Import Costs of Green Hydrogen via Ships for Germany

David Franzmann*, Maximilian Stargardt, Heidi Heinrichs, Detlef Stolten

*d.franzmann@fz-juelich.de

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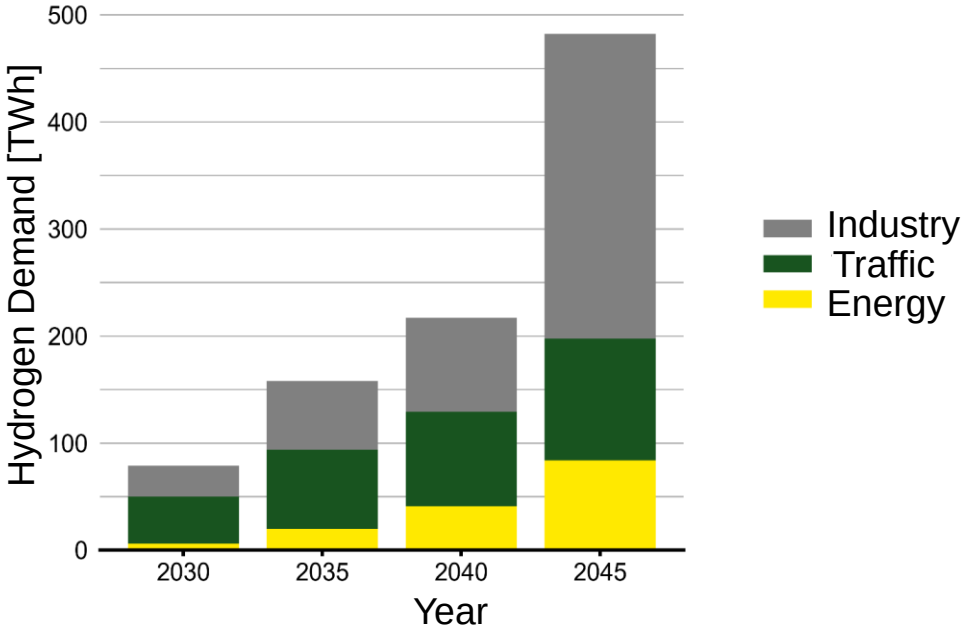
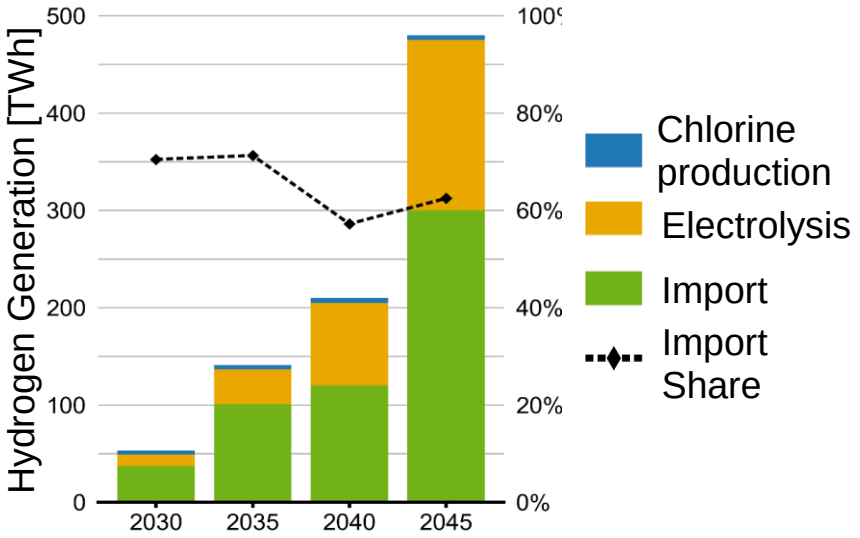
IEK-3: Institute of Techno-Economic Systems Analysis

