

Hydrogen Market Attractiveness Rating (HyMAR)

April 2023

Part of the European Hydrogen Market Service

Redacted Version





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- **European Hydrogen Markets Attractiveness Report (HyMAR):** Hydrogen market sizing, and demand scenarios by country and sector
- **APAC Biannual Hydrogen Market Reports:** Summary of policy developments with a deep-dive on Australia
- Global electrolyser project database
- Analysis of demand and supply drivers



Investment Case Analysis

- Hydrogen production economics based on our in-house power, gas, and carbon price forecasts
- Forecasted Hydrogen prices out to 2060



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Explore scenarios through EOS, our dynamic online platform, featuring a full library of reports & datasets.

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Regular insight reports on topical issues in the evolving hydrogen market covering country, policy, and technology deep dives



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- Regular updates on hydrogen policies and incentives across power, heat, transport, and industry
- Thought leadership on required policies and incentives to grow the hydrogen sector



Group Meetings

- Presentation of the most recent market reports
- Networking opportunity with developers, investors, & Governments—the 'go-to' roundtable to discuss hydrogen developments



Analyst Support

Biannual workshops and support from our bank of analysts, including native speakers and on-the-ground experts

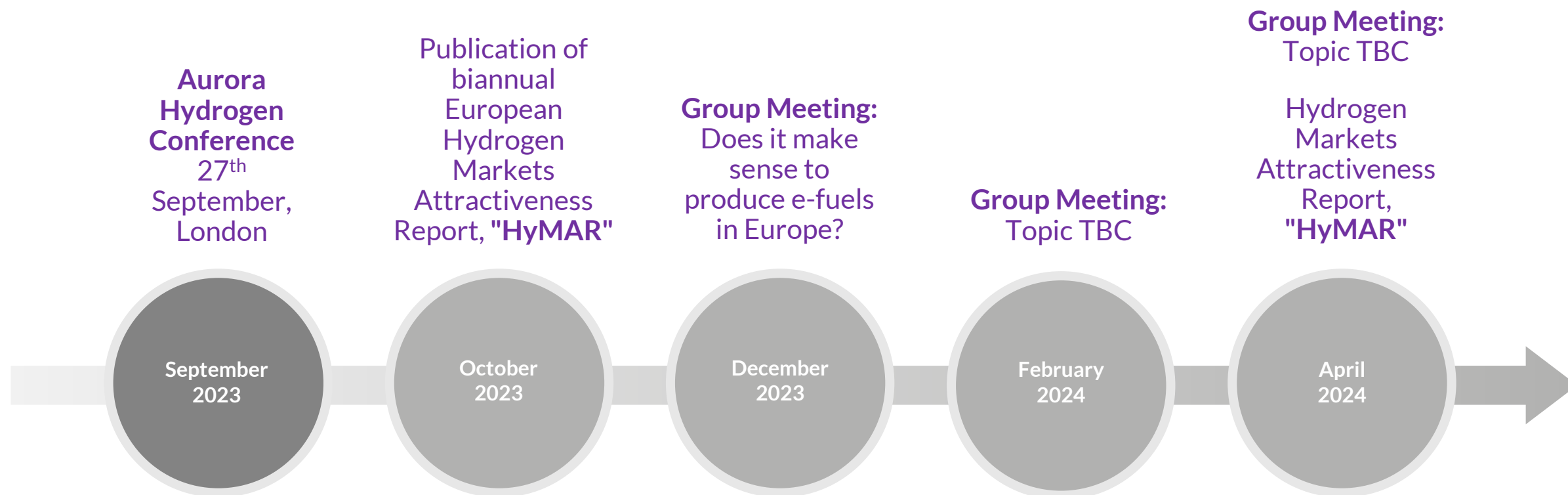
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What's coming up for the Hydrogen Market Services?

EUROPEAN Hydrogen Market Service



Discover the major players across the value chain subscribing to our **European Hydrogen Market Service**

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Supply Chain



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Government & regulation



Upstream gas & networks



I. Hydrogen Market Attractiveness Rating (HyMAR)

II. Aurora's global electrolyser database

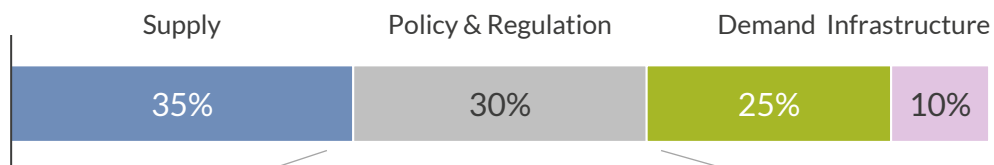
III. Low-carbon hydrogen prices

Aurora's Hydrogen Market Attractiveness Rating (HyMAR) condenses down many indicators into an overall attractiveness score

How do we score countries by their attractiveness?

Aurora's Hydrogen Market Attractiveness Rating (HyMAR) combines indicators to derive an overall attractiveness score

