The European hydrogen policy landscape

April 2024 (Report 02)

Disclaimer

The aim of this report is to reflect the situation in the European and national policies, legislations, strategies and codes & standards which impact the deployment of hydrogen technologies and infrastructures, as of August 2023, unless stated otherwise. The authors believe that this information comes from reliable sources, but do not guarantee the accuracy or completeness of this information.

The data of the European Hydrogen Observatory will continuously be updated. These updates will take place annually for most datasets, while for some it can also be done on a case by case basis. As a result, the information used as of writing of this report might differ from the updated data that is presented on the European Hydrogen Observatory.

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Executive summary

This report aims to summarise the status of the European hydrogen policies and standards landscape. It is based on the information available at the European Hydrogen Observatory (EHO) platform, the leading source of data and information on hydrogen in Europe (EU27, EFTA and the UK), providing an overview of the European and national policies, legislations, strategies and, codes and standards which impact the deployment of hydrogen technologies and infrastructures.

The EHO database covers a total of 29 EU policies and legislations that directly or indirectly affect the development and deployment of hydrogen technologies. To achieve its net zero ambitions, the EU started with cross-cutting strategies, such as the EU Green Deal and the EU Hydrogen Strategy, setting forward roadmaps and targets that are to be achieved in the near future. As a next step, the EU has developed legislations, such as those bundled in the Fit for 55 package, to meet the targets they have put forward. The implemented legislations, including funding vehicles and initiatives, have an impact on the whole value chain of hydrogen including production, transport, storage and distribution, and end-uses.

At national level, as of July 2023, 63% of the European countries have successfully published their national strategies in the hydrogen sector, while 6% of the countries are currently in the draft stage. Several European countries have strategically incorporated quantitative indicators within their national strategies outlining their targets and estimates across the hydrogen value chain. This deliberate approach reflects a commitment to providing clear and measurable goals within their hydrogen strategies.

A target often used in the national strategies is on electrolyser capacity as an effort to enhance the domestic renewable hydrogen production. Germany took the lead with an ambitious goal of achieving 10 GW by 2030, followed by France (6.5 GW) and Denmark (4 - 6 GW). Other targets that some of the countries use in their strategies are on the number of hydrogen refuelling stations, fuel cell electric vehicles and total (renewable) hydrogen demand. A few countries also have targets on renewable hydrogen uptake in industry and hydrogen injection limit in the transmission grid.

To monitor the policies and legislation that are adopted on a national level across the hydrogen value chain, a survey was launched with national experts, which was validated by Hydrogen Europe. In total, 28 European countries have participated to the survey. On production, the survey revealed that 61% of country specialists report that their country provides support for capital expenditure (CAPEX) in the development of renewable or low-carbon hydrogen production plants. Moreover, 7 countries also provide support for operational expenditure (OPEX). Furthermore, 8 countries have instituted official permitting guidelines for hydrogen production projects, while 5 countries have enacted a legal act or established an agency serving as a single point of contact for hydrogen project developers. For transmission, only two countries reported to provide support schemes for hydrogen injection. Several countries have policies in place that clearly define the hydrogen limit in their transmission grid for now and in the future, ranging from 0.02% up to 15%, while a few countries define within their policies the operation of hydrogen storage facilities.

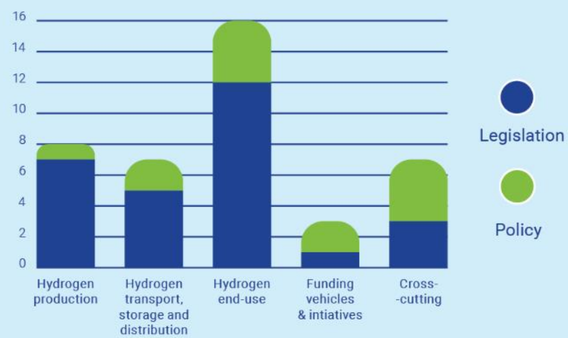
On end-use, the majority of countries, totalling 71%, reported to have implemented support schemes aimed at promoting the adoption of hydrogen in the mobility sector. Purchase subsidies stand out as the predominant form of support for fuel cell electric vehicles (FCEVs), with implementation observed in 17 countries. In the context of support schemes for stationary fuel applications, for heating or power generation, only two countries have adopted such measures. A slightly larger group of four countries do provide support for the deployment of residential and commercial heating systems utilizing hydrogen. For hydrogen end-use in industry, a total of 9 countries reported to provide support schemes with a major focus on ammonia production (8) and the chemicals industry (7). On the topic of technology manufacturing, 7 countries, have reported to have support schemes of which grants emerge as the mainly used method (4).

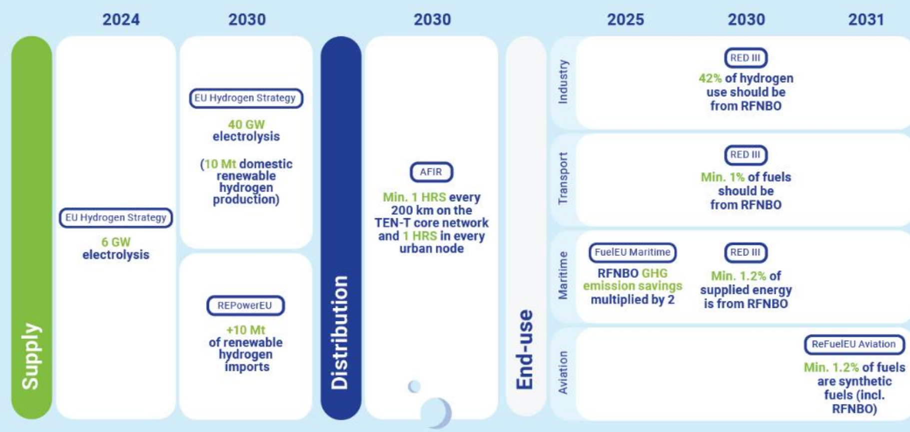
Exploring the latest advancements into European codes and standards relevant to the deployment of hydrogen technologies and infrastructures, a total of 11 standards have been revised and developed between January 2022 and September 2023. This includes standards covering the following areas: 6 for fuel cell technologies, 2 for gas cylinders, 2 for road vehicles and 1 for hydrogen refuelling. Moreover, 5 standards were published since September 2023, which will be added to the EHO database in its next update. This includes ISO/TS 19870:2023, which sets a methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate. This landmark standard, which was unveiled at COP28, aims to act as a foundation for harmonization, safety, interoperability and sustainability across the hydrogen value chain.

Key insights

EU Policies & Legislation

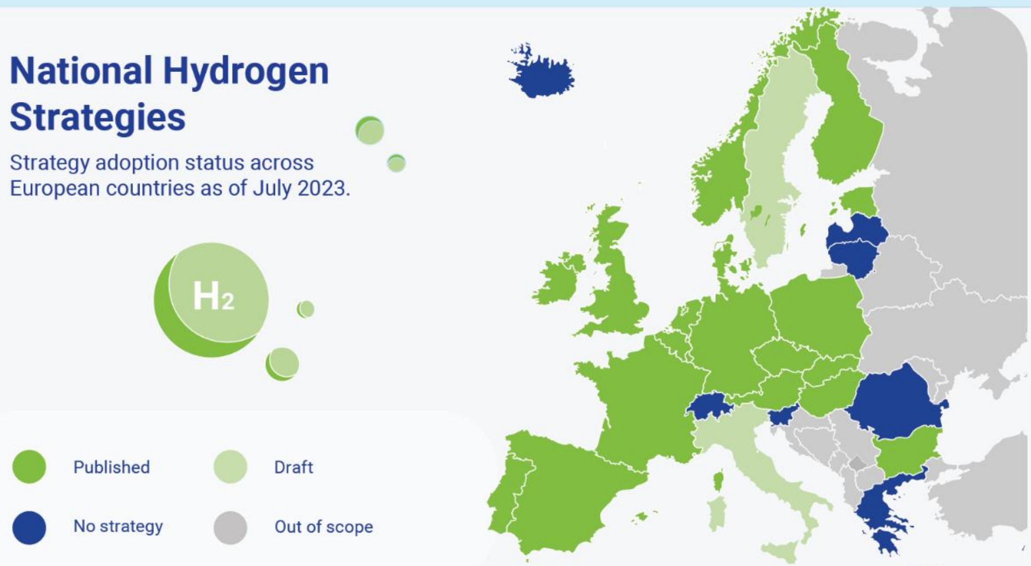
The EHO database covers a total of 29 EU policies and legislations, of which some are applicable to various categories in the hydrogen value chain.





National Hydrogen Strategies

Strategy adoption status across European countries as of July 2023.



Production

11 countries have targets on **electrolysis** capacity **ranging between 0.07 and 10 GW by 2030.**

Transmission

4 countries have targets on **hydrogen blending limits** in their **natural gas transmission** networks with a **hydrogen concentration of 2 to 15% by 2030.**

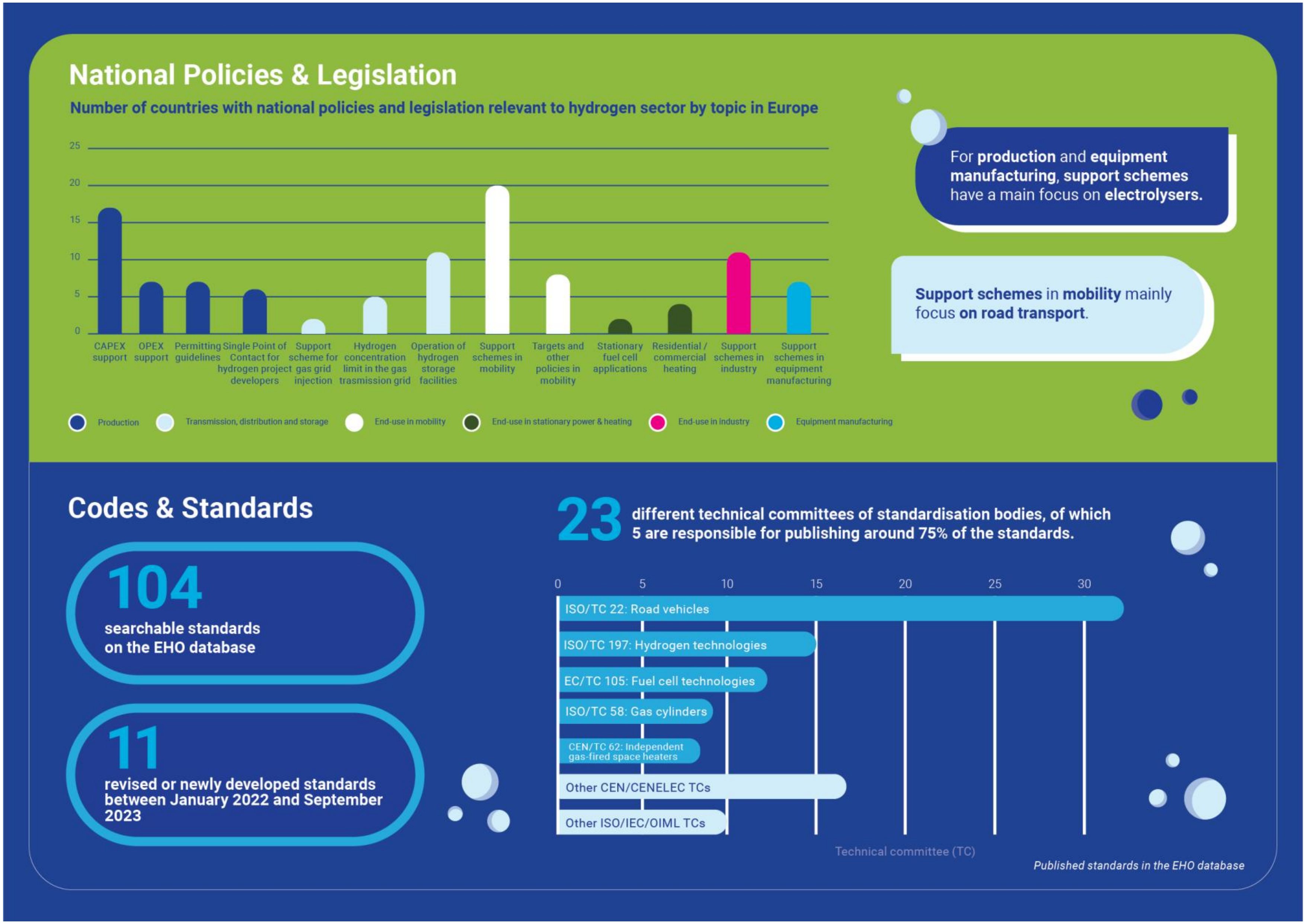
End-use

9 countries have estimated their future **hydrogen demand ranging** from **0.16 to 130 TWh by 2030.**

6 countries have targets on the number of **HRS ranging** from **15 to 125 units by 2030.**

6 countries have targets on the number of **FCEV** with a major focus on **road transport.**

Key insights



Overview

A growing number of governments are acknowledging the importance of the hydrogen sector and are implementing policy support measures, which are required to ensure technology readiness, enhance market penetration, and stimulate market growth. Policies and standards collectively shape the landscape for hydrogen technologies and infrastructures. They provide a regulatory framework, financial support, and strategic direction to promote the sustainable deployment of hydrogen across European countries.

This report aims to summarise the status of the European hydrogen policies and standards landscape. It is based on the information available at the European Hydrogen Observatory (EHO) website, the leading source of data on hydrogen in Europe. The data presented in this report is based on research conducted by Hydrogen Europe until the end of August 2023, but also goes beyond this timeline for major policies, legislations or standards implemented recently. It includes information on European policies and legislation, national strategies, national policies and legislation, and codes and standards. Interactive data dashboards can be accessed on the website: https://observatory.clean-hydrogen.europa.eu/.

The EU policies and legislation section provides insights into the main European policies and legislation relevant to the hydrogen sector, which are briefly summarized on content and their potential impact to the sector.

The national hydrogen strategies chapter offers a comprehensive examination of the hydrogen strategies adopted in Europe. It summarizes the quantitative indicators that have been published (targets and estimates) and provides brief summaries of the different national strategies that have been adopted.

The section referring to national policies and legislation focuses on the policy framework, measures, incentives and targets in place that have an impact on the development of the respective national hydrogen markets within Europe.

The codes and standards section provides information on current European standards and initiatives developed by the standardisation bodies, including CEN, CENELEC, ISO, IEC, OIML The standards are categorised according to the different stages of the hydrogen value chain: production, distribution and storage, and end-use applications.

01

EU Policies and legislation

This chapter provides an overview of the current European policies and legislation relevant to the deployment of hydrogen technologies and infrastructure.

It provides a brief description of the policies and the main expected impacts for the sector.

The data on European policies and legislation presented on the European Hydrogen Observatory website are based on content analysis, publicly available information, and expert knowledge from Hydrogen Europe, and reflects the situation as of July 2023.

Interactive data dashboards on EU policies and legislation can be accessed on the European Hydrogen Observatory website.

1.1.

Overview

The European Hydrogen Observatory (EHO) covers a total of 29 policies, both of legislative and non-legislative nature enacted that directly or indirectly affect the development and deployment of hydrogen technologies at the EU level. Legislative content typically involves a directive (e.g. Renewable Energy Directive) or a regulation (e.g. Regulation setting CO_2 emission performance standards for new passenger cars and light-duty vehicles). Non-legislative content involves a high-level political strategy, roadmap, or communication (e.g. EU Green Deal communication or the Hydrogen Strategy).

The EHO website provides more information on these policies based on their relevance and impact across various value chain levels of the clean hydrogen industry. The EU policies are broken down into the following categories: (1) cross-cutting, (2) hydrogen production, (3) hydrogen transport, storage and distribution, (4) hydrogen end-uses and (5) funding vehicles and initiatives.

In Figure 1 an analysis is made on the number of EU policies and legislations, that are available in the EHO database, applicable to different categories within the hydrogen value chain. Moreover, Table 1 gives a complete overview of the different policies and legislations that are presented in the EHO website. The content of these policies and legislations are summarized in the following subsections, broken down according to the different steps in the value chain.

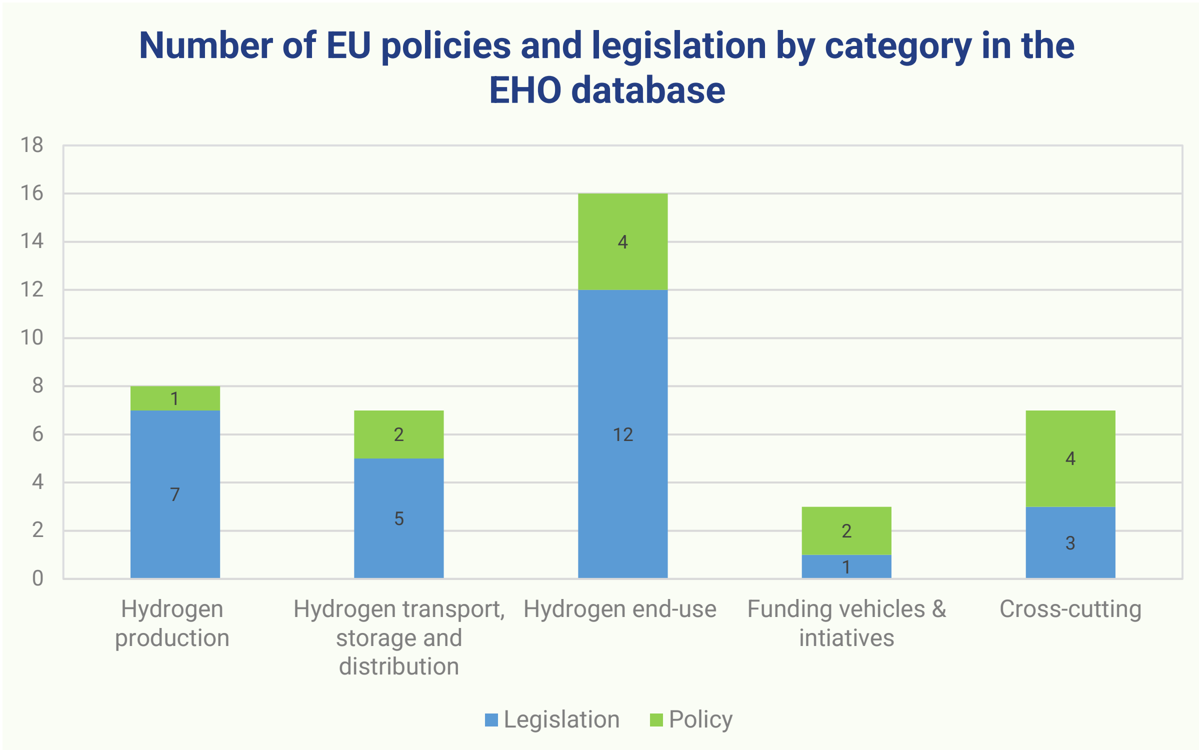


Figure 1. Number of EU policies and legislation in the EHO database by category

Table 1. EU policies and legislations covered in the EHO database sorted by topic as explained in this report

Cross-cutting	
EU Green Deal	European Climate Law
EU Energy System Integration Strategy	EU Hydrogen Strategy
Industrial Strategy	Sustainable finance
REPowerEU	
Production	
Energy Efficiency Directive	Renewable Energy Directive
EU Emissions Trading Scheme	Carbon Border Adjustment Mechanism
Hydrogen and Decarbonised Gas Market Package	Net Zero Industry Act
Critical Raw Materials Act	Offshore Renewable Energy Strategy
Transport, storage and distribution	
Sustainable and Smart Mobility Strategy	TEN-T Regulation
Alternative Fuels Infrastructure Regulation	FuelEU Maritime
REFuelEU Aviation	
End-use	
Energy Taxation Directive	Renovation wave
Energy Performance of Buildings Directive	CO_2 emission performance standards for passenger cars and light duty vehicles
CO_2 emission performance standards for new heavy-duty vehicles	Public procurement for clean vehicles
Funding vehicles and initiatives	
State Aid	Innovation Fund
Hydrogen Bank	

Most of the policies and legislations presented in this chapter cover the broader energy transition topic that also directly or indirectly includes the deployment of hydrogen technologies. In some of the policies and legislations clear targets and commitments are set forward, specifically for hydrogen technologies deployment or hydrogen uptake. These targets and commitments are summarized in Figure 2, also broken down according to the different steps in the value chain.

