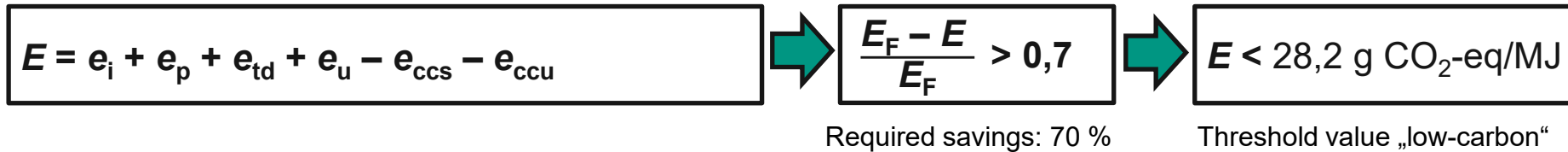


An estimation of greenhouse gas (GHG) emissions from blue and turquoise H₂

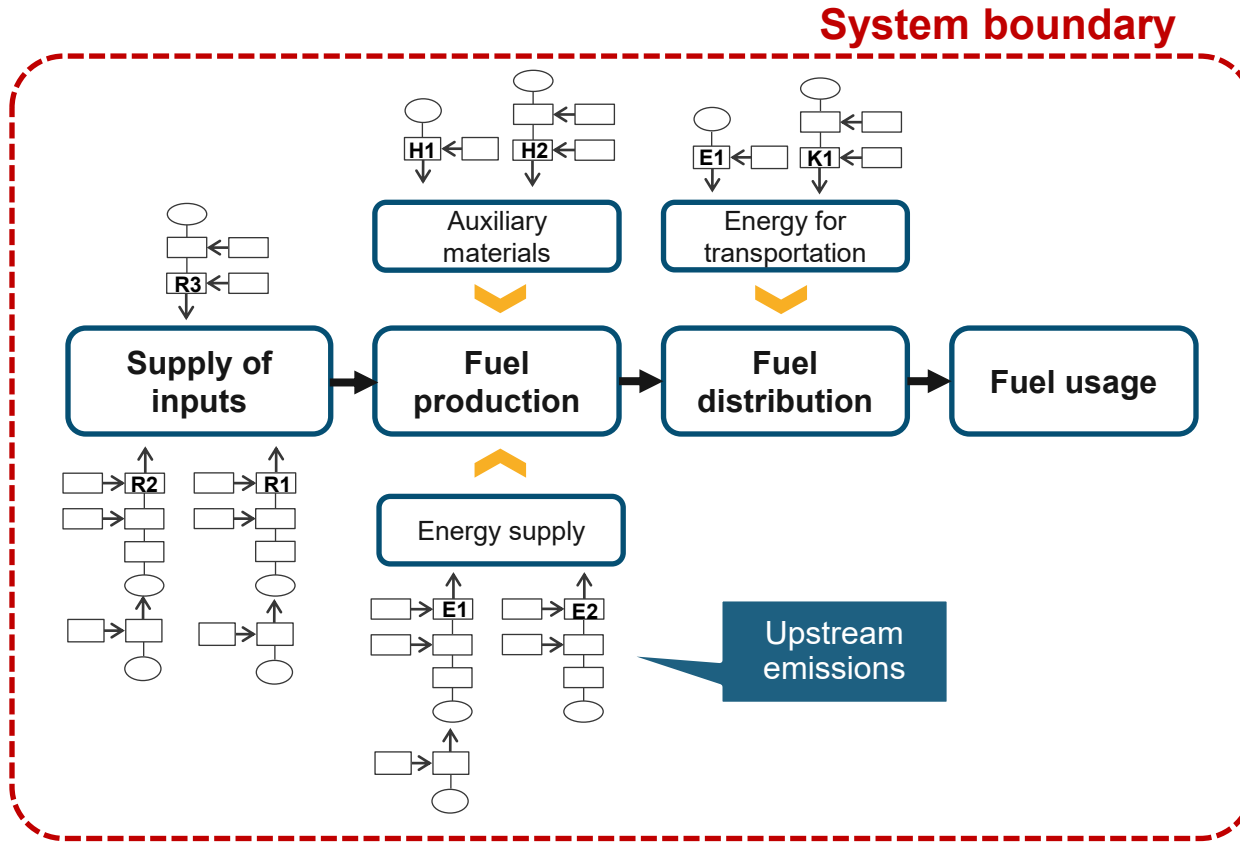
Within the context of Delegated Regulation (EU) 2025/2359 on low-carbon fuels

Maximilian Heneka, Florentin Glockner, 28.01.2026

The total greenhouse gas emissions of a low-carbon fuel are calculated using the following formula:

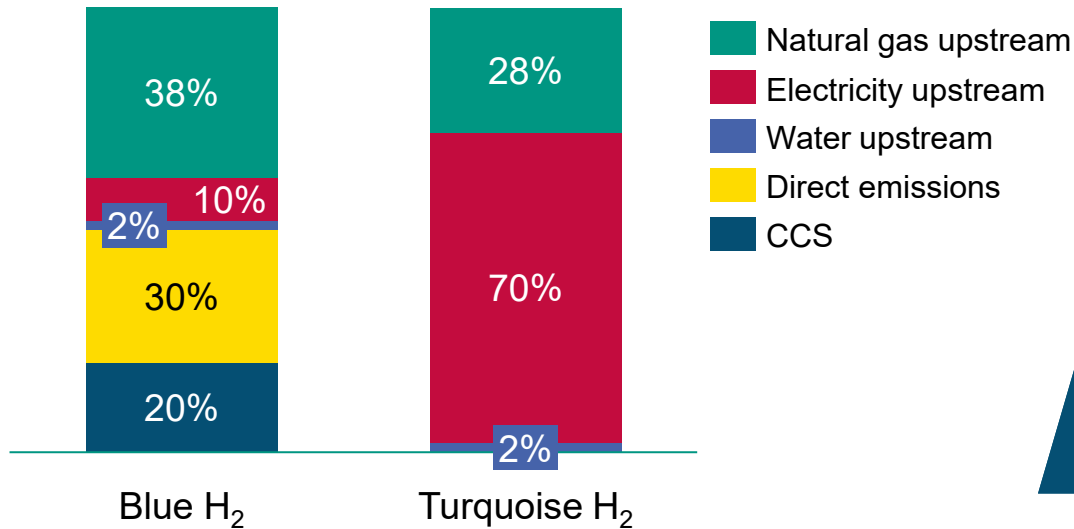


- E :** total emissions from the use of the fuel (g CO₂-equivalent per MJ Brennstoff)
- E_F :** fossil reference value (= **94 g CO₂-eq/MJ (LHV)** according to (EU) 2023/1185))
- e_i :** emissions from supply of inputs
- e_p :** emissions from processing
- e_{td} :** emissions from transport and distributions
- e_u :** emissions from combusting the fuel in its end use
- e_{ccs} :** net emission savings from carbon capture and storage
- e_{ccu} :** net emission savings from carbon captured and permanently chemically bound in long-lasting products



- All GHG emissions are accounted for across the entire process chain, including upstream emissions (CO₂, CH₄, N₂O)
- Every energy and material flow must be taken into account
- **The minimum GHG-savings relative to the fossil reference value must be demonstrated at the end-user stage!**

Composition of the Carbon Footprint of blue and turquoise H₂



Current situation (previous analysis):



- **Blue hydrogen**
Strong influence of upstream natural-gas emissions + carbon-capture rate on the carbon footprint
- **Turquoise hydrogen**
Strong influence of upstream emissions of electricity on the carbon footprint

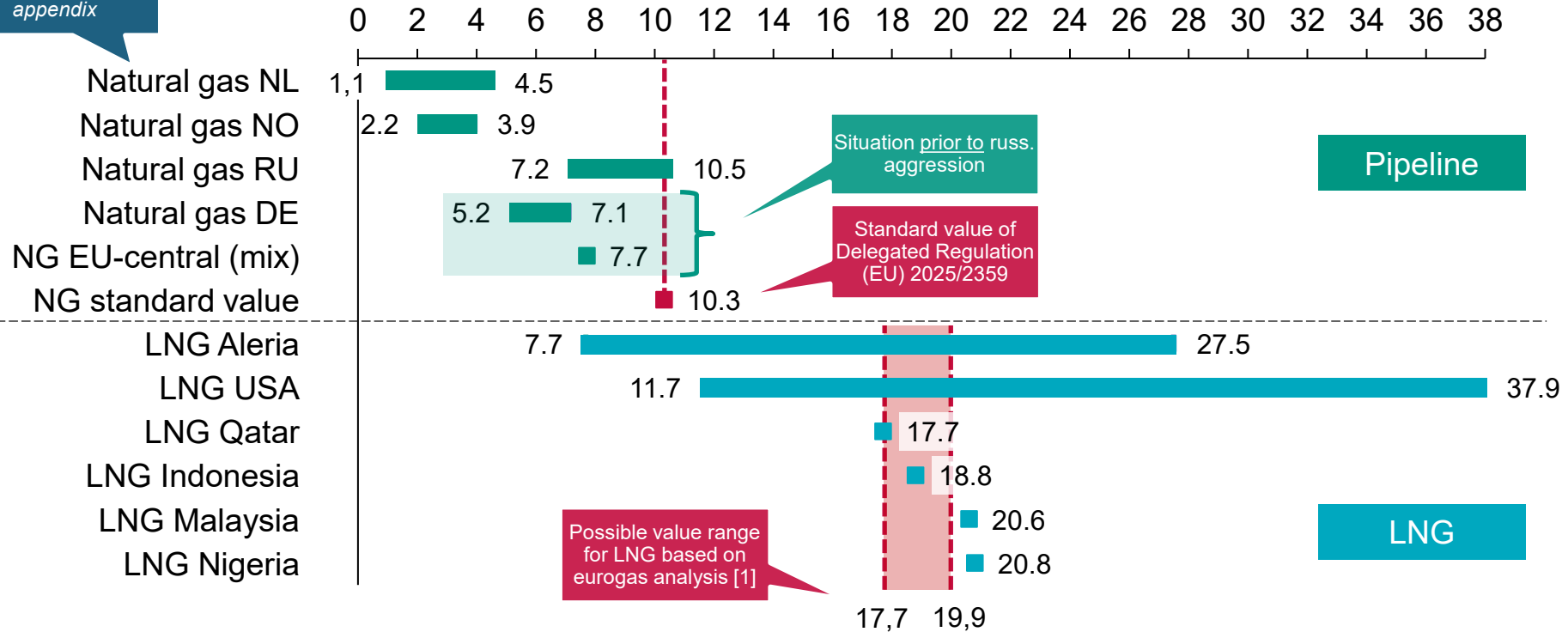
Source:

F. Mörs und M. Heneka, "CO₂-Footprint von Wasserstoff – von blau über türkis bis grün", 3. Mai 2022. [Online]. Available at: <https://www.dvgw.de/medien/dvgw/forschung/events/h2-lunch-learn-03052022-erzeugungsverfahren-fmoers.pdf>. Zugriff am: 25. Juni 2023.

