



ASIA CLEAN ENERGY FORUM 2026

Beyond Transition: Building Secure, Resilient, Inclusive, and Intelligent Energy Systems

8-11 June | ADB Headquarters, Metro Manila, Philippines



COMMITTED Session:

Collaborative Pathways for Asia's Clean Energy Future: Modeling, Resilience, and Security

Hydrogen Trade Reshapes Global Demand for Critical Minerals

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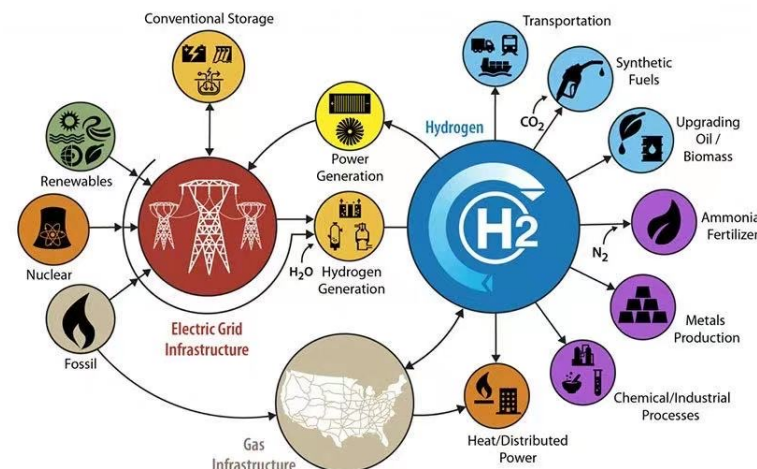
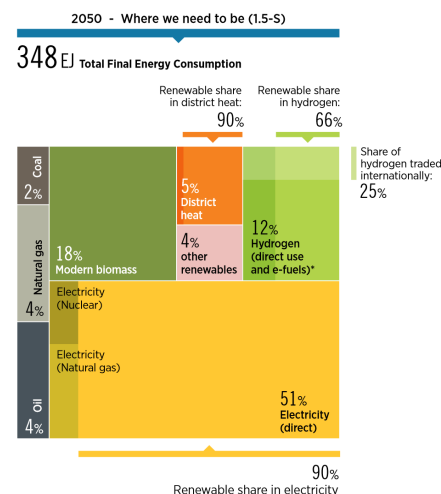
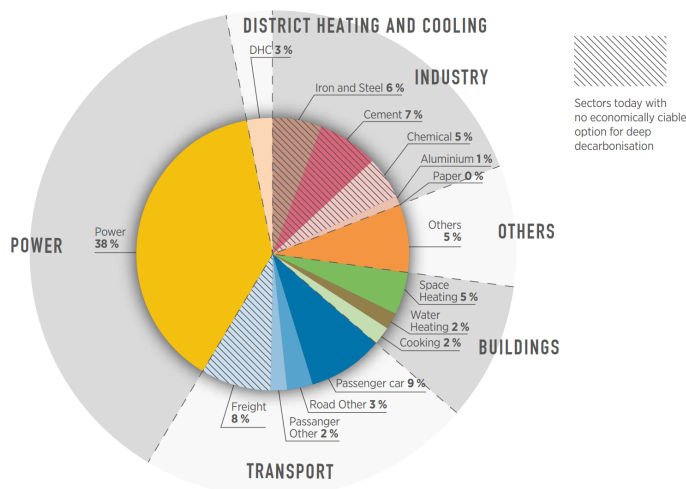
Why we need hydrogen?

- **Electrification** can't solve all emissions reduction problems
- **Hydrogen** provides emission cuts for energy systems, deepens reductions in industry and transport, and is key in the power system
- According to the IRENA's *World Energy Transitions Outlook 2022*, **12%** of the final energy demand is supplied by **Hydrogen** in 1.5°C scenario 2050

Source: Hydrogen from renewable power

Source: World Energy Transitions Outlook 2022

Source: U.S. National Clean Hydrogen Strategy and Roadmap





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The Global Hydrogen Economy: 2025 Snapshot