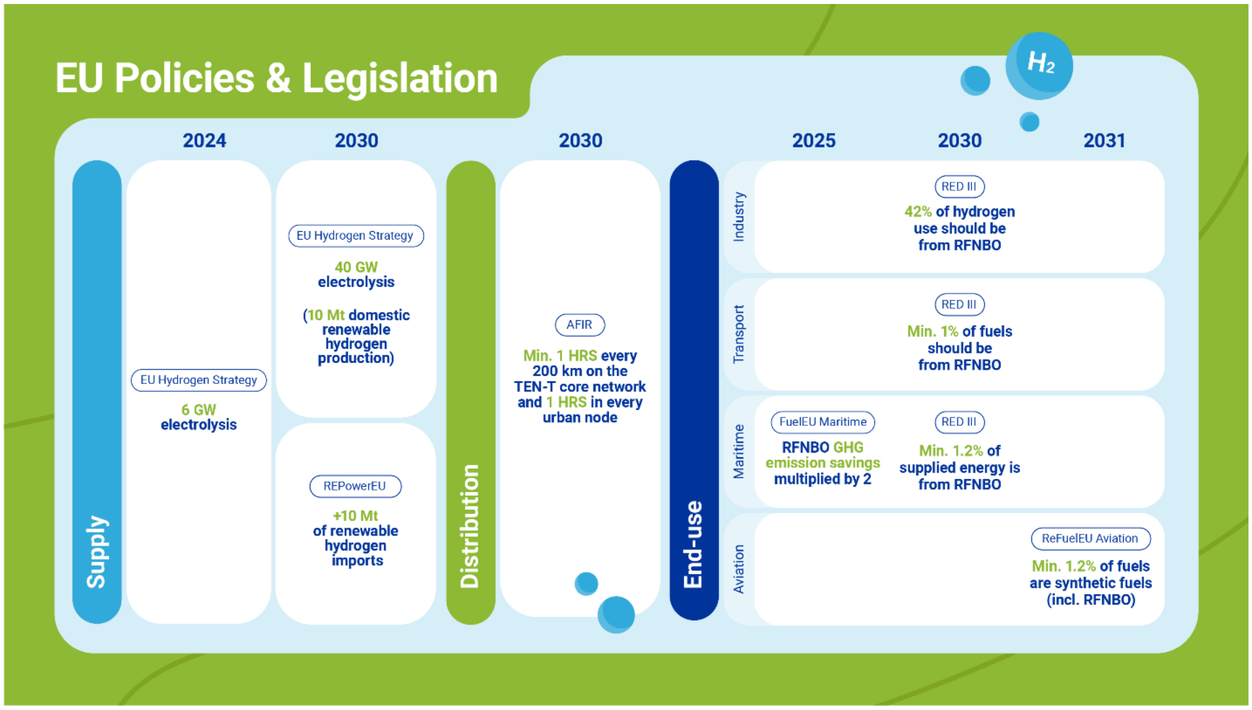


Figure 2. Direct targets and commitments by EU policies and legislations towards hydrogen technologies deployment and hydrogen uptake across the value chain

1.2.

EU Policies and legislation by category

1.2.1.

Cross-cutting

The European energy and climate policy landscape is going through significant changes, with the objective of increasing the ambition to establish a regulatory framework conducive to the transition towards a climate neutral economy, accelerate greenhouse gas reductions, and foster the emergence of clean technologies, such as hydrogen. This section summarizes these major EU policies and legislations that have been implemented and that have an impact across all sectors, including hydrogen deployment.

European Green Deal [1] and Climate Law [2]

In late 2019, the newly elected European Commission presented its proposal for a European Green Deal. This policy roadmap is meant to be an EU's new growth strategy. It provides significantly stronger emphasis on the decarbonisation dimension of the Energy Union through a resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. It also aims to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts. The Green Deal objectives are now being executed in many legislative and non-legislative initiatives, aimed at implementing the increased level of ambition. Most importantly, the European Climate Law, was adopted by EU institutions in June 2021 and it sets into EU law the binding target of net zero greenhouse gas emissions by 2050 (so-called 'carbon neutrality' or sometimes 'climate-neutrality') as well as a 55% greenhouse gas reduction target by 2030 for the EU.

Fit for 55 package [3]

The European climate law turns reaching the EU's climate goal of reducing EU emissions by at least 55% by 2030 to a legal obligation. To meet this obligation, the EU countries have been working at new legislations with the Fit for 55 package. The legislations presented in Table 2, that are of relevance to hydrogen, were either adopted or revised as part of the Fit for 55 package. They will be explained in more detail in the following subsections based on their impact on the different steps of the value chain (production, distribution and storage or end-use).

Table 2. Legislative policies that were adopted or revised in the Fit for 55 package and are of relevance to hydrogen.

Hydrogen related legislations in Fit for 55 package	
EU Emissions Trading System (ETS)	Alternative Fuels Infrastructure Regulation (AFIR)
Effort Sharing Regulation	ReFuel EU Aviation Regulation
CO_2 emissions standards for cars and vans	FuelEU Maritime Regulation
Carbon Border Adjustment Mechanism (CBAM)	Energy Performance of Buildings Directive
Renewable Energy Directive	Energy Taxation Directive
Energy Efficiency Directive	Hydrogen and gas markets decarbonisation package

1 The European Green Deal-European Commission (europa.eu)
2 European Climate Law-European Commission (europa.eu)
3 Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality-European Commission (europa.eu)

Energy System Integration Strategy and the European Hydrogen Strategy[4]

Before the adoption of the new legislations from the Fit for 55 package, in 2020, the European Commission released two new major hydrogen relevant strategies, the Energy System Integration Strategy and the European Hydrogen Strategy, that show the importance of hydrogen in a decarbonised future economy, in applications such as high temperature industry (cement, etc.), feedstock in industry (steel, fertilisers), and heavy and long-haul transport (maritime, aviation, heavy duty vehicles, etc.). In these two strategies, hydrogen is seen as a key technology to link the components of the energy system (due to its versatility and its potential for energy storage and for decarbonisation of hard-to-abate sectors). In the European Hydrogen Strategy, the Commission sets clean hydrogen production targets: aiming for at least 6 GW of renewable hydrogen production capacity (i.e. electrolysers) by 2024 in the EU (resulting in the production of 1 million tonnes of renewable hydrogen) and for at least 40 GW by 2030.

EU Industrial Strategy[5]

In 2020, under its EU Green Deal, the Commission also proposed a brand-new EU Industrial Strategy to deliver on three key priorities: maintaining European industry's global competitiveness and a level playing field, making Europe climate-neutral by 2050 and shaping Europe's digital future. With the European Industrial Strategy as well as the European Hydrogen Strategy of 2020, the Commission acknowledged the potential of hydrogen in contributing to the energy transition and announced the creation of the European Clean Hydrogen Alliance (ECH2A) in July 2020. Its aim is to bring governmental, institutional and industrial partners together with investors, to identify and build up a pipeline of viable investment projects along the hydrogen value chain, in order to deliver the green transition and create a clean hydrogen market which contributes to growth and jobs and reduction of GHG emissions.

Sustainable finance under the EU Green Deal[6]

To achieve the goals set by the European Green Deal, besides implementing legislations, the Commission also strives to channel finance to sustainable investment options, compatible with the climate neutrality objective. Concretely, the Commission wants to direct financial flows to green investment and avoid stranded assets, via increased available funds for sustainable investment and reviewed taxonomy. The Commission has put in place the European Green Deal Investment Plan (EGDIP), also referred to as Sustainable Europe Investment Plan (SEIP), as part of the Green Deal. This includes the Just Transition Mechanism, which focuses on ensuring a fair and just transition to a green economy. It is mobilising significant investments

[4] Powering a climate-neutral economy: An EU Strategy for Energy System Integration-European Commission (europa.eu)

[5] European industrial strategy - European Commission (europa.eu)

[6] Strategy for Financing the Transition to a Sustainable Economy-European Commission (europa.eu)

over the period 2021-2027 to support citizens of the regions most impacted by the transition.

REPowerEU[7]

In the more recent years, as a response to the energy market disruptions caused by the invasion of Russia in Ukraine, the Commission also presented the REPowerEU Plan on 18 May 2022. The Plan seeks to rapidly reduce the EU's dependency on Russian fossil fuels and proposed a series of amendments to increase the ambition of several files being revised under the Fit for 55 package. Within the section devoted to the hydrogen sector of the REPowerEU Plan, the Commission sets the key, indicative target to increase the 2023 target from renewables from 40% to 45% and to achieve 10 million tonnes of domestic hydrogen production and 10 million tonnes of imported renewable hydrogen by 2030.

The Green Deal Industrial Plan[8]

As a further response to the most recent challenges related to the pandemic, the unjustified aggression of Ukraine and the rapid changes in the global geopolitical order, the European Commission also published in February 2023 its Green Deal Industrial Plan. This plan is updating the EU industrial strategies to enhance the competitiveness of Europe's net-zero industry and is accelerating the transition to climate neutrality. It does so by creating a more supportive environment for scaling up the EU's manufacturing capacity for the net-zero technologies and products required to meet Europe's ambitious climate targets.

1.2.2. Production

Legislations that fall under the Fit for 55 package that can have an impact on hydrogen production include the Energy Efficiency Directive, the Renewable Energy Directive, the EU Emissions Trading Scheme, the Carbon Border Adjustment Mechanism and the Hydrogen and Gas Market Decarbonisation Package. Moreover, the Green Deal industrial plan will also have an impact on hydrogen production with the newly proposed Net-Zero Industry Act and Critical Raw Materials Act legislations. The following sections will briefly summarize these legislations and their potential impacts on the hydrogen sector.

Energy Efficiency Directive[9]

The Energy Efficiency Directive (EED) (2012/27/EU) lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy. Its main provisions are organised within chapters on efficiency in energy use and in energy supply. A

[7] REPowerEU-European Commission (europa.eu)
[8] The Green Deal Industrial Plan-European Commission (europa.eu)
[9] Energy Efficiency Directive-European Commission (europa.eu)

substantial revision ('recast') of the EED came as part of the Fit for 55 legislative package in order to deliver on the increased climate ambition of the EU Green Deal. In the final agreement, member states must collectively ensure a reduction of final energy consumption of at least 11.7% by 2030, compared with the energy consumption forecasts for 2030 made in 2020. This translates into an upper limit to the EU's final energy consumption of 763 million tonnes of oil equivalent. The EED provides a regulatory framework that indirectly influences the hydrogen sector by promoting energy efficiency, sector integration, and building standards, among other measures.

Renewable Energy Directive[10]

The current version of the Renewable Energy Directive that has been legally binding since June 2021 sets a 32% target share of renewable energy in the EU's gross final energy consumption by 2030. In October 2023, the European Council had adopted the new Renewable Energy Directive to raise the share of renewable energy in the EU's overall energy consumption to 42.5% by 2030 with an additional 2.5% indicative top up to allow the target of 45% to be achieved. All member states will contribute to achieving more ambitious sector-specific targets in transport, industry, buildings and district heating and cooling. These sector-specific targets also include targets directly relevant for hydrogen. In industry, 42% of the hydrogen used should come from renewable fuels of non-biological origin (RFNBOs) by 2030 and 60% by 2035. Moreover, there is also a minimum requirement of 1% of RFNBOs in the share of renewable energies supplied to the transport sector in 2030.

EU's Emission Trading System[11]

The EU's Emission Trading System (EU ETS), in addition to the new CBAM, is the EU's main policy for reducing greenhouse gas emissions. It applies to all EU countries plus Iceland, Liechtenstein and Norway and until now covered energy intensive installations (power stations & industrial plants) and airlines operating between these countries. With the revision, as part of the Fit for 55 package, this list is now extended to the maritime sector. In addition, a separate ETS is set up for buildings and road transport (ETS II), which come into effect in 2025. The system is a cap-and-trade system, where a cap is set on the total amount of CO_2 that can be emitted by installations covered by the system. Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. The cap is reduced over time, following a linear reduction factor (LRF). Under the EU's Fit for 55 legislative package, the ETS was revised to accommodate the bloc's higher climate ambition. This means that in expanding the current ETS's ambition of 43% emission reduction until 2030 (compared to 2005 levels), the revision will aim for a reduction of 62% by 2030. Also, the revision raised the LRF from 2.2%

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[10] Renewable Energy Directive-European Commission (europa.eu)
[11] EU's Emission Trading System-European Commission (europa.eu)

to 4.3-4.4%. The scope of the EU ETS corresponds in many aspects to GHG-emitting economic activities where hydrogen can act as a clean energy carrier substitute in a cost-effective and purpose-fit manner. With the revision of the system, it is expected that the impact for hydrogen could be even bigger, since the amount of allowances will be progressively reduced, which could raise their price, incentivising decarbonisation efforts. Furthermore, with the revision, the ETS now includes the coverage of all hydrogen production methods exceeding 5 tonnes per day, including with electrolysers, making renewable and low-carbon hydrogen facilities eligible for free allowances.

Carbon Border Adjustment Mechanism[12]

The Carbon Border Adjustment Mechanism (CBAM) is part of the European Union's Fit for 55 package and was presented on 14th July 2021 by the European Commission. CBAM aims to establish a mechanism which equalises the price of carbon between domestic products and imports in selected sectors. Under the scheme, EU importers will be subject to a carbon price (via a CBAM certificate) whose price level mirrors that of the ETS (i.e. the carbon price that would have been paid, had the production taken place in the EU). The mechanism will be introduced gradually and first apply to selected products at high risk of carbon leakage: iron, steel, cement, fertiliser, aluminium, electricity generation and (non-renewable) hydrogen production. As for timing, the scheme will kick off with a transition period of around 2 years, from October 2023 to the end of 2025, during which importers will have to report emissions embedded in their goods. From 2026 onwards, a long phase-in of the CBAM will start, whereby it will gradually replace ETS free allowances until the complete phase in of the scheme in 2034. In general, the mechanism is expected to accelerate decarbonisation efforts both in the EU and abroad, by equalising the carbon price of domestic products and imports. With the progressive phase-out of free allowances under the ETS, the industrial sectors covered by the mechanism will be subject to the full carbon price. This would create a stronger incentive to decarbonise industrial processes. Thus, the role of renewable hydrogen is expected to increase, especially in sectors where there are few other alternatives, such as in steel and fertilisers production.

Gas Market Decarbonisation Package[13]

Building on the Energy System Integration and Hydrogen Strategies, in December 2021, the Commission proposed a new regulatory framework for the development of hydrogen and other clean alternative gas technologies in Europe in the Hydrogen and Gas Market Decarbonisation Package. Aiming at system integration and future-proofing the existing natural gas infrastructure, the package consists of revisions of the Gas Directive and Gas Regulation which set the common rules for the

[12] Carbon Border Adjustment Mechanism-European Commission (europa.eu)
[13] Hydrogen and Gas Market Decarbonisation Package-European Commission (europa.eu)

internal market in natural gas, and with the proposed revision also for renewable natural gas and hydrogen. Thereby aligning the existing legislation with the Clean Energy Package provisions on incentives for clean energy solutions, prosumer behaviour, easier switching of providers and clear certification for low carbon hydrogen. The role of low-carbon hydrogen as an enabler of decarbonization in the short and medium term is foreseen, with the intent to support the uptake of renewable fuels such as renewable hydrogen. In general, the proposed internal market rules for hydrogen are similar to the existing ones for natural gas and electricity sectors. Yet, the proposals establish a degree for flexibility to ramp-up the development of the hydrogen market.

Net-Zero Industry Act[14]

The Net-Zero Industry Act, jointly with the Critical Raw Materials Act, are complementary pieces of legislation under the first pillar of the Green Deal Industrial Plan. This pillar aims to create a simpler, faster and more predictable regulatory framework, secure the volumes needed for raw materials, and ensure users are able to benefit from the low costs of renewables. The objectives of the NZIA are to provide investment certainty, lower administrative burdens through facilitated permitting and access to information, and facilitate market access through public procurement, auctions, and schemes to support private demand by consumers. Additionally, the development of skills for quality job creation in these technological sectors is also addressed.

Under the proposal, electrolysers and fuel cells are in the scope of the regulation, making them strategic technologies. Upstream components of electrolysers and fuel cells are also included within its scope. The granting of Net-Zero Strategic Project status can be awarded to those projects that contribute to an increase of production capacity of components or parts related to strategic technologies for which the EU heavily depends on imports, or to projects that provide a systemic benefit towards EU competitiveness, with spill-over effects on manufacturing capacities, sustainability performances, skilling and reskilling.

Critical Raw Materials Act[15]

The proposed regulation targets several issues related to critical raw materials, such as low diversification of EU supply sources, the untapped potential of local supply, weak monitoring and risk management capacity to anticipate and prevent supply disruptions of critical raw materials, adverse social and environmental impacts of production of CRMs, insufficient support for circularity and insufficient research and innovation. The proposed policies will also be important to hydrogen technologies, such as electrolysers and fuel cells, since they are dependent on CRMs. Their availability and future prices will be a crucial aspect affecting the speed at which the hydrogen market can grow.

[14] Net Zero Industry Act-European Commission (europa.eu)
[15] Critical Raw Materials Act-European Commission (europa.eu)

1.2.3. Transport, storage and distribution

Besides the legislations that already have been mentioned, other legislations that fall under the Fit for 55 package that can have an impact on hydrogen transport, storage and distribution include the FuelEU Maritime, RefuelEU Aviation and the Alternative Fuels Infrastructure Regulation. Before the introduction of these legislations, the European Commission published in December 2020 its Sustainable and Smart Mobility Strategy that provides a vision on the European transport system and transport policies, not least in the perspective of the sector's decarbonisation.

Sustainable and Smart Mobility Strategy[16]

The main message of this strategy consists in the ambition of making mobility more sustainable, smarter and more resilient by 2030. In a nutshell, the Strategy adopts an integrated approach by looking at demand, supply, infrastructure, and fuels in the transport sector. Specifically for hydrogen, it will have an estimated share of 31-40% in road transport fuels in 2050, and e-fuels will account for 10-17%. In terms of infrastructure, the Strategy will aim to deploy 500 hydrogen refuelling stations by 2025 and 1,000 by 2030.

