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IAM COMPACT Final Conference, Athens, 29 August 2025

Renewable hydrogen trade in a global decarbonised energy system

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- **Introduction**
  - ✓ Overview of the current and future hydrogen markets
  - ✓ Key drivers for international trade
  - ✓ The significance of financing costs
- **Data and Methodology**
  - ✓ Country and technology-specific WACC
  - ✓ Modelling framework and scenario analysis
- **Results**
  - ✓ Global hydrogen demand, prices and costs
  - ✓ International trade flows
  - ✓ Investment requirements by sector and region
- **Conclusions**
  - ✓ Key takeaways and policy implications

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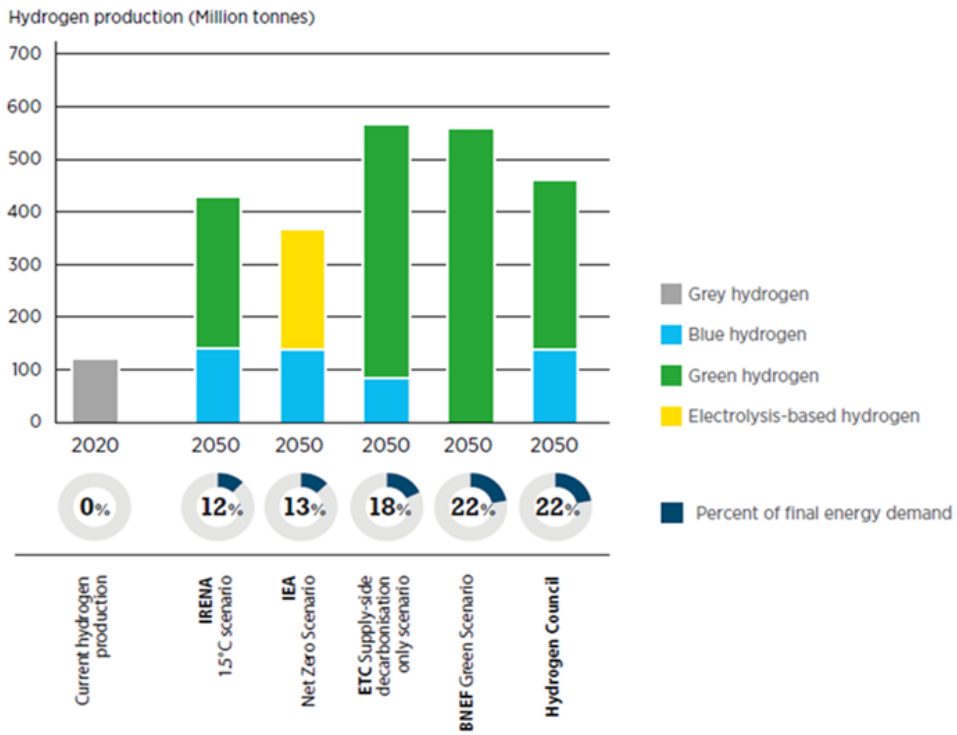
❑ Current Hydrogen Markets:

- ➢ Dominated by Fossil Fuels: over 95% of hydrogen production using natural gas, coal and oil (as a by-product)
- ➢ On-Site Industrial Consumption: produced and consumed on-site
- ➢ Leading Users: ammonia and oil refining sectors

❑ Future Hydrogen Markets:

- ➢ Renewable-based Production: rapidgrowth is expected driven mainly bynet-zero targets
- ➢ Other Key Factors: energy security, and the declining costs of renewable energy and electrolysis technologies



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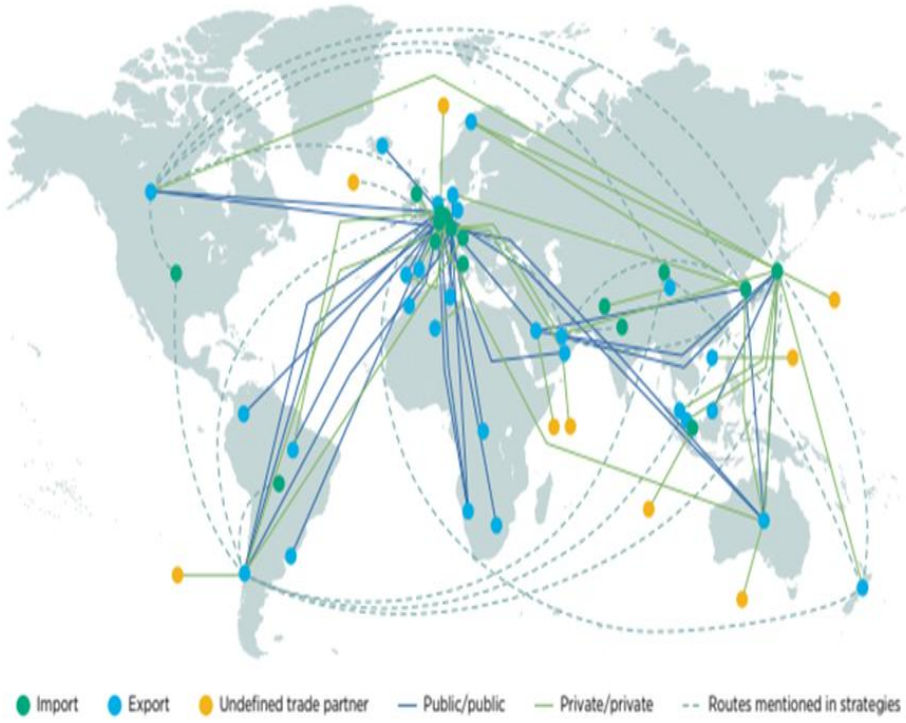
❑ Main drivers for international trade:

- ➢ Abundance of renewable resources
- ➢ Regional production costs advantages

❑ Early signs of global trade:

- ➢ Trade agreements: in recent years around 90 hydrogen trade agreements have been announced
- ➢ Most active as potential importers: Germany, the Netherlands and Japan
- ➢ Potential exporting countries: Chile, Morocco, Egypt, Saudi Arabia, Oman, Australia, and Spain and several others



Bilateral trade announcements for global hydrogen trade (source: IRENA, 2022)

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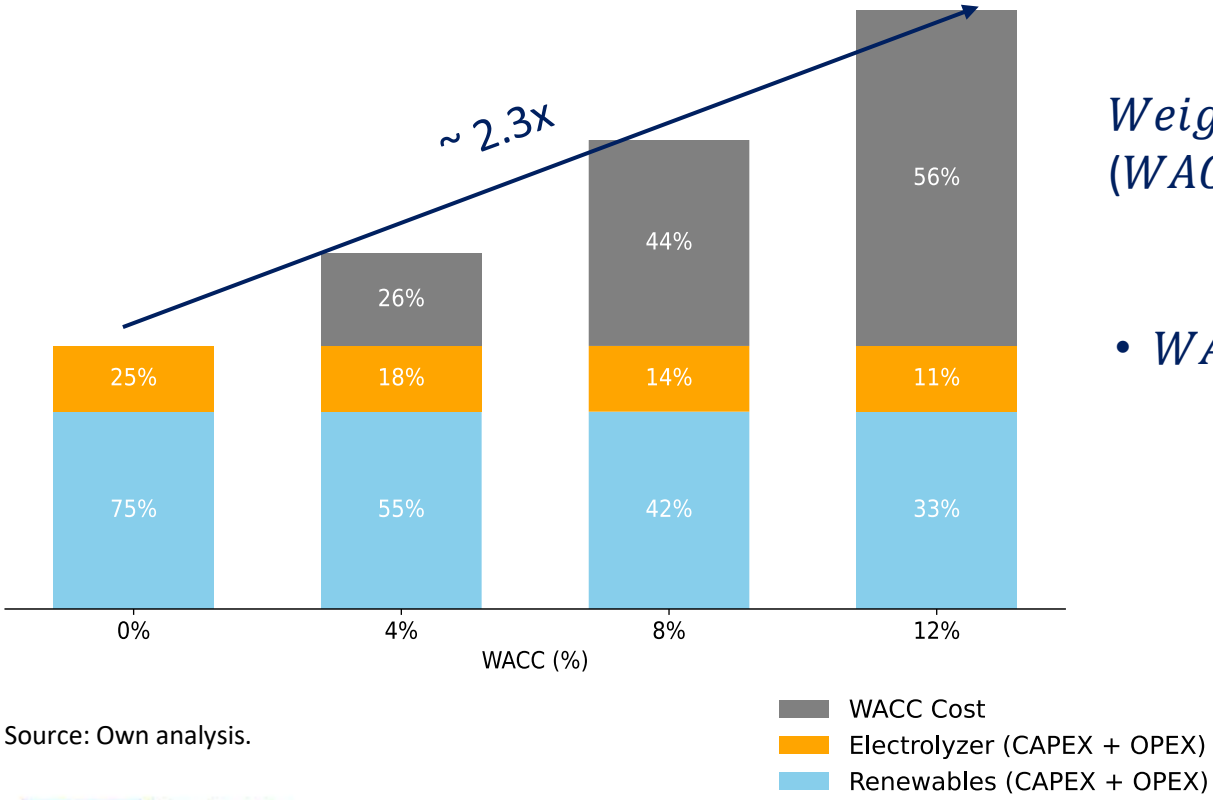
Renewable hydrogen projects are capital-intensive, making financing costs a critical factor in determining their competitiveness

Levelized cost of hydrogen (USD/kg)



Source: Own analysis.

Weighted Average Cost of Capital (WACC):

- $WACC = \underbrace{\frac{E}{E+D} \cdot C_E}_{\text{Equity Contribution}} + \underbrace{\frac{D}{E+D} \cdot C_D \cdot (1-T)}_{\text{Debt Contribution (after tax)}}$

where:

