Universität Stuttgart
IER Institut für Energiewirtschaft
und Rationelle Energieanwendung



Future environmental impacts of hydrogen distribution modelled in a prospective LCA framework

DemoDerby Brightcon 2026

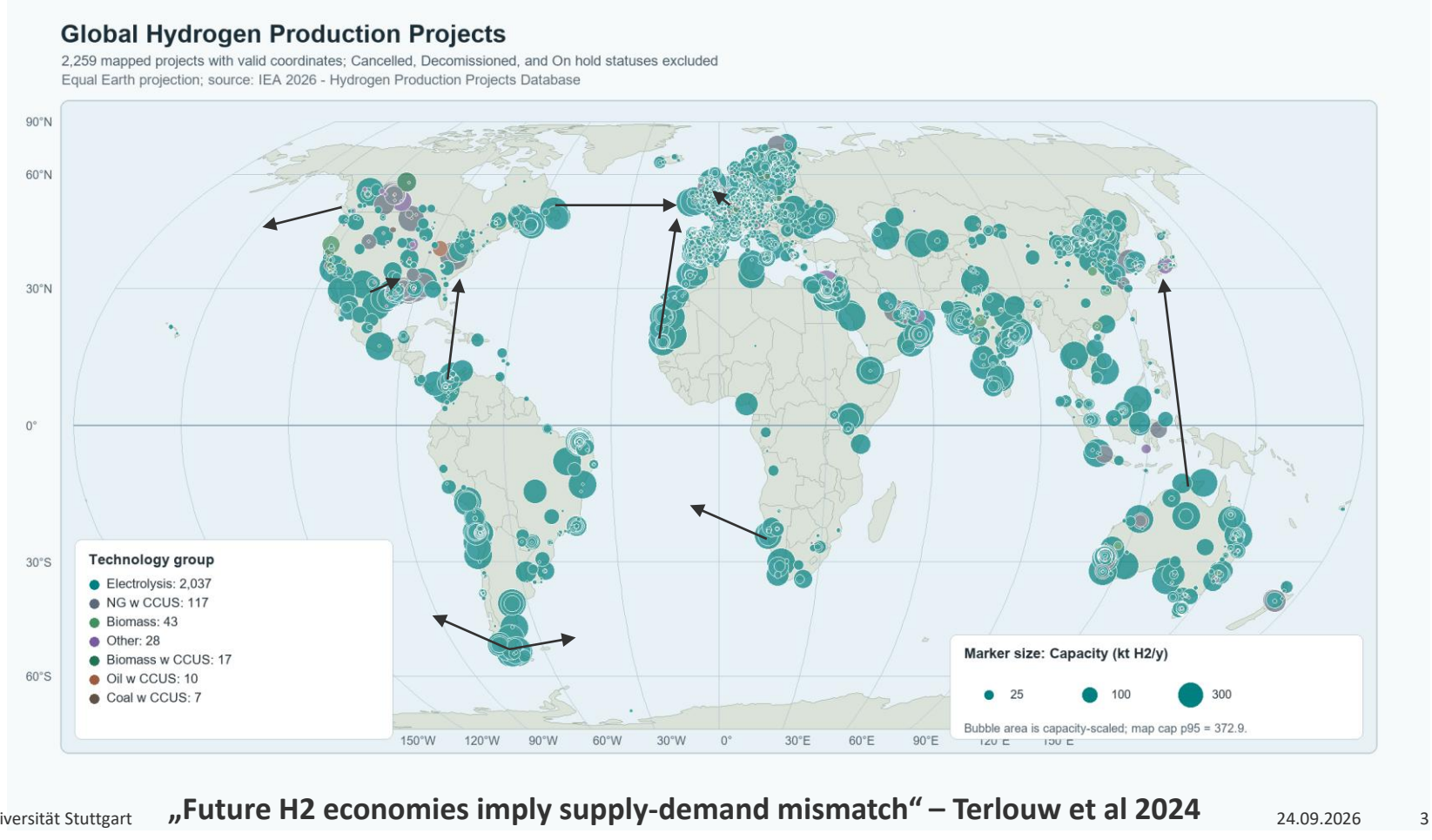
Tobias Schließ
Karin Treyer
Romain Sacchi

Agenda

1. Motivation and Context
2. Walkthrough (notebook)
3. Results
4. Discussions

1. Motivation for the study

Future hydrogen production locations worldwide



„Future H2 economies imply supply-demand mismatch“ – Terlouw et al 2024

1. Motivation

Goal & Research Question

Goal:

enhance the representation of hydrogen distribution in a prospective LCA framework (premise) to investigate future environmental impacts

Research Question:

- How does more explicit modelling of hydrogen distribution technologies change the future environmental impacts across regional hydrogen markets?

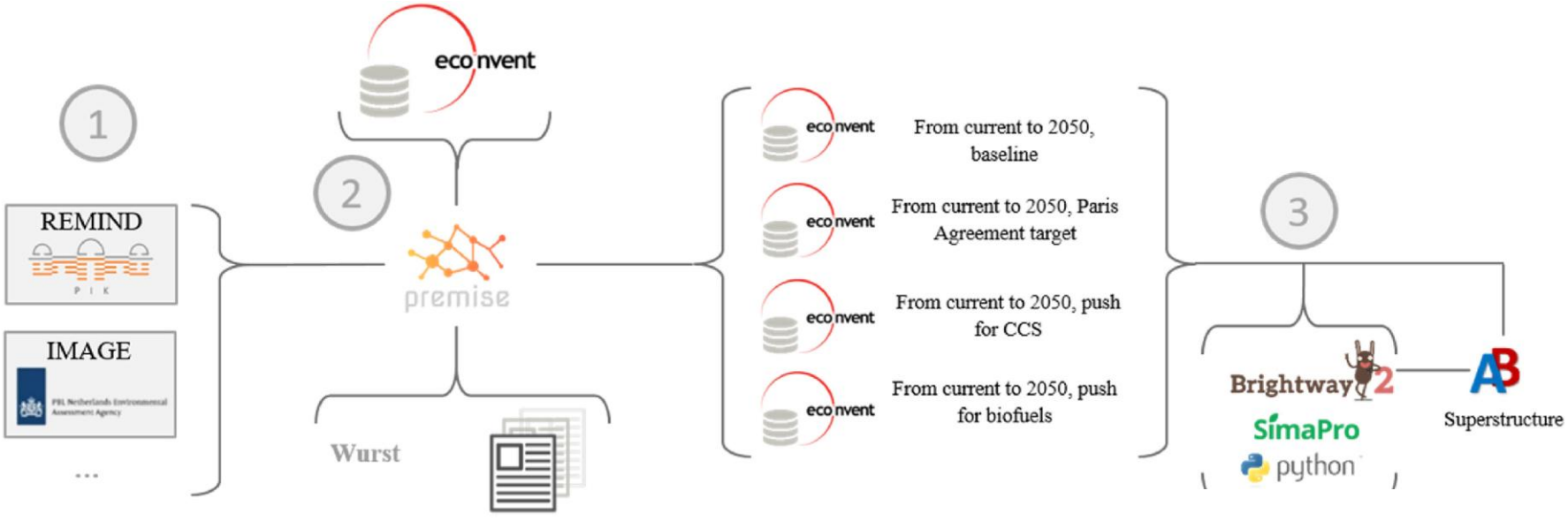
2. Methodology

Hydrogen distribution mode depends on:

- Transport distance
- Size of the offtaker
- Costs for delivery

premise – prospective environmental impact assessment

Python tool for prospective database creation



„10 Mt of H2 production by 70 % PEM and 30 % SMR in Europe in 2030“

„market for Hydrogen, gaseous, low pressure, Europe“

adapted from Sacchi et al 2022

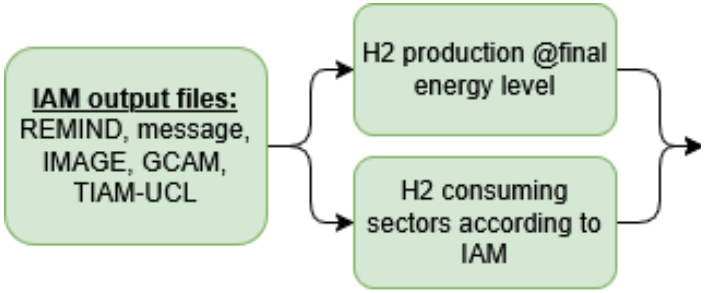
2. Methodology

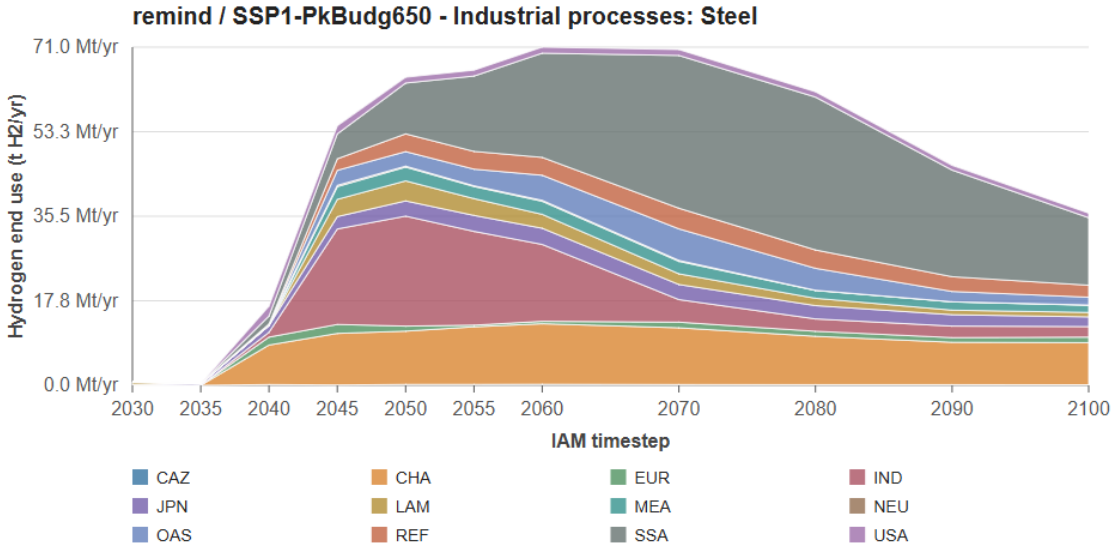
Approach to modelling H2 distribution in premise

IAM = low spatial resolution → hydrogen distribution is not explicitly modelled

→Develop methodology to determine distribution modes and their shares

→Sectors: Steel, Cement, Chemicals, Transport, „Other industries“ (e.g. Paper, Glass, …)

