Hydrogen production technologies and costs

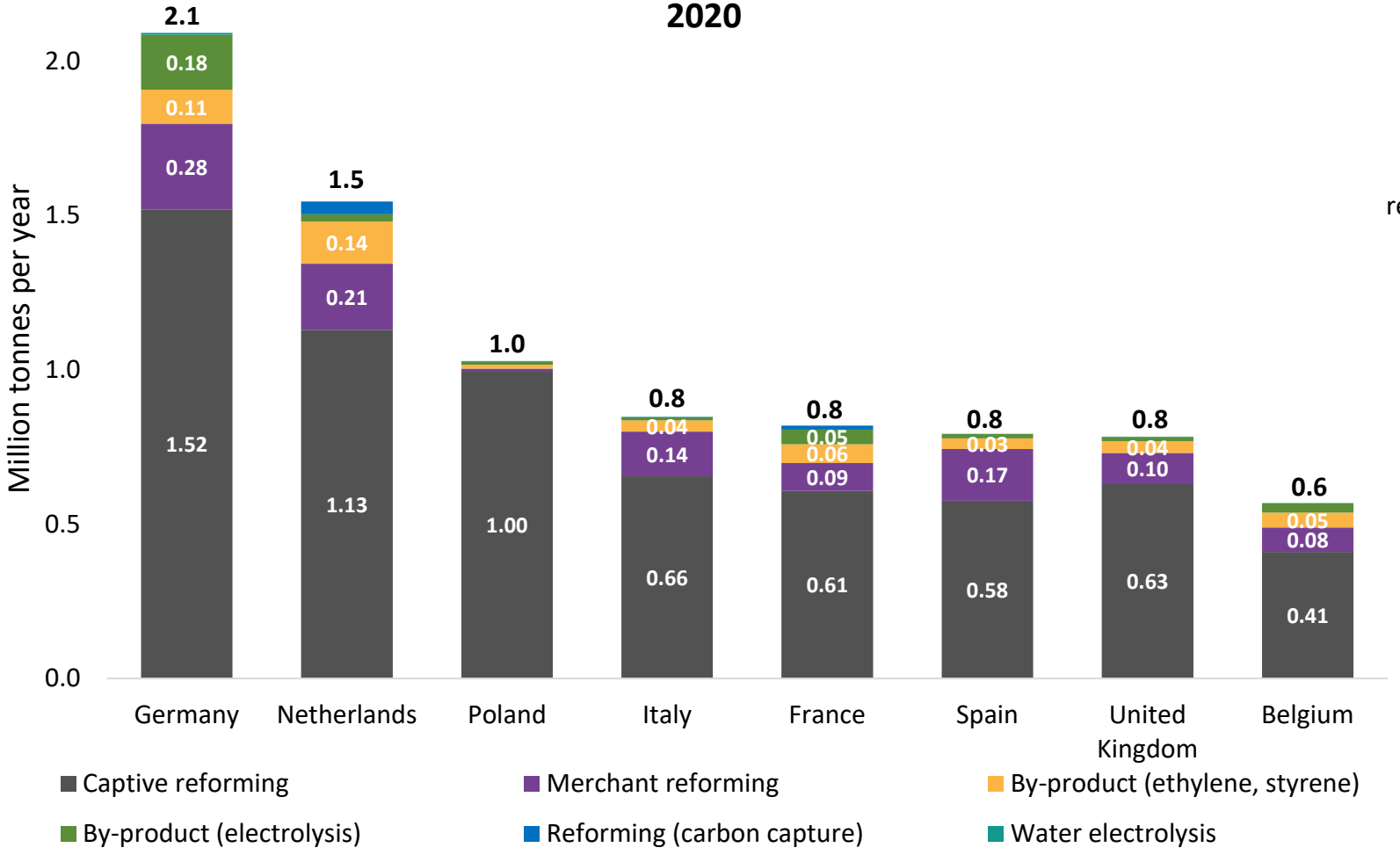
Group of Experts on Gas 23-24 March

Hydrogen Europe

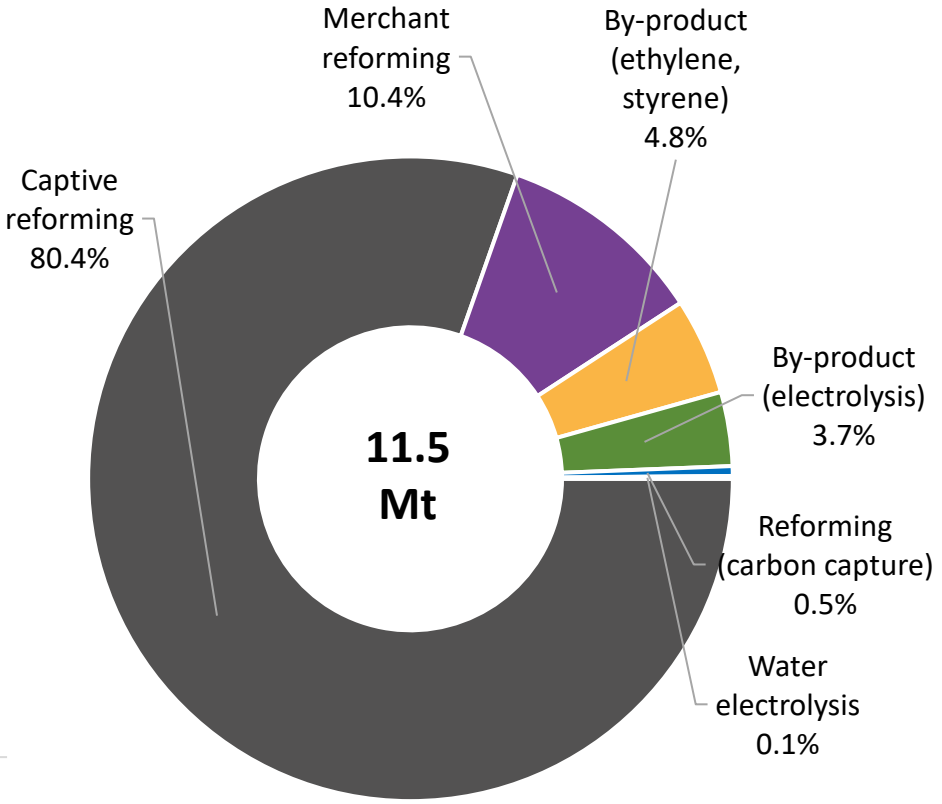
Current hydrogen production capacity

95% of 11.5 Mt of hydrogen production capacity in Europe is from fossil fuels

Production capacity of the eight largest hydrogen producers in Europe in 2020



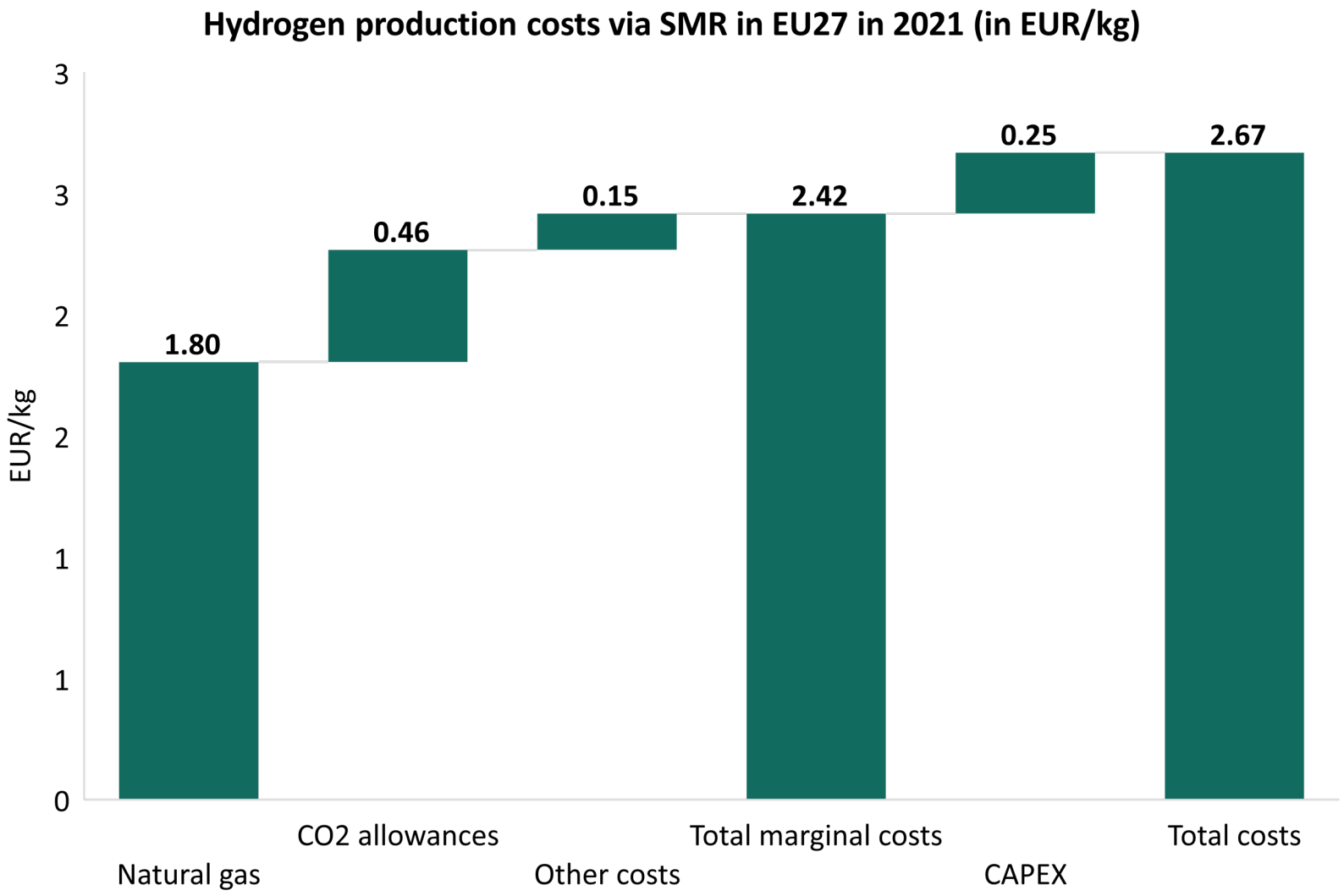
Production capacity by process in 2020



Source: Hydrogen Europe based on work for Fuel Cells and Hydrogen Observatory

Cost of conventional hydrogen production

Marginal costs represent 90% of the total cost for steam methane reforming



- Average estimated costs of „grey hydrogen" production in the EU in 2021 was around **2.67 EUR/kg**
- Long-term average of the last 5 years is **1.5 – 2 EUR/kg**
- Average estimated costs of „grey hydrogen" production in the EU in 2022 is around **8.5 EUR/kg**