Upstream emission intensity of natural gas and LNG

Sources and data overview, see appendix

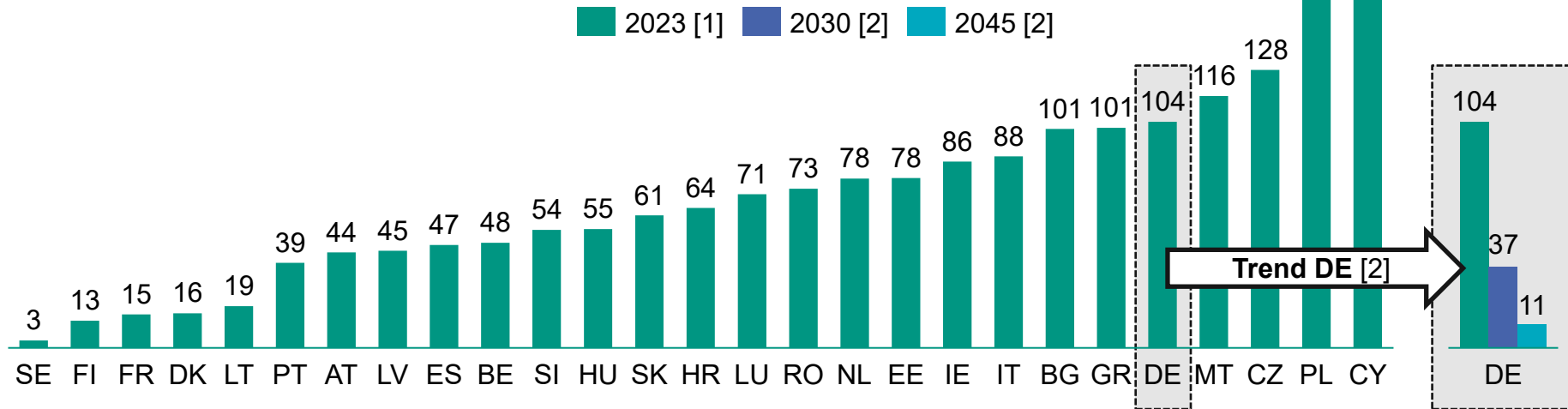
Upstream emissions* of natural gas/LNG in g CO₂-eq/MJ (LHV)



*The term upstream emissions refers to the greenhouse gas released during the extraction, processing, and transportation stages of production. This includes direct emissions such as carbon dioxide (CO₂) and methane. Notably, for liquefied natural gas (LNG), additional emissions are associated with the processes of liquefaction, LNG transport, and regasification; [1] Eurogas, "Low Carbon Delegated Regulation: Eurogas assessment compared to the May 2025 draft", 8. Juli 2025.

GHG emissions of electricity mix 2023 in EU-27 according to Delegated Regulation (EU) 2025/2359

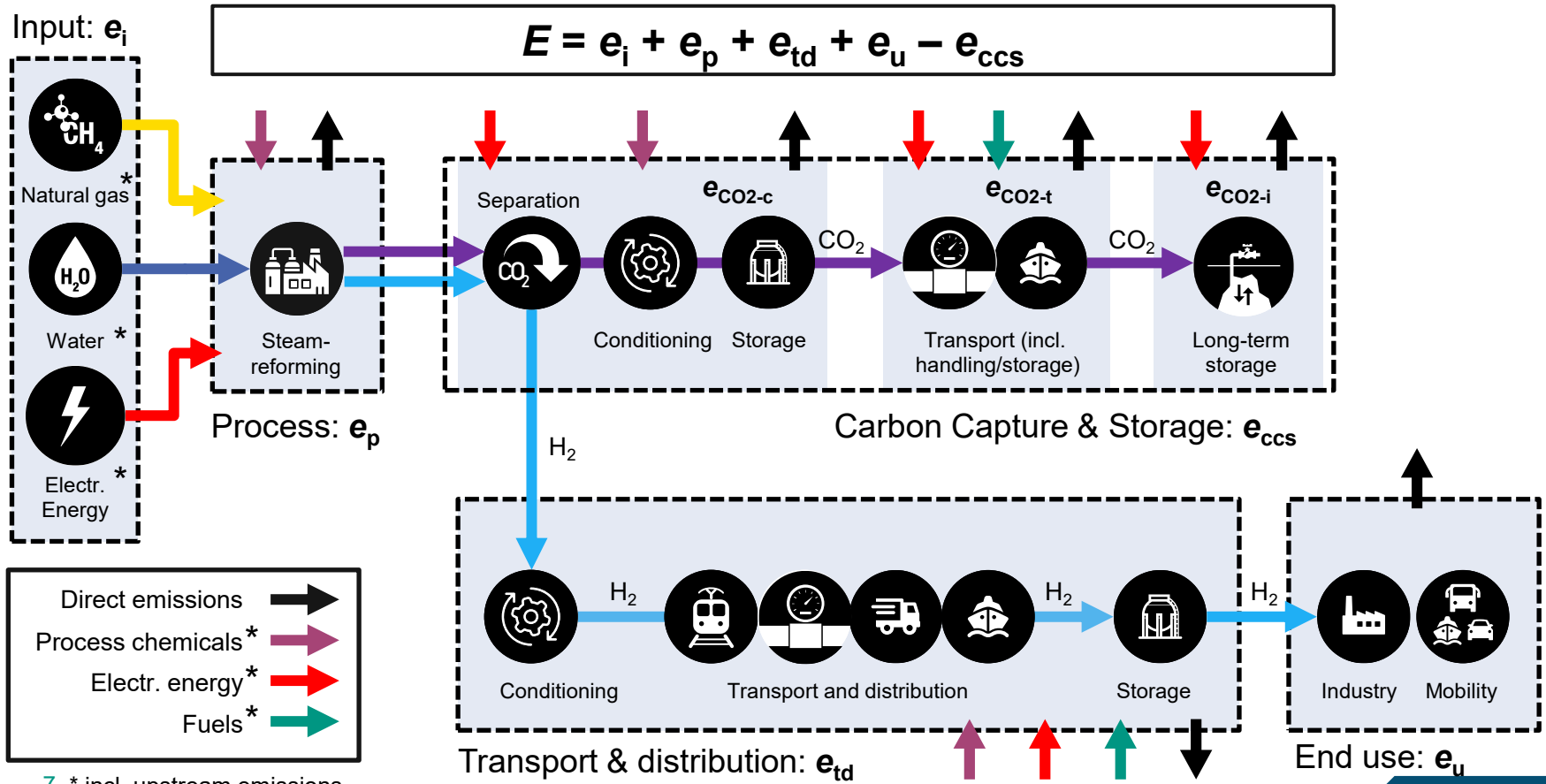
GHG emissions of electricity mix in EU-27 in g CO₂-eq/MJ



