

June 2024. Technology Snapshot

# Hydrogen in Catalonia

**ACCIÓ**  
Government of Catalonia



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Carried out by  
Strategy and Competitive Intelligence Unit of ACCIÓ

Barcelona, June 2024

Executive Summary

1. Hydrogen Definition

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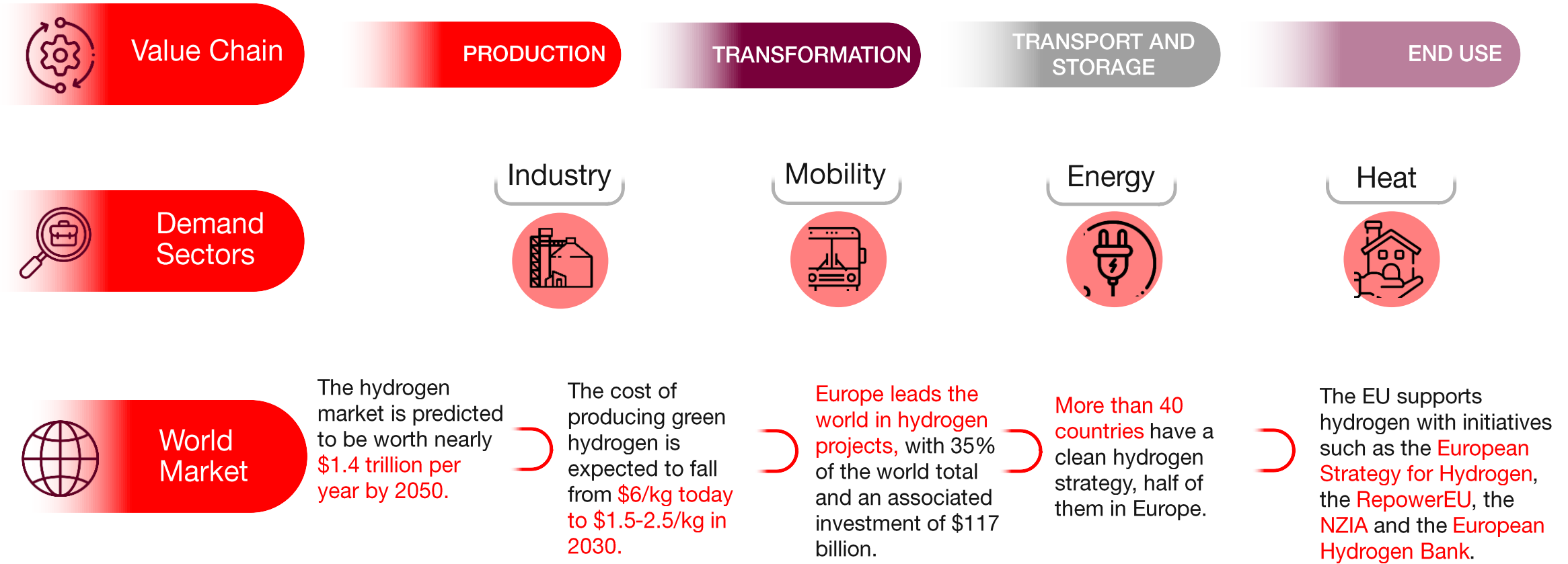
4. Hydrogen in Catalonia

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# Executive Summary: Hydrogen Value Chain and Key Data

Clean hydrogen will contribute to the decarbonization of the economy, either in its energy vector applications such as heavy-duty mobility or electric generation, or as a feedstock in industries such as chemicals.



Catalonia has all the elements of the value chain to position itself as a **benchmark hydrogen valley in Southern Europe**.

## 198 companies along the value chain



**41%** more companies than in 2022.

Turnover of **€700 million (64%)** across **2,313 jobs (+74%)**.

**70.4%** of them are part of the auxiliary and engineering industries.

## Ecosystem of agents present in all segments of the value chain



**14** technology and research centers

**14** universities and training centers

**21** associations and clusters

**18** institutions and public administration

## Benchmarking Initiatives



Catalonia's Hydrogen Valley  
Ebro Hydrogen Corridor  
Center for the Decarbonization of the Chemical Industry  
H2CAT Network  
Dedicated Hydrogen Research Center  
Hydrogen boost for America's Cup

High-Capacity **Ports and Airports**

1st **Petrochemical Hub** in Southern Europe

**Geo-strategic position for the use of hydrogen in heavy-duty mobility, the European pipeline network and import-export channels**

**H2MED (Barcelona-Marseille)** to transport hydrogen to the rest of Europe

**Ebro Hydrogen Corridor** with the North of the Iberian Peninsula

Hydrogen in Catalonia

# 1. Hydrogen Definition

## Hydrogen as a Matter

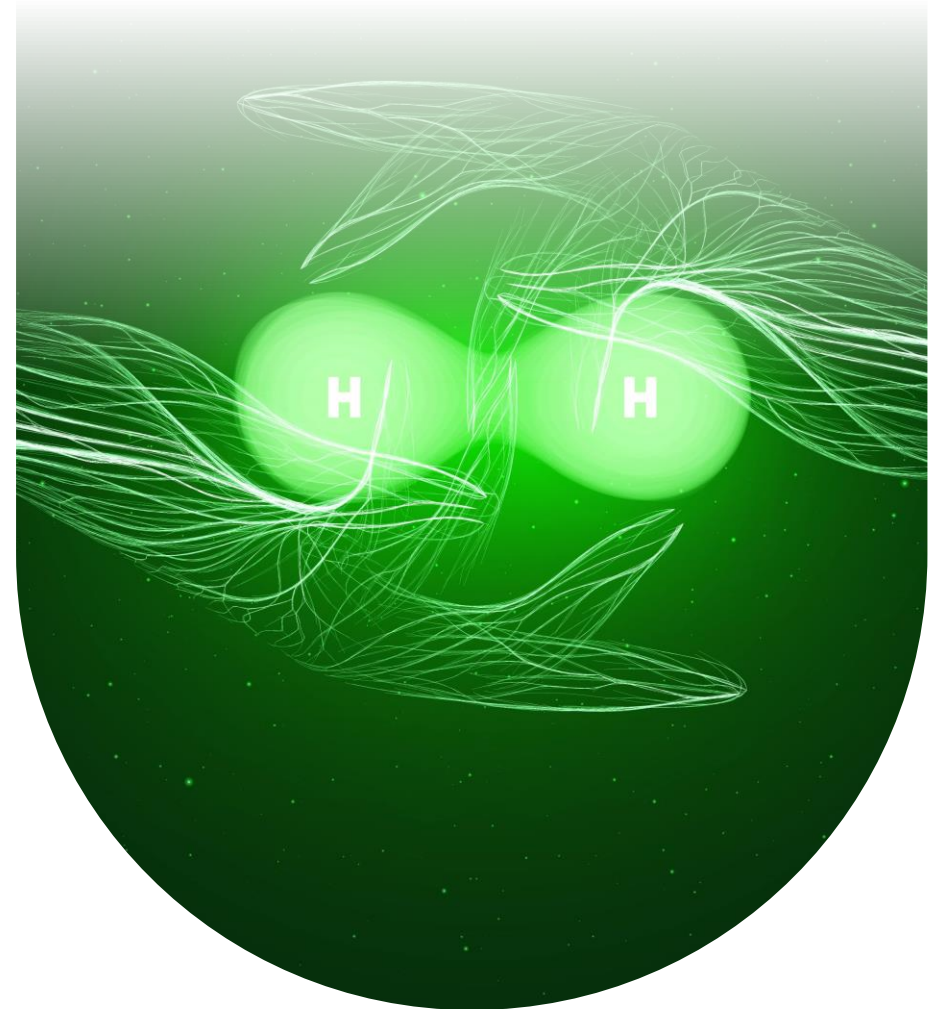
Hydrogen makes up about 75% of the matter in the universe and has three times the energy content of natural gas.

Hydrogen is the first element in the periodic table and is the lightest chemical element in the universe: the atom consists of one proton and one electron and is stable as a diatomic molecule ( $H_2$ ). Under normal conditions, hydrogen is in a gaseous state and is tasteless, colorless and odorless.

It makes up about 75% of the matter in the universe, but combines with other elements such as oxygen to form water molecules or carbon to form organic compounds.

It has the highest energy content by weight of any conventional fuel, around three times that of diesel, natural gas or bioethanol. However, it is a very light gas, with a density of only  $0.09 \text{ kg/m}^3$ .

It is an almost permanent gas and only liquefies at very low temperatures (below  $-253^\circ\text{C}$ ). It is usually stored under pressure because of its very low density. Liquefaction increases its density by a factor of 800. Its characteristic property is its excellent flammability.



## Hydrogen as an Energy Vector

Hydrogen can be produced from a variety of abundant precursors, including natural gas, coal, water, and renewable energy sources.

Hydrogen has three times the energy content of diesel and natural gas.

Hydrogen is not an energy source but an energy vector, a substance or device that stores energy for later use.

