

# Hydrogen Market Attractiveness Rating

April 2023



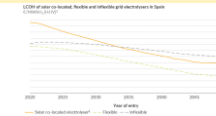
# Our European Hydrogen Market service offers regular insights, policy/market updates & roundtable discussions

## Hydrogen Market Attractiveness Rating (HyMAR)



- Summary of policy developments and incentives across Europe
- Global electrolyser project database
- Hydrogen market sizing: demand scenarios by country and sector
- Analysis of demand and supply drivers

## Investment case analysis



- Hydrogen market price forecasts based on Aurora's in-house hydrogen model
- Granular electrolyser business cases, including optimised grid-connected and renewables co-located models
- For use in strategy formulation, transactions and JV negotiations

## Strategic Insight Reports



- Regular insight reports on topical issues in the evolving European hydrogen market covering country, policy and technology deep dives
- Upcoming reports on next slide

Access anytime via EOS online platform

## Group Meetings



- Presentation of Market Attractiveness reports and Strategic Insight reports
- Networking opportunity with developers, investors and Governments – the 'go-to' roundtable to discuss hydrogen developments in Europe

## Policy updates & thought leadership



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

## Workshops and analyst support



- Bilateral workshops to discuss Aurora's analysis and specific implications
- Ongoing analyst support to answer questions about our research

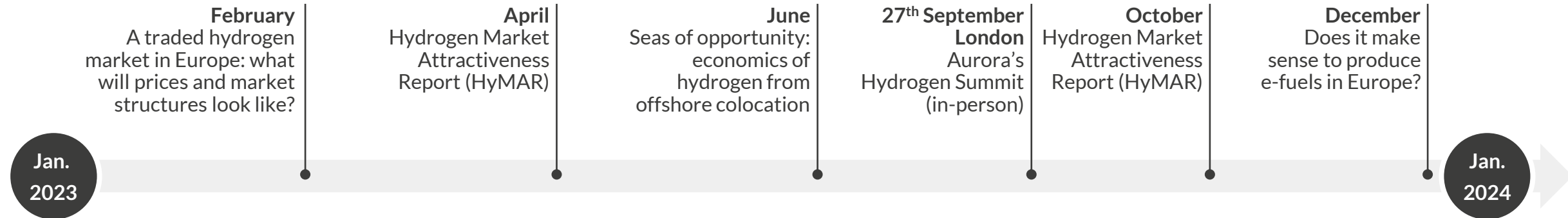
For more information, please contact  
**Alex Hutcheson, Commercial Associate**



[Alex.Hutcheson@auroraer.com](mailto:Alex.Hutcheson@auroraer.com)  
+44 (0) 7799105126

# Aurora's existing and planned reports in the European Hydrogen Service

## Major deliverables of European Hydrogen Service in 2023



## Selected existing reports<sup>1</sup>

### Strategic Insights

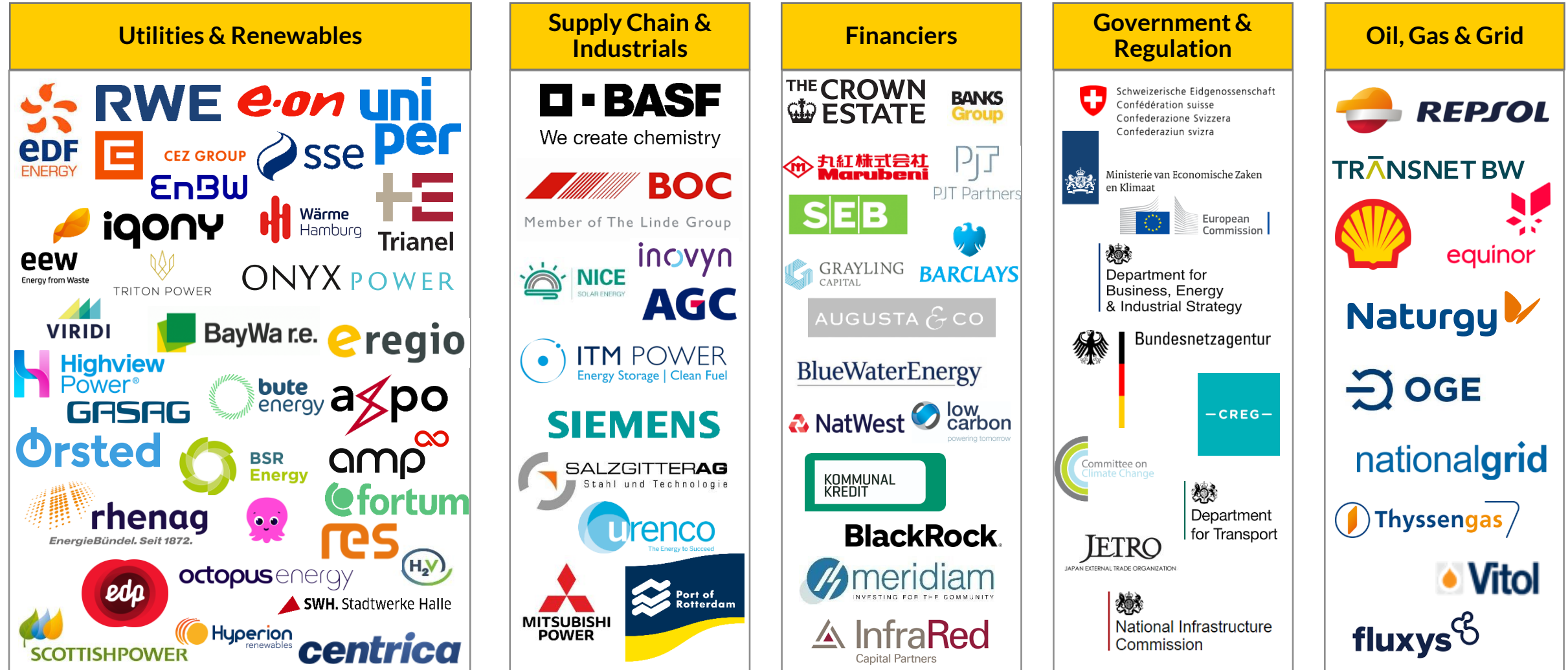
- Seas of opportunity: economics of hydrogen from offshore colocation
- A traded hydrogen market in Europe: what will prices and market structures look like?
- The economics of hydrogen imports: Better to stay local?
- Financing electrolyzers: Overview of market trends in Europe
- Hydrogen in mobility: understanding the economics and incentives
- Shades of green (hydrogen) – part 2: in pursuit of 2 €/kg
- Shades of green (hydrogen) – part 1: optimising electrolyser business models