Trans-European Network for Transport[17]

The Trans-European Transport Network (TEN-T) regulation sets the basis for the European's transport network policy and constitutes a key instrument for the development of coherent, efficient, multimodal, and high-quality transport infrastructure across the EU. First adopted in 2013, the Regulation is currently being under revision to put the transport sector on track to cut its emissions by 90%, as stated in the Green Deal Plan and Smart and Sustainable Mobility Strategy. It aims to increase connectivity in Europe, foster the resilience of the transport system, shift more passengers and freight to sustainable modes of transport and to focus more on sustainable urban mobility. The revision of the TEN-T guidelines have the objective to strengthen the network's sustainability and it offers the opportunity to integrate requirements for hydrogen development across all transport modes. It provides the basis for the implementation of other legislations, such as the Alternative Fuels Infrastructure Regulation and FuelEU Maritime. The TEN-T guidelines also determines the eligibility for funding under the CEF Transport programme.

Alternative Fuels Infrastructure Regulation[18]

The Alternative Fuels Infrastructure Regulation (AFIR) establishes a common framework of

[16] Sustainable and Smart Mobility Strategy-European Commission (europa.eu)
[17] Trans-European Network for Transport-European Commission (europa.eu)
[18] Alternative Fuels Infrastructure Regulation- European Commission (europa.eu)

measures for the deployment of alternative fuels infrastructure in the Union in order to minimize dependence on oil and to mitigate the environmental impact of transport by supporting the uptake of alternative fuels in the transport sector. Under the Fit for 55 package, the European Commission proposed a revision of the directive, upgrading it into a regulation. This makes the targets binding and directly applicable in all member states. This regulation recognises hydrogen as a key alternative fuel with a potential for long-term oil substitution. It further sets out the legal framework for hydrogen refuelling stations for road transport, the lack of which contributes to the limited penetration of hydrogen-powered vehicles in the EU market – namely the deployment of hydrogen refuelling infrastructure from 2030 onwards in all urban nodes and every 200 km along the TEN-T core network, to serve both cars and lorries. The framework ensures refuelling certainty and, as such, lays the foundation for the scale up of hydrogen powered mobility.

FuelEU Maritime[19]

FuelEU Maritime seeks to steer the EU maritime sector towards decarbonisation via limiting the carbon intensity of the energy used on board ships, therefore indirectly supporting the uptake of sustainable maritime fuels. This Regulation establishes limits on the annual average GHG intensity of the energy used on board, increasing from 2% in 2025 to 80% in 2050. The Regulation also includes provisions incentivizing the use of renewable fuels from non-biological origin (RFNBOs) by ships. First, until 2033 a multiplier of 2 can be used on RFNBOs to reward their use by early movers. Additionally, an RFNBO 'sunrise clause' was introduced, which states that if in 2031 the share of RFNBOs in the yearly energy used on-board ships is less than 1%, a mandatory quota of 2% RFNBOs shall apply by 2034. This incentivizes the use of e-fuels and renewable hydrogen to decarbonize shipping as it falls into the scope of RFNBOs and will lead to an uptake of demand for hydrogen-based maritime e-fuels, as ammonia or methanol.

ReFuelEU Aviation[20]

The ReFuelEU Aviation regulation sets minimum obligations for all fuel suppliers to gradually increase the share of SAFs (sustainable aviation fuels) in the fuel supplied to operators at EU airports. The SAF requirements increase from 2% by 2025 to 70% by 2050. Within this SAF requirements, a sub-obligation is also set for synthetic aviation fuels (RFNBOs complying with the lifecycle emissions saving threshold of 70%, thus including renewable hydrogen), increasing from 1.2% by 2030-2031 to 35% by 2050. This historic agreement, the first-of-a-kind mandate for green aviation fuel, will allow SAFs projects to be deployed at a larger scale, adding certainty on the definition of those fuels for investors and suppliers.

[19] FuelEU Maritime- European Commission (europa.eu)
[20] ReFuelEU Aviation- European Commission (europa.eu)

1.2.4.
End-use

Besides the legislations that already have been mentioned in the earlier sections, other legislations that fall under the Fit for 55 package that can have an impact on hydrogen end-uses include the Energy Taxation Directive, the Energy Performance of Buildings Directive and CO_2 emissions standards for cars and light duty vehicles.

The Energy Taxation Directive could have an impact on all end-uses and aims to shift the tax burden from labour to pollution. For hydrogen end-use in buildings, the Energy Performance of Buildings Directive is of main importance and is currently being revised with the aim to set out the vision and tools to achieve zero emissions by 2050 in buildings, as a part of the Renovation Wave for Europe strategy. For hydrogen use in transport, in addition to the legislations mentioned in the previous section, the CO_2 emissions standards for cars and light duty vehicles and to the CO_2 emissions standards for heavy-duty vehicles regulations are of relevance. These regulations set ambitious targets for reducing the average emissions of new vehicles that could, together with the public procurement for clean vehicles, result in an increase of the fuel cell electric vehicles fleet. For industry, no additional legislations are covered in this section, as the main relevant legislation were already covered in the section of production, such as the EU emissions trading system, the Carbon Border Adjustment Mechanism and the Renewable Energy Directive.

Energy Taxation Directive[21]

In its EU Green Deal, the European Commission clearly states that the tax burden should shift from labour to pollution. The Energy Taxation Directive sets minimum levels of taxation and lays down the conditions for applying tax exemptions and reductions. The Directive is currently being revised under the Fit for 55 legislative package. The main proposed change relates to the move to base taxation of energy products on their energy content (instead of volumes) and rank them with different minimum taxation rates depending on their environmental performance. Moreover, it also proposes to phase-out exemptions for certain products and home heating, and lastly, fuels for intra-EU air, maritime and fishing are no longer fully exempt from taxation.

Energy taxation will be a cornerstone to facilitate a prosperous future for hydrogen. As a sustainable alternative fuel and considering the uptake the Commission wants to provide them under the Fit for 55, hydrogen could benefit from financial incentives. Under the proposed revision of the directive, the switch to renewable and low-carbon fuels is heavily incentivised. Carbon-intensive fuels are to be taxed more, while preferential tax rates for renewable and low-

[21] Energy Taxation Directive--European Commission (europa.eu)

carbon hydrogen will serve to stimulate their use in multiple applications.

Renovation Wave for Europe[22]

The European Commission published its Renovation Wave for Europe strategy in October 2020. The strategy aims to help improve the energy performance of buildings and deliver on the European Green Deal ambitions, as buildings are responsible for about 40% of the EU's energy consumption, and for 36% of greenhouse gas (GHG) emissions in the EU. The Strategy provides a roadmap of EU targets to be achieved by 2030 and is accompanied by a series of policy measures. Some of these policy measures include the revisions of the Renewable Energy Directive, the EU Emissions Trading System Directive and the Energy Performance of Buildings Directive as part of the Fit for 55 package.

Energy Performance of Buildings Directive[23]

In December 2021, the European Commission published its proposal for a revision of the Energy Performance of Buildings Directive (EPBD). According to the Commission's proposal, all new buildings in the EU must be zero-emission buildings as of 2030, while all new public buildings must be zero-emission as of 2027. Existing provisions on renovation will be complemented by the introduction of minimum EU-level efficiency standards, triggering an increase in the renovation rate of the worst-performing buildings. Non-residential buildings with a class G (lowest) energy performance certificate (EPC) will need to be renovated and improved to at least EPC class F by 2027 and class E by 2030. The worst-performing residential buildings will need to reach at least class F by 2030 and class E by 2033. To ensure comparable national standards, all EPCs must be based on a harmonised scale of energy performance by 2025 and subject to future rescaling with view to reaching a zero-emission building stock by 2050. The legislation will help the EU to gradually phase out boilers powered by fossil fuels and will also enable hydrogen-based heating solutions to contribute to this important objective.

CO_2 emissions performance standards for cars and light duty vehicles[24]

The revised regulation for setting CO_2 emission performance standards for new passenger cars and light commercial vehicles was published in April 2023. The regulation incentivises manufacturers to integrate an increasing share of low- and zero-emission vehicles in their fleet to meet their average CO_2 emission reduction targets. The average allowed emissions reduce over time with a final target in January 2035, when all new passenger cars and new light commercial vehicles should have zero emissions.

[22] Renovation Wave for Europe-European Commission (europa.eu)
[23] Energy Performance of Buildings Directive-European Commission (europa.eu)
[24] CO_2 emissions performance standards for cars and light duty vehicles-European Commission (europa.eu)

CO_2 emissions performance standards for heavy-duty vehicles[25]

This regulation adopted in 2019 was the first to set EU-wide CO_2 emission standards for heavy-duty vehicles. Similar to the CO_2 emission performance standards for new passenger cars and light commercial vehicles, the regulation sets targets for reducing the average (fleet-wide) emissions from new trucks and other heavy goods vehicles for 2025 and 2030. Currently, the Regulation is being reviewed with a proposal from the European Commission published on 14th February 2023. The new proposed targets would mandate the reduction of average emissions from heavy-duty vehicles by 45% from 2030, 65% by 2035 and 90% from 2040 onwards. The proposal also includes a 100% target for city buses as of 2030. The regulation will incentivise manufacturers to integrate an increasing share of low- and zero-emission vehicles in their fleet to meet their average CO_2 emission reduction targets. The first due date, by which manufacturers will have to reach their individual emission reduction target of 15%, is set for 2025. This means that decarbonisation efforts will start as of now in order for manufacturers to be compliant in 2025. Due to the many incentives this regulation gives and the characteristics of hydrogen, it is expected that hydrogen fuel cell technology will benefit and expand in HDV fleet.

Public procurement for clean vehicles[26]

Public procurement refers to the process by which public authorities, such as government departments or local authorities, purchase work, goods or services from companies. In the context to a transition to carbon-neutral economy, public procurement is seen as an important tool to stimulate innovation and promote competitiveness and growth of industries, as public procurement accounts for a significant part of national GDP. Through public procurement, demand for sustainable technologies is increased, triggering effects across the product's value-chain, thereby supporting the development of economies of scale and innovation. The Clean Vehicle Directive, that sets public procurement targets for clean vehicles, together with the Green Public Procurement instrument, which is a voluntary instrument to help public authorities use their purchasing power to choose environmentally friendly goods, are expected to boost demand for clean vehicles (including FCEVs) and the deployment of infrastructure for the distribution of clean transport fuels like hydrogen.

[25] CO_2 emissions performance standards for heavy-duty vehicles-European Commission (europa.eu)
[26] Public procurement for clean vehicles-European Commission (europa.eu)

1.2.5.
Funding vehicles & initiatives

In 2020, the European Union provided an unprecedented response to the coronavirus crisis that hit Europe and the world. At its heart is a stimulus package worth 2.018 trillion EUR. It consists of the EU's long-term budget for 2021 to 2027 of 1.211 trillion EUR, topped up by 806.9 billion EUR through NextGenerationEU, a temporary instrument to power the recovery. In June 2023, the Commission proposed to reinforce the EU's 2021-2027 long-term budget in a targeted manner, to make sure the EU budget can continue to deliver on the most essential objectives.

Most of the NextGenerationEU budget (723.8 billion EUR) is allocated to the Recovery and Resilience Facility. The additional budget of NextGenerationEU is used to reinforce several existing EU programmes of the Multiannual Financial Framework (MFF). MFF programmes that have an impact on the development and deployment of hydrogen technologies include the cohesion policy and investEU, in addition to programmes managed by CINEA such as Connecting Europe Facility, Innovation Fund, Horizon Europe and Life programme. Many of these programmes make use of the European Investment Bank (EIB), which is the lending arm of the European Union that provides loans and financial support for various sustainable projects, including those related to hydrogen infrastructure and technologies. Next to these EU funded programmes, also the revised state aid rules and Important Projects of Common European Interest (IPCEI) will result in an increased deployment of hydrogen technologies.

Recovery and Resilience Facility [27]

The Recovery and Resilience Facility (RRF) is the centrepiece of the EU's NextGenerationEU recovery plan. Its goal is to make EU economies and societies greener, digital and resilient. The RRF will provide 723 billion EUR[28] to invest in reforms and projects at 2022 prices, of which 337.97 billion EUR in grants and 385.85 billion EUR in loans. Project financing depends on what each EU country has included in its plan. The funds under the Recovery and Resilience Facility are distributed according to national recovery and resilience plans prepared by each Member State, in cooperation with the European Commission.

InvestEU[29]

The InvestEU programme consists of three components: the InvestEU Fund, the InvestEU Advisory Hub and the InvestEU Portal. The InvestEU Fund is expected to mobilise more than

[27] Recovery and Resilience Facility-European Commission (europa.eu)
[28] This represents the maximum amount foreseen by the RRF Regulation.
[29] InvestEU-European Commission (europa.eu)

372 billion EUR of public and private investment through an EU budget guarantee of 26.2 billion EUR that backs the investment of financial partners such as the European Investment Bank (EIB) Group and others. The InvestEU fund provides for an EU guarantee to support financing and investment operations, carried out by implementing partners that contribute to objectives of the EU's policies. Implementing partners and other financial intermediaries will provide finance as guarantees, loans, risk-sharing or equity. The EIB Group will have access to 75% of this guarantee and will act as the main implementing partner for the fund. The InvestEU Advisory Hub provides advisory support for the development of investable projects and access to financing. The InvestEU Portal boosts the project's visibility to a large network of international investors.

Cohesion Policy[30]

The EU Cohesion Policy contributes to strengthening economic, social and territorial cohesion in the European Union. The European Regional Development Fund (ERDF), Cohesion Fund (CF) and the Just Transition Fund (JTF) are part of the EU's Cohesion Policy. ERDF and CF support innovation and entrepreneurship in the transition to a climate-neutral economy. Some regions may allocate ERDF funds to hydrogen projects as part of their clean energy strategies. JTF aims to reduce the social and economic impact resulting from the transition to climate neutrality in the most affected regions, given their dependence on fossil fuels or on carbon-intensive industries. The Commission provides grants that are disbursed to the member states in line with their territorial just transition plans. These plans identify the eligible territories, i.e. those expected to be the most negatively impacted by the green transition.

Modernisation Fund[31]

The Modernisation Fund is a fund supporting 10 lower-income EU countries' transition to climate neutrality through the modernisation of their energy systems and improved energy efficiency. It supports investments in the production and use of renewable hydrogen; hydrogen fuelled trains, trucks and cars, high-efficiency hydrogen CHP.

Connecting Europe Facility[32]

The Connecting Europe Facility (CEF) is a key EU funding instrument in delivering the European Green Deal and an important enabler towards the Union's decarbonisation objectives for 2030 and 2050. It supports the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services. In addition to grants, the CEF offers financial support to projects through innovative financial instruments such as guarantees and project bonds. The Connecting Europe Facility for Energy (CEF-E) is a funding instrument that supports the implementation of the Regulation on Trans-

[30] Cohesion Policy-European Commission (europa.eu)
[31] Modernisation Fund-European Commission (europa.eu)
[32] Connecting Europe Facility-European Commission (europa.eu)

European Networks for Energy (TEN-E), which is focused on linking the energy infrastructure of EU countries. It may fund cross-border hydrogen transmission & distribution projects, storage and large-scale electrolysers (>100 MW of capacity). The Connecting Europe Facility for Transport (CEF-T) contributes to the implementation of the Trans-European Transport Network (TEN-T) and finances projects that upgrade infrastructure and remove bottlenecks while promoting sustainable and innovative mobility solutions. These projects cover all EU countries and all transport modes (road, rail, maritime, inland waterways).

Innovation Fund[33]

Innovation Fund is one of the world's largest funding programmes for the demonstration of innovative low-carbon technologies. The Fund is highly relevant as a tool to deploy clean hydrogen technologies, as its project eligibility scope covers areas where, in each of them, clean hydrogen technologies could have significant potential (energy-intensive industries decarbonisation, energy storage, and innovative renewable energy generation) or be positively impacted (CCS/U). The Fund may amount to 20 billion EUR (for a carbon price of 40 EUR ton/CO2), depending on the carbon price. The Innovation Fund supports up to 60% of relevant costs of projects. Support is already available in the form of grants. Additional support via blending is also possible, with 100 million EUR currently assigned from the Innovation Fund to InvestEU to enable support in the form of financial instruments (i.e., debt or equity-type debt) via the Green Transition Product. Under the umbrella of the European Hydrogen Bank funded by the Innovation Fund, the Commission has also launched in November 2023 a first auction (i.e., competitive bid) for supporting the production of renewable hydrogen (budget of 800 million EUR). Funding will be awarded as a fixed premium in €/kg of verified and certified RFNBO hydrogen produced. Moreover, a mechanism, called Auctions-as-a-Service (AaaS), will enable countries of the EEA to use their national budget resources to support projects located on their territory while relying on an EU-wide auction mechanism to identify the most competitive projects.

Horizon Europe[34]

Horizon Europe 2021-2027 is the EU's key funding programme for research and innovation, with a budget of 95.5 billion EUR. Pillar II and III of Horizon Europe are focused on the deployment of low-carbon industry applications and breakthrough technologies, including hydrogen. It must involve the research and innovation element. The Clean Hydrogen Partnership is a public-private initiative under Horizon Europe that aims to accelerate the development of a clean hydrogen economy in Europe. It may involve funding opportunities and collaboration with industry stakeholders.

[33] Innovation Fund-European Commission (europa.eu)
[34] Horizon Europe-European Commission (europa.eu)

LIFE programme [35]

LIFE 2021-2027 is the only EU funding programme entirely dedicated to environment, climate and energy. It includes the Clean Energy Transition sub-programme. It is oriented to projects in early phase demonstration, in governance, and in catalyst projects for large-scale deployment solutions.

The Clean Energy Transition Partnership [36]

The Clean Energy Transition Partnership is an initiative co-funded by the European Union that brings together public and private stakeholders in the research and innovation ecosystems in European Member States and Associated Countries. Its aim is to boost and accelerate the energy transition and to support the implementation of the European Strategic Energy Technology Plan (SET Plan). The Clean Energy Transition Partnership has 7 Transition Initiatives (TRIs) focusing on the R&D challenges described in the Strategic Research and Innovation Agenda (SRIA), which also include R&D challenges for clean hydrogen technologies.

State aid[37]

The Commission has been revising the rules on state aid in a number of priority areas, including climate, energy and environment. Currently, three documents compose the EU framework for state aid, which is pivotal for hydrogen, plus a fourth one that refers to the compatibility of state aid with the Important Projects of Common European Interest (IPCEIs):

- Guidelines on State aid for climate, environmental protection and energy (CEEAG);
- General Block Exemption Regulation (GBER);
- the EU Temporary Crisis and Transition Framework for State Aid;
- the Communication on Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest (2021);

The revision of state aid rules will facilitate public support to the development of key industrial sectors and innovative value chains and can give leverage to the deployment of hydrogen and fuel cell technologies and their role in steering the energy transition, via potential increased funding channels and amounts. This is especially the case under the new GBER, where different categories of state aid measures can directly or indirectly support the hydrogen sector in a wide range of activities, operative costs needs may be considered and aid intensities may reach 100% in case of competitive bidding processes.

