DVGW Research Center at Engler-Bunte-Institut of Karlsruhe Institute of Technology (KIT)

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An estimation of greenhouse gas (GHG) emissions from blue and turquoise H_2

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

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Calculation of GHG emissions
according to Delegated Regulation (EU) 2025/2359

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

$$E = e_i + e_p + e_{td} + e_u - e_{ccs} - e_{ccu}$$

→

$$\frac{E_F - E}{E_F} > 0{,}7$$

Required savings: 70 %

→

$$E < 28{,}2 \text{ g } CO_2\text{-eq/MJ}$$

Threshold value „low-carbon“

E: total emissions from the use of the fuel (g CO_2-equivalent per MJ Brennstoff)

E_F: fossil reference value (= **94 g CO_2-eq/MJ (LHV)** according to (EU) 2023/1185))

e_i: emissions from supply of inputs

e_p: emissions from processing

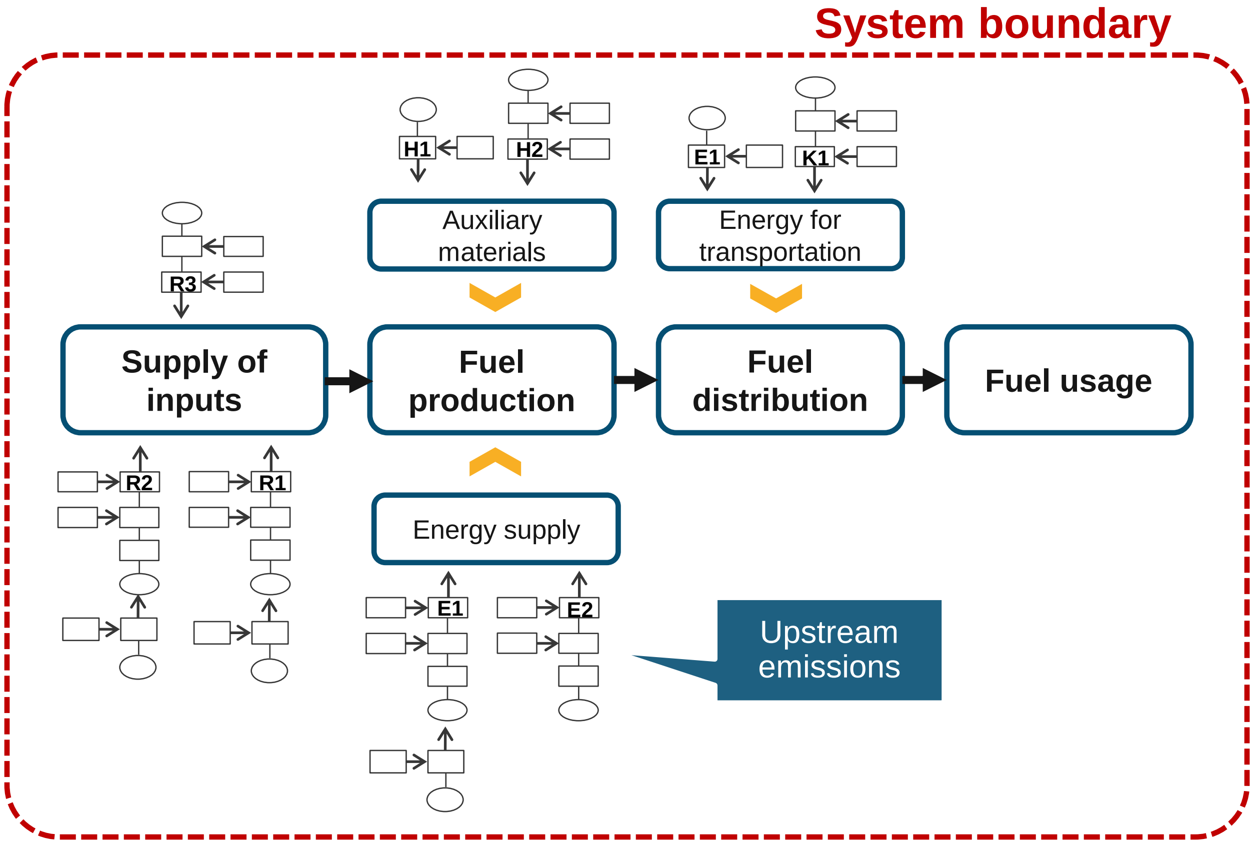
e_{td}: emissions from transport and distributions

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

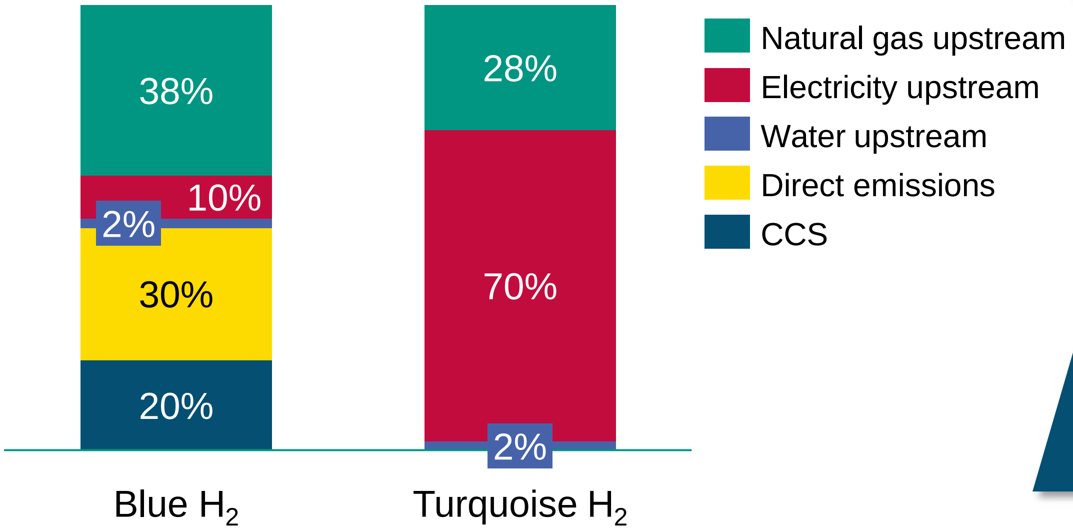
General balancing logic (simplified)