### Country deep-dives

- Hydrogen in the NLD: From natural gas to green hydrogen hub
- The role of green hydrogen in the I-SEM
- Policies, regulation, and economics of green hydrogen in France
- Green hydrogen in Germany- Could colocation become a new business model for renewables?
- The role of green hydrogen in Iberia
- Hydrogen for a Net Zero Great Britain
- Low carbon hydrogen in the Nordics
- Net Zero and the role of hydrogen for the Italian power system

<sup>1</sup>) Existing reports are available in our EOS platform under the European Hydrogen Product

# Aurora is already providing hydrogen market analysis to major players across the value chain



I. Hydrogen Market Attractiveness Rating (HyMAR)

II. Aurora's global electrolyser database

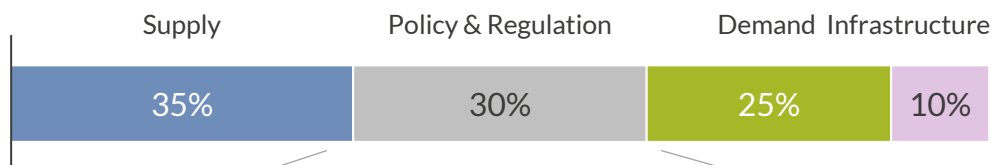
III. Low-carbon hydrogen prices

# 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

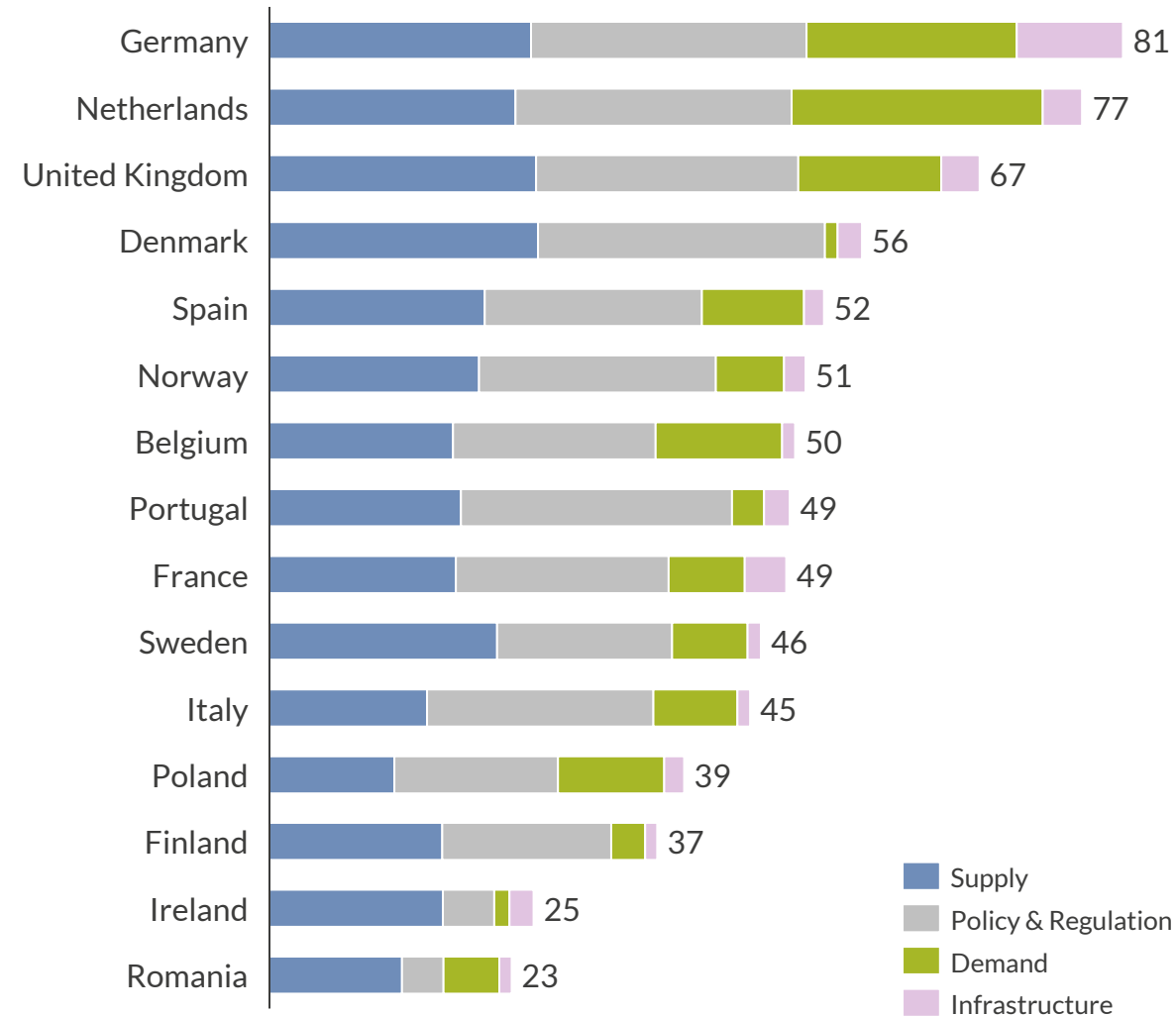
- We use 23 metrics for the assessment<sup>1</sup>
- These metrics are structured around four top-level categories: Supply, Demand, Policy & Regulation and Infrastructure