Hydrogen Imports for a Greenhouse Gas Neutral Germany in 2045



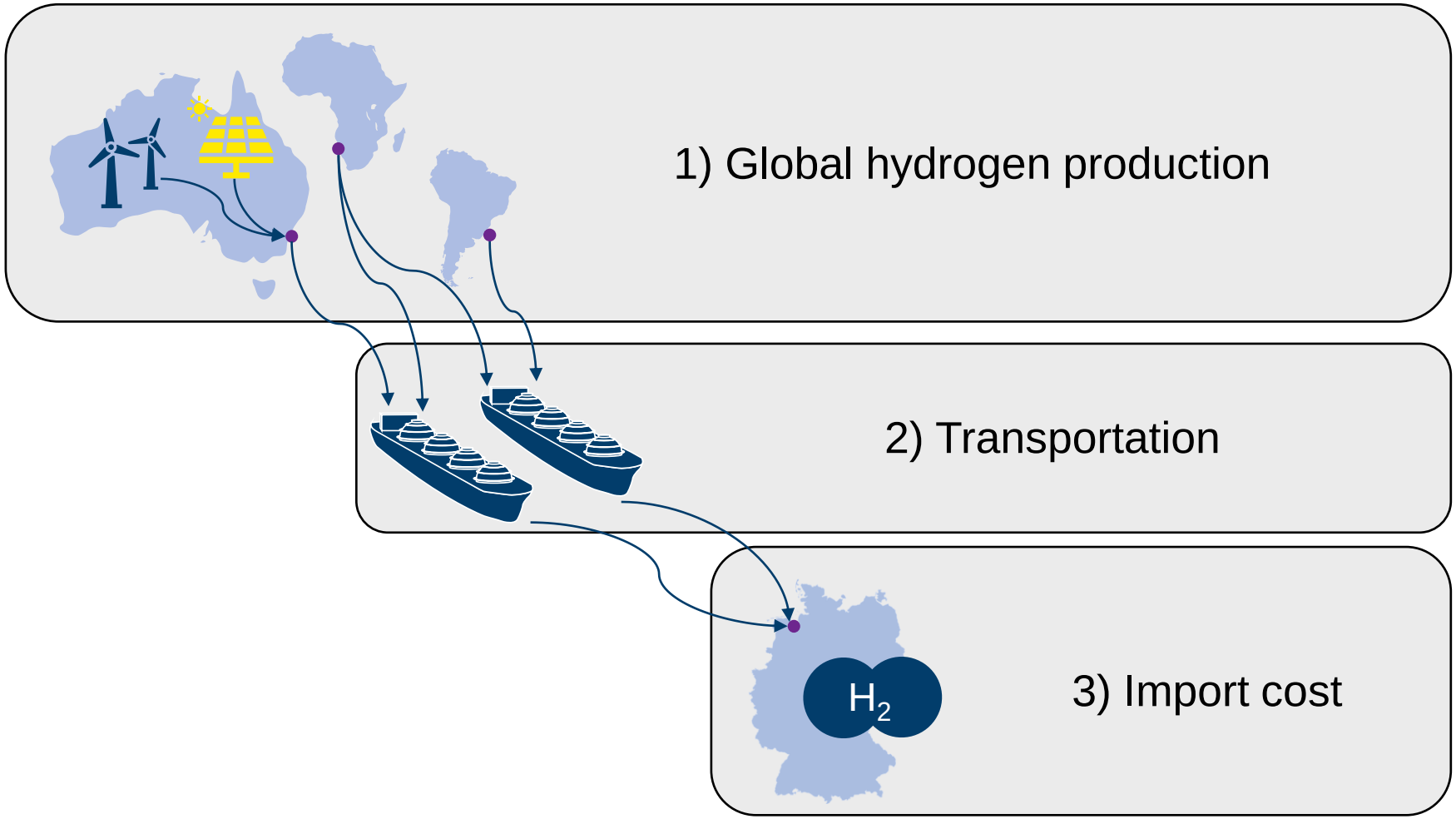


- Hydrogen demand is rising tremendously
  - >450 TWh H_2 in 2045 expected
  - > 1/3 of the electricity demand 2045

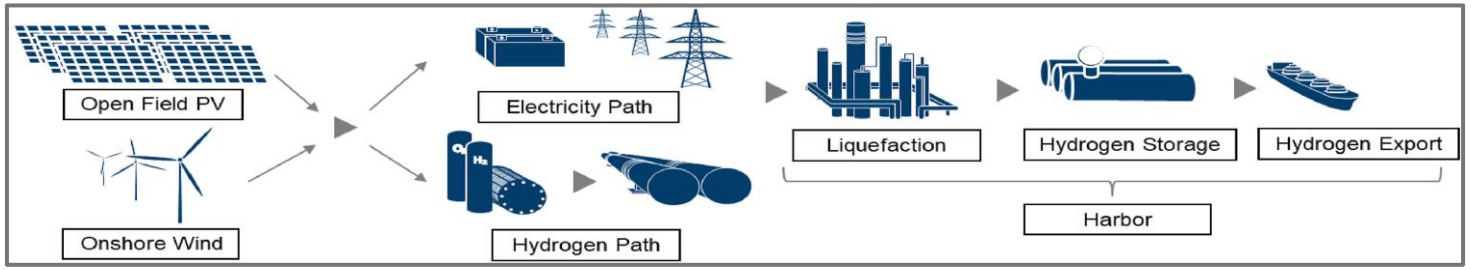
- 30-40% of the generated hydrogen could be supplied locally
- 60-70% need to be imported