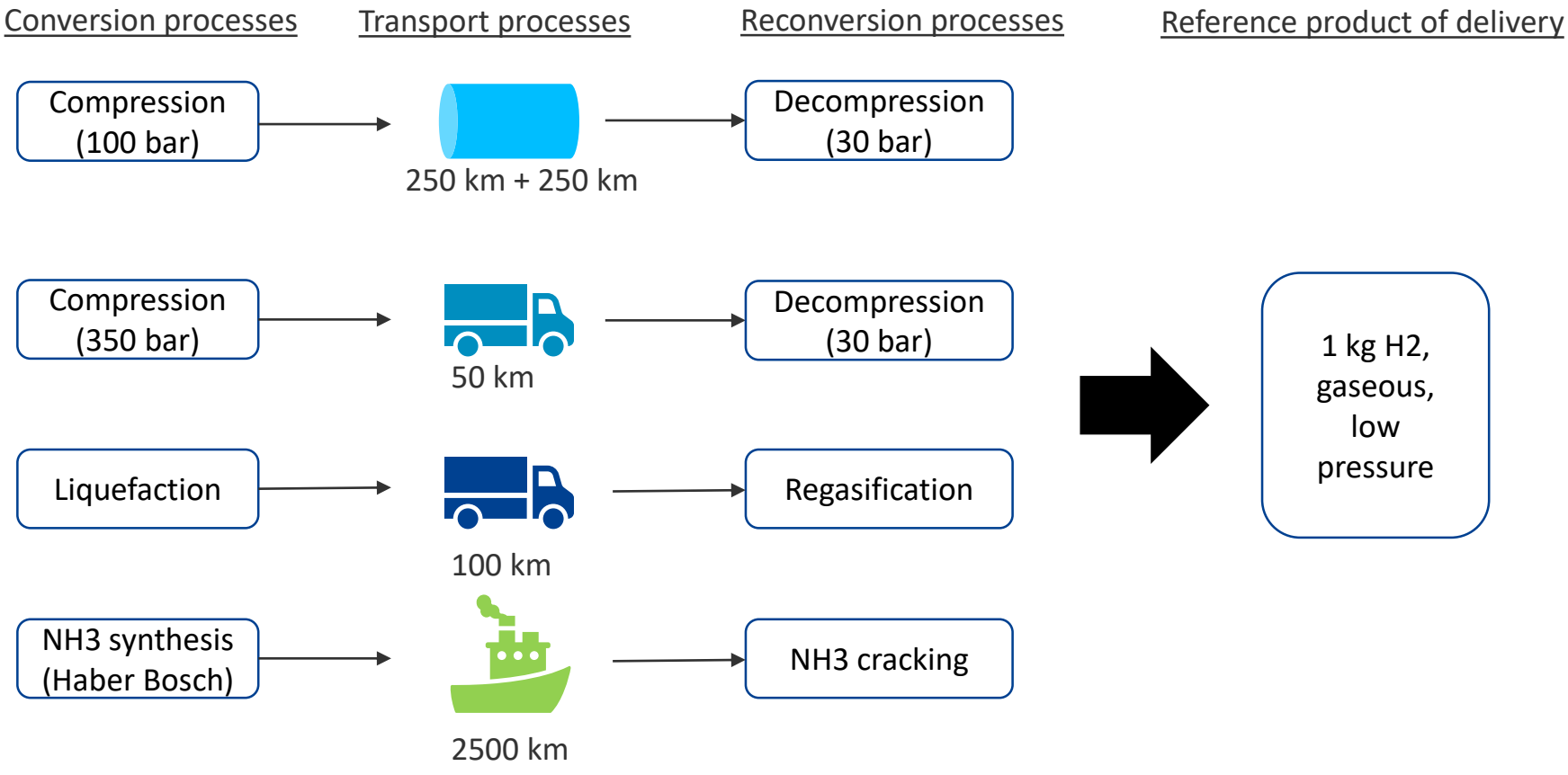




Parolin et al 2022, Reuß et al 2019, Ortiz-Cebolla et al 2022, Hampp et al 2023, Sterner et al 2025