~100 Mt

**Global H₂ demand
2024**

Up from 97 Mt in 2023

~1 Mt

**Low-emission H₂
2025**

< 1% of total production

~5 GW

**Installed electrolyzer
capacity (end-2024)**

> 50% by China

\$4.3B

**Capital spending on
low-emission H₂ 2024**

80% increase from 2023

Source: IEA Global Hydrogen Review 2025; Hydrogen Council Global Compass 2025



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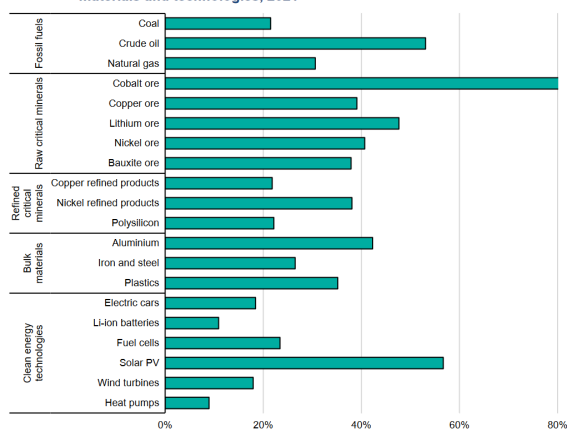


Hydrogen → Critical minerals

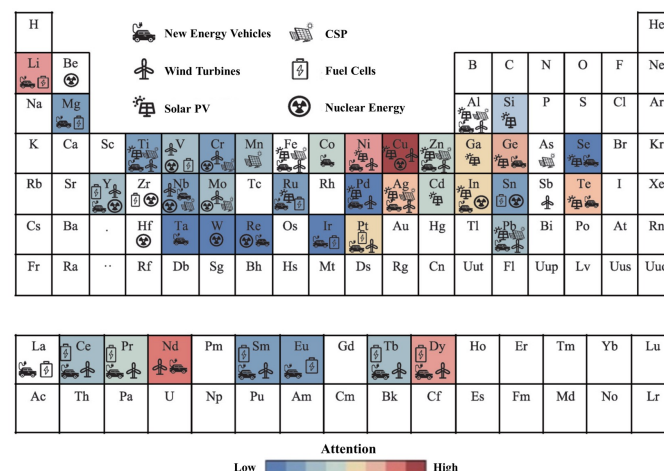
- Green hydrogen from renewables best reduces emissions
- Green hydrogen production of relies on critical metals for **PV, wind turbine, batteries, and electrolyzers**
- Significant **spatial mismatch** between the supply and demand of energy-related critical metals, with import dependence exceeding **50%** in most regions

Source: IEA, 2023

Figure 2.9 Share of inter-regional trade in global production for selected minerals, materials and technologies, 2021



Source: Wanq et al., Resources Science, 2021



Source: IEA, 2023

Figure 2.10 Trade balance along supply chains in selected countries/regions, 2021

		China	Europe	United States	Japan	Korea
Energy technology	Li-ion batteries	13%	-30%	-7%	27%	-14%
	Electric cars	8%	-27%	3%	76%	58%
	Fuel cells – mobility	5%	-92%	-4%	61%	8%
	Electrolysers	0%	0%	0%	0%	0%
	Solar PV – modules	52%	-100%	-65%	-92%	45%
	Wind turbines	14%	6%	-38%	-46%	80%
	Heat pumps	14%	-25%	2%	17%	8%
Critical minerals	Lithium ore	-75%	0%	-100%	0%	0%
	Cobalt ore	-98%	-100%	100%	-100%	0%
	Nickel ore	-88%	-66%	100%	-100%	-100%
	Copper ore	-80%	-40%	30%	-100%	-100%
	Nickel refined products	-51%	-22%	-100%	23%	-58%
	Copper refined products	-25%	-11%	-45%	41%	-1%
	Solar PV – polysilicon	-54%	37%	17%	40%	64%
Fossil energy	Coal	-8%	-43%	15%	-100%	-99%
	Oil	-78%	-72%	-18%	-97%	-100%
	Natural gas	-41%	-57%	9%	-98%	-98%
Bulk materials	Iron and steel	5%	2%	-24%	31%	17%
	Plastics	-21%	-10%	21%	6%	44%
	Aluminium	-7%	-53%	-80%	-100%	-100%
Averages	Energy technology average	15%	-38%	-16%	6%	26%
	Critical minerals average	-85%	-52%	33%	-75%	-50%
	Refined critical minerals average	-43%	1%	-43%	35%	2%
	Energy (fossil) average	-42%	-57%	2%	-98%	-99%
	Bulk materials average	-8%	-20%	-28%	-21%	-13%



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Hydrogen trade reshapes minerals demand