### 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

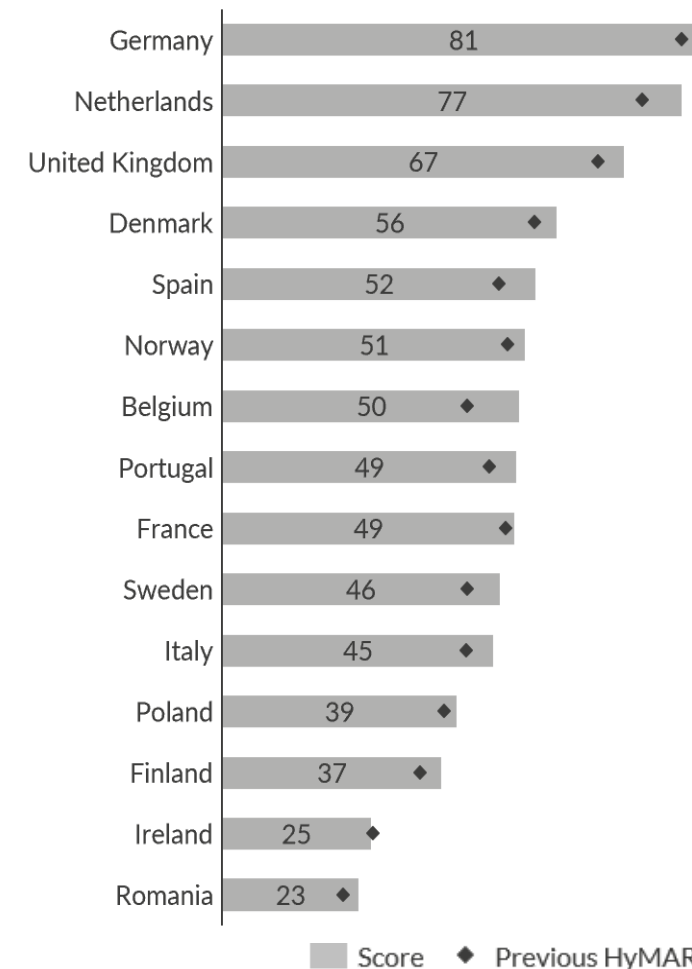


1) Detailed list of metrics and the corresponding weighing factors are available in the appendix.

# 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 <sup>1</sup>
Netherlands	2	 2	Elaborate NHS <sup>2</sup> with imminent support to blue and green H <sub>2</sub> projects
United Kingdom	3	 3	Highest H <sub>2</sub> production targets and electrolyser manufacturing capability
Denmark	4	 4	Healthy project pipeline, detailed H <sub>2</sub> strategy and a net exporter of H <sub>2</sub>
Spain	5	 6	Healthy electrolyser pipeline (5.8 GW by 2030) and competitive LCOH <sup>2</sup>
Norway	6	 5	Frontrunner in terms of blue H <sub>2</sub> and offering the cleanest grid by 2025
Belgium	7	 9	Recently updated NHS <sup>3</sup> with the ambition of becoming a H <sub>2</sub> transit hub
Portugal	8	 8	A net exporter of H <sub>2</sub> as early as 2025 and ambitious electrolyser targets
France	8	 7	Large H <sub>2</sub> 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 <sub>2</sub> 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 <sub>2</sub> auctions funded by the European Commission

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

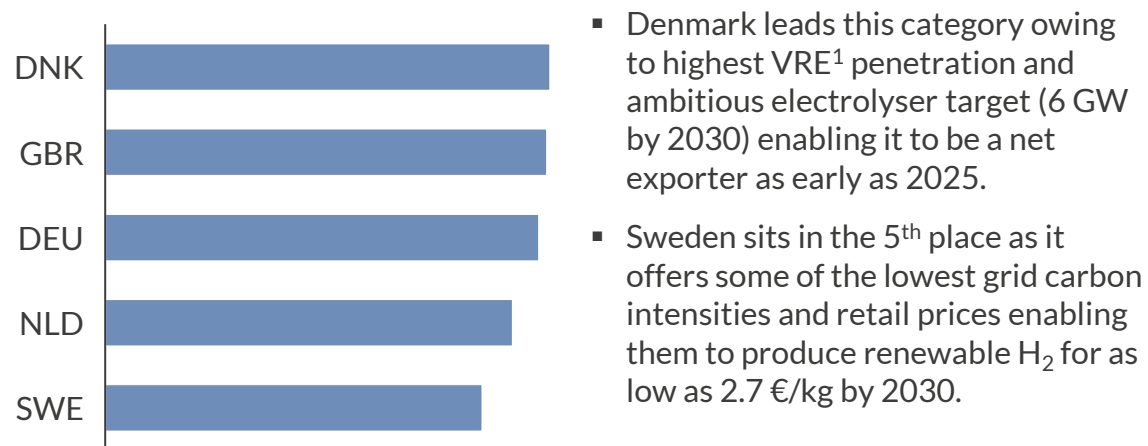


1) Hydrogen refueling station 2) Levelised cost of hydrogen 3) National Hydrogen Strategy