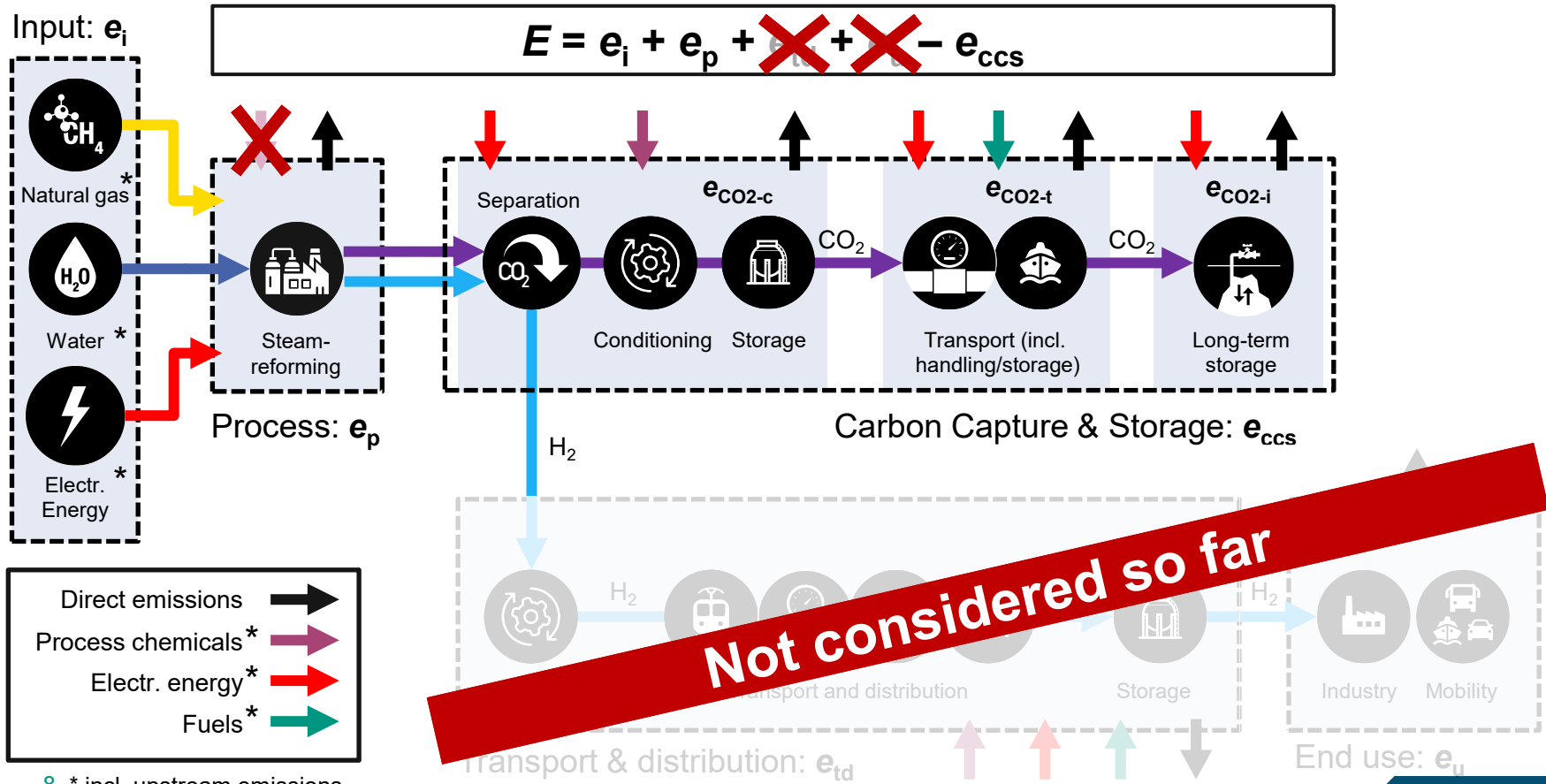
[1] ANNEX to the COMMISSION DELEGATED REGULATION (EU) 2025/2359 supplementing Directive (EU) 2024/1788 of the European Parliament and of the Council by specifying a methodology for assessing greenhouse gas emissions savings from lowcarbon fuels, 2025.

[2] Öko-Institut e.V., Fraunhofer ISI, IREES, Thünen-Institut, "Kernindikatoren des Projektionsberichtes 2024 (Datentabelle)", 2024. [Online]. Available at: <https://www.govdata.de/dl-de/by-2-0>.

