# OVERVIEW OF THE CURRENT STATE OF HYDROGEN MANAGEMENT AND ITS TECHNOLOGY IN THE EUROPEAN UNION ON THE EXAMPLE OF SELECTED EUROPEAN COUNTRIES

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# Introduction

In 2020, the European Union adopted a hydrogen strategy. The document, called COM/2020/301, proposes policy actions in five areas: investment support, support for production and demand, creation of a hydrogen market and infrastructure, research and cooperation, and international cooperation. Hydrogen is also an important element of the EU strategy for energy systems integration (COM/2020/299).

By the first quarter of 2022, the EU had implemented and delivered 20 key hydrogen measures:

- Developing an investment programme within the framework of the European Clean Hydrogen Alliance to stimulate the development of hydrogen production and use and build a concrete pipeline of projects.
- You support strategic investments in clean hydrogen in the context of the Commission's recovery plan, in particular through the InvestEU strategic European investment window.
- To propose measures to facilitate the use of hydrogen and its derivatives in the transport sector in the Commission's forthcoming Sustainable and Smart Mobility Strategy and related policy initiatives.
- Explore additional support measures, including demand-side policies in end-use sectors, for renewable hydrogen based on existing legislation and renewable energy directives.
- Work to introduce a common threshold/low-carbon standard to promote hydrogen facilities based on their full-life-cycle GHG efficiency.
- Work to introduce comprehensive terminology and EU-wide certification criteria for renewable and low-carbon hydrogen.
- Develop pilot schemes - preferably at EU level - for a carbon differential contract programme, in particular to support the production of low-carbon and closed-loop steel and basic chemicals.
- Begin planning for hydrogen infrastructure, including Trans-European Networks for Energy and Transport and Ten-Year Network Development Plans including planning for filling station networks.
- Accelerate the implementation of different refuelling infrastructures as part of the revision of the Alternative Fuels Infrastructure Directive and the revision of the Trans-European Transport Network Regulation.
- A project to enable the introduction of market principles for hydrogen deployment, including the removal of barriers to the efficient development of hydrogen infrastructure, and to provide hydrogen producers and customers with access to liquid markets and the integrity of the internal gas market through upcoming legislative reviews (e.g. review of gas legislation for competitive decarbonised gas markets).
- Launch of a 100 MW electrolyser and a call for proposals for green airports and ports under the Horizon 2020 European Green Deal call.



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- Establish the proposed Clean Hydrogen Partnership, focusing on the production, storage, transport, distribution and key components of renewable hydrogen to provide priority end-uses for clean hydrogen at a competitive price.
- Steering the development of key pilot projects to support hydrogen value chains, in coordination with the SET Plan.
- Facilitate the demonstration of innovative hydrogen-based technologies by launching calls for proposals under the ETS Innovation Fund.
- Call for pilot actions for inter-regional innovation under the Cohesion Policy on hydrogen technologies in carbon-intensive regions.
- Strengthening the EU's leadership role in international fora dealing with technical standards, regulations and definitions for hydrogen.
- Developing a hydrogen mission as part of the next Mission Innovation (MI2) mandate.
- Promote cooperation with partners from the Southern and Eastern Neighbourhood and the Energy Community countries, especially Ukraine, on renewable electricity and hydrogen.
- Defining the renewable hydrogen cooperation process with the African Union under the Africa-Europe Green Energy Initiative.
- Development of a benchmark for euro-denominated transactions.

The ' Fit -for-55' package presented in July 2021 presents a series of legislative proposals that translate the European Hydrogen Strategy into a concrete framework for European hydrogen policy. This includes proposals to set targets for the use of renewable hydrogen in industry and transport by 2030. It also includes the Hydrogen and Decarbonised Gas Market Package , which sets out proposals to support the creation of optimal and dedicated infrastructure for hydrogen, and the Hydrogen and Decarbonised Gas Efficient Hydrogen Market Package.



The Clean Energy Rebuilding and Resilience Facility has been made available to EU member states to invest in hydrogen projects across the value chain.

Investment support has also been provided by important projects of common European interest (IPCEI) on hydrogen. The first IPCEI called " IPCEI Hy2Tech ", which comprises 41 projects and was approved in July 2022, aims to develop innovative technologies for the hydrogen value chain to decarbonise industrial processes and the mobility sector, with a focus on end-users.

In September 2022. The Commission approved " IPCEI Hy2Use ", which complements IPCEI Hy2Tech and which will support the construction of hydrogen-related infrastructure and the development of innovative and more sustainable technologies for the integration of hydrogen in the industrial sector.

In November 2021, the Clean Hydrogen Partnership was established. The main objective of the Clean Hydrogen Partnership is to contribute to the European Green Deal and the hydrogen strategy through optimised funding of research and innovation activities. The Clean

Hydrogen Partnership is the successor to the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) and took over its existing portfolio as of 30 November 2021.