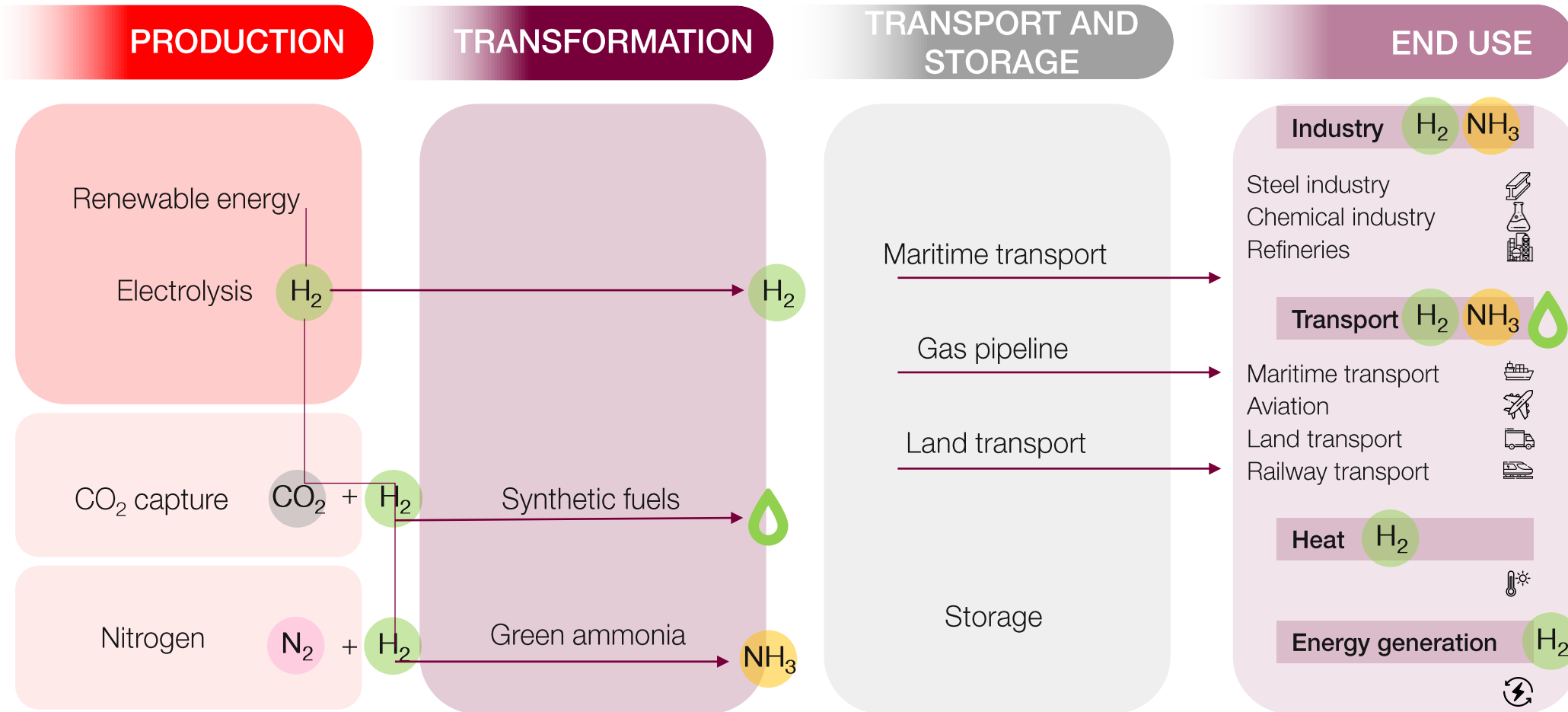
Hydrogen is a good energy vector because it can be produced from a variety of abundant precursors, including natural gas, coal, water, and renewable energy sources.

The use of hydrogen will make it possible to diversify the energy supply with greater use of national resources, thereby reducing dependence on oil and gas imports.





# Clean Hydrogen Value Chain

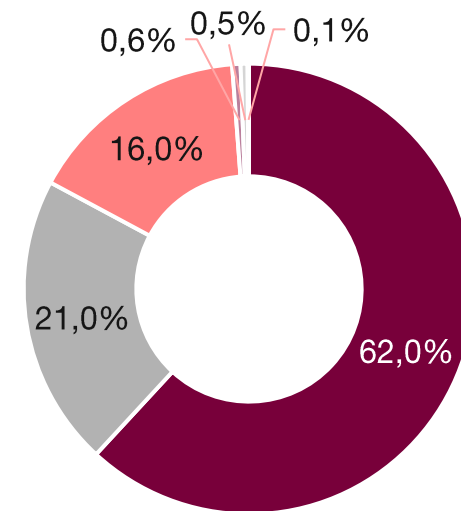


# Hydrogen Production

Global hydrogen production is still dominated by the use of fossil fuels.

- World hydrogen production reached about **95 million tons** in 2022, 3% more than in 2021.
- Production was dominated by the **use of fossil fuels**:
  - Natural gas** without Carbon Capture, Utilization and Storage (CCUS) accounted for **62%** of world production.  
In the case of **coal**, China was responsible for **21%** of world production.
  - The **hydrogen produced as a by-product** in refineries and the petrochemical industry accounted for **16%** of world production.
- The production of **low emission hydrogen**, which includes carbon capture and electrolysis processes, from both renewable and grid sources, was less than 1 million tons (**0.7%** of world production).
- The production and use of hydrogen resulted in more than **900 million tons of CO<sub>2</sub> emissions** in 2022.

Hydrogen Production By technology (2022)



- Natural gas without carbon capture (62%)
- Coal (21%)
- By-product of petrochemical processes (16%)
- Fossil fuels with CO<sub>2</sub> capture (0.6%)
- Other fossil fuels (0.5%)
- Electricity (0.1%)

Source: IEA (2023) Global Hydrogen Review 2023

From colors to emissions.



Hydrogen is a key element in decarbonizing, diversifying Europe's energy sources and reducing its dependence on external sources



The need for critical materials for the manufacture of electrodes and hydrogen batteries hampers manufacturing and economic viability and can lead to a supply chain crisis.



There is not enough green hydrogen being produced to meet the needs of the industry.



Color sorting emphasizes known production methods, often mixing processes with raw materials or emissions.

**Low carbon, renewable, clean or circular hydrogen:** Switch from the color palette to a more realistic system based on the intensity of carbon emissions, both from a production and a life cycle perspective.

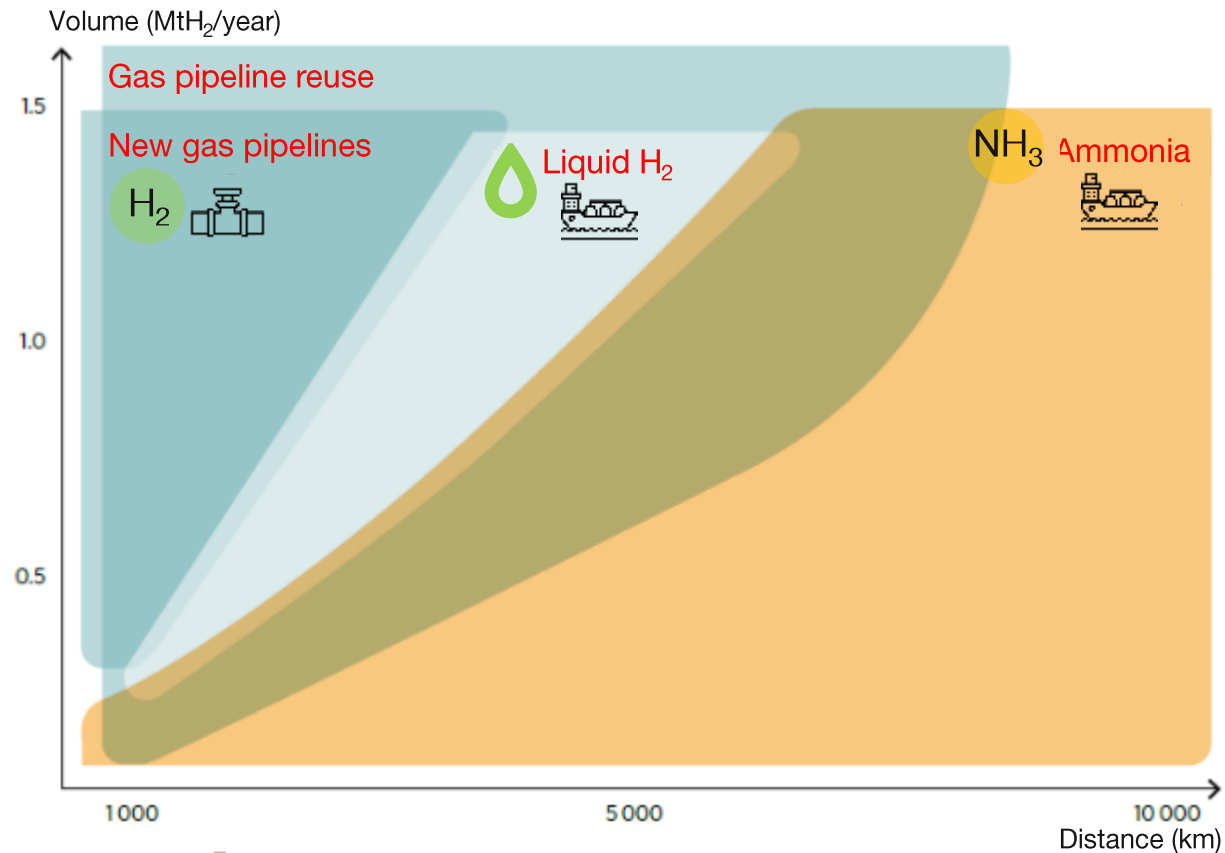
To be considered **low-carbon**, hydrogen production must be below the EU's proposed emission limit of **3.38 kg CO<sub>2</sub> equivalent per kg\* of hydrogen**, which is 70% lower than fossil fuels, including transportation and other non-production emissions.

*\*In the United States, to qualify for the tax benefits of hydrogen production under the IRA, the limit is 4.0 kg of CO<sub>2</sub> equivalent per kg of hydrogen.*

Sources: Hydrogen Science Coalition , IEA, Department of Energy US Government, World Economic Forum, Hydrogen Europe, European Commission, Commission sets out rules for renewable hydrogen, February 2023; Capgemini

Gas pipelines and ships are the two main methods of transporting hydrogen; distance and volume determine the most efficient method.

## Hydrogen Transportation Options Considering Volume and Distance



### Methods for transporting hydrogen by ship



#### Liquid hydrogen

Hydrogen molecules must be cooled to -253°C at port terminals before being loaded into highly insulated tankers, an energy-intensive process. An alternative is to use organic compounds (LOHC) that can absorb and release hydrogen without the need for refrigeration.