- All GHG emissions are accounted for across the entire process chain, including upstream emissions (CO_2, CH_4, N_2O)
- 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!**

Factors influencing the carbon footprint of blue and turquoise H_2

Composition of the Carbon Footprint
of blue and turquoise H_2



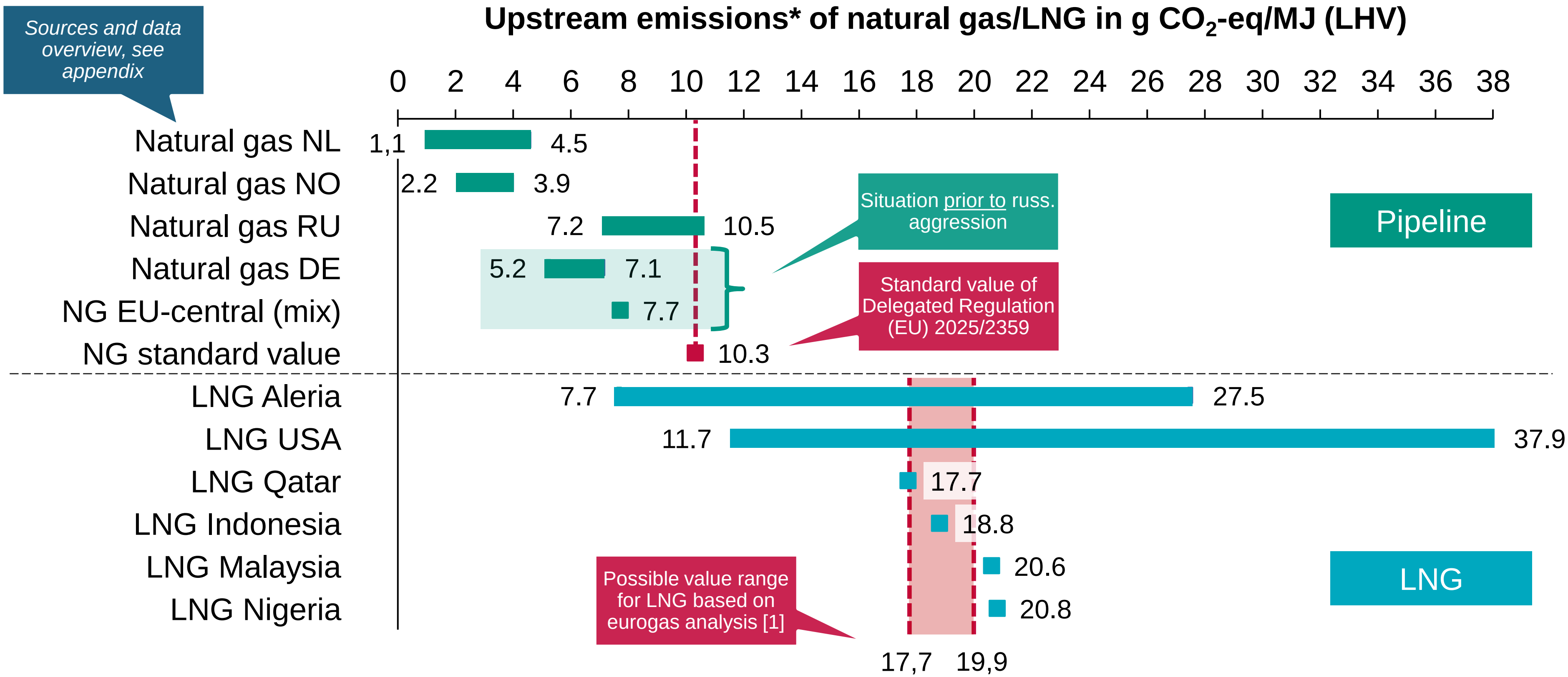
Current situation
(previous analysis):

- **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:

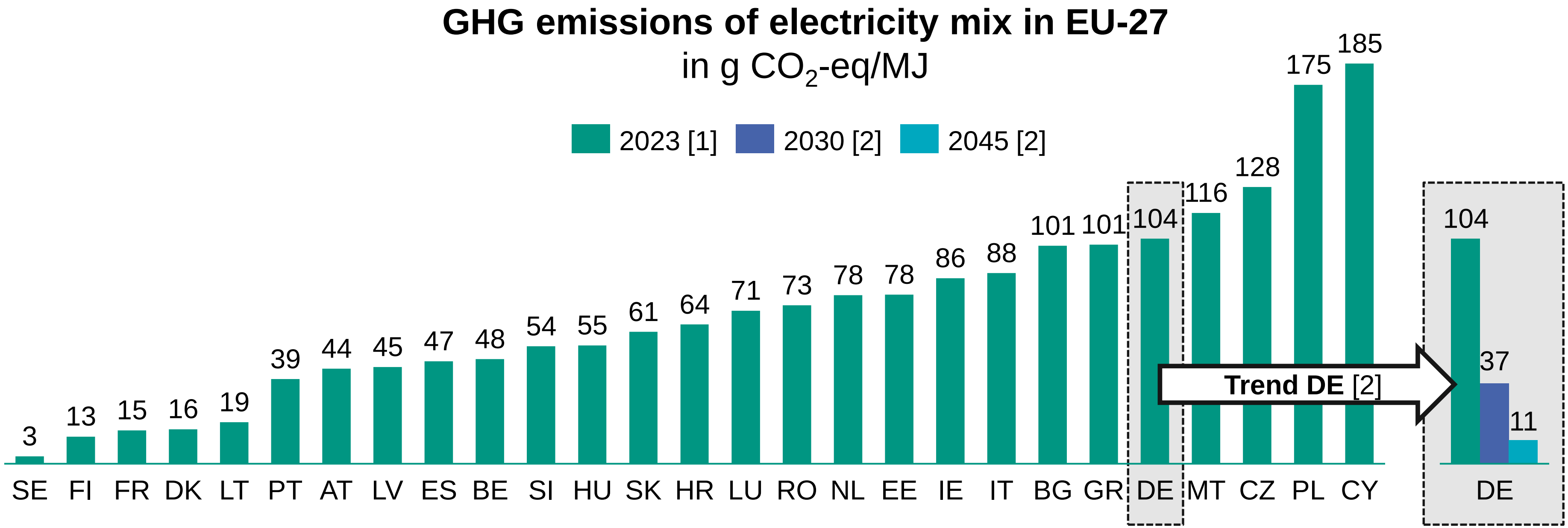
F. Mörs und M. Heneka, "CO2-Footprint von Wasserstoff – von blau über türkis bis grün", 3. Mai 2022. [Online]. Available at: https://www.dvgw.de/medien/dvgw/forschung/events/h2-lunch-learn-03052022-erzeugungsverfahren-fmoers.pdf. Zugriff am: 25. Juni 2023.

Upstream emission intensity of natural gas and LNG



*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 (CO_2) 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.

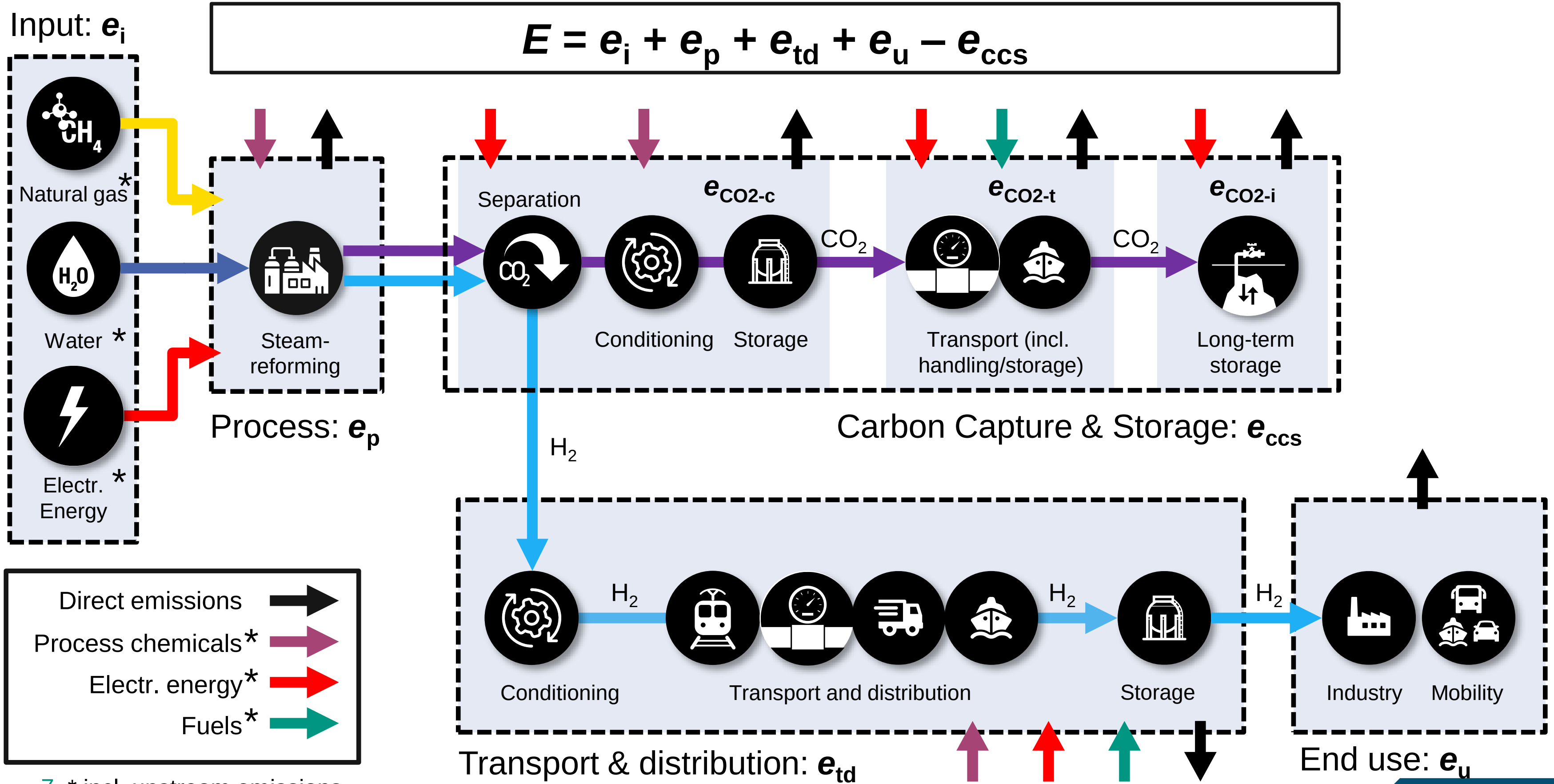
GHG emissions of electricity mix 2023 in EU-27
according to Delegated Regulation (EU) 2025/2359



[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.