Source: Hydrogen Europe

Water electrolysis isn’t new

Water electrolysis was an industrial hydrogen production process

Rjukan, Norway 1927 – 1971

~167 MW, ~24kt/y of H2 at 8,000 h/y

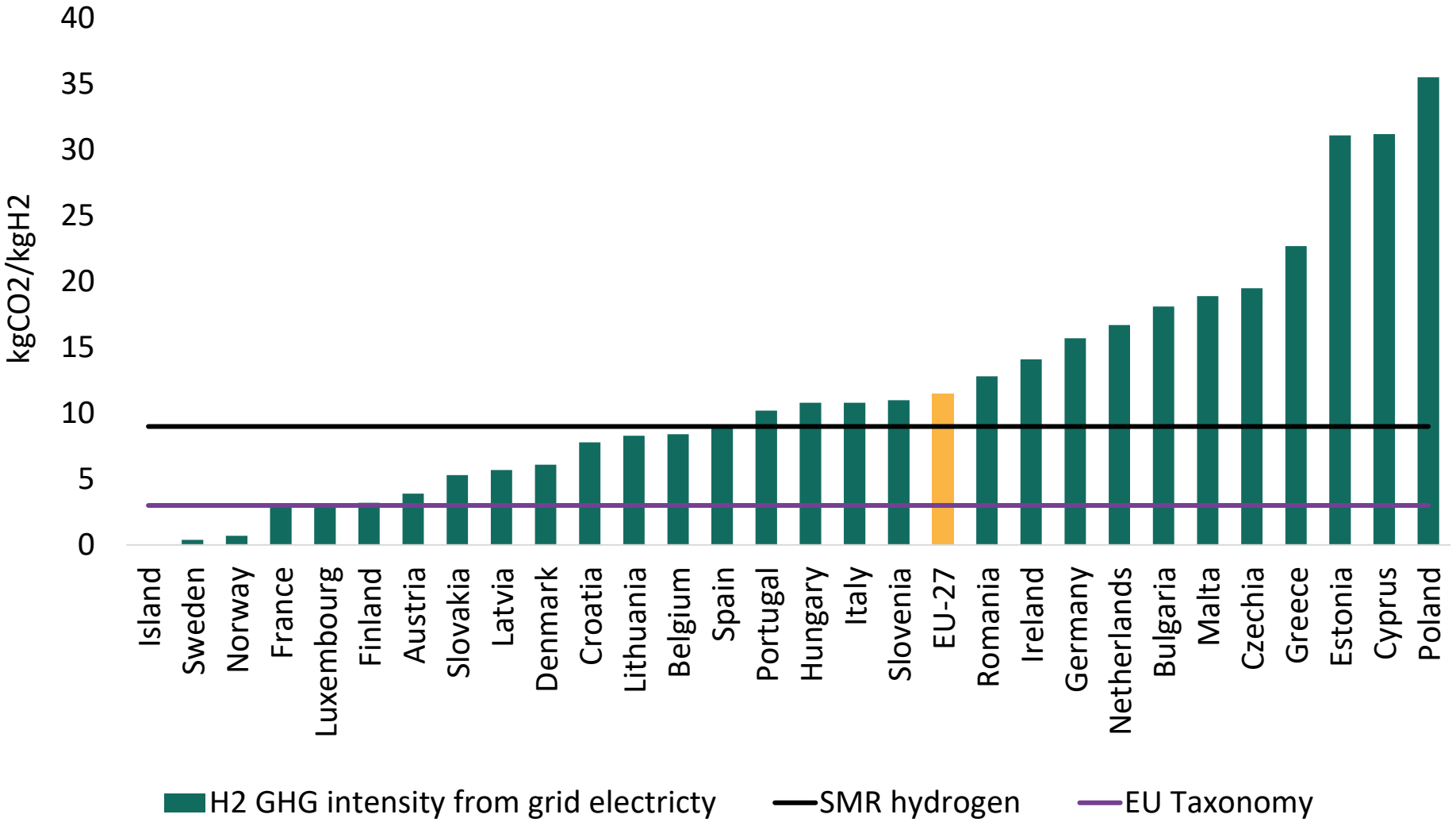
Glomfjord, Norway 1949 – 1993

150 MW, ~21 kt/y of H2 at 8,000 h/y

Source: Norsk Hydro

GHG emissions from grid connected electrolytic hydrogen

Even though average emissions keep falling down – the emissions are on average still higher than from natural gas

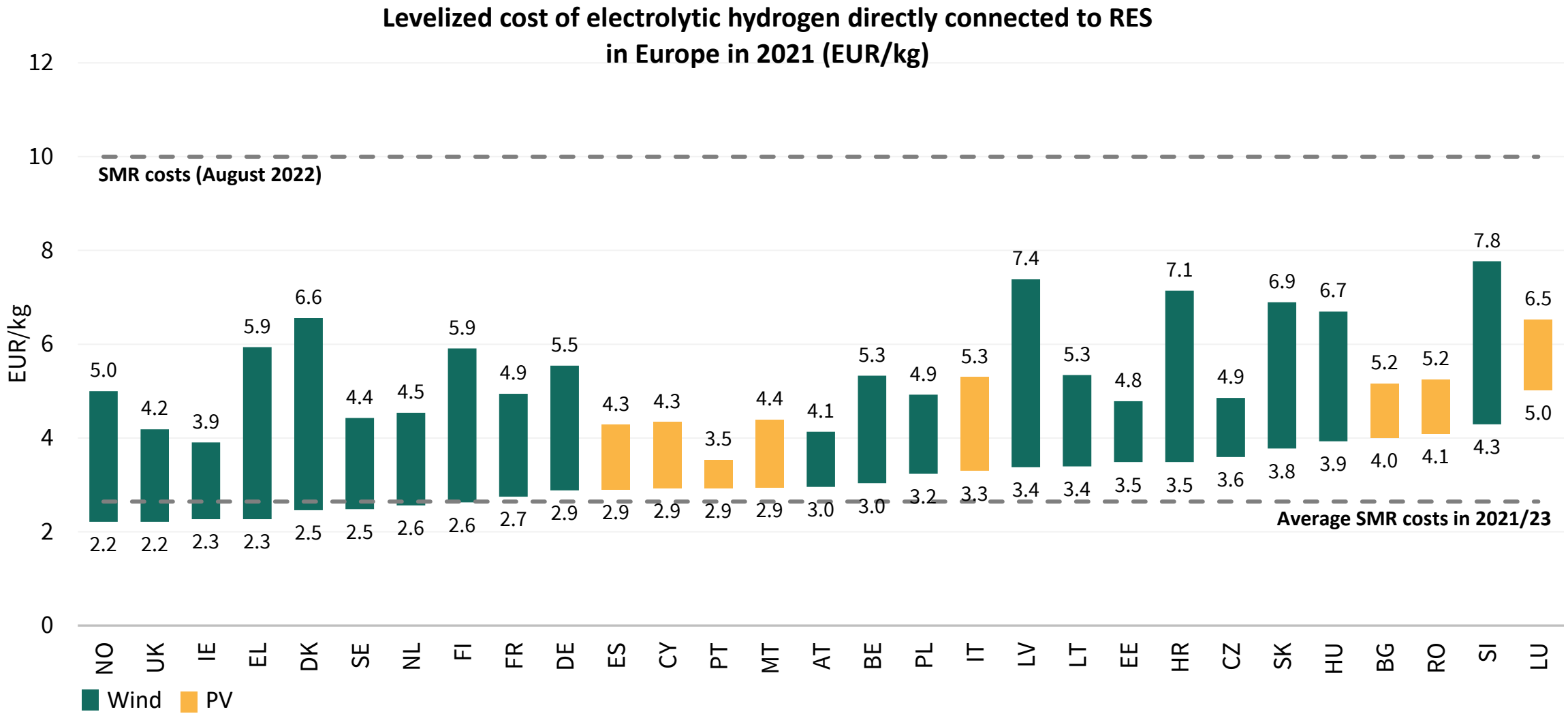


Production of hydrogen using the EU-27 average electricity mix in 2021 would have resulted in emissions of 11.5 $kgCO_2/kgH_2$ (vs 12.8 $kgCO_2/kgH_2$ in 2020)