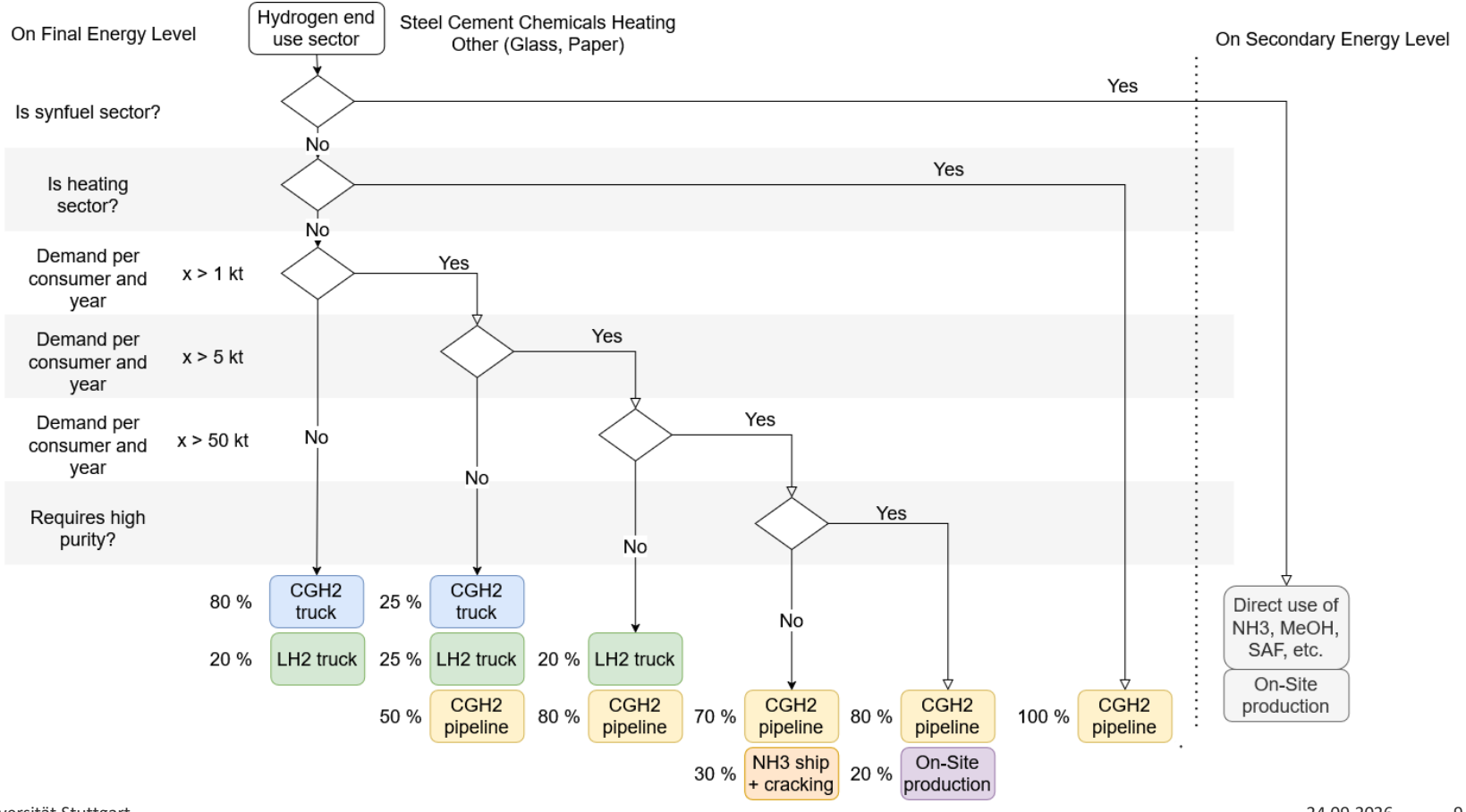
2. Methodology

Distribution options overview



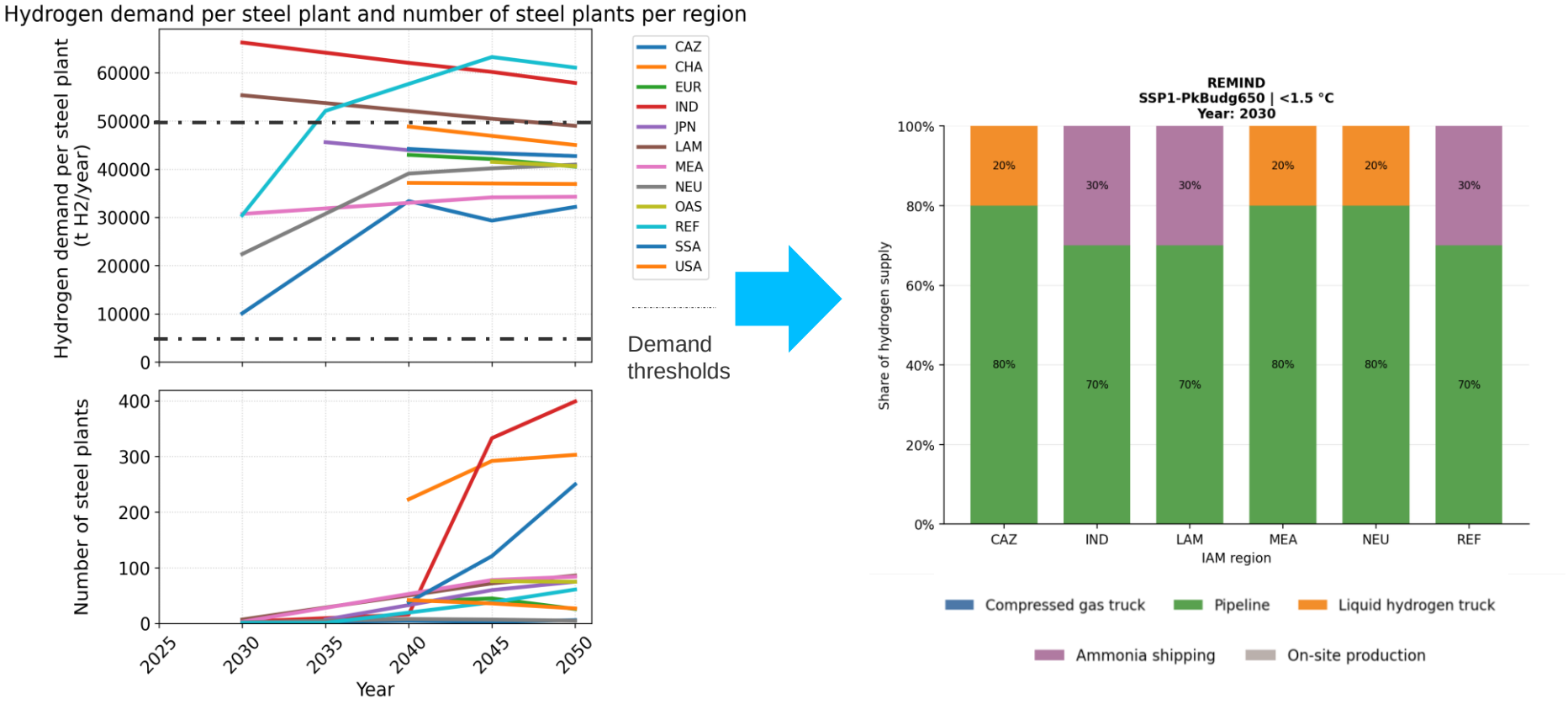
2. Methodology

Hydrogen distribution decision tree



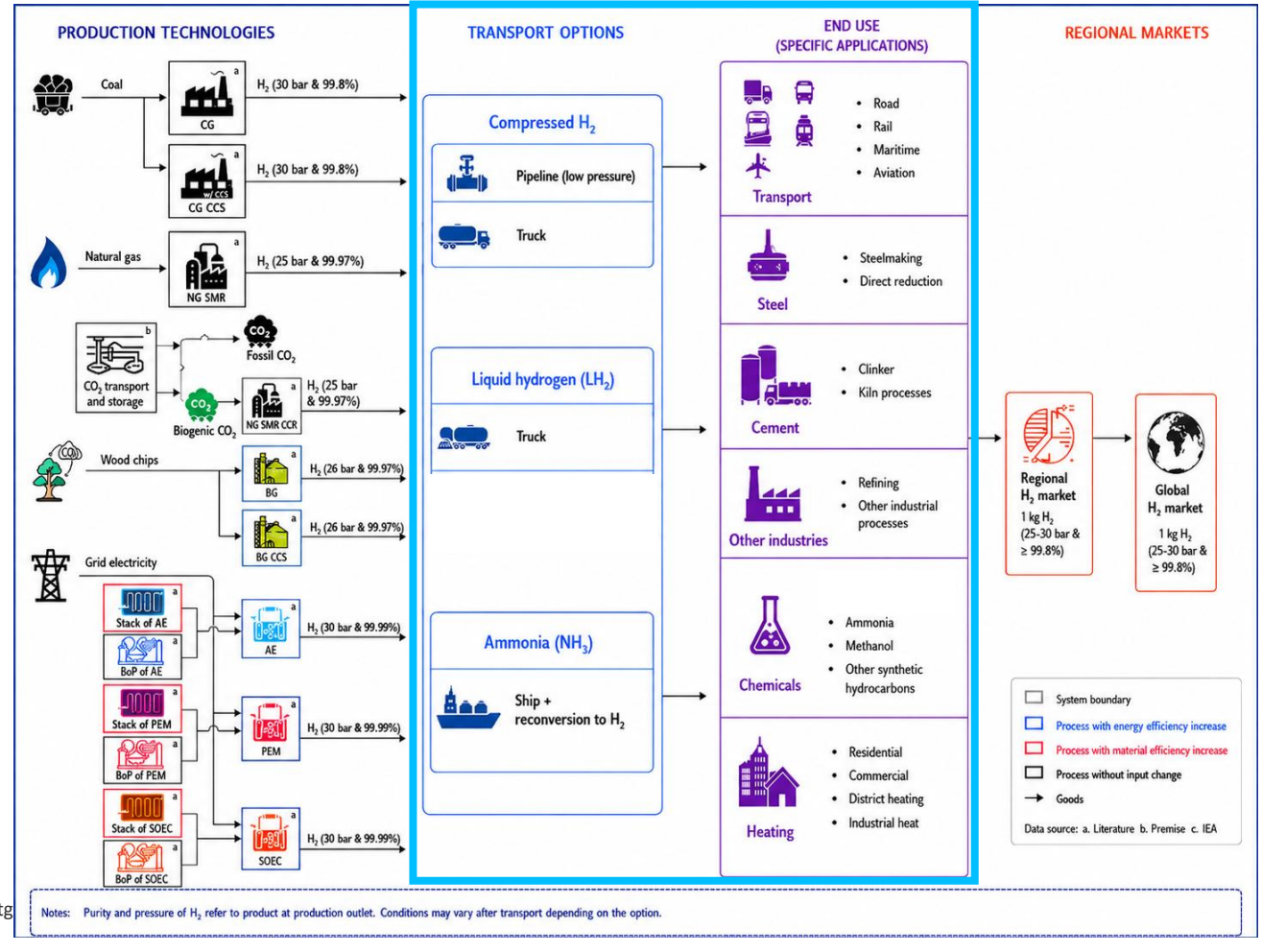
2. Methodology

H2 demand nodes at the example of the steel and transport sector (REMIND <1.5 °C)



3. Results

New representation of the hydrogen sector



Adapted from Wei et al 2024

2. Methodology

Scope of the pLCA study

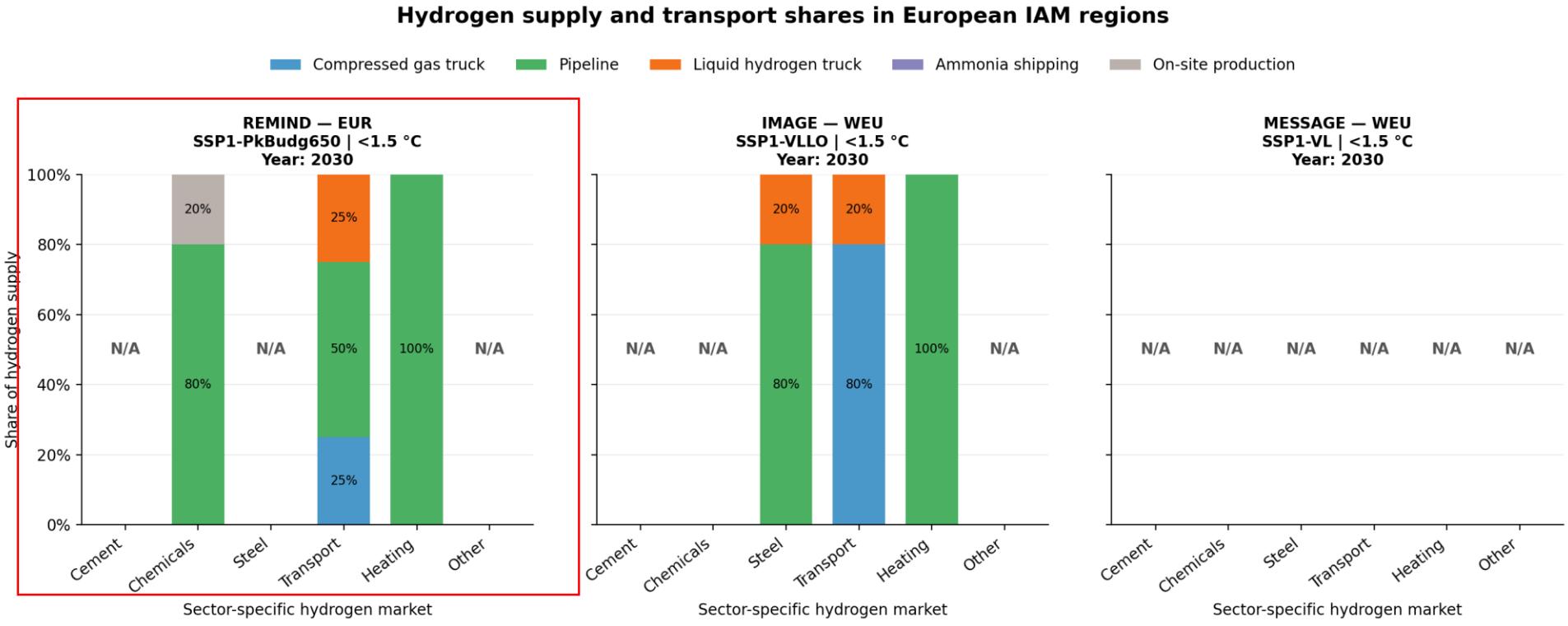
- Scope: Cradle-to-delivery Gate LCA following ISO 14040/44
- Functional unit: 1 kg of hydrogen, gaseous, low pressure, for „specific sector“

- Time horizon: 2030, 2050
- Scenarios:

<1.5 °C	REMIND SSP1-PkBudg650
	IMAGE SSP1-VLLO
	MESSAGE SSP1-VL

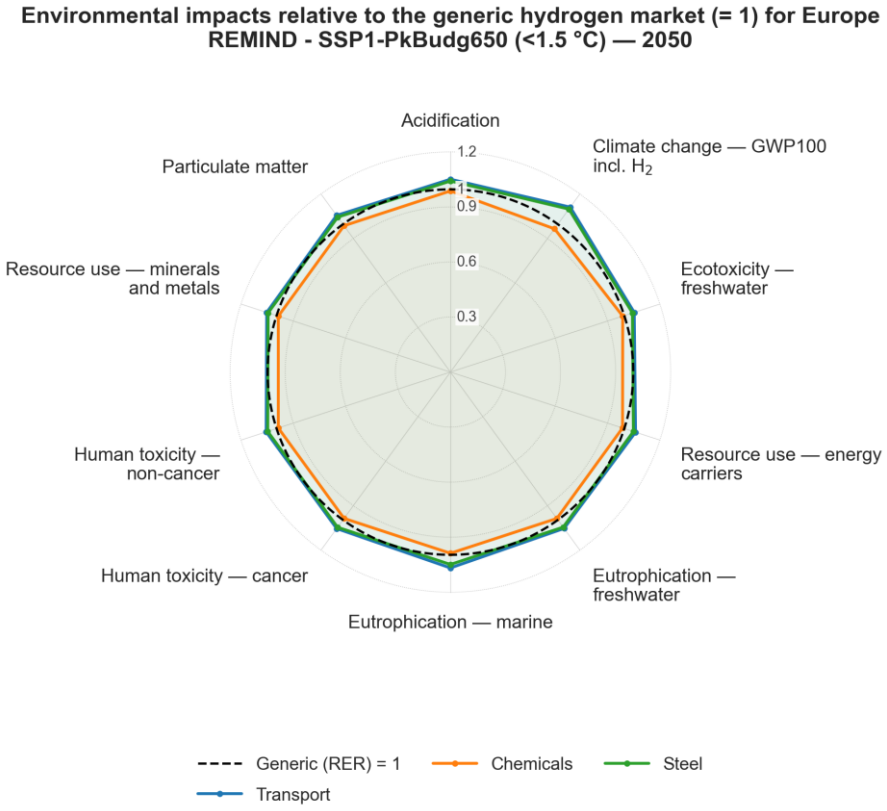
3. Results

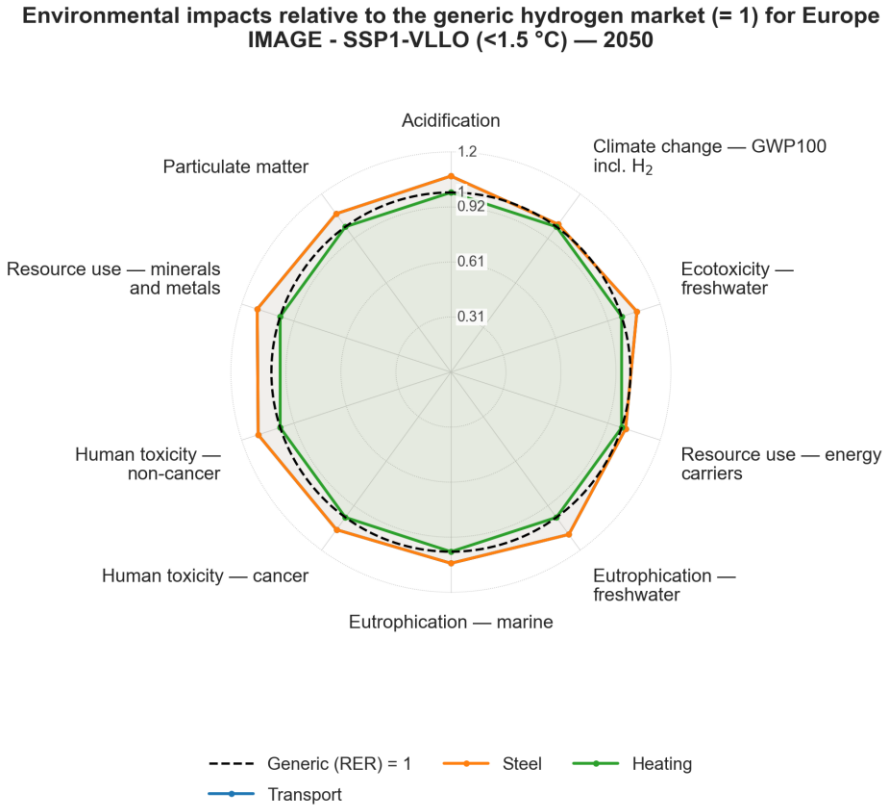
Transport shares per IAM and hydrogen market for 2030 in Europe