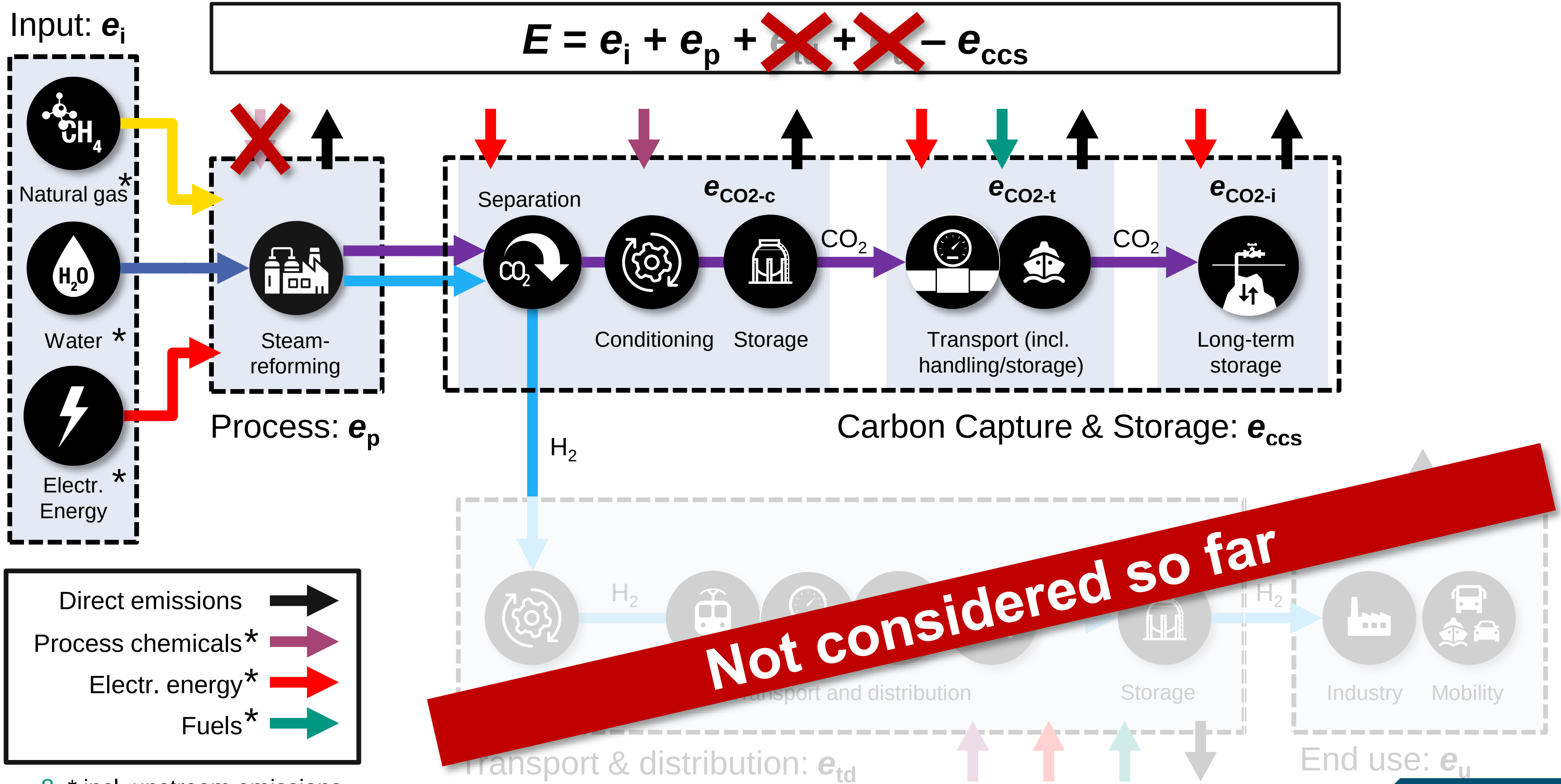
[2] Öko-Institut e.V., Fraunhofer ISI, IREES, Thünen-Institut, "Kernindikatoren des Projektionsberichtes 2024 (Datentabelle)", 2024. [Online]. Available at: https://www.govdata.de/dl-de/by-2-0.