Source: Hydrogen Europe

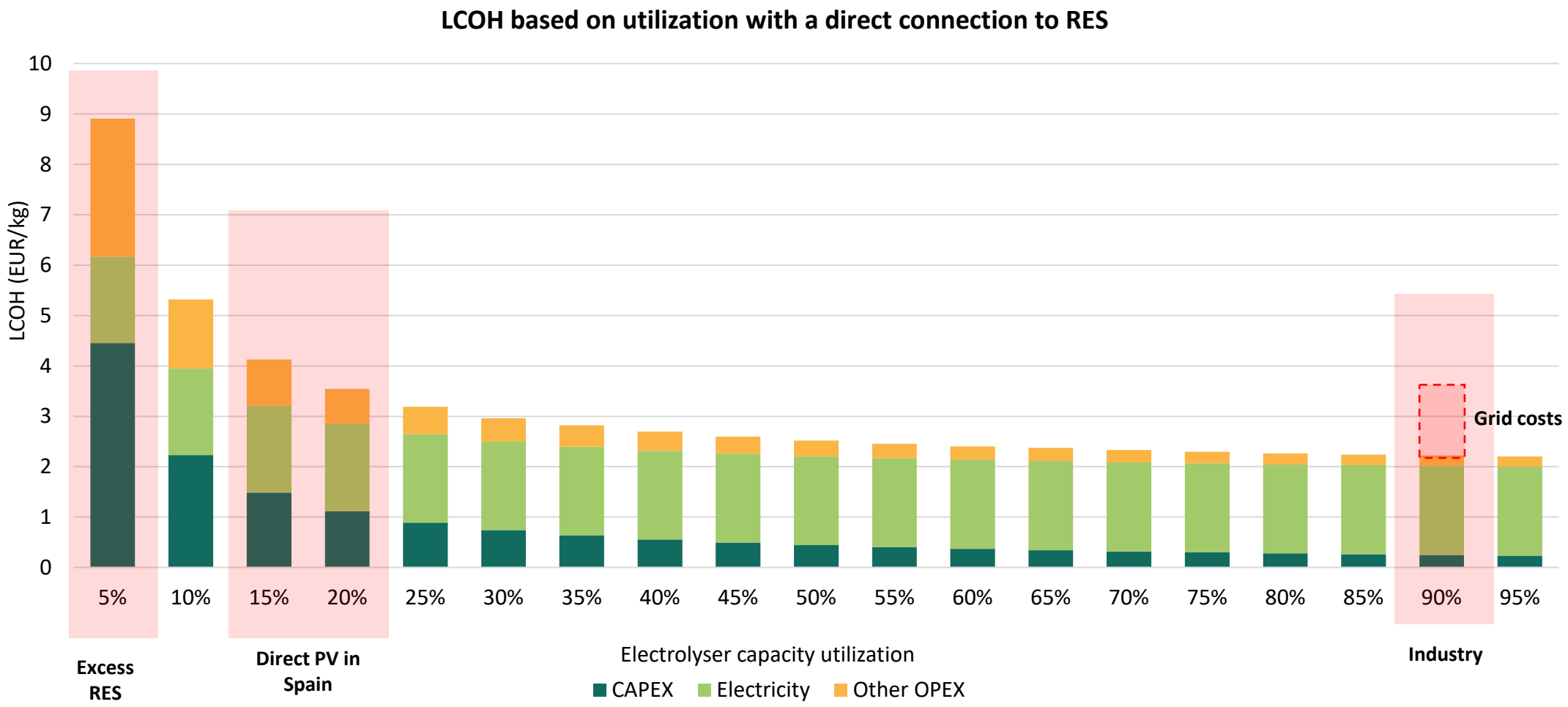
Levelized cost of electrolytic hydrogen directly connected to RES

Electrolytic hydrogen directly connected to RES started becoming competitive in 2021