#### Ammonia

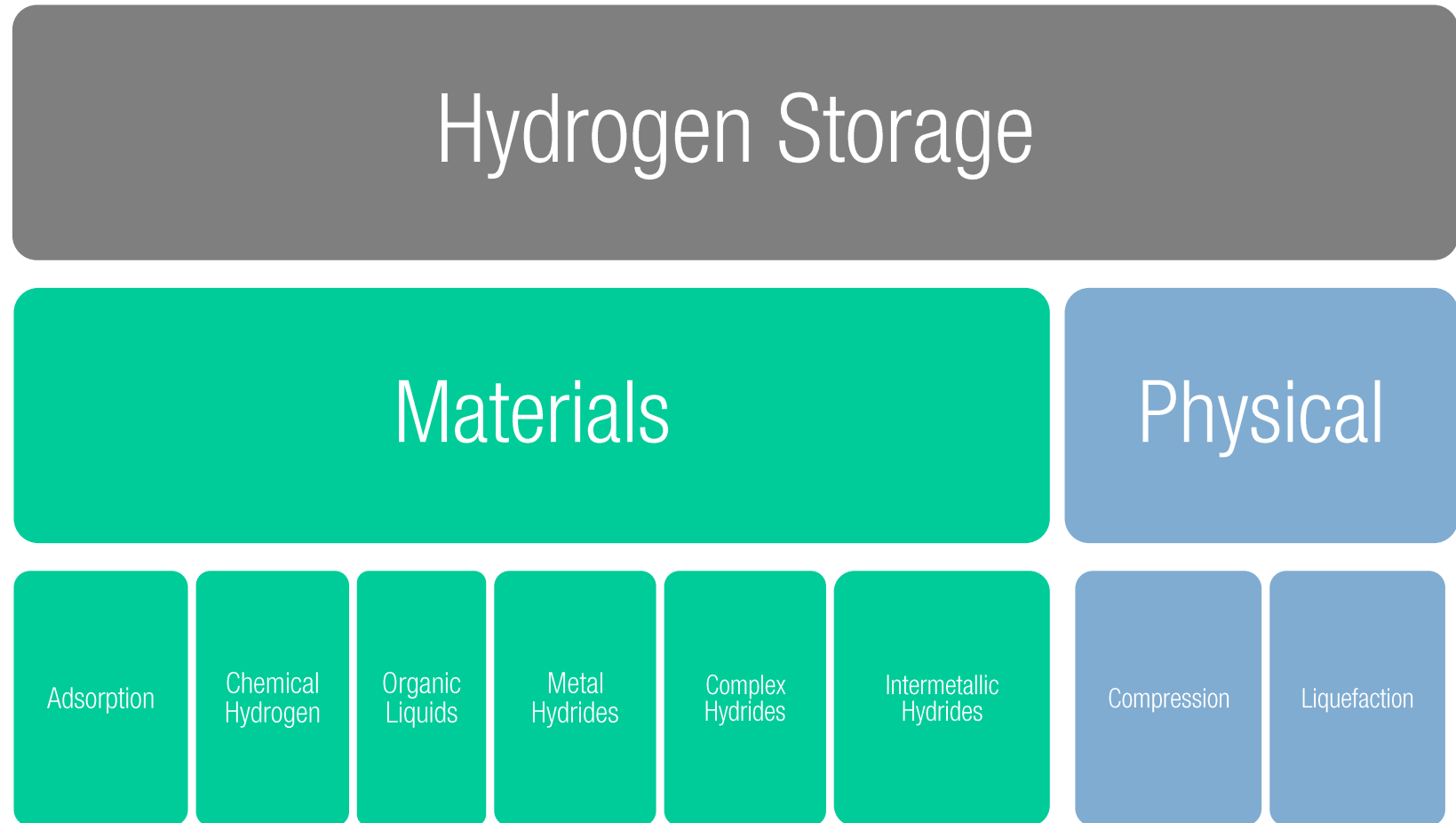
Hydrogen is converted to ammonia by reaction with nitrogen. There is a well-established international trade in ammonia; it is currently used as a raw material to make fertilizers, but could also be used as a fuel for decarbonization. The disadvantage is that it is toxic in case of leakage.

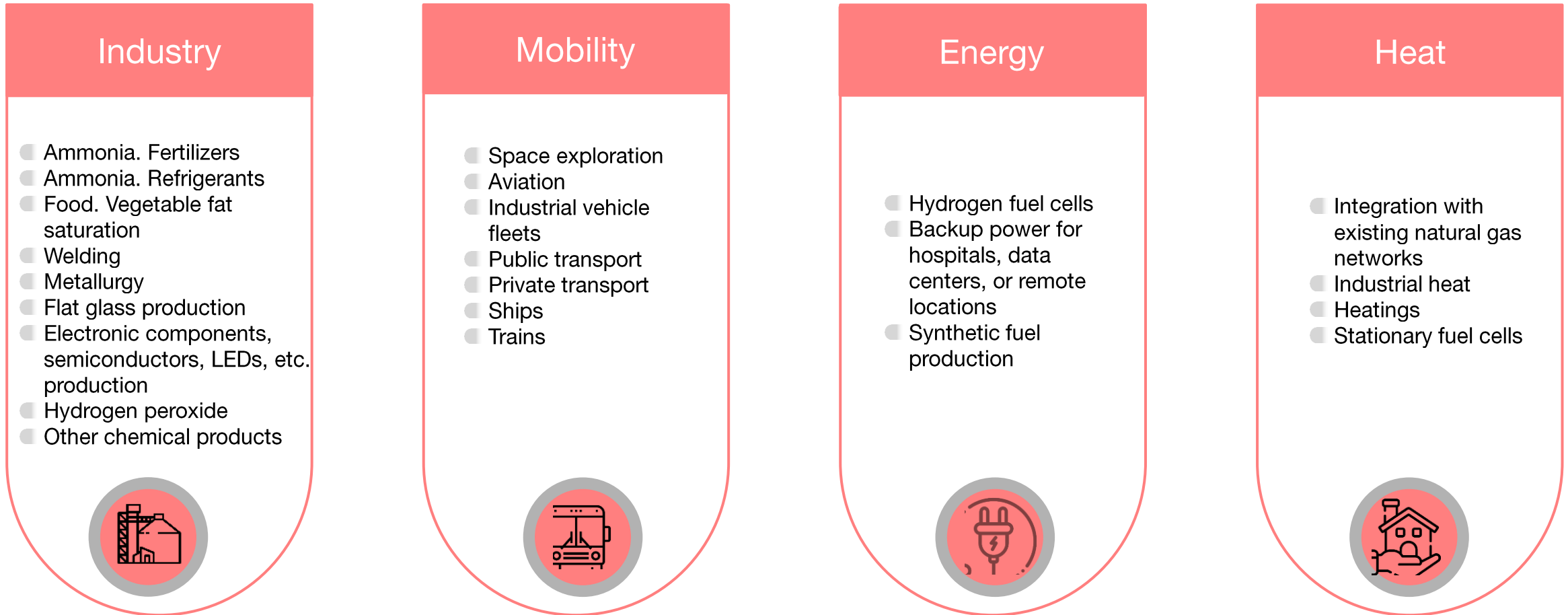
Source: IRENA (2023): *Geopolitics of the Energy Transformation*

CataloniaConnects

The transition to a carbon neutral economy and the need for energy storage are the main factors driving the development of hydrogen storage.

- Most storage methods require compression, refrigeration, or the use of hydrogen-bonding material.
- Hydrogen is typically stored in gaseous form in pressure vessels, in liquid form in cryogenic tanks, or chemically by adsorption or absorption.
- In terms of materials, ammonia, metal hydrides, and hydrogenation of carbon dioxide are the major and emerging hydrogen storage technologies.

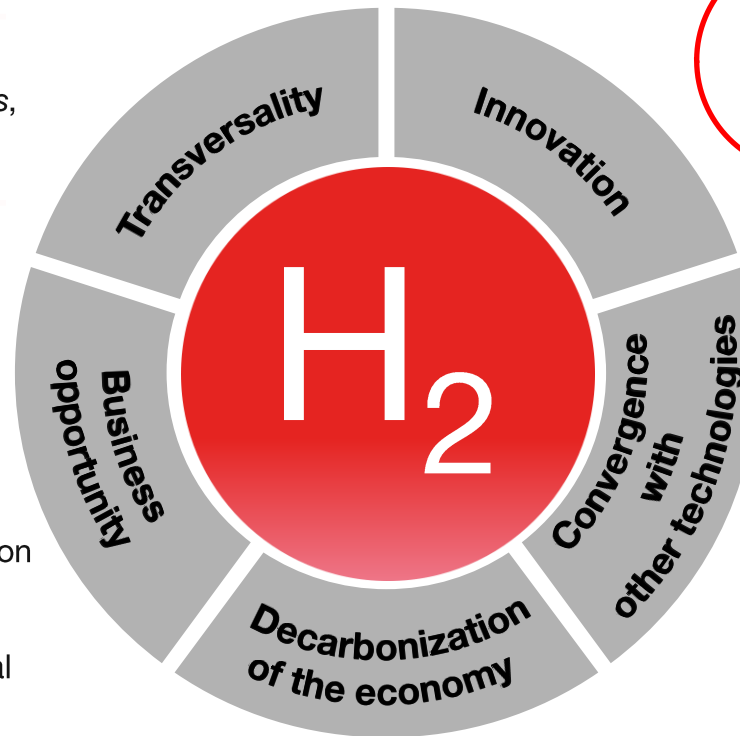




*Note: Hydrogen combustion can be useful to produce heat reaching high temperatures > 300°C without emitting particles or CO<sub>2</sub>, but it is necessary to strictly control NOx emissions to ensure that the combustion is sustainable and meets the requirements of greenhouse gas emissions such as NOx.*

The use of hydrogen can have an impact in many areas, from infrastructure to *smart cities*, going through the production processes.

