

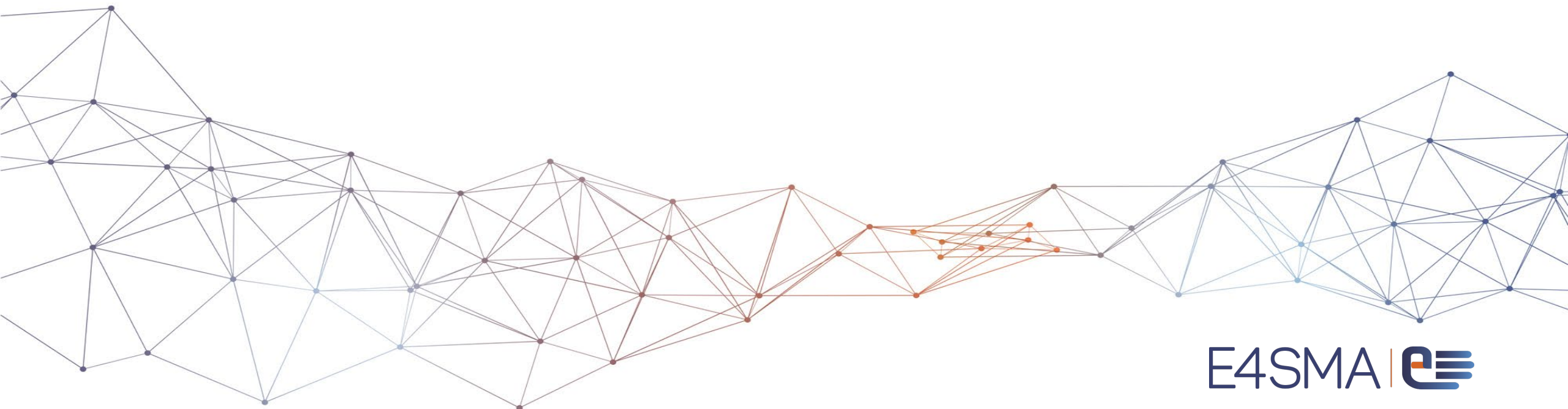
Hydrogen Trade Prospects and Transport Modelling with TIMES-GEO Global Model

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Introduction

Why this analysis?

- To not miss the chance of achieving a **well-below 2 degrees Celsius**, the energy sector is called for a **change in its fundamentals**, achieving net-zero emissions.
- Renewables are the raising star of the energy markets, but still many regions remain **heavily reliant on fossil fuels**.
- **Electrification** has been proven an effective measure to increase efficiency and reduce emissions. However, one solution does not fit all.
- **Hard-to-abate sectors** (aviation, shipping, heavy industry) are facing increasing **pressure to decarbonize**, with limited room for electrification.
- **Hydrogen-based fuels** may play a significant role for these sectors, contributing to the achievement of net-zero goals.
- **Energy trade** plays a critical role in ensuring the efficient allocation of energy resources across regions with varying production capacities and demand levels.

Study objectives

- **Assess future hydrogen demands and available supply options**
- Explore energy markets transformation, particularly analysing **hydrogen trade flows** and regional cooperation under a **1.5°C scenario**

Methodology

Scenario-based integrated assessments

- The analysis employs the **TIMES-GEO** model, an integrated global energy system optimization model (ESOM).
- The model was originally developed in 2022 by E4SMA (Italy) and University College Cork (Ireland) within the [Chimera](#) project, research project funded by the Science Foundation Ireland and National Science Foundation of China.
- TIMES-GEO is the first of a kind fully **open-access** model:
 - Full model: <https://github.com/MaREI-EPMG/TIMES-GEO>
 - Zenodo: <https://doi.org/10.5281/zenodo.14999069>
 - Documentation: https://www.i2am-paris.eu/detailed_model_doc/times-geo
- It enables high-resolution **scenario analysis** to identify least-cost pathways towards policy and climate goals.