3. Results

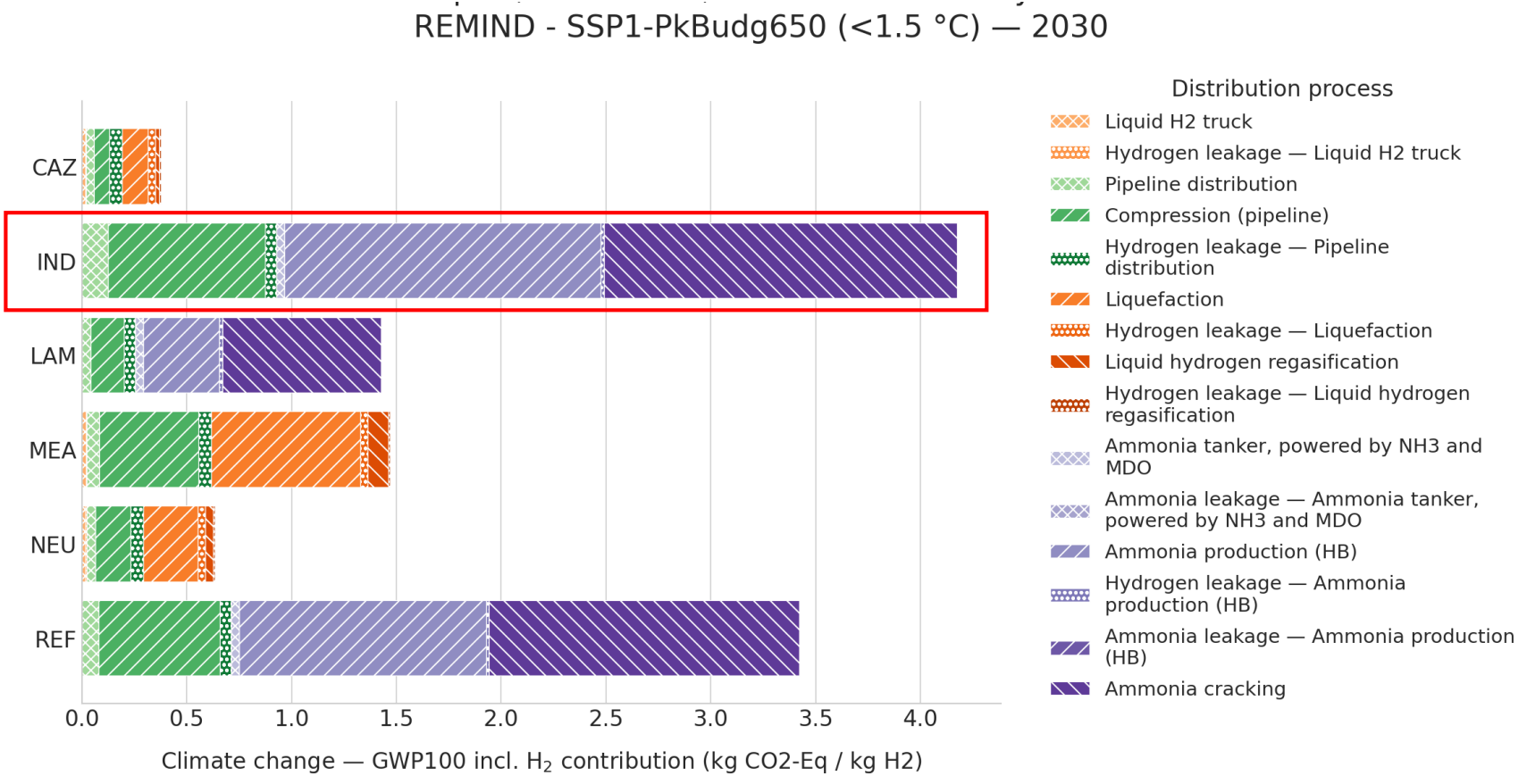
Difference in env impacts compared to status quo (Europe)





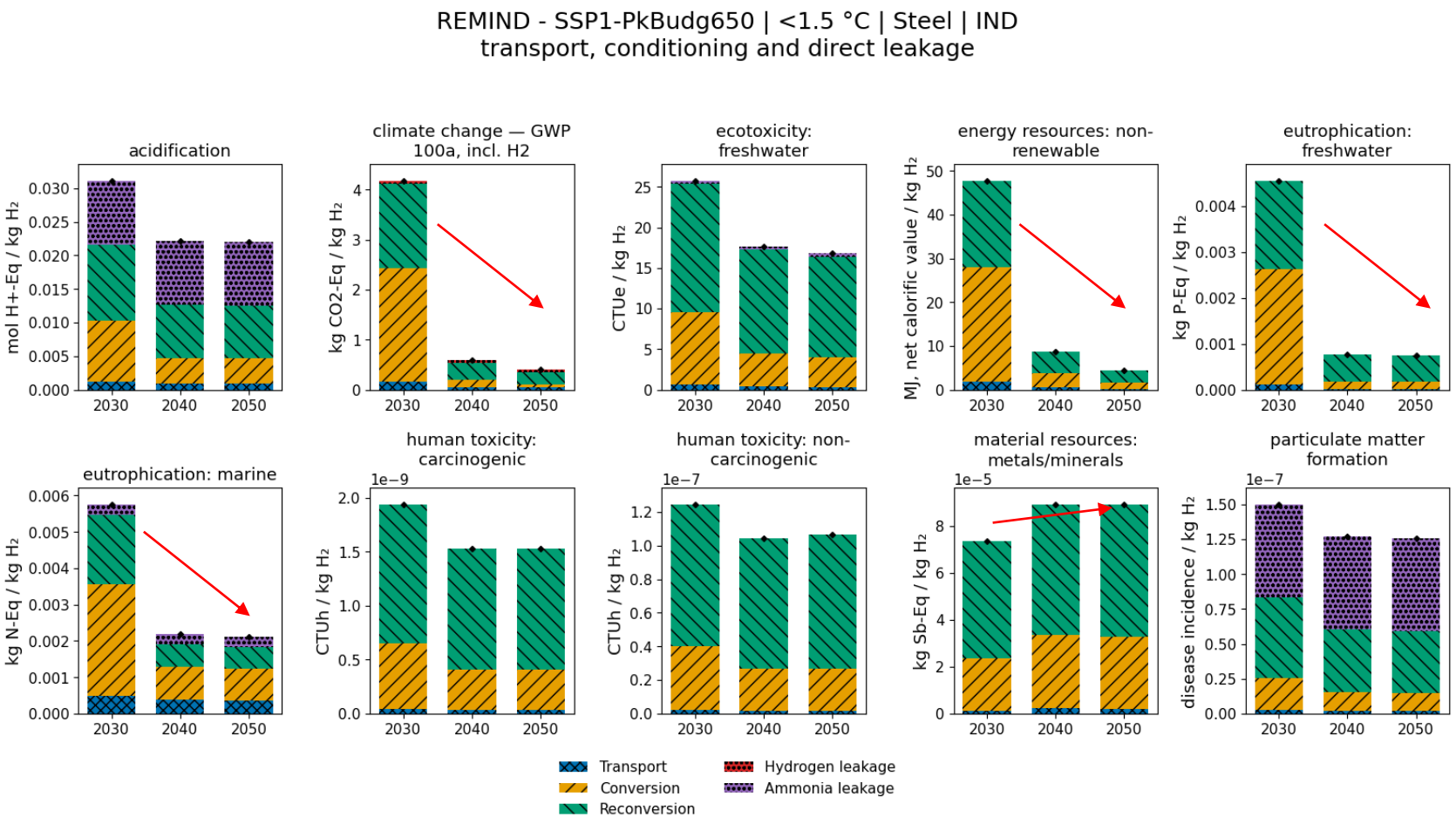
3. Results

Comparison of regions across hydrogen markets for the steel sector - 2030



3. Results

Trade-offs across hydrogen markets for the steel sector – 2030 to 2050



4. Discussion

Insights and limitations

- Hydrogen only shows up in deep defossilization scenarios
- Implementing hydrogen distribution options enhances the full picture of the hydrogen sector
- Conversion and reconversion of hydrogen for distribution should be kept as low as possible → Liquefaction, heat supply for NH3 cracking → analyse full process chain
- Higher losses of NH3 route leads to increased env. impacts: Cracking recovery rate

Limitations:

- IAM‘s initially don‘t have H2 distribution or cross border trade → secondary energy level changes
- Exact shares are hard to foresee → spatial modelling of H2 infrastructure needed
- Distribution options: rail, barge for GH2 and LH2 + other carriers: LOHC

Discussion

In your opinion ….

- Which feature would you implement in premise?
- Which sector needs higher detail of representation?

Universität Stuttgart
IER Institute of Energy Economics
and Rational Energy Use

Thank you!