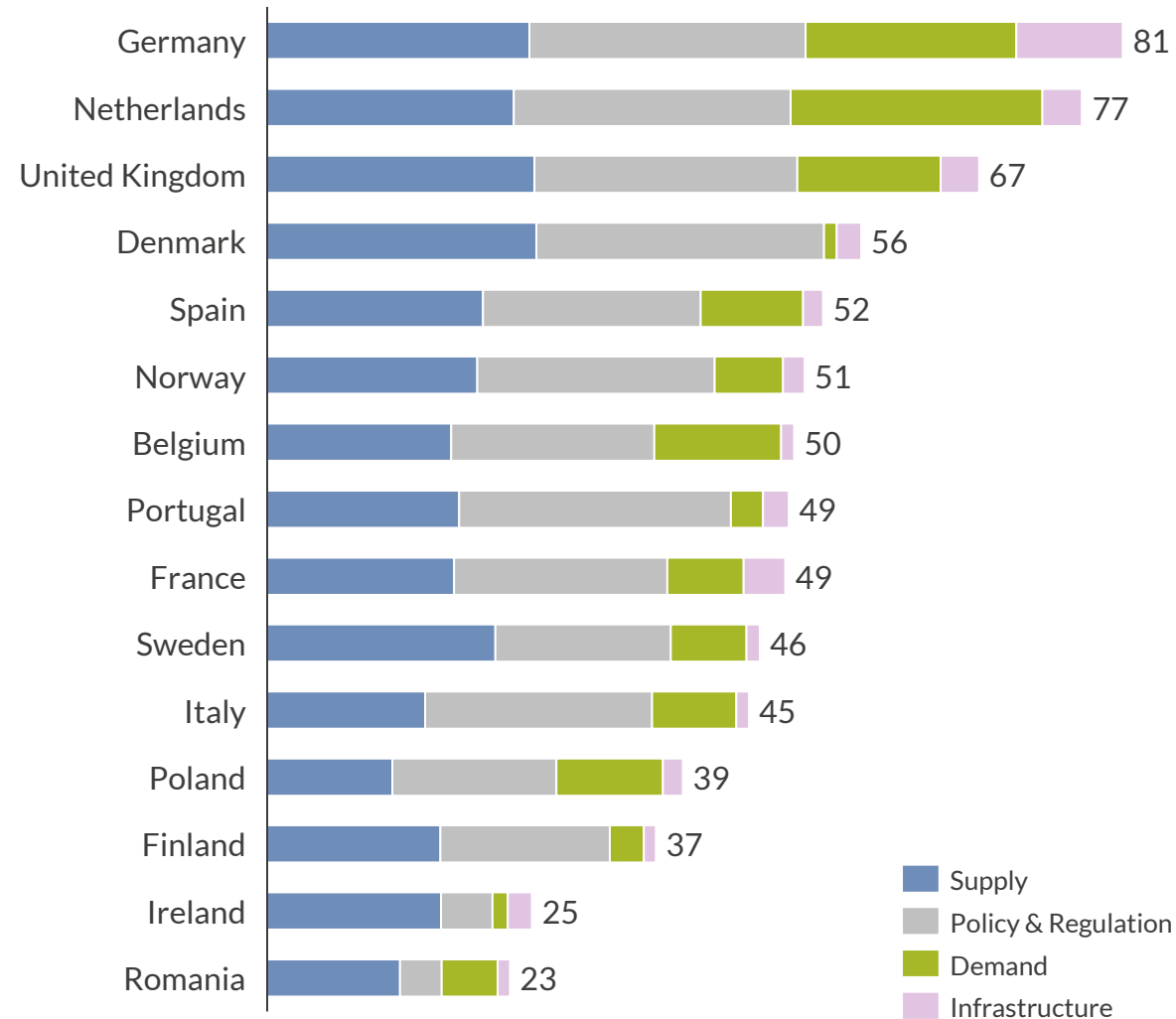
- We use 23 metrics for the assessment¹
- These metrics are structured around four top-level categories: Supply, Demand, Policy & Regulation and Infrastructure



Within policy & regulation we include five metrics
















- National hydrogen strategy
- Policy incentives on supply side
- Policy incentives on demand side
- National budget
- Existing legal and administrative barriers

Overall scores of countries by major categories consider in the analysis

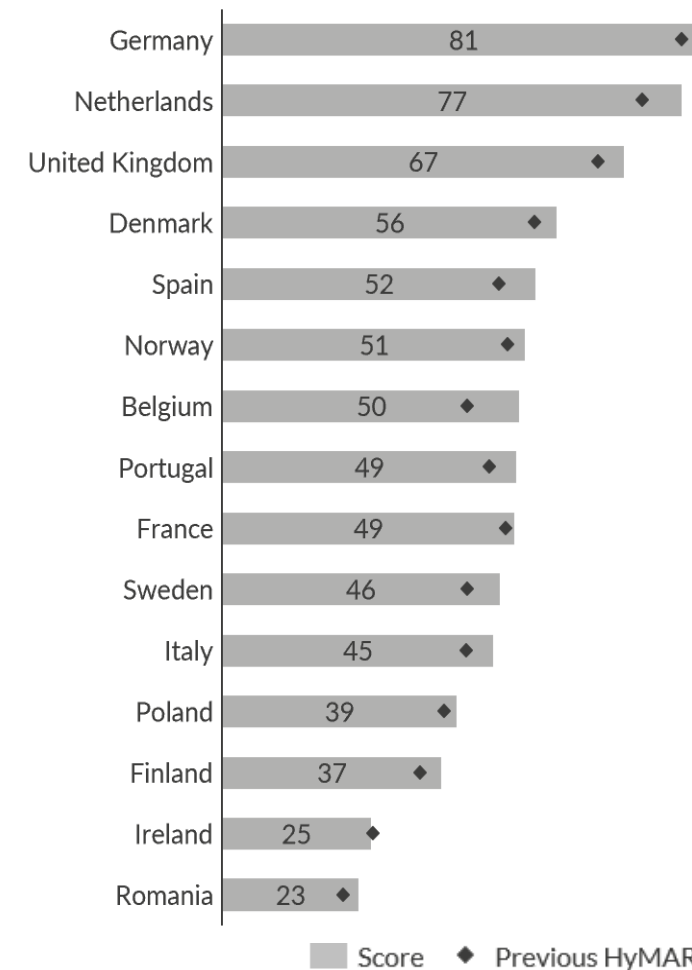


1) Detailed list of metrics and the corresponding weighing factors are available in the appendix.