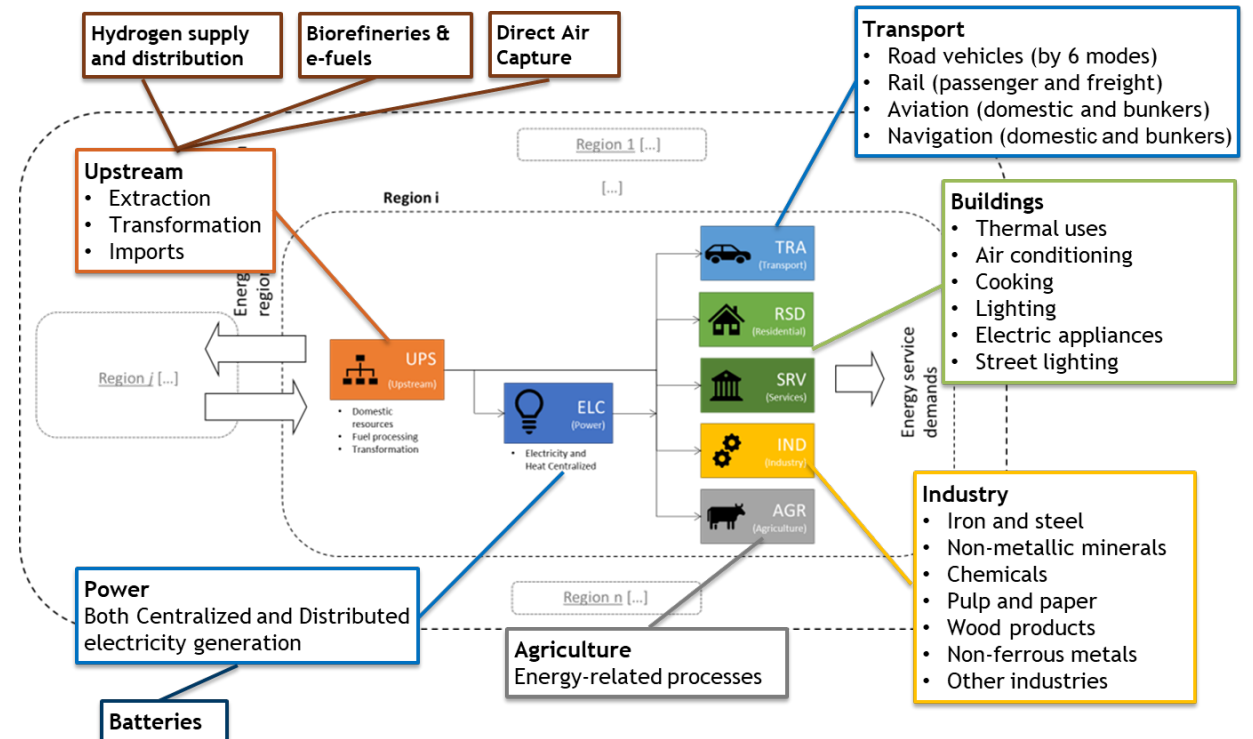
TIMES-GEO

Overview



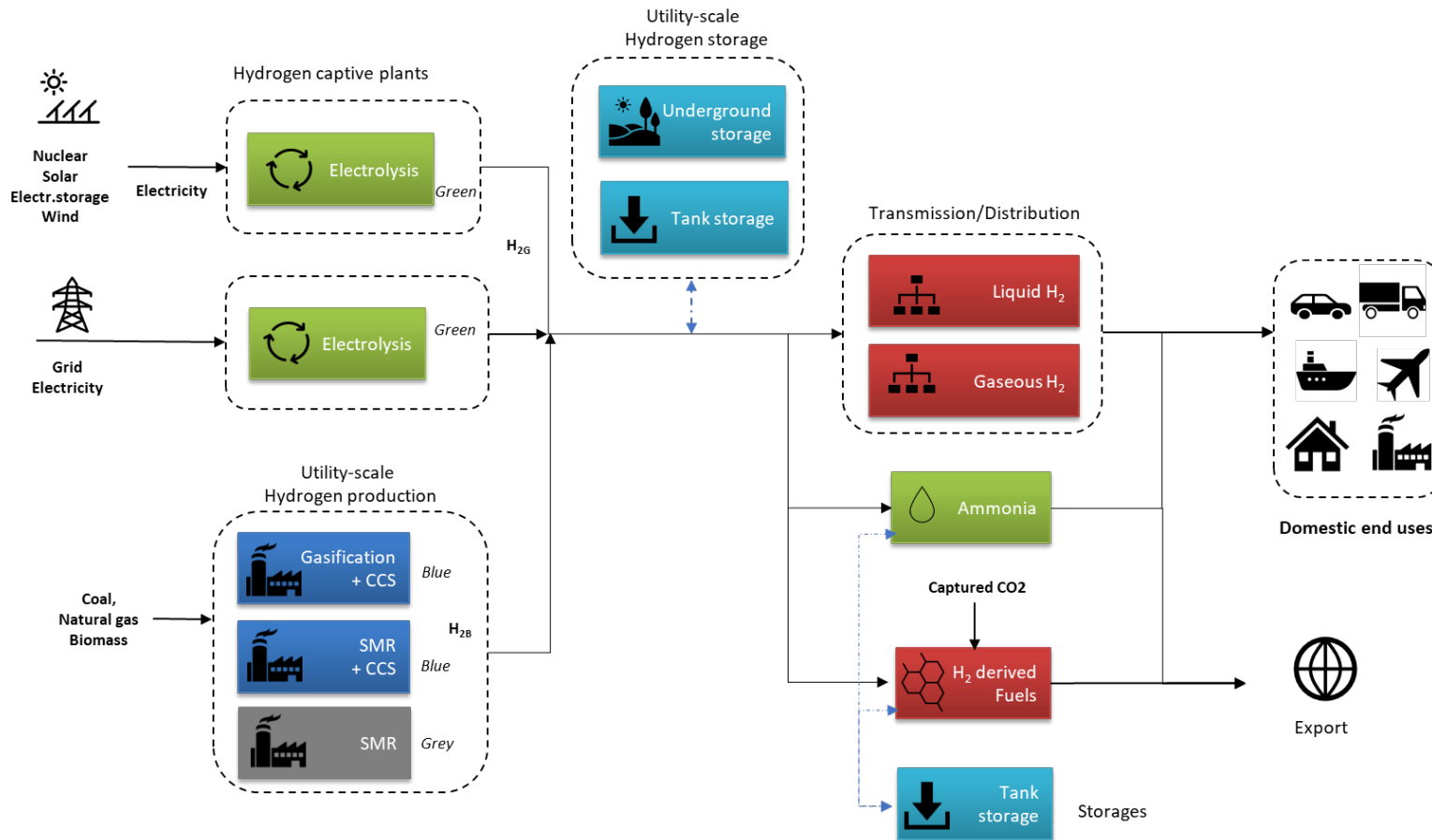
Highlights

- Employs most reliable **open-access data sources**
- 31 regions (16 individual countries and 15 regional aggregates)
- Scenarios up to 2100
- Includes a wide range of energy commodities:
 - Electricity
 - Fossil fuels
 - Biomass and biofuels
 - Hydrogen & other synfuels
- Technology-rich: ~1000 technologies
- Dedicated modules for most innovative mitigation technologies:
 - Hydrogen supply and transformation
 - Biorefineries and e-fuels
 - Direct Air Capture
 - Batteries



TIMES-GEO

The hydrogen module



Highlights

End-to-end modelling:

- Production
- Storage
- Conversion
- Transport

Production pathways:

- Grey H₂: gasification, SMR
- Blue H₂: as grey + CCUS
- Green H₂: electrolysis (PEM & Alkaline)

Applications:

- Direct use (industry, transport)
- Ammonia (NH₃)
- Liquefaction
- Synthetic fuels (H₂ + CO₂)

TIMES-GEO

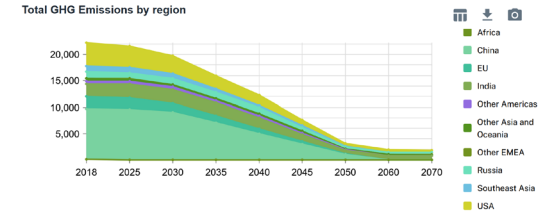
Enhanced trade module

- For this assessment, the model has been equipped with a new custom **Trade Module**.*
- Characterizes with much detail:
 - Existing and possible trading routes
 - Route-specific cost assessments
- Based on an extensive data collection and comparison of the available literature and open data.
- Given the uncertainties related to shipping routes and possibility of rerouting existing gas pipelines, two alternative scenarios are analysed:
 - Key hydrogen routes
 - Extended hydrogen routes

Component	Source
Hydrogen trade cost	IRENA (2022), Global hydrogen trade to meet the 1.5°C climate goal: Part I
Comparison of transport costs between different hydrogen vectors (H2L, methanol, ammonia)	Evaluation of hydrogen shipping cost for potential trade routes (Chen et al. 2025), WMU Journal of Maritime Affairs.
Freight rates and routes for crude oil and refined oil products	Argus Tanker Freight report 2024
IEA hydrogen infrastructures	IEA hydrogen infrastructure database
Gaseous Hydrogen infrastructure costs	Analysing future demand, supply, and transport of hydrogen, European Hydrogen Backbone (EHB) 2021

* Credits to Claudio Di Tuccio, who has been responsible for the data collection, elaboration and setup of the module.