E : Market value of equity

D : Market value of debt

C_E: Cost of equity

C_D: Cost of debt

T : Corporate tax rate

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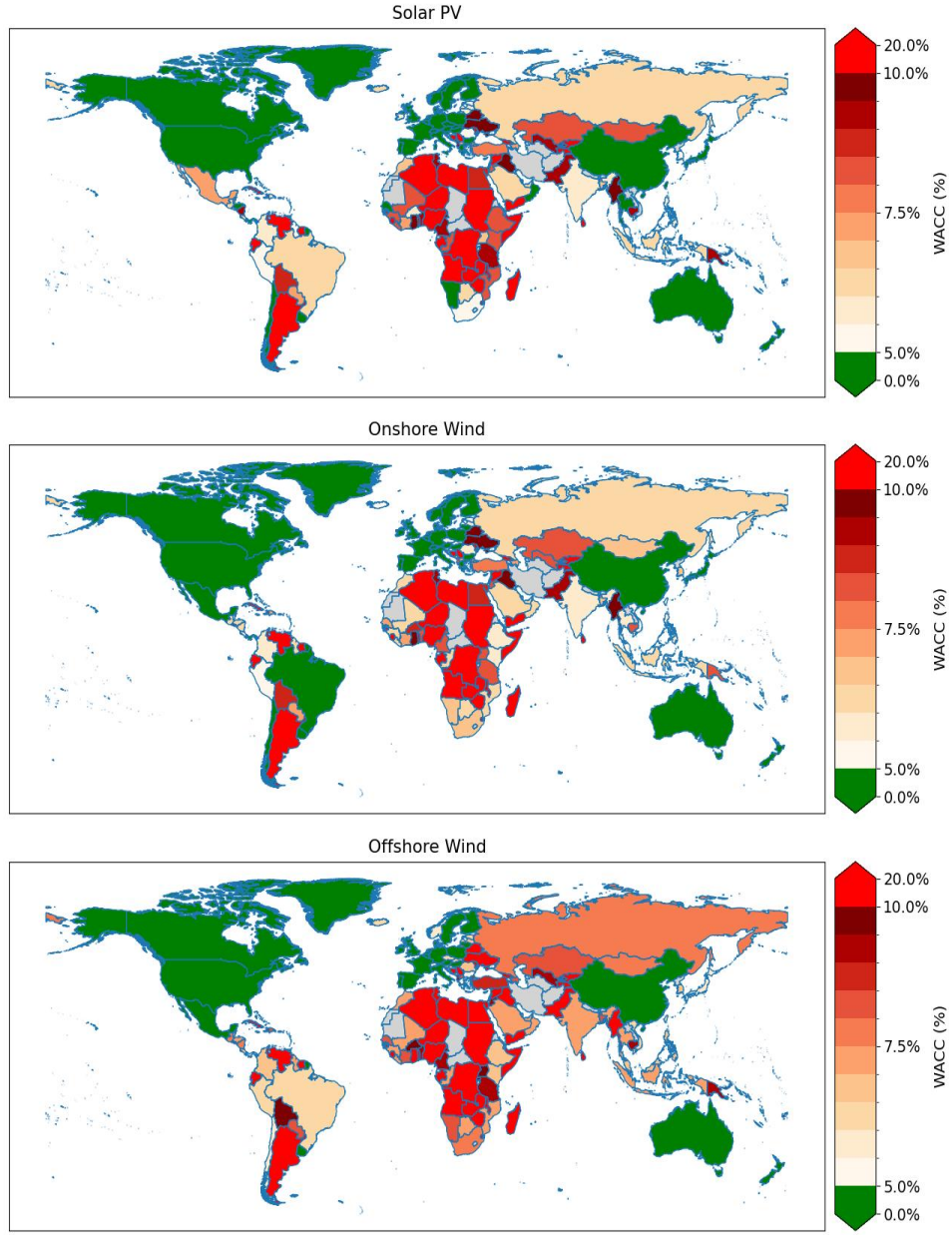
Data and Methodology: Country and technology-specific WACCs

- Reliable data has been long missing in the literature
- A uniform WACC is often assumed
- However, …

IRENA recently published WACC data based on expert surveys

- Developing countries face higher WACC
  - Despite abundant renewable resources, high WACC hinder their competitiveness
- Drivers for high WACC:
  - Real and perceived risks at country, technology and project levels



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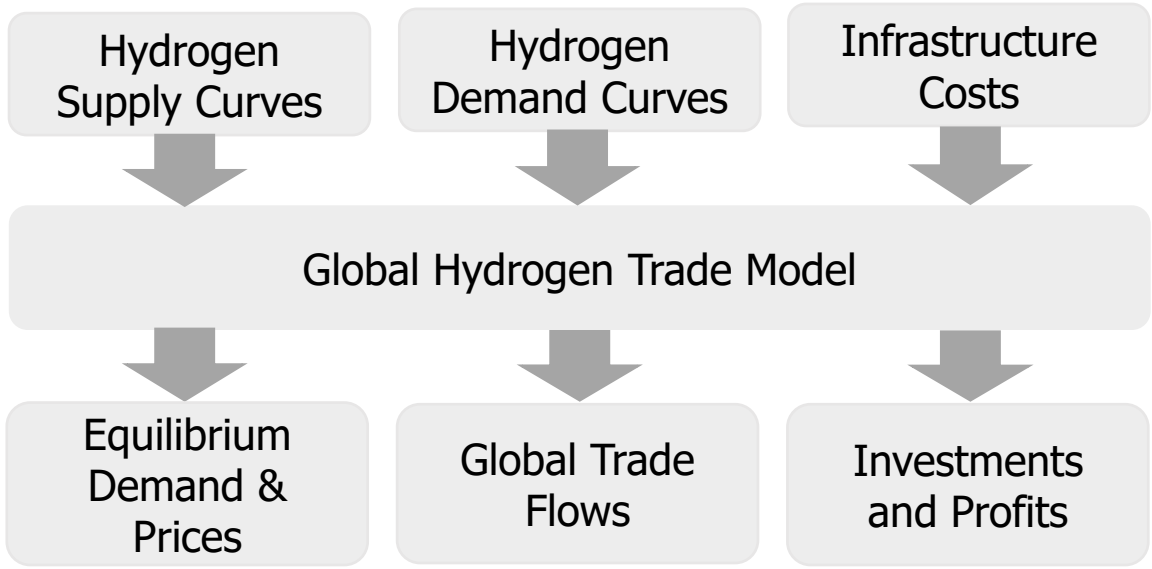
❑ Main components of the modelling framework:

- ➢ Hydrogen Supply Curves
- ➢ Hydrogen Demand Curves
- ➢ Infrastructure Costs
- ➢ Global Hydrogen Trade Model
- ➢ Profit maximization approach

❑ Scenario analysis:

- ➢ Given the high uncertainty in hydrogen market development and long-term WACC projections, scenario analysis helps assess trade and policy competitiveness