Important Projects of Common European Interest[38]

Where private initiatives supporting breakthrough innovation and infrastructure fail to materialise

[35] LIFE programme-European Commission (europa.eu)
[36] Clean Energy Transition Partnership (cetpartnership.eu)
[37] State aid-European Commission (europa.eu)
[38] Important Projects of Common European Interest-European Commission (europa.eu)

because of the significant risks such projects entail, EU state aid rules enable EU countries to jointly fill the gap to overcome these market failures with an IPCEI. IPCEIs are ambitious, cross-border, integrated projects, important due to their contribution to EU objectives while limiting potential competition distortions and ensuring positive spill-over effects for the internal market and the Union. The Hy2Tech and Hy2Use IPCEI's were specifically focused on hydrogen technologies for which > 10 billion EUR of state aid has been approved.

02

National hydrogen strategies

Introduction

This chapter provides an overview of the national hydrogen strategies adopted in EU27, UK and EFTA countries. For each strategy, quantitative indicators (i.e. targets or estimates) have been identified. A qualitative summary of the strategy's content is also provided, describing and classifying the main priorities and corresponding measures along the hydrogen value chain. It is important to note that the information is sourced from the European Hydrogen Observatory based on data gathered by Hydrogen Europe until July 2023. Therefore, there may be additional strategies for some countries that are not captured in this report.

Interactive data dashboards on national hydrogen strategies can be accessed on the European Hydrogen Observatory website.

2.1. Overview

European countries have developed national hydrogen strategies to support the transition to a low-carbon economy and achieve their climate targets. Hydrogen is seen as a key component of this transition, as it can be produced from renewable sources and used as a clean energy carrier in various sectors, such as industry, transport and energy. These strategies aim to scale up renewable hydrogen production and utilization while supporting the development of associated infrastructure and technologies, with targets set for hydrogen deployment across sectors and plans in place to foster innovation and create economic opportunities within the hydrogen sector.

In addition, national hydrogen strategies aim to promote international cooperation and coordination, as hydrogen is a global commodity that requires international collaboration to ensure its safe and efficient production, transport, and use. Overall, national hydrogen strategies are an important tool for countries to achieve their climate targets and support the transition to a low-carbon economy, while also promoting innovation and economic growth.

Some European countries, including Germany, France, Netherlands, Portugal, Spain, and Italy, have developed hydrogen roadmaps in addition to their national hydrogen strategies. These roadmaps are an important tool for countries to provide a more detailed plan for the deployment of hydrogen technologies and infrastructure in the country, including specific targets and timelines, to ensure that they are on track to meet their national and international climate targets. However, it is important to note that the current focus of the EHO database is primarily on hydrogen strategies rather than specific roadmaps.

Figure 3 gives an overview of the adoption status of national strategies in European countries, relevant to the deployment of hydrogen technologies and infrastructures. 63% of the European countries (20 out of 32), have already published such strategies, while in 6% of the countries (2 out of 32), national hydrogen strategies are at a draft stage and have not yet been officially adopted. The remaining counties, 31% (10 out of 32), have no official national hydrogen strategy adopted yet.

Figure 4 provides a geographical representation of the current adoption status of national hydrogen strategies across European countries.

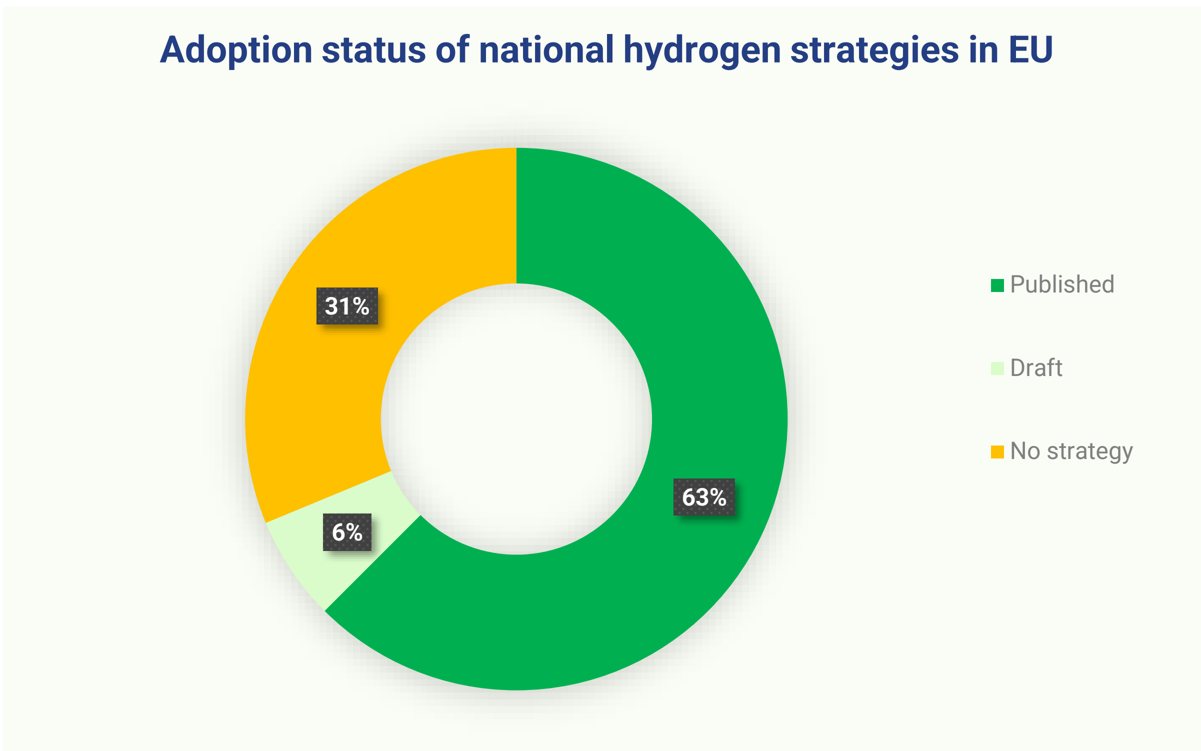

Figure 3. Adoption status of national hydrogen strategies in Europe

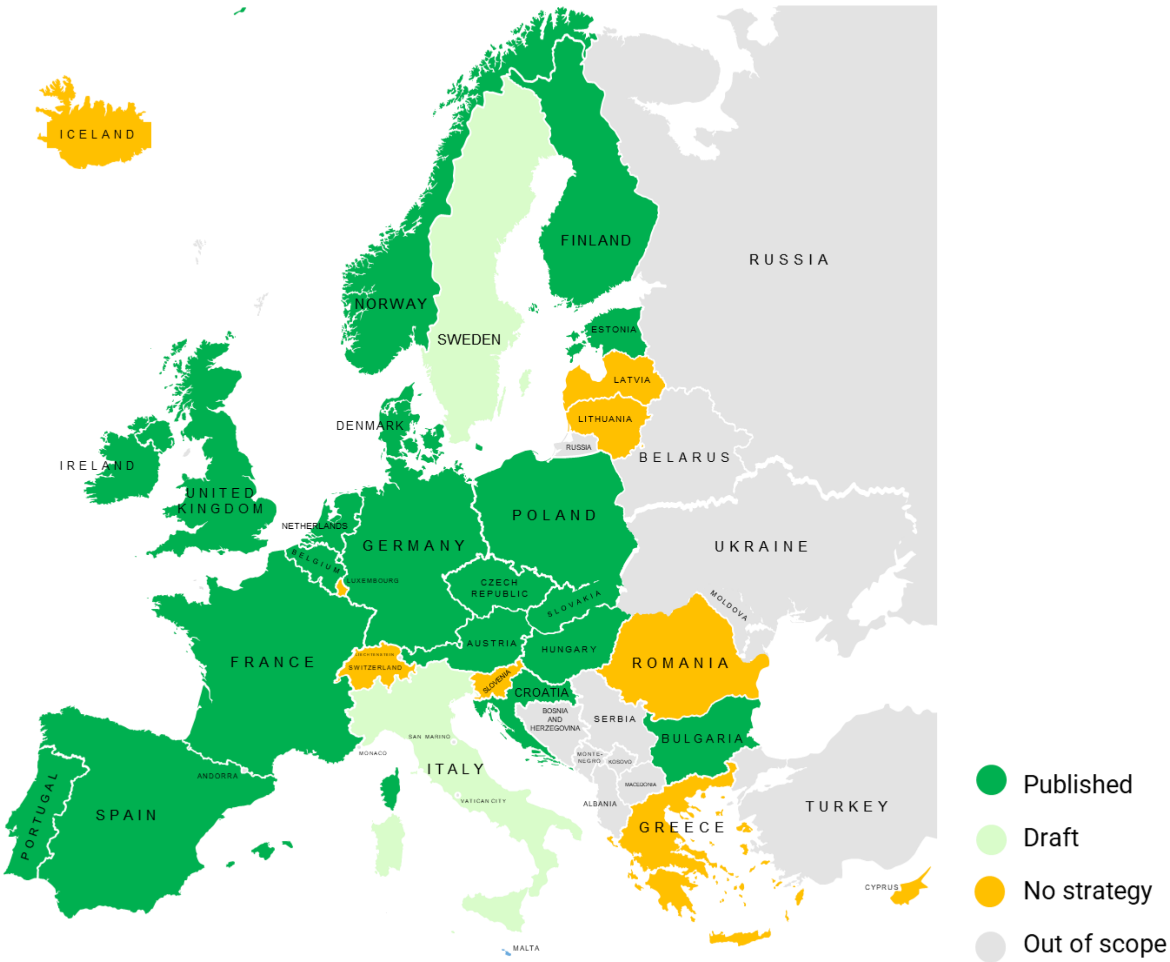

Figure 4. Map of strategies adoption status across European countries

Figure 5 shows which topics are covered by European national strategies, based on the summaries made on the European Hydrogen Observatory. The figure illustrates the distribution and adoption of hydrogen strategies within distinct stages of the value chain by European nations. The analysis of hydrogen strategies reveals a distinct pattern of adoption among European countries. Notably, all strategies cover hydrogen production. In contrast, strategies directed towards the development of hydrogen import and export routes exhibit lower adoption rates, with only 8 countries opting for such initiatives. Most of the strategies (18 out of 20) underscore ambitions aimed at expanding or introducing a hydrogen distribution and storage network, in addition to the application of hydrogen technologies in mobility (also 18 out of 20) and industry (16 out of 20). Conversely, less emphasis is placed on hydrogen use for heating and energy, as well as in manufacturing, with only 8, 10, and 8 countries, respectively, incorporating these aspects into their strategies. A table is also added in the Appendix that categorizes and summarizes the main measures (qualitative representation) within the hydrogen value chain for each European country that has published strategies.

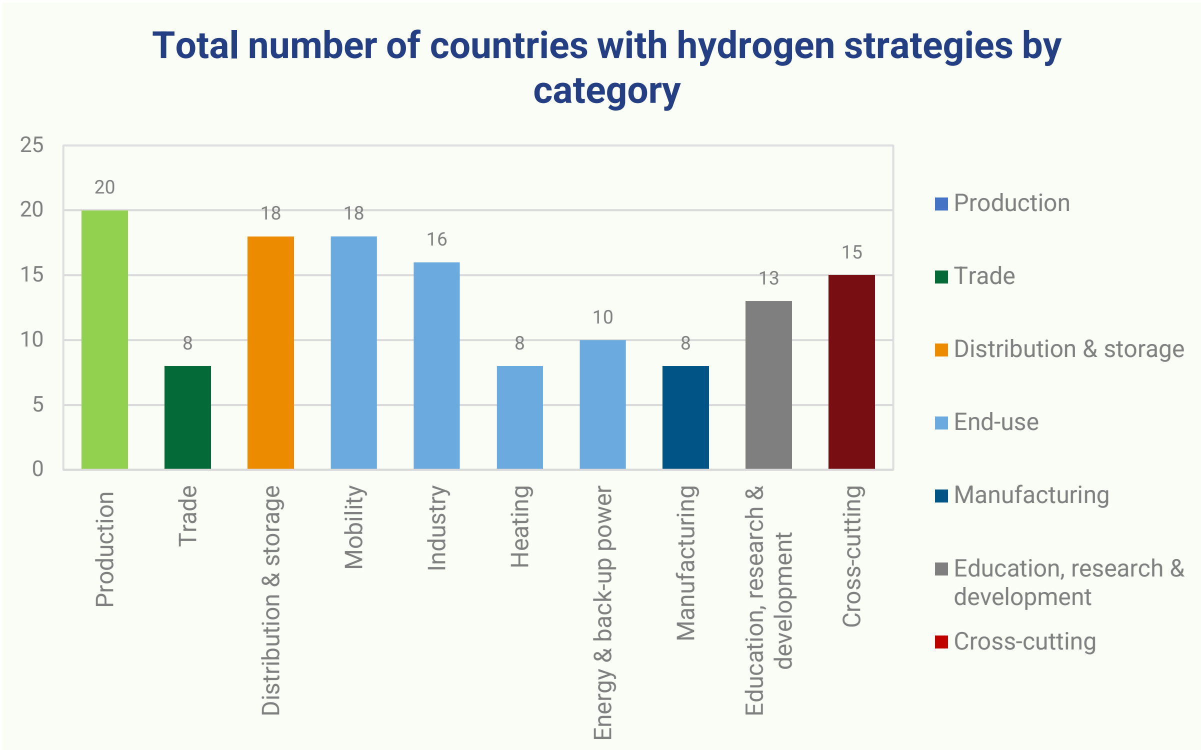

Figure 5. Total number of countries with hydrogen strategies by category

2.2.

Qualitative summary by country

This section provides a qualitative summary for each European national hydrogen strategy. This summary aims to describe and classify the principal measures undertaken along the hydrogen value chain, offering insights into the diverse approaches and key initiatives adopted by each nation.

Austria

The Austrian hydrogen strategy focuses on two key concepts for hydrogen production: renewable hydrogen (water electrolysis with renewable electricity or processes based on biomass of sustainable origin) and climate-neutral hydrogen (produced from methane via reformation with carbon capture, utilization, and storage (CCUS) or pyrolysis, with no greenhouse gas emissions and no nuclear energy used). Referring to gas infrastructure, the priority is the reconversion of existing natural gas pipelines, while hydrogen blending is not seen as a viable option due to the scarcity of renewable hydrogen, although an increase of the current limit of hydrogen in the natural gas grid will be examined. Hydrogen technologies will be applied in mobility for long-range and high-load vehicles, as well as in aviation and maritime applications. In industry, Austria aims to replace fossil-based hydrogen with climate-neutral hydrogen in energy-intensive industries, including the chemical industry, the production of iron and steel and other industrial processes (e.g. cement, and glass industries) where temperature requirements, process management, and other requirements, make direct electrification not viable.

Belgium

The Belgian hydrogen strategy aims to have all hydrogen in the national energy mix of renewable origin by 2050, with a phased approach allowing hydrogen production from steam methane reforming (SMR) and autothermal reforming (ATR) with carbon capture and storage (CCS) and pyrolysis to play a transitional role. Electrolysis capacity will remain limited due to the limited local renewable energy potential. Belgium will position itself as an import and transit hub for renewable molecules, with focus on three key import routes: north sea route (pipeline), southern route (pipeline), and shipping route. The development of a hydrogen transport network is thus a key aspect of the strategy, taking advantage of existing natural gas pipelines and aiming for interconnections with neighbouring countries. Hydrogen is expected to have applications in aviation, inland navigation, shipping, and high-temperature heating in industry (chemical, steel industries). The strategy includes federal instruments to support R&D for hydrogen production, transport, and storage.

Bulgaria

Bulgaria's hydrogen strategy includes financing pilot installations for renewable hydrogen production, developing hydrogen valleys, and evaluating RFNBO production zones. Measures for transmission and distribution involve analysing hydrogen export potential, identifying storage sites, and developing the regulatory framework for grid access. Bulgaria aims to develop financial mechanisms for hydrogen mobility, create a deployment plan for the first 20 hydrogen refuelling stations, update the regulatory regime on hydrogen transport, develop a system of quotas for renewable hydrogen in industry, and adapt electricity market rules for Power-to-X (PtX) integration. The education strategy includes identifying needed professions, developing standards, and supporting higher education. Research and development will focus on hydrogen integration in energy systems, storage, transport, mobility, industry, and synthetic fuels.

Croatia

The Croatian hydrogen strategy aims to link hydrogen production to mobility and industry until 2026, guarantee sufficient renewable hydrogen for industrial processes until 2030, and ensure production meets national needs after 2030 and 2040 as hydrogen demand increases. The development of hydrogen infrastructure will occur in two phases: in the first phase, production will take place near demand sites with limited infrastructure needs, while in the second phase, infrastructure will transport hydrogen for various applications including industrial, mobility, heating, and electricity system balancing. The hydrogen strategy focusses on hydrogen use in mobility including market development starting through public procurement and the development of a refuelling network. The focus in industry is on replacing fossil fuels with renewable hydrogen and using hydrogen for high-temperature thermal energy. Hydrogen technologies are also envisaged for back-up power systems for both military and civil uses. Research and development will increase efficiency and develop new methods for hydrogen production. Education will integrate new programs for hydrogen technologies and promote hydrogen knowledge to the general public.

Czech Republic

The hydrogen strategy in Czech Republic focuses on different hydrogen productions methods including renewable hydrogen, hydrogen from natural gas with carbon capture, electrolytic hydrogen from nuclear energy and pyrolysis. As the country will continue to be a net importer of hydrogen, a gradual transition from natural gas pipelines to hydrogen is foreseen, but construction and repurposing of hydrogen pipelines will begin only after 2031. Mobility is the main end-use envisaged in the first phases of the strategy due to the cost-parity and technological readiness levels. For industry, the main barrier identified for replacement of grey hydrogen with renewable is price parity. It is expected that after 2026, operational verification of hydrogen use in industry could begin and the transition to commercial hydrogen use in industry will begin only after 2031. It is not expected that production and transport of large quantities of low-carbon hydrogen will take place before 2040. Areas with the greatest potential for research and development identified include hydrogen-powered vehicles specifically buses, trucks and cars, and hydrogen production equipment, focusing on electrolysis and pyrolysis.

Denmark

The Danish hydrogen strategy puts forward a target of increasing electrolysis capacity. A key emphasis point is that hydrogen must be of renewable electricity origin following EU methodology. The strategy puts focus on using PtX technology, (converts electricity into other forms of energy, such as hydrogen, synthetic fuels, or chemicals), for difficult-to-abate sectors such as shipping, aviation, agriculture, parts of industry and parts of heavy-road transport. The government will initiate dialogue with neighbouring countries on hydrogen infrastructure development and present an energy and supply package with a proposal for regulating ownership, financing, and operation of hydrogen infrastructure.

Estonia

The Estonian hydrogen strategy includes implementing EU-funded projects, defining legal frameworks, increasing renewable energy capacity, and sustainable sourcing of water and CO_2. The strategy aims to set the legislative framework for hydrogen infrastructure and transport, with cylinders on trucks and pipelines as viable options. Mobility focuses on establishing refuelling stations and analysing fuel-cell ferries. For back-up power, they are evaluating the use of locally produced hydrogen for crisis reserves. Manufacturing hydrogen technologies is supported by the national budget and recovery plan. The strategy focuses on training specialists and engineers and promoting regional cooperation for hydrogen production and manufacturing.