Stolten et. al:, Energy Perspectives 2030, 2023

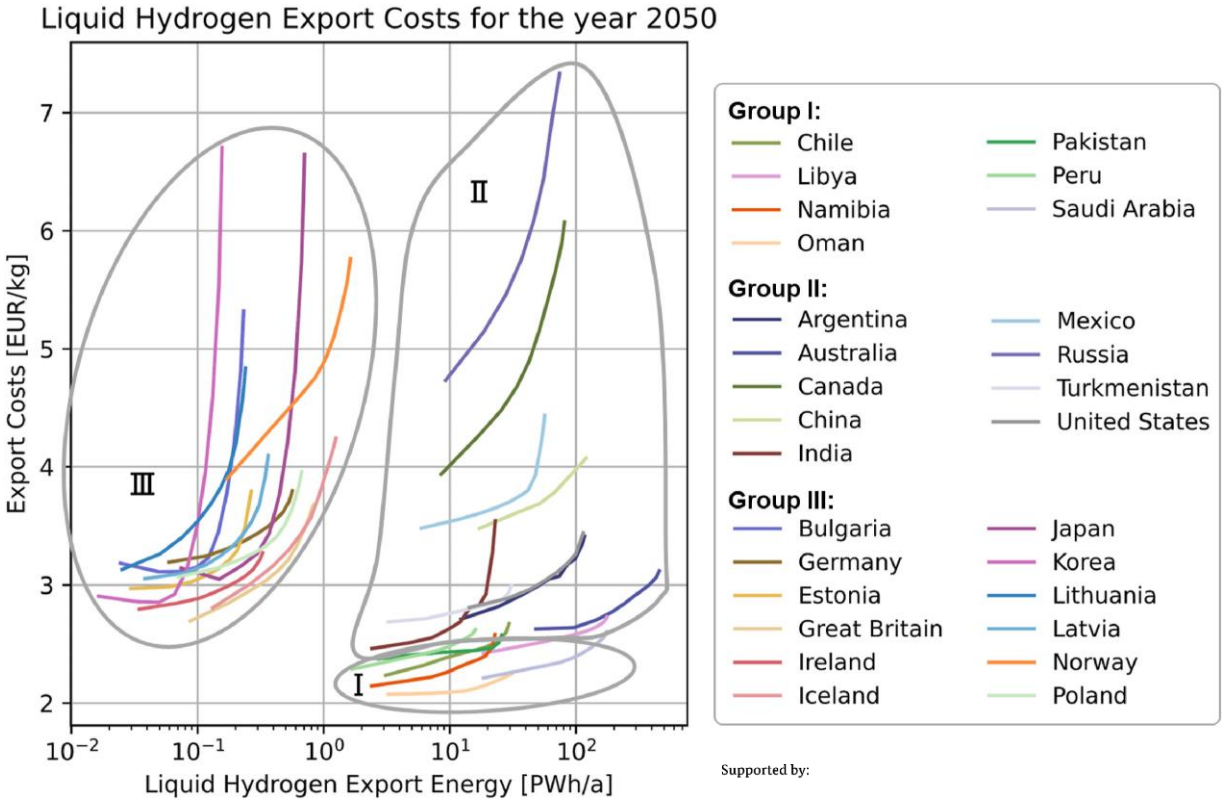
Approach: Import Costs of Green Hydrogen via Ships for Germany



Global Hydrogen Export Potentials



energy systems optimizations for 28 different countries



[1] Franzmann et al.; Green hydrogen cost-potentials for global trade; International Journal of Hydrogen Energy; 2023

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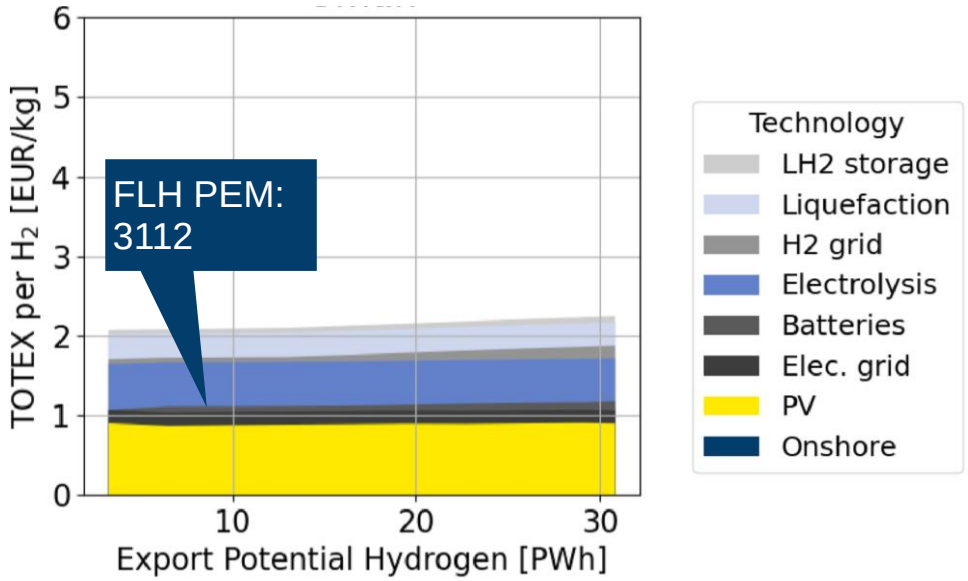
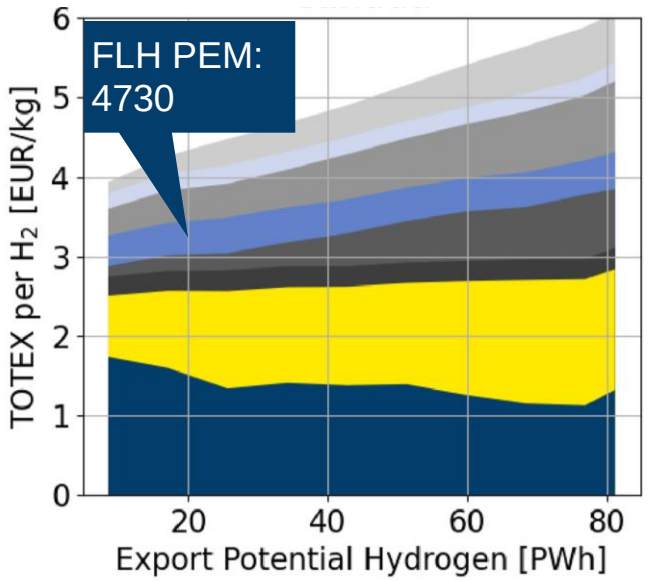
PV-Dominant vs. Wind-Dominant Export Countries