System boundary for blue H₂ based on Delegated Regulation (EU) 2025/2359



System boundary and simplifications for the current GHG analysis of blue H₂

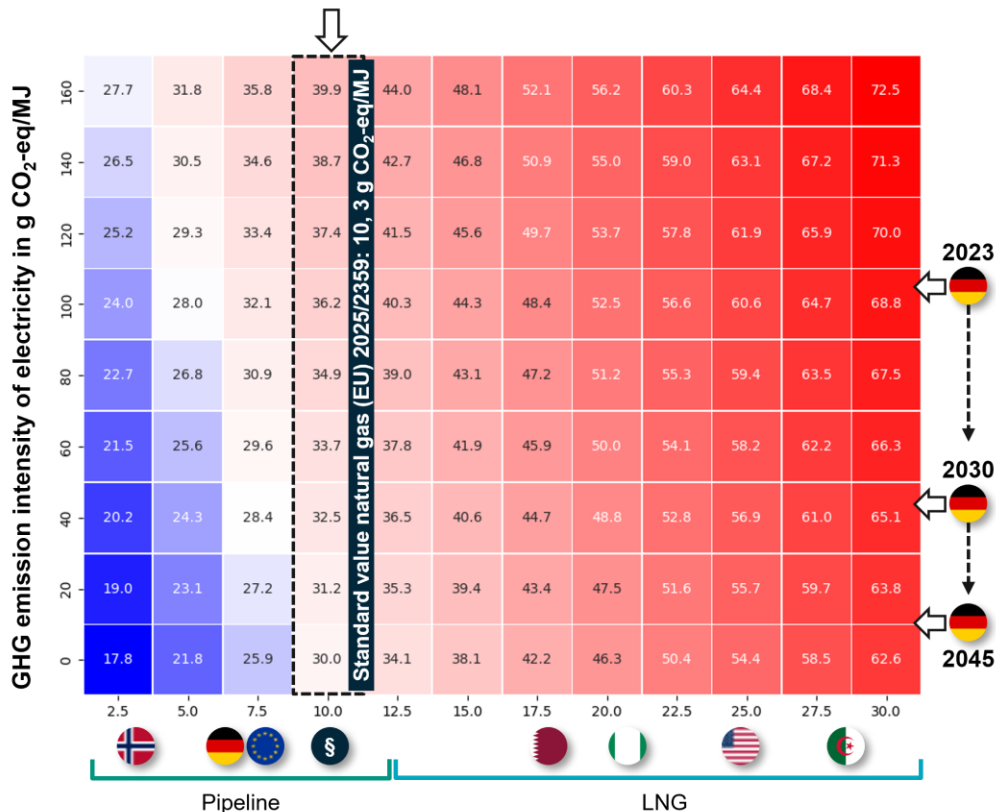


GHG emission intensity of blue hydrogen

in relation to upstream emissions from natural gas and electricity supply (I)

- **EU threshold (low carbon H₂):**
28.2 g CO₂-eq/MJ H₂ (LHV)
- Carbon Capture rate: **90 %**
- GHG downstream emissions of CO₂-process chain: 6 g CO₂-eq/MJ H₂ (LHV)
(Assumptions based on industry literature)

GHG emission intensity of hydrogen in g CO₂-eq/MJ (LHV)



Upstream GHG emission intensity of natural gas in g CO₂-eq/MJ (LHV)

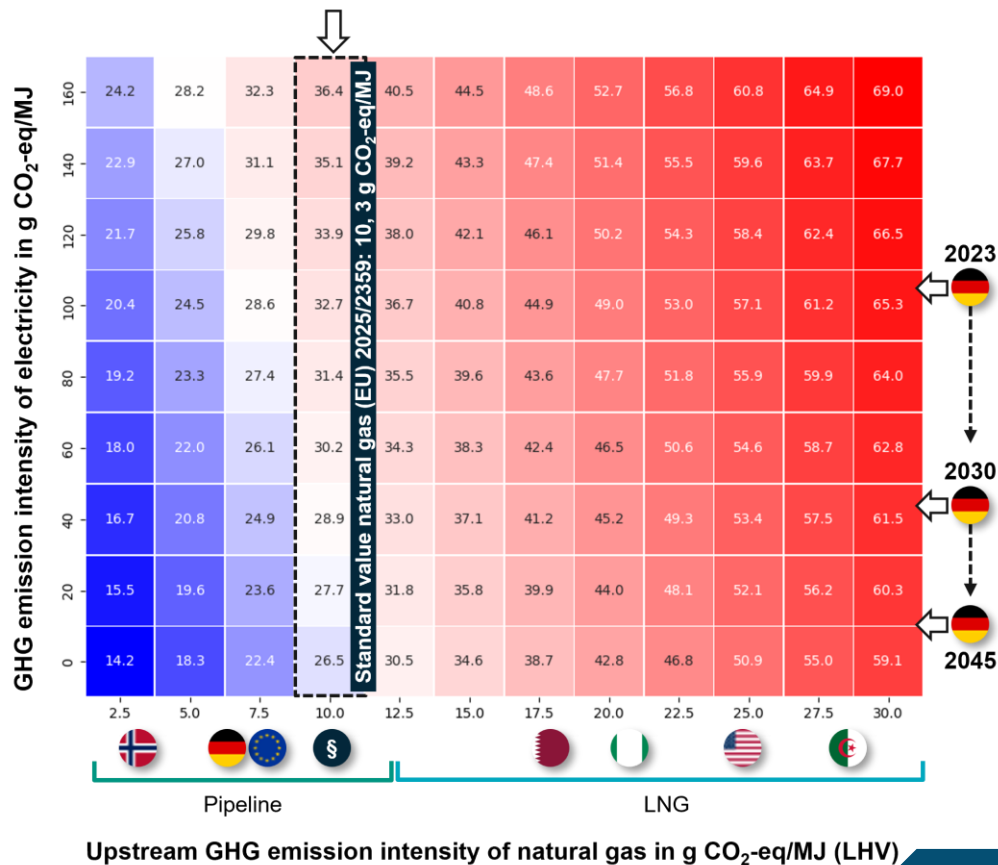
GHG emission intensity of blue hydrogen

in relation to upstream emissions from natural gas and electricity supply (II)

