

July 2022. Technology snapshot

Green hydrogen

in Catalonia

**ACCIÓ**

**Regional Government of Catalonia (Generalitat de Catalunya)**



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## Execution

ACCIÓ Strategic and Competitive Intelligence Unit

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Green hydrogen in Catalonia

# 1. Definition of hydrogen

The EU is making steady progress towards achieving climate neutrality by 2050, and the hydrogen vector can play a leading role.

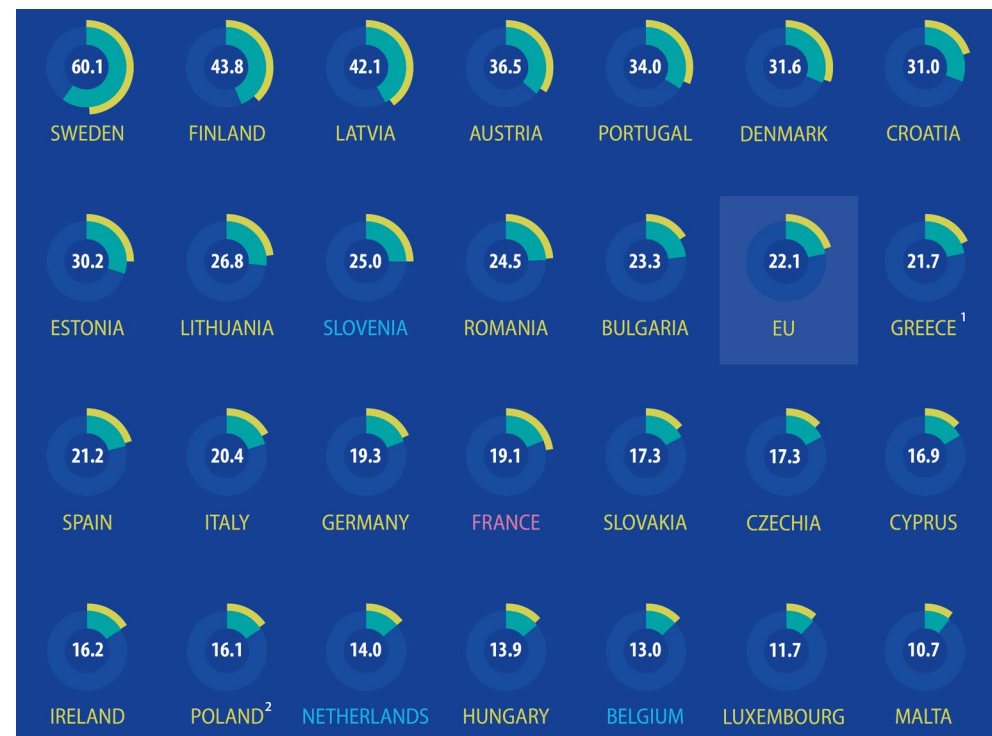
Under the new Fit for 55 program, the EU has set a target of **40%** renewable energy by 2030, although some European countries are still far away from it.

With the **European Green Deal**, the EU is stepping up its climate ambition and aims to become the **first climate-neutral continent by 2050**. To this end, the Commission is committed to align existing legislation with a 55% emission reduction by 2030. In this context, **the hydrogen vector may play a prominent role**.

In 2020, throughout the EU **the production of renewable energies, such as solar and wind power, exceeded that of fossil fuels**, such as coal or gas, for the first time.

The generation of electricity from renewable sources is the major pending issue in Catalonia, as it only accounted for 19.8% of total production in 2020, far behind nuclear energy (54.9%).

## Renewable energy contribution by EU Member States (% of final energy consumption, 2020)



Note: on the graph, in yellow: each country's 2020 target; in turquoise green: % of each country's consumption in 2020

Sources: Europa.eu/energy; Eurostat; Green Deal; ICAEN

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## Hydrogen as an energy carrier

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

- Hydrogen has an energy content three times higher than diesel and natural gas.
- Hydrogen is not an energy source, but is considered an **energy carrier**, in other words, a substance or device that stores energy and which can later be used.
- Hydrogen is a good energy carrier, as **it can be produced from a variety of abundant precursors**, such as **natural gas, coal, water** and **renewable energy sources**.
- The use of hydrogen in fuel cells, especially in the mobility industry, **will allow future energy supply to be diversified**, with greater use of national resources, so as to **reduce reliance on oil imports**.



## Colours of hydrogen

Green hydrogen is the only carbon-free hydrogen and will be key to climate neutrality.

Hydrogen is classified on the basis of how it is obtained:

**H<sub>2</sub> Grey/Black**  
Reforming

Hydrogen obtained from natural gas by methane reforming.

**H<sub>2</sub> Grey/Black**  
Gasification

Hydrogen produced from fossil fuels, generally by gasification.

**H<sub>2</sub> Turquoise**  
Pyrolysis

Hydrogen produced by methane pyrolysis. Coal is obtained instead of CO<sub>2</sub>.

**H<sub>2</sub> Blue**  
Reforming or gasification

Grey or brown hydrogen, but CO<sub>2</sub> is captured and stored or can be used in other industrial processes.

**H<sub>2</sub> Pink/Purple/Red**  
Electrolysis

Hydrogen produced by electrolysis using nuclear energy.

**H<sub>2</sub> Yellow**  
Electrolysis

Hydrogen produced by electrolysis using grid electricity

**H<sub>2</sub> Green**  
Electrolysis

Hydrogen produced by the electrolysis of water, harnessing renewable sources like hydro, wind or solar.