In an environment that is increasingly aware of climate change and the desire to achieve carbon neutrality, the use of hydrogen can create new business models derived from its possible applications in different fields such as industrial and domestic heating, mobility, etc.



The large-scale use of hydrogen presents challenges and opportunities for the development of technologies that can be applied in different sectors and along the entire value chain.

The development of hydrogen technologies includes other areas such as the design of materials, the search for transportation and storage systems and methods, the adaptation of products and processes, and safety elements.

Clean hydrogen will contribute to the decarbonization of the economy, either in its energy vector applications or as a feedstock in industries such as chemicals.

Hydrogen in Catalonia

## 2. The World Hydrogen Market

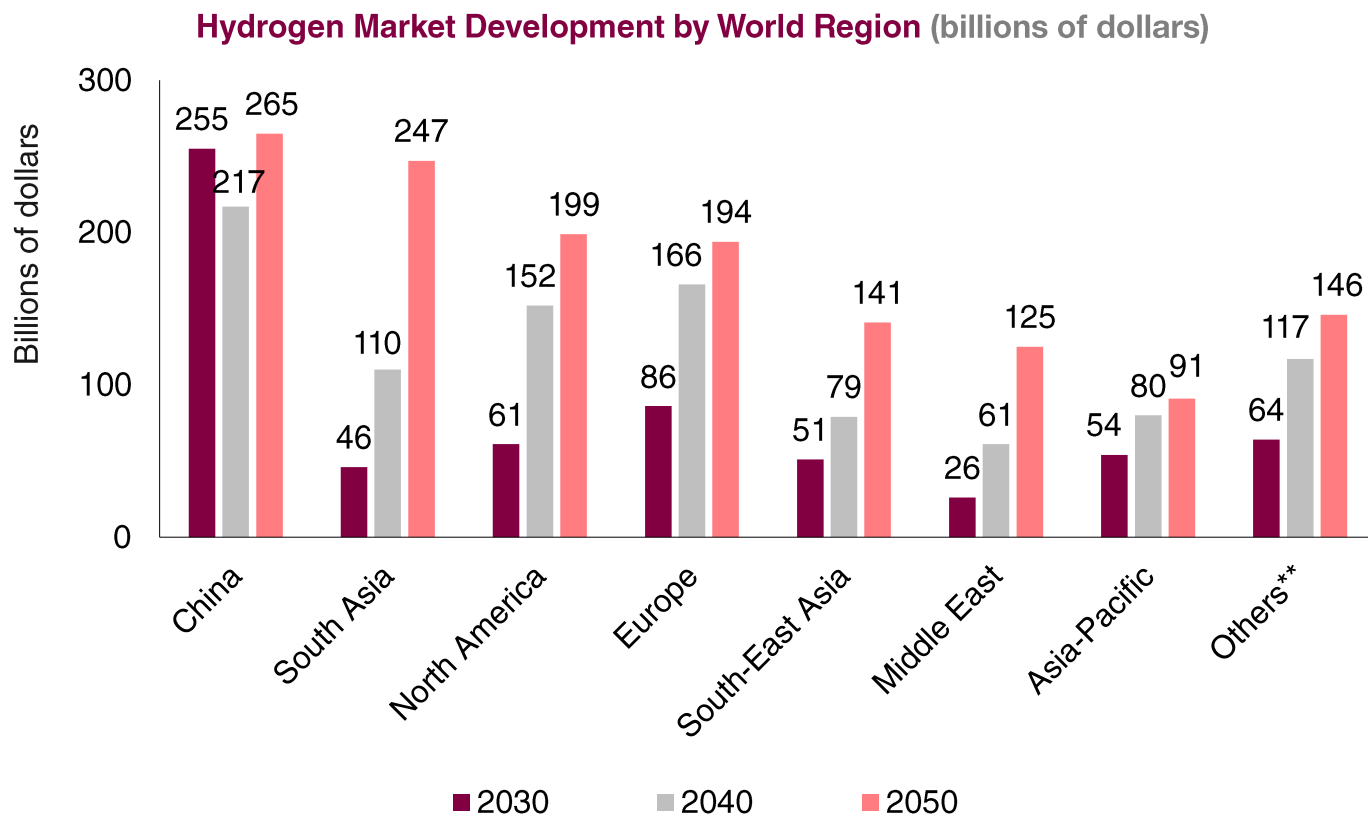




## Hydrogen on a Global Scale

The clean hydrogen market is expected to exceed the value of the global LNG trade\* by 2030 and continue to grow to **\$1.4 trillion annually by 2050.**

- **More than \$9 trillion of cumulative investment will be needed** in the global clean hydrogen supply chain to meet the 2050 zero emissions goals.
- Clean hydrogen can serve as a catalyst to **support 2 million jobs globally each year** between 2030 and 2050.
- **Interregional trade is key** to unlocking the full potential of the clean hydrogen market, supported by a **diversified transportation infrastructure.**
- **The forecast for 2050 is that China and South Asia** will end up being the main trading poles for this technology, with a market value of **\$265 billion and \$247 billion** respectively, followed by **North America in third place with \$199 billion.**
- The global hydrogen trade will generate more than **\$280 billion in annual export revenues by 2050.**

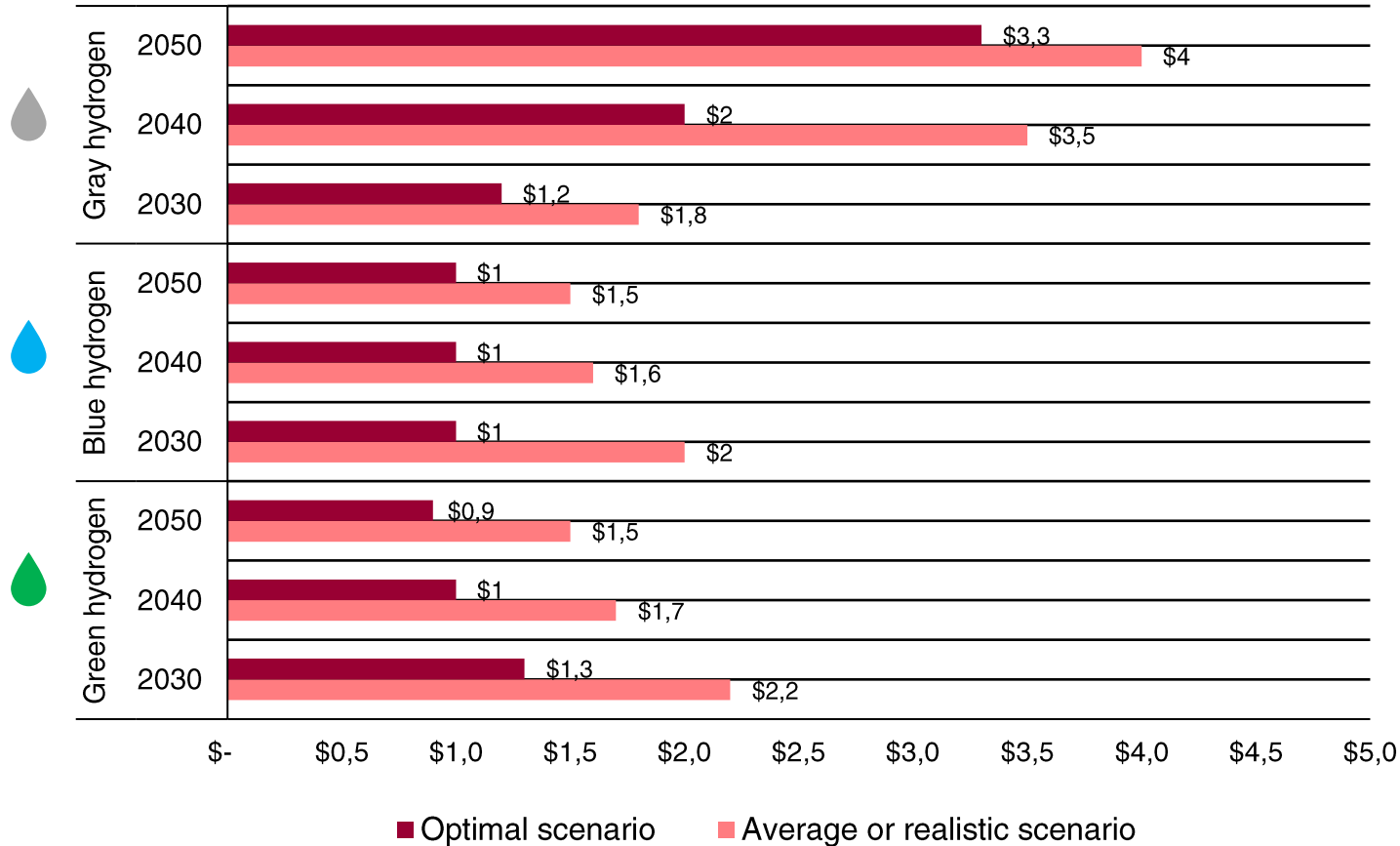


\*LNG: Liquefied Natural Gas.

\*\*Others: Included in order of highest business volume: Eurasia, Latin America and Africa.