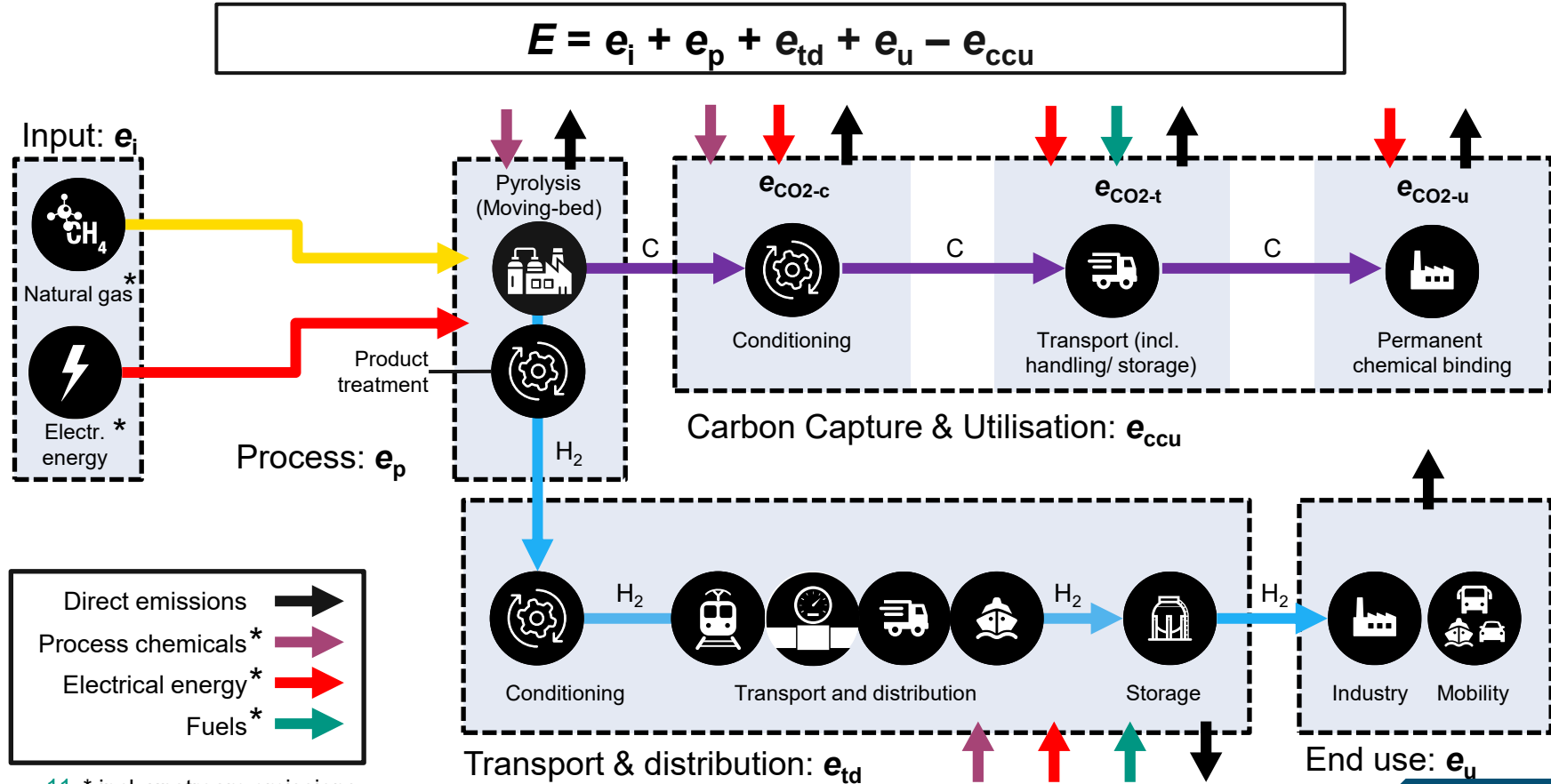
- **EU threshold (low carbon H₂):**
28.2 g CO₂-eq/MJ H₂ (LHV)
- Carbon Capture rate: **95 %***
- GHG downstream emissions of CO₂-process chain: 6 g CO₂-eq/MJ H₂ (LHV)
(Assumptions based on industry partners and literature)

*Simplified Assumption: The energy demand for CO₂ capture does not increase when the capture rate is raised.

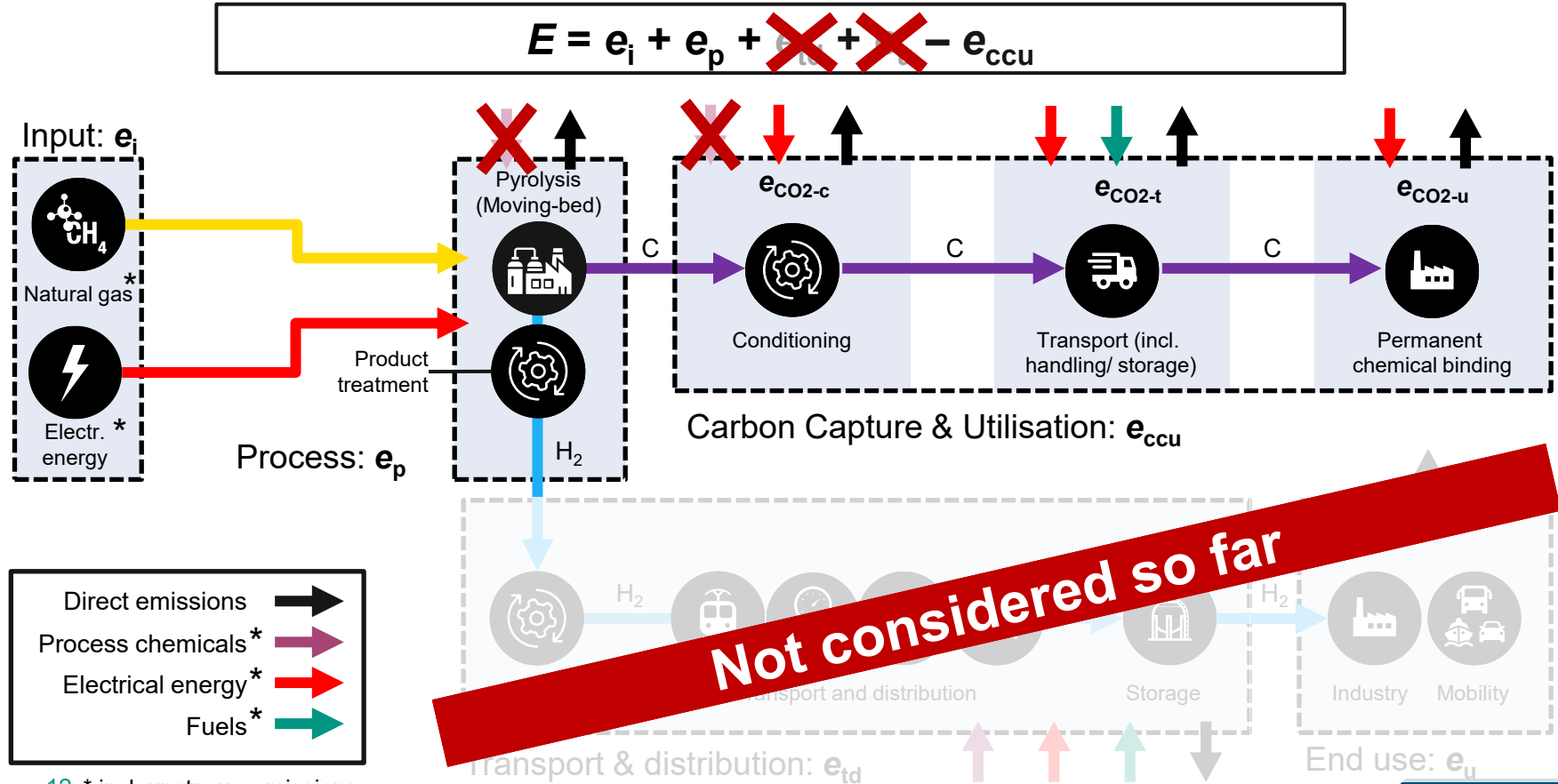
GHG emission intensity of hydrogen in g CO₂-eq/MJ (LHV)