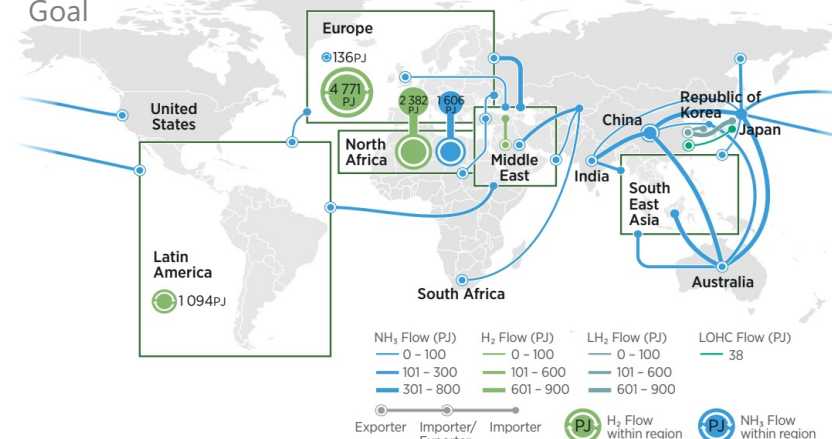
- Global renewable variances cause **varied hydrogen costs**
- Higher-cost regions choose to import hydrogen to satisfy their own demand
- IRENA predicts **25%** of 2050 hydrogen demand met by international trade

Research Question:

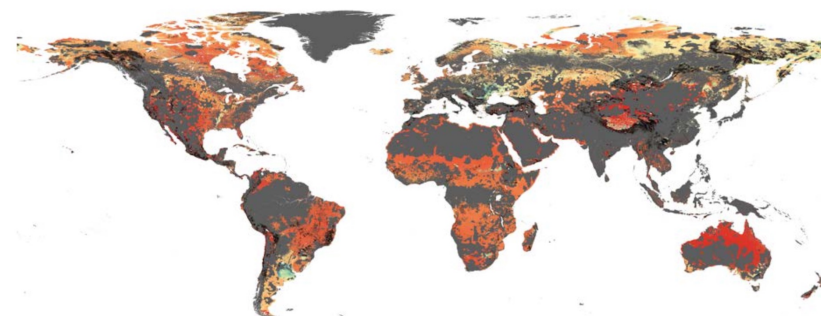
What impact will the future global hydrogen trade pattern have on the demand for critical minerals?



Source: Global Hydrogen Trade to Meet the 1.5°C Climate Goal



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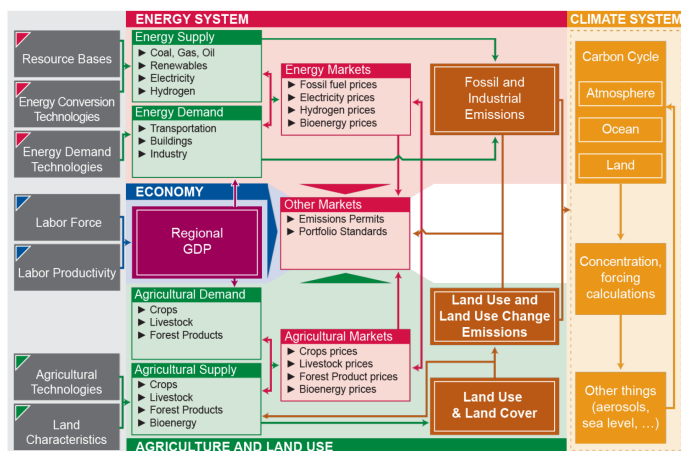
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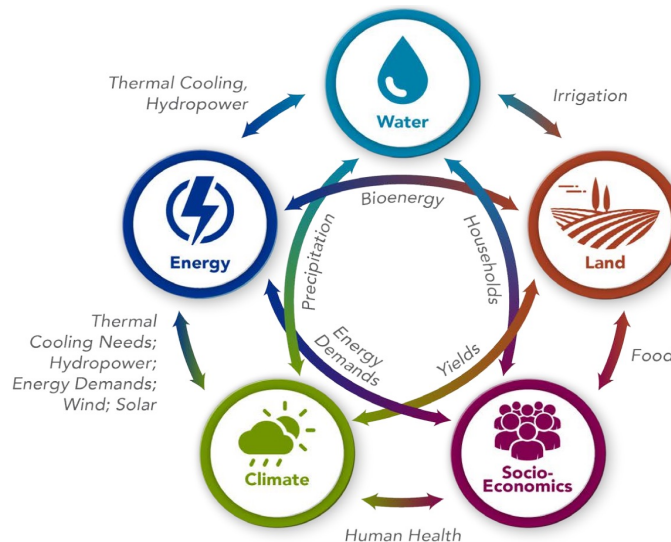