# Evolution of Clean Hydrogen Prices

Hydrogen Production Cost\* (\$/kg)



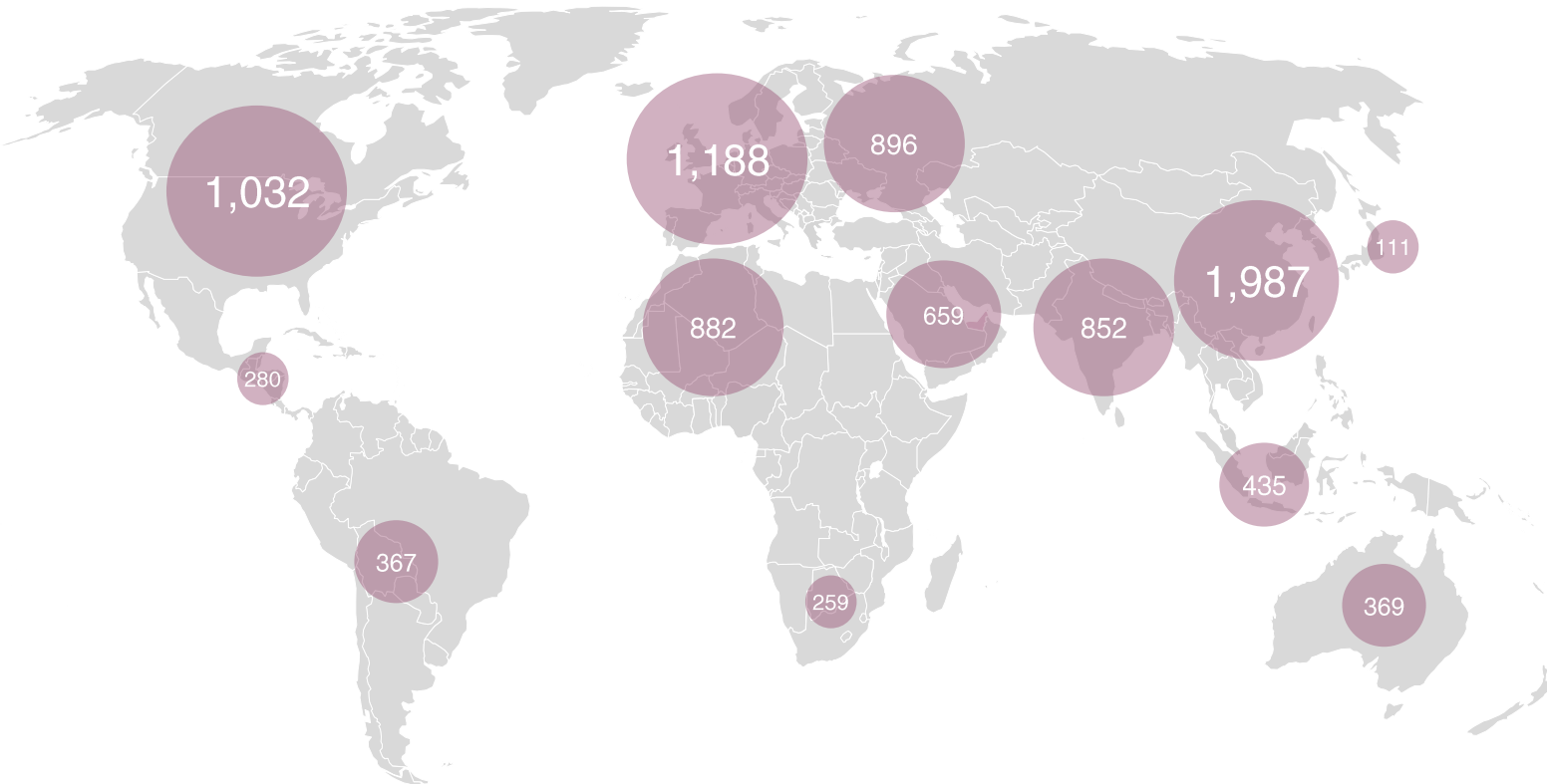
\*Note: Green hydrogen: produced by electrolysis and renewable energy (0 CO<sub>2</sub> emissions); Blue hydrogen: produced from natural gas, CO<sub>2</sub> is generated and captured during production; Gray hydrogen: produced from fossil fuels, CO<sub>2</sub> is generated that is not sequestered and released.

- Estimates point to a **gradual decrease in the cost of clean hydrogen** and a **gradual increase in the cost and CO<sub>2</sub> emission rates**, which may exceed \$300/t CO<sub>2</sub>e on average by 2050 (for produced hydrogen that generates CO<sub>2</sub> or gray hydrogen).
- For green hydrogen, **production costs are estimated to fall to \$1.5-2.5/kg by 2030, \$1-1.7-2/kg by 2040, and \$1-1.5/kg by 2050. Currently**, the production cost of **green hydrogen** is higher (**about \$6/kg**) than gray hydrogen, making it less competitive.
- As for the production cost of blue hydrogen, it will decrease and will be between **\$1-1.5/kg by 2030** and is expected to **stabilize around these prices** by 2050.
- Estimated demand for clean hydrogen is expected to grow to approximately 660 million metric tons per year by 2050, and clean hydrogen will reach a **competitive cost that will be applied in many sectors**.

Source: McKinsey Hydrogen Insights in Carbon Pricing 2023 (World Bank Group)

## Cumulative Investment in Clean Hydrogen Supply Chain in 2050

(billions of dollars)

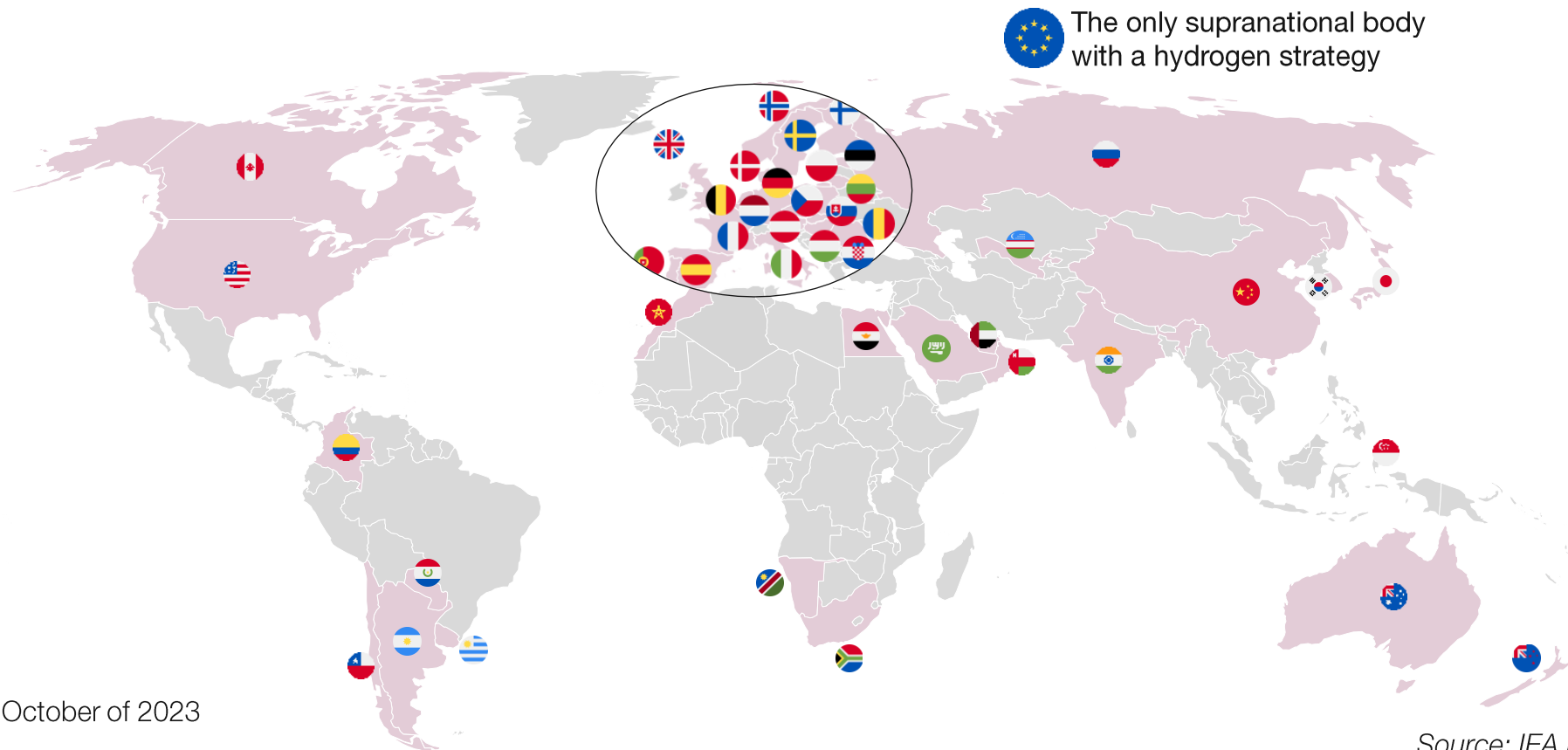


- The forecast of cumulative investment in the clean hydrogen supply chain through 2050 places **China and Southeast Asia, Europe, and North America as the major global players** in clean hydrogen.
- **Investment in China and Southeast Asia** is expected to exceed **\$1.98 trillion**; in **Europe, \$1.18 trillion**; and in **North America, \$1.03 trillion**.
- Other regions of the world will also develop their clean hydrogen infrastructure with significant investments in their supply chain, positioning themselves as **suppliers or international transport hubs**, such as the **Maghreb, South Asia or Eastern Europe**.

# National Hydrogen Strategies Worldwide

More than **40 countries** have a **national strategy** or agreement to promote hydrogen and related technologies, **half of them in Europe**.

## Countries with Strategies Related to Hydrogen



Note: Updated in October of 2023

## European Strategy for Hydrogen

The strategy, adopted in 2020, promotes the production of clean hydrogen in the EU and makes it a priority for economic growth.

2020 - 2024

Install **6 GW of electrolyzers in the EU** to produce **1 million tons of hydrogen**.

2025 - 2030

Generate **40 GW** and produce **10 million tons of hydrogen**.

2030 - ...

**Large-scale deployment of clean hydrogen.**

## Other hydrogen promotion tools

### REPowerEU

Plan to deal with energy market disruptions caused by the war in Ukraine:

- **€200 million** intended for green hydrogen research.
- **10 Mt** of green hydrogen imports by 2030.
- Promote the **regulatory framework** for green hydrogen.