Simplified overview of the modelling framework

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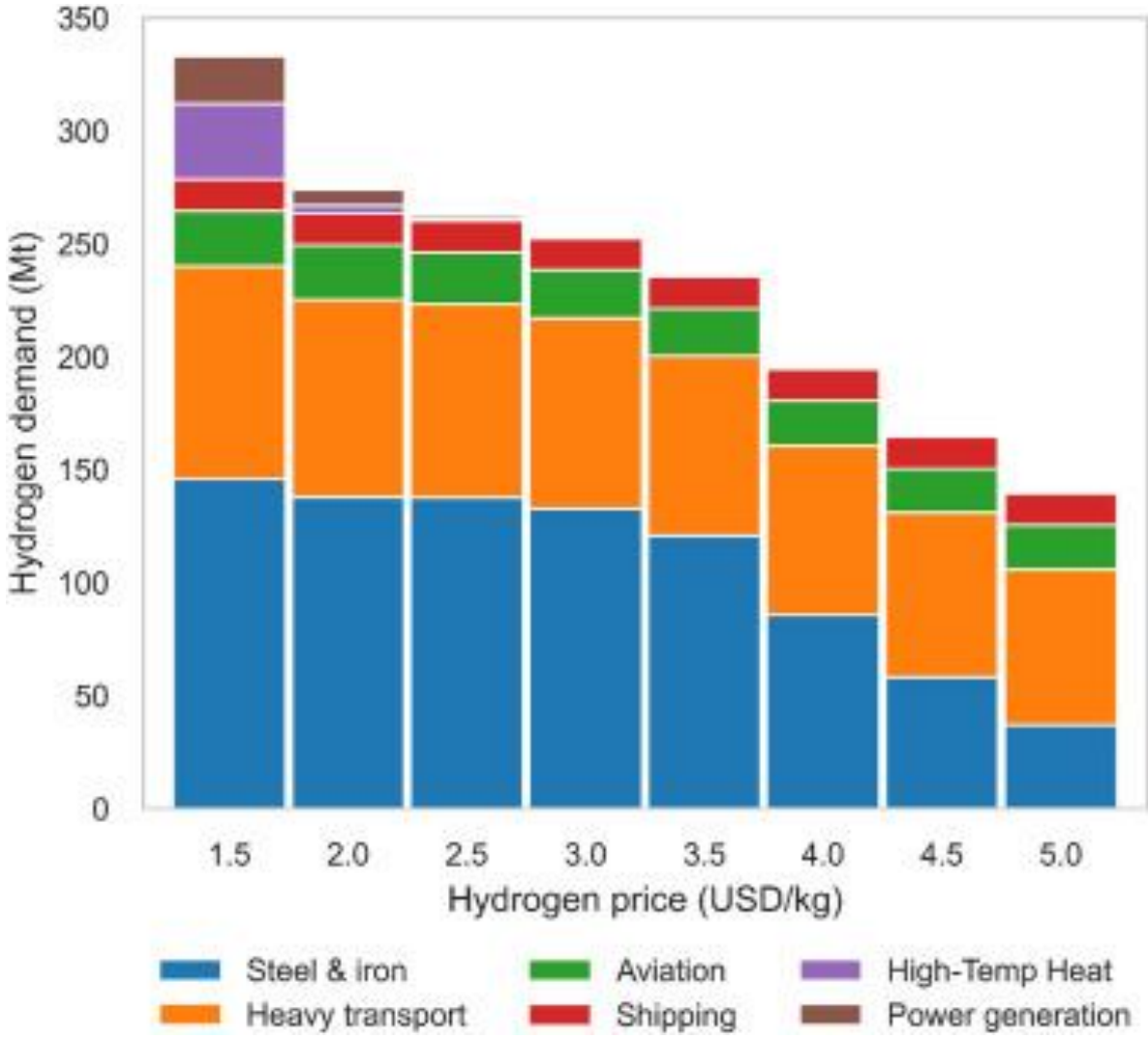
Hydrogen demand curve



Global hydrogen demand as a function of the assumed willingness-to-pay prices for the year 2050 in 1.5C Scenario

At 1.5 USD/kg, potential annual demand of 332 Mt is expected in 1.5 C scenario in 2050.

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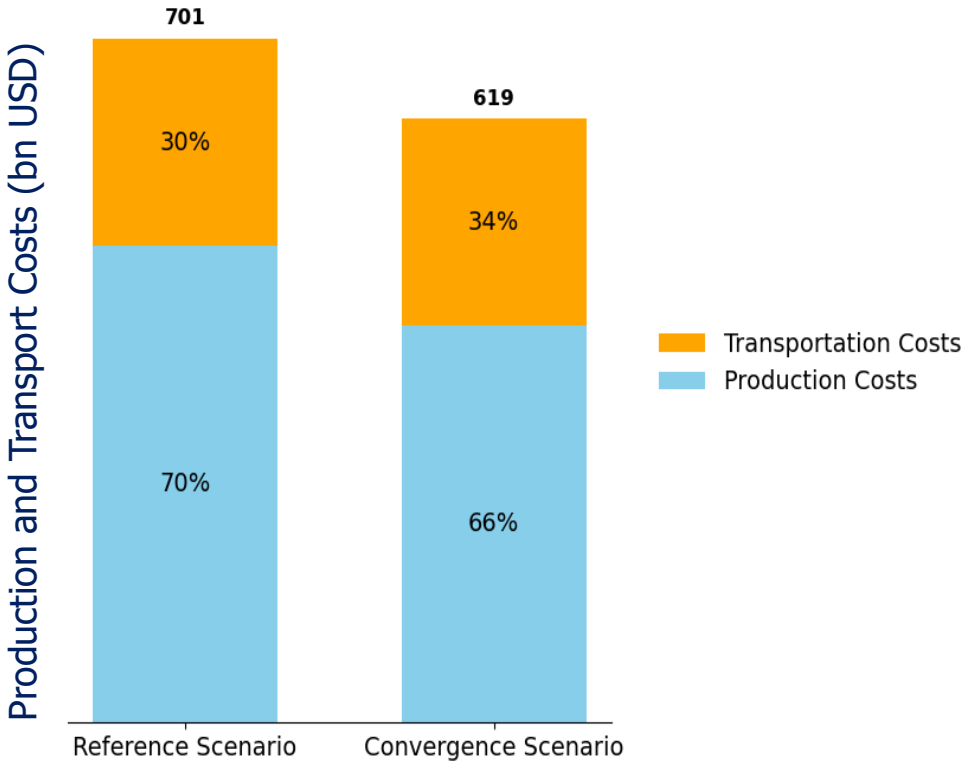
- We investigate two scenarios to assess hydrogen market development by 2050 under current and improved WACCs for developing countries

