	0.06
Spec. **CO_2 captured** $kg/Nm^3\ H_2$	0	0.43	0.72
CO_2 capture rate	0	0.51	0.92

GHG emissions from NG based H2 production



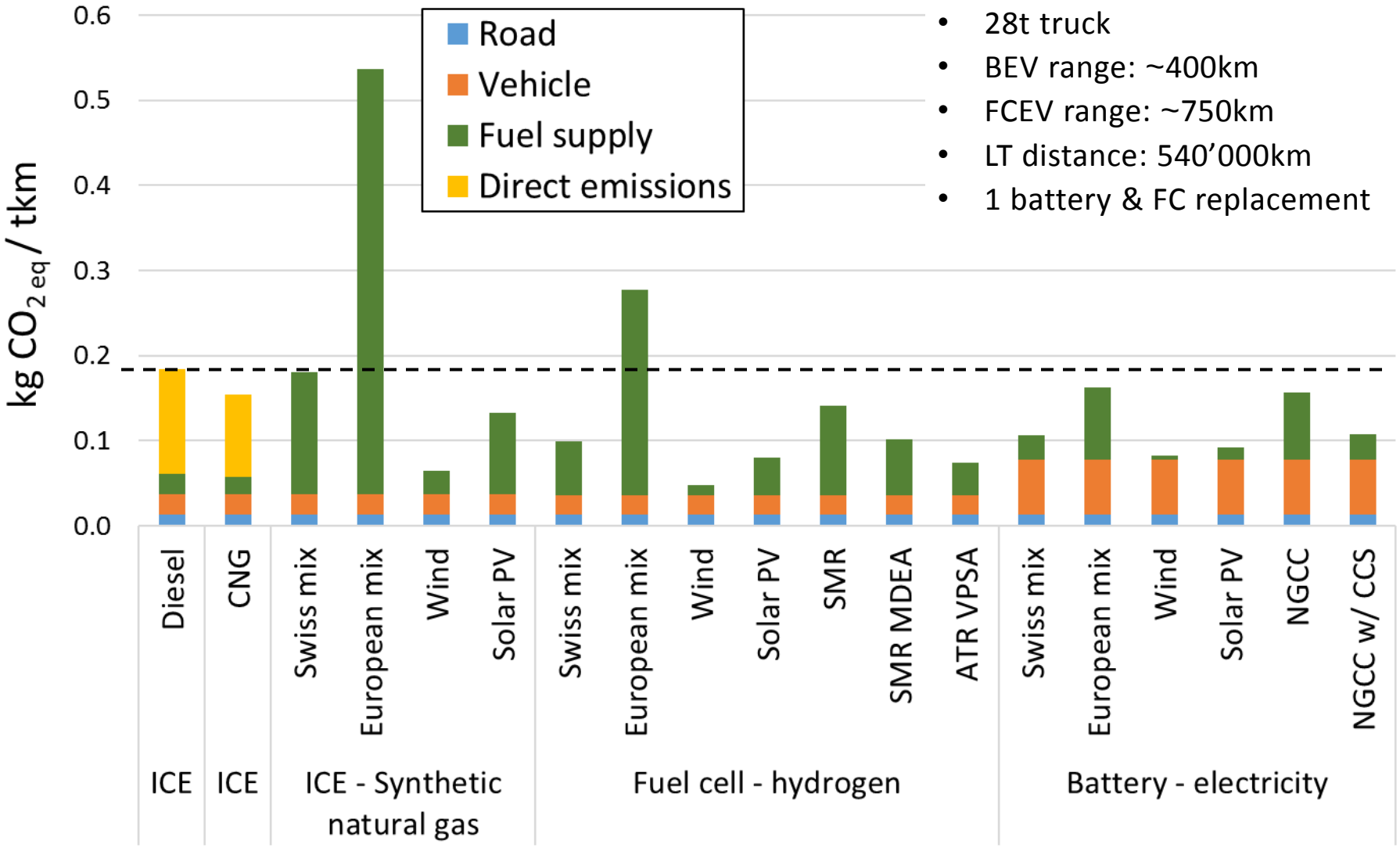