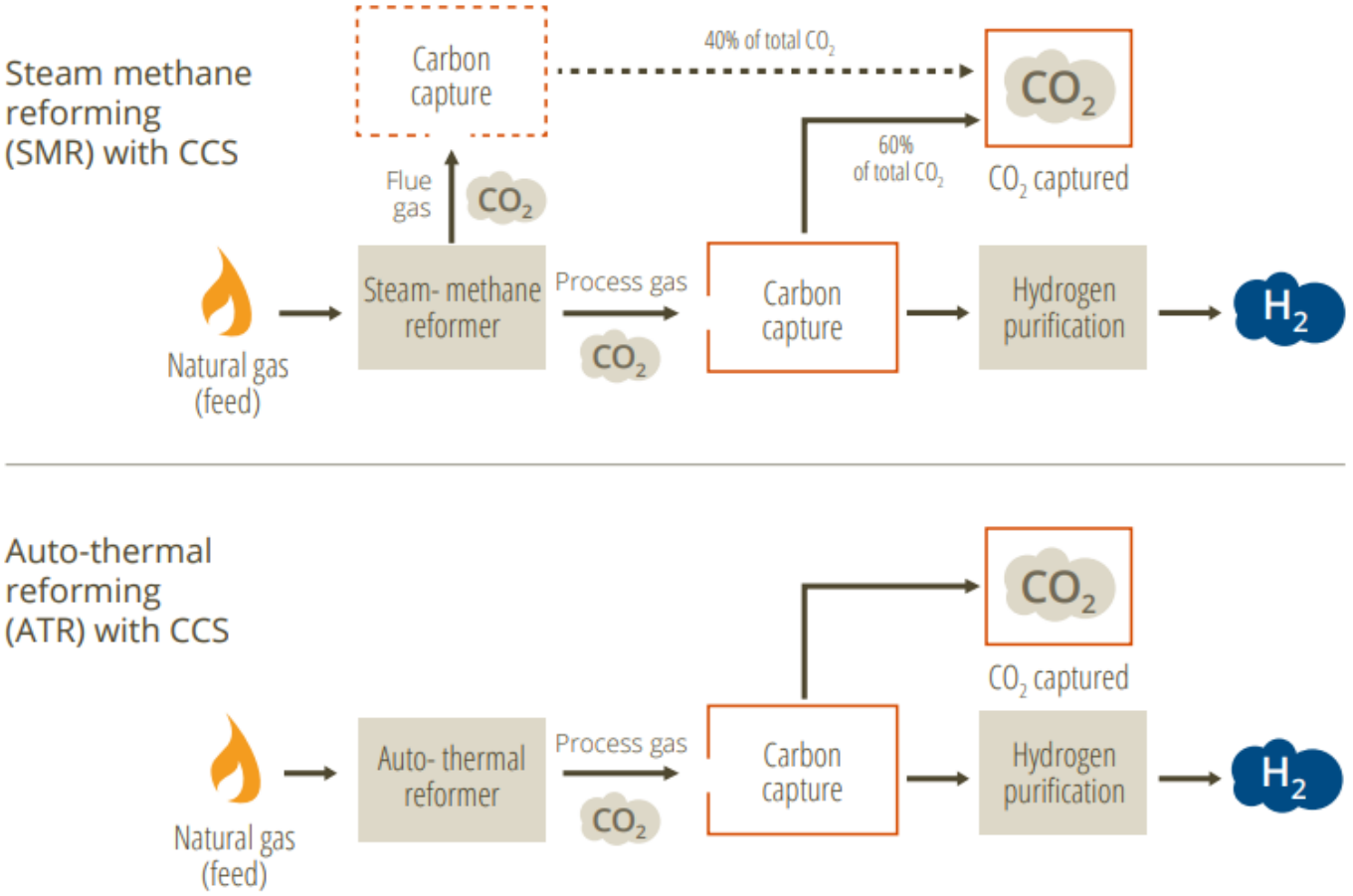
Notes: Costs refer to calculated costs based on electrolyzer CAPEX and OPEX, cost of renewables, etc.
Source: Hydrogen Europe

LCOH with a direct RES connection



Notes: Assumptions electricity cost at 34 EUR/MWh
Source: Hydrogen Europe

What about blue hydrogen?



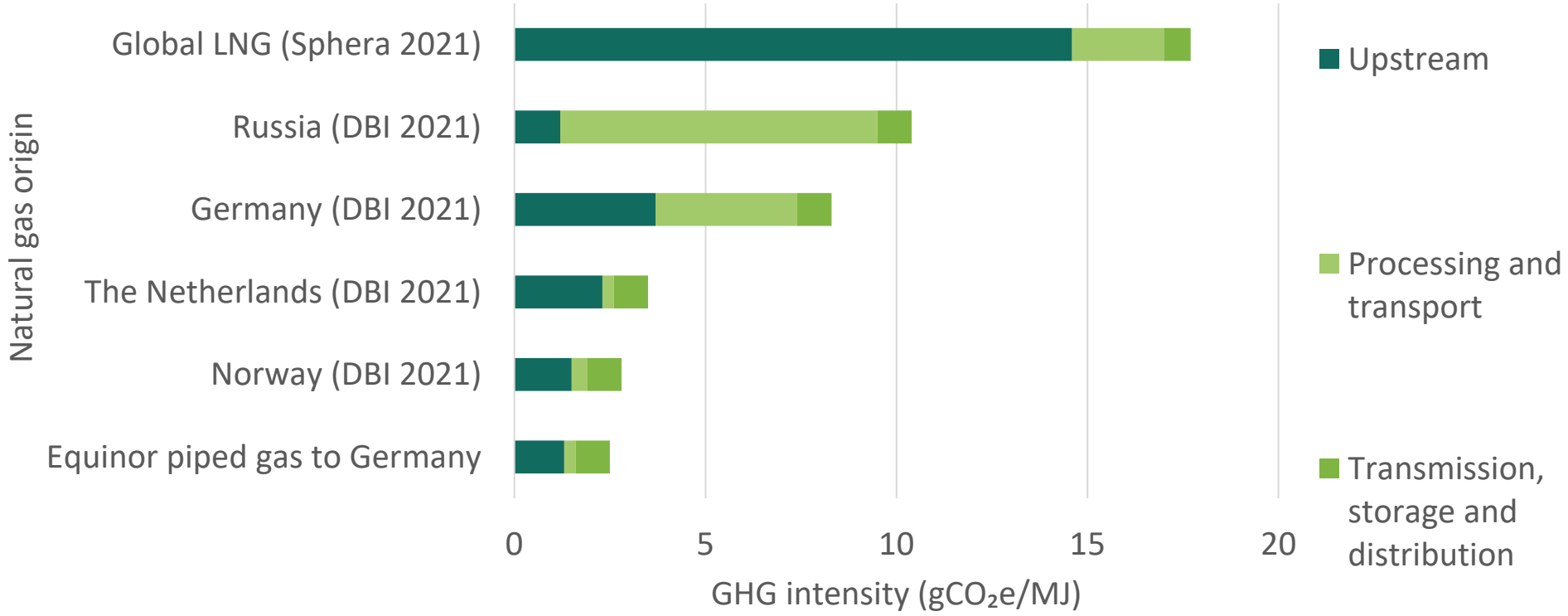
Source: PEMBINA INSTITUTE

Source: DNV

What about blue hydrogen?