System boundary for blue H_2 based on Delegated Regulation (EU) 2025/2359



 * incl. upstream emissions

System boundary and simplifications for the current GHG analysis of blue H_2



 * incl. upstream emissions

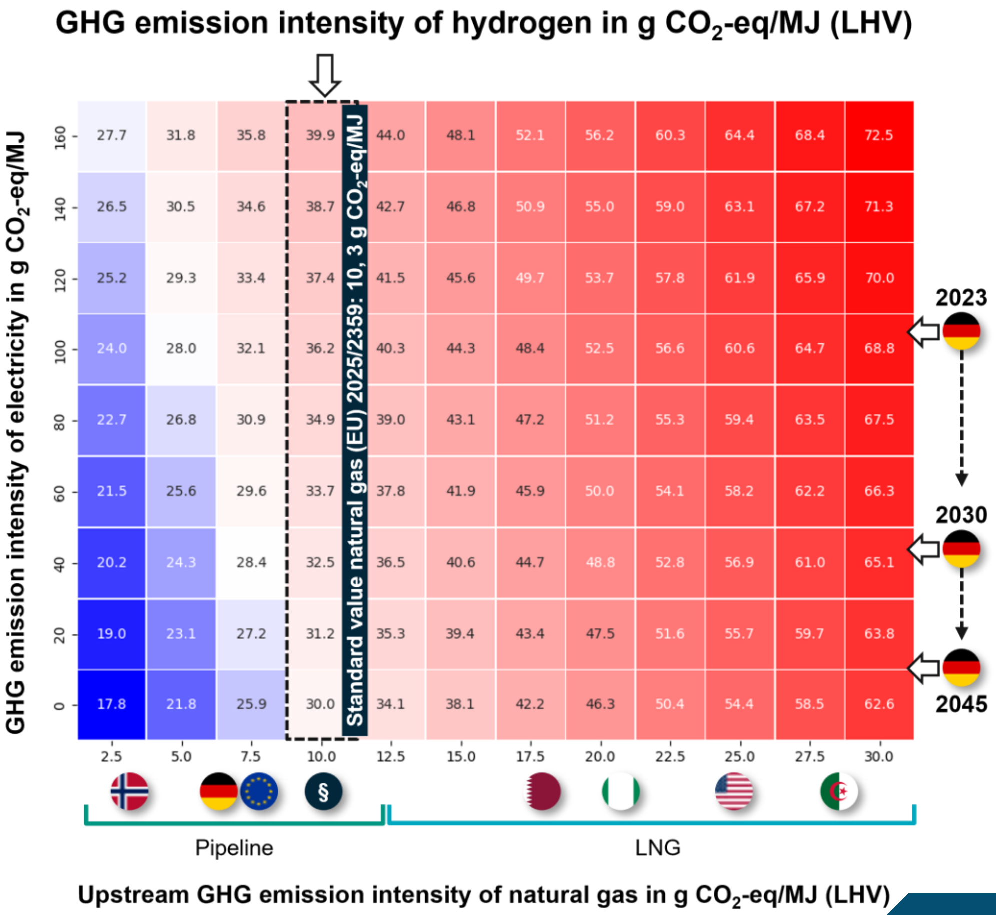
GHG emission intensity of blue hydrogen

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

- **EU threshold (low carbon H_2):**
  28.2 g CO_2-eq/MJ H_2 (LHV)

- Carbon Capture rate: **90 %**

- GHG downstream emissions of CO_2-process chain: 6 g CO_2-eq/MJ H_2 (LHV)
  (Assumptions based on industry literature)



Electricity \ Natural gas	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0
160	27.7	31.8	35.8	39.9	44.0	48.1	52.1	56.2	60.3	64.4	68.4	72.5
140	26.5	30.5	34.6	38.7	42.7	46.8	50.9	55.0	59.0	63.1	67.2	71.3
120	25.2	29.3	33.4	37.4	41.5	45.6	49.7	53.7	57.8	61.9	65.9	70.0
100	24.0	28.0	32.1	36.2	40.3	44.3	48.4	52.5	56.6	60.6	64.7	68.8
80	22.7	26.8	30.9	34.9	39.0	43.1	47.2	51.2	55.3	59.4	63.5	67.5
60	21.5	25.6	29.6	33.7	37.8	41.9	45.9	50.0	54.1	58.2	62.2	66.3
40	20.2	24.3	28.4	32.5	36.5	40.6	44.7	48.8	52.8	56.9	61.0	65.1
20	19.0	23.1	27.2	31.2	35.3	39.4	43.4	47.5	51.6	55.7	59.7	63.8
0	17.8	21.8	25.9	30.0	34.1	38.1	42.2	46.3	50.4	54.4	58.5	62.6

GHG emission intensity of blue hydrogen

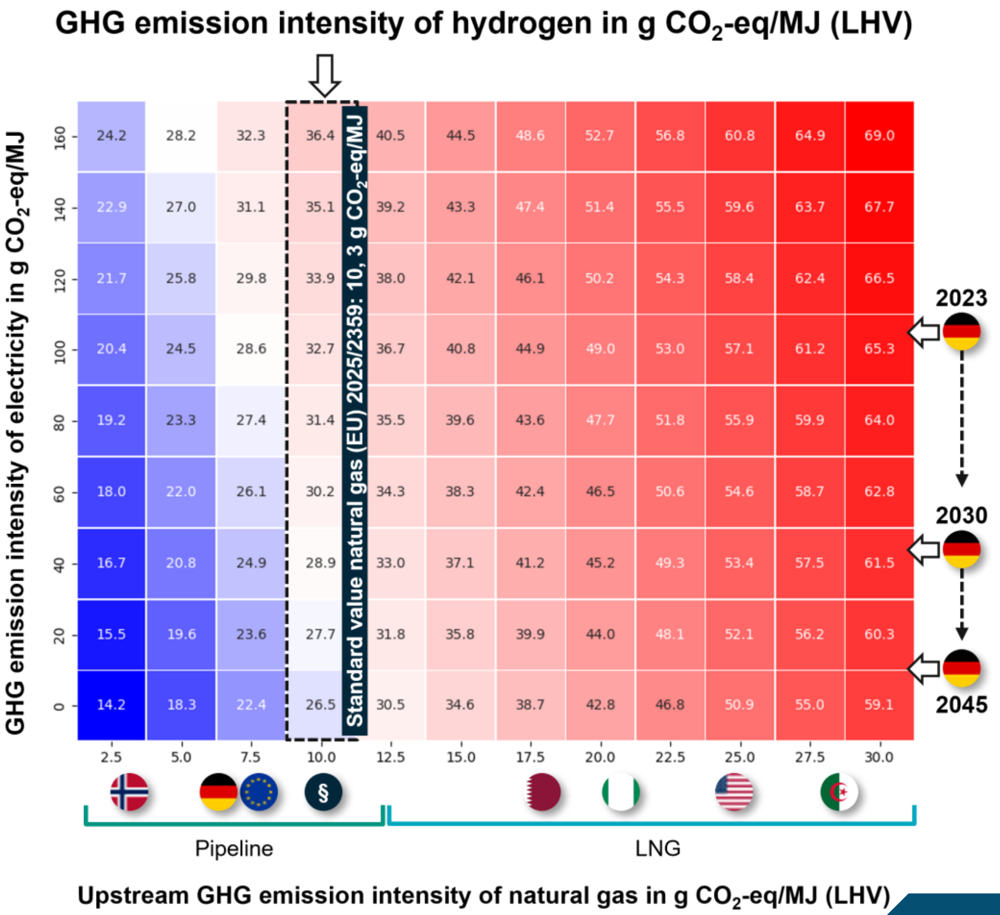
in relation to upstream emissions from natural gas and electricity supply (II)