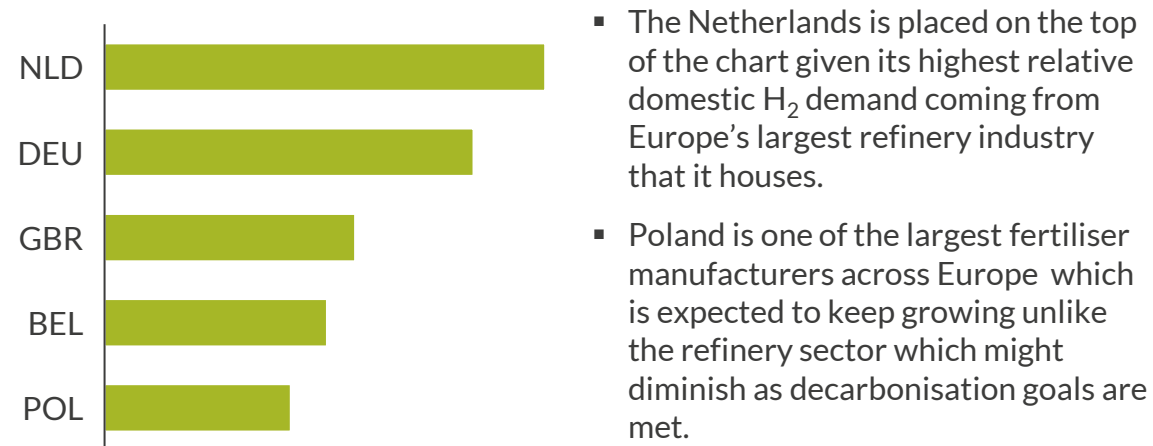


# The United Kingdom, Germany and the Netherlands consistently rank among the top 5 under each macro-level category

## Macro-level category: Supply



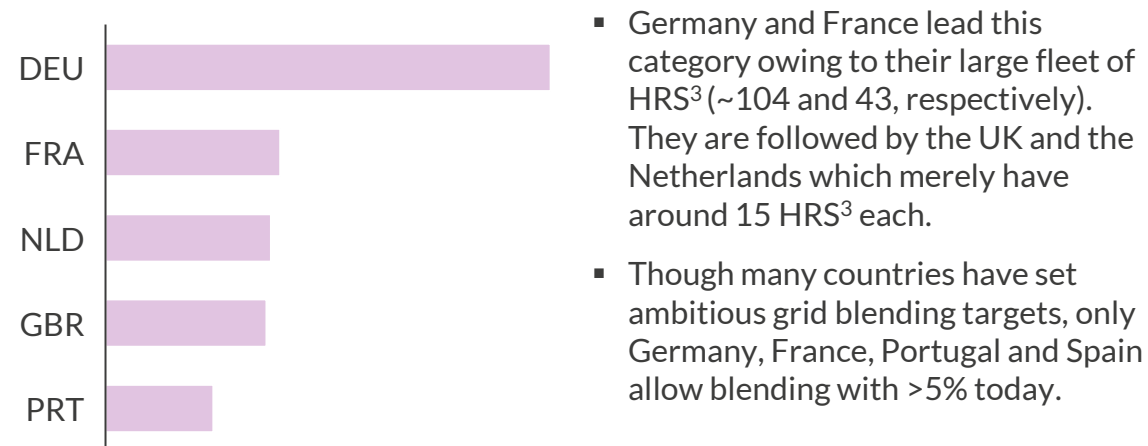
## Macro-level category: Demand



## 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

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I. Hydrogen Market Attractiveness Rating (HyMAR)