The European Commission has launched a pilot mechanism as part of the recently adopted Decarbonised Gases and Hydrogen Package to support the development of the European hydrogen market.

The initiative aims to accelerate investment by providing clearer market insights to both suppliers and consumers of hydrogen. The pilot mechanism will be part of the European Hydrogen Bank and will run for five years, starting in mid-2025.

The primary objective of the Hydrogen Pilot Mechanism is to facilitate the development of the hydrogen market in Europe. By collecting and processing data on the demand and supply of renewable and low-carbon hydrogen and its derivatives, the mechanism aims to create a more transparent market. This transparency is expected to help European consumers match European and foreign suppliers, thereby speeding up final investment decisions and securing offtake agreements.

A key aspect of this initiative is to improve visibility in the market. The mechanism will provide detailed information on hydrogen flows and prices, enhancing the ability of suppliers and consumers to make informed decisions. This improved visibility is expected to lead to faster final investment decisions, thus contributing to the overall growth of the hydrogen sector in Europe. A procurement exercise to find a service provider to develop an IT platform to operate the pilot mechanism has already started and the Commission plans to sign a contract by the end of this year.



While the European Commission's efforts to revitalise the hydrogen market are commendable, it is necessary to compare these initiatives with industry benchmarks to fully understand their potential impact. The first large-scale electrolysers are already being built in Europe and initial offtake contracts have been signed. However, the success of the pilot mechanism will depend on its ability to attract significant investment and support robust market dynamics.

Hydrogen is expected to play a key role in achieving the objectives of the European Green Deal. It is seen as a key element in phasing out Russian fossil fuels and supporting the decarbonisation and competitiveness of European industry. A hydrogen pilot mechanism, by increasing market transparency and accelerating investment, could make a significant contribution to achieving these goals. However, continuous monitoring and evaluation of the mechanism's operation is needed to ensure that it meets its objectives.

In her speech, Ursula von der Leyen summarised the commitment of a united Europe to decarbonise our environment:

"I want Europe to be a leader, a frontrunner in building a global hydrogen market. Last spring, the European Commission was part of a coalition of countries that committed to creating 100 hydrogen valleys around the world. Of course, we want most of them to be in Europe, so clean hydrogen is becoming part of the conversation with all our global partners, including of

course our African partners. Africa has the greatest untapped potential for renewable energy production. Converting clean energy into clean hydrogen could be a solution to store this energy, both to sell abroad and to power Africa's growing industries. With this in mind, I have proposed investing in the African hydrogen sector, thus creating a new market for clean hydrogen between the two shores of the Mediterranean. This could bring clean energy to Europe and sustainable development to the African continent."



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## Netherlands

As a signatory to the Paris Climate Agreement, the Netherlands has enshrined in law its commitment to a decarbonised future and has agreed ambitious targets in its national climate agreement (see box). For one of the most densely populated and industrialised countries in the world, meeting these targets will pose major challenges. Billions of euros will be allocated in the coming decade to accelerate the energy transition. The Dutch are planning huge investments in renewable energy, especially offshore. Other key policies aim to take advantage of all this carbon neutrality, by electrifying cars at large, home heating and industrial processes.

However, even with these ambitious policies, challenges remain. For example, the country's large industrial sector requires huge amounts of high-temperature process heat, as well as alternatives to fossil fuels. As we become increasingly reliant on intermittent energy sources such as wind and solar power, we urgently need solutions to store large amounts of energy, both on a short-term and seasonal basis. Another challenge is the decarbonisation of the shipping and road transport sectors.

Hydrogen is widely seen as a key technology to overcome the fundamental obstacles to full decarbonisation. Many see it as the missing link required for a successful energy transition. It can be an alternative to natural gas in industrial processes, as a feedstock for chemicals and as a carbon-neutral fuel in virtually all modes of transport, especially those for which electrification is not yet an option. Through electrolysis, hydrogen can be used to store and distribute large amounts of renewable energy, paving the way for further large-scale investments in wind and solar power, creating new opportunities for grid balancing, seasonal storage and even global export of renewable energy.



The Dutch approach to building a hydrogen future has several distinctive features. Firstly, it is clearly driven by the climate policy and commitments described above. Secondly, its scope encompasses the entire value chain. Rather than seeing hydrogen production and different applications as separate issues, the Dutch have adopted an integrated approach to developing a 'hydrogen economy'. Dozens of pilot projects with companies and research institutes are building a complete hydrogen economy and hydrogen ecosystem, focusing not only on the technology, but also on demand creation, business models and addressing regulatory and safety issues. This is often done in public-private partnerships and in a very pragmatic way.

The Dutch have an open approach to innovation, which encourages experimentation.

More than 50 years ago, the Dutch discovered natural gas deposits and developed one of the most extensive and advanced gas networks in the world. At gas storage facilities in the northern province of Groningen, hundreds of millions of cubic metres of gas can be stored in underground salt caverns. The same infrastructure - along with thousands of kilometres of gas pipelines across the country - is being mobilised to enable a second gas revolution, replacing fossil fuels with neutral hydrogen.