Tobias Schließ

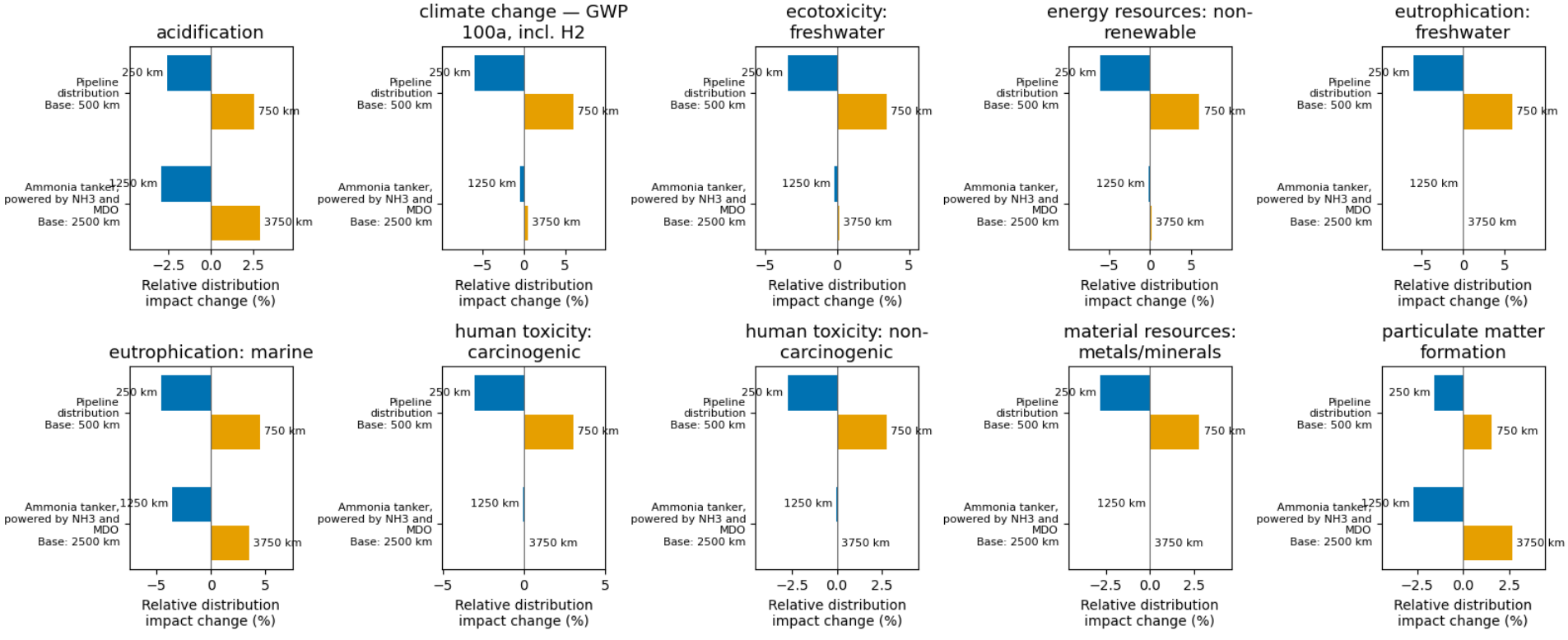
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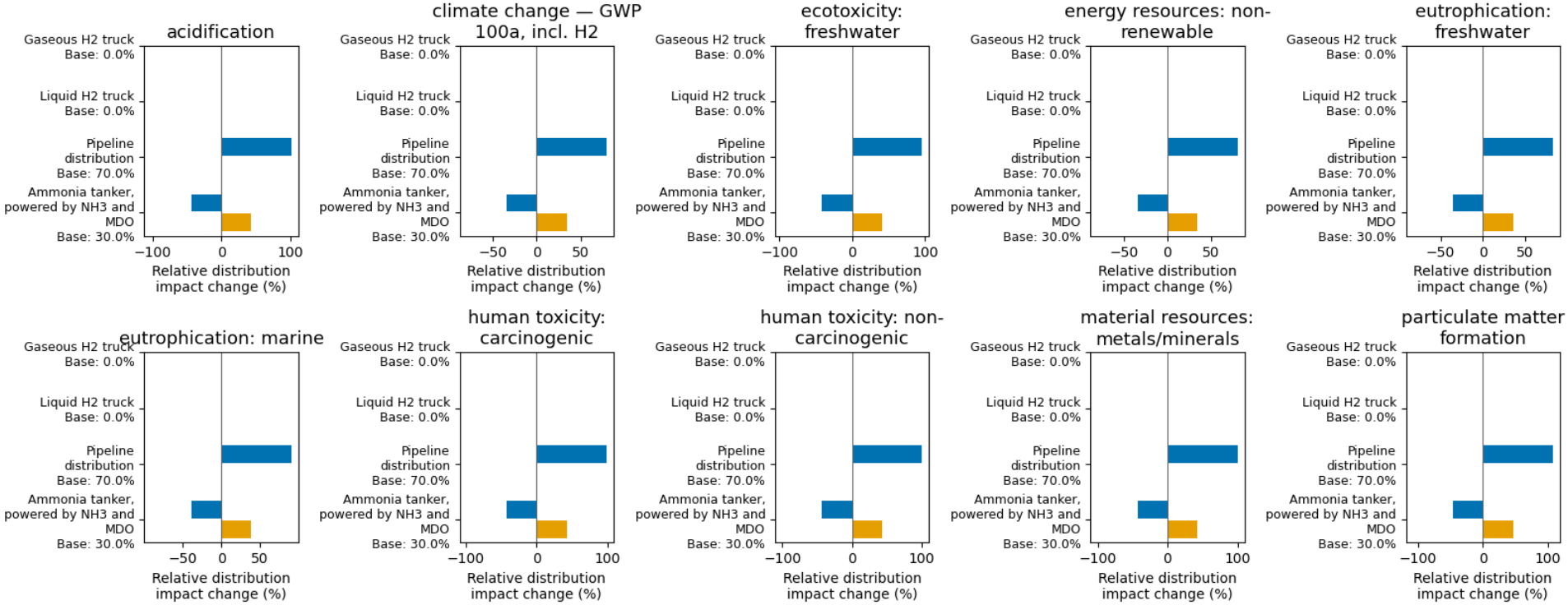
References

- Terlouw, T., Rosa, L., Bauer, C. *et al.* Future hydrogen economies imply environmental trade-offs and a supply-demand mismatch. *Nat Commun* **15**, 7043 (2024). https://doi.org/10.1038/s41467-024-51251-7
- R. Sacchi, T. Terlouw, K. Siala, A. Dirnaichner, C. Bauer, B. Cox, C. Mutel, V. Daioglou, G. Luderer, PRospective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models,Renewable and Sustainable Energy Reviews, Volume 160, 2022, 112311, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2022.112311.
- Federico Parolin, Paolo Colbertaldo, Stefano Campanari, Optimal design of hydrogen delivery infrastructure for multi-sector end uses at regional scale, International Journal of Hydrogen Energy, Volume 79, 2024, Pages 839-849, ISSN 0360-3199, https://doi.org/10.1016/j.ijhydene.2024.06.049.
- Reuß, Markus & Grube, Thomas & Robinius, Martin & Stolten, Detlef, 2019. "A hydrogen supply chain with spatial resolution: Comparative analysis of infrastructure technologies in Germany," Applied Energy, Elsevier, vol. 247(C), pages 438-453.
- Ortiz Cebolla, R., Dolci, F. and Weidner Ronnefeld, E., Assessment of hydrogen delivery options, EUR 31199 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-56421-8 (online), doi:10.2760/869085 (online), JRC130442.
- Hampp J, Düren M, Brown T (2025) Import options for chemical energy carriers from renewable sources to Germany. PLOS ONE 20(1): e0314578. https://doi.org/10.1371/journal.pone.0314578
- de Kleijne, K., Huijbregts, M.A.J., Knobloch, F. *et al.* Worldwide greenhouse gas emissions of green hydrogen production and transport. *Nat Energy* **9**, 1139–1152 (2024). https://doi.org/10.1038/s41560-024-01563-1
- Michael Sterner, Andreas Hofrichter, Alexander Meisinger, Franz Bauer, Karsten Pinkwart, Annabelle Maletzko, Felix Dittmar, Carsten Cremers, 19 Import options for green hydrogen and derivatives - An overview of efficiencies and technology readiness levels, International Journal of Hydrogen Energy, Volume 90, 2024, Pages 1112-1127, ISSN 0360-3199, https://doi.org/10.1016/j.ijhydene.2024.10.045.
- Sebastian Kolb, Jakob Müller, Natalia Luna-Jaspe, Jürgen Karl, Renewable hydrogen imports for the German energy transition – A comparative life cycle assessment, Journal of Cleaner Production, Volume 373, 2022, 133289, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2022.133289.
- Lei, T., Wang, D., Yu, X. *et al.* Global iron and steel plant CO_2 emissions and carbon-neutrality pathways. *Nature* **622**, 514–520 (2023). https://doi.org/10.1038/s41586-023-06486-7
- Toni Busch, Jonas Derichs, Theresa Klütz, Jochen Linßen, Detlef Stolten, The hydrogen supply chain — A comprehensive literature review incorporating purity analysis, International Journal of Hydrogen Energy, Volume 164, 2025, 149367, ISSN 0360-3199, https://doi.org/10.1016/j.ijhydene.2025.04.532.
- Shijie Wei, Romain Sacchi, Arnold Tukker, Sangwon Suh, Bernhard Steubing; Future environmental impacts of global hydrogen production. *Energy Environ. Sci.* 2024; 17 (6): 2157–2172. https://doi.org/10.1039/d3ee03875k

REMIND - SSP1-PkBudg650 | <1.5 °C | Steel | 2030 | IND
Distance sensitivity: −50 % / +50 %

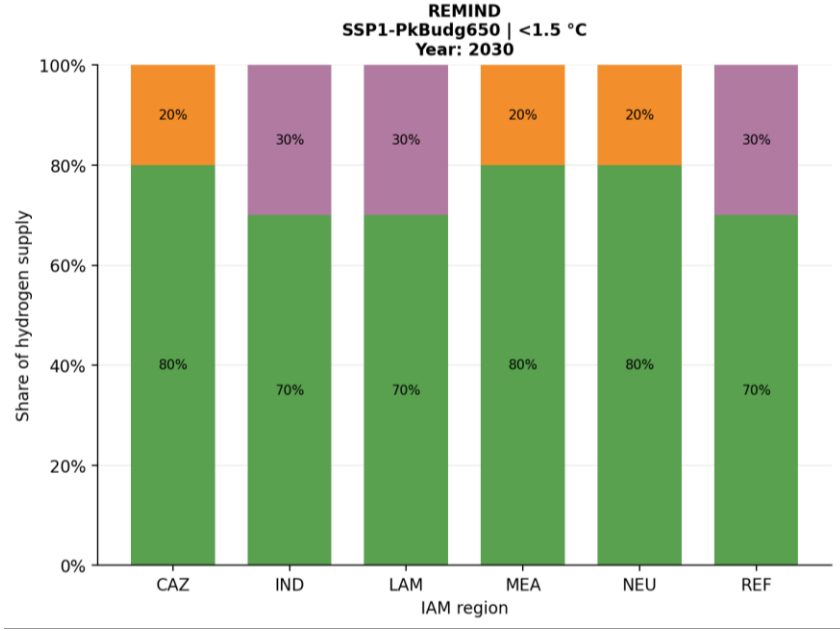


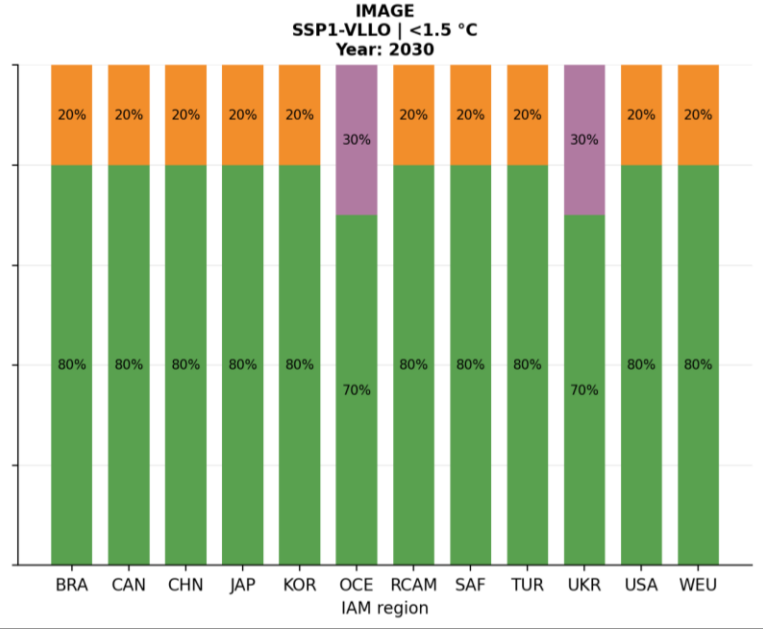
REMIND - SSP1-PkBudg650 | <1.5 °C | Steel | 2030 | IND
Variation in distribution shares: -50% / +50%