**H<sub>2</sub> White**  
By-product in industrial processes

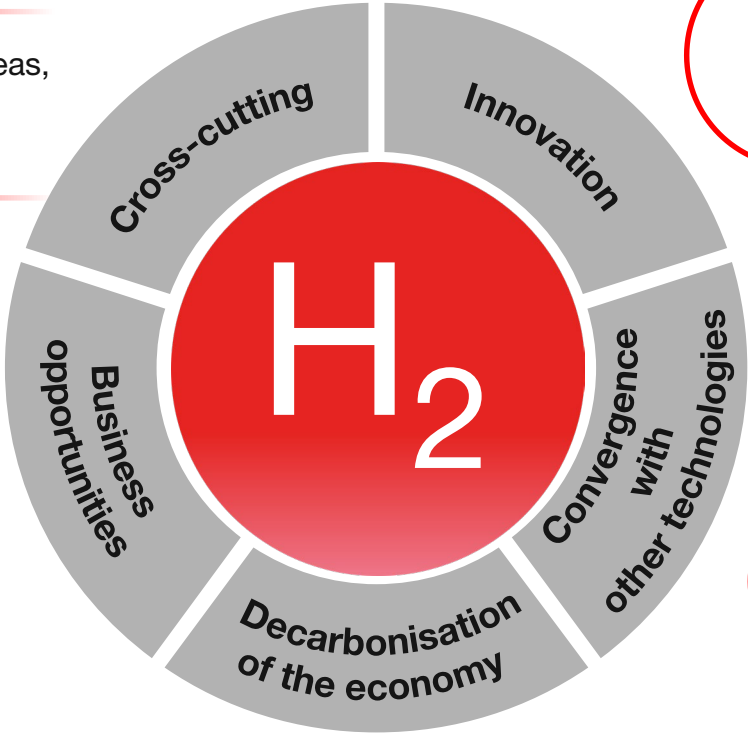
Hydrogen obtained as a by-product in industrial processes.



# The importance of hydrogen to industry

The use of hydrogen can impact many areas, from infrastructures to smart cities and production processes.

Large-scale hydrogen use presents challenges and opportunities for the development of technologies that enable its application in different sectors and throughout the value chain.



In an increasingly climate-change-aware environment and with the aim to deliver on climate neutrality, hydrogen can be tapped to create new business models based on its potential applications in different fields, such as heating for industry and homes, mobility, etc.

The development of hydrogen technologies encompasses other areas, such as materials design, research into transportation and storage systems and methods, product and process adaptations, as well as security features.

Green hydrogen will help to decarbonise the economy, both in its applications as an energy carrier and as raw material in industries like the chemical industry.



Green hydrogen in Catalonia

## 2. The global hydrogen market

The green hydrogen market will grow by **56.3%** annually until 2025, when it will reach a turnover of \$16.54 billion **worldwide**.

## Trends

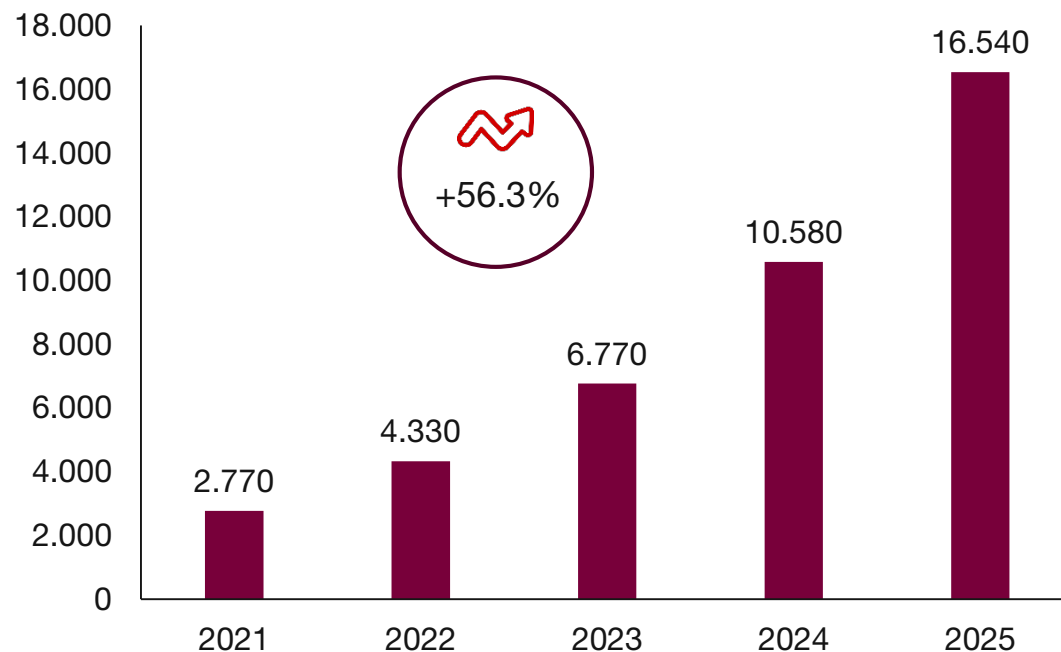
Innovation towards a carbon-free economy:

- Green hydrogen helps bring about the transition from a carbon-intensive ecosystem to a CO<sub>2</sub>-free ecosystem.

The future of mobility:

- Vehicles powered by fossil fuels are replaced by electric vehicles (powered by batteries or fuel cells using green hydrogen).

Global evolution of green hydrogen turnover (\$M) 2021 – 2025



Source: Frost & Sullivan (2021): TOP 50 EMERGING TECHNOLOGIES: 2021 EDITION

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## Evolution and price prospects for hydrogen

Production costs could fall by 62% between 2020 and 2030, from \$6 to \$2/kg.

- **Reduction in electrolyser investment requirements:** around 200-250 USD/kW is expected to be required by 2030, some **30-50% less** than in 2020.
- **Reduction in renewable energy costs: 15% cost reduction** driven above all by the rollout of photovoltaic power in areas with high solar radiation, such as Chile, Spain, Saudi Arabia and Australia.
- **Rise in the use of hydrogen:** higher levels of electrolyser utilisation, centralisation of production, better combination of renewable energies and integrated design optimisation.

Rising fossil fuel prices in the wake of the war in Ukraine may lead to a shortening of the timeframe for price convergence between green and grey hydrogen.



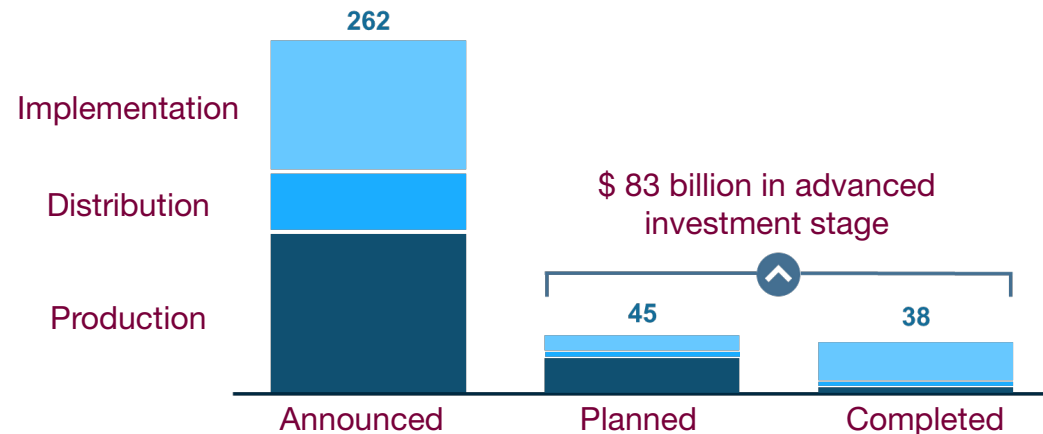
## Global initiatives around hydrogen

More than \$340 billion is expected to be invested by 2030, most of which will take place in Europe.