Model introduction

Utilized the **GCAM v7.0** global multi-regional model which integrates energy, economy, climate, water, and land-use systems to **energy system transition pathways** under different climate scenarios and capture the interactions and feedback between various systems



· Documentation: <https://jgcri.github.io/gcam-doc/>



32 Energy Economy Regions



235 Water Basins



384 Land Regions



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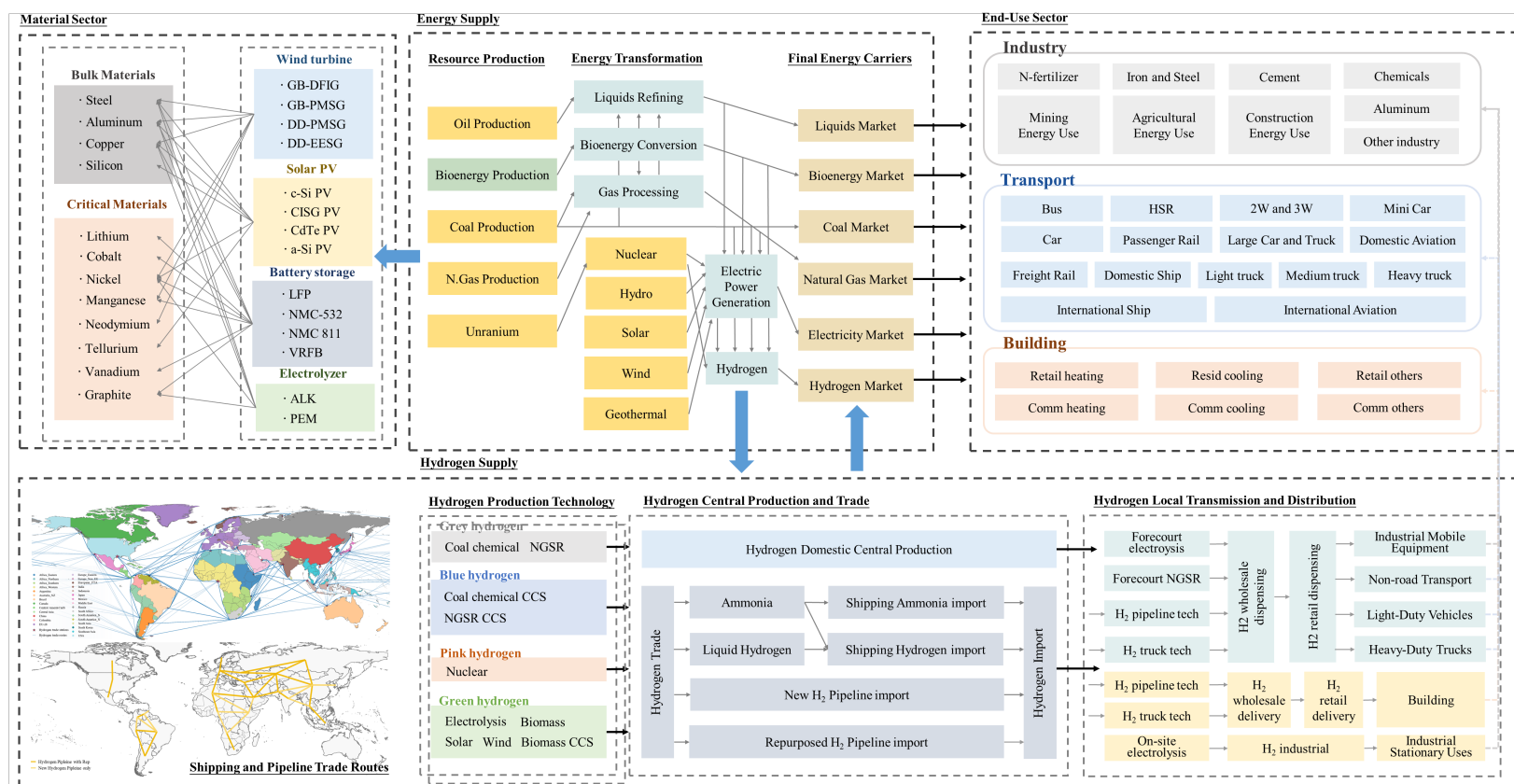
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Research framework

Enhanced GCAM with a **hydrogen trade module** simulating bilateral trade and transport competition, integrating **critical minerals inputs** in the power sector

Ref: Qiu, Y., Iyer, G., Graham, N., Binsted, M., Wise, M., Patel, P., & Yarlagadda, B. (2024). The impacts of material supply availability on a transitioning electric power sector. *Cell Reports Sustainability*, 1(10).