In the last 6 months, the most and the least attractive countries remain unchanged while Spain and Belgium move up the ranking

Country	Latest Rank (Apr-23)	Previous Rank (Oct-22)	Highlights
Germany	1	 1	Highest electrolyser project pipeline (14 GW by 2030) and over 100 HRS ¹
Netherlands	2	 2	Elaborate NHS ² with imminent support to blue and green H ₂ projects
United Kingdom	3	 3	Highest H ₂ production targets and electrolyser manufacturing capability
Denmark	4	 4	Healthy project pipeline, detailed H ₂ strategy and a net exporter of H ₂
Spain	5	 6	Healthy electrolyser pipeline (5.8 GW by 2030) and competitive LCOH ²
Norway	6	 5	Frontrunner in terms of blue H ₂ and offering the cleanest grid by 2025
Belgium	7	 9	Recently updated NHS ³ with the ambition of becoming a H ₂ transit hub
Portugal	8	 8	A net exporter of H ₂ as early as 2025 and ambitious electrolyser targets
France	8	 7	Large H ₂ refuelling infrastructure and low-carbon grid
Sweden	10	 9	Low grid intensity coupled with very competitive retail power prices
Italy	11	 11	In last 6 months, electrolyser pipeline grew to 1 GW by 2030
Poland	12	 12	Currently, one of the largest demand centres of H ₂ across Europe
Finland	13	 13	A net exporter of hydrogen as early as 2030
Ireland	14	 14	Ambitious electrolyser targets set for 2030 in the latest Climate Action Plan
Romania	15	 15	Recently announced H ₂ auctions funded by the European Commission

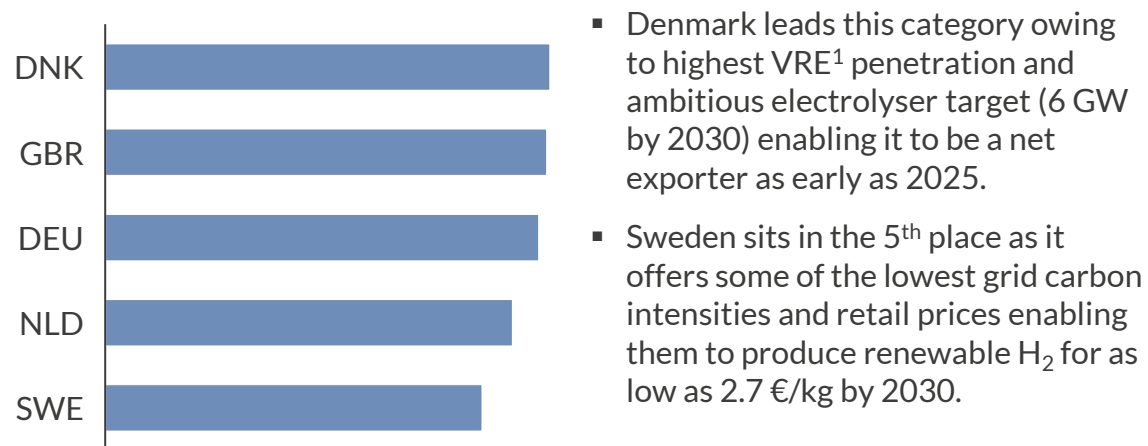
Overall scores and changes since October 2022 (out of 100)



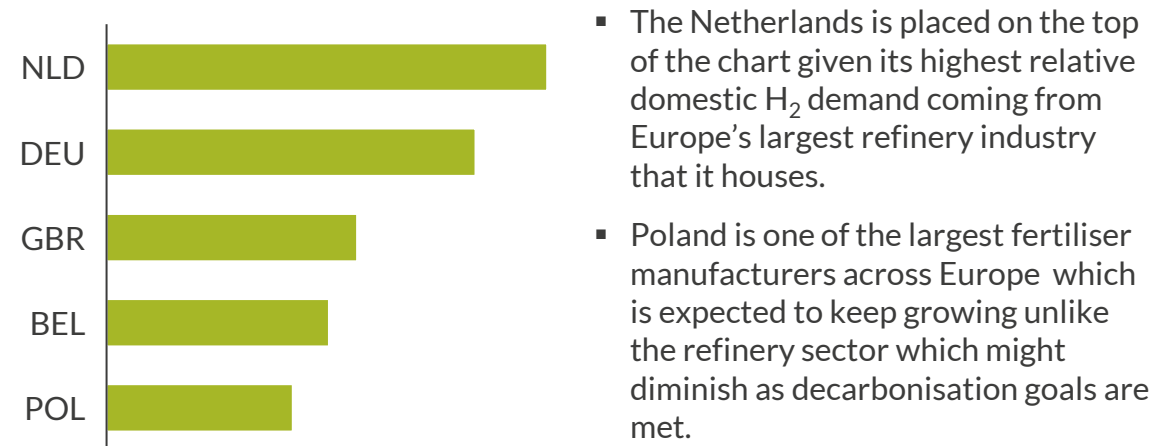
1) Hydrogen refueling station 2) Levelised cost of hydrogen 3) National Hydrogen Strategy

The United Kingdom, Germany and the Netherlands consistently rank among the top 5 under each macro-level category