Group I (PV): Oman



- Lowest cost hydrogen globally from countries with high FLH PV resources (here 2061 FLH)
- Hydrogen costs dominated by PV (38%) and PEM costs (22%)
- Main strategy is direct curtailment of PV generation

Group II (Wind): Canada



- Combination of low-cost PV and high FLH wind: still 50-70% of capacity is from PV
- Cost from RES (42%) and evenly distributed between PEM, storages and transportation

PV: Photovoltaic, FLH: Full load hours, PEM: Polymer electrolyte membrane (electrolysis), RES: Renewable energy sources, LH_2: liquid hydrogen [1] Franzmann et al.; Green hydrogen cost-potentials for global trade; International Journal of Hydrogen Energy; 2023

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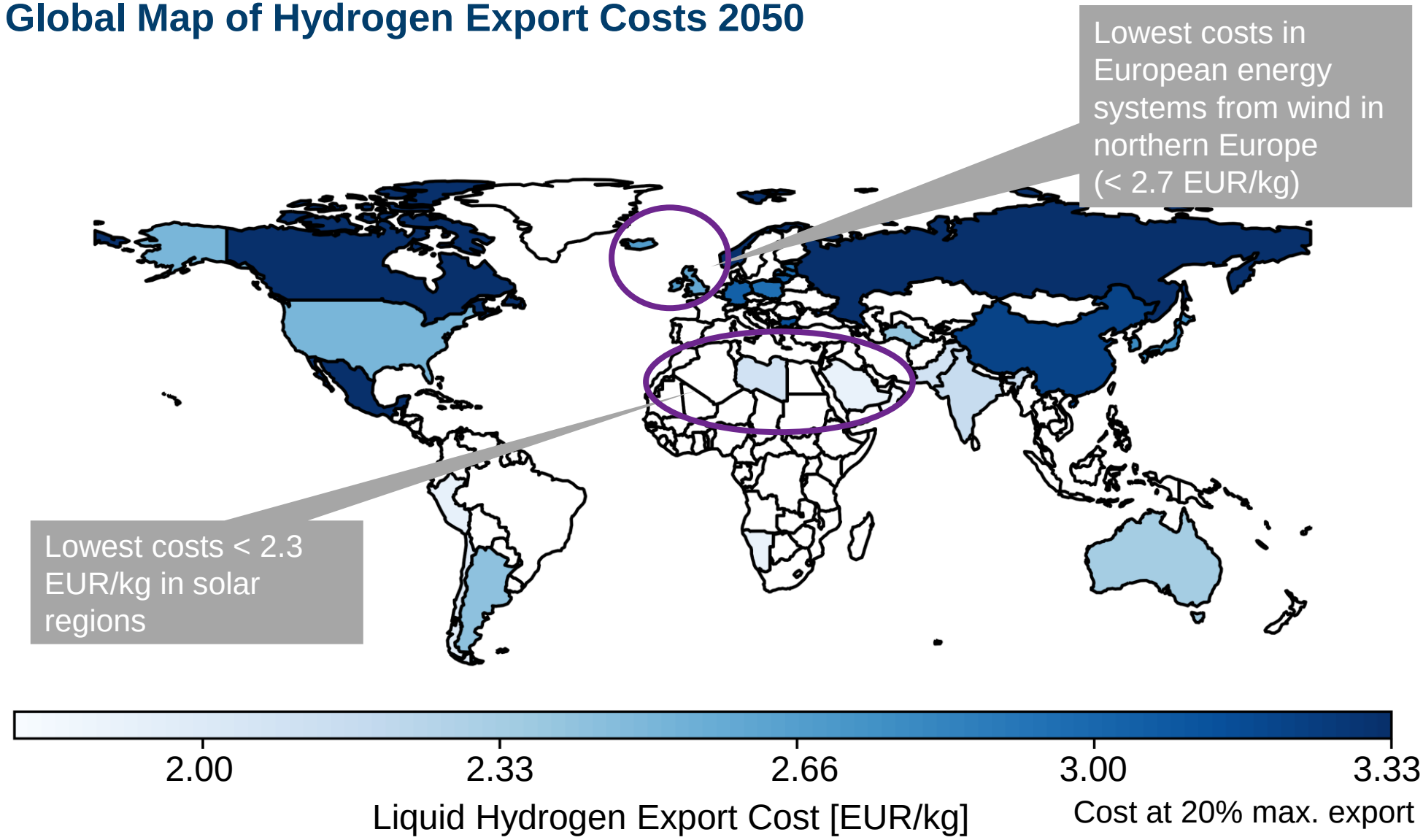
Global Map of Hydrogen Export Costs 2050



OFPV: Open field PV, Source: ETSAP-D project results [1] Franzmann et al.; Green hydrogen cost-potentials for global trade; International Journal of Hydrogen Energy; 2023