Finland

The Finnish hydrogen strategy emphasizes the importance of all emission-free forms of hydrogen production in a technology-neutral way. Additionally, a regulatory framework for CCS/CCU will be promoted at the EU level. The natural gas transmission system operator (TSO) in Finland has already been tasked by the state to promote the development of the national hydrogen network, international infrastructure cooperation and the hydrogen market in the Baltic Sea. E-fuels will be included in the fuel distribution obligation at the beginning of 2023. By 2030 the aim is to have a minimum 3% share of e-fuels in all fuels supplied with the possibility to increase the target in line with the Renewable Energy Directive. The use of hydrogen is being piloted for transport, in particular for heavy road and sea transport, as well as in offroad machines. The Finnish government agency will support R&D&I activities in hydrogen technology. The development and deployment of carbon capture, storage and utilization (CCS/CCU) technologies and solutions will be accelerated, including by funding pilot and demonstration projects. Different risk and cost sharing instruments, such as the carbon contracts for difference (CCfD) will be used to develop a low-carbon industry, while international cooperation, networks and joint projects will be promoted.

France

France is a leading country in nuclear energy production, with over 70% of its electricity generated from nuclear power plants. The country aims to produce 10% of its hydrogen from renewable sources by 2023 and is exploring the use of nuclear energy for hydrogen production. Moreover, the French strategy targets the installation of enough electrolysers to make a significant contribution to the decarbonisation of the economy. The hydrogen strategy prioritizes heavy-duty mobility for captive fleets covering long distances in just-in-time operations, such as commercial vehicles, buses, and trains in non-electrified areas. The strategy aims to support the production of reliable vehicles, high-performance equipment, and skills development for vehicle fleet production and maintenance. In relation to industry, it aims to replace fossil fuel-based production processes of hydrogen for refining, chemicals, electronics, and food processing. Proposed tools include support for hydrogen greening projects in the refining sector, a guarantee of origin mechanism, and a support scheme for investment and operating costs. The strategy proposes support for pooling demand in the industry and mobility sectors, through territorial hydrogen hubs. The government will also support pedagogical training on engineering and new curricula for schools, higher education, and companies to remain a leader in the field.

Germany

The German hydrogen strategy aims to increase electrolyser capacity through land and offshore electrolysis. System coupling and system-friendly electrolysis will be emphasized to limit the need for grid expansion. The strategy foresees importing most of the national demand, with ship-based ammonia as the primary import until 2030. Green methane, synthetic methanol, LOHC, and liquid hydrogen may play a role in the medium- to long-term. After 2030, pipeline-based green hydrogen will be imported from Europe and neighbouring regions, with a focus on minimizing risk through diversification. An expansion of the pipelines network is targeted by 2030, interconnection with neighbouring countries and ensuring sufficient supply without emissions or bottlenecks. The hydrogen strategy aims to prioritize aviation, shipping, and heavy-duty mobility, replace fossil fuels in high heat applications in the industry sector, and ensure system compatibility in the energy sector. Hydrogen is not expected to play a significant role in space heating, but waste heat recovery from electrolysers should be considered. The government will continue using funding programs for infrastructure, research and development, and international standards for transport applications of hydrogen. Germany aims to become a leader in hydrogen technology supply by 2030, with national companies covering significant parts of the value chain.

Hungary

The Hungarian hydrogen strategy focuses on low-carbon production capacities for industry and mobility, with a target of increasing electrolysis capacity by 2030. through licensing and international cooperation, with a focus on supporting SMEs and accessing external markets. Domestic automotive manufacturers will also cooperate in the field of hydrogen technologies. Green hydrogen will be produced using solar PV, nuclear energy, and grid electricity, in addition to promoting CCS technologies by establishing a regulatory framework. There is a focus on using natural gas infrastructure for storage, starting with a pilot project, but with the target of hydrogen blending. The strategy promotes heavy-duty vehicles in the mobility sector, low-carbon hydrogen consumption in the petrochemical and chemical industries and meeting industrial heat demand with hydrogen in the cement, iron, and steel industries. The energy sector will pilot co-firing natural gas with hydrogen and introduce hydrogen applications in the electricity market for flexibility services. Cross-cutting measures include the establishment of a National Hydrogen Technology Laboratory and dissemination of information among the general public to increase public acceptance of hydrogen technologies.

Ireland

The Irish hydrogen strategy includes hydrogen production from grid-connected electrolysers during periods of high wind and curtailment. Low-carbon hydrogen production is not expected to have a major role. The main obstacle is the development of a new hydrogen industry. Hydrogen transport will first take place via compressed tanks, with infrastructure development in clusters and an overall plan to transit from natural gas to hydrogen over time. Infrastructure development will be integrated and consider energy systems, networks, storage, and ports. Hydrogen use in mobility focuses on freight, HDV, aviation, and maritime transport. The national policy framework on alternative fuels infrastructure will be updated to include hydrogen considerations. Hydrogen will have a role in medium and high-grade heat applications in industry, and in enabling flexible power generation in the energy sector. Further assessments will be carried out to understand the actual quantities of hydrogen needed in a net-zero integrated energy system. The development of hydrogen clusters will be promoted. Specific attention is paid to safety issues and therefore a safety roadmap will be developed. On standardisation and certification, the establishment of a certification scheme for hydrogen is foreseen, with the integration of electricity guarantees of origin to avoid double counting.

Luxembourg

The hydrogen strategy in Luxembourg targets hydrogen demand by 2050, with limited green hydrogen production and most hydrogen being imported or produced locally with imported renewable electricity, and participation in cross-border mechanisms for renewable hydrogen production. Instruments to guide economic actors, such as quota systems for SAF in aviation, cross-border tenders for hydrogen production support, and obligations for development of refuelling infrastructure for heavy-duty vehicles will be set. There is a focus on participation in European initiatives and development of European rules for hydrogen infrastructure, with priority given to granting projects of common interest status to projects exclusively dedicated to hydrogen and derivatives. The strategy includes measures on decarbonizing mobility with renewable fuels, substitution of grey hydrogen with green in industry, and using hydrogen as an alternative to decarbonize heat networks and in high-efficiency cogeneration plants. Several research priorities in the strategy are special materials used for photoelectrolysis of water, fuel cells, hydrogen storage and optimal use of rare resources. The strategy envisions active participation in the definition of rules at the EU level, focusing on certification of renewable hydrogen.

Netherlands

The Dutch hydrogen strategy aims to bridge the gap between grey and green hydrogen prices, with support through DEI+ and SDE++ programs, applied research, and innovative pilot projects, and analysis of linking offshore wind energy production with hydrogen production. Focus is given on developing hydrogen infrastructure, repurposing the gas grid, the Netherlands' role in the north western hydrogen market, blending in the natural gas system, and examining market regulation and infrastructure for security of supply and low-social costs. The strategy includes a national rollout of hydrogen mobility, subsidy schemes for zero emissions transport, encouragement of refuelling stations, and targets for Sustainable Aviation Fuel (SAF) in aviation. The strategy also aims to set prerequisites for safe application of hydrogen in the built environment. Moreover, coordination with other

European countries on guarantees of origin, direct contact with the European Commission, participation in regional forums, and guidance on precise locations for electrolysers in consultation with industrial clusters is part of the strategy.

Norway

The Norwegian hydrogen strategy supports hydrogen production mainly through development and demonstration projects, researching more efficient ways to produce hydrogen. On the topic of hydrogen exports, both pipeline and ship exports to Europe are considered. An alternative to be investigated is the export of natural gas towards Europe, with hydrogen production on site with CCS and import of CO_2. The strategy includes support for equal rules in FCEV and BEV mobility, public procurement, zero emissions solutions in shipping, and funding for hydrogen technology development in industry. Research activities will focus on achieving low-emissions society, but specifically more efficient electrolysis plants are highlighted.

Poland

The Polish hydrogen strategy considers integrating hydrogen production in locations closer to consumption and available energy sources, while also setting the legal regime to produce hydrogen from nuclear energy. The strategy prioritizes safety in transmission, distribution, and storage, adapting energy legislation, conducting a feasibility study for a "Hydrogen Highway," and foresees blending hydrogen in the natural gas system. For mobility, priority is given to construction of refuelling stations in densely populated areas for buses and rail transport, as well as on TEN-T corridors. For the industry, the focus is on the use of low-carbon hydrogen in the petrochemical, chemical and fertiliser industries, through industrial hydrogen valleys. In the heating and power sectors, there is a focus on research and development mainly in co-firing of hydrogen in gas turbines, co-generation and poly-generation systems, and hydrogen storage. The strategy intends to foster the development of manufacturing capacities for the entire hydrogen value-chain. Research, development and commissioning pilot projects will be carried out in relation to co-generation and poly-generation plants where hydrogen is the primary fuel, as well as low-carbon hydrogen production technologies. To implement the strategy, the ministry of energy will conclude a polish hydrogen agreement with industrial interested parties.

Portugal

The Portuguese hydrogen strategy includes legislative changes to allow licensing of hydrogen production plants, promotion of hydrogen production in waste-water treatment plants, and development of a support mechanism for sale of renewable hydrogen. In subsequent stages of development of the sector, Portugal can become an exporter of green energy products through the Sines port or through pipelines connecting the Iberian Peninsula with the rest of Europe. Hydrogen is a way to increase the value of existing pipelines and reduce their amortisation. Consequently, a legal framework for hydrogen blending will be developed. The focus for hydrogen use in mobility is mainly on buses, heavy-duty vehicles, captive fleets, trains, and maritime transport. In industry, it focuses on cement, glass, ceramics, refining, and chemicals, in addition to power-to-gas technologies for energy. The strategy includes ambitions for legislative changes, support for refuelling stations, production of synthetic fuels, replacement of grey with green hydrogen, development of quality and safety standards, and support for hydrogen pilot projects. Cross-cutting measures focus on international cooperation multilateral and bilateral cooperation, development of guarantees of origin for hydrogen and the promotion of sector-coupling.

Slovakia

The Slovakian hydrogen strategy considers all low-carbon methods to produce hydrogen, including electrolysers using electricity from nuclear power plants, high temperature pyrolysis and gasification of non-recyclable waste. The strategy includes a technical analysis on repurposing natural gas infrastructure, establishment of safety regulations, and expansion and connection of the national grid with neighbouring countries. The focus for hydrogen use in mobility is mainly on public transportation, freight, planes, boats, and machinery in various sectors. For end-use in industry, the strategy targets low-carbon hydrogen in the chemical, petrochemical, and steel industries. A network of hydrogen refuelling stations will be developed, and a study on replacing natural gas with hydrogen will be carried out. The development and production of materials for transport and storage of hydrogen is considered. Emphasis is placed on harmonisation of standards and regulatory measures, specifically on the low-carbon hydrogen value-chain and guarantees of origin. International cooperation will be also fostered.

Spain

The Spanish hydrogen strategy supports the production of renewable hydrogen by establishing a regulatory framework for Power-to-X (PtX) technologies. For infrastructure, the regulatory requirements for hydrogen blending and storage will be revised. Evaluations will be carried for the need to modify end-use equipment both for industrial users and domestic ones. In mobility, there will be hydrogen-specific legislation for green hydrogen production and refuelling stations, plans for vehicle purchase and infrastructure deployment, a study on FCEV locomotives, and measures for hydrogen technologies and refuelling stations in ports. In industry, there will be financial support for the transition to renewable hydrogen. For energy, there will be a change in the regulatory framework to allow PtX facilities in the energy market and promotion of green hydrogen in generation and co-generation plants. Research and development will be supported across the entire value-chain for hydrogen, but focus will be given on hydrogen use in cogeneration, recycling of components, and hydrogen turbines. An analysis will be carried on indirect taxation impact on renewable hydrogen. On certification, the strategy foresees participation in international standardisation bodies and development of a guarantee of origin system within the EU.

United Kingdom

United Kingdom's national hydrogen strategy targets to increase low-carbon hydrogen production, with at least half coming from electrolysers. The government is exploring opportunities to export hydrogen from UK to Europe in its long-term vision, while guaranteeing domestic supply. There are ongoing discussions on hydrogen blending. In mobility, there is updated guidance on flexibility of RFNBOs, the launch of the second phase of tees valley hydrogen transport hub, and support for clean maritime transport and road freight transport demonstration. In industry, there is support for hydrogen-ready industrial boilers, low-emissions industrial products, and CHP decarbonization pathways. For energy, there is an assessment of hydrogen use in power plants, alignment of capacity mechanisms, consultation on decarbonization readiness requirements and research on long-duration electricity storage in the energy system. For heat, there is consultation on improving boiler standards, introducing hydrogen heating in communities, and researching its use for heating. Our strategy involves adapting regulations, engaging investors, setting ambitious goals, establishing a hydrogen certification scheme by 2025, and international collaboration.

2.3.

Quantitative targets

Several European countries have incorporated quantitative indicators within their national strategies, outlining targets and estimates across the hydrogen value chain. This deliberate approach reflects a commitment to providing clear and measurable goals within their hydrogen strategies.

These quantifiable indicators serve as robust tools for assessing the ambitions of each country's hydrogen strategy. By setting specific targets these nations are advancing their commitment to the development and integration of hydrogen within their energy landscapes.

The following sections summarize, the quantitative indicators that were set forward in the national hydrogen strategies of European countries according to the different steps of the value chain.

2.3.1.
Production and trade

One of the key areas of focus for the deployment of hydrogen, is hydrogen production, as this is a critical step in the development of a sustainable hydrogen economy. This section presents the main targets that have been set by various countries for hydrogen production.

One of the strategies employed to enhance domestic renewable hydrogen production involves efforts to increase electrolyser capacity. Figure 6 illustrates the 2030 targets for electrolyser capacity, established by various European countries.

Germany emerges with the highest goal, aiming to achieve an electrolyser capacity of 10 GW by 2030. Following behind, is France, with a target of 6.5 GW of electrolyser capacity by 2030, while Denmark and the United Kingdom aim to increase their capacity to approx. 5 GW by 2030. The targets of the remaining countries fall below 5 GW of electrolyser capacity.

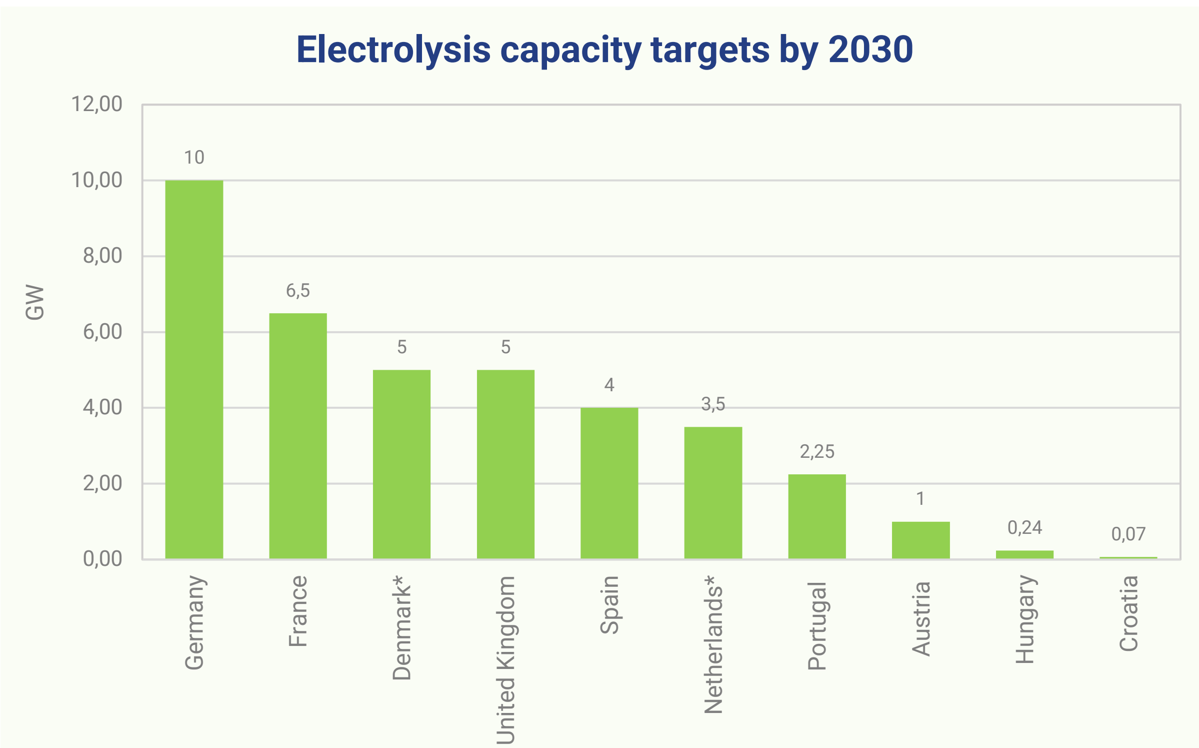

*Figure 6. Targets on electrolysis capacity set by European countries by 2030. *Average values were used for Denmark and the Netherlands.*

Not all countries have set targets for the year 2030. Belgium, for example, only has a target for 2026, aiming to have 0.15 GW installed. Some other European countries have committed to scaling up both renewable and low-carbon hydrogen production as part of their hydrogen production targets. For example, the Czech Republic aims to produce 101 kt/year of low-carbon hydrogen by 2050, while Hungary targets 16 kt/year and 20 kt/year of renewable and low-carbon hydrogen production, respectively. Estonia expects to increase the renewable hydrogen production to 2-40 kt/year by 2030. Additionally, countries such as the United Kingdom aim to increase low-carbon hydrogen production capacity, with a target of 10 GW, at least half of which will be electrolytic, while Poland has set a target of 2 GW of low-carbon hydrogen production capacity, with a focus on integrating production closer to consumption and available energy sources.

The trade of hydrogen is interconnected with production and reflects a combination of economic, environmental, and strategic considerations. The nature of hydrogen trade allows European countries to leverage their strengths, address domestic shortages, and contribute to a more sustainable and diversified hydrogen economy. As an example, Belgium aims to import 20 TWh of hydrogen and its derivatives by 2030, and 200-350 TWh by 2050, partially intended for transit (mainly to Germany). Hungary is another example, with ambitions to ensure that all new liquefied natural gas (LNG) terminals are equipped to handle hydrogen or its derivatives.

2.3.2. Transmission

Currently, hydrogen use, mainly as a feedstock, is confined to local industrial clusters, but it is envisaged that it will also become a main energy vector transporting energy over longer distances across Europe and storing it over longer periods of time. Hydrogen, as an energy carrier, could be transported in pipelines across Europe either by blending hydrogen with natural gas and transporting the resulting mixture using the current gas network or transporting hydrogen as such in a dedicated separate network, part of which might be provided by refitted existing infrastructure.

It is clear that the blending strategy, while already contributing to the reduction of carbon dioxide emissions, can only have a transitional role, since full decarbonisation of the EU economy requires a much greater penetration of hydrogen in the EU energy mix than what could be accommodated through blending. The ambitions of Germany in their national hydrogen strategy is to establish a hydrogen network spanning approximately 1,800 km by 2030. This network will be constructed either through new infrastructure or by repurposing existing networks to facilitate the transportation of hydrogen.

Blending of minor shares of hydrogen into natural gas does not create particular technical problems in the transportation and usage of the resulting mixture. At present, European countries impose different limits on hydrogen blending in natural gas networks. Figure 7 gives an overview on the targets set by European countries on limits on hydrogen blending in natural gas networks. In

Portugal, a legal framework for hydrogen blending will be developed, setting a target of 10 - 15% hydrogen injection in natural gas grid. Regarding Austria, hydrogen blending is not seen as a viable option, considering the scarcity of renewable hydrogen, although an increase of the current limit of 10% of hydrogen in the natural gas grid will be examined. In Poland, the strategy also foresees 10% blending of hydrogen in the natural gas system. In the case of Hungary, based on the lack of hydrogen storage potential, the strategy focuses on the use of natural gas infrastructure for storage, starting with a pilot project, but with the target of minimum of 2% of blending.