Macro-level category: Supply



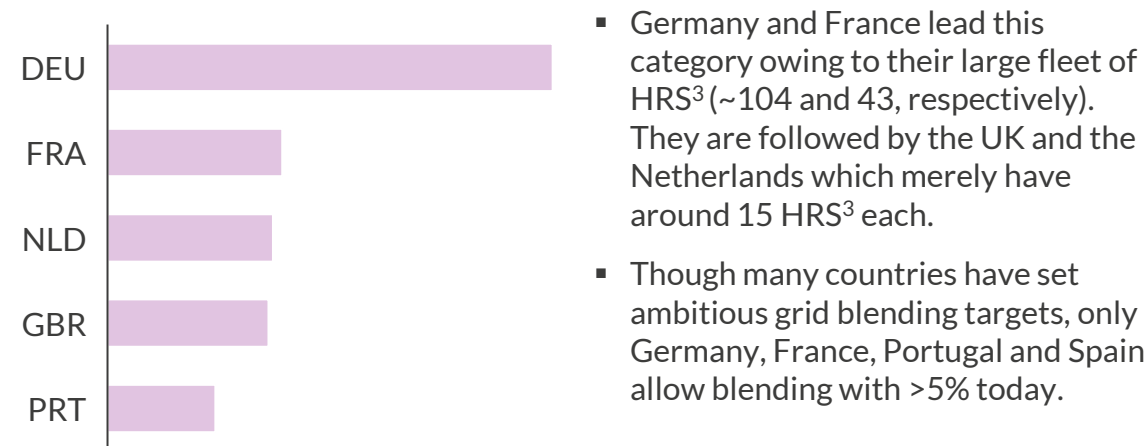
Macro-level category: Demand



Macro-level category: Policy and Regulation



Macro-level category: Infrastructure



1) VRE: Variable Renewable Energy 2) NHS: National hydrogen strategy 3) HRS: Hydrogen Refueling Station 3) The auctions in the Netherlands are not dedicated for hydrogen but hydrogen can participate as a low-carbon technology.

Agenda

I. Hydrogen Market Attractiveness Rating (HyMAR)

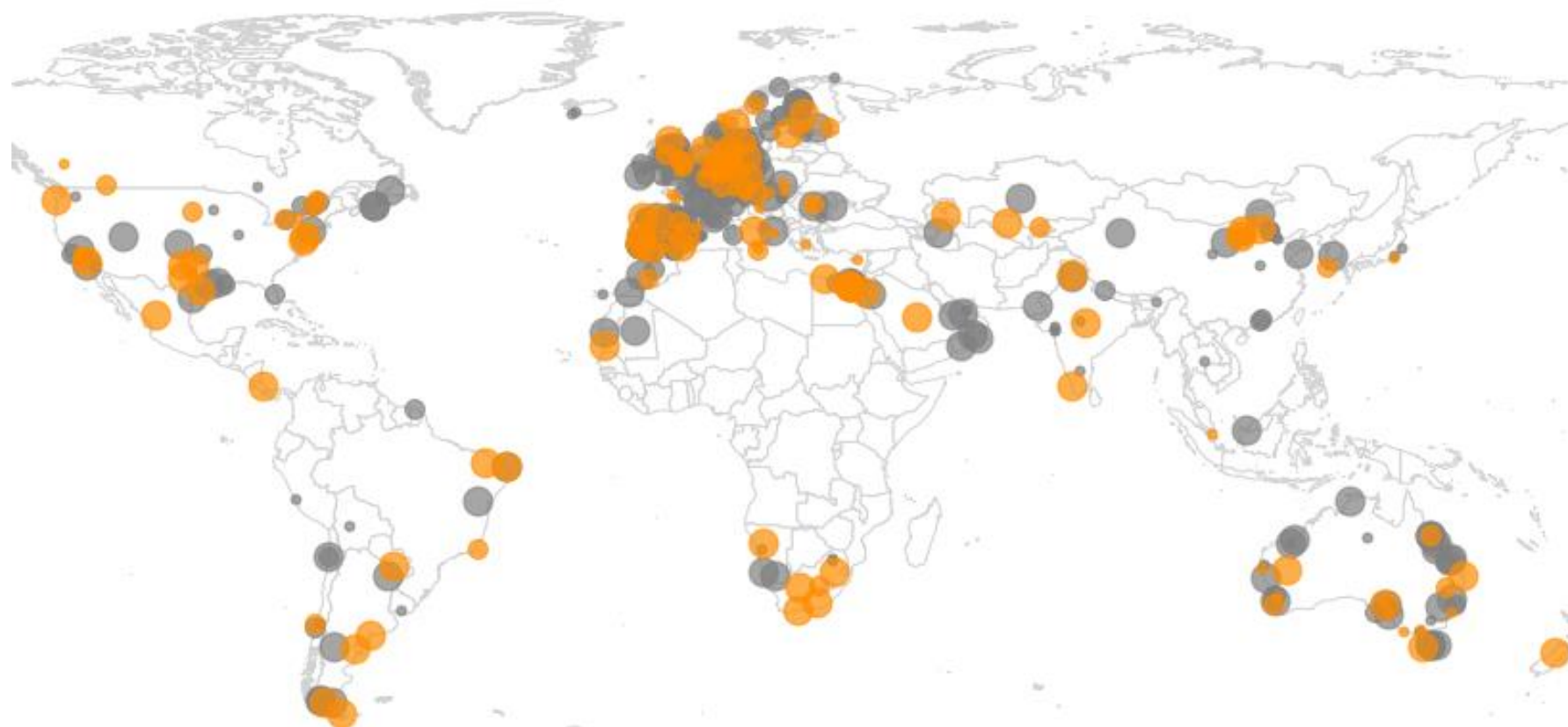
II. Aurora's global electrolyser database

III. Low-carbon hydrogen prices



Aurora's electrolyser database has grown by ~18% in planned capacity, reaching over 1.1 TW requiring 5 PWh of electricity¹

A U R  R A



- Previously reported projects
- New projects (Since Oct-22)
- <100 MW
- 100-1000 MW
- >1000 MW

Aurora's database has grown by 167 GW since October 2022

- Since October 2022, 191 projects have been added or updated in the database.
- A total of 167 GW of electrolyser capacity has been added since Oct-22.
- Newly-added giga-scale projects make up 77% of the latest announcements by size. 28 giga-scale projects were added.
- Latest announcements are distributed all around the world. Front-runners are the Americas with 41 GW, ~10% of which is planned in the US, and Europe with 30 GW

Find out more about Aurora's electrolyser database from **Alex Hutcheson**



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1) 5 PWh electricity is needed to power 1125 GW electrolyzers with 50% load factor for a year.