- It is estimated that **more than \$340 billion will be allocated** to announced projects by 2030, which are investments needed to meet government production targets and spending forecasts across the value chain.
- Given the sector's early stage, **75% of these investments** (\$262 billion) **are announced projects** that do not yet have financing commitments.
- 25%** (\$83 billion) **are investments that are considered** mature; more than half (\$45 billion) are at a planning phase, while the rest (\$38 billion) are committed and/or operational projects.

### Announced investments by maturity\*

(in \$M)



**Most of the investment are planned in Europe** (around 45%), **followed by Asia**, where China leads with almost half of the investment.

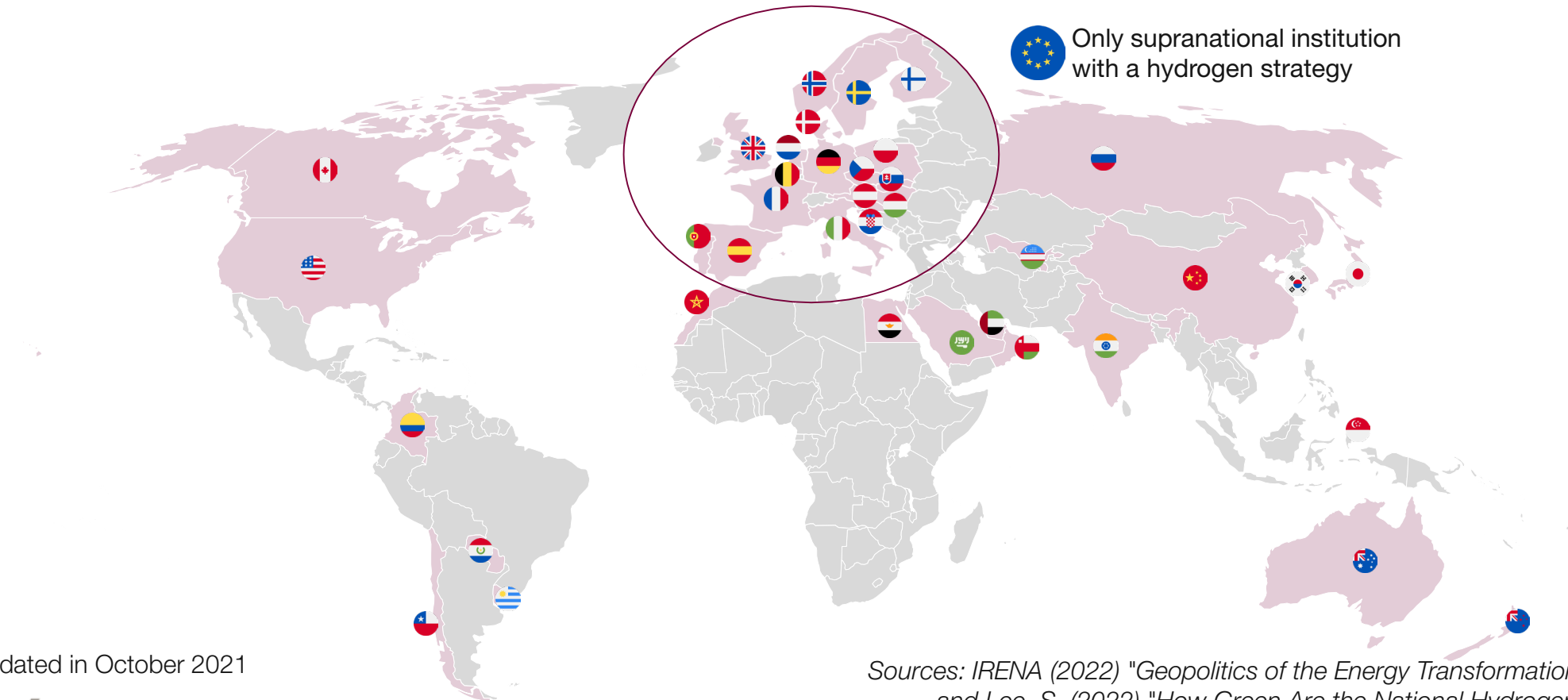
By value chain, **hydrogen production accounts for most of the investments**, while **those corresponding to end applications have a greater share in mature projects**, due to funding of fuel cells and car platforms.

\*Announced: at the preliminary study stage. Planned: at the feasibility study or front-end engineering and design stage. Completed: projects under development, being implemented and at operational stage.

# National hydrogen strategies around the world

More than 35 countries have a strategy to lead the adoption of green hydrogen, half of which are European.

## Countries with strategies related to green hydrogen



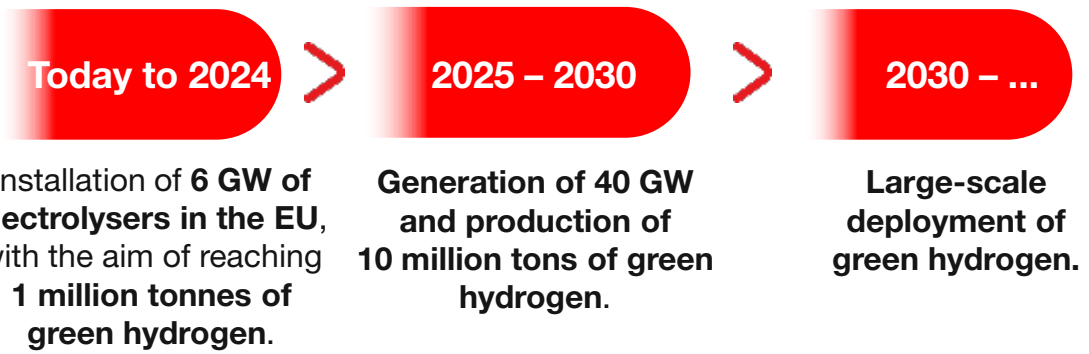
Note: updated in October 2021

Sources: IRENA (2022) "Geopolitics of the Energy Transformation"; Cheng, W. and Lee, S. (2022) "How Green Are the National Hydrogen Strategies?"