GHG: GreenHouse Gas

Particulate matter formation from NG based H2



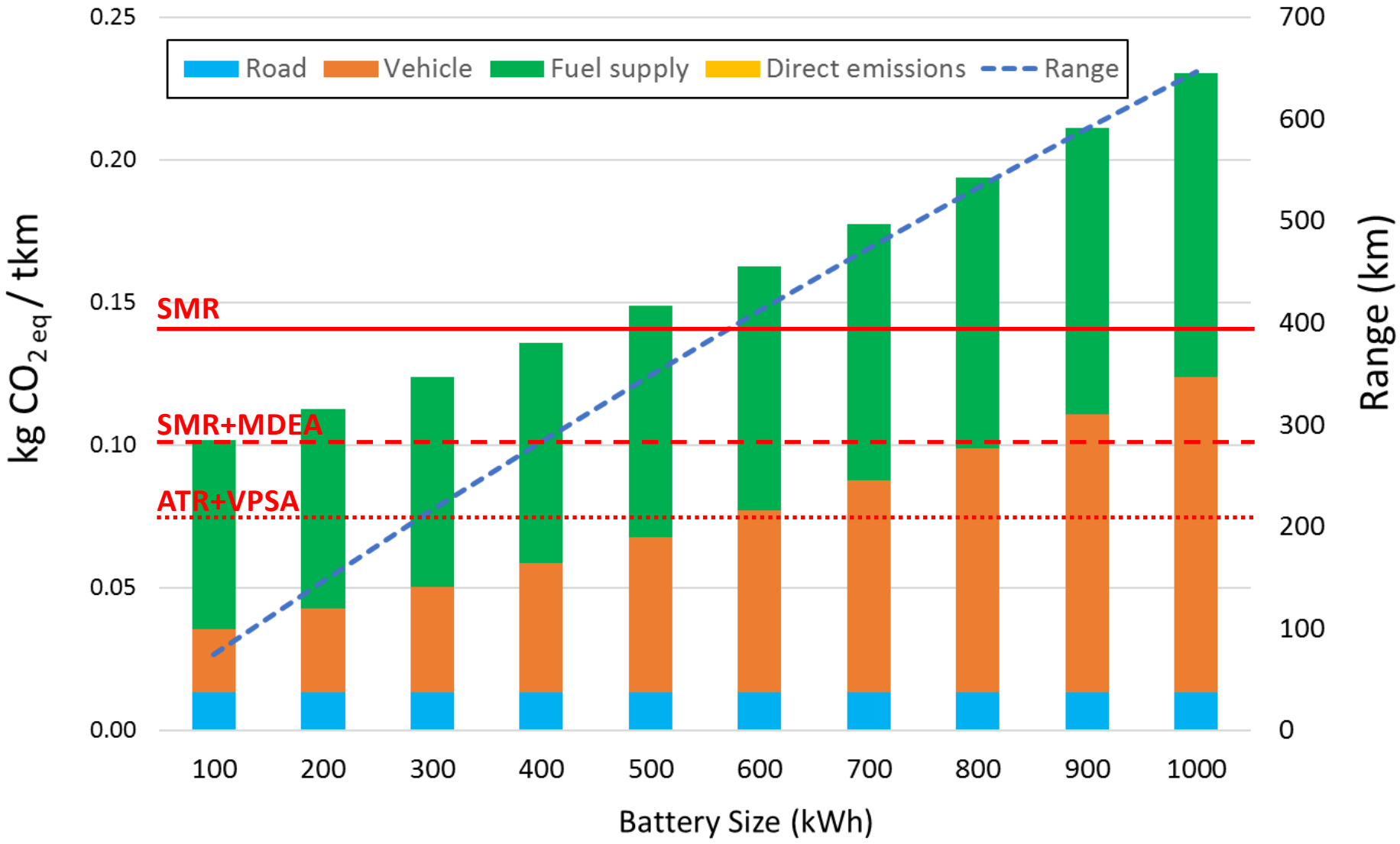
PMF: Particulate Matter Formation