The easiest way to transport hydrogen is through pipelines. Few countries are as well prepared to build a nationwide hydrogen network as the Netherlands. This is because the foundations are already in place. The country already has a dedicated hydrogen pipeline network of more than 1,000 km, connecting it to industrial sites in Belgium and France.

But perhaps even more significant is that it has one of the densest and most advanced natural gas networks. This network includes 136 000 km of pipelines and more than 7 million connections, reaching almost every Dutch home and business. This infrastructure can already be used to transport hydrogen. Not just by mixing hydrogen with natural gas but by replacing one with the other. Various projects have shown that, with minor changes, existing infrastructure can be used to transport hydrogen. In the province of Zeeland, a 12-kilometre industrial gas pipeline transports around 400 000 tonnes of hydrogen per year, and almost a dozen pilot projects in residential areas to replace natural gas with hydrogen, using existing infrastructure. This trend will accelerate in the coming years. One of the key policies of the Dutch climate agenda is that more than 2 million homes must stay on natural gas by 2030. And as the demand for natural gas decreases, a large part of the network capacity becomes available for hydrogen transport, especially as the network includes many 'parallel pipelines. It is estimated that by 2026. The Dutch could develop a national 'hydrogen backbone network connecting the country's five main industrial clusters.

In addition to hydrogen transport, the existing natural gas infrastructure also offers storage capacity to help offset seasonal fluctuations in the availability of renewable energy or to balance the energy grid. In the north of the country, for example, the Dutch are storing natural gas in huge salt caverns with a capacity of hundreds of millions of cubic metres. Pilot projects are underway to demonstrate that hydrogen can also be stored safely here. In addition, Dutch scientists and industry experts are already investigating the technical and economic feasibility of storing hydrogen in empty gas fields, both onshore and in the North Sea. The potential storage and transport capacity is enormous and could easily accommodate the approximately 11 GW of offshore wind energy planned for the Dutch North Sea in the next 10 years.



Building a hydrogen economy requires other and more flexible means of transport beyond pipelines, and in this respect the Dutch are working on a number of innovative solutions. For example, researchers at TNO and industrial partners are developing special hydrogen storage tanks. This includes the development of new materials that make it possible to store hydrogen under very high pressure or at extremely low temperatures, paving the way for safe and cost-effective transport by road, rail or sea.

Other Dutch projects focus on binding hydrogen with other materials such as nitrogen, carbon dioxide or toluene to create a carrier liquid that is much easier to transport, sometimes even in existing tankers.

The country's 136 000 km of pipelines offer unique opportunities for the hydrogen industry.

While such innovations open up new opportunities for hydrogen distribution at the last few stages of the value chain, they can also be applied to large-scale transport over very long

distances. There is an urgent need for such solutions, as the potential of the global hydrogen market is enormous.

Studies indicate that in areas with abundant sunshine and/or favourable wind conditions, the cost of renewable electricity could fall to less than $1 per kWh within 10 years. This will increase the viability of large-scale electrolysis producing carbon-neutral hydrogen for other markets. Europe is expected to become a net importer of clean hydrogen in the next few decades.

Anticipating this, the Dutch are positioning their country as a major hydrogen centre.

Again, they benefit from an excellent starting position. Some of the busiest transport corridors in Europe converge in the Netherlands thanks to excellent road, rail and inland waterway infrastructure, road, rail and inland waterway infrastructure, and pipeline connections to most of Europe. The Port of Rotterdam is the largest port for oil and (liquefied) natural gas in Europe and is working with industrial partners to build a similar position for hydrogen.

Several international companies are already building electrolysers in Rotterdam and work has started on dedicated hydrogen pipeline infrastructure. Other companies are focusing on the technology needed for large hydrogen tankers and storage infrastructure not only in the Netherlands, but also in countries that want to realise their potential as a hydrogen exporter.

In 2020, the north of the Netherlands was recognised as Europe's first hydrogen valley by the Clean Hydrogen Partnership and the EU.



In their geographical scope, Hydrogen Valleys encompass many elements of the green hydrogen value chain, from hydrogen production to hydrogen storage and transport and distribution to industrial, mobility and built environment customers via various modes of transport.

Within Europe's first Hydrogen Valley, the following key aspects have been developed in recent years and expansion continues with new announcements. The Valley acts as a business magnet, attracting business and investment and triggering innovation and the creation of educational programmes that match the ambitions of North Holland, while setting an example for other member states in Europe.

**Hydrogen in industry**

- 32 MW Chloro Alkali Nobian (as a starting point HEAVENN for high green hydrogen uptake)
- CHP upgraded to hydrogen for industrial heat and power.