- **EU threshold (low carbon H_2):**
  28.2 g CO_2-eq/MJ H_2 (LHV)

- Carbon Capture rate: **95 %***

- GHG downstream emissions of CO_2-process chain: 6 g CO_2-eq/MJ H_2 (LHV)
  (Assumptions based on industry partners and literature)

***Simplified Assumption: The energy demand for CO_2 capture does not increase when the capture rate is raised.



Electricity (g CO_2-eq/MJ) \ Natural gas upstream (g CO_2-eq/MJ)	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0
160	24.2	28.2	32.3	36.4	40.5	44.5	48.6	52.7	56.8	60.8	64.9	69.0
140	22.9	27.0	31.1	35.1	39.2	43.3	47.4	51.4	55.5	59.6	63.7	67.7
120	21.7	25.8	29.8	33.9	38.0	42.1	46.1	50.2	54.3	58.4	62.4	66.5
100	20.4	24.5	28.6	32.7	36.7	40.8	44.9	49.0	53.0	57.1	61.2	65.3
80	19.2	23.3	27.4	31.4	35.5	39.6	43.6	47.7	51.8	55.9	59.9	64.0
60	18.0	22.0	26.1	30.2	34.3	38.3	42.4	46.5	50.6	54.6	58.7	62.8
40	16.7	20.8	24.9	28.9	33.0	37.1	41.2	45.2	49.3	53.4	57.5	61.5
20	15.5	19.6	23.6	27.7	31.8	35.8	39.9	44.0	48.1	52.1	56.2	60.3
0	14.2	18.3	22.4	26.5	30.5	34.6	38.7	42.8	46.8	50.9	55.0	59.1