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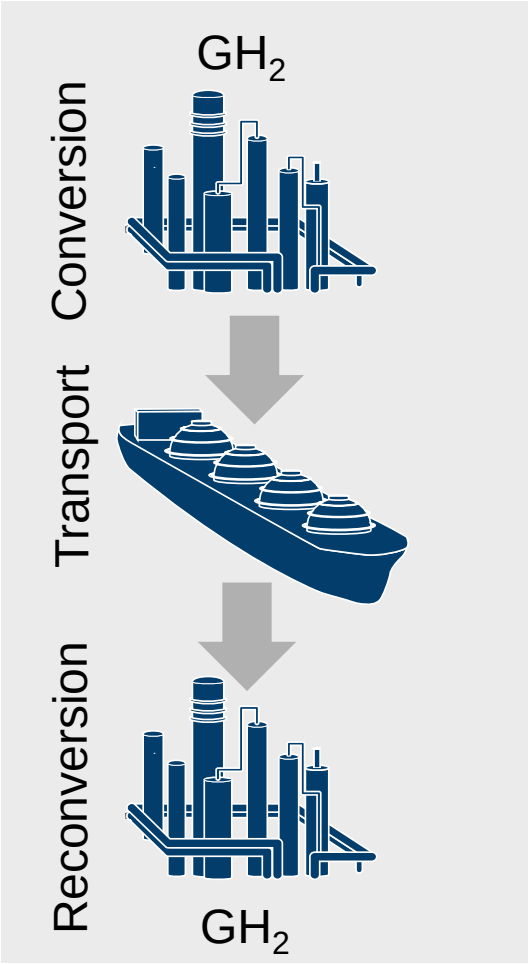
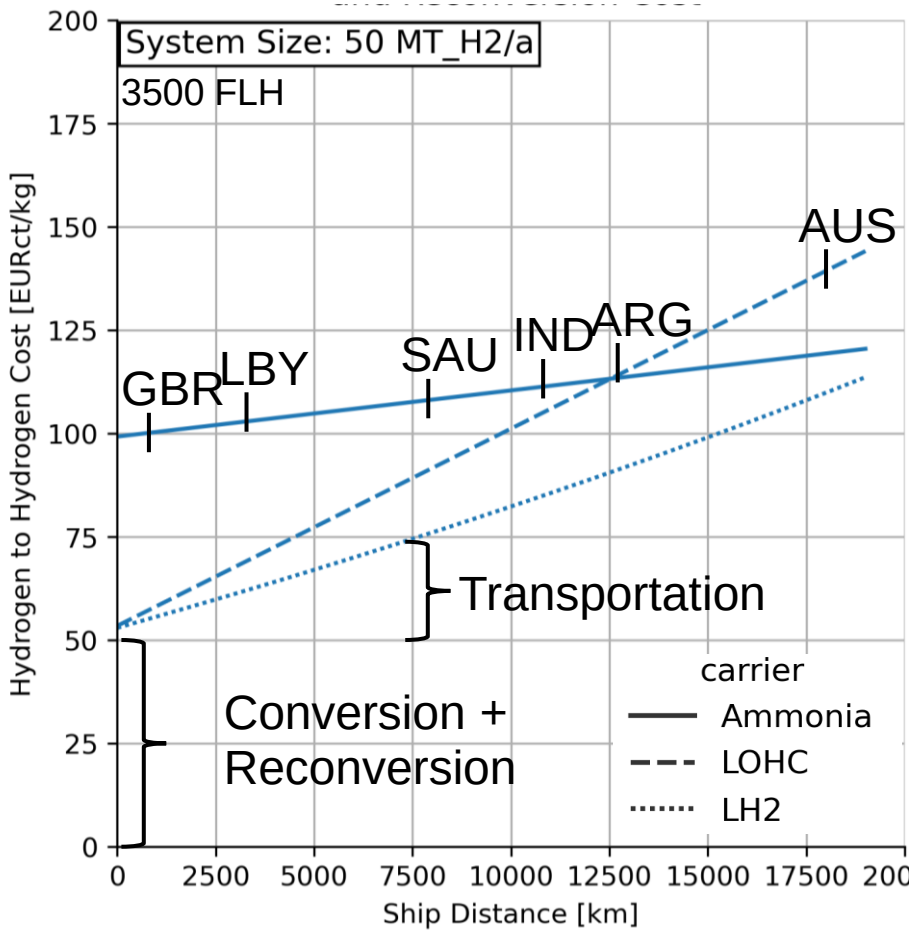
GH_2 to GH_2Transport Costs in 2050: Liquefaction is the Cheapest Option