### Net-Zero Industry Act

Promote 8 technologies to achieve carbon neutrality:

- Envisages that 40% of them will be manufactured in the EU **electrolyzers and batteries of combustible** in 2040.
- Simplify the **regulatory framework** for manufacturing these technologies.

### European Hydrogen Bank

Financial instrument to unlock investment in the hydrogen value chain:

- It has organized **auctions to narrow the gap between the production costs of clean and fossil hydrogen**. A new auction is planned from April 2024.

## Hydrogen Roadmap

### Key Figures in 2030

**€8.9 billion** in investments

**4 GW** of installed electrolyzer capacity

**25%** of the industry's energy consumption

**100 - 150** of public access hydrogen stations

## Hydrogen Network

Cantabrian cornice axis, Ebro valley axis and Llevant axis, with connection Barcelona-Marseille (**H2MED**)

Via de la Plata axis (connected to Puertollano Hydrogen Valley)



## PERTE

### PERTE of Renewable Energy, Hydrogen and Storage (ERHA)

**€16.3 billion** in investments mobilized  
**€1.55 billion** in clean hydrogen projects

### PERTE of Industrial Decarbonization

**€3.1 billion** in investments mobilized  
**€450 million** in clean hydrogen projects

## H2 Pioneers Program

**1st call**  
**€150 million**  
19 funded projects

**2nd call**  
**€150 million**  
14 funded projects

# Major Companies in the Hydrogen Market Worldwide

By sector, the gas companies stand out, and by nationality, the North American companies.

## Hydrogen Production



## Green hydrogen



## Fuel cells



 Presence in Catalonia

Hydrogen in Catalonia

## 3. Hydrogen Opportunities and Challenges



## Hydrogen Opportunities

- **Clean hydrogen is a key vector for achieving decarbonization goals**, especially in energy-intensive industrial sectors or heavy-duty mobility.
- **Developing electrolyzers** with flexible systems that increase multi-range efficiency and half-life, reduce cost and dependence on critical materials, and improve productivity. **Catalyst development.**
- **New storage media development.** Design of tank materials to avoid hydrogen leakage and fragility issues.
- **New business models and opportunities** for the auxiliary industry in the adaptation of materials and equipment, as well as nozzles, turbines, valves, coatings, welding and the creation of networks of hydrogen plants or specific distribution of hydrogen.
- **Development of specific technologies** for different applications and with better efficiency. The availability of H<sub>2</sub> opens up new avenues for hydrogenation of CO<sub>2</sub> and other carbon-based molecules, enabling the production of chemical products and synthetic fuels in gaseous or liquid form, the latter for aviation, shipping or heavy machinery. Special emphasis on maritime and rail transportation.
- The hydrogen value chain will require **new technologies and new sectors** such as catalysts, solvents, carbon capture, membranes, pipes, etc., and skilled personnel such as technicians, engineers, manufacturers, installers, etc.



## Hydrogen Challenges

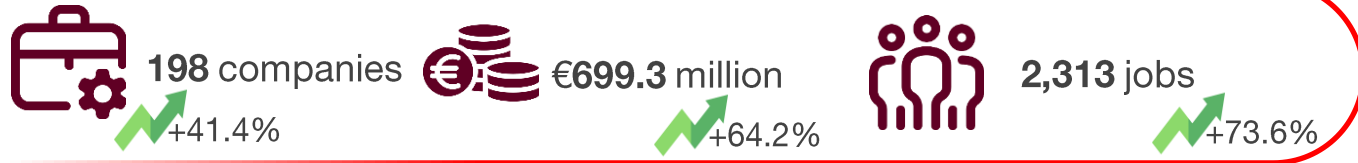
- The production of clean hydrogen, especially from renewable sources, will require significant cost reductions. **The cost of renewable electricity is 75% of the cost of hydrogen.**
- Although hydrogen has a very high gravimetric density, it has a very low volumetric energy density, which means that it **must be compressed and processed at high pressures and very low temperatures** for storage and transportation.
- Hydrogen is a **very reactive gas and can cause embrittlement in various materials** such as steel. It also has a high burning rate. The infrastructure to deliver hydrogen to the point of use must be reformed and adapted.
- **Hydrogen is an energy carrier** that can combust (react with oxygen) under certain conditions and therefore must be handled with strict safety measures. However, the goal is to use it electrochemically or in chemical processes. There is a lack of a harmonized regulatory framework to facilitate the introduction of hydrogen on a large scale.
- **The cost and adaptability of fuel cells to different environments** are still unresolved, and some technologies, such as SOECs, are at a pre-commercial stage.
- Electrolyzers depend on **critical raw materials such as rare earths**, which are dominated by China. Without control of the entire value chain, EU sourcing and manufacturing objectives cannot be met.



Hydrogen in Catalonia

## 4. Hydrogen in Catalonia

# Mapping the Hydrogen Ecosystem in Catalonia



57.9% of companies are SMEs

79.6% have a turnover of more than one million euros and 57.7% more than 10 million euros.



19.4% are less than 10 years old

4.6% are startups



52.6% are exporters

## Per segments\*



25.5% of the companies are in the hydrogen production phases



59.7% are part of the transformation, transport and storage process and fuel cells

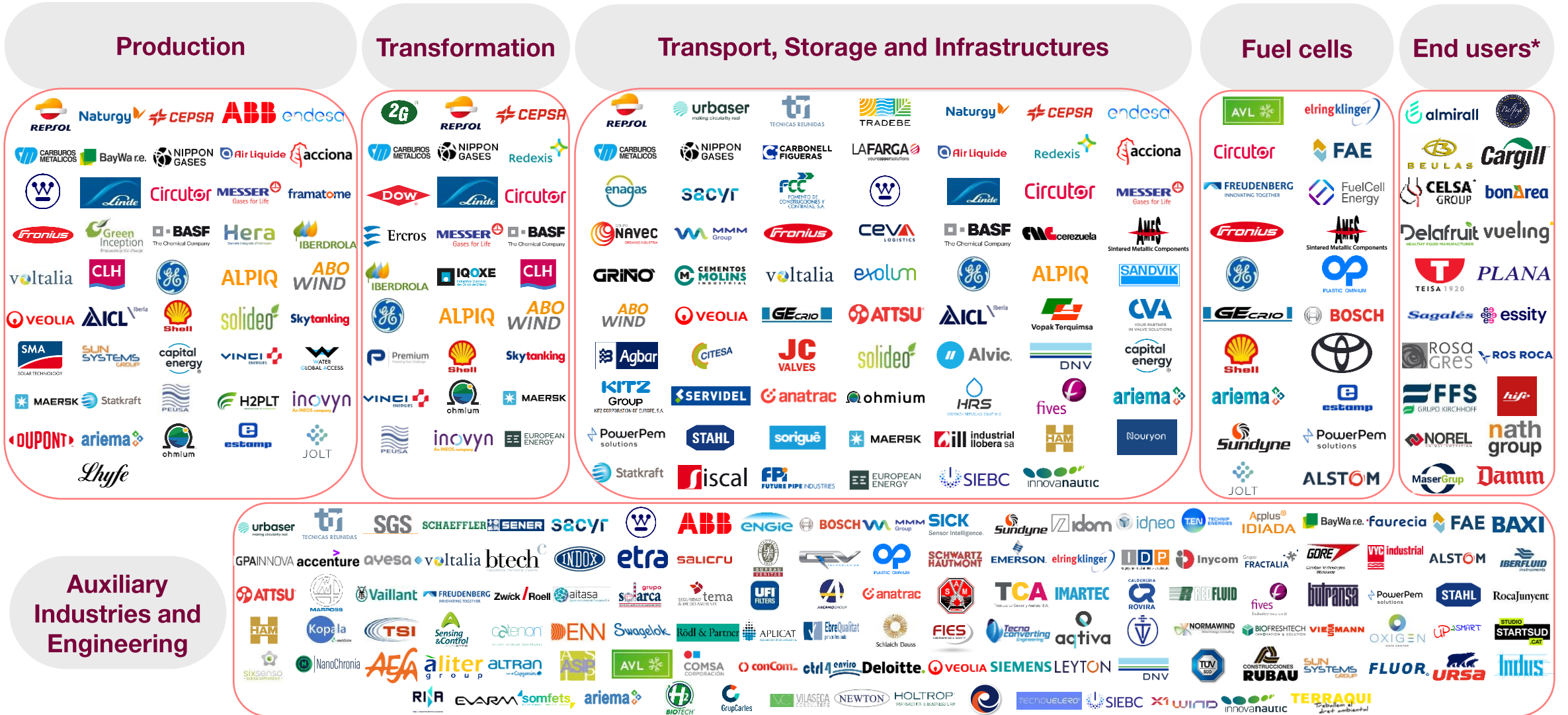


70.4% are part of the auxiliary and engineering industries



\*Companies may belong to more than one segment of the hydrogen value chain.