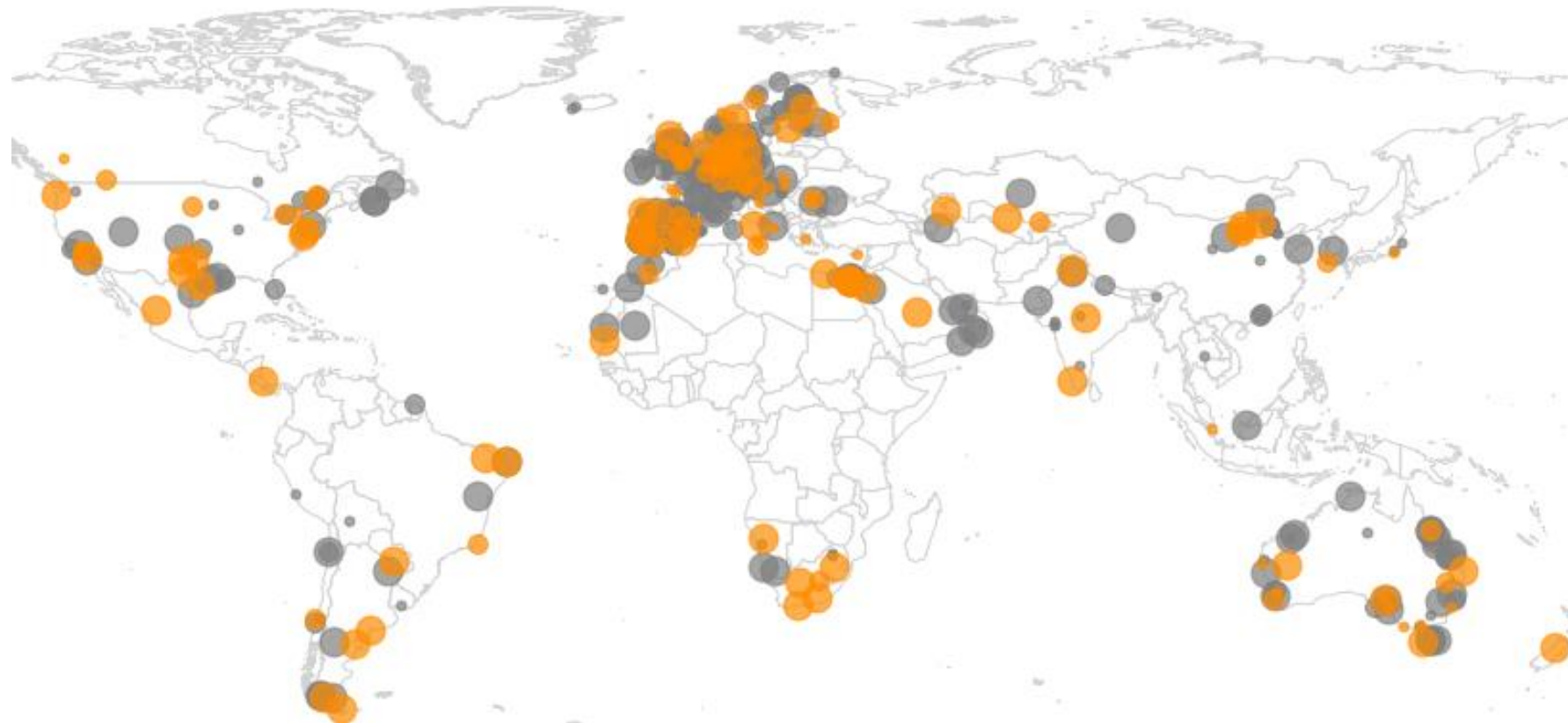
II. Aurora's global electrolyser database

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 electricity<sup>1</sup>

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## 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

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



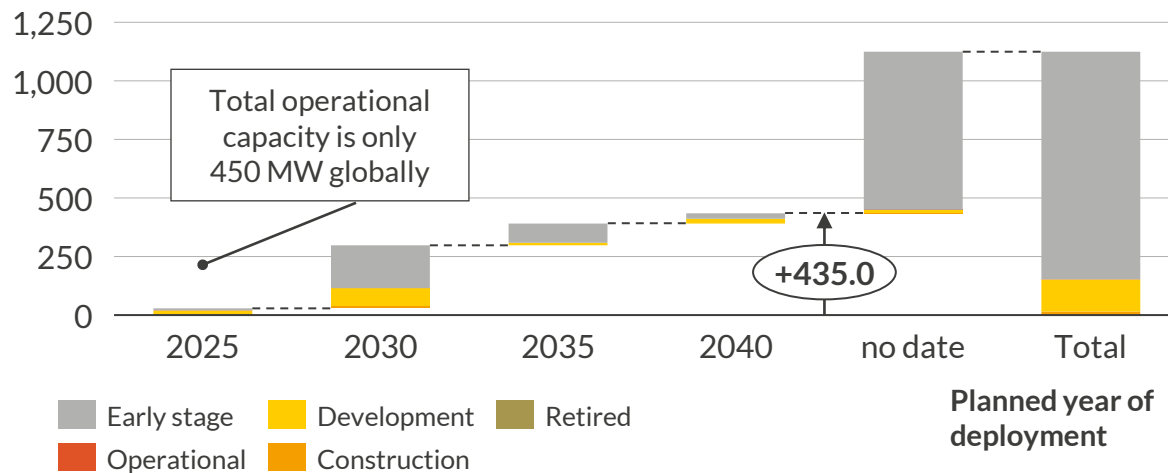
# Excluding early stage projects, Aurora's electrolyser pipeline has grown by 28% globally, indicating some momentum for H<sub>2</sub>

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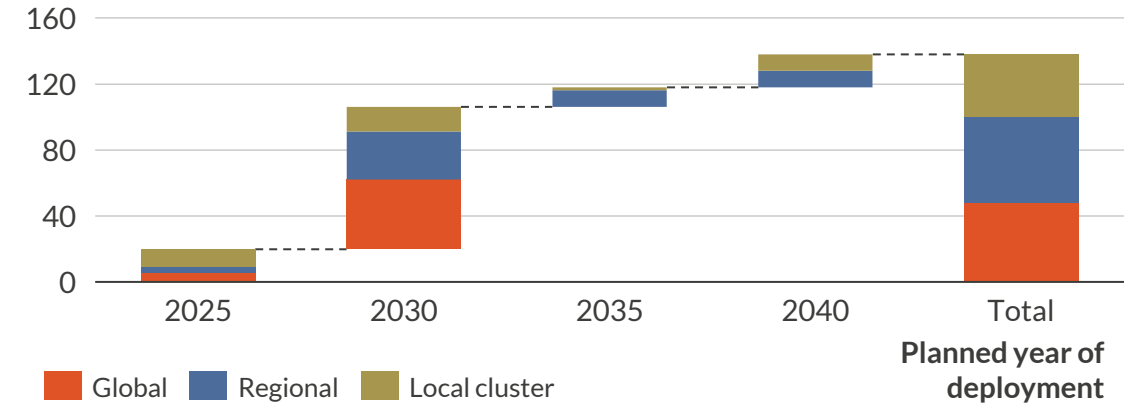
## Global cumulative electrolyser project capacities

- 1 Since our last HyMAR, 122 GW of Early stage<sup>1</sup> 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 regional<sup>2</sup> 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.