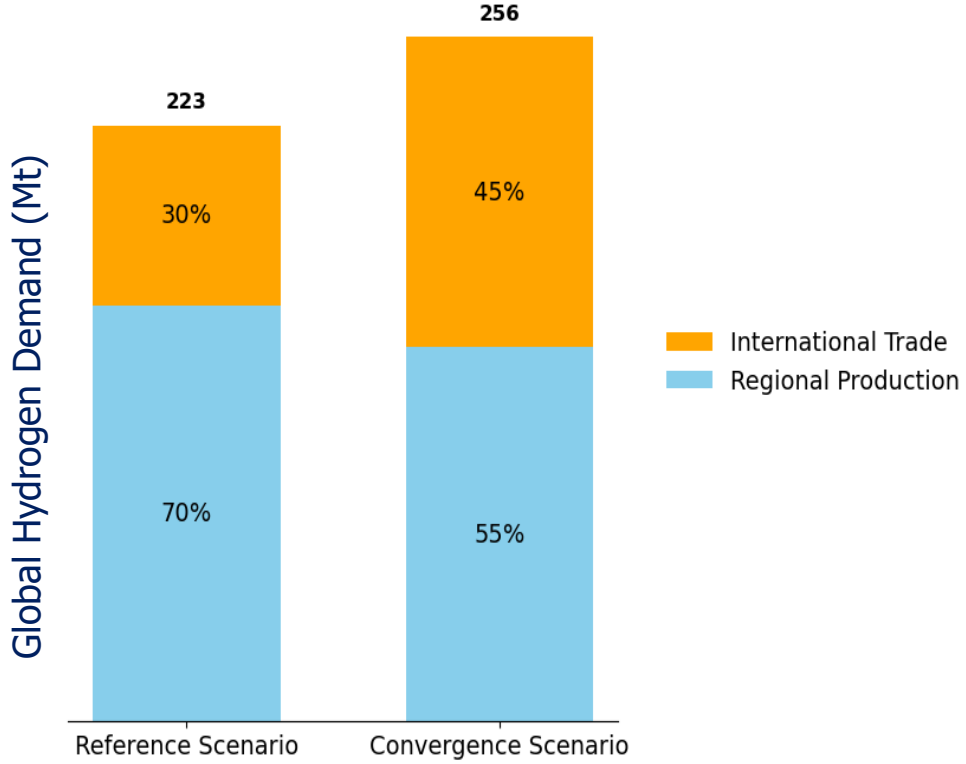
Scenario	Reference Scenario	Convergence Scenario
Scenario Objective	Analyse future hydrogen market development under existing country and technology-specific cost of capital	Analyse hydrogen market development assuming renewable-rich developing countries gain access to low-cost capital through multilateral banks, concessional financing, and other mechanisms
Regions Impacted	All regions	Africa, Middle East, Latin America, and Developing Asia
Renewables Investments	Based on current WACC data	Assumes WACC values matching the lowest observed data (e.g., Germany): Solar PV: 1.25% Onshore wind: 1.25% Offshore wind: 2.5%
Electrolyser and infrastructure investments	Electrolysers incur a 5% premium, while infrastructure (pipelines, storage, shipping) follows the same cost of capital as electrolyser projects	

Comparing cost savings, global demand, and trade between the Convergence and Reference Scenarios

Cost savings of **82 bn USD** annually is achieved



Global demand increases by **33 Mt** annually and international trade rising by **15%**



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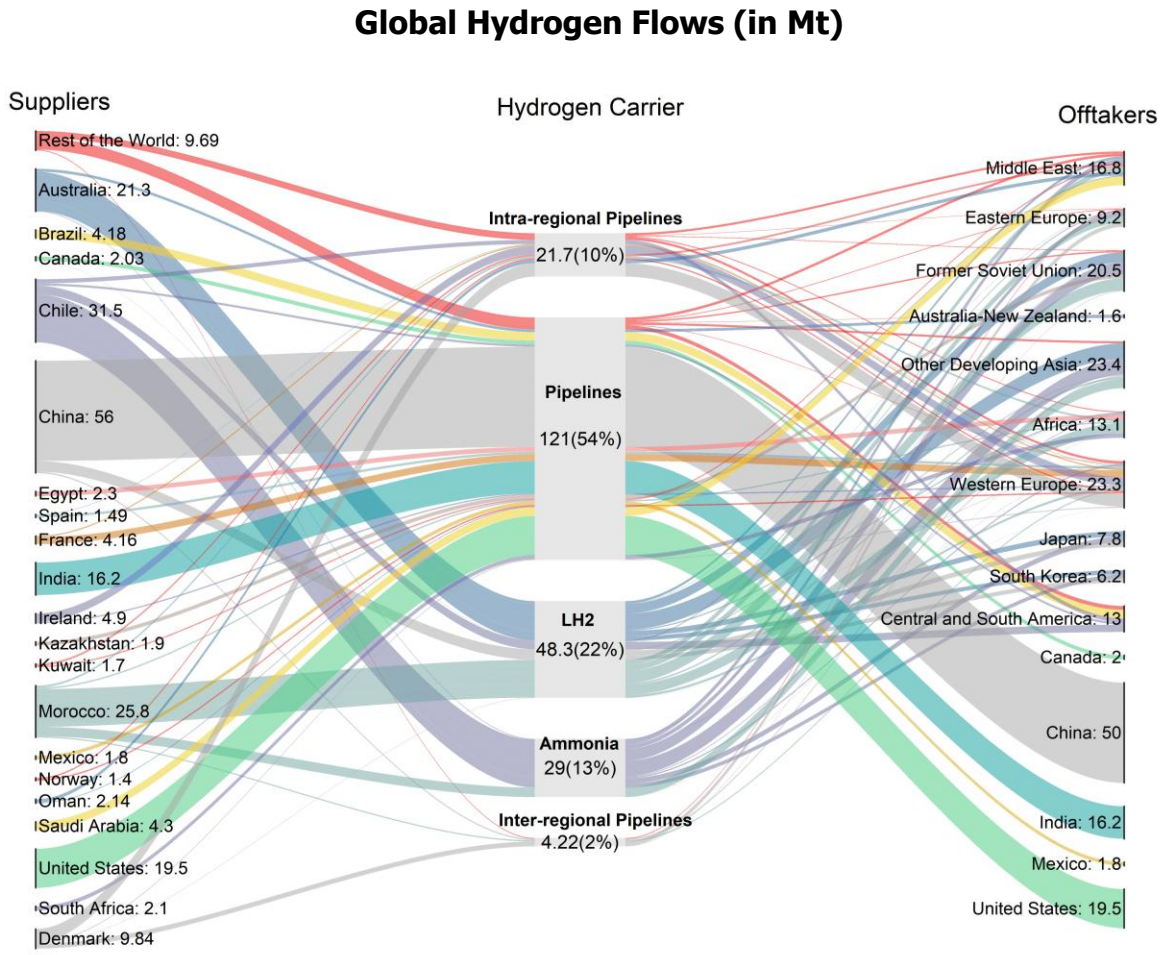
❑ Global hydrogen flows