**Education and research**

- Waterstof Werkt 1
- HyDelta 1 and follow-up HyDelta 2
- Preparation of a Hydrogen Valley campus in Europe

**Hydrogen in mobility**

- Dozens of hydrogen passenger cars currently on the market pathway.
- 32 hydrogen buses.
- Many street sweepers, refuse trucks and delivery vehicles vans.
- Five existing hydrogen refuelling stations and five in development.
- Several (small) hydrogen boats.
- First inland waterway transport hydrogen-powered vessel under construction.
- Successful piloting of a hydrogen-powered train.
- Trailer hydrogen refuelling station with HRS for ship refuelling permitted, directly connected to the electrolyser at Delfzijl.
- Development of zero-emission ground-mounted power units at Hydrogen Valley Airport.

**Storage**

- Successful pilot of HyStock warehouse for injection moulding hydrogen in salt caverns. The next step is the full-scale development of salt cavern storage, which is expected to be operational in 2023.

**Transport**

- Chemical Park Delfzijl hydrogen pipeline
- Emmen hydrogen pipeline
- Green hydrogen distribution trailers to HRS I industrial customers
- It was recently announced that the start of development of the hydrogen backbone by Gasunie, supported by the Dutch state
- Several smaller dedicated pipelines (polymer-based) have been announced to connect production and customers.

**Production**

- Five electrolysers with a total capacity of 35.7 MW installed power
- Electrolyser capacity 220 MW in FID phase.
- Several electrolysers have received permits
- New announcements have recently been made with a capacity of around 200 MW+, which is already the height of ambition for large-scale offshore projects

**Hydrogen in the built environment**

- Small hydrogen home
- Substantial support from the national government for start-ups Development of 100 new hydrogen homes in Hoogeveen.



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**HEAVEN Valley success factors**

✓ **First key success factor**: A convincing project concept with consideration of the value chain and selection of technologies that use local resources and meet local needs. HEAVENN is praised for its convincing project concept because it was the most complete valley including every part of the value chain, using local resources and meeting local needs (the region needs the business) - local conditions and more specifically benefits and perspectives have been carefully analysed and are constantly reviewed.

✓ **Second key success factor**: A viable commercial structure that enables developers to have first real business cases (including any public funding). Mobility helps to accelerate mobility vs. industry), and mobility has a high visibility factor in public society. It is therefore safe to conclude that everyone is familiar with buses and cars. Their constant traffic increases visibility, recognition and acceptance.

✓ **Third key success factor**: Public-private financing from multiple sources, which includes enough public funding to fill all the gaps. HEAVENN secured funding in the initial phase through a combination of public and private resources. The public contribution included support from the region and the state. In practice, this proved more difficult than anticipated, as regional funding is already available. National funding is in the pipeline. An important element of delay is the excessive complexity of state aid rules. Outdated regulations need to be set aside to revitalise the hydrogen economy.