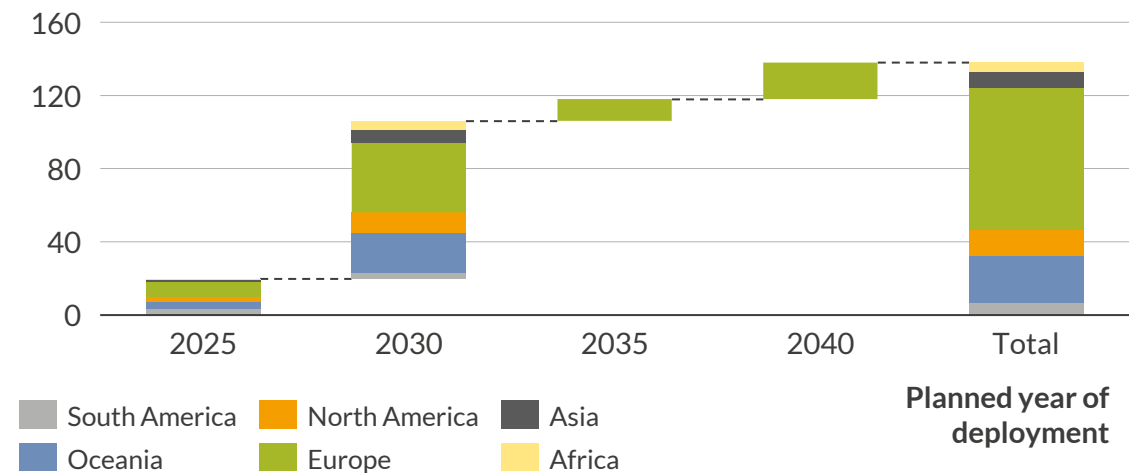
### 1 Capacity by project stage (including early stage projects)<sup>3</sup>, GW



### 2 Capacity by consumption cluster (excluding early stage projects)<sup>3</sup>, GW



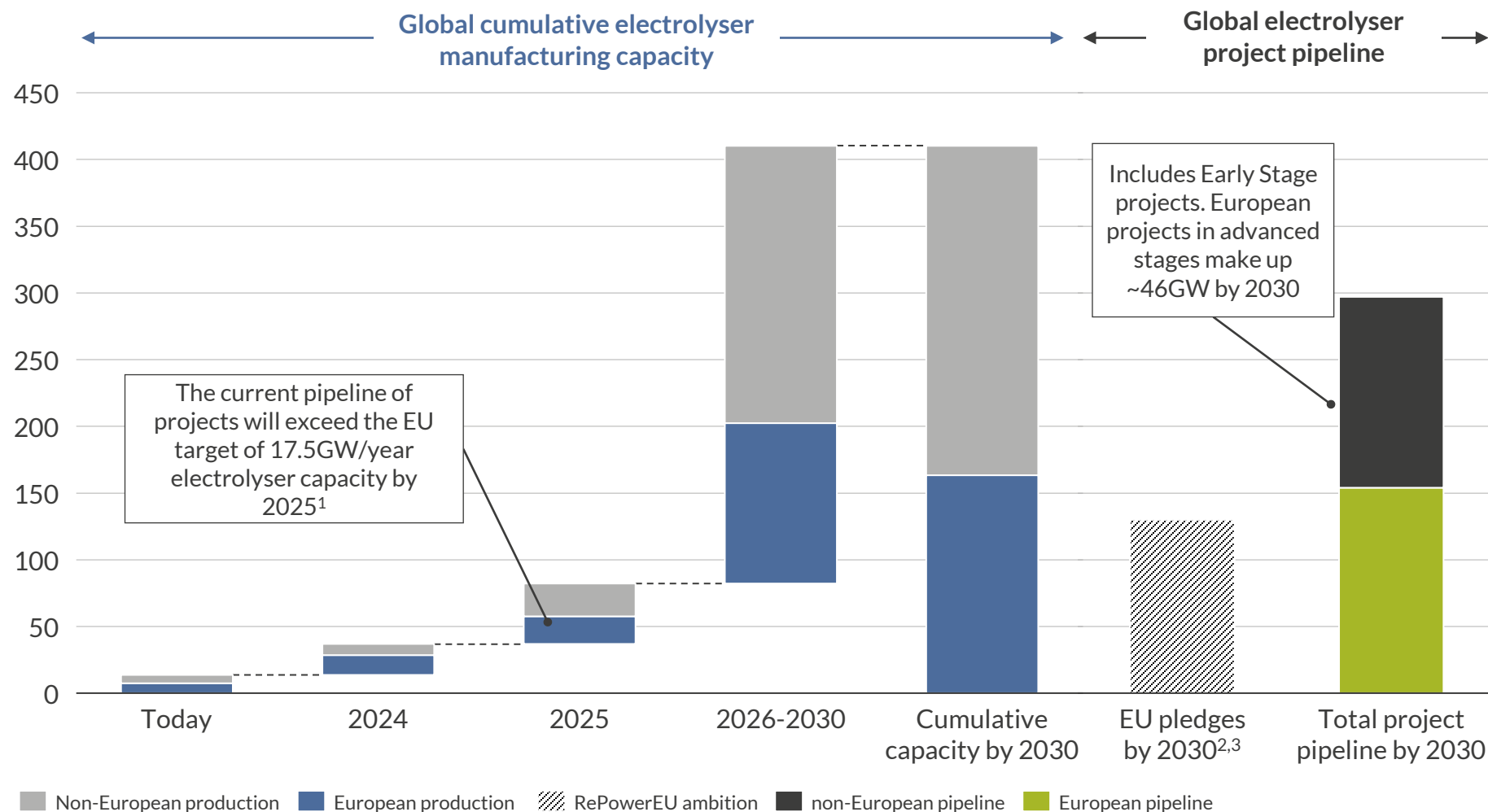
### 3 Capacity by continent (excluding early stage projects)<sup>3</sup>, GW