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Electrolyzer Technologies and Their Mineral Demands

Technology	Key Minerals	CapEx (\$/kW)	Efficiency	Market Share
Alkaline (ALK)	Nickel, Zirconium, Cobalt	\$350–1,500	60–70% LHV 51–55 kWh/kg H ₂	64% installed capacity
PEM	Iridium, Platinum, Titanium	\$1,000–2,500	65–75% LHV 46–53 kWh/kg H ₂	Growing fast; best for renewables
Solid Oxide (SOEC)	Lanthanum, Yttrium, Zirconium, Nickel	\$2,000–3,000	80–94% LHV 37–45 kWh/kg H ₂	Emerging; highest efficiency
AEM	No PGMs required; Nickel, Cobalt	TBD	~70% LHV ~50 kWh/kg H ₂	Early-stage; PGM-free promise

Source: World Bank Electrolyzers Report 2026; IEA; industry data



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Hydrogen Trade Pattern

By 2050:

Australia → Japan/Korea

Woodside H2Perth: construction 2026, operations 2031.
Liquid H₂ & NH₃ export. AU\$6.7B in production tax credits.

Middle East → Asia/Europe

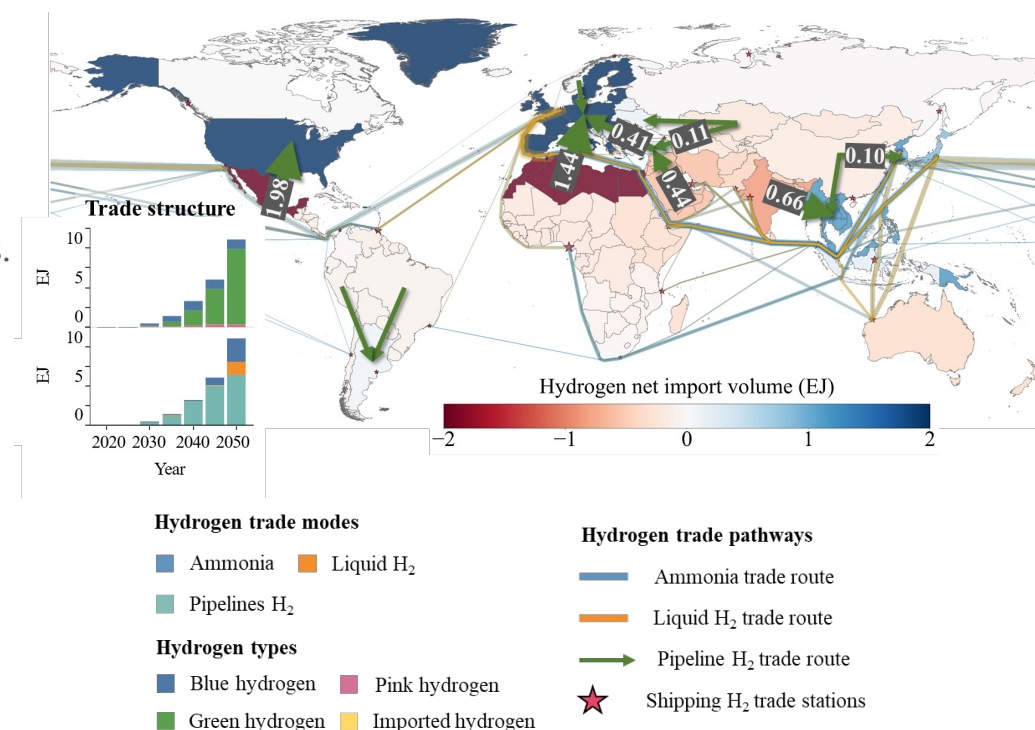
NEOM green hydrogen (2 GW Thyssenkrupp alkaline).
UAE/Masdar scaling clean ammonia exports.

Chile → Europe

Excellent renewables for green H₂. Geographic distance favors ammonia carriers. EU primary import target.