# The EU hydrogen strategy

## European Hydrogen Strategy

The Strategy, adopted in 2020, boosts green hydrogen production in Europe and makes it a priority to foster economic growth.



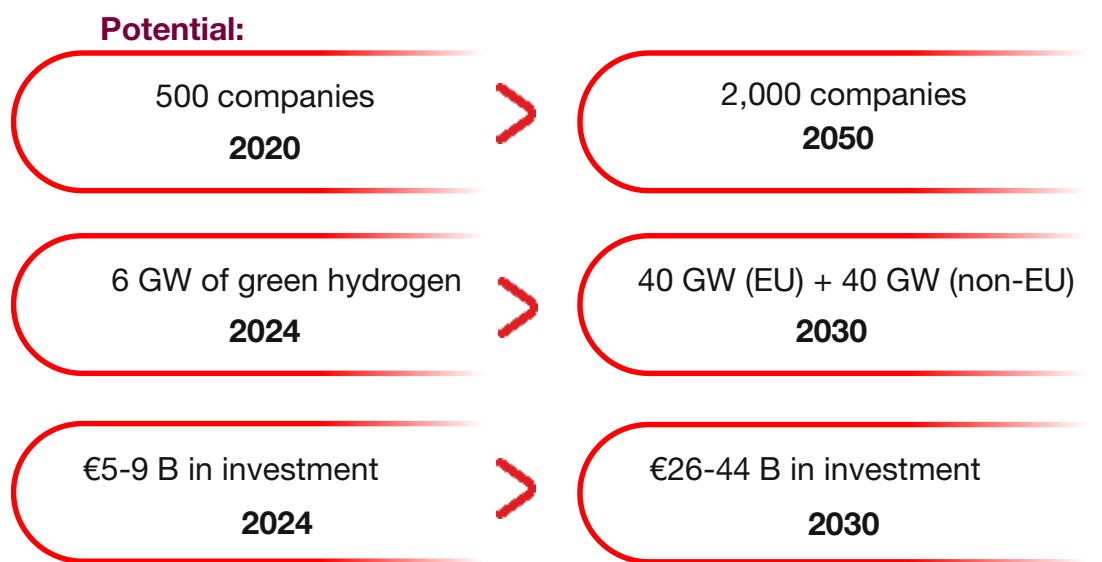
The Strategy is supplemented by **REPowerEU**, the European plan to address the energy market disruptions caused by the war in Ukraine:

- €200 million earmarked for green hydrogen research under Horizon.
- 10 million tonnes of green hydrogen imports by 2030.
- Push for green hydrogen production through early adoption in IPCEIs by summer 2022.
- Boosting the regulatory framework for green hydrogen.

## European Clean Hydrogen Alliance



The aim of the Alliance, which was launched in parallel to the Strategy, is to create an investment agenda and support the hydrogen industry value chain.



## European hydrogen valleys

**Catalonia is a European Valley** to boost green hydrogen.

- The **European Hydrogen Valleys Partnership** is part of the S3 Industrial Modernisation platform, promoted by the European Commission and of which Catalonia is a member.
- The partnership addresses **global warming to minimise its effects on society and ecosystems** and encourage green hydrogen production and use in industry, mobility and power generation.
- The main aims of the S3 Hydrogen Valleys platform are to:

**1** Develop the **technological readiness** and **commercial availability** of FCH (fuel cell and hydrogen) applications.

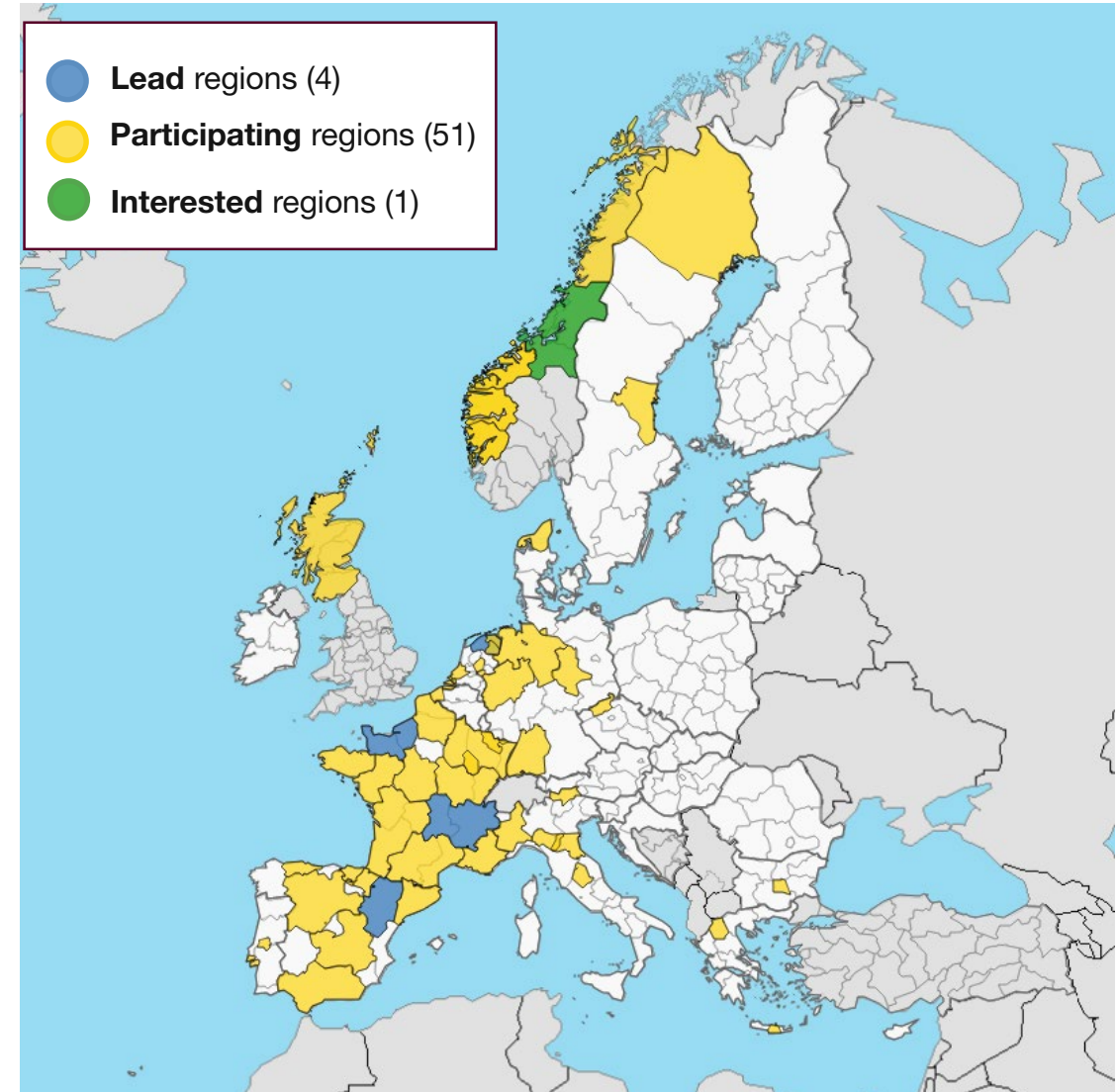
**2** **Overcome the lack of access to information** and expertise between European regions.