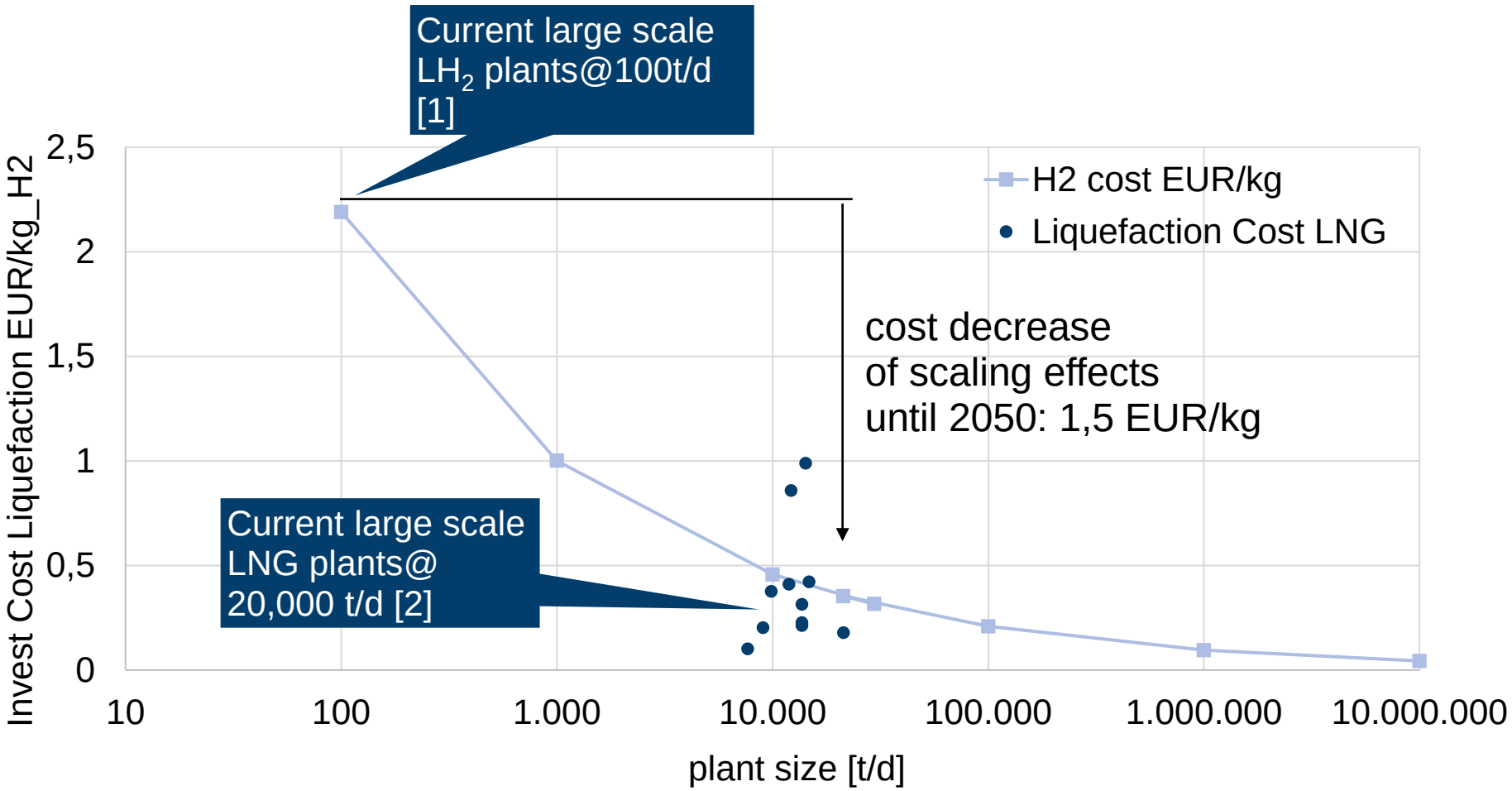




- Lowest transportation costs via NH_3:
  - 1.05 EUR/kg/tkm
- Lowest conversion cost for LH_2 and LOHC:
  - 0.5 EUR/kg

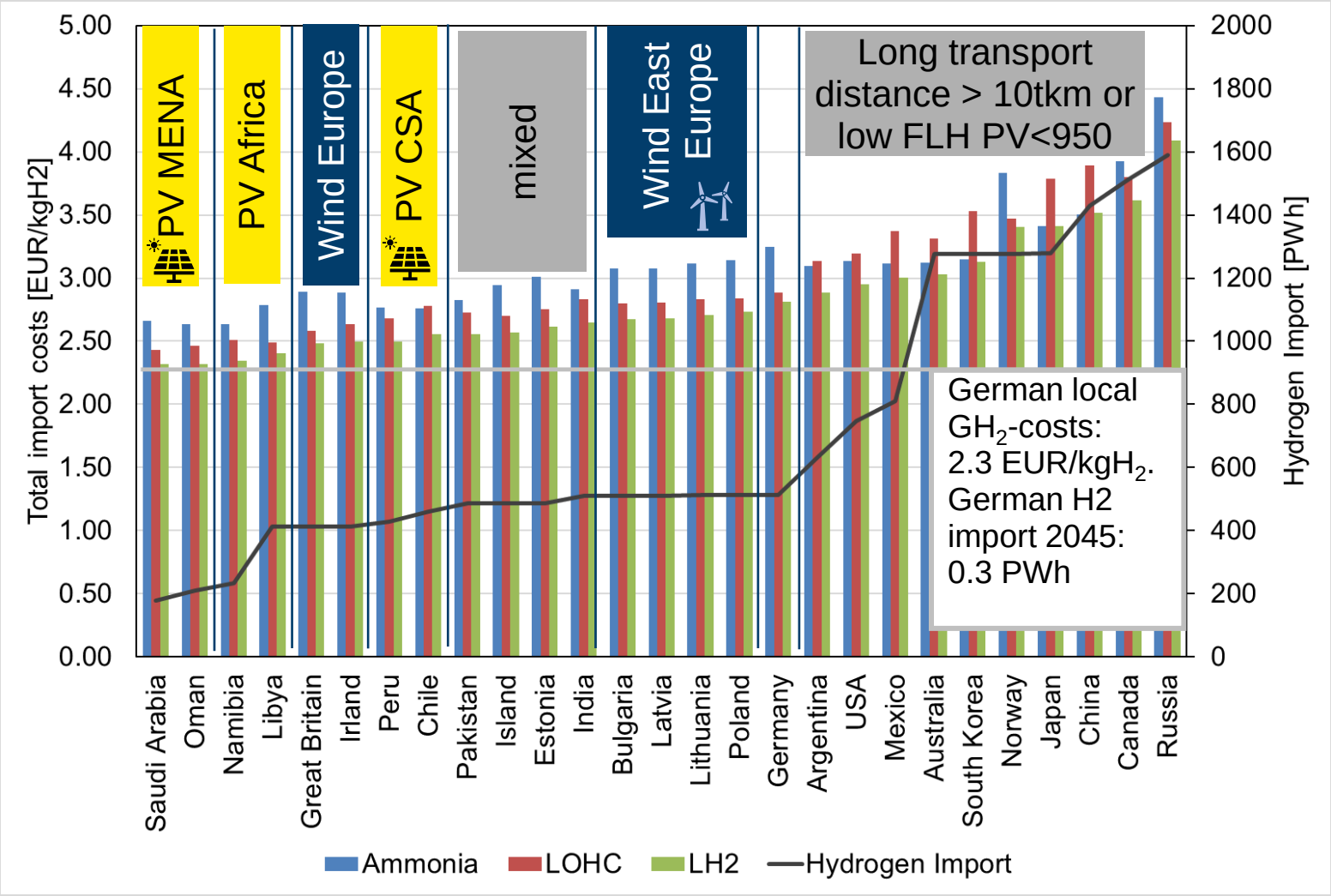
GH_2: gaseous hydrogen, LH_2: liquid hydrogen, LOHC: liquid organic hydrogen carriers [1] Morgan ER. Techno-Economic Feasibility Study of Ammonia Plants Powered by Offshore Wind [PhD Dissertation] 2013 [2] Teichmann D., Konzeption und Bewertung einer nachhaltigen Energieversorgung auf Basis flüssiger Wasserstoffträger (LOHC). 2014, Universität Erlangen-Nürnberg: Aachen. [3] Kamiya S., Nishimura M., and Harada E. Study on Introduction of CO2 Free Energy to Japan with Liquid Hydrogen. Physics Procedia 2015;67. p. 11 - 19. [4] MAN Diesel & Turbo. Propulsion Trends in Tankers. MAN Diesel & Turbo. 2013. [5] MAN Diesel & Turbo. Propulsion Trends in LNG Carriers: Two-stroke Engines. MAN Diesel & Turbo. 2013.