- ➢ Pipelines are the primary hydrogen carrier followed by LH2 and ammonia
- ➢ Major exporters : Australia Denmark



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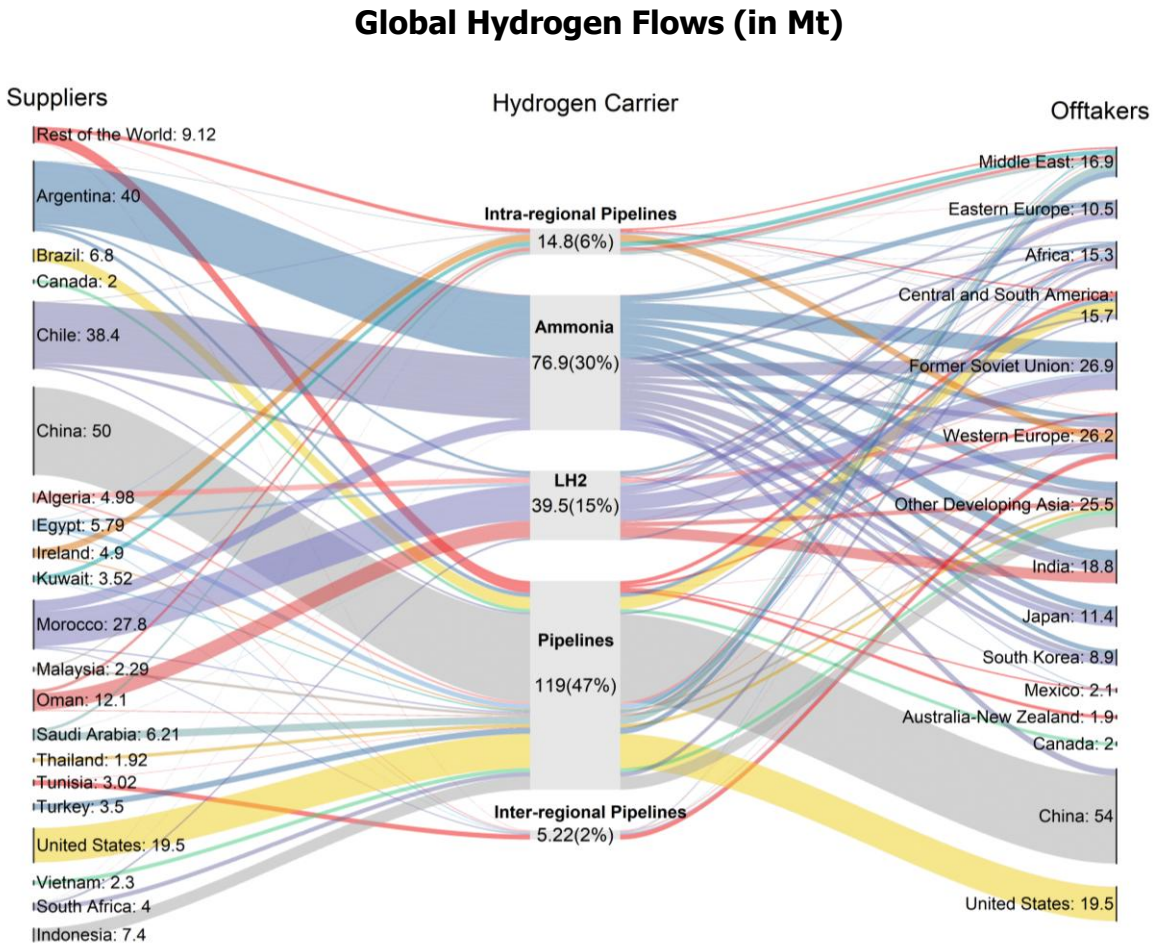
❑ Global hydrogen flows

- ➢ Increased role of hydrogen shipping with ammonia and LH2 compared to the Reference Scenario
- ➢ Exporting countries such as Australia, China, USA, Denmark see their role diminish in the Convergence Scenario and
- ➢ A new hydrogen exporters emerge in MENA and Latin America