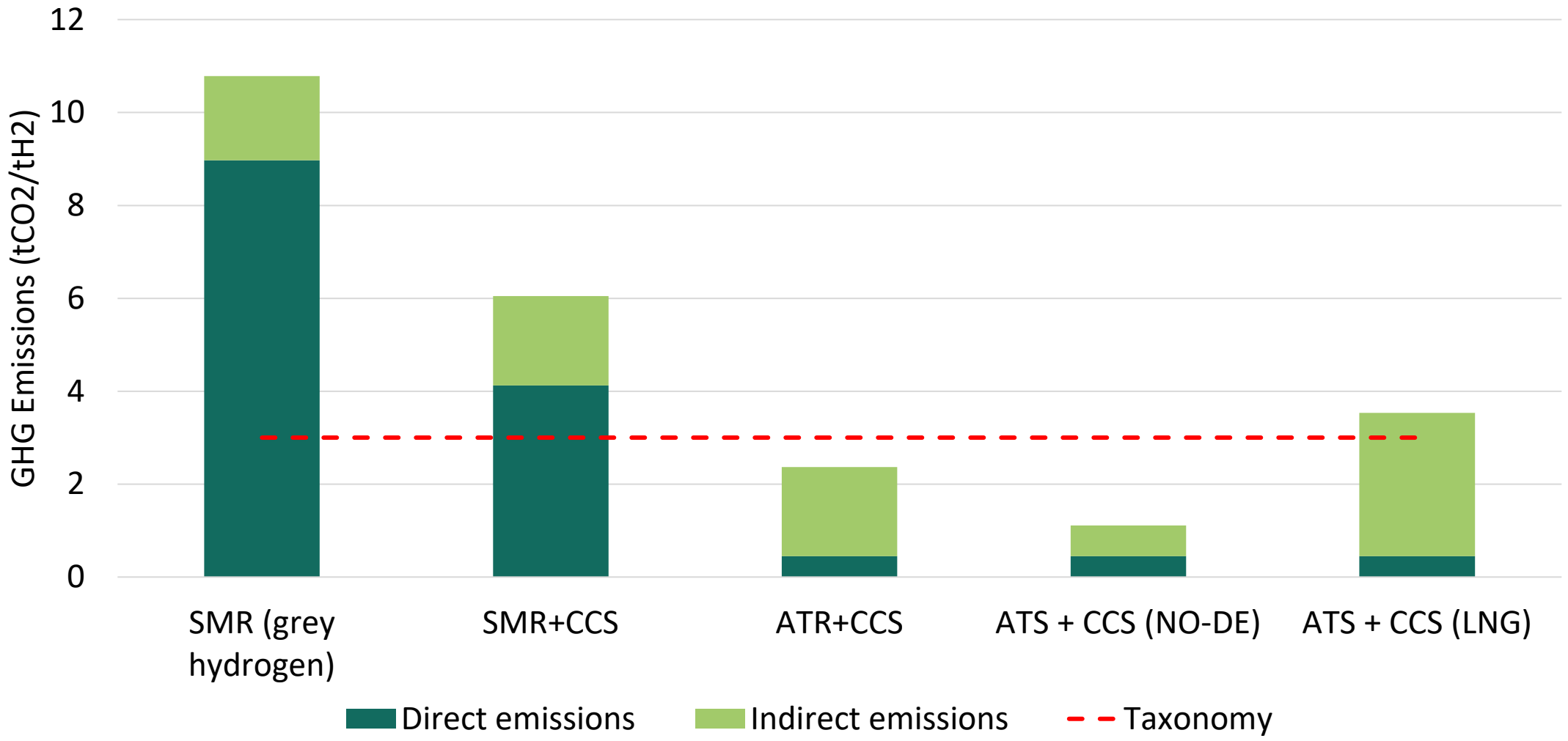
Indirect emissions

Comparison of GHG intensity of Equinor's Norwegian piped gas to Germany in 2020 and the German piped gas supply. Downstream data for Equinor's piped gas to Germany is derived from DBI 2021