North Africa → Europe

Pipeline-based trade most cost-effective. Morocco, Egypt receiving development finance for H₂ projects.



Key insight: 85% of announced trade projects target ammonia as the carrier. Europe is the destination for 75% of export-oriented projects.



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Hydrogen Trade Pattern

By 2050:

• Exporters:

North Africa, Middle East, Mexico, India, Australia

• Importers:

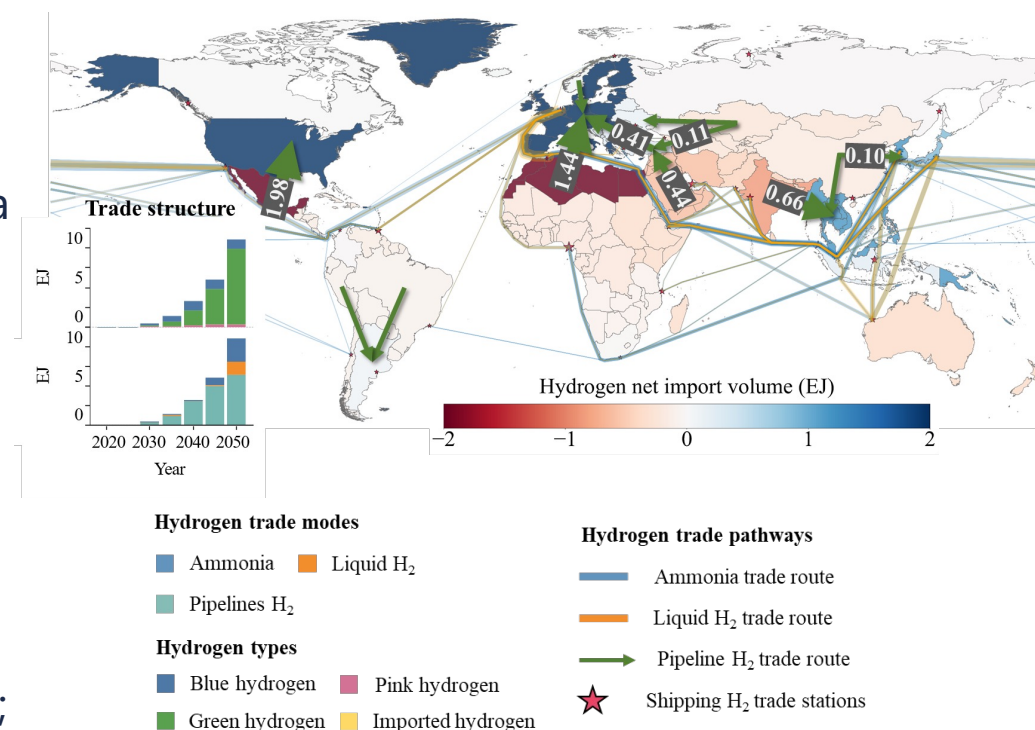
EU, USA, Japan, Southeast Asia, S. Korea

• Trade volume: **8.8EJ (70+ MtH₂)**

17% of total H₂ consumption

• **Trade medium:** **58%** pipeline, **27%** ammonia shipment; **87%** of traded hydrogen is green

• **Key pipeline routes:** near EU & Southeast Asia; North Africa to EU dominates





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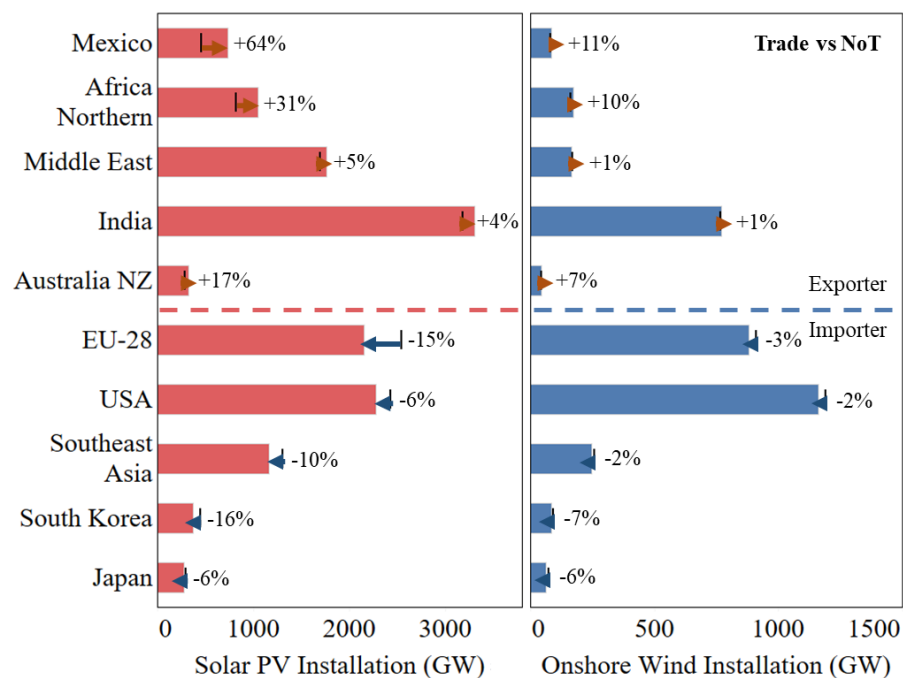
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Impact on Renewable Energy Installations