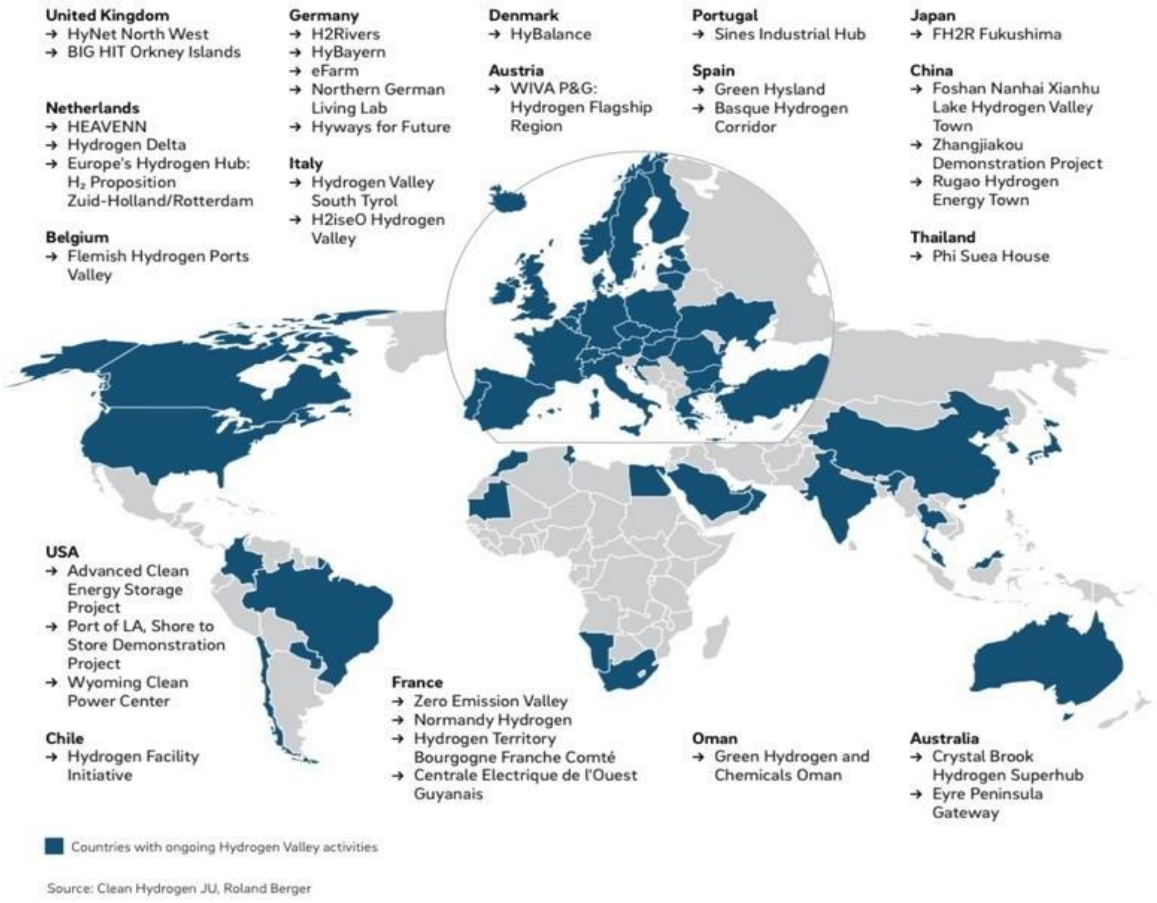


✓ **Fourth key success factor**: Partner and stakeholder collaboration that spans the entire scope of the project and ensures the ongoing involvement of all parties involved. For a consortium of 30 parties from seven EU countries, stakeholder management and partnership is of paramount importance. HEAVENN has implemented a dedicated governance mechanism and created a project organisation for day-to-day coordination with dedicated project manager(s) and clear rules and allocation of responsibilities within the consortium. It should be noted that the consortium is compact and has a common goal.

✓ **Fifth key success factor**: Political support and public advocacy for the smooth and continuous development of the project. Perhaps the most influential success factor is political support, advocacy and public support. In the Netherlands, the project is recognised in the National Hydrogen Strategy, and in Europe, the development of the Hydrogen Valley is actively supported by the current European Commissioner Ursula von der Leyen, who refers to HEAVENN and the North of the Netherlands as a leading region. At the regional level, HEAVENN receives a lot of support, while at the national policy level intensification is desirable. Discussions with regulators are conducted on a case-by-case basis; environmental agencies are now showing increasing interest. Local communities are also involved on a case-by-case basis, making it necessary to raise awareness of the overall advantages of hydrogen as a future solution.

**The HEAVENN Hydrogen Valley faced the following challenges to becoming a Hydrogen Valley:**

- Renewable energy availability. Most people support the energy transition and hydrogen, but a large number of solar and wind farms are needed to produce enough renewable energy, but these are not always accepted by the public.
- Permits. The initial phase of the Hydrogen Valley is mainly using existing legislation and regulations. However, the limitations of current legislation and regulations and the establishment of additional regulations will take time.
- Old and new infrastructure. In a region with an existing business infrastructure, adapting to the required infrastructure (e.g. new processes, procedures, exchange of materials, etc.) can be challenging.
- Future perspective. The first period of creating a Hydrogen Valley is not profitable; large investments are needed. It is only profitable when hydrogen is produced on a large scale, which takes time. The challenge is to convince different kinds of stakeholders, because it will take time to get a return on investment.
- Connections with other Hydrogen Valleys. Connections with other Hydrogen Valleys bring more business benefits and flexibility in terms of storage and use. Ideally, the Hydrogen Valleys should grow with them. Realistically, however, different regions have different procedures, especially at the beginning when there are several Hydrogen Valleys.



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However, these challenges do not outweigh the fact that Hydrogen Valleys are needed worldwide for decarbonisation, as it is the only alternative to fossil fuels.

The Netherlands traditionally has a strong international orientation and the Dutch economy is largely driven by trade with foreign countries. Furthermore, energy and knowledge are important pillars of the Dutch economy. Dutch companies and institutions have a lot of experience and knowledge about gases, including hydrogen. They are ready to share this knowledge and expertise to unlock the potential of the regions with which they trade.

The hydrogen economy is only at the beginning of what is becoming a major transformation that will continue for many decades. Based on decades of experience with natural gas, the Netherlands has gained a great deal of knowledge in handling particles. This means that the Netherlands was and is in a position to start a hydrogen economy quickly and effectively. From this position, the Netherlands can also share knowledge with other regions and countries and help them in their energy transition, as many countries and regions will produce hydrogen and use and/or export it. For the Netherlands, this is a great opportunity to use the knowledge and experience of Dutch companies involved in the hydrogen value chain.