# Hydrogen Ecosystem in Catalonia



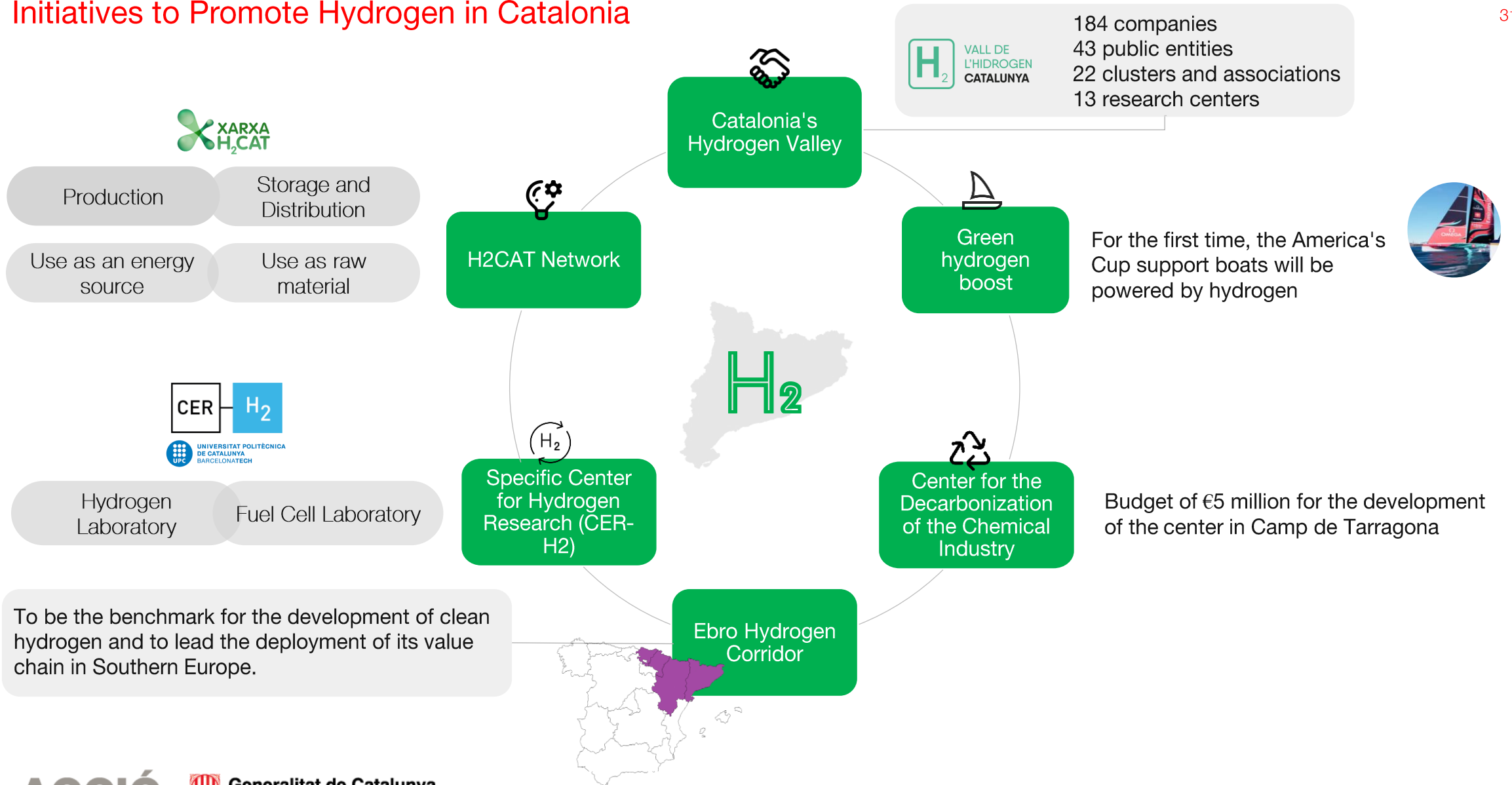
## Auxiliary Industries and Engineering

\*Representative sample. Companies are not quantified for business mapping purposes.

# Agents of the Hydrogen Ecosystem in Catalonia



# Initiatives to Promote Hydrogen in Catalonia



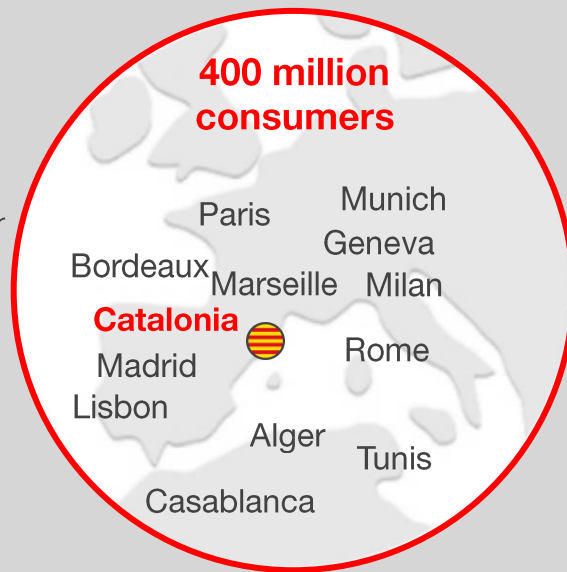
## Strategic distribution capacity: a hub of international connections ready for hydrogen

Catalonia's excellent geo-strategic location allows for **efficient intercontinental connections** with Asia and America, as well as **quick and easy distribution** in Southern Europe and North Africa. This strategic location will serve to become a reference point capable of supplying hydrogen to the rest of Europe.

### Unmatched distribution capacity

Its strategic location and extensive network of infrastructures make Catalonia the gateway to Southern Europe and the leading distribution center in the Mediterranean.

The logistics network can reach **400 million consumers** in Europe and the Mediterranean/Africa in less than 48 hours\*.



\* By all means of transportation: air, rail, truck and ship.

### H2MED will support the development of hydrogen in Europe

The H2MED\* foresees the maritime connection between Barcelona and Marseille to send **2 million tons of green hydrogen per year** to the rest of Europe.

This will allow Catalonia to be a hub for both hydrogen reception and production and export to serve a very demanding hydrogen market in the coming years.



\* Expected to be implemented in 2030.



# Integrated logistics hub: two of the most important Mediterranean ports



## Port of Barcelona



- Specialized in general cargo and high value-added goods, the Port of Barcelona is connected to 178 ports around the world by 88 regular lines.
- It has one of the highest productivity levels in Europe and is a benchmark port in the Euro-Mediterranean region.
- It is the state leader in the value of goods and the most important transportation and services infrastructure in Catalonia.
- It houses a hydrogen plant to support the celebration of the 37th America's Cup.

## Port of Tarragona



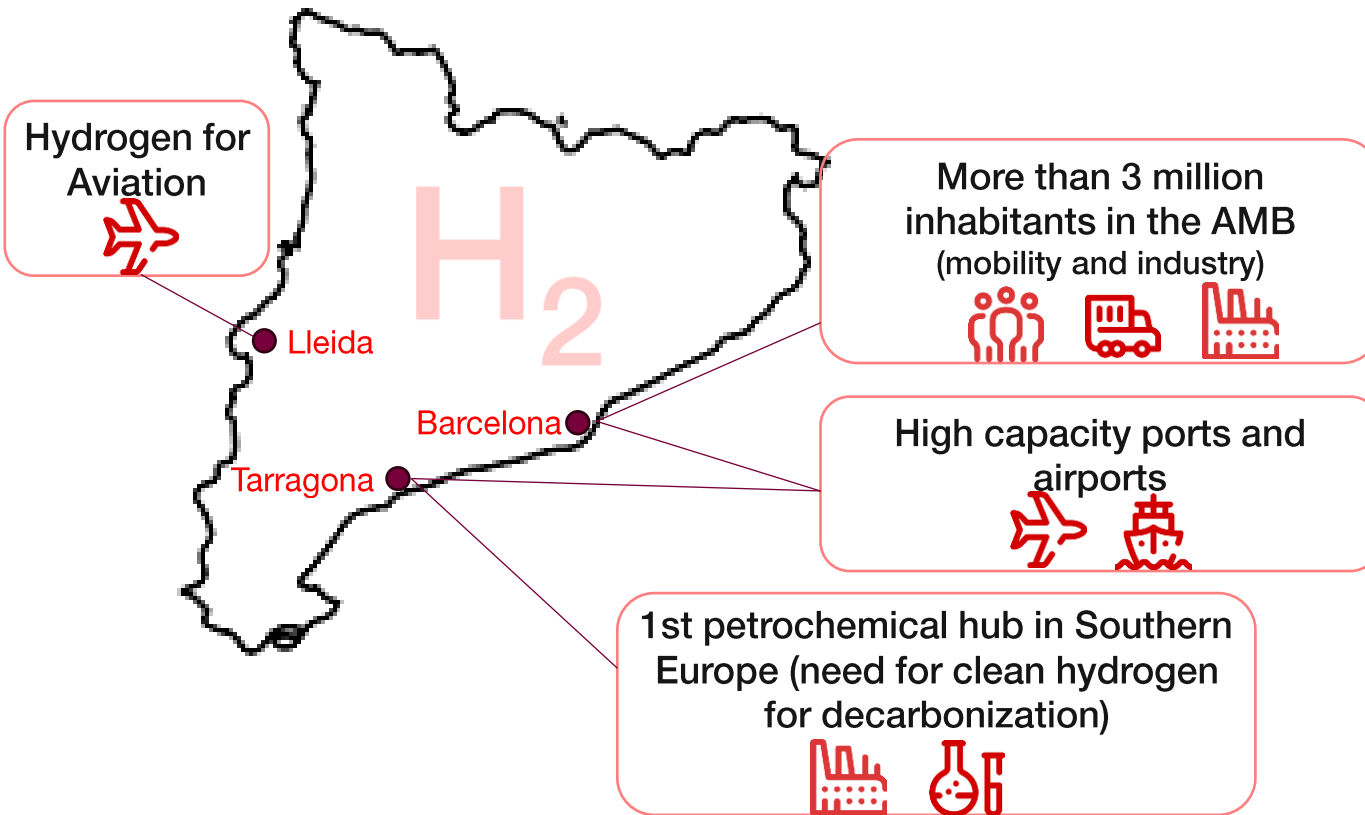
- With world-class infrastructure and designs, it is positioned as a hub in the Mediterranean for the storage and distribution of energy products.
- The investment in Moll de la Química has made it possible to double the area of the port dedicated to the storage of all types of bulk liquids, whether hydrocarbons, chemical products or other derivatives of the energy transition, such as ammonia for the capture and storage of hydrogen.
- The current storage capacity is over 800,000 m<sup>3</sup> and the intention is to increase the capacity year by year until it reaches 1.2 million m<sup>3</sup>.