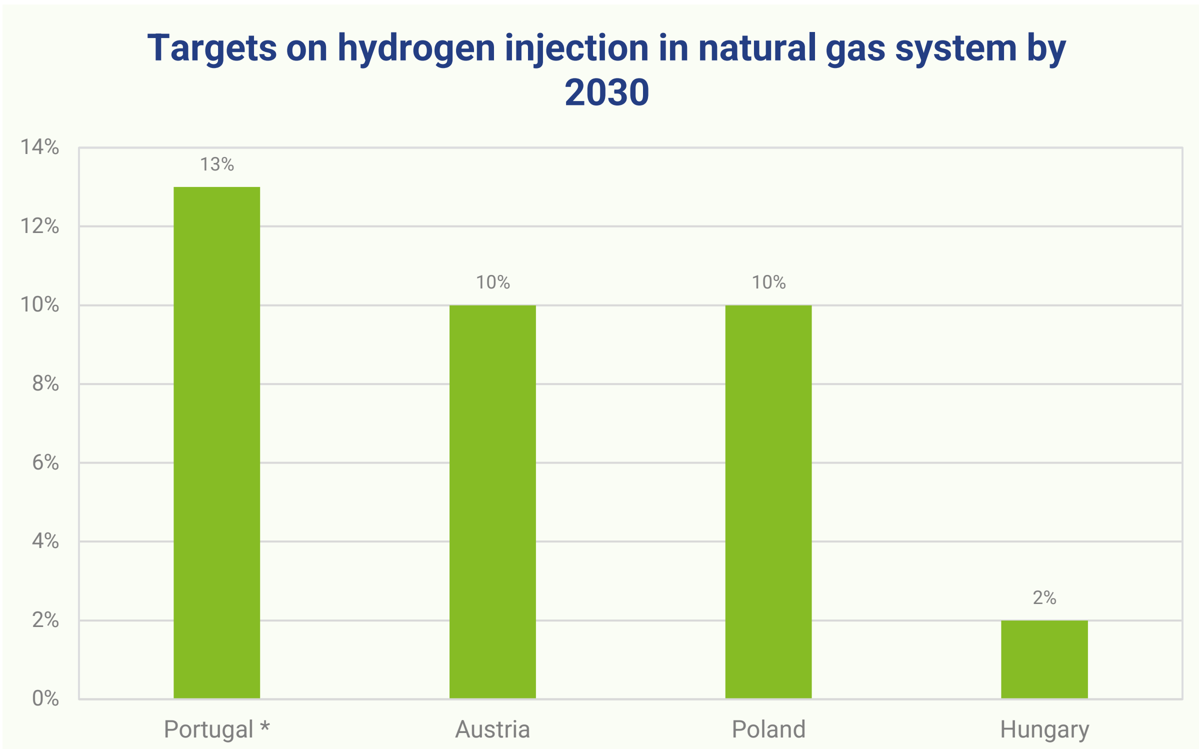

*Figure 7. Targets on hydrogen injection limit (%) in the natural gas network by 2030 set by European countries. *Average value was used for Portugal.*

2.3.3.
End-use

Demand

Table 3 gives an overview of the expected total hydrogen demand in the European countries by 2030, 2040 and 2050. In Belgium the use of renewable hydrogen as a feedstock and for high-temperature heating in industry is a priority (chemical, steel industries) with demand for renewable molecules expected to rise to 125-200 TWh by 2050.

A total hydrogen demand of 95 to 130 TWh is forecasted in Germany for the year 2030. This includes the projected demand for hydrogen derivatives such as ammonia, methanol, or synthetic fuels.

The demand for gaseous energy carriers (methane and hydrogen) in relevant sectors in Austria in the year 2040 is estimated to range between 89 and 138 TWh, according to calculations. The range is derived from a scenario analysis, where on the one hand, assuming application-specific efficiency maximization and extensive electrification yields lower the demand value of 89 TWh (energy efficiency). On the other hand, assuming a comparatively higher but less efficient utilization of existing technological infrastructure and processes results in the upper demand value of 138 TWh.

Table 3. Expected total hydrogen demand in European countries. by 2030, 2040 and 2050. [39][40]

Country	Target year	Target value	
		TWh	kton
Austria	2040	89-138	2670-4140
Belgium	2050	125-200	3750-6001
Croatia	2030	0.16	4.8
Czech Republic	2030	3.2	97
Germany	2030	95-130	2850-3900
Ireland	2050	19.8-74.6	594-2238
Luxembourg	2050	4-10	120-300
Portugal	2030	3.3	99
Slovakia	2030	6.7	200
	2050	13.3-20	400-600

The total estimated hydrogen demand in Ireland for 2050 is 19.8-74.6 TWh, distributed across various sectors as follows: 3.6-13.3 TWh in flexible power generation or integrated energy parks for large energy users, 0-1.5 TWh in commercial and residential, 0-14.9 TWh in industry and processing, 1-9.3 TWh in road and rail transport, 13-26 TWh in aviation, 2.2-2.6 TWh in maritime and 0-7 TWh in other potential non-energy uses.

In Luxembourg the goal of achieving a hydrogen demand of 4-10 TWh by 2050 (1-4 TWh in industry, 2-4 TWh in road, air, water, rail transport, and 1-2 TWh in integrated energy system) would require doubling of the national electricity consumption, therefore renewable hydrogen production will be limited, with most of the hydrogen being imported or produced locally with imported renewable electricity.

Based on the existing utilization of hydrogen, it can be assumed that in Slovakia, the annual

[39] Conversion factor: kton=(TWh*1000)/33.33

[40] For Croatia and Portugal, the total demand was estimated, using data from Eurostat

consumption of hydrogen will reach 200 kilotons by 2030. Intensive use of hydrogen anticipates a total consumption increase by 2050 to a range of 400 to 600 kilotons.

In Portugal, the projected total demand for 2030 is estimated to be 3.3 TWh, with 2-5% allocated in the industry, 3-5% in road transport, and 3-5% in domestic maritime transport. Meanwhile, in the Czech Republic, the estimated total demand for the same period is 3.2 TWh.

Mobility

Hydrogen may be a realistic alternative to gasoline, accelerating the transition to clean modes of transportation. The key to making this shift is the widespread availability of hydrogen refuelling stations (HRS).

Figure 8 gives an overview on the targets set by European countries on the number of hydrogen refuelling stations by 2025 and 2030.

Netherlands has set a target of 50 refuelling stations by 2025, while in Poland the strategy on mobility includes the construction of 25 refuelling stations by 2025 in densely populated areas for buses and rail transport, as well as on TEN-T corridors. Specific actions include the development of hydrogen refuelling and bunkering infrastructure, replacement of diesel locomotives with hydrogen-powered ones and change of applicable legislation to enable construction of HRS and use of hydrogen in transport.

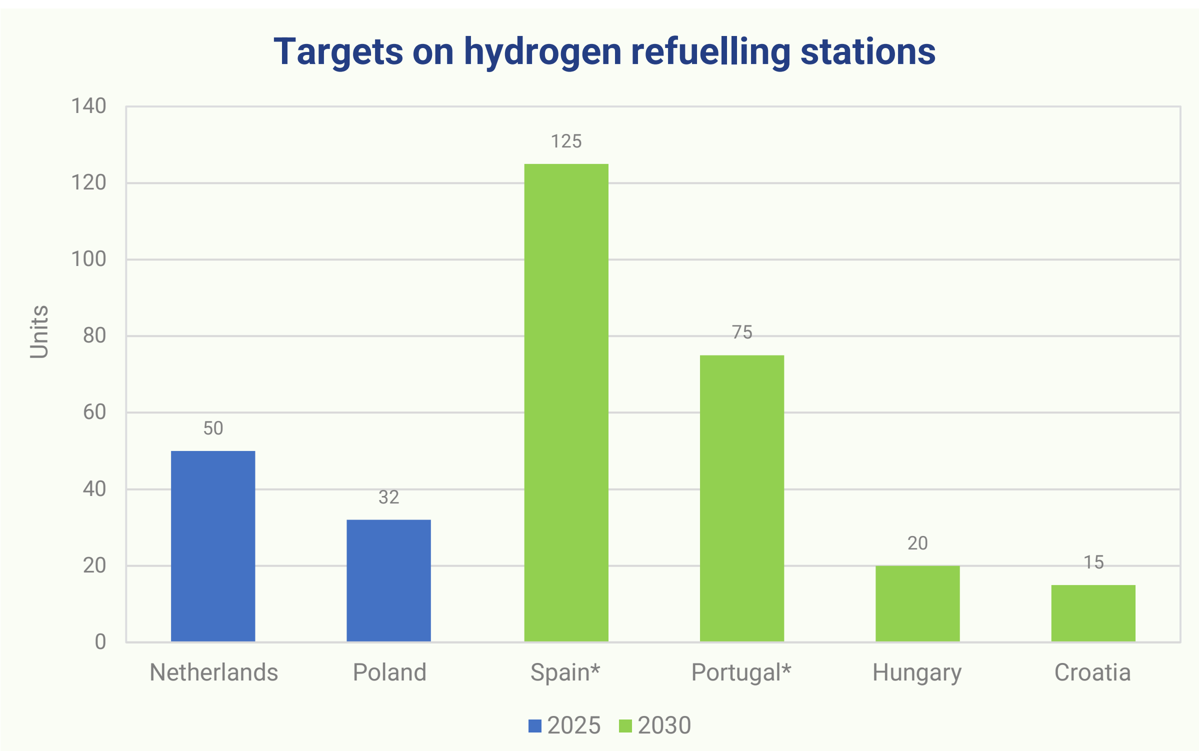

*Figure 8. Targets on the number of hydrogen refuelling stations set by European countries. * Average value was used for Portugal and Spain*

Spain has set the highest goals for 2050, aiming a network of at least 100-150 publicly accessible hydrogen stations. These should be located in easily accessible places, distributed throughout the territory with a maximum distance of 250 km between each hydrogen station and the nearest one. Following closely behind is Portugal with the objective to create 50 to 100 hydrogen refuelling stations.

In contrast, Hungary and Croatia has set lower targets, with the establishment of at least 20 hydrogen refuelling stations (with two refuelling points per refuelling station) and a network of 10 refuelling stations linked to large city centres, respectively. Figure 9 shows the targets set by European countries on the deployment of different types of fuel cell electric vehicles by 2025 and 2030.

In 2025, the Netherlands has established the highest goals in the deployment of fuel cell electric vehicles (FCEVs), targeting 15,000 passenger cars and 3,000 heavy-duty vehicles (HDV) and light-duty vehicles (LDV). Similarly, Portugal aims to deploy 400-500 FCEV passenger cars and 20-50 HDV and LDV. Conversely, Poland's priority lies in increasing the number of FCEV buses to 100-250.

Looking towards the long term, many countries have outlined more comprehensive targets for the deployment of FCEVs by 2030. Specifically, there is a notable emphasis on passenger cars. The Czech Republic aspires to reach 45,000 FCEV passenger cars, the Netherlands aims to double its passenger car deployment compared to 2025, targeting 30,000, and Portugal has a more conservative goal of 750-1,000.

Moving on to HDV and LDV, the Czech Republic, Spain, and Portugal aim to deploy 4,000, 5,000-7,000, and 250-400 FCEVs, respectively. Regarding buses, the Czech Republic and Poland have set their sights on reaching 900 and 800-1,000 FCEV buses, respectively. In contrast, Hungary has taken a holistic approach, setting a target for the total number of FCEVs across all vehicle types, with a goal of reaching 4,800 units.

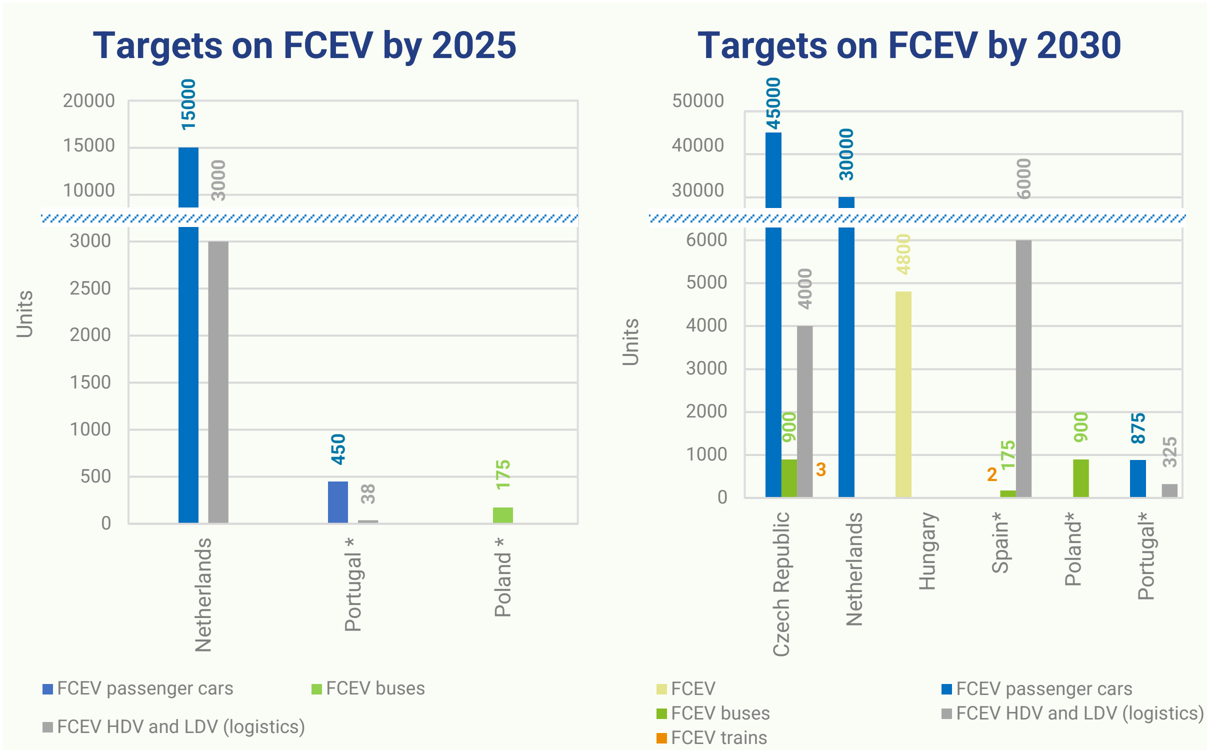

*Figure 9. Targets on the number of hydrogen fuel cell electric vehicles by 2025 and 2030 set by European countries. * Average value was used for Poland, Portugal and Spain*

Industry

Recognized as a cornerstone of economic activity, industries hold significant potential to drive the transition towards sustainable energy practices. As major consumers of energy, industries have the capacity to both benefit from and contribute to the widespread adoption of hydrogen technologies. This section delves into targets set by European countries on the replacement of fossil-based gases with renewable hydrogen in their industries.

In several European countries, there is a concerted effort for the transition from fossil-based to renewable hydrogen within the industrial sector, with the establishment of specific targets in place. Austria aims to replace fossil-based hydrogen with climate neutral hydrogen in energy intensive industries by 80 % until 2030.

Regarding Czech Republic, by 2030, only 5% of the grey hydrogen is expected to be replaced in chemical industry by low carbon gases. The same percentage applies for the replacement of natural gas by low carbon gases in chemical industry.

Portugal promotes the hydrogen production near consumption, 75-100% replacement of grey ammonia with green ammonia produced from renewable hydrogen by 2030 and the development of quality and safety standards for hydrogen equipment are priorities in industry.

Additionally, support for hydrogen pilot projects in industry will be developed.

Spain targets a minimum contribution of renewable hydrogen of 25% of the total hydrogen consumed in 2030. It is expected to contribute in all industries that consume hydrogen both as a feedstock and as an energy source, such as refineries and the chemical industry.

2.3.4.
Education, research and development

In the European context, the majority of countries have incorporated hydrogen into their strategic initiatives concerning education and research for the advancement of hydrogen technologies. These strategies emphasize the training of specialists, experts, and engineers to facilitate the development of hydrogen-related technologies. Additionally, they highlight ongoing research and development (R&D) initiatives undertaken by universities and companies, as well as funding and program activities in this domain.

Croatia shows a good example, having set quantitative targets for research and development in hydrogen technologies. The country aims to attain five patents related to the hydrogen economy by the year 2030 and 50 patents by 2050. This commitment reflects Croatia's dedication to measurable outcomes in the pivotal field of hydrogen technology.

03

National Policies and legislation

This chapter provides an overview of the main national policies and legislation relevant to the hydrogen sector in EU Member States, EFTA countries and the UK, excluding Liechtenstein.

The data is collected by means of a comprehensive questionnaire completed by country specialists. The questionnaire focuses on the policy framework, measures, incentives and targets in place that have an impact on the development of the respective national hydrogen markets.

The information reflects the situation as of August 2023.

Interactive data dashboards on national policies and legislation can be accessed on the European Hydrogen Observatory website.

3.1. Overview

Figure 10 gives an overview of the total number of European countries that have adopted policies and legislation relevant to the hydrogen sector in six distinct topics:

- Production
- Transmission, distribution and storage
- End-uses for
  - Mobility
  - Stationary power and heating
  - Industrial use (including as a feedstock)
- Equipment manufacturing.

On a total of 28 countries, it is evident, that a significant proportion of European countries have implemented policies and legislation related to various aspects of hydrogen production. More specifically, 17 country specialists (61%) have indicated that their country has adopted a policy or legislation offering support for Capital Expenditure (CAPEX) in the development of renewable or low-carbon hydrogen production plants. 7 countries (25%) have implemented policies and legislation providing Operational Expenditure (OPEX) support and official permitting guidelines specifically tailored to hydrogen production projects, while 6 countries (21%) have established policies and legislation designating a Single Point of Contact for hydrogen project developers, streamlining the communication and coordination process.