**3** **Strengthen the value chain of hydrogen technologies** and, specifically, fuel cells through interregional cooperation.

**4** Contribute to the **decarbonisation of the EU's economy**.

**5** Enhance the **production of green hydrogen**.

**6** **Be an active stakeholder on EU policy making** on hydrogen.





## Hydrogen Roadmap

The aim of the plan presented by the Ministry for Ecological Transition and the Demographic Challenge is to encourage the use of green hydrogen to achieve climate neutrality.

### Key figures for 2030

**€8.9 B** in investment

**25%** of industrial energy consumption

**4 GW** of installed power from electrolysers

**100 – 150** publicly accessible hydrogen plants

## PERTE

The Spanish Recovery Plan promoted by the Next Generation funds provides for the figure of PERTEs (strategic projects for economic recovery and transformation), with the aim of creating and strengthening different value chains in the country.

### Renewable Energy, Hydrogen and Storage PERTE

**€16.3 B** of allocated investment

**€4.355 B** of which were allocated to green hydrogen projects

# Main companies in the hydrogen market worldwide

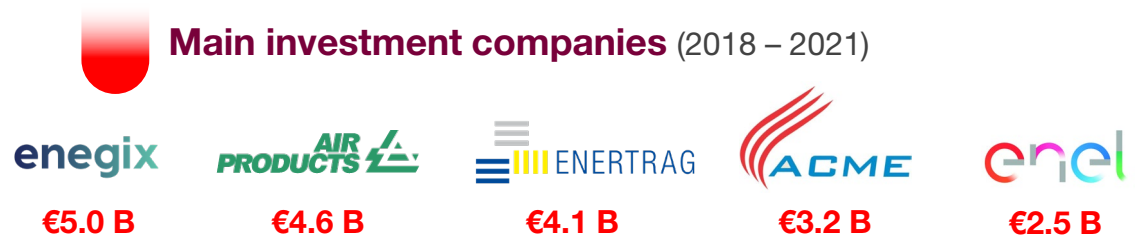
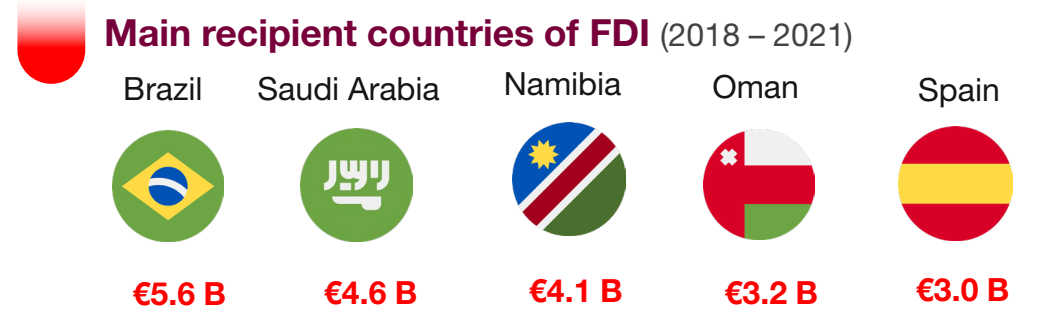
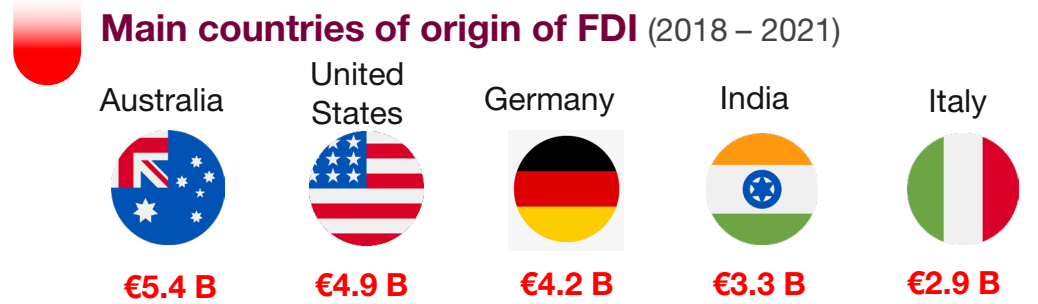
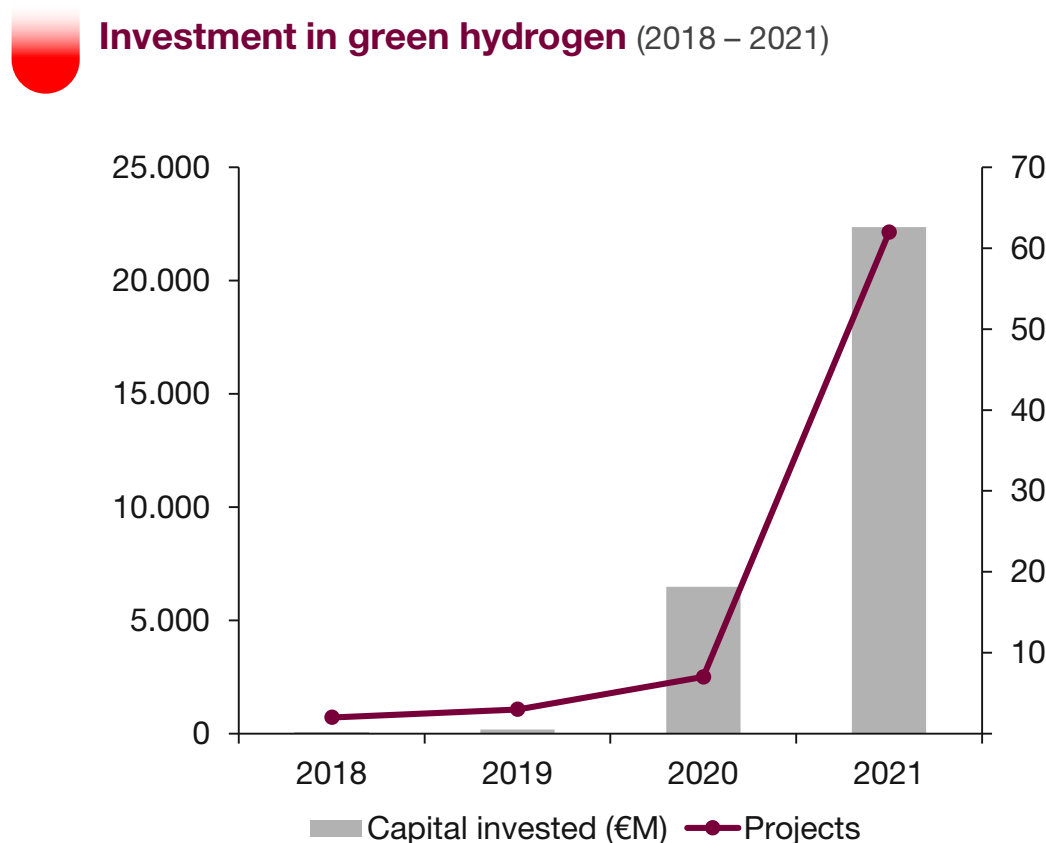
By sectors, of note are gas companies and, by nationality, US companies.