In order to position the Netherlands as a hydrogen expert country, accelerate international trade relations and position Dutch companies as the 'first choice' for exporting countries, it is important to establish so-called 'hydrogen centres' in selected locations. The hydrogen centres function as support points for trade and at the same time provide visibility for the Netherlands in the producing country. Hydrogen centres can also initiate and develop new projects and facilitate business opportunities for the producing region and the Netherlands. The Ministry of Trade and Development and the Ministry of Climate and Energy refer to this suggestion in the National Climate Strategy.



Once hydrogen centres have been established, as suggested above, it is recommended that dedicated offices and functions be established in hydrogen-leading countries. For example, by installing a hydrogen attaché in those hydrogen hubs that work closely with attachés from other areas where hydrogen production will be used (e.g. mining, agriculture, fisheries, etc.). However, a hydrogen hub can also assist in the creation and use of financial instruments to help companies and knowledge institutions position themselves in these strategic countries and regions in the high-risk phase - prior to the conclusion of a commercial agreement.

The Netherlands pretends to play a very important role in the international hydrogen economy, which benefits Dutch companies and/or organisations, contributing to international stability and prosperity.

## Spain

In the race towards a greener and more sustainable future, hydrogen has become a game-changer in the energy landscape. Just three years ago, the concept of hydrogen was met with scepticism, but today it has become the focus of ambitious projects across Spain, each aiming to create its own 'hydrogen valley'.

These public-private business ecosystems aim to promote the production and consumption of hydrogen, and Spain has envisaged 11 such valleys spread across the country, from Puertollano and Huelva to Soria, A Coruña and even Majorca. According to the Spanish Hydrogen Association (AEH2), the collective investment in these initiatives will reach a staggering €21.9 billion by 2030.

The primary objective of these hydrogen valleys is to support the decarbonisation of various sectors, including industry, residential energy and mobility, with a particular focus on air and maritime transport. The potential impact is huge, with the International Renewable Energy Agency calculating that hydrogen production will account for up to 12% of the energy mix by 2050.AEH2 estimates that the development of green hydrogen projects will lead to the creation of around 227,000 new jobs in Spain by 2030. Key players such as Repsol, Cepsa and Enagás are at the forefront of creating business and university ecosystems with the common goal of producing between 1 and 1.7 million tonnes of hydrogen per year. This production will not only meet national demand, but also contribute 10% of the total target hydrogen consumption in Europe.



The European Union recommends the creation of hydrogen valleys because of their many advantages. By bringing together public institutions, research entities and private companies, these valleys enable increased hydrogen production and distribution over larger geographical areas. This configuration facilitates the efficient development of hydrogen sectors while optimising production, transformation and logistics costs.

One of the key aspects of these valleys is their involvement in large-scale projects that can significantly boost the local economy. For example, the Andalusian Green Hydrogen Valley alone is expected to create 10,000 jobs and raise the level of economic activity of more than 400 small and medium-sized enterprises (SMEs) in the region. This energy ecosystem provides access to affordable, safe and sustainable energy, driving industrial activity in the area while remaining close to production centres.

From north to south, Spain is witnessing the emergence of significant hydrogen valleys. Puertollano, located in Ciudad Real, occupies a key position and houses the headquarters of the National Hydrogen Centre. As part of the H2Med project, this city will be connected to Germany by a green hydrogen pipeline stretching from Huelva to Barcelona. Iberdrola operates Europe's largest green hydrogen plant for industrial use in Puertollano, capable of producing 3,000 tonnes of hydrogen per year for Fertiberia. Several other infrastructure projects by Repsol and RIC Energy are also underway at this location, with a potential capacity of 30 MW, to be increased to 100 MW in the future. The Castilla-La Mancha

hydrogen cluster continues to drive hydrogen initiatives in Puertollano through the collaboration of 41 companies and partnerships with universities and technology centres in Spain and the Netherlands.

In the south of Spain, the Andalusian Green Hydrogen Valley stands out, headed by Cepsa with a substantial budget of €3 billion. This ambitious project comprises two poles: one in Palos de la Frontera (Huelva) in the vicinity of Fertiberia and another in San Roque (Campo de Gibraltar, Cadiz) in collaboration with EDP. The combined capacity of these plants is expected to reach 2 gigawatts (GW), allowing the production of 300,000 tonnes of green hydrogen per year to fuel sustainable biofuels for aviation and land and sea freight transport.

In Catalonia, the H2ValleyCat project, led by Repsol, Enagás and Universitat Rovira i Virgili, takes centre stage. This ambitious ecosystem includes more than 260 public and private entities, including the Port of Barcelona, Cepsa, FCC and Vueling. It is well connected to the Aragon Hydrogen Valley, the Green Hydrogen Agenda of Navarra and the Basque Hydrogen Corridor through the Ebro Hydrogen Corridor. The latter initiative is led by Repsol's SHYNE consortium, with the participation of 22 other companies and 11 associations.