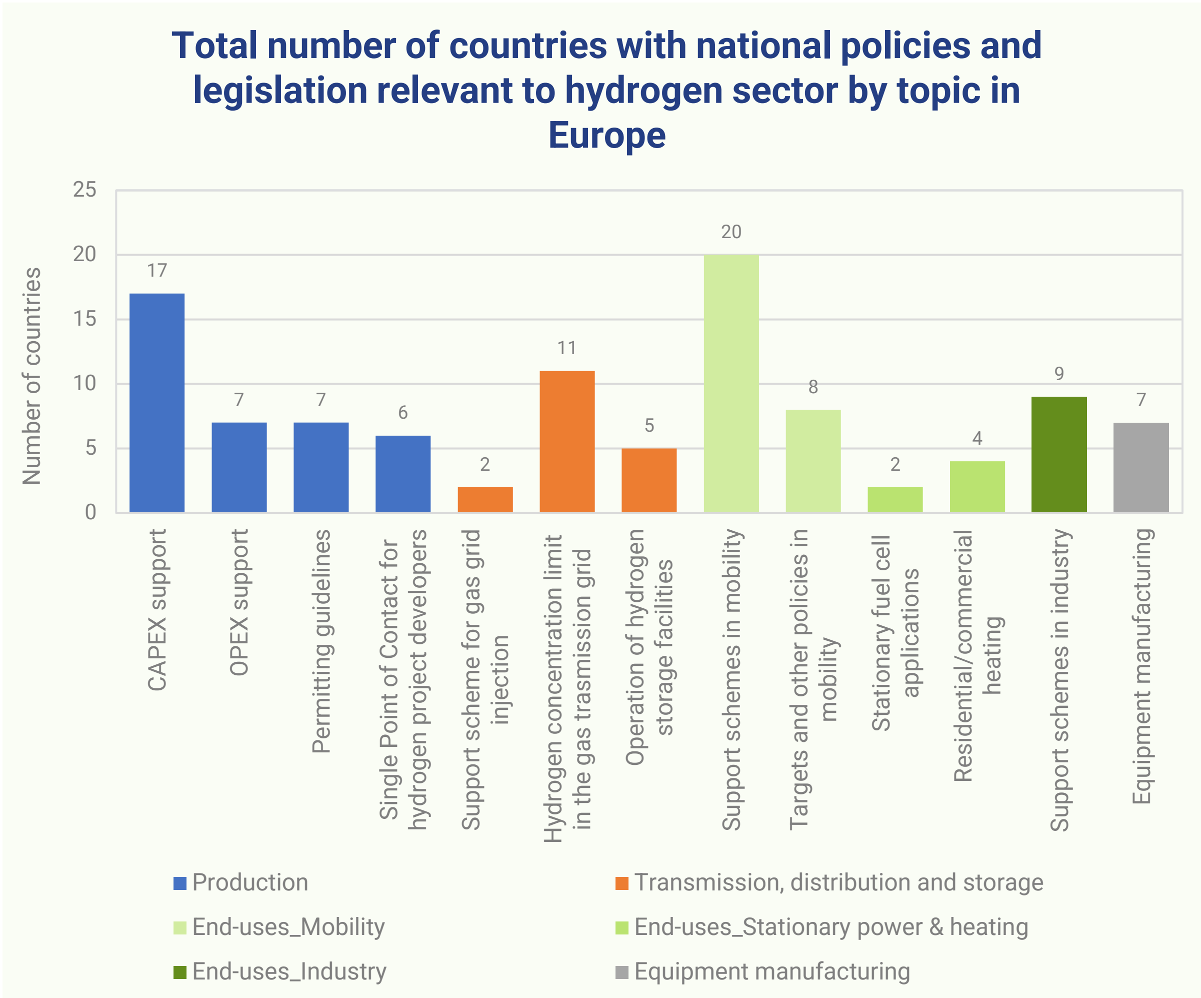

Figure 10. Total number of countries adopted national policies and legislation relevant to the hydrogen sector by topic in Europe

Based on the questions asking about policies and legislation related to the transmission, distribution, and storage of hydrogen in Europe, 2 countries (7%) were found to have adopted support schemes for gas grid injection. Policies and legislations that have installed a legal hydrogen concentration limit into the gas transmission grid have been adopted by eleven countries (39%), while those addressing the operational aspects of hydrogen storage facilities, have been implemented by 5 countries (25%).

In the context of hydrogen end-use, the questionnaire revealed that the majority of countries, 20 in total (71%), have proactively implemented support schemes to encourage the adoption of hydrogen in the mobility sector. 8 countries (29%) have also established targets and policies to promote the use of hydrogen in the mobility sector. 2 countries (7%) have incorporated applications for stationary fuel cells into their regulatory frameworks. 4 countries (14%) have developed policies offering support for the deployment of hydrogen in residential and commercial heating applications, while 9 countries (32%) have implemented support schemes aimed at promoting the use of renewable or low-carbon hydrogen in industrial processes. Finally, 7 countries (25%) have established support schemes specifically focused on the manufacturing of electrolysers and related components.

These findings underscore the diverse strategies and priorities adopted by countries in promoting the use of hydrogen across various parts of the value chain, reflecting an evolving landscape of national policy initiatives.

3.2. National policies and legislation by topic

3.2.1. Production

This section covers the questions answered by country specialists related to national policies and legislations on hydrogen production.

The questionnaire sought to answer whether policies are in place, their economic value (in EUR or as % of total investments), their application (electrolysers, low-carbon hydrogen, etc.), and any other relevant details about the policy.

The main questions covered in the questionnaire related to policies and legislation related to hydrogen production included:

- Is there any CAPEX support for renewable/low-carbon hydrogen production plants?
- Is there any OPEX support for renewable/low-carbon hydrogen production plants?
- Are there official permitting guidelines in place for H_2 production projects?
- Is there a Single Point of Contact for hydrogen project developers?

CAPEX support

Figure 11 gives an overview of the countries that are providing CAPEX support for renewable and low-carbon hydrogen production plants. In total, 17 countries have reported to provide CAPEX support, which is mostly provided to water electrolysis plants. The conditions of the support differ from country to country.

Most countries give a grant in relationship to the investment cost. In Croatia, a grant of 40-60% of the CAPEX is planned to be provided for a 10 Mwe electrolyser. In the UK, 30% of the CAPEX is supported for low carbon hydrogen projects under the Net Zero Hydrogen Fund. In Germany, 45% of the CAPEX can be subsidized under their National Innovation Programme Hydrogen and

Fuel Cell Technology. The minimum electrical output of the entire system should be 1Mwe and 100 percent electricity from renewable energy sources should be used. Also, Austria provides a maximum support of 45% for the additional investment costs. Belgium offers a 15 – 55% subsidy for the extra cost of the investment with the Ecology premium plus instrument. The subsidy percentage depends on the scope of the enterprise and the technology. In Lithuania, 70% of the eligible expenses is covered. Spain gives support for large-scale electrolysis demonstration projects with a capacity of more than 20 Mwe, according to the additional investment costs. The additional investment costs are calculated by referencing it to a similar, less environmentally friendly investment that could realistically have been made without the aid. The similar benchmark investment for the renewable hydrogen production infrastructure will be a methane steam reforming facility of equivalent power, estimated at 0.25 M€/Mwe.

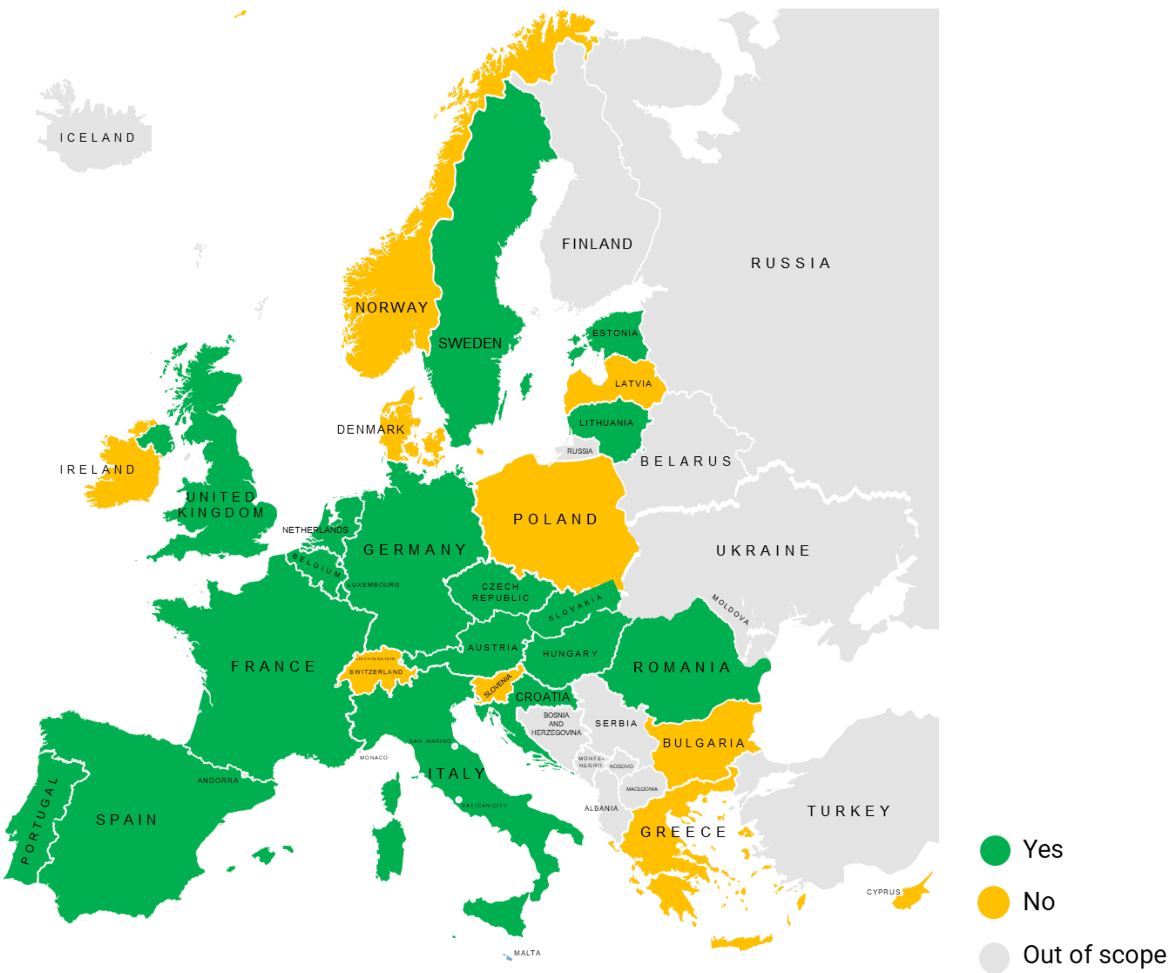

Figure 11. Map of countries providing CAPEX support applications for renewable and low-carbon hydrogen production plants by country

For many of the countries, the subsidy is part of a program that has a maximum budget which is available for the production of renewable hydrogen and other renewable gases. Of those countries that have reported their budget in the EHO questionnaire, a total investment of approximately 1526.9 million euros (MEUR) was dedicated to CAPEX support schemes for renewable and low-carbon hydrogen production plants in Europe.

Figure 12 illustrates the distribution of these CAPEX support schemes across European countries. Italy has a program of 450 MEUR for electrolyser plants with a size between 1 Mwe and 10 Mwe. France has two programs, a 175 MEUR budget that targets specifically the establishment of a hydrogen mobility infrastructure and another 250 MEUR budget for hydrogen technology building blocks and demonstrators, with a maximum support of 15 MEUR per project.

The Netherlands has a 246 MEUR subsidy for scaling up renewable hydrogen production via electrolysers, which covers both CAPEX and OPEX costs for electrolysers with a power rating between 0.5 and 50 Mwe. In Portugal, a total budget of 83 MEUR was foreseen in 2023, with a maximum of 15 MEUR per beneficiary.

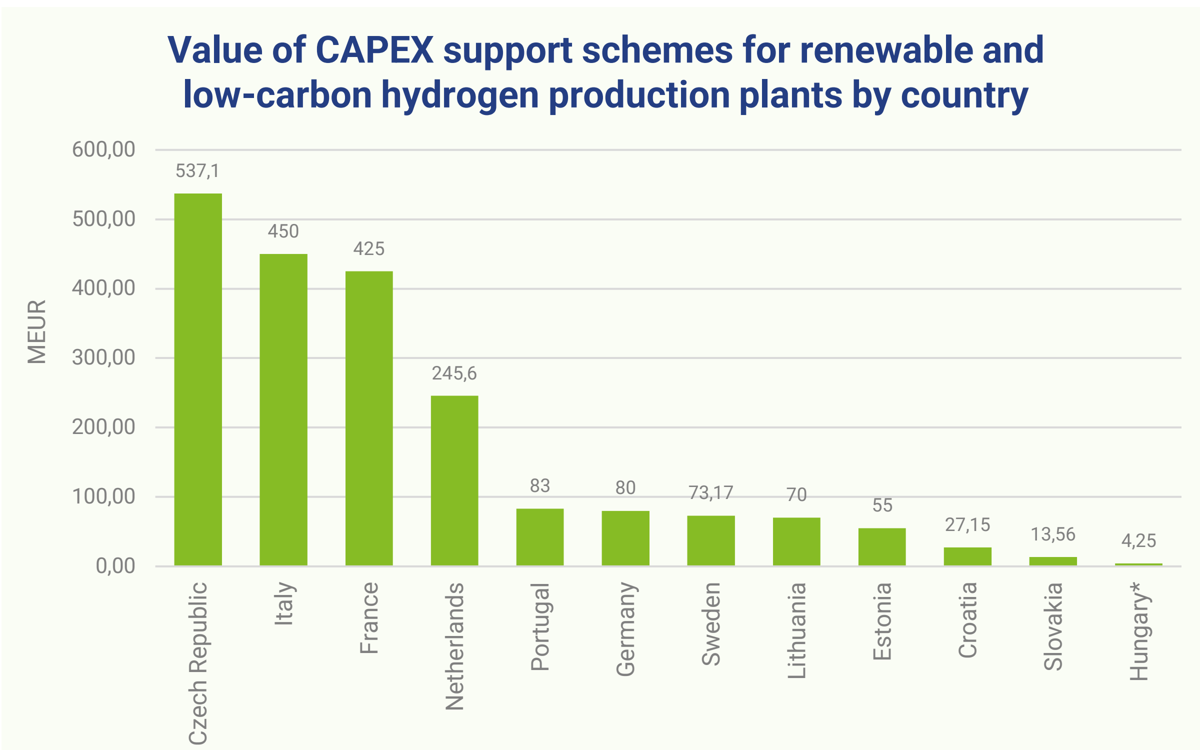

*Figure 12. Value (in MEUR) of CAPEX support schemes for renewable and low-carbon hydrogen production plants by country *An average of 2,500,000-6,000,000 € was taken for Hungary. Conversion factor: 1 SEK=0.090 euros*

OPEX support

Figure 13 gives an overview of the European countries that provide OPEX support for renewable and low-carbon hydrogen production plants. The primary focus of OPEX investments is also directed towards supporting the production of hydrogen with electrolyser

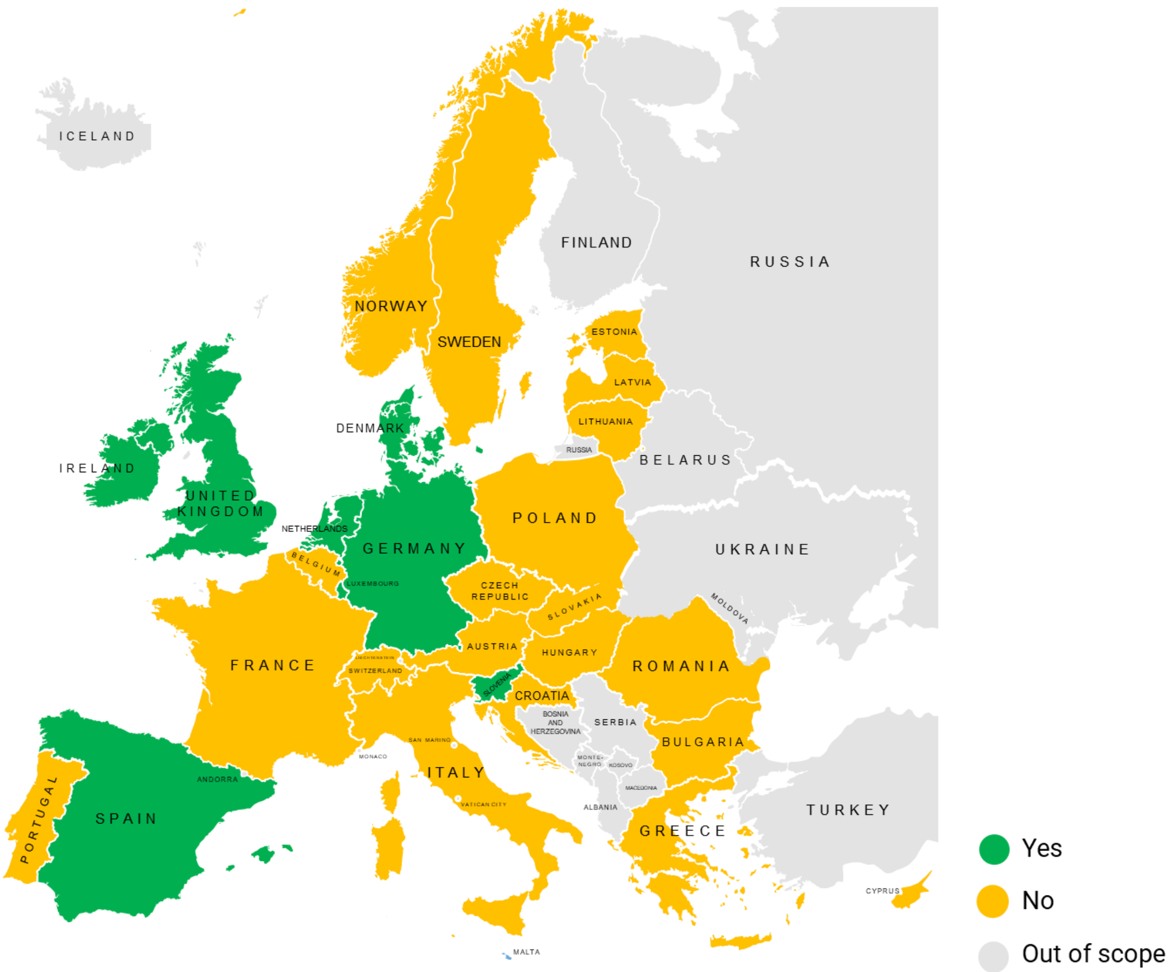

Figure 13. Map of countries providing OPEX support for renewable and low-carbon hydrogen production plants

Denmark has a PtX tender of approx. 167 MEUR which provides a support scheme to bid for the finance of operational expenditures related specifically to hydrogen production. The UK had the 2022 Joint Net Zero Hydrogen Fund and Hydrogen Business Model Electrolytic Allocation Round, which was both a CAPEX and OPEX funding mechanism. It took into account the difference between a Strike Price (reflective of the producer's unit cost of production and negotiated on a project-by-project basis) and a Reference Price (based on the price at which the producer sells their hydrogen, with a floor at the natural gas price i.e. the most relevant fossil fuel alternative). Moreover, the Renewable Transport Fuel Certificates can serve as an additional funding mechanism for producers of low carbon hydrogen. The instrument of Spain that provides CAPEX support, as mentioned above, also contains specific items in order to finance part of the operating costs. The Netherlands can provide OPEX support with their SDE++ grants to facilities that lower CO_2 emissions or produce renewable energy, that would otherwise be unprofitable. The precise support depends on market prices. If market prices are sufficiently high, the level of support may be 0. In Germany, the support equalled 0.037 EUR/kWh. in 2022, which was a measure taken for the reduction of the EEG surcharge

Permitting guidelines

Figure 14 provides a geographical representation of the European countries with official permitting guidelines for hydrogen production projects. Among the 29 European countries examined, 8 were identified to have established such guidelines. These nations include Austria, Denmark, Luxembourg, Norway, Portugal, Spain, Sweden, and the United Kingdom. Table 4 provides a detailed breakdown of the titles and explanations of the guidelines for each country.