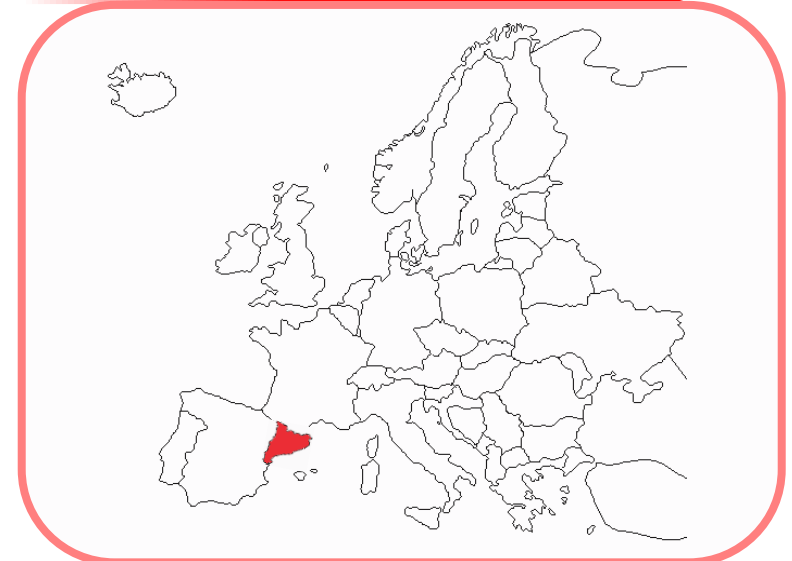
Catalan ports:  
**Port of Barcelona**  
**Port of Tarragona**

Both ports have services and infrastructure specialized in the handling and shipment of certain types of products, which favors their import and export.

# Catalonia's Hydrogen Capacities



**Geo-strategic position** for the use of hydrogen in heavy-duty mobility, the European pipeline network and import-export channels



**H2MED** (Barcelona-Marseille) to transport hydrogen to the rest of Europe



**Ebro Hydrogen Corridor** with the North of the Iberian Peninsula

**Interuniversity Master in Hydrogen Technologies:** to train professionals in the various technologies of the hydrogen value chain in generation, storage, transport, distribution, conversion and applications. The 3rd edition was launched in 2023.



## Degrees

## Masters and Postgraduate

## Professional Training



Degree in Energy Engineering and Sustainability



Master in Renewable Energy and Energy Sustainability



Course on Green Hydrogen Production by Electrolysis (HELEC)



Degree in Energy Engineering

Master in Power Electronics



Master's Degree in Automotive Engineering

Master's Degree in Energy Engineering

Master's Degree in Interdisciplinary & Innovative Engineering



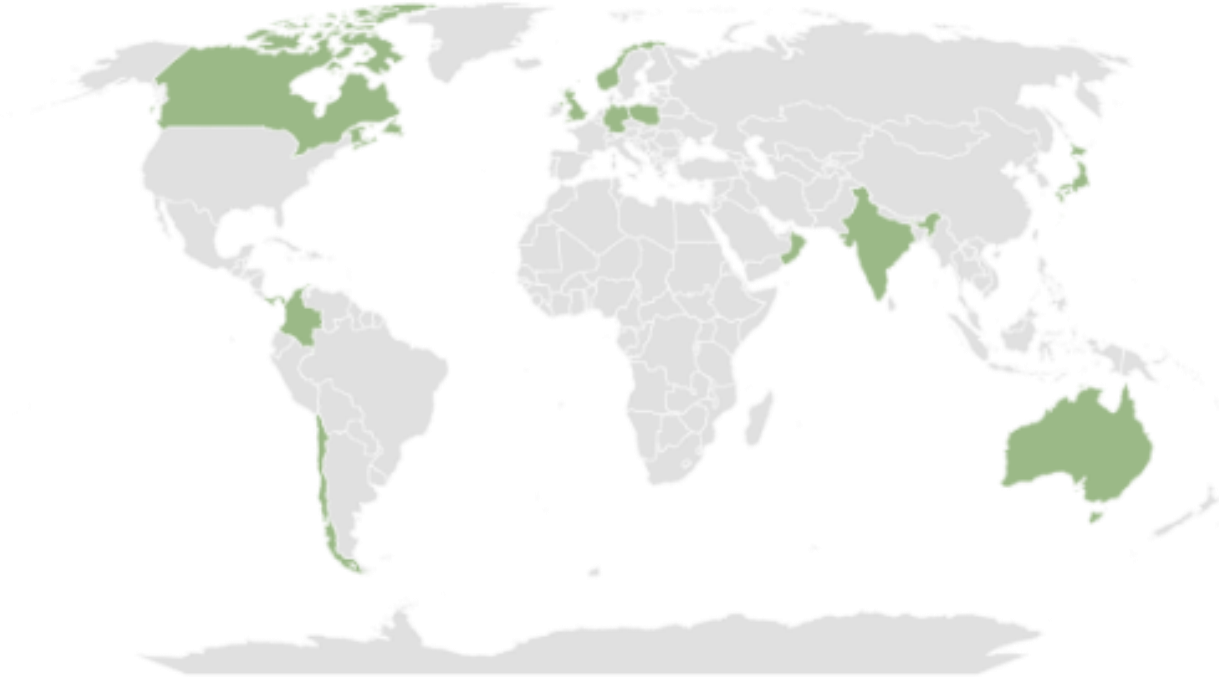
**Training for a Hydrogen Economy based Renewable Energy Society in the Anthropocene:** First European PhD program for legal specialists in the field of hydrogen.



Hydrogen as an Energy Vector: Technologies and Application



# International Opportunities for Hydrogen



**Panama**  
 Equipment, Technology and Engineering Services for Green Hydrogen Projects

**Canada**  
 Canadian Energy Market: Clean Technologies and Sustainability

**Chile**  
 Chile 2050 Energy Plan

**Colombia**  
 At the Forefront of Energy Diversification

**United Kingdom**  
 Net Zero 2050: Government Commitment

**Australia**  
 Hydrogen and Renewable, the Government's Big Bets for 2023-2024

**Poland**  
 Hydrogen as the Axis of Decarbonization in Poland

**Norway**  
 Norway, Where the Energy Future Exists

**Belgium**  
 Belgian Commitment to Green Energy and European Strategic Pillar

**Germany**  
 Technological Challenges for the German Renewable Energy Sector

**Netherlands**  
 A 100% Sustainable Industry by 2050

**Japan**  
 Japan, an Automotive Powerhouse on the Way to the Vehicle of the Future

**Singapore**  
 Singapore Seeks to Diversify its Energy Sources

**Oman**  
 Infrastructures that Will Boost Tourism, Trade and the Economy

**India**  
 Green Energy Alternatives for Mobility

Source: Global Map of International Business Opportunities 2023

# Hydrogen SWOT in Catalonia

## Strengths



Large presence of intensive industry in the use of hydrogen, especially chemicals



Participation in the Ebro Corridor and other European initiatives



Presence of research centers and universities



TMB - AMB is a pioneer in Spain in the application of the H<sub>2</sub> in vehicle fleets

## Weaknesses



Few specialized companies



Low penetration of renewable energy



Lack of investment in industrial research and development



Political, regulatory and standards uncertainty

## Opportunities



A firm commitment to climate neutrality and decarbonization in the EU: clean hydrogen will be key



Need to connect the H<sub>2</sub>MED to the Port of Tarragona



Next Generation EU grants



Creation and development of applied technologies along the value chain

## Threats



Cost of renewable hydrogen remains high compared to fossil fuels



Some technologies are immature



Significant energy is lost in the production and conversion of hydrogen



Lack of regulation and certification

Hydrogen in Catalonia

## 5. Success Stories in Catalonia

## Success Stories in Catalonia



**Lleida-Alguaire Airport** will install an electrolyzer to produce hydrogen with its photovoltaic park and a hydrogen generator.



**Vueling** is committed to sustainable fuels, in line with the objectives of the European strategy ReFuelEU Aviation.



The **Port of Tarragona** is adapting its infrastructure to export and import hydrogen from around the world, becoming a logistics hub.



The **Port of Barcelona** will host the 2024 America's Cup, where support boats will run on hydrogen supplied by **Carbuross Metálicos**.



**Evarm** has developed the first prototype hydrogen car and the hydrogen powered truck that participated in the last Dakar.



**Applus IDIADA** collaborates with various partners in the development of fuel cell and hydrogen vehicles.



**Hydrogenizing BCN** is an initiative that aims to create an ecosystem for SMEs and startups that allows them to participate in the hydrogen economy.



**TMB** has made a commitment to the use of hydrogen in public transport. 36 more will be added to the 8 hydrogen buses already circulating in Barcelona.



**QEV Technologies** will have electric and hydrogen platforms for buses and heavy trucks at the D-Hub in the Free Zone.



**Hydrogen-Refueling-Solutions** has chosen Barcelona for its first office outside of France to accelerate the hydrogen supply network.



**Repsol** is leading a consortium to install a 150 MW electrolyzer to supply renewable hydrogen to the Tarragona petrochemical complex.



**Celsa** is testing the production of green hydrogen with new technologies applicable to the steel industry for the valorization of by-products.



**Jolt** has patented the technology, which consists of a new surface coating process to produce more efficient industrial electrodes.



**Indox** has developed a green hydrogen plant for industrial self-consumption.



**MMM** specializes in the clean, efficient and decentralized production of hydrogen and biogas.



**AMES** is leading a project to develop high-temperature electrolysis technology for efficient renewable hydrogen production.



**NanoChronia**, a **URV** spin-off that has developed nanosensors to detect specific gases such as hydrogen.



The PRIMA platform, developed by **IREC** in Gurb since 2022, is a platform for the integration of renewable energy and storage.

We would like to thank all the institutions that contributed to this study for their time and knowledge.







Check out the report here:



More information about the sector, news and opportunities:



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