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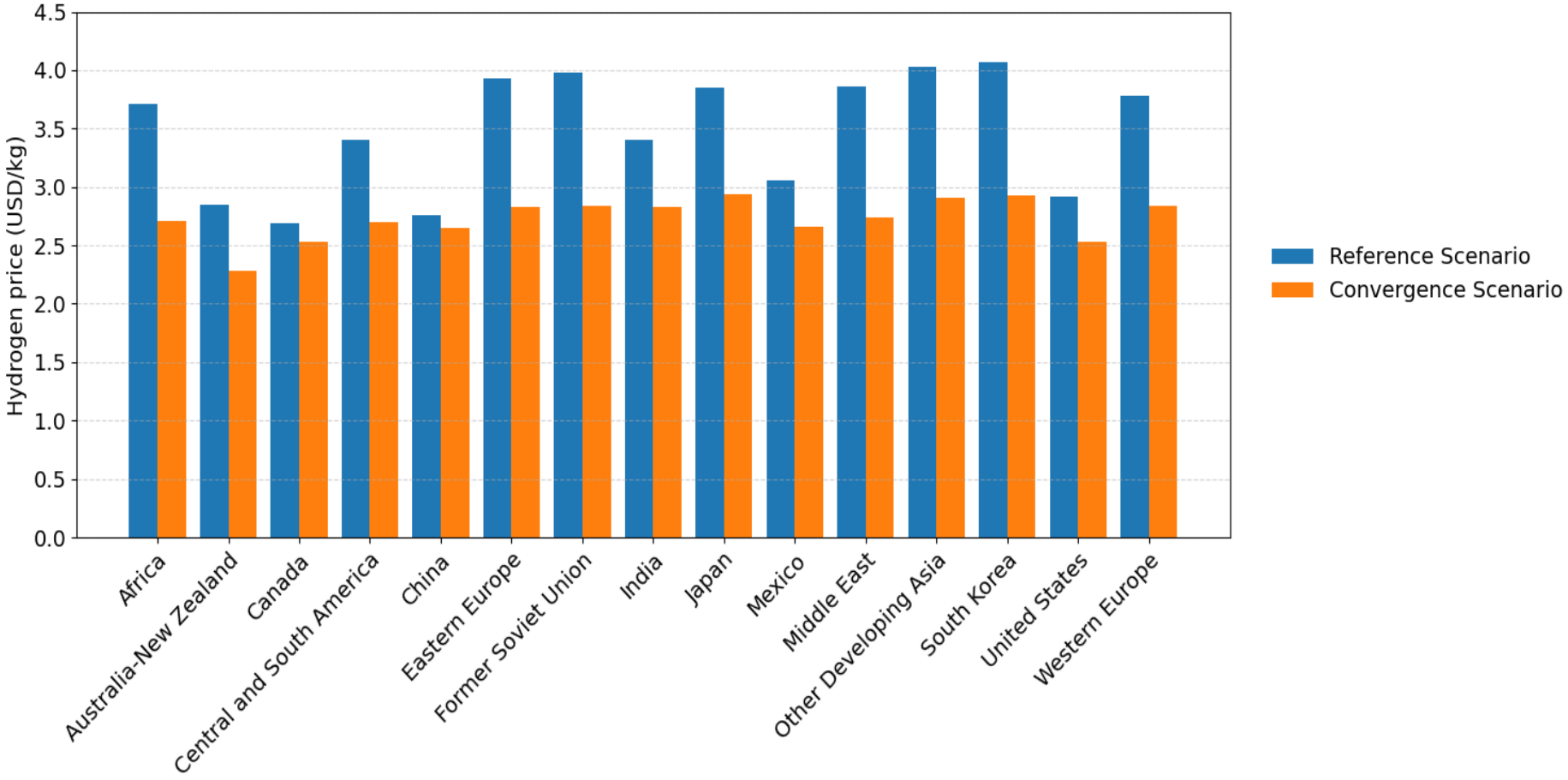
Prices vary significantly across scenarios, with global average prices at $3.5/kg in the Reference Scenario and $2.7/kg in the Convergence Scenario



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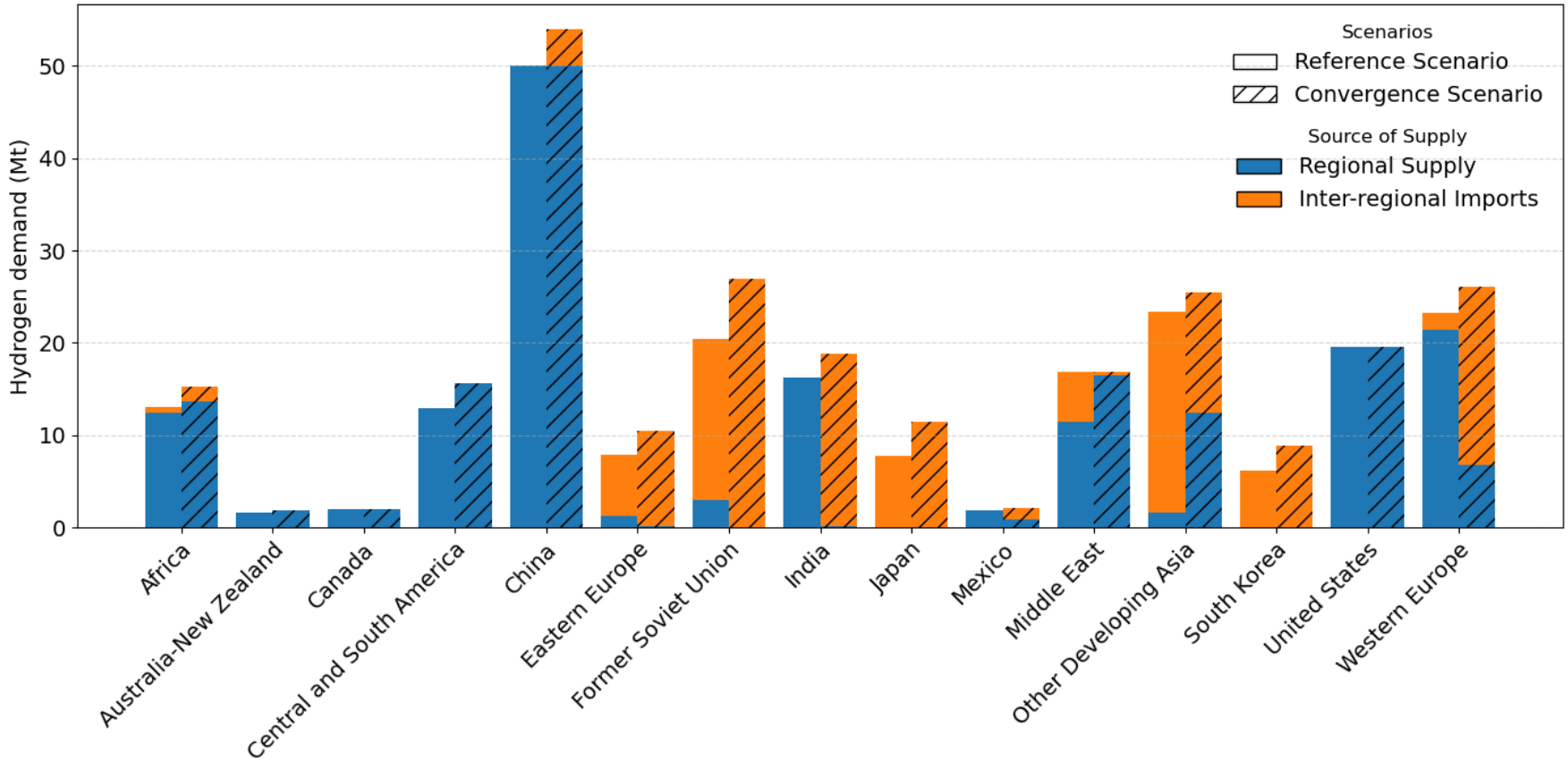
Demand grows across most regions, with a notable shift toward inter-regional imports, especially in Europe, India, and Other Developing Asia