 Presence in Catalonia

# Foreign Direct Investment (FDI) in green hydrogen

Green hydrogen FDI has increased exponentially during 2021, both in terms of invested capital (**€22.4 billion**) and the number of projects (**62**). Brazil is the main recipient country, raising more than €5.5 billion between 2018 and 2021.



# Main hydrogen startups in the world

The most promising startups focus on hydrogen production, transportation and storage, as well as the manufacture of fuel cells for the mobility sector.

## Startups with the greatest innovation potential by sector

### Hydrogen production



### Hydrogen transportation and storage



### Fuel infrastructures



### Hydrogen fuel cells

#### Mobility



#### Advanced materials



#### Power sources



Green hydrogen in Catalonia

### 3. Main applications by demand sector and SDGs

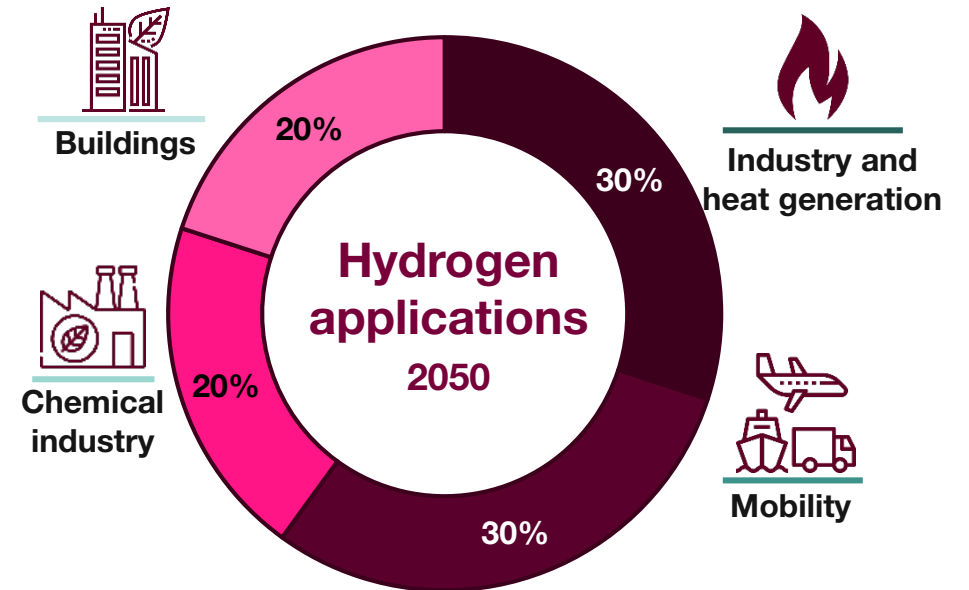
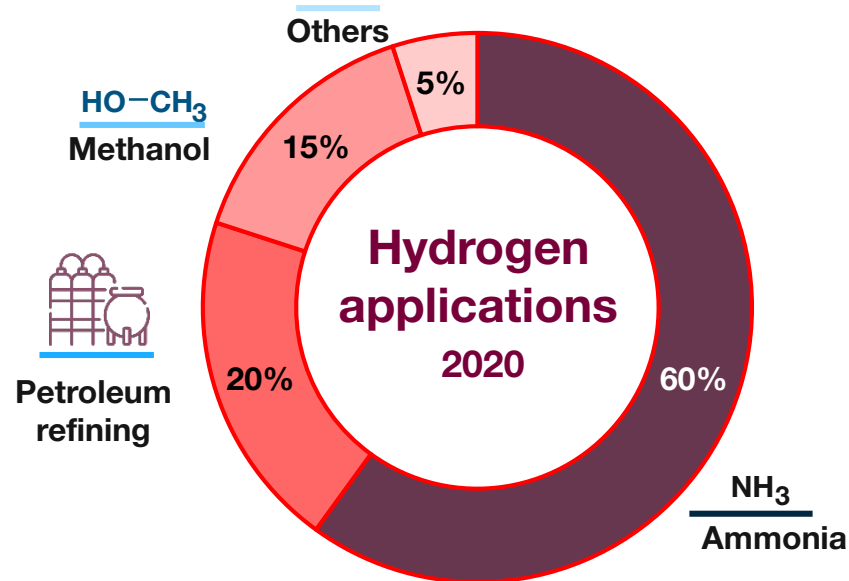
# Hydrogen applications by sector (I)

Hydrogen is expected to gain traction by 2050 so as to decarbonise several sectors.