System boundary for turquoise H₂ based on Delegated Regulation (EU) 2025/2359



System boundary and simplifications for the current GHG analysis of turquoise H₂



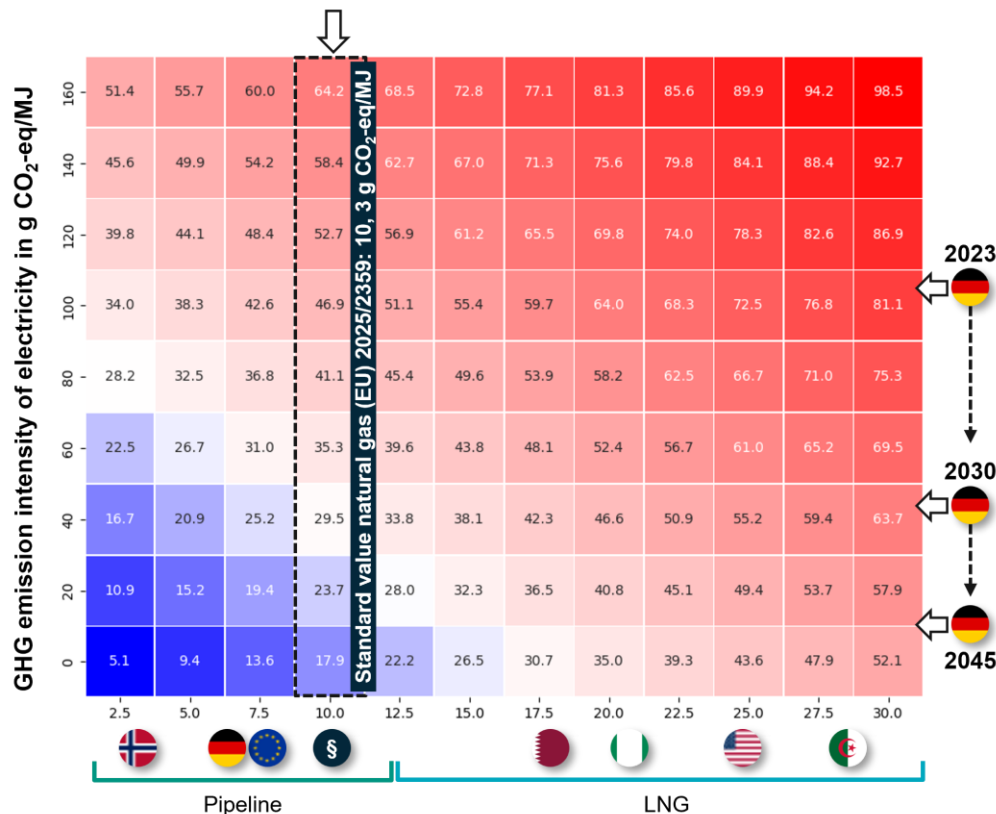
12 * incl. upstream emissions

GHG emission intensity of turquoise hydrogen

in relation to upstream emissions from natural gas and electricity supply (I)

- EU threshold (low carbon H₂):
28.2 g CO₂-eq / MJ H₂ (LHV)
- Assumption **allocation factor***
H₂/C = 100% / 0% without Allocation
- GHG emissions for **carbon-downstream chain** are not taken into account!
- GHG emissions for **H₂ downstream chain** are not taken into account!

GHG emission intensity of hydrogen in g CO₂-eq/MJ (LHV)



*without allocation („C“ is not a Co-Product)

GHG emission intensity of turquoise hydrogen

in relation to upstream emissions from natural gas and electricity supply (II)

- EU threshold (low carbon H₂):

28.2 g CO₂-eq / MJ H₂ (LHV)