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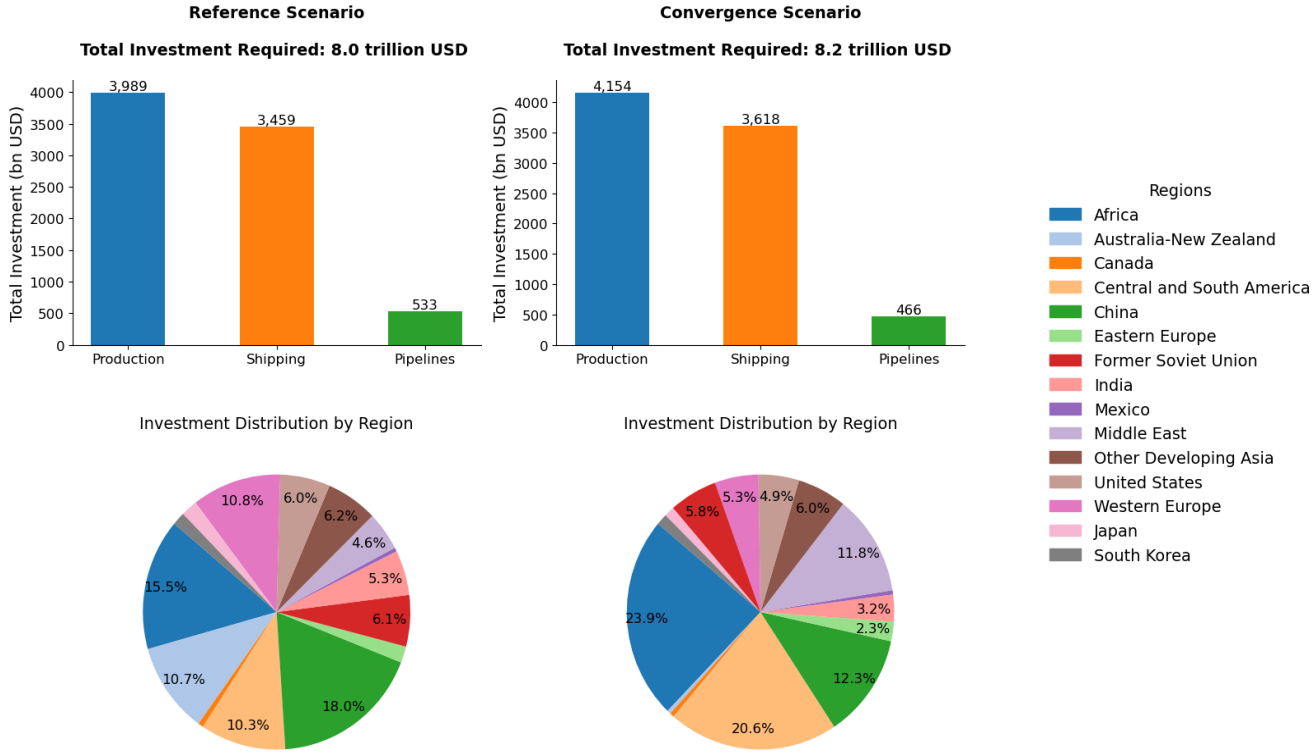
Cumulative investment required by 2050 is $8 trillion in the Reference Scenario, increasing to $8.2 trillion in the Convergence Scenario

- $200 billion increase in the Convergence Scenario driven by a 15% rise in hydrogen demand
- Investments shift from Australia, Western Europe to MENA and Latin America regions
- Hydrogen pipelines require significantly lower investments compared to shipping



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- High financing costs **hinder** hydrogen trade competitiveness, especially in developing regions
- Access to low-cost financing in developing countries can unlock significant **trade potential** and **cost savings**
- Recommendations for stakeholders:
  - **For Policymakers:** Policies to reduce financing costs (e.g., multilateral bank support, concessional financing) are critical to boost global hydrogen market
  - **For Investors:** Significant opportunities for export-oriented renewable hydrogen projects in MENA and Latin America if high financing costs are addressed
- Further research directions:
  - Explore **region-specific policies** to address financing challenges, including real and perceived investment risks
  - Address **uncertainties in long-term WACC projections** by integrating macroeconomic models with hydrogen trade models

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Thank you!

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