- The main growth driver for the hydrogen market will be its increasing application in several industries, as well as the demand for clean and green fuel. Current applications differ from **2050** forecasts. As shown on the graph, the main fields are as follows:

## Hydrogen applications (2020)

Current applications involve ammonia and the chemical industry. Values in the mobility and building sectors are still very residual.

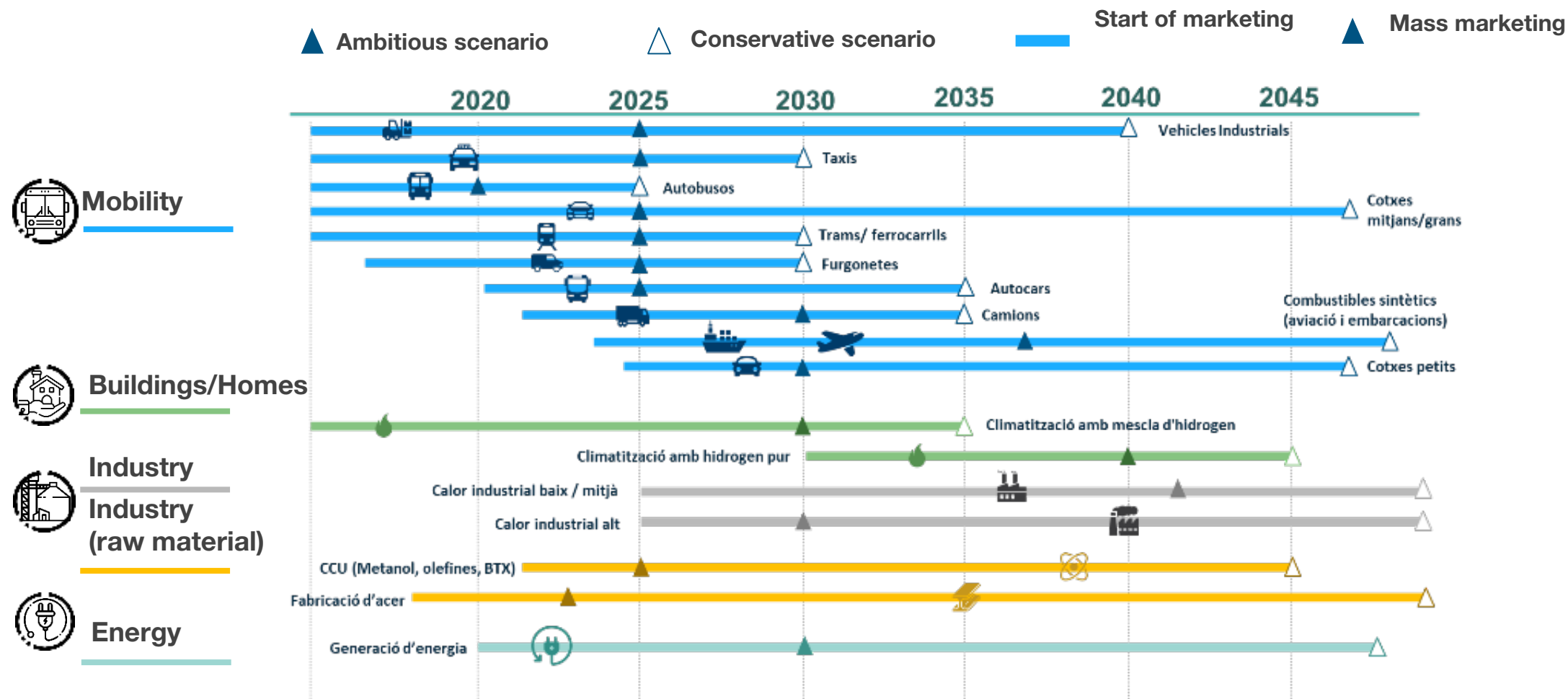


## Hydrogen applications (2050)

The consolidation of hydrogen as a heat generator and the use of hydrogen as a transition vector towards the decarbonisation of mobility are foreseen.

## Hydrogen applications by sector (II)

Hydrogen impact over time will depend on the evolution of investments by sector.



Source: Hydrogen Roadmap Europe  
CataloniaConnects



## Green hydrogen production directly impacts the achievement of 7 Sustainable Development Goals



### 3. Good health and well-being

Hydrogen can help decarbonise much of the economy, leading to improved air quality and reducing pollution and associated premature deaths.



### 11. Sustainable cities and communities

In the field of mobility, it can play a key role in the overall reduction of emissions in public transport, heavy-duty transportation and household use.



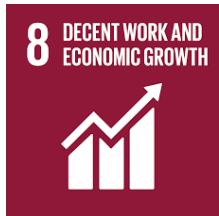
### 7. Affordable and clean energy

As an energy carrier, hydrogen has the long-term potential to supplement the energy produced by renewables and provide a solution to decarbonise industries.



### 12. Responsible consumption and production

Hydrogen plays a key role in establishing sustainable production models. It uses green energy as its main source and enables a clean production cycle.



### 8. Decent work and economic growth

As an energy carrier, hydrogen has the long-term potential to supplement the energy produced by renewables and provide a solution to decarbonise industries.



### 13. Climate action

Green hydrogen is emission-free in production or consumption. Hydrogen technology is set to become a key pillar in achieving emission neutrality.



### 9. Industry, innovation and infrastructure

The possibilities of using hydrogen make it versatile in many fields. It could even be used to store green energy.

Green hydrogen in Catalonia

## 4. Green hydrogen opportunities and challenges



# Hydrogen opportunities and challenges (I)

## Opportunities

- **Development of electrolyzers** with flexible systems that increase efficiency across different ranges and average lives, reduce costs and dependence on critical materials and improve productivity. **Development of catalysts.**
- **Development of new storage media.** Design of materials for devices that prevent hydrogen leaks and brittleness problems.
- **New business models and opportunities** for the ancillary industry in the adaptation of materials and equipment, as well as nozzles, turbines, valves, coatings, welds and the creation of hydrogen stations or dedicated hydrogen distribution networks.
- **Development of specific technologies** for different applications and with improved efficiencies. The availability of H<sub>2</sub> opens new ways for the hydrogenation of CO<sub>2</sub> and other carbon-based molecules, which makes it possible to obtain value-added chemicals, as well as synthetic fuels in gas or liquid form, the latter for aviation, shipping or heavy machinery, with special emphasis on shipping and rail.
- The hydrogen value chain will require **new technologies and sectors**, such as catalysts, solvents, carbon capture, membranes, pipelines, etc. Qualified personnel, such as technicians, engineers, manufacturers, installers, etc. will be needed.