Scenarios



Pathway: The model simulates energy **net-zero pathways**, consistent with the achievement of a well-below 2 degrees scenario, largely reflecting **NDCs and long-term pledges** under the Paris Agreement.



Scenario assumptions include international fossil fuel prices from the IEA, SSP2 demand and population trends, IPCC emission factors, etc.



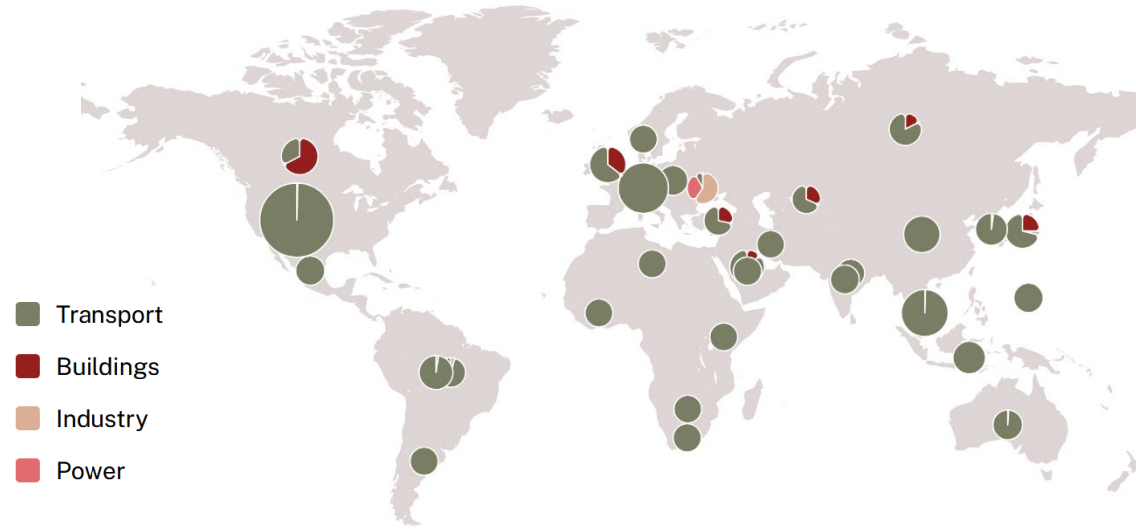
Scenario variants differing for available international trading options:

- i) **Key H₂ routes**
- ii) **Extended H₂ routes**

Results

Hydrogen demands (Key Routes scenario)

H₂ demands (2050)

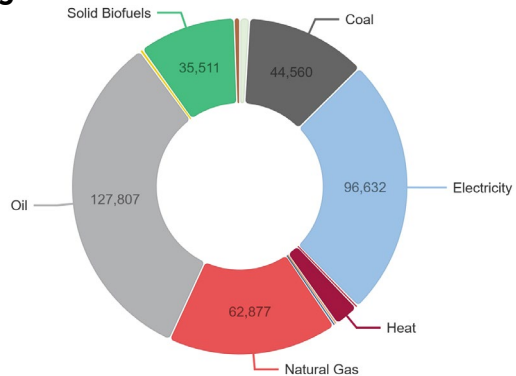


Highlights

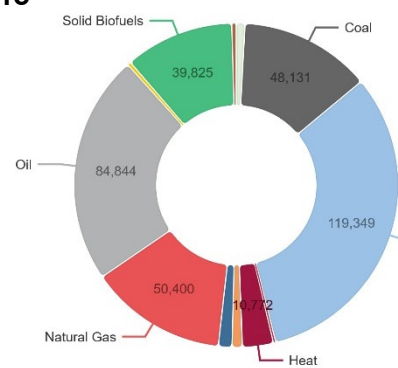
- H₂ and H₂-derived fuels are expected to account for 2.3%, 9.4% and 11.5% of global energy demand by 2040, 2050 and 2070.
- By 2050, US (~28%), EU (~21%) and South-East Asia (~12%) are the most prominent H₂ markets.