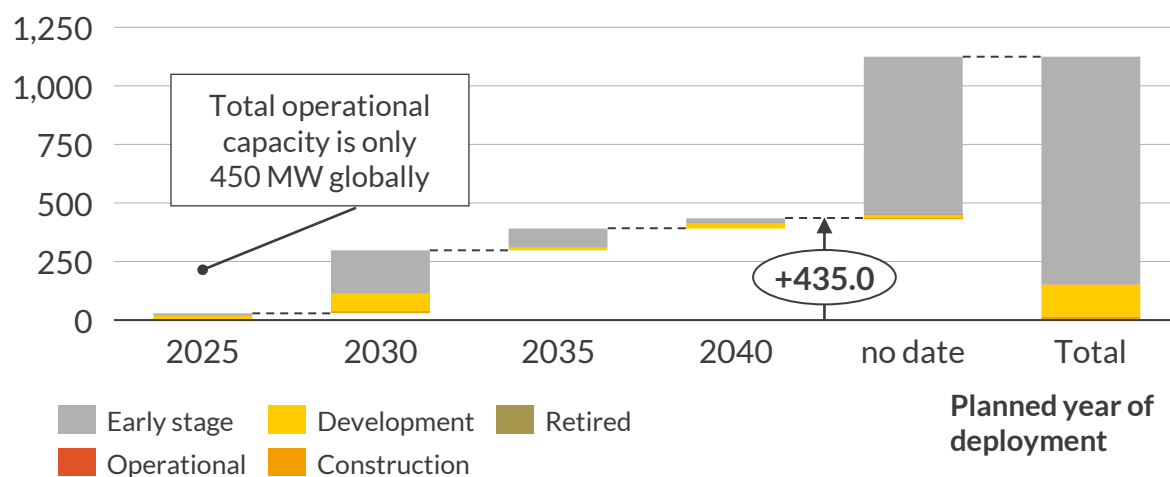


Excluding early stage projects, Aurora's electrolyser pipeline has grown by 28% globally, indicating some momentum for H₂

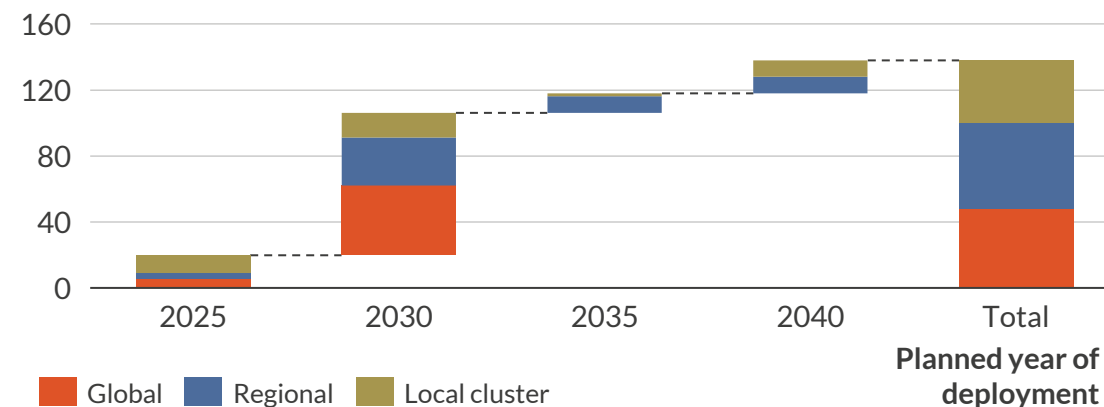
Global cumulative electrolyser project capacities

- 1 Since our last HyMAR, 122 GW of Early stage¹ projects were added, compared to about 17 GW of more developed projects.
 - The total operational capacity increased slightly to 450 MW, with Baofeng Energy's project in China accounting for 150 MW.
- 2 Most of the projects under development in the database expect regional² offtake, followed by global and local clusters.
- 3 Although Europe dominates the developed level project pipeline with its large planned capacity, its share has decreased from 63% to 56%. The largest capacity increase compared to Oct-22 is seen in North America with ~11 GW, which is followed by Europe with 10 GW.

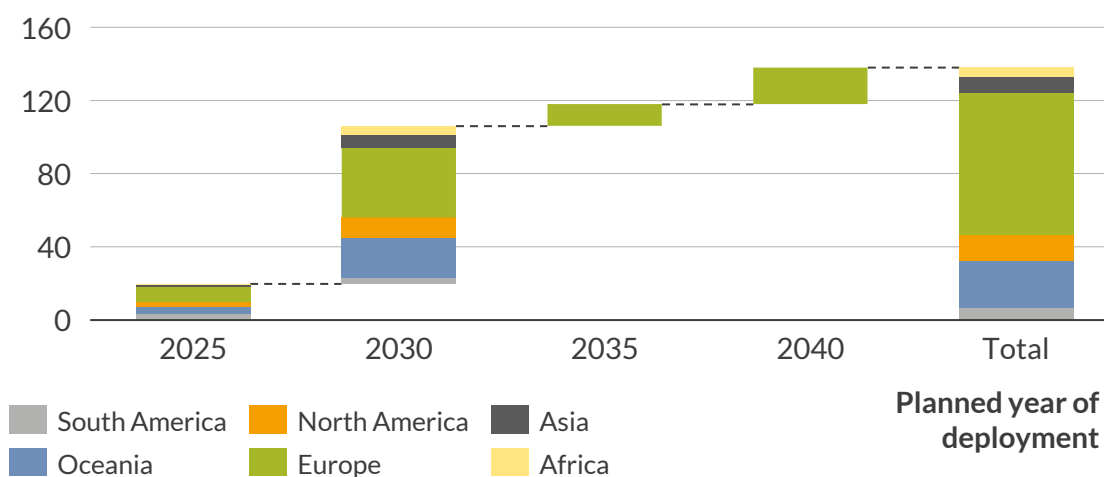
1 Capacity by project stage (including early stage projects)³, GW