System boundary for turquoise H_2 based on Delegated Regulation (EU) 2025/2359

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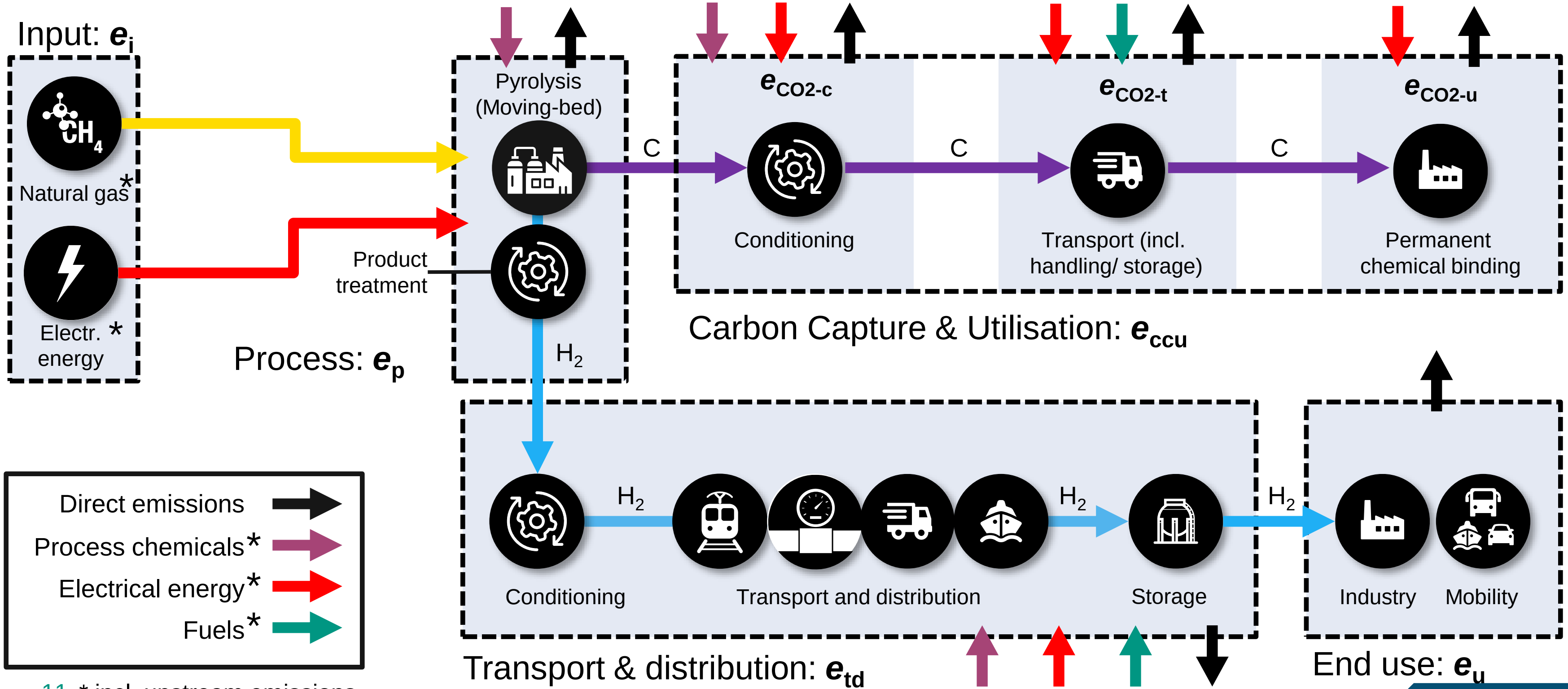
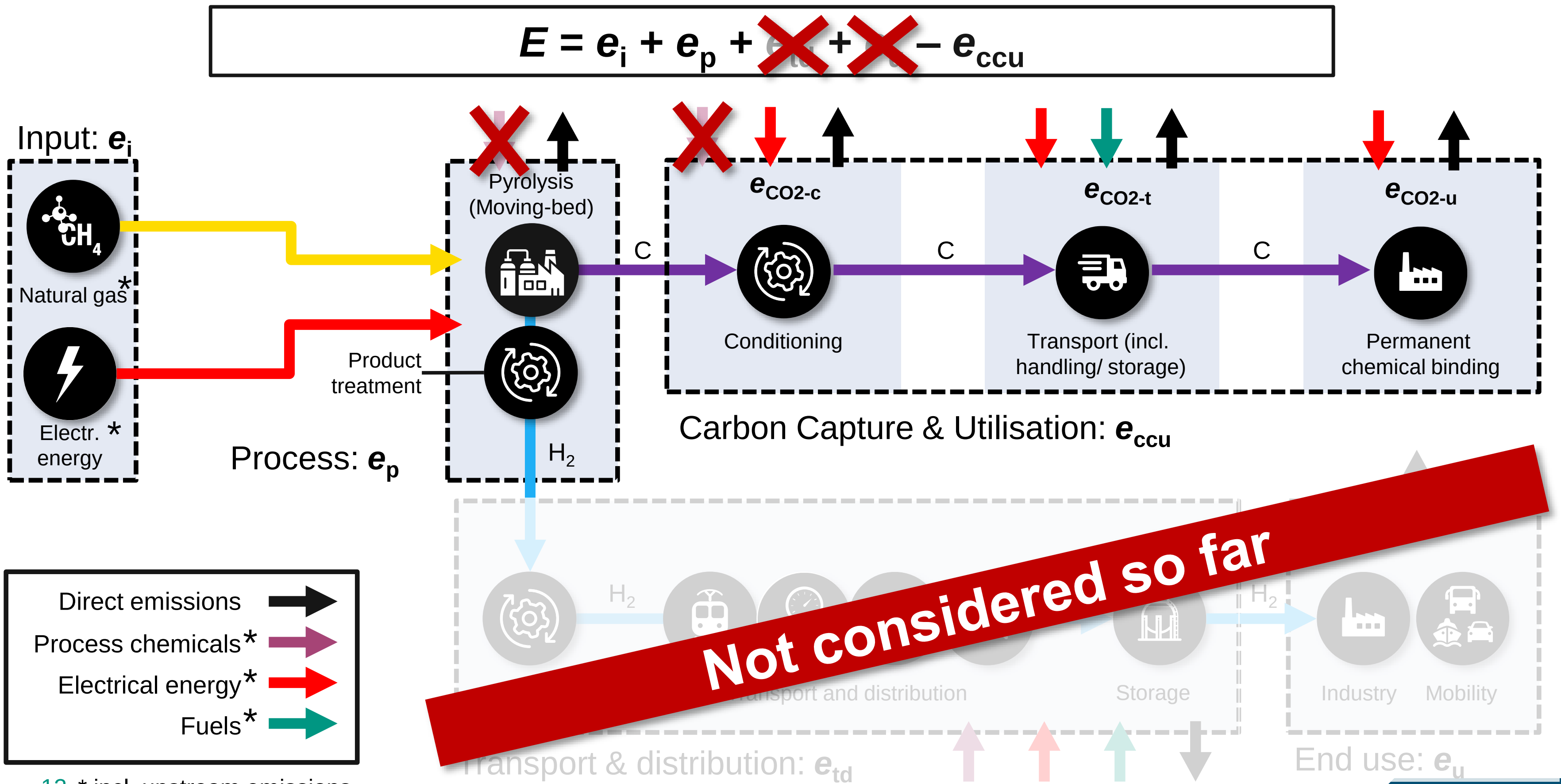
$$E = e_i + e_p + e_{td} + e_u - e_{ccu}$$



* incl. upstream emissions

System boundary and simplifications for the current GHG analysis of turquoise H_2