Final energy consumption (EJ)

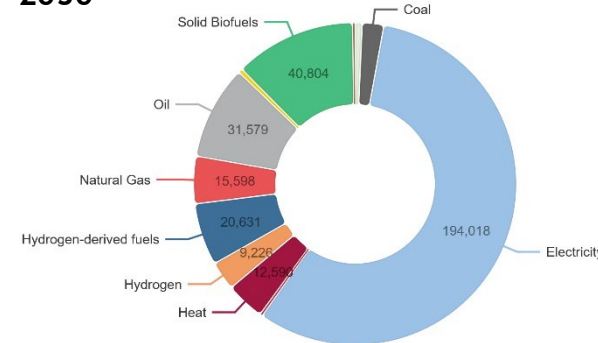
2025



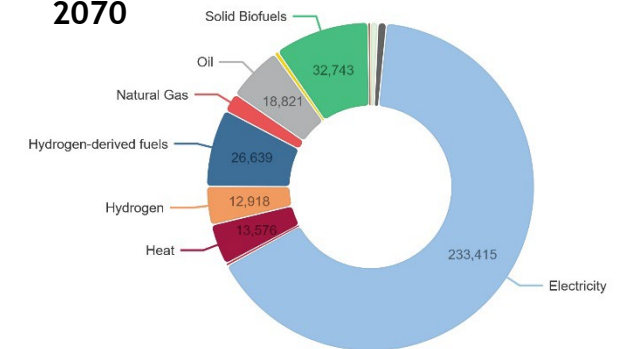
2040



2050



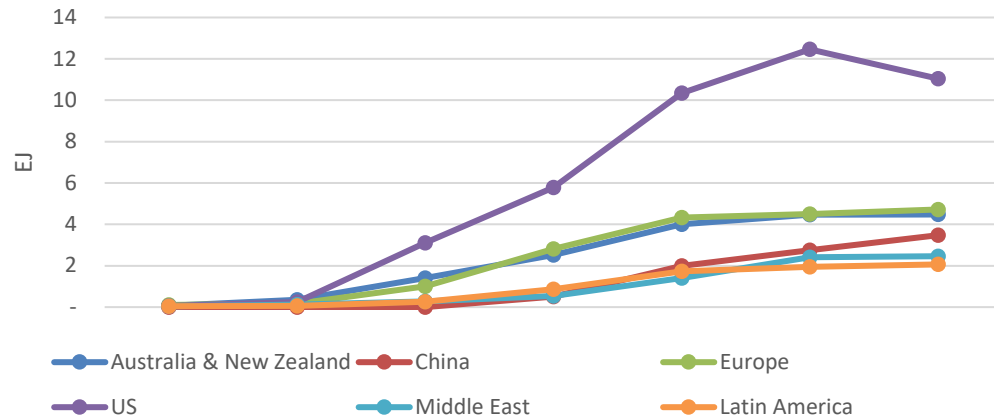
2070



Results

Hydrogen supply (Key Routes scenario)

Top 6 hydrogen producers



Highlights

- H₂ production reaches ~30 and 39 EJ by 2050 and 2070.
- Results shows competition between blue and green production route, (75%-25% by 2050, 50%-50% by 2070) highly influenced by technology learning, availability of cheap gas and renewable potentials. Extended trade shows a more pronounced production from green routes (54% in 2070).
- US, Australia, EU and China are shown as the main global supplier of H₂ in 2050. Middle East and Latin America follows.