- Assumption **allocation factor***

H₂/C = 55 % / 45 %

Allocation based on energy content

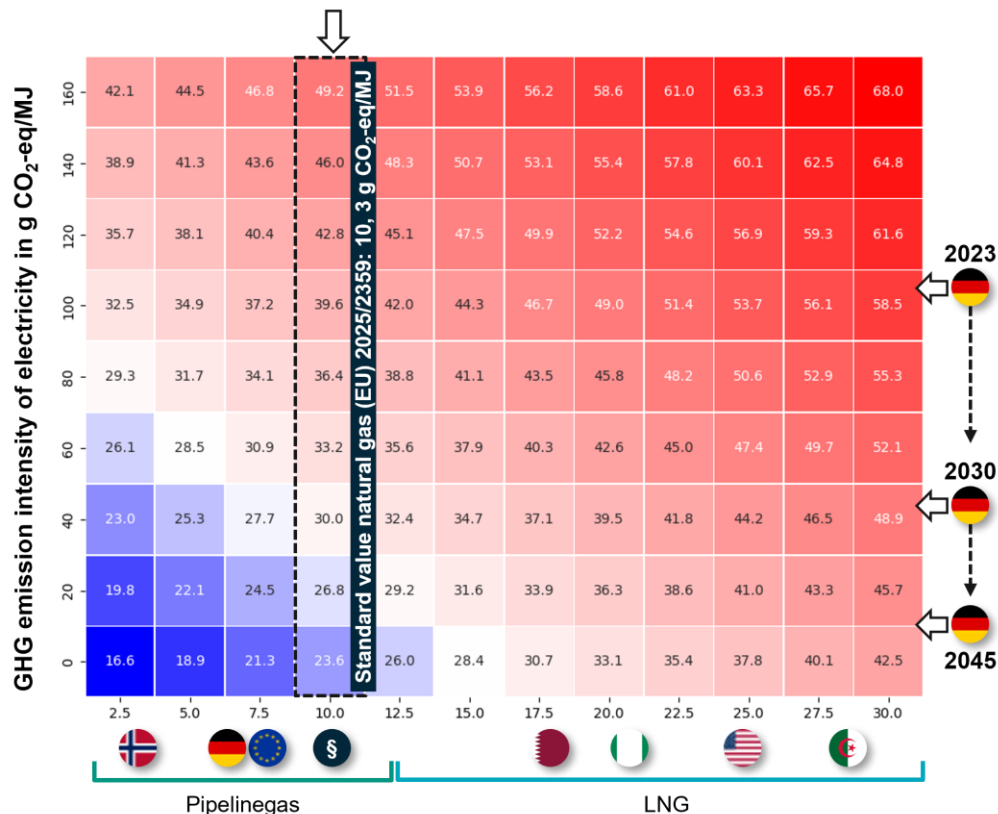
- GHG emissions for **carbon-downstream chain**

are not taken into account!

- GHG emissions for **H₂ downstream chain**

are not taken into account!

GHG emission intensity of hydrogen in g CO₂-eq/MJ (LHV)



*Allocation based on energy content („C“ is a Co-Product)

- The **upstream emissions of natural gas** have the greatest impact on the carbon footprint of blue H₂. For turquoise H₂, this impact is less pronounced
- Compared with literature values for the upstream emissions of the natural gas supply, **the EU reference value of 10.3 g CO₂-eq/MJ is very conservative**. It corresponds roughly to the upper range of the carbon footprint of Russian natural gas in 2018 (10.5 g CO₂-eq/MJ).
- When the EU reference value for the upstream emissions of natural gas is used, **it is difficult to qualify blue hydrogen as a „low-carbon fuel“**. It is advisable to employ reliable, site-specific data for the methane intensity whenever they are available.
- The **GHG intensity of the electricity mix** has a secondary, but not negligible, influence on blue H₂. For turquoise H₂, the electricity employed must contain a high share of renewable energy to meet the minimum GHG-saving requirement (GHG intensity of electricity < 40 g CO₂-eq/MJ).
- **Previously omitted steps in the process chain** (H₂ transport, H₂ distribution, H₂ utilisation, carbon capture, carbon transport, etc.) can hinder the qualification of both blue and turquoise hydrogen as “low-carbon”.
- **Allocation of GHG emissions** for turquoise H₂ to the co-products hydrogen and carbon must, in our understanding, be performed based on the **energy content** of each product. An Allocation that follows economic value is not permissible in this specific case.





Thank you for your attention.

Questions?

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Appendix

Upstream emissions	GHG emissions in a CO ₂ -eq/MJ (LHV)
Pipeline\Gas-NL-2020 [1]	1.05
Pipeline\Gas-NO-2020 [1]	2.15
Natural gas NO->EU 2020 [2]	2.50
Natural gas from NO - 2018 [3]	2.60
Natural gas from NL 2018 [3]	3.00
Natural gas NO->DE 2020 [2]	3.50
Natural gas NO->EU central 2018 [4]	3.93
Natural gas NL->EU central 2018 [4]	4.53
Gas-mix-DE-2020 [1]	5.23
Natural gas-Mix DE 2018 [4]	6.59
Natural gas consumer mix DE 2018 [3]	7.10
Pipeline\Gas-RU-2020 [1]	7.22
Handling DZ->DE\LNG-2020 [1]	7.68
Natural gas mix EU central 2018 [4]	7.72
Del. Reg. (EU) 2025/2359 Low Carbon Fuels [6]	10.32
Natural gas RU->EU-Zentral 2018 [4]	10.39
Natural gas from RU - 2018 [3]	10.50
Handling US->DE\LNG-2020-frack-med [1]	11.66
LNG Qatar [5]	17.70
LNG Indonesia [5]	18.80
LNG Malaysia [5]	20.60
LNG Nigeria [5]	20.80
LNG USA [5]	22.70
LNG Algeria [5]	27.50
Handling US->DE\LNG-2020-frack-high [1]	37.94
LNG EU (mix) [7]	17.9
LNG global (mix) [7]	17.7

■ Sources:

- [1] Globales Emissions-Modell integrierter Systeme (GEMIS). v 5.1, 2023. [Online]. Available at: <https://iinas.org/downloads/gemis-downloads/>
- [2] J. Pettersen, "Low carbon hydrogen from Natural Gas", 14. Juni 2022.
- [3] M. Baumann und O. Schuller, "Emissionsfaktoren der Stromerzeugung - Betrachtung der Vorkettenemissionen von Erdgas und Steinkohle", Dessau-Roßlau, Sep. 2021.
- [4] C. Große, M. Eyßer, S. Lehmann und M. Behnke, "Carbon Footprint Natural Gas 1.1: Abschlussbericht", Leipzig, 15. Jan. 2021.
- [5] D. Münster und A. Liebich, "Analyse der Treibhausgasintensitäten von LNG-Importen nach Deutschland: Studie im Auftrag der Wissenschaftsplattform Klimaschutz", Berlin, Mai 2023.
- [6] ANNEX to the COMMISSION DELEGATED REGULATION (EU) 2025/2359 supplementing Directive (EU) 2024/1788 of the European Parliament and of the Council by specifying a methodology for assessing greenhouse gas emissions savings from lowcarbon fuels, 2025.
- [7] O. Schuller, S. Kupferschmid, J. Hengstler und S. Whitehouse, "2nd Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel: On behalf of SEA-LNG and SGMF" Final Report, 15. Apr. 2021.