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 H<sub>2</sub> RePowerEU target. 3) 70% efficiency, 50% load factor assumed for the electrolyser.

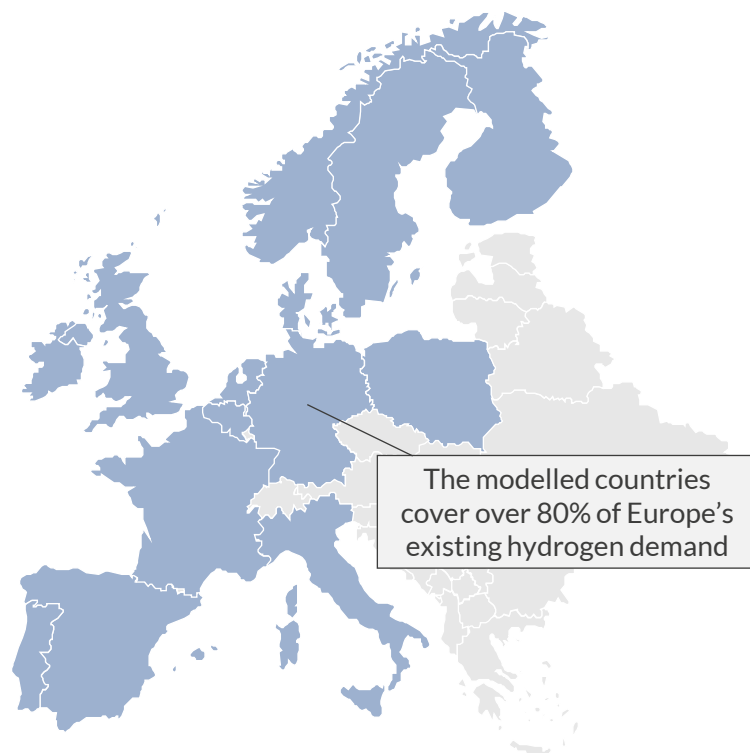
# Agenda

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- I. Hydrogen Market Attractiveness Rating (HyMAR)
- II. Aurora's global electrolyser database
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# 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 H<sub>2</sub> and e-fuels
- New demand from industry, transport and heating for H<sub>2</sub> and e-fuels
- H<sub>2</sub> demand for power generation is determined by the production of H<sub>2</sub> power plants

### 2 Hydrogen production:

- Grey hydrogen
- Blue hydrogen
- Electrolysers

### 3 Hydrogen infrastructure:

- Pipelines
- Shipping
- Storage

## Hydrogen market outcomes

### Hydrogen supply/demand balance:

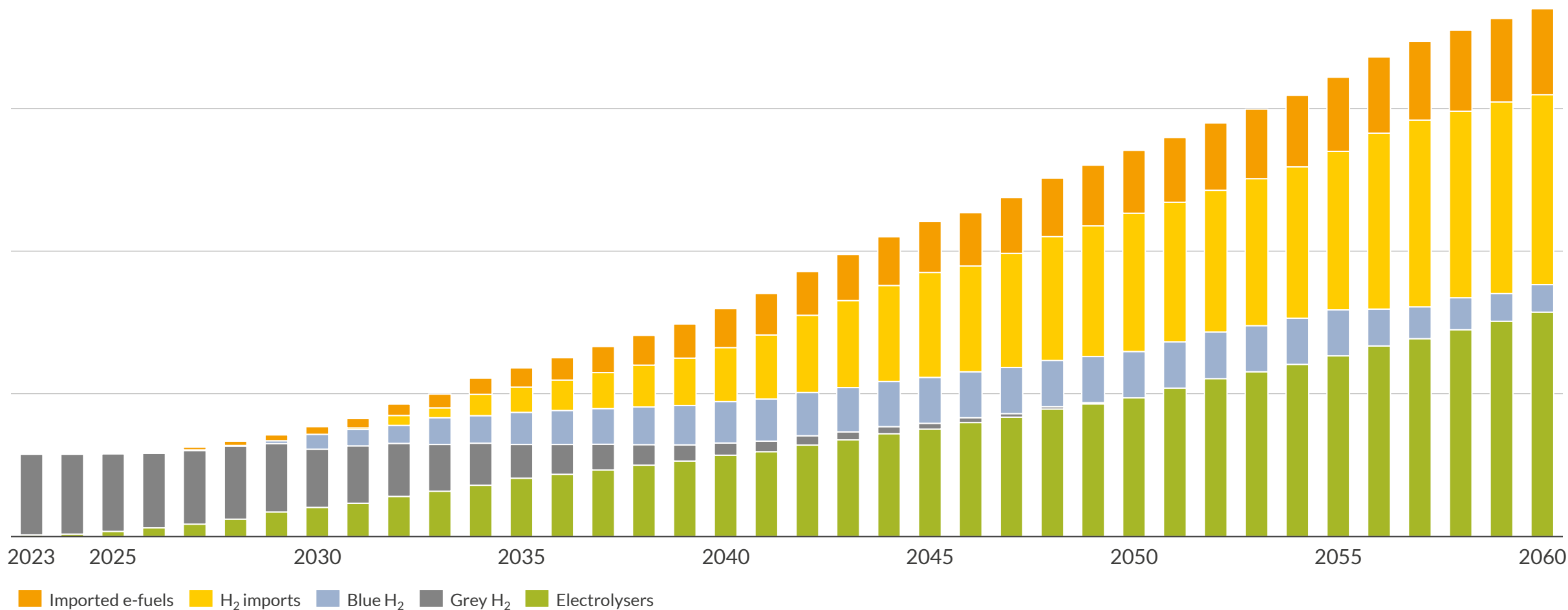
- What is the contribution of each supply source to demand?
- What is the behaviour of electrolysers?
- What is the impact of hydrogen imports and exports across regions?
- How is hydrogen storage used?