The hydrogen revolution is not limited to Spain; the whole of the European Union is actively promoting hydrogen production to achieve energy independence. Spain is a key player in this endeavour, standing shoulder to shoulder with countries such as the Netherlands and Germany. In particular, the Dutch NorthH2 project aims to generate 4 GW of green hydrogen by 2030 using offshore wind power, while the German AquaVentus consortium envisages building 10 GW by 2035. 62 hydrogen initiatives have been selected in Spain with a total investment of €33 billion , potentially receiving €8 billion in public funding.



The European Union's vision is to produce 10 million tonnes of green hydrogen by 2030 and import an additional 10 million tonnes from countries outside the EU. This clean energy movement is attracting significant investment, with a McKinsey report estimating that investment in hydrogen projects across Europe amounts to a staggering €117 billion, representing 35% of global hydrogen investment.

As Spain occupies a central position in the green hydrogen revolution, the Hydrogen Action Plan envisages a hydrogen production capacity of 11 GW by 2030 with an investment of €8.9 billion from companies and the public sector. This surge in hydrogen production is expected to provide between 1 and 1.7 million tonnes of hydrogen per year in Spain and an additional 750,000 tonnes in Portugal, meeting domestic demand while exporting surplus hydrogen to Europe, particularly to high-consumption markets such as Germany. The future of hydrogen valleys in Spain carries the promise of cleaner energy, robust job creation and a sustainable path to decarbonise different sectors and contribute to a greener Europe.

In October 2023, the Spanish government approved the Hydrogen Action Plan, emphasising that green hydrogen is a key element in achieving climate neutrality and a 100% renewable electricity system

With an investment of €8,900 million, targets have been set for 2030, which include generating 4 GW of installed electrolysis capacity and ensuring that 25% of the hydrogen consumed in the industry comes from renewable sources

The Spanish Government's Ministry of Ecological Transformation and Demographic Challenge has given the green light to the 'Hydrogen Action Plan: a commitment to renewable hydrogen', highlighting that green hydrogen is a key element in achieving climate neutrality and a 100% renewable energy system by 2050.

Spain has thus joined other countries such as Japan , China and France , which have decided that the road to decarbonisation requires placing green hydrogen as the central axis of their future energy strategy.

Through the use of green hydrogen, the Spanish authorities want to promote the development of innovative industrial value chains, create jobs and economic activity and contribute to the revival towards a high-value-added green economy.

In the nomenclature adopted in Spain, green hydrogen is an energy vector.Hydrogen is not a primary energy source (like the sun or wind), but an energy vector. This means that the manufactured product is able to store energy that can be released later. When renewable energies are used in the production process, the hydrogen obtained is considered 'green hydrogen' or 'renewable hydrogen'.

The preparation of the Hydrogen Action Plan involved citizens and stakeholders in the hydrogen value chain.



Renewable hydrogen is positioned as one of the main energy vectors , as its production and consumption is climate-neutral and generates no emissions.

It also has a variety of applications, including land, sea, air and rail mobility, industry and power generation. It is one of the important players in the energy transition as it enables the decarbonisation of all sectors and allows for seasonal energy storage.

**Spain's hydrogen targets**

The roadmap sets national targets for the promotion of renewable hydrogen by 2030 and, based on these, develops a vision for 2050, the year in which Spain should achieve climate neutrality and have a 100% renewable energy system.

**In line with the objectives set by the European Commission in its Hydrogen Strategy, Spain has set the following development goals:**

- Generate 4 GW of installed electrolysis capacity - a facility to produce renewable hydrogen using clean energy and water - representing 10% of the EU-wide target set by the European Commission.
- By 2030. 25% of the hydrogen used in industry will come from renewable sources.
- In terms of mobility, by 2030, a fleet of at least 150 buses; 5,000 light and heavy vehicles; two commercial railway lines powered by renewable hydrogen have been proposed.

Similarly, a network of at least 100 hydrogen generators and hydrogen-powered handling machines should be installed in the first five ports and airports.

- In addition, the document proposes 60 actions, grouped into four areas of action: regulatory; sectoral; cross-cutting (to raise awareness of the potential of renewable hydrogen throughout society) and promoting related research, development and innovation.

The action plan identifies the opportunities for Spain to promote domestic production and the use of renewable hydrogen and is considered in the category of development opportunities for Spain.

Spain joins other countries that believe that the road to decarbonisation requires placing green hydrogen as the central axis of their energy strategy for the future.

The document highlights how the development of renewable hydrogen in Spain will bring environmental, business, economic and social benefits , such as:

Eliminate emissions of pollutants and greenhouse gases to the environment in sectors or processes that are difficult to decarbonise in order to achieve the goals of a climate-neutral economy by 2050.

Developing hydrogen economy value chains and positioning Spain as a reference in the technology.

Enabling the penetration of a higher percentage of renewables in the electricity system, promoting greater manageability.



Reducing national and European energy dependence.

Making Spain one of the European powers of renewable energy generation, due to its favourable climatic conditions and large free areas for the installation of renewable energy plants, both solar and wind.

Encourage decarbonisation of isolated energy systems, especially in island territories.