Hydrogen trade will significantly impact **renewable energy capacity** in exporting and importing regions, with a more pronounced effect on **Solar PV**



• Impact on Exporting Regions:

- PV installations increase by **4%-64% (46-286 GW)**
- Wind installations increase by **1%-11% (1-16 GW)**

• Impact on Importing Regions:

- PV installations decrease by **6%-15% (19-380 GW)**
- Wind installations decrease by **2%-7% (5-28 GW)**



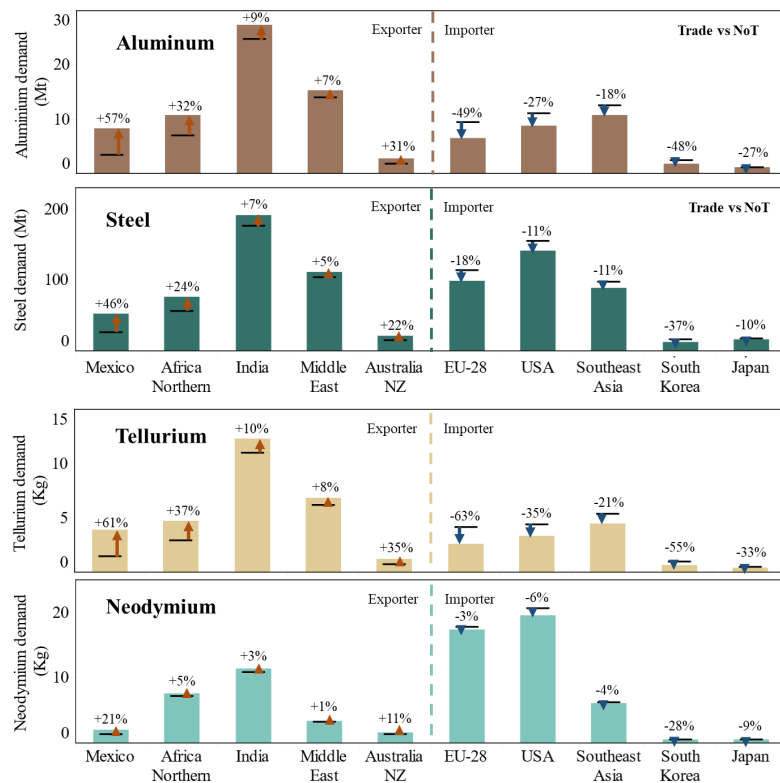
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Impact on Global Minerals Demand



- **Bulk minerals (e.g., aluminum, steel):**
 - Decrease by **10%-49%** in importing regions
 - Increase by **5%-57%** in exporting regions
- **Critical minerals (e.g., tellurium, neodymium):**
 - Increase by **1%-61%** in exporting regions
 - Decrease by **3%-63%** in importing regions
- **Aluminum and tellurium** experience the most significant changes due to their strong association with PV



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Impact on Global Minerals Demand

- **Shift in Production and Demand Centers:** Hydrogen trade moves production and mineral demand **southward** to regions rich in renewables, often developing areas
- **Improved Efficiency:** Optimized resource allocation enhances mineral utilization efficiency for renewable hydrogen production by **9%** globally