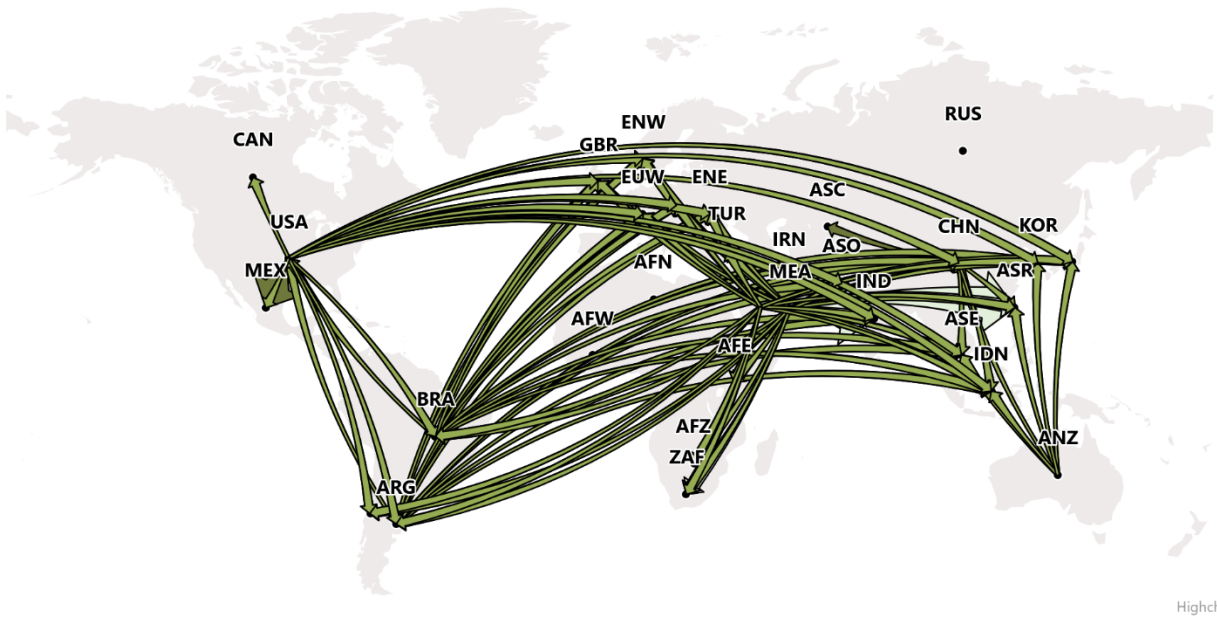
Global H₂ supply (2050)



Results

Hydrogen trade (Key Routes scenario)

Main Hydrogen trade routes (2050)



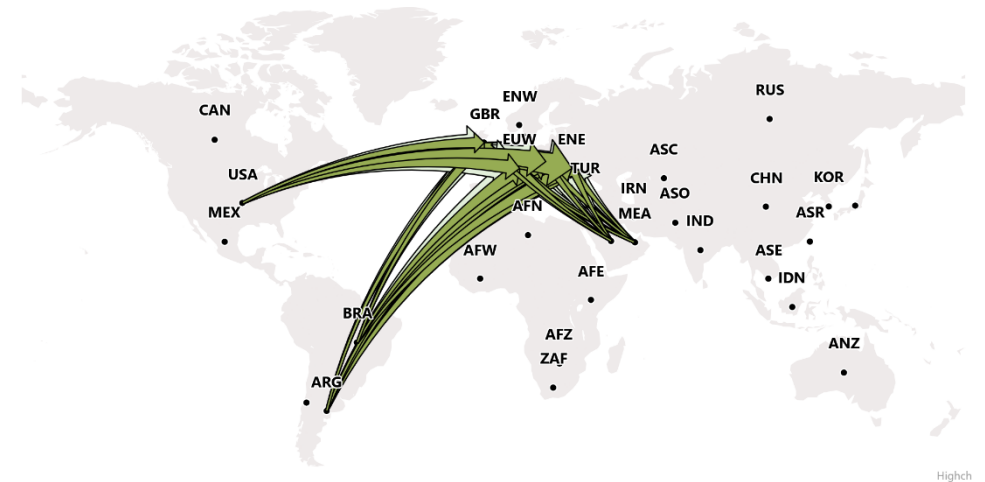
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Highlights

- In this context **Australia, US, China and Latin America** are the emerging as key exporting countries, primarily driven by fossil and renewable resources.
- Main importers of H₂ and derived fuels are **South-East Asia, Europe and South Asia** (Japan & South Korea), accounting approx. for 62%, 23%, and 16% of global imports
- For Europe imports accounts approx. for 15% of 2050 hydrogen demand

Trade patterns to Europe (2050)