Promoting Spanish energy research, development and innovation as a pillar of sustainable economic growth.

**Key projects**

To draw up the Hydrogen Action Plan, the Ministry of Ecological Transformation and Demographic Challenge held a public consultation to gather feedback from citizens and institutions potentially involved in the hydrogen value chain, which included Enagás.

The green hydrogen company, as it is 100% renewable, is heavily involved in specific projects. It also has an infrastructure technically prepared to transport and store hydrogen and other renewable gases such as biogas/biomethane.

In fact, it is one of eleven European gas infrastructure companies that are implementing the European Hydrogen Backbone plan to develop a specific hydrogen transmission infrastructure.

**Actions taken by Spain to achieve its objectives.**

- Among other things, the Hydrogen Roadmap sets ambitious national targets for 2030 and 2050. Spain expects to achieve climate neutrality and have a 100% renewable energy system.
- published at the end of June 2023, the draft of the first update of the 2021-2030 Integrated National Energy and Climate Plan (PNIEC) overstates the targets for increasing large-scale hydrogen production and use. This sets the installed capacity of electrolysers at 11 gigawatts (GW) for renewable hydrogen production in Spain by 2030, compared to the 4 GW planned in the draft approved three years ago.
- The REPowerEU programme envisages the development of five hydrogen corridors connecting producer countries to demand centres. In this context, Spain is not only a potential major producer, but also has export potential to other EU countries.
- One of the projects that has attracted Spain's attention is Europe's first renewable hydrogen corridor. The project, called H2Med, is a key infrastructure that will enable the transmission of up to 2 million tonnes of renewable hydrogen per year. This is10% of the expected consumption across Europe.
- H2Med will transport up to 2 million tonnes of renewable hydrogen per year.
- The corridor, promoted by Enagás in Spain and French transmission system operators GRTgaz and Teréga, as well as Portugal's REN, includes connection points to Portugal and France. Germany is also involved, so hydrogen can travel to the centre of Europe from the south of the continent.
- Together with H2Med, Enagás also presented the first two axes of Spain's hydrogen backbone network to projects of common interest to the European Union. One includes the Cantabrian Coast Axis, the Ebro Valley Axis and the Levante Axis, the other is the Vía de la Plata axis connected to the Puertollano Hydrogen Valley. A proposal was also made to explore possible underground storage facilities in the Basque Country and Cantabria. All received a first positive technical qualification issued by the European Commission to be eligible for EU funding.



One of the largest hydrogen investments in Spain and the most j ambitious project is the Andalusian Green Hydrogen Valley project. The project, which involves investments of more than €3 billion , will involve the construction of two green hydrogen plants in energy parks in Palos de la Frontera (Huelva) and San Roque (Campo de Gibraltar, Cadiz). The plants will have a total electrolysis capacity of 2 GW and will produce up to 300,000 tonnes of green hydrogen per year. Their construction will also increase the production of 2G biofuels and related products such as green ammonia and methanol, helping customers in the manufacturing and heavy road transport sectors in their decarbonisation efforts.

The construction of a hydrogen ring in Huelva (Spain) was announced in 2023. The pioneering engineering achievement resulting from the construction of this piece of

infrastructure is to connect hydrogen producers with consumers, provide a more sustainable, efficient, secure and competitive supply and exploit synergies across all adjacent industries.

The development of the Andalusian Green Hydrogen Valley will create 10,000 jobs , including 1,000 direct jobs, and stimulate the economic activity of more than 400 SMEs in the area. It will also stimulate industrial activity in the region by facilitating access to affordable, accessible, safe and sustainable energy near production centres. Andalusia already consumes 40% of the hydrogen currently used in Spain.

Important industrial clusters already exist in the Andalusia region, so it is an important objective to promote partnerships and cooperation in order to make the region more competitive. In this sense, the Andalusian Green Hydrogen Valley will be a centre of attraction for other links in the hydrogen value chain , such as electrolyser factories, green fertiliser plants or hydrogen transport technologies.

In addition, the project will make a significant contribution to improving skills and qualifications in the hydrogen industry. The leaders of this project will invest in the training of new professional profiles through training centres in energy parks, as well as other partnerships with universities in the region.

Andalusia is best placed to be one of the most competitive and efficient regions in the world in the production of green hydrogen. It is one of the places in Europe with the most competitive wind and photovoltaic generation capacity: more than 80% of the cost of producing green hydrogen comes from the cost of renewable electricity.



Andalusia consumes 40% of the hydrogen currently used in Spain, so Palos de la Frontera and San Roque, where there is already a significant industrial fabric, are the best locations for large-scale projects. Only such projects, providing access to a wide range of renewables and high end-user demand, can be competitive.

The location of the plant will contribute to a greater integration of renewable energy projects in the Autonomous Community and improve their use by harnessing surplus renewable energy generation during off-peak hours, accelerating the region's and Spain's decarbonisation targets