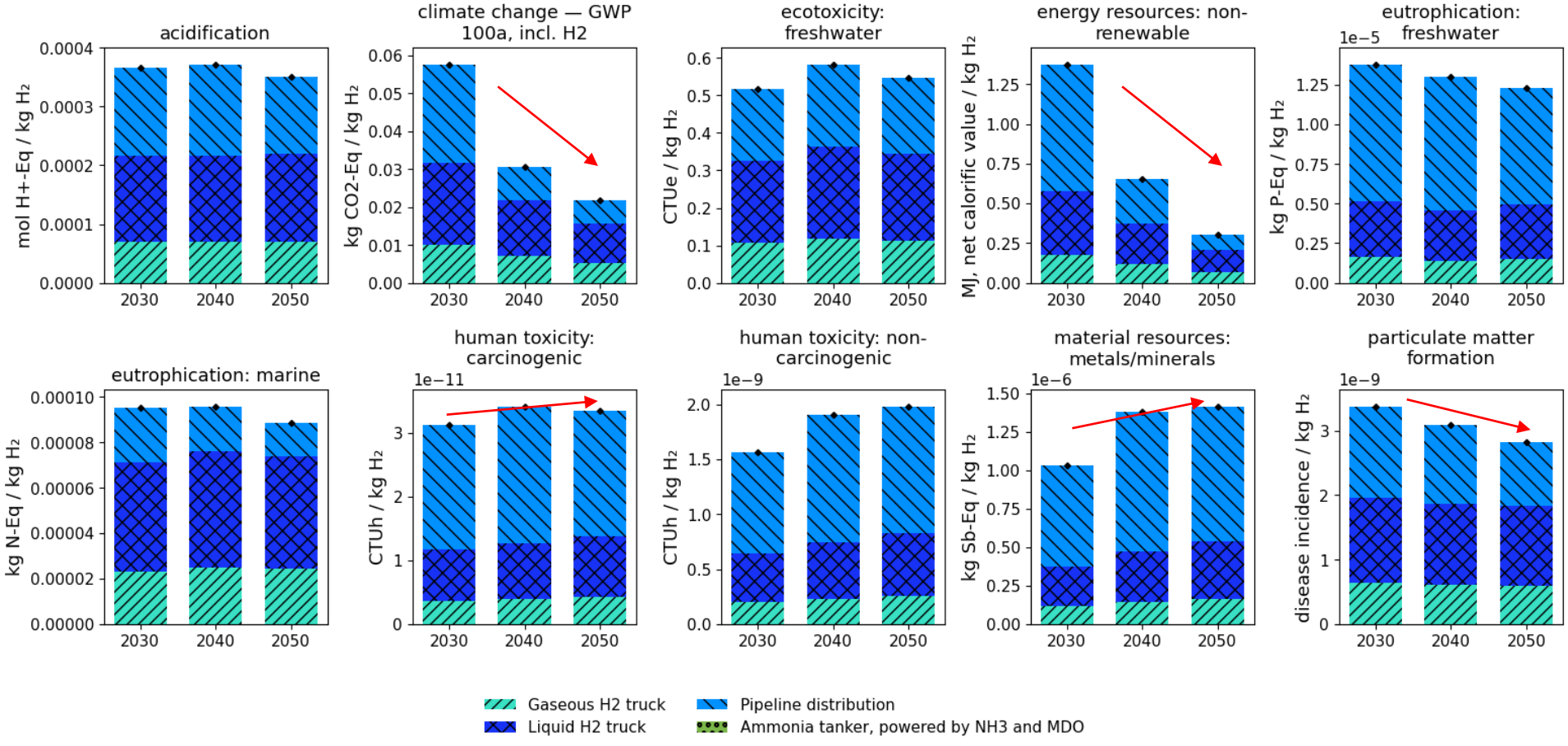
3. Results

Comparison of regions across hydrogen markets for the steel sector (2030)