2 Capacity by consumption cluster (excluding early stage projects)³, GW



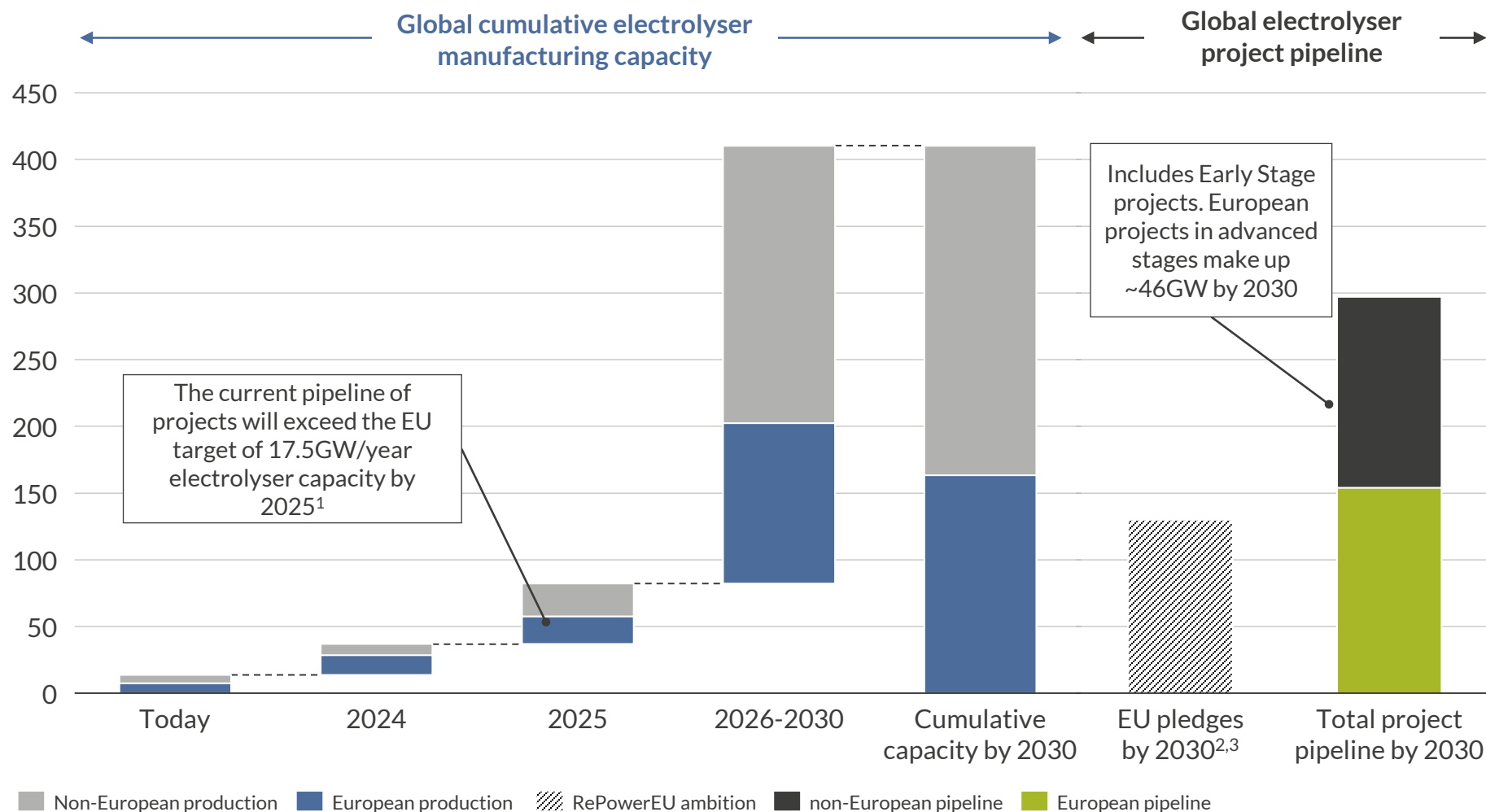
3 Capacity by continent (excluding early stage projects)³, GW



1) We define early stage projects as installations and programs still in planning or discussion stages, and which have not reached FID 2) Regional projects produce hydrogen in the vicinity of the offtaker (not necessarily the offtaker site). 3) These project capacities are extracted from Aurora's global electrolyser database, which keeps track of all announced electrolyser projects globally. The timeline and the capacities provided in these charts do not need to be achieved fully.

Based on announcements from the last 6 months, Europe is no longer a frontrunner in terms of electrolyser manufacturing capacities

Cumulative electrolyser manufacturing capacity vs project pipeline in Europe
GW



With global manufacturing capabilities reaching 410 GW by 2030, the electrolyser project pipeline can be met

- This analysis assumes that:
 - There are no supply chain constraints – for example, no barriers to the availability of precious metals is assumed.
 - Electrolyser manufacturing plants operate at maximum capacity which may seem unlikely.
- Europe may be an exporter of electrolyser technology but, given the current market outlook, the continent may end up being a net importer of electrolyser hardware following a trend similar to the one observed in the solar industry.