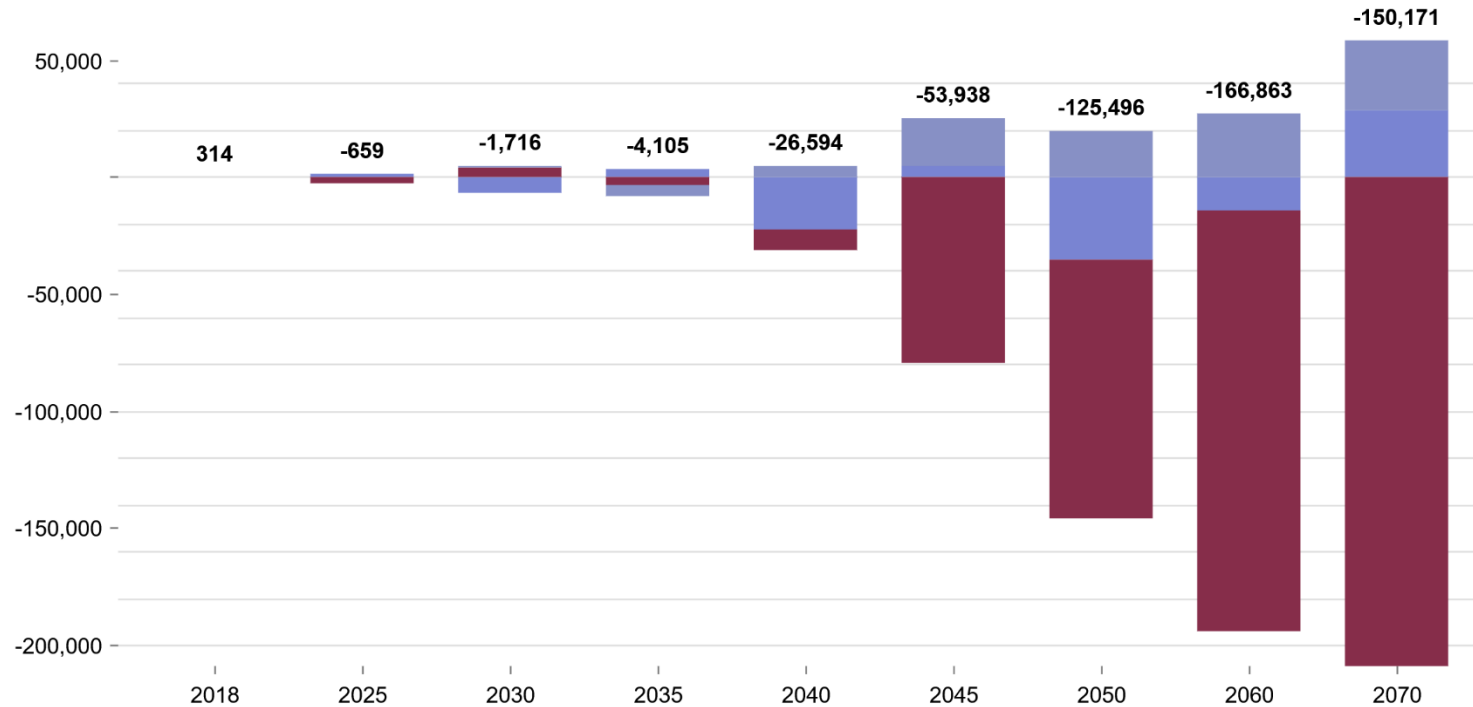


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Results

Market opening (Key vs Extended routes)

Comparing scenario costs (MUSD)



Highlights

- Open hydrogen markets drive higher investments, but at the same time contribute in reducing fuel supply costs

- Annualized investment cost
- Fuel supply cost
- O&M cost

Discussion

- Hydrogen and its derivative plays a **pivotal role** in the achievement of net zero goals, contributing (along with other strategies such as renewables, electrification, efficiency) decarbonising hard-to-abate sectors, such navigation, heavy industries and buildings.
- Results indicate that this growing hydrogen demand can be largely met by **internal markets**, but **international trade** of hydrogen can accelerate and make more efficient meeting this demand.
- Countries like **Australia, the US and China** are seen as the main potential exporter actors, given their availability of unexploited fossil and renewable resources.
- The extended routes scenario shows that an increased **integration between markets** drives to more efficient transition patterns, contributing to reducing prices.

Conclusions and next steps

- TIMES-GEO is a powerful platform for shaping future energy strategies and support evidence-based policy-making. This study demonstrates how the model can reveal **investment opportunities**, guide **strategic development**, and assess **technology transitions**.
- Yet its full potential grows through community engagement. Its value lies not only in the tool itself, but in how it is used and expanded by its users.
- TIMES-GEO has recently been adopted by the Horizon Europe-funded “[DIAMOND](#)” project as the foundation for developing **OMNIA**, a new-generation open-source integrated assessment model.



As an open initiative, we invite modellers, energy experts, and policymakers to **join us, collaborate, and co-create** the next generation of global energy insights.

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