Impact of Scaling Effects on Liquefaction Costs



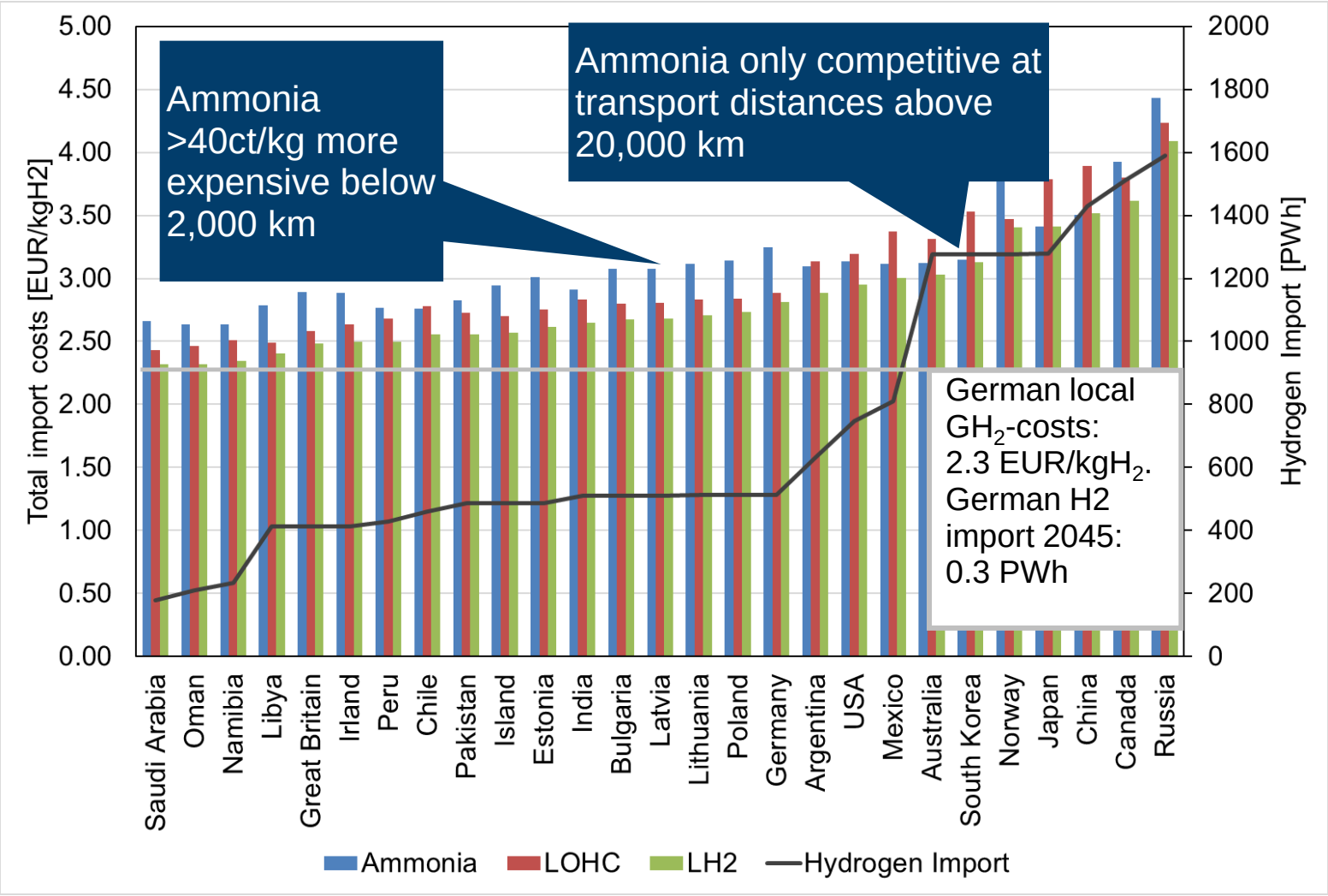
[1] https://mediatum.ub.tum.de/doc/1442078/1442078.pdf [2] https://giignl.org/wp-content/uploads/2022/05/GIIGNL2022_Annual_Report_May24.pdf [3] Heuser, Philipp; Weltweite Infrastruktur zur Wasserstoffbereitstellung auf Basis erneuerbarer Energien, 2020