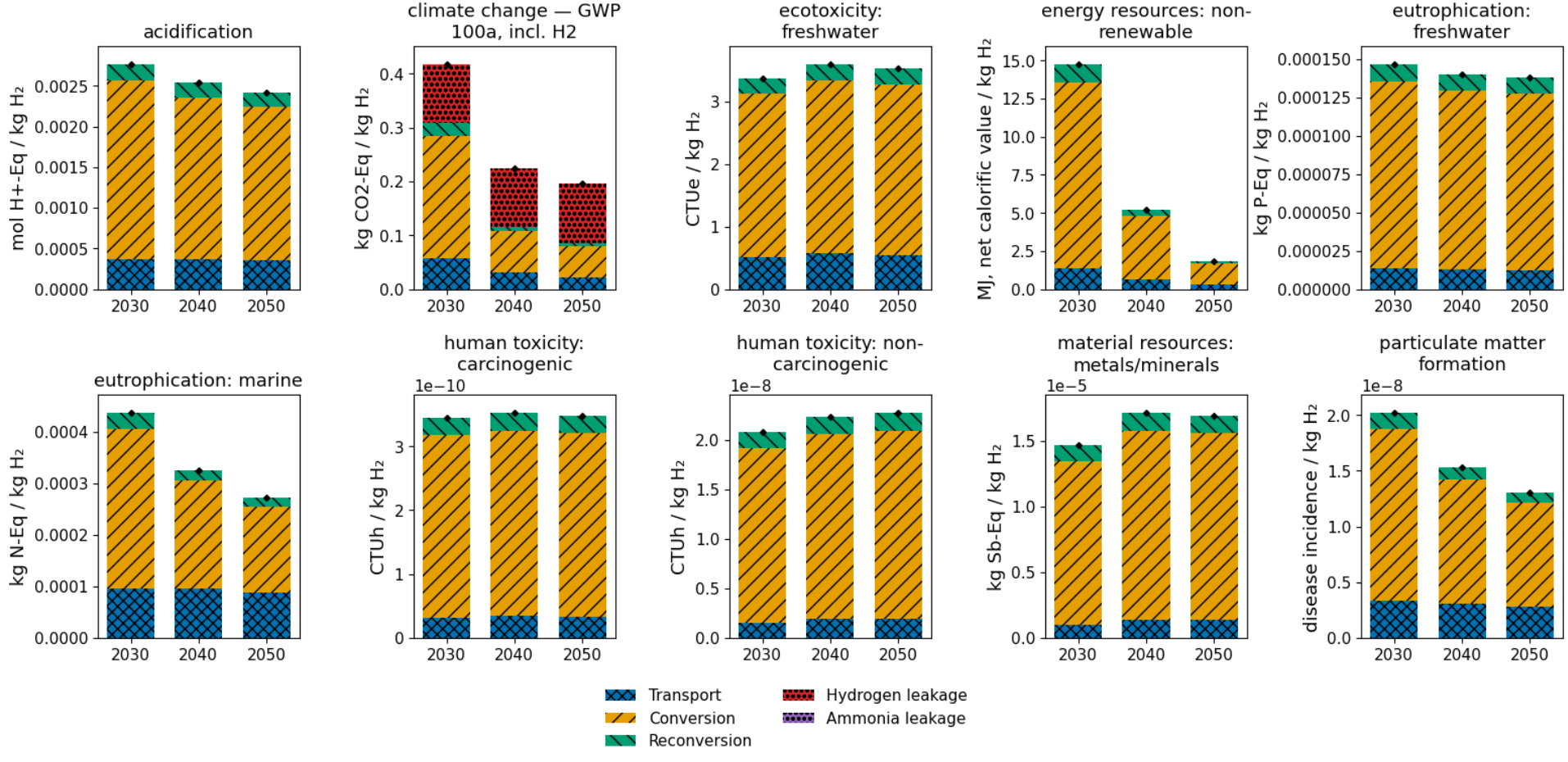




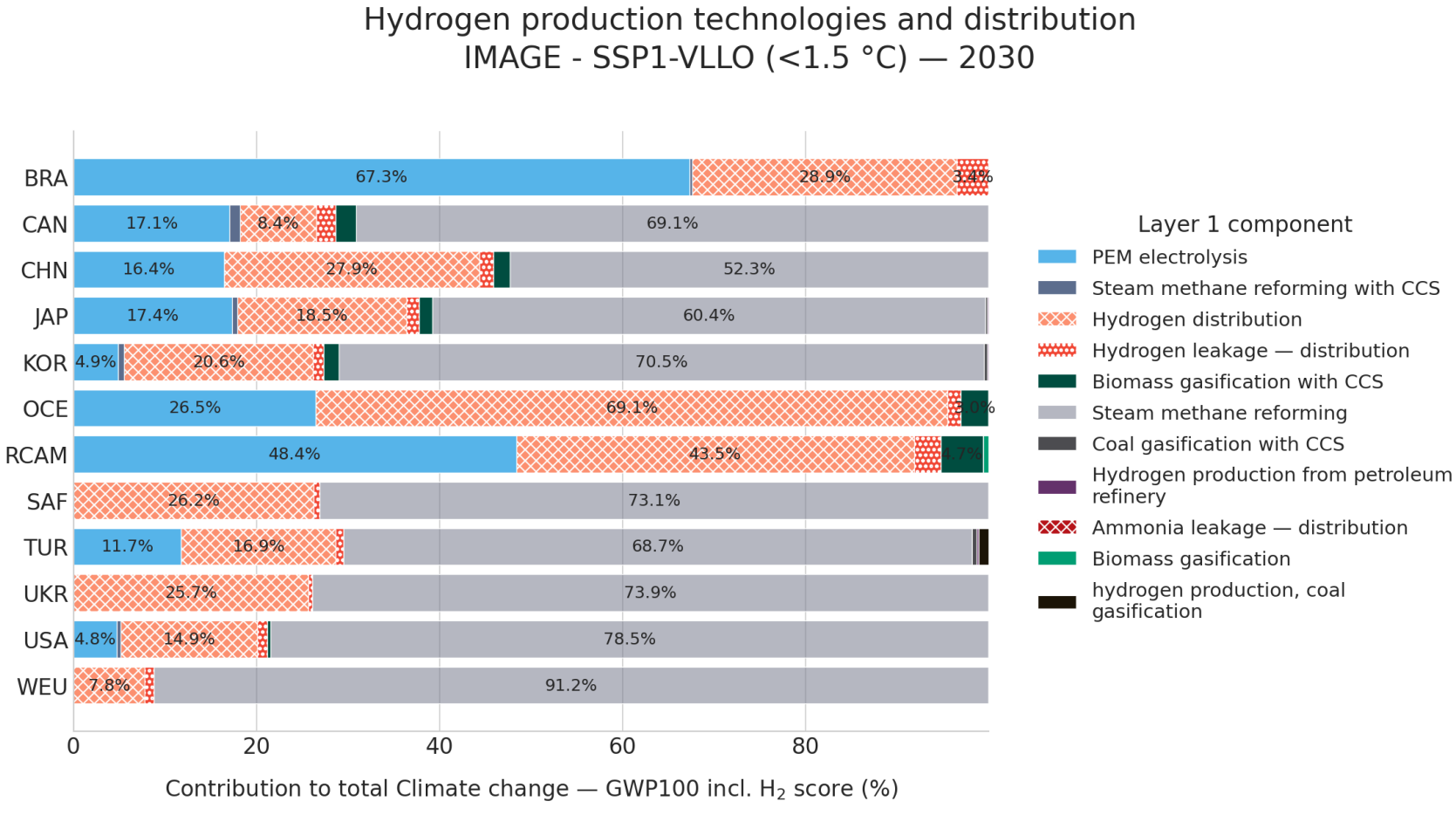
REMIND - SSP1-PkBudg650 | <1.5 °C | Transport | EUR
absolute transport impacts



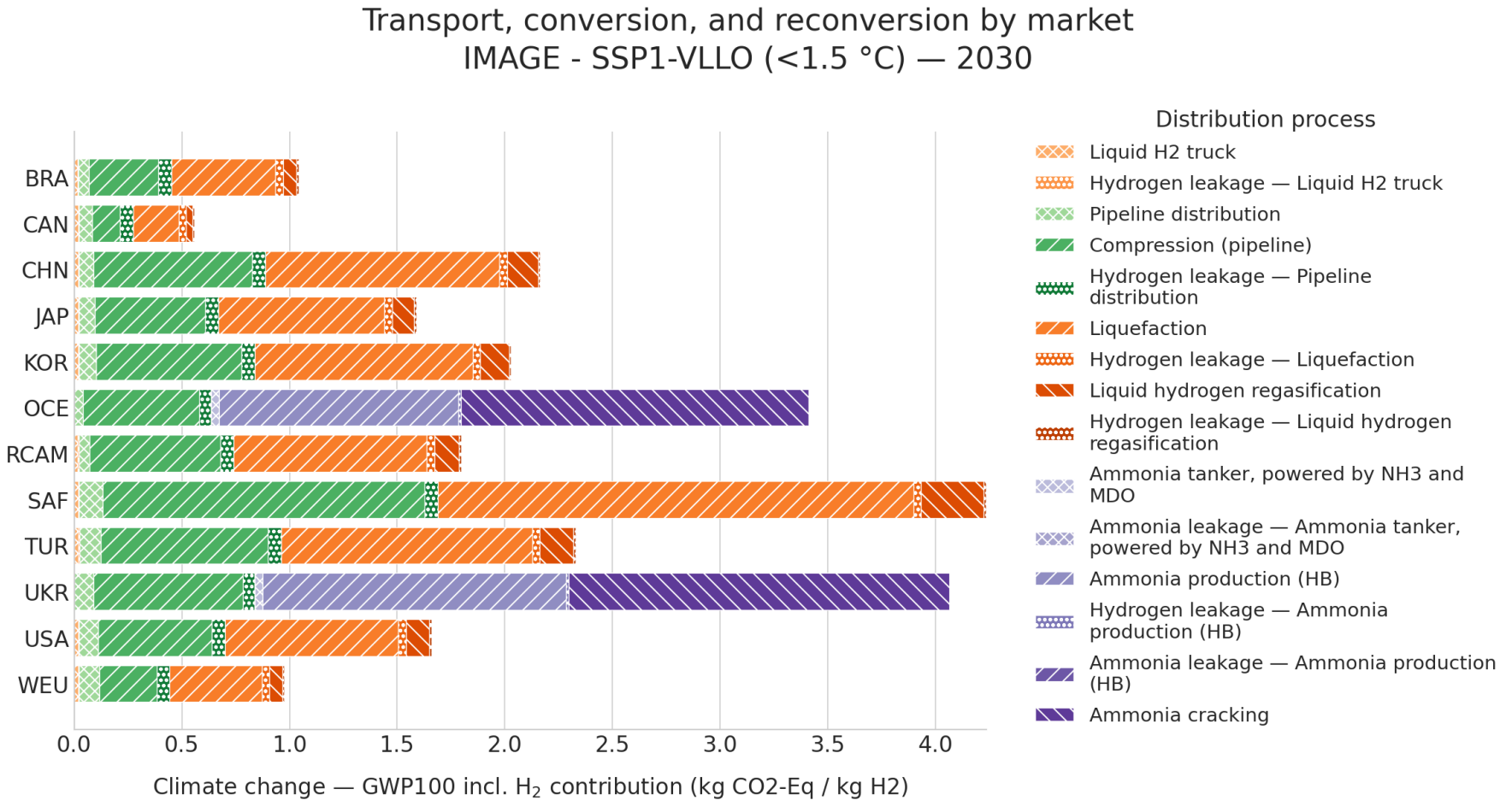
REMIND - SSP1-PkBudg650 | <1.5 °C | Transport | EUR
transport, conditioning and direct leakage



Backup: IMAGE 1.5 °C



Backup: IMAGE 1.5 °C



REMIND - SSP2-PkBudg1000 | <2.0 °C | Transport | EUR
transport, conditioning and direct leakage

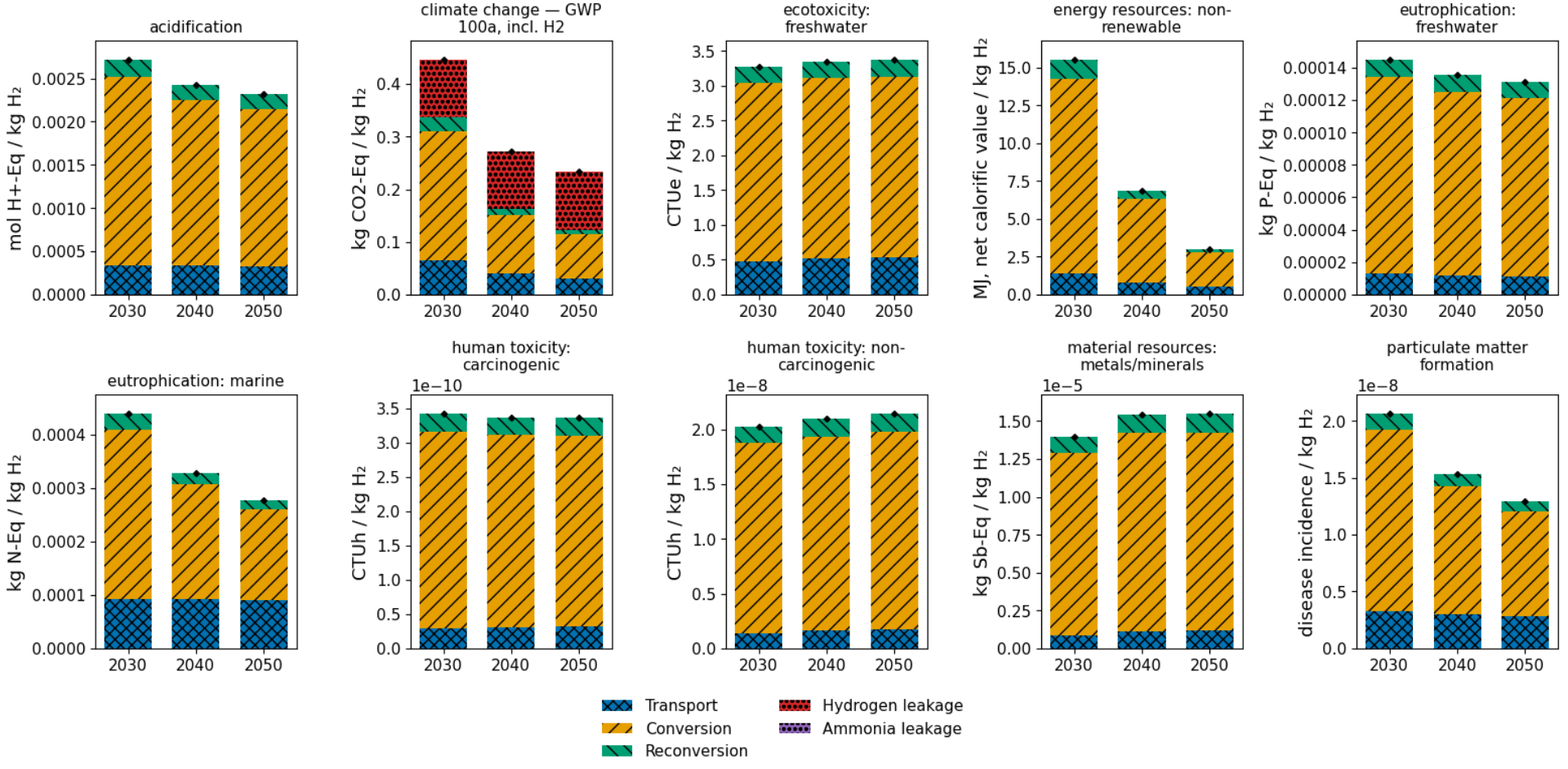
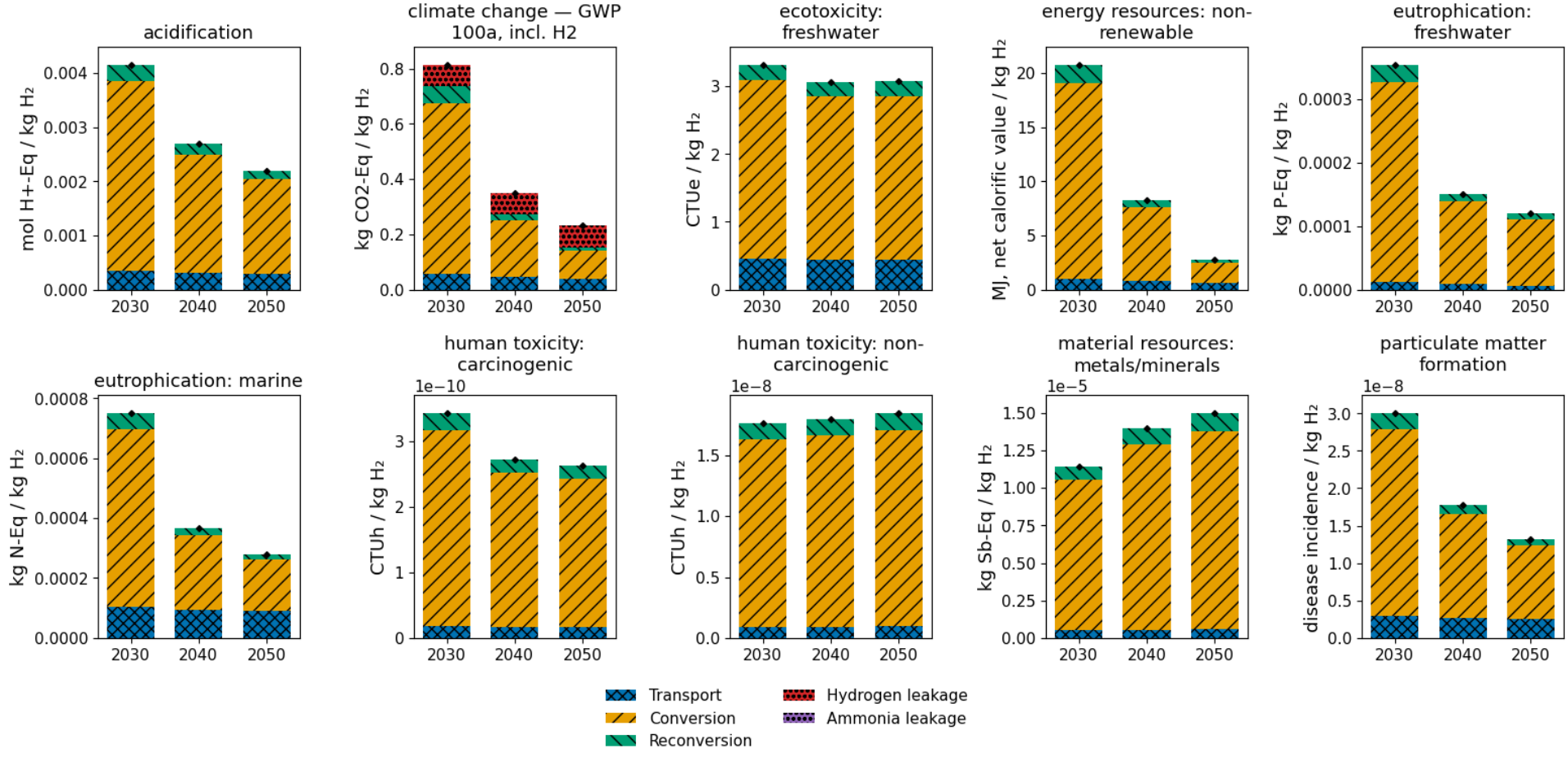