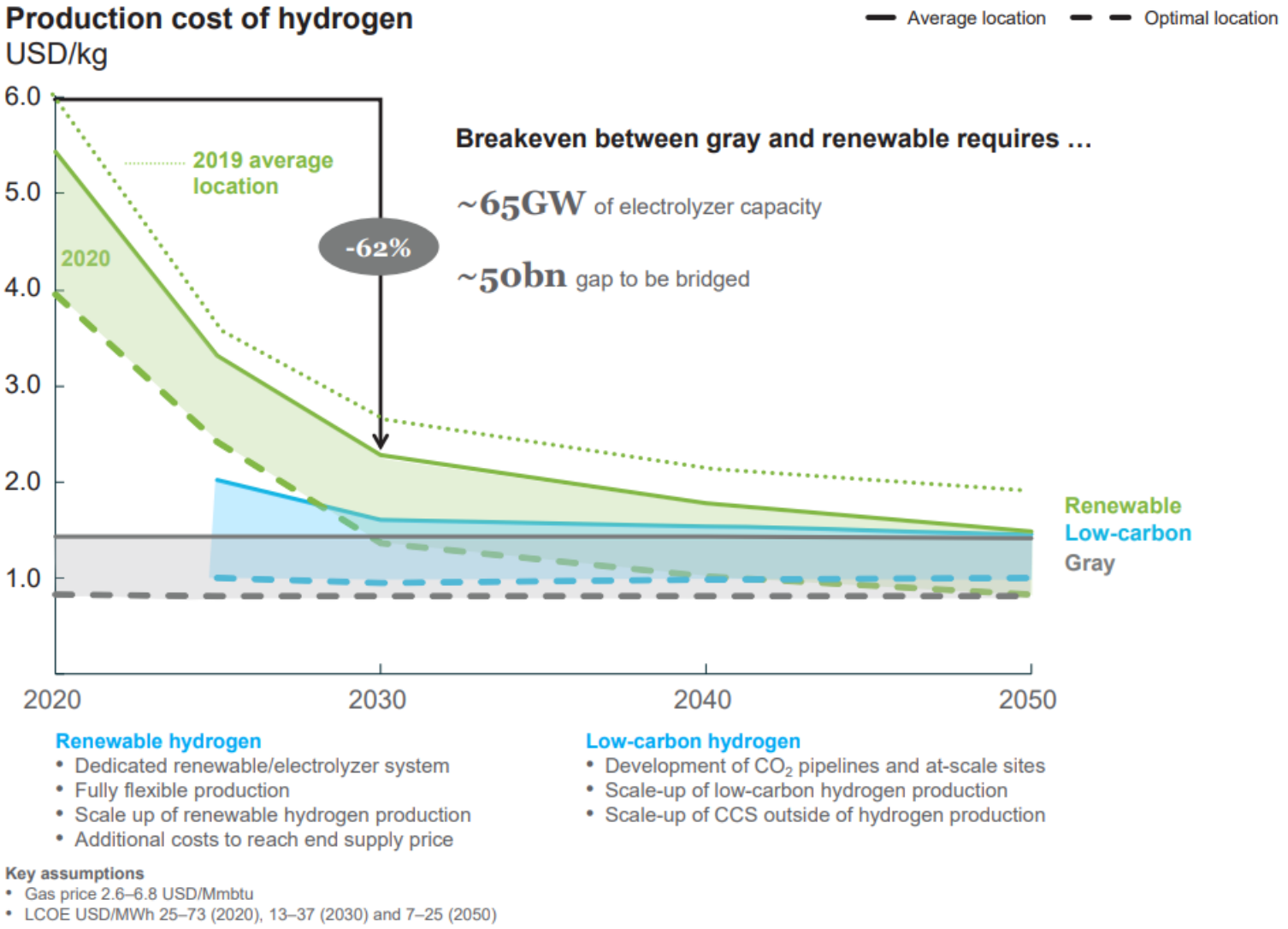
„Blue" hydrogen carbon footprint range

Depending on NG supply route and reforming technology blue hydrogen can be clean ... or not clean at all



Modelled costs for different production methods

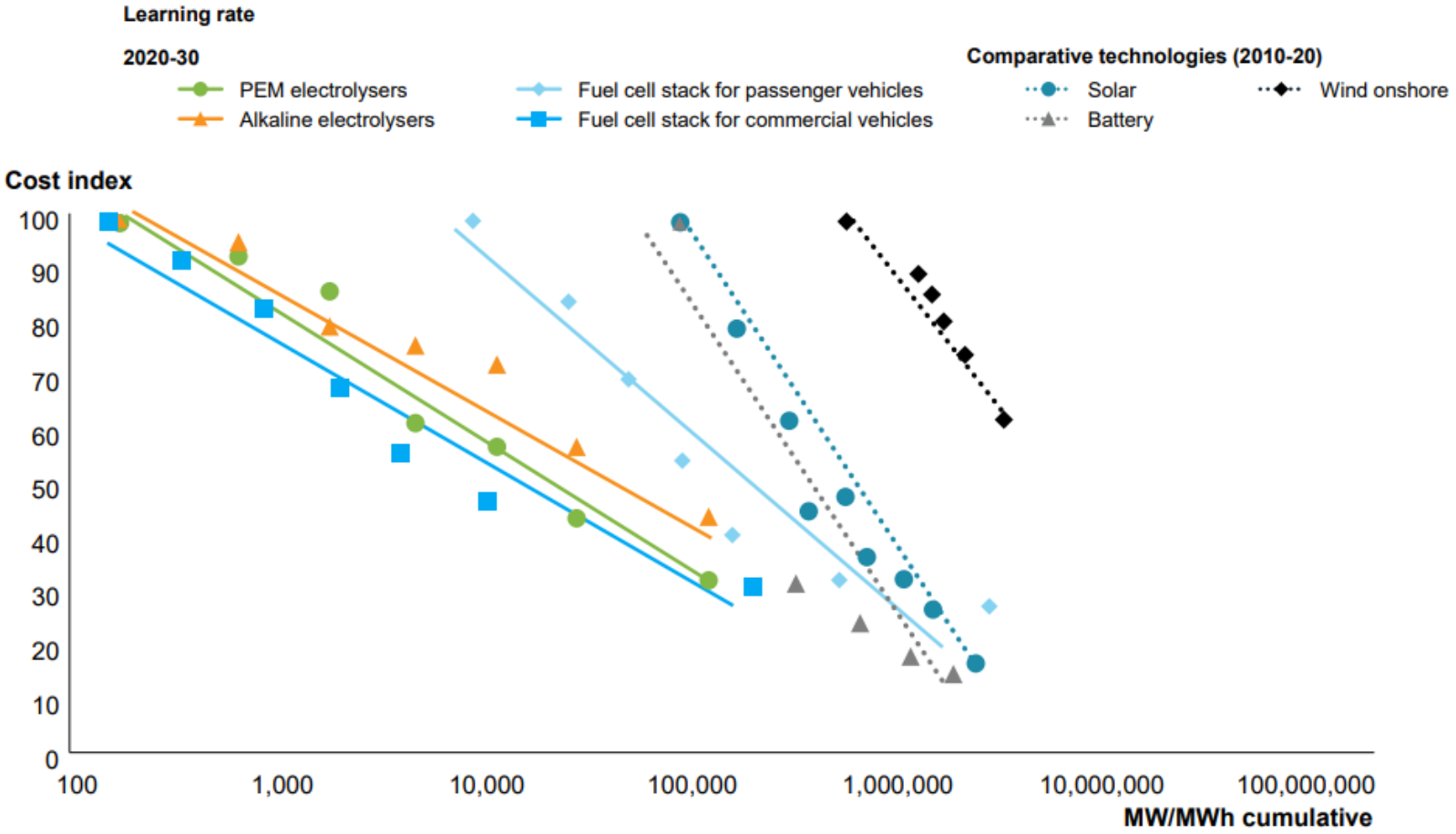
Unlike other hydrogen production methods, renewable H2 will continue to decrease



Source: McKinsey

Hydrogen technology learning rates

Capex development of selected technologies over total cumulative production
Indexed to 2020 values (2010 for comparative technologies)[1]