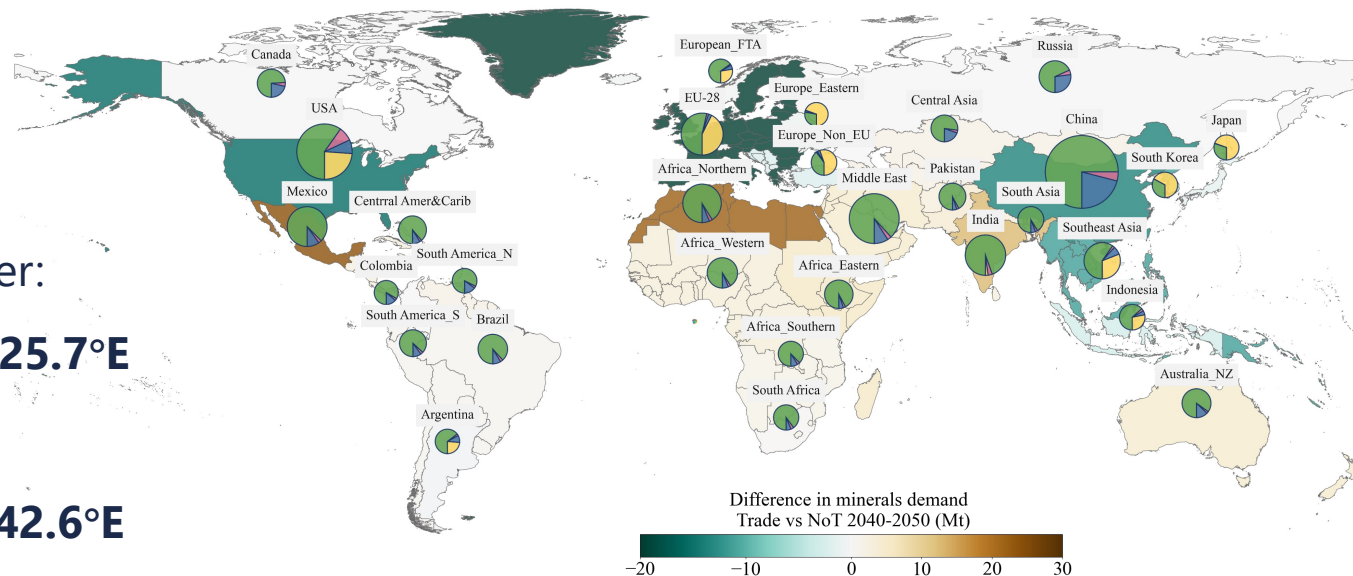
NoT vs Trade

Hydrogen production center:

30.9°N, 34.4°E to 27.8°N, 25.7°E

Minerals demand center:

28.2°N, 43.7°E to 27.6°N, 42.6°E





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Conclusion

- **Hydrogen Trade by 2050:**

- Accounts for **17%** of global hydrogen consumption
- Predominantly flows from the **Global South** to the **Global North**, driven by solar resource distribution

- **Impact on Renewable Installations:**

- Alters solar PV and wind turbine installations across regions
- Shifts mineral demand centers **southward**

- **Resource Efficiency:**

- Optimized resource allocation improves global minerals utilization efficiency by **9%**



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Discussion

- **Role of the Global South in Decarbonization:**

- Emphasize the South's potential as a key energy supplier
- Advocate for financial and technological support to foster energy hubs in the South
- Optimizing the allocation of resources and improving the efficiency of mineral use

- **Supply Chain Security:**

- Address the need for multi-level supply chain security
- Highlight the importance of securing the entire value chain, from energy to equipment to critical minerals



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Strategic Recommendations for Policymakers

1

Diversify Mineral Supply Chains

Accelerate investment in allied-nation mining and processing. Reduce single-country dependency below 65% for all strategic minerals. Fast-track permitting for domestic extraction projects.

2

Invest in Material Substitution R&D

Fund breakthrough research to reduce or eliminate PGM dependence in electrolyzers. Scale AEM and SOEC technologies as hedges against PEM mineral constraints.

3

Build Strategic Mineral Reserves

Establish coordinated stockpiling programs for iridium, platinum, rare earths, and cobalt. Implement early warning systems for supply disruption through joint EU-US intelligence.

4

Align Hydrogen and Mineral Policies

Integrate critical mineral sourcing requirements into hydrogen subsidies and procurement standards. Ensure clean hydrogen targets are consistent with realistic mineral supply timelines.

5

Strengthen International Partnerships

Deepen bilateral mineral-for-hydrogen trade agreements. Support capacity-building in mineral-rich developing nations through blended finance and technology transfer.



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Thank you

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