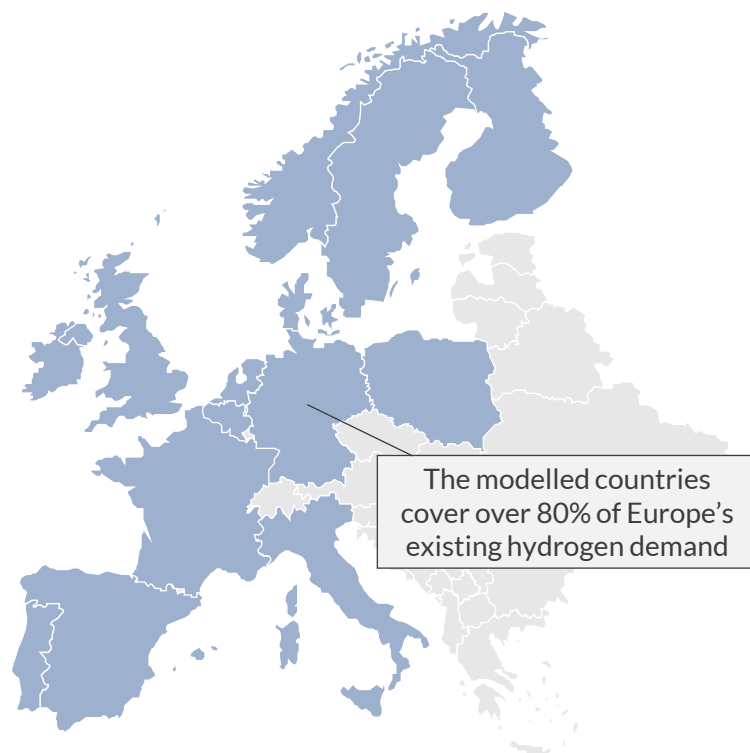
1) In May 2022, an agreement was signed by the European Commission, Hydrogen Europe and 20 industrial players to increase the current electrolyser manufacturing capacity 10-fold. 2) Aurora's estimate of electrolyser capacity following the 10 Mt renewable H₂ RePowerEU target. 3) 70% efficiency, 50% load factor assumed for the electrolyser.

Agenda

- I. Hydrogen Market Attractiveness Rating (HyMAR)
- II. Aurora's global electrolyser database
- III. Low-carbon hydrogen prices

Aurora has built a Central Scenario using its new European hydrogen market model to provide an in-depth analysis of future market dynamics

Geographical coverage



 Countries included in Aurora's European Hydrogen Market model

Key assumptions

1 Hydrogen demand:

- Existing demand of H₂ and e-fuels
- New demand from industry, transport and heating for H₂ and e-fuels
- H₂ demand for power generation is determined by the production of H₂ power plants

2 Hydrogen production:

- Grey hydrogen
- Blue hydrogen
- Electrolysers

3 Hydrogen infrastructure:

- Pipelines
- Shipping
- Storage

Hydrogen market outcomes

Hydrogen supply/demand balance:

- What is the contribution of each supply source to demand?
- What is the behaviour of electrolysers?
- What is the impact of hydrogen imports and exports across regions?
- How is hydrogen storage used?

Evolution of hydrogen market prices:

- What is the expected hydrogen market price in each region?
- How does the hydrogen market price compare with the costs of each production technology?
- What role does large-scale infrastructure play in the formation of hydrogen market prices across Europe?

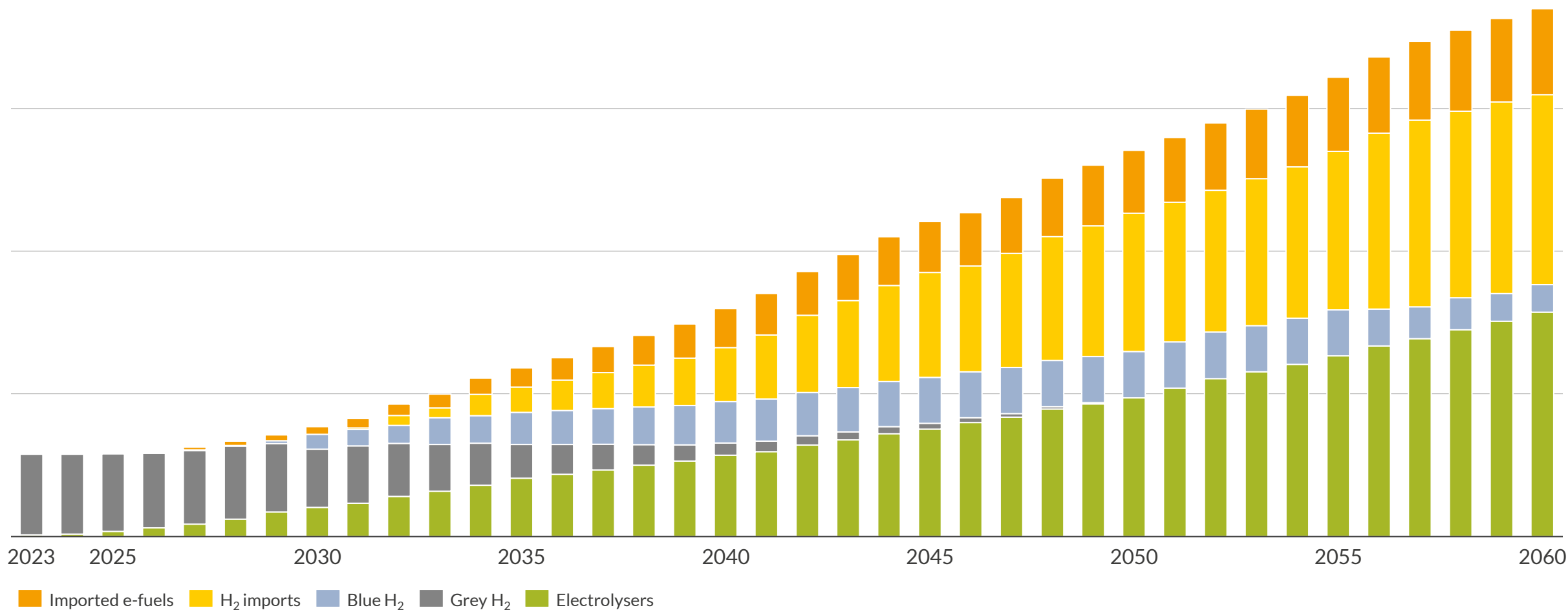
For more information on the European hydrogen market model, please contact
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Domestic low-carbon hydrogen production in Europe supplies nearly half of the demand by 2060