LCA results: GHG emissions of trucks



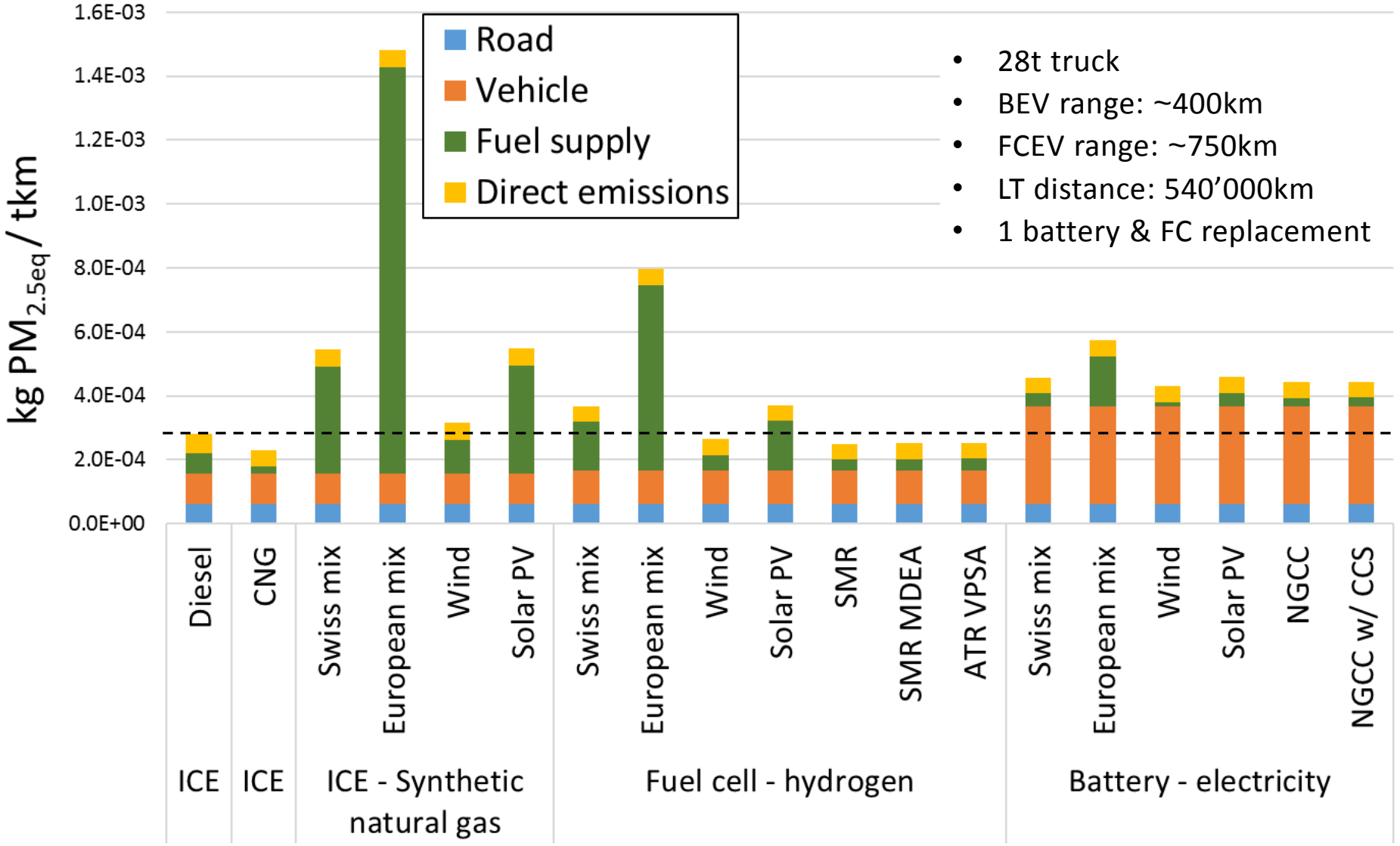
- 28t truck
- BEV range: ~400km
- FCEV range: ~750km
- LT distance: 540'000km
- 1 battery & FC replacement