Final Import Costs per Country: Cheapest H_2 from PV MENA / North Africa



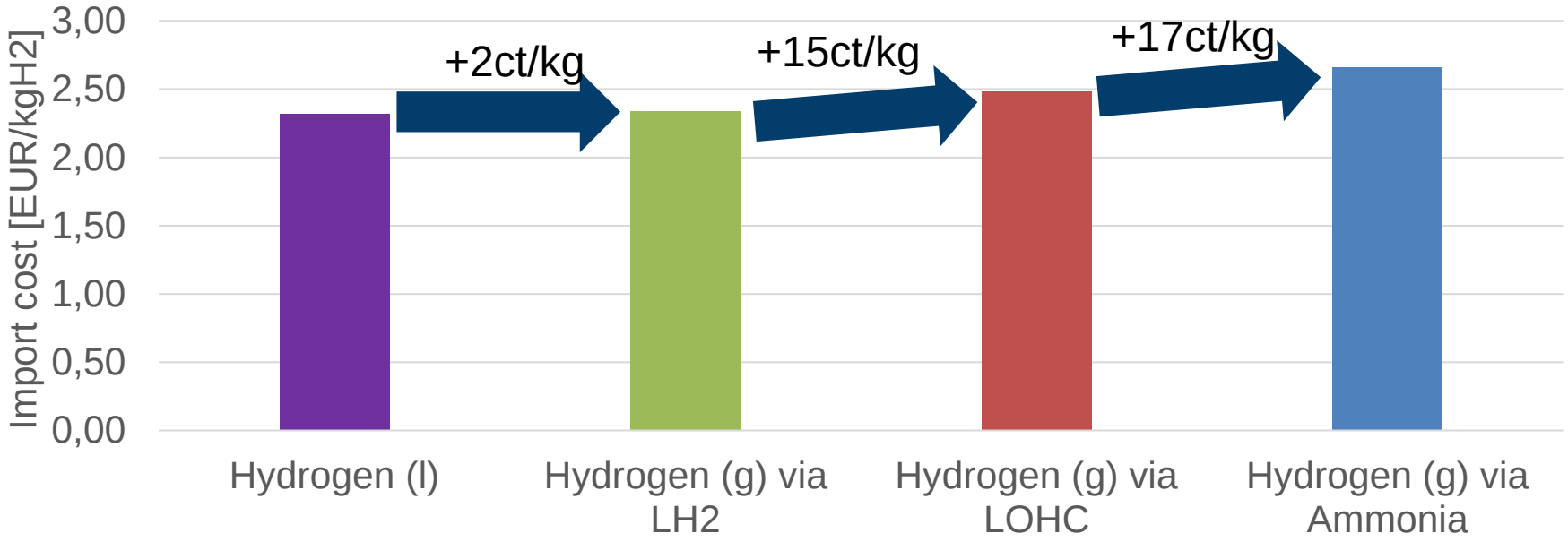
[1] own calculations

Final Import Costs per Country: LH_2 Always Cheapest Option



[1] own calculations

Costs per carrier: Direct LH_2 Usage is the Cheapest Option



- LH_2 import cheapest option: 2.32 EUR/kg_{LH2}
- Direct usage of LH_2 leads to only small cost increase (1%)
- Direct usage of ammonia still more expensive than LH_2 at 74 EUR/MWh (GH_2 via LH_2: 70 EUR/MWh) due to cheap cracking

[1] own calculations

Summary

Global hydrogen production	▪ Technical green hydrogen potentials are huge (1,540 PWh/a in 28 countries) ▪ 79 PWh_{LHV}/a at costs below 2.3 EUR/kg_{LH2} in 2050 ▪ PV-rich countries are dominating low-cost hydrogen production
Transportation	▪ Transport via LH_2 can be the cheapest option in 2050 ▪ Strongly depending on scaling effects of future liquefaction plants ▪ Ammonia has the cheapest cost for shipping but high costs for conversion
Import cost to Germany	▪ Lowest import cost from PV-rich countries in MENA and Africa at 2.33 EUR/kg ▪ Local production the cheapest option at 2.30 EUR/kg ▪ LH_2 transportation cheapest option ▪ Benefit from direct usage of the LH_2 carrier at only 1%

LH2: liquid hydrogen

Thank you for your attention!

For further questions, please contact:

David Franzmann
+49 151 21424296
d.franzmann@fz-juelich.de

Prof. Dr. Detlef Stolten
+49(0)2461 61 5147
d.stolten@fz-juelich.de

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