Supply balance of H₂ and e-fuels in Europe¹
TWh, final energy consumption



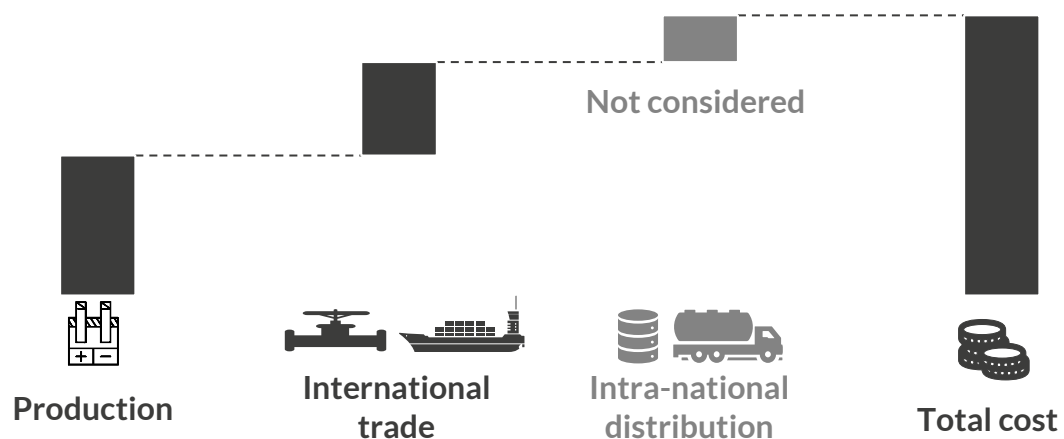
1) Supply balance of hydrogen and its derivatives for each country are available to the subscribers of Aurora's European Hydrogen Service

Aurora considers a hydrogen market price that is based on the marginal cost of production required to meet demand

Definition of a hydrogen price in Aurora's European hydrogen market model

Our modelled prices only reflect production costs and international trade

Illustrative breakdown of hydrogen price supply chain components

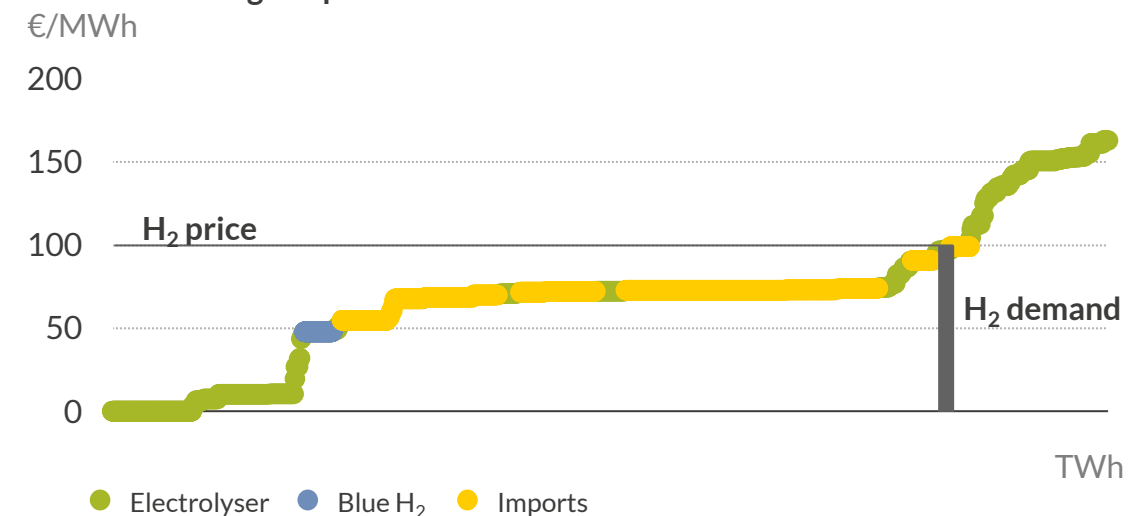


- Our price projections include the cost of production by technology (electrolysers, grey and blue H₂) as well as the cost of transporting hydrogen across regions. We do not model hydrogen distribution *within each region*.
- In reality, we expect production to be located close to demand in the near future. With the deployment of large-scale storage and pipelines, the location of production and demand can be progressively decoupled.
- The prices resulting from this approach could be further improved by adding project-specific distribution costs for more accurate projections.

We assume a liquid wholesale market for hydrogen in Europe

- Currently there is no market liquidity and prices are mostly determined bilaterally between producers and consumers. In the future, we expect a growing market liquidity once there is a robust transport and storage network across Europe.
- We assume that the price in each region is determined by the most expensive unit of H₂ required to meet demand (marginal pricing), which is formed through the merit-order curve based on the short-run marginal cost of each source.

Illustrative marginal price formation



We model two different price metrics depending on whether the market is fully low-carbon or whether grey H₂ is also a price setter

Hydrogen wholesale market price

Hydrogen prices¹, €/kg H₂

10

Prices in the near term are mostly set by the running costs of grey H₂

Long-term prices are mostly set by imports from outside Europe (i.e. international shipping)

0

2025 2030 2035 2040 2045 2050 2055 2060

— Country-specific prices — Avg. Europe

1) Annual low-carbon hydrogen prices for each country are available to the subscribers of Aurora's European Hydrogen Service

Source: Aurora Energy Research

Low-carbon hydrogen wholesale market price

Hydrogen prices¹, €/ kg H₂

10

Prices in the near term are mostly dictated by the running costs of grid-connected electrolyzers

Long-term prices are mostly set by imports from outside Europe (i.e. international shipping)

0

2025 2030 2035 2040 2045 2050 2055 2060

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