BEV: Battery size sensitivity

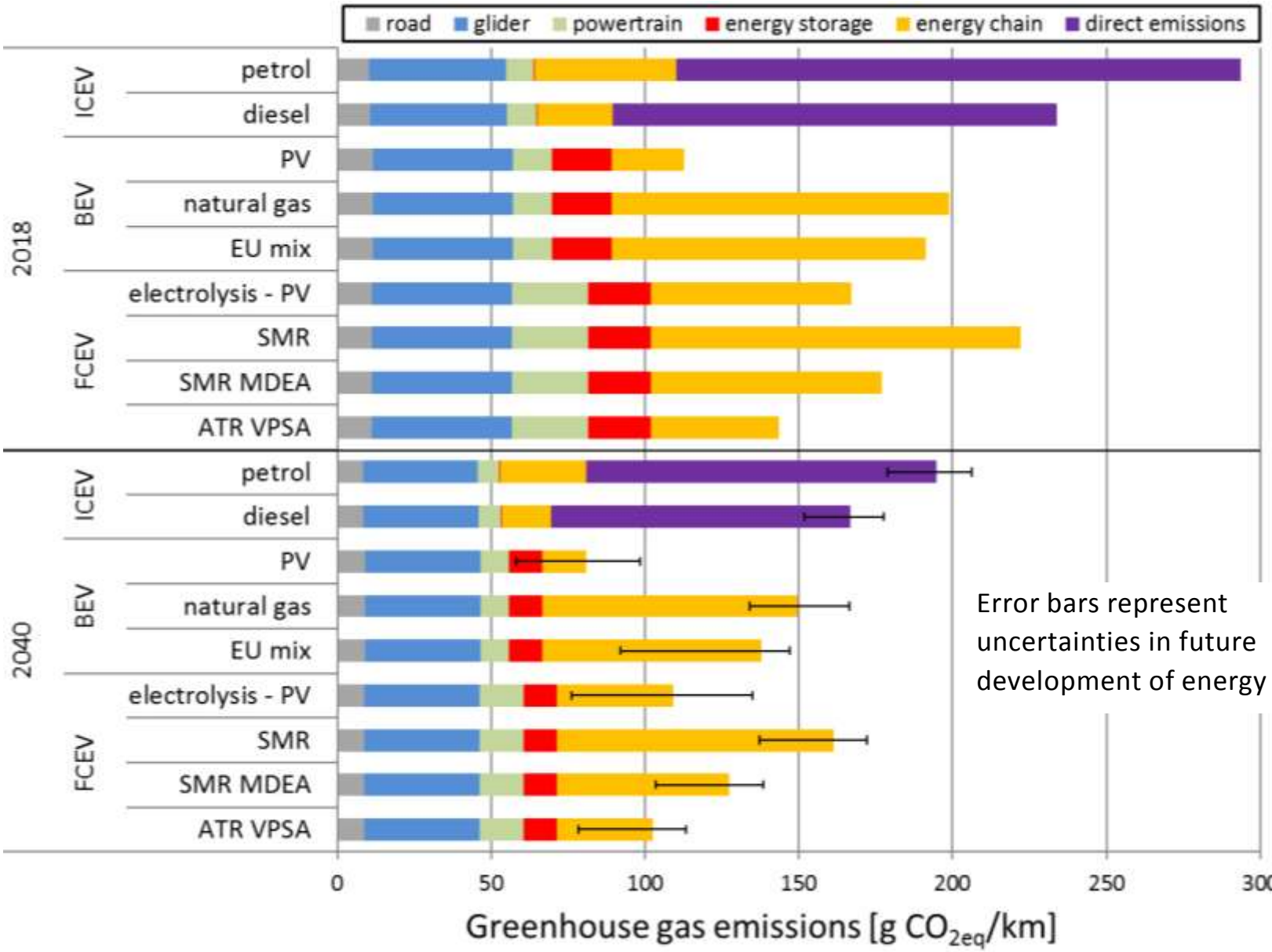


EU electricity mix for BEV charging

LCA results: Particulate matter formation of trucks

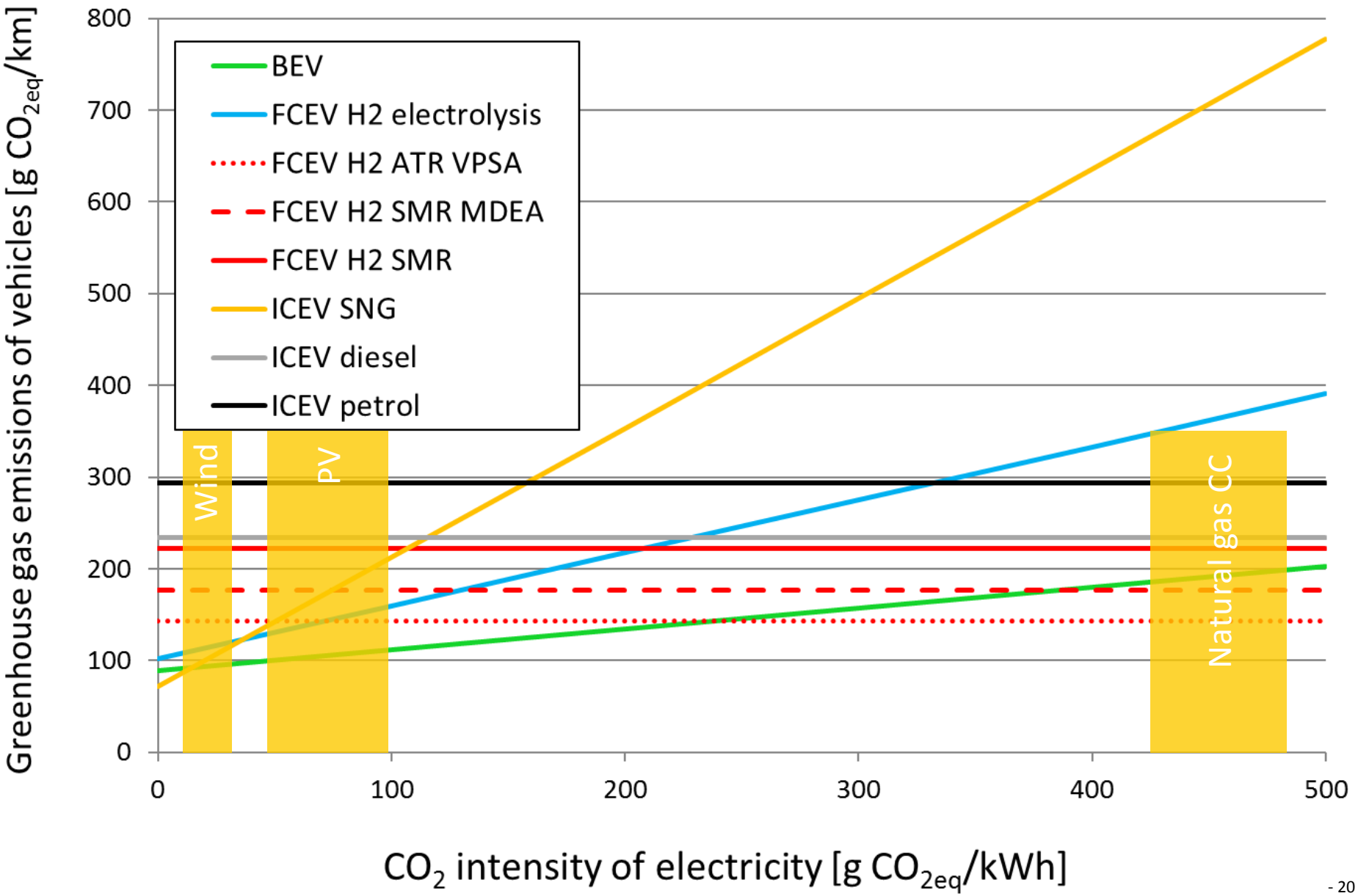


LCA results: GHG emissions of passenger cars



Error bars represent uncertainties in future development of energy supply

Passenger cars: GHG intensity of electricity



Take home messages

- Currently it is hard to directly electrify heavy-duty trucks

- **Reforming based H_2 with CCS** can represent a **clean alternative fuel**
- For trucks, **reforming based H_2** has **similar life-cycle GHG footprint as renewable-based electrolysis**, which are the **lowest of all fuels/drivetrains**

- Passenger vehicles: BEV with renewable electricity more beneficial

- **Electric drivetrains** offer **secondary benefits**: local air quality
- However, **partial shift of burdens** to vehicle (and fuel) production, which is difficult to reduce

- Just a **switch to hydrogen or battery vehilces** will **not** allow for a **sufficient decarbonization** in line with «1.5-2°C» due to upstream emissions -> additional measures required

Wir schaffen Wissen – heute für morgen

Thanks to

- Co-authors
- Brian Cox (PSI)
- ELEGANCy

ACT ELEGANCY, Project No 271498, has received funding from DETEC (CH), BMWi (DE), RVO (NL), Gassnova (NO), BEIS (UK), Gassco, Equinor and Total, and is cofunded by the European Commission under the Horizon 2020 programme, ACT Grant Agreement No 691712

Contact:
christian.bauer@psi.ch
https://www.psi.ch/ta/