### 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?

# Domestic low-carbon hydrogen production in Europe supplies nearly half of the demand by 2060

Supply balance of H<sub>2</sub> and e-fuels in Europe<sup>1</sup>  
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

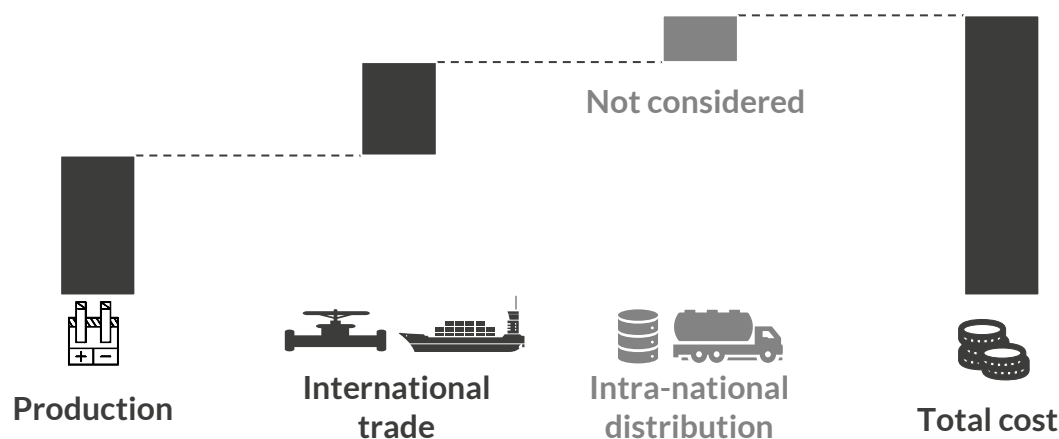


# Aurora considers a hydrogen market price that is based on the marginal cost of production required to meet demand

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

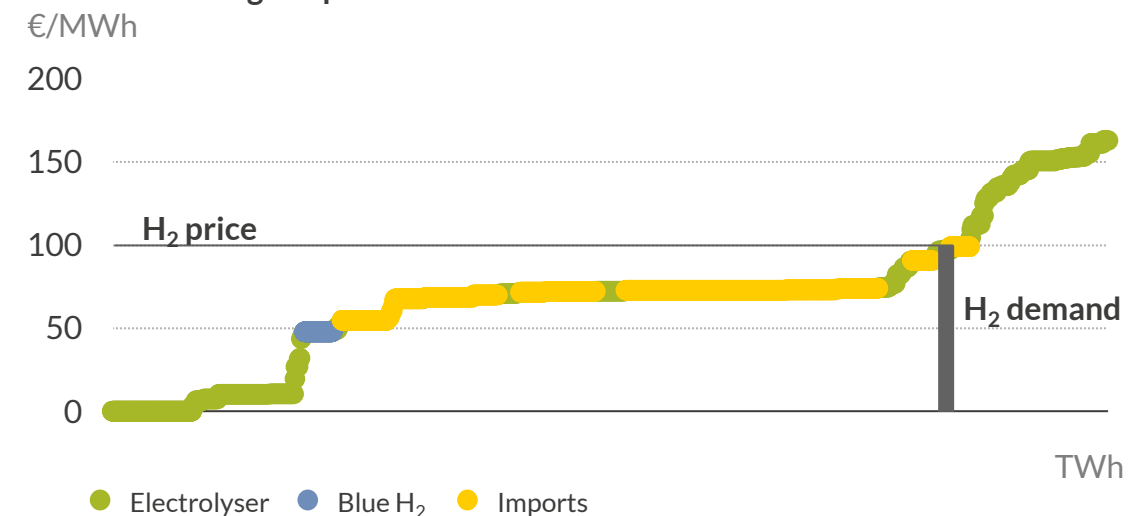


- Our price projections include the cost of production by technology (electrolysers, grey and blue H<sub>2</sub>) as well as the cost of transporting hydrogen across regions. We do not model hydrogen distribution *within each region*.
- In reality, we expect production to be located close to demand in 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 H<sub>2</sub> 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 H<sub>2</sub> is also a price setter

## Hydrogen wholesale market price

Hydrogen prices<sup>1</sup>, €/kg H<sub>2</sub>

10

Prices in the near term are mostly set by the running costs of grey H<sub>2</sub>

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

## Low-carbon hydrogen wholesale market price

Hydrogen prices<sup>1</sup>, €/ kg H<sub>2</sub>

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

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

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