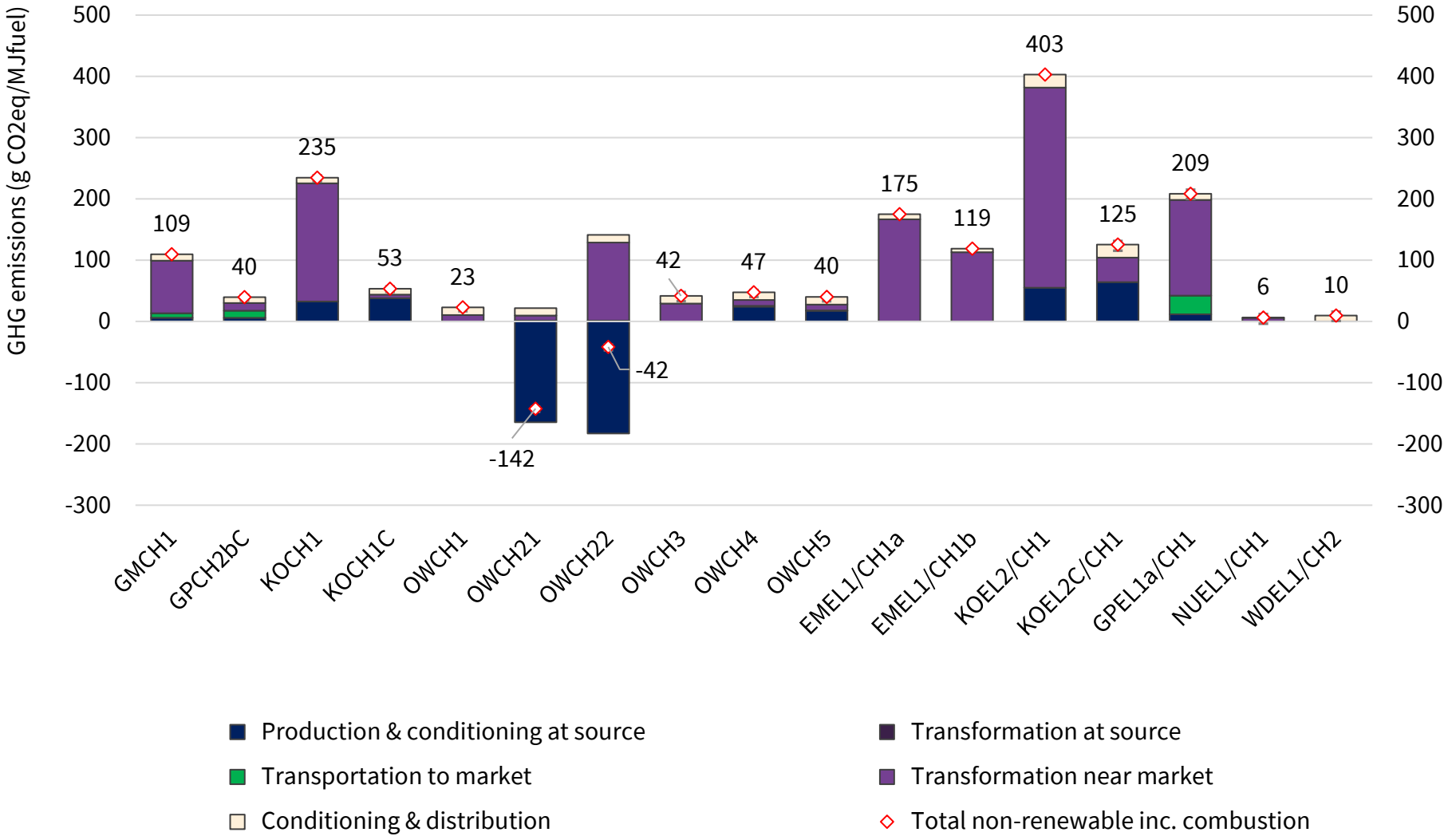


1. Installed base: assuming 50/50 split of electrolysers volume with 50-75% utilisation; assuming 115 kW for PV, 250 kW for buses and 300 kW for trucks; LCOE used for solar cost; batteries in MWh

SOURCE: McKinsey; IRENA; BNEF; Ruffini & Wei (2018) (learning rates); DoE

- Learning rate – describes decreasing cost of a technology with deployment
- Assumed learning rate is much lower than historical learning rates noticed with RES technologies
- The increase in deployment/ely manufacturing capacity is expected to decrease unit cost by 65% for PEM

There are more ways to produce hydrogen in a sustainable way



GMCH1 *- EU-mix natural gas supply, transport to EU by pipeline (1900 km), transport inside EU (500 km), distribution through high-pressure trunk lines and low-pressure grid, steam reforming at retail station, compression to 88 MPa.*

GPCH2bC *Piped natural gas supply, transport to EU by pipeline (a, 4300 km to EU border and 700 km inside EU) or Southern Asia / Middle East (b, 4000 km), distribution through high pressure trunk lines, central large scale reformer with CCS, hydrogen pipeline, compression to 88 MPa at retail station.*

KOCH1 / KOCH1C *- EU-mix hard coal without/with CCS, hydrogen pipeline transport, compression at retail site.*

OWCH1 - *Upgraded biogas from municipal organic waste sent to onsite SMR, Hydrogen compression to 88 MPa at retail site. Closed digestate storag.*

OWCH21 *and* ***OWCH21*** *Upgraded biogas from wet manure sent to onsite SMR. Digestate storage closed (21) or open (22)*

OWCH3 *- Upgraded biogas from sewage sludge sent to onsite SMR. Closed digestate storage*

OWCH4 *- Upgraded biogas from maize (wole plant) sent to SMR. Closed digestate storage*

OWCH5 *- Upgraded biogas from double cropping (barley/maize) sent to SMR. Closed digestate storage*

EMEL1/CH1a *and* ***EMEL1/CH1b -*** *EU-mix electricity supply (based on actual averages), High voltage. (1) on site electrolysis, (2) central electrolysis with hydrogen pipeline transport. Hydrogen compression to 88 MPa.*

KOEL2/CH1 *and* ***KOEL2C/CH1 -*** *Hard coal (EU-mix), IGCC with or without CCS. On site electrolysis, hydrogen compression to 88 MPa.*

GPEL1a/CH1 - *Natural gas: CCGT, natural gas supplied over 5000 km pipeline (Russia). Electrolysis: on retail site, hydrogen compression to 88 MPa.*

NUEL1/CH1 - *Electricity from nuclear energy. Electrolysis: on retail site, hydrogen compression to 88 MPa.*

WDEL1/CH2 - *Electricity from wind energy. Central electrolysis, hydrogen pipeline transport, hydrogen compression to 88 MPa.*

JEC Well-To-Wheels report v5

Thank You

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