## Hydrogen opportunities and challenges (II)

### Challenges

- New production pathways, in particular renewable energy-based electrolysis, although substantial cost reductions still need to be achieved. **The cost of renewable electricity accounts for 75% of the cost of hydrogen.**
- Despite having a very high gravimetric density, hydrogen has a very low volumetric energy density, meaning that it **must be compressed and worked with at high pressure and very low temperatures** for storage and transportation purposes.
- Hydrogen is a **highly reactive gas and can cause brittleness in some materials**, such as steel. It also has a high combustion rate. Infrastructure needs to be refurbished and adapted to deliver hydrogen to the point of final consumption.
- **Fuel cells can be a very efficient solution** for both mobility and heat production applications. However, the cost and adaptability to different environments has not been solved, and some technologies, such as SOECs, are in a pre-commercial state.
- **Hydrogen is an energy carrier** which, under certain conditions, can ignite (react with oxygen), so it needs to be handled with strict safety measures. Despite the above, the aim is to use it electrochemically or in chemical processes. A harmonised regulatory framework is needed to facilitate the large-scale introduction of hydrogen.



Green hydrogen in Catalonia

## 5. Hydrogen in Catalonia





## Mapping the hydrogen ecosystem in Catalonia


 **140**  
companies

 **€426 M**

 **1,332 jobs**


 **57.9%** of the companies  
are SMEs

 **15%** are less than 10 years  
old

 **82.1%** have a turnover of more  
than €1 M and **57.9%** more than  
€10 M

**2.9%** are startups

 **55.0%** are exporters

 **11.4%** have women in  
management positions

By segments\*, **22.9%** of the companies work in hydrogen production stages, **61.4%** are part of the processing, transportation and storage as well as fuel cell business, and **61.4%** belong to the ancillary and engineering industries.

\*Companies can be classified into more than one segment within the hydrogen value chain.





# Hydrogen ecosystem in Catalonia

## Production



## Processing



## Transportation, storage and infrastructures



## Fuel cells



## End users\*



## Ancillary industry



## Engineering firms



\*Representative sample. Hydrogen end users were not considered for the purposes of business mapping.



# Hydrogen ecosystem agents in Catalonia



## Technology and research centres



## Universities and training centres



## Associations



## Institutions and public administration



# Initiatives to boost green hydrogen in Catalonia

## The Ebro Hydrogen Corridor

Targets for 2025 – 2030

**400 MW** of green hydrogen production in 2025 and **1.5 GW** in 2030.

**A network of 20** hydrogen stations in 2025 and **100** in 2030.

**250,000 tonnes** of green hydrogen products by 2030.

### Territories that make up the Hydrogen Corridor

Catalonia      Navarre  
Aragon        Basque Country

## Hydrogen Valley of Catalonia

Members

144 companies

41 public bodies

11 clusters and associations

8 research centres

## H2ValleyCAT

Among the 27 emblematic projects selected to apply to the **Next Generation EU Fund** to boost green hydrogen in Catalonia.

Budget

€6.6 B



**"Next Generation EU is turning Catalonia into a European hydrogen valley"**

Ursula von der Leyen, president of the European Commission

In 2021, the master's degree in Hydrogen Technologies, promoted by the UPC and the URV, was launched. The rest of the university and training offer is framed within the field of renewable energies.

## Degrees

- Electrical Engineering
- Electronic, Industrial and Automation Engineering
- Energy and Sustainability Engineering
- Environmental Sciences + Degree in Geology
- Renewable Energy and Energy Efficiency Engineering
- Energy Engineering

## Master's

- Hydrogen Technologies
- Architecture and Environment: Integration of Renewable Energies in Architecture
- Renewable Energies and Energy Sustainability
- Circular Economy
- Interdisciplinary and Innovative Engineering
- Energy Engineering
- Automotive Engineering
- Power Electronics

## Vocational training

- Technologies and applications of hydrogen as an energy source
- Course on green hydrogen production by electrolysis (HELEC)
- Advanced course on Electric Vehicles and Charging Stations
- Course on Hybrid and Electric Vehicles
- Technical course on Renewable Energies

## Catalan centres that provide hydrogen training



Green hydrogen in Catalonia

## 6. Case studies in Catalonia



## Case studies in Catalonia



Transports  
Metropolitans  
de Barcelona

TMB is committed to the use of hydrogen in public transport and already has hydrogen buses in Barcelona.



Iberdrola has built the first public-use plant in Spain to supply hydrogen of renewable sources produced by hydrolysis.



EVARM creates prototypes of hydrogen-powered vehicles.



The RIS3CAT CoSin project aims to store synthetic fuels.



Naturgy will build 4 hydrogen stations in Catalonia to supply hydrogen in urban and interurban environments.



CER-H2 (UPC) aims to be the new knowledge hub focused on R&D&I and hydrogen technology transfer.



Heat-Fuel aims to deliver the next generation of sustainable fuel production technologies.



UltraSOFC is a fuel cell-based power generation technology.



SUN2HY is an innovative project that will enable the direct conversion of solar energy into hydrogen through a photoelectrocatalysis plant (PEC technology).



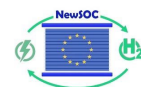
EU-funded LESGO aims to store energy in the C-H bond of reduced graphene oxide (rGO-H).



EPISTORE develops reversible stacking technology that operates as a fuel cell and electrolyser for applications, transportation and offshore renewable generation.



HyBCN is developing a prototype integrated reversible system capable of generating emission-free power and hydrogen from renewable electricity.



NewSOC aims to improve the durability, performance and competitiveness of solid oxide cell technology.



MoRE Zero aims to develop a modular hydrogen range extension system for electric vehicles.



H2SENSE is developing a new generation of IoT sensors to detect hydrogen leaks in chemical industries.



TECHNIP  
ENERGIES

TECHNIP ENERGIES IBERIA, enginyeria i tecnologia per a desenvolupar tota la cadena de valor de l'hidrogen verd.

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

### Companies



### Business associations and entities



### Research and technology transfer



### Government agencies



# Thanks!

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