 * incl. upstream emissions

GHG emission intensity of turquoise hydrogen

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

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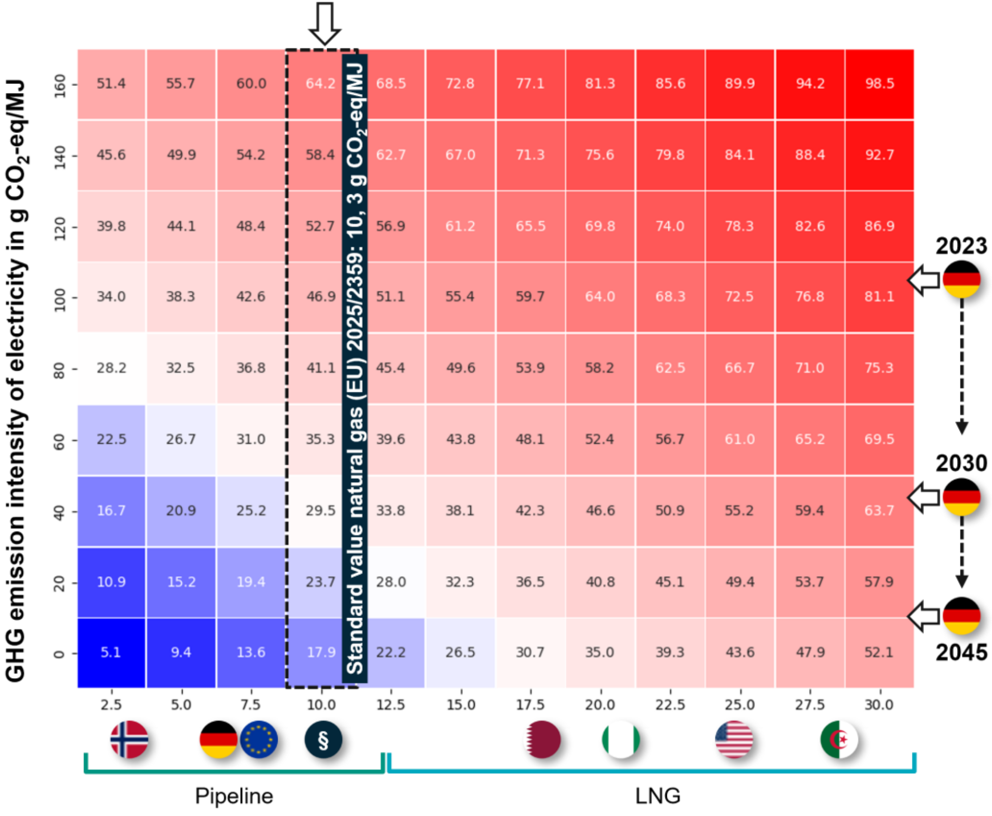
- **EU threshold (low carbon H_2):**
  28.2 g CO_2-eq / MJ H_2 (LHV)
- Assumption **allocation factor***
  H_2/C = 100% / 0%
  without Allocation
- GHG emissions for **carbon-downstream chain** are not taken into account!
- GHG emissions for **H_2 downstream chain** are not taken into account!

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

GHG emission intensity of hydrogen in g CO_2-eq/MJ (LHV)



Upstream GHG emission intensity of natural gas in g CO_2-eq/MJ (LHV)

GHG emission intensity of turquoise hydrogen

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

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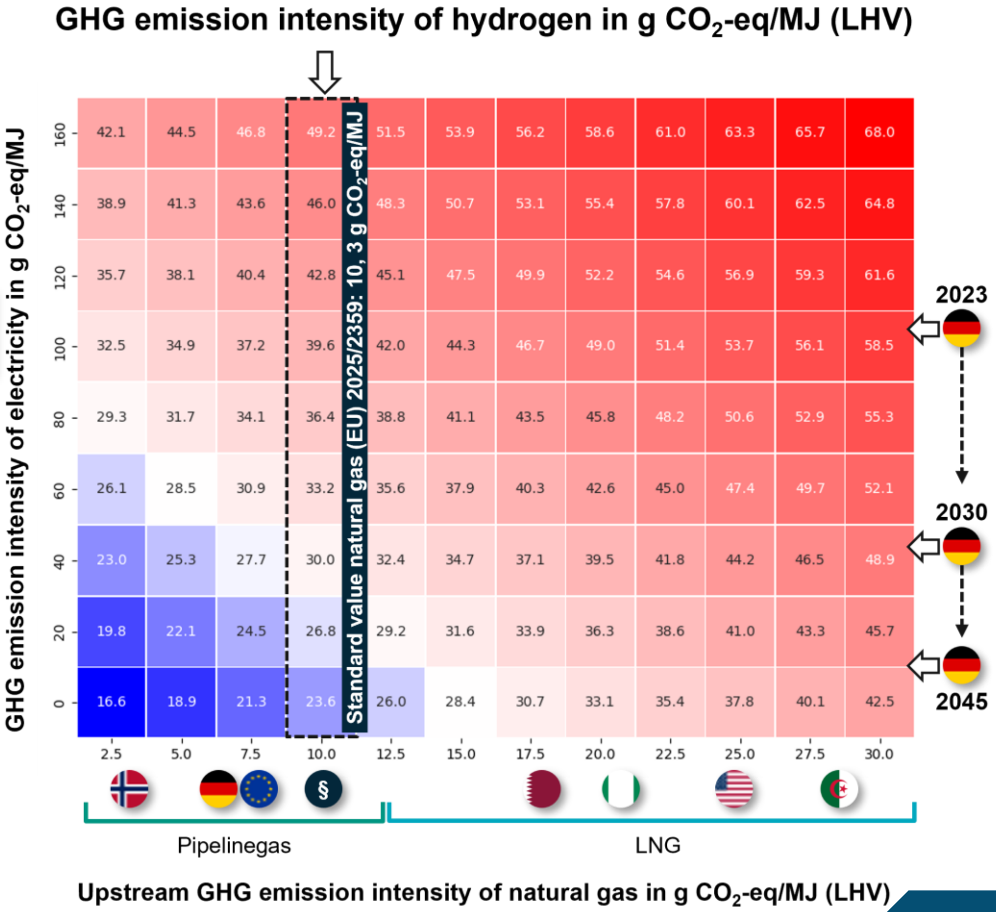
- **EU threshold (low carbon H_2):**
  28.2 g CO_2-eq / MJ H_2 (LHV)

- Assumption **allocation factor***
  H_2/C = 55 % / 45 %

Allocation based on energy content

- GHG emissions for **carbon-downstream chain** are not taken into account!

- GHG emissions for **H_2 downstream chain** are not taken into account!



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

Conclusion

- The **upstream emissions of natural gas** have the greatest impact on the carbon footprint of blue H_2. For turquoise H_2, 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 CO_2-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 CO_2-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 H_2. For turquoise H_2, the electricity employed must contain a high share of renewable energy to meet the minimum GHG-saving requirement (GHG intensity of electricity < 40 g CO_2-eq/MJ).
- **Previously omitted steps in the process chain** (H_2 transport, H_2 distribution, H_2 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 H_2 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 of natural gas/LNG in the literature

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Upstream emissions	GHG emissions in g 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. Münter 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.