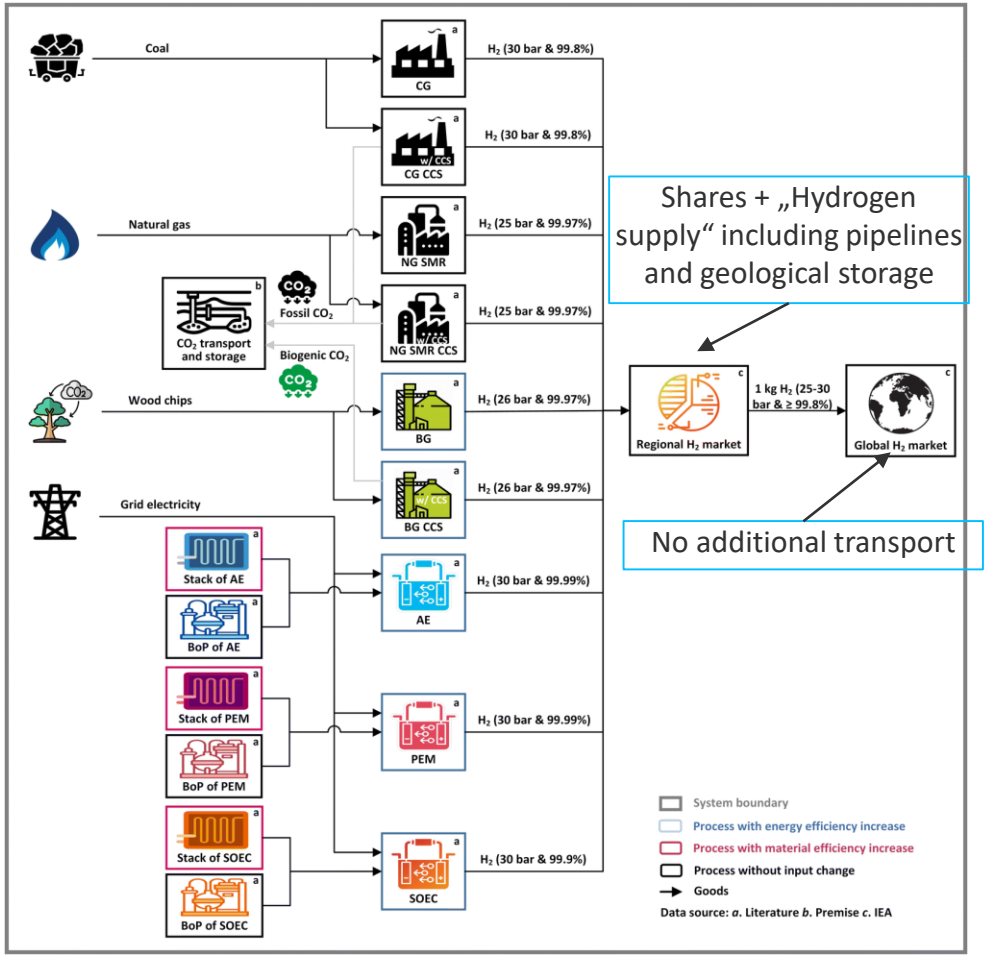
IMAGE - SSP2-VLHO | <2.0 °C | Transport | EUR
transport, conditioning and direct leakage



1. Motivation

Status quo of the Hydrogen sector in premise

- Hydrogen production technologies
- For every region, regional markets are created containing technology specific shares of hydrogen production based on IAM scenarios.
- Generic pipeline transport (500 km)



Adapted from Wei et al 2024

2. Methodology

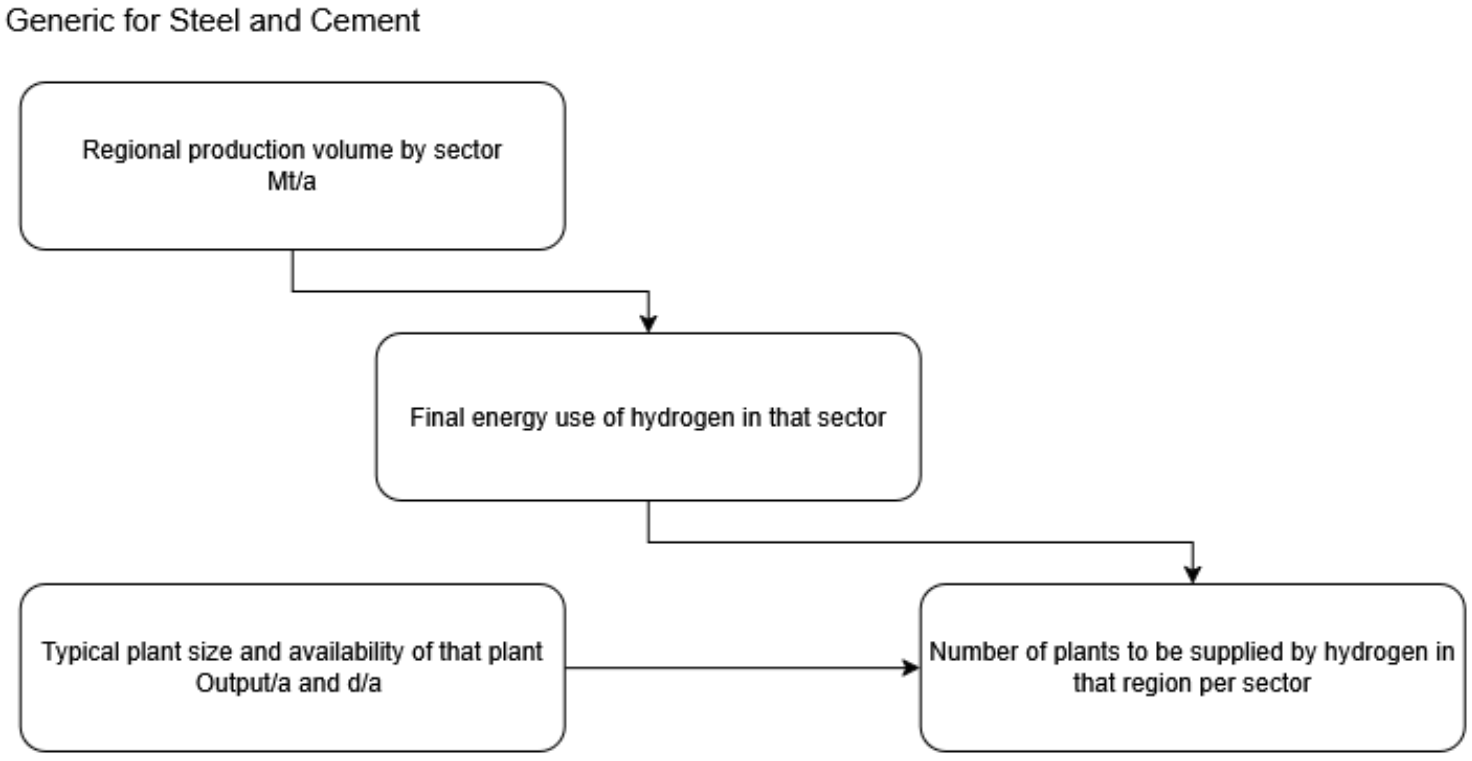
Literature Review on H2 transport

- Regional study with majority of H2 being transported **by pipeline and GH2 and LH2 trucks** used for short distances (Parolin et al 2022)
- Pipeline widely associated with the lowest costs up to 2.500 km → switch towards ships (**LOHC < NH3 in terms of TRL**) (IEA 2019 & Sterner et al 2025)
- Stepwise **transition from trucks to pipeline** → H2 distribution modes are complementary (Reuß et al 2019)
- Large scale offtakers (e.g. BASF) have their own **on-site H2 production**
- Up to 10 Mt of hydrogen shall be **imported** to Europe by 2030 (EU 2024)
- DRI of iron to steel can use **lower purity hydrogen** → possibility for H2 from NH3 cracking (Busch et al 2025)

→ Choosing the transport mode depends the scale of hydrogen demand

2. Methodology

Building plant archetypes



2. Methodology

H2 demand nodes at the example of the steel and cement sector (REMIND <1.5 °C)