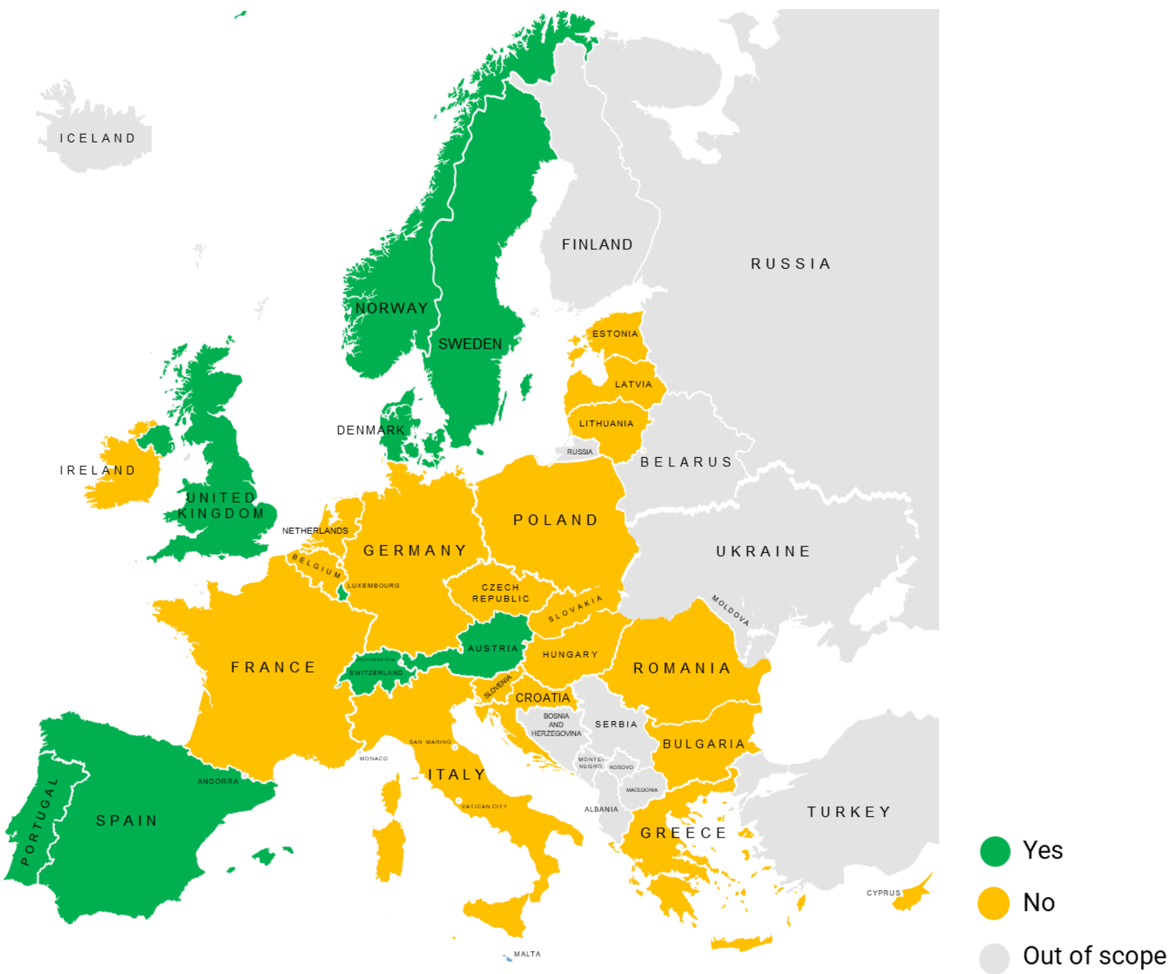

Figure 14. Map of countries with official permitting guidelines for hydrogen production projects

Table 4. Titles and explanation of official permitting guidelines for hydrogen production projects per country

Country	Title/name	Explanation
Austria	H E100 guideline "Rule of ÖVGW" H_2-production plants	The ÖVGW guideline, put together by industry professionals and reviewed by authorities, covers planning, construction, approval, and initial testing, referencing key national and international norms for gas and water systems.
Denmark	Implementation of PtX-plants Onshore	The Danish Energy Agency issues guidelines specifying permissions required for constructing and operating new PtX production plants, hydrogen storage, and pipelines.
Luxembourg	Procedures for permitting request	The "Permitting Procedures" authorize requests related to technology implementation, renewable energies, electricity, hydrogen, heat, cold, and more. Priority is given to renewable hydrogen production, consumption technologies, and construction projects.
Norway	Hydrogen and ammonia	Companies planning hydrogen facilities under the Major Accident Law must obtain approval from the Norwegian Directorate for Civil Protection (DSB). This applies to those with bunkering plans for hydrogen and ammonia use in ships as well.
Portugal	Guia do promotor "Legislação e regulação para a Economia do Hidrogénio"	The guidelines are regularly updated to outline permitting requirements for hydrogen production, listing relevant standards and legislation. They also offer guidance on submitting permitting requests and outline the overall process
Spain	Royal Decree 815/2013, of 18 October, approving the Regulation on industrial emissions and implementing Law 16/2002, of 1 July, on integrated pollution prevention and control.	Hydrogen production, whether through chemical processes or renewable energy electrolysis, is currently regulated under industrial chemical activity regulations (RD 815/2013).
Sweden	Guidelines for H_2 production projects	H_2-TSA 2023, by "Energigas Sverige," guides Hydrogen Refuelling Stations (HRS) for vehicles. Aligned with the international standard SS-ISO 19880-1, it addresses design, installation, commissioning, operation, monitoring, and maintenance, with some adjustments.
Switzerland	Energy Law decree (Loi sur l'énergie)	Article 16 outlines authorization procedures for constructing renewable energy plants. Cantons aim for swift approvals, with commissions and agencies under Article 25 overseeing the process. The Federal Council may assign a federal office to coordinate position statements or authorization procedures.

United Kingdom	Emerging techniques for hydrogen production with carbon capture	Guidance on preventing or minimising environmental impacts of industrial hydrogen production from methane or refinery fuel gas with carbon capture for storage.

Single point of contact for hydrogen project developers

Figure 15 provides a geographical representation of the European countries with a legal act or agency as a single point of contact for hydrogen project developers. Among the 29 European countries examined, 5 were identified to have established such legal acts or agencies. These nations include Denmark, Lithuania, Norway, the Netherlands, Portugal and Spain. Table 5 provides a detailed breakdown of the name and explanations of the legal acts or agencies operating as a single point of contact for hydrogen project developers for each country.

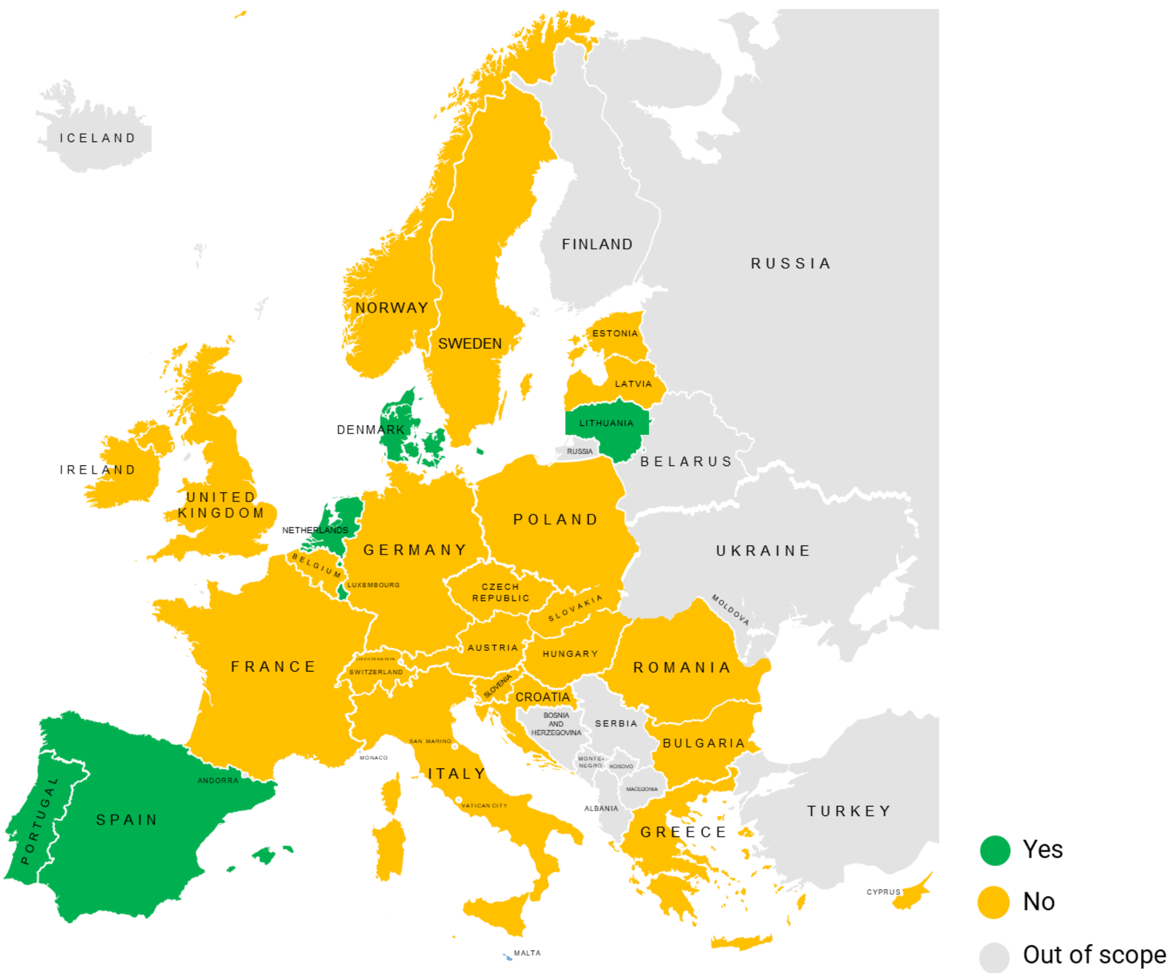

Figure 15. Map of countries with a legal act or agency as a Single Point of Contact for hydrogen project developers

Table 5. Titles and explanation of the legal acts or agencies operating as a single point of contact for hydrogen project developers per country

Country	Title/name	Explanation
Denmark	The PtX Secretary	The Danish Energy Agency has an authoritative working group with public employees from approving entities for PtX plant implementation, mainly hydrogen production. The agency is the primary authority for hydrogen, with Energinet and Evida as Single Points of Contact for hydrogen infrastructure.
Lithuania	Vytautas Budreika	Advisor to the Ministry, Strategic Change Management Group, Ministry of Energy of Republic of Lithuania
Netherlands	Ministerial order applying the coordination order to national hydrogen infrastructure	This ministerial order appoints a national authority that oversees and coordinates all relevant permits needed for the project. Such an order only exists for transport infrastructure of hydrogen.
Portugal	E.Portugal	E.Portugal portal streamlines industrial tasks, including hydrogen production permits. Simulate requirements and submit formal requests on the same platform.
Spain	Institute for Energy Diversification and Saving	This is the body in charge of managing the IDAE aid within the framework of the recovery, transition and resilience plan (PRTR)

3.2.2.

Transmission, distribution & storage

This section covers the questions answered by country specialists related to national policies and legislations on hydrogen transmission, distribution and storage.

The questionnaire sought to answer whether policies are in place and any other relevant details about the policy.

The main questions covered in the questionnaire concerning policies and legislation related to hydrogen transmission, distribution and storage included:

- Is there any support scheme for hydrogen when injected into the gas grid?
- Is there a legal framework for the operation of hydrogen storage facilities within national energy law?
- Is there a legal hydrogen concentration limit into the transmission gas grid?
- What is the acceptable limit of H_2 into the transmission gas grid?

Support scheme for gas grid injection

Support schemes for hydrogen injection into the gas grid were identified only two countries, Ireland and the Netherlands.

In Ireland, current legislation allows renewable hydrogen to be eligible for Guarantees of Origin (GOs) when injected into the gas grid. However, the existing registry is currently operational only for biomethane, as no hydrogen production is currently taking place in Ireland. The processes for issuing Guarantees of Origin specifically for renewable hydrogen have not been developed yet. Anticipated revisions to CEN 16325 are expected to provide guidelines on accounting for renewable electricity converted into hydrogen within the framework of Guarantees of Origin.

In the Netherlands, there's a subsidy scheme promoting the production of renewable hydrogen. This initiative offers a market premium, calculated by comparing the costs of producing renewable hydrogen to the costs of producing grey hydrogen. The program has a budget of 245.6 MEUR and can run for 7 to 15 years.

Moreover, facilities that help lower CO_2 emissions or produce renewable energy receive operational support (SDE++), even if these projects might not be profitable otherwise. The total budget for this support is 8,000 MEUR, but the actual assistance depends on market prices. If market prices are high enough, the support may be reduced to zero.

Hydrogen concentration limit in the gas transmission grid

The maximum concentration of hydrogen (as a percentage) allowed in the gas transmission grid per country in Europe is presented in Figure 16. The Netherlands imposes the most stringent limit, allowing only 0.02% hydrogen concentration into the transmission gas grid. In contrast, Portugal has set a more progressive approach, with regulation stating that the maximum quota for the blending of other gases in the national gas transmission network is 5% until 2025 and 10-15% until 2030. Austria also sets one of the highest acceptance limits with a 10% maximum concentration of hydrogen within the natural gas grid.

For Ireland and Estonia, the acceptable limit of H_2 into the transmission gas grid is <0.1 mol% and 0.1 vol%, respectively. In Germany, due to the different requirements of end-use components no generally applicable limit value for hydrogen was specified in the current set of rules. The limit values result from the application areas of the gas infrastructure. In Slovenia, the share of hydrogen or any other gas that may be injected into the existing gas network is not nationally regulated. The rules can be found in the Gas Supply Act.

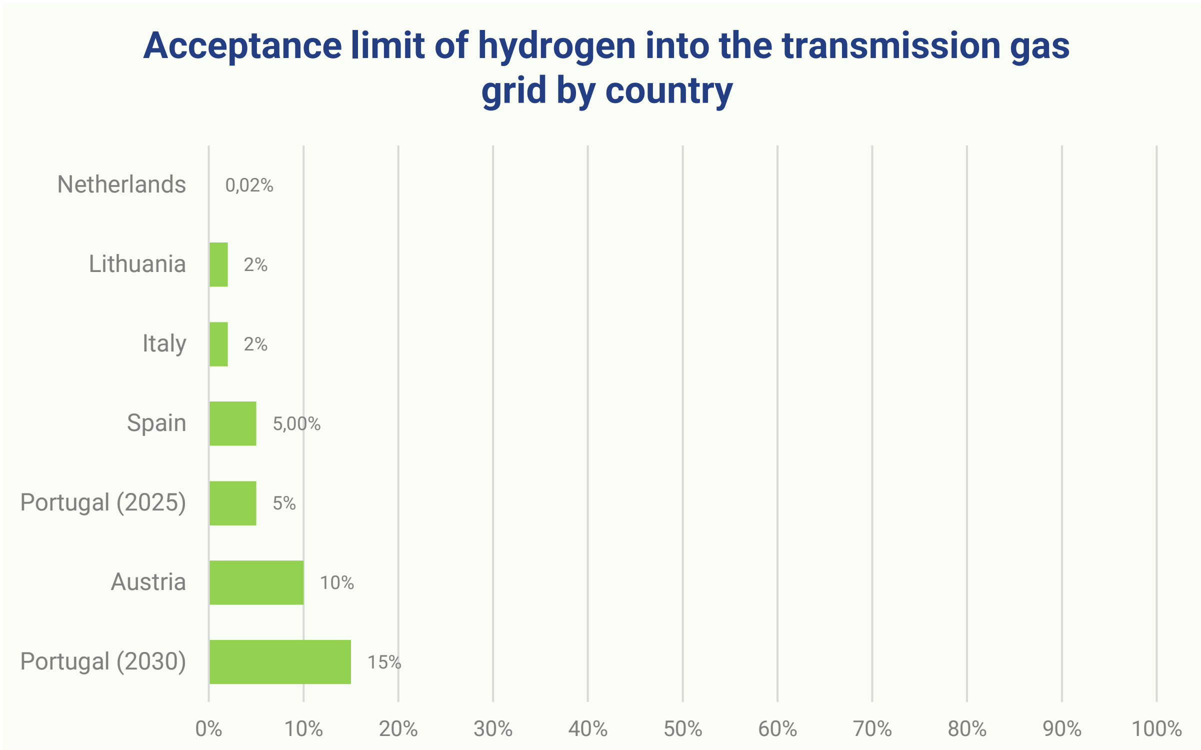

Figure 16. Acceptance limit of hydrogen (%) into the transmission gas grid by country

Operation of hydrogen storage facilities

The development of policies and legislation for hydrogen storage operations play a pivotal role in ensuring safety, environmental protection, infrastructure development, market confidence, standardization, innovation, and energy integration. By providing a clear regulatory framework, governments create an enabling environment for the growth of the hydrogen economy. Several European countries have therefore established a legal framework for the operation of hydrogen storage.

For example, France has incorporated within its national hydrogen policy a regulatory framework concerning underground storage, as outlined in "Article L211-2 of the new Mining Code (Code Minier)," which was modified in April 2022. This legislation describes the specific activities encompassed within the scope of underground storage operations.

Norway has several laws and regulations under the authority of the Norwegian Directorate for Civil Protection (DSB), a leading Standard Norway's committee for hydrogen technology, "SN/K 182 Hydrogenteknologi". Hydrogen and ammonia handling, including its equipment and installations used in the handling, is regulated in the "Law on handling of flammable and reactionary and pressurized substances". If a company stores minimum 5 tons hydrogen or minimum 50 tons ammonia, the Major Accident Law (Storulykkeforskriften) will apply. This law is based on the EU Seveso III Directive (2012/18/EU). Norway has also implemented the EU ATEX user directive (1999/92/EC) and the EU Pressure Directive (2014/68/EU).

In Spain a working group is currently engaged in the development of regulations relating to hydrogen refuelling stations, professional qualifications, hydrogen production, storage and transport, as well as the homologation of hydrogen vehicles, fuel cells and their possible uses.

The Swedish policy law includes a handling regulation for flammable gas and flammable aerosols (MSBFS 2020:1) with requirements for, among other things, tightness, materials, signage, and ventilation, but also requirements for pipelines, loose containers, tanks, etc.

3.2.3.
End-uses: mobility

This section covers the questions answered by country specialists related to national policies and legislations on hydrogen end-use in mobility.

The questionnaire sought to answer whether policies are in place, their economic value (in EUR or as % of the vehicle cost or tax due), the type of support schemes (e.g purchase subsidy, tax benefits etc.), which modes of transport they apply to (heavy-duty vehicles, passenger cars, boats etc.), and any other relevant details about the policy.

The main questions covered in the questionnaire concerning policies and legislation related to hydrogen end-use in mobility included:

- Are there any support schemes offered to FCEVs?
- Are there any national FCEV deployment targets?
- Is there any support offered for HRS deployment in your country?
- Is hydrogen used as fuel taxed in your country?
- Are there any national HRS deployment targets?
- Are there official guidelines in place that cover permitting of HRS?

FCEV

Figure 17 presents the number of countries with support schemes for Fuel Cell Electric Vehicles (FCEVs) for different support types. Purchase subsidies emerge as the predominant support mechanism for FCEVs, with 17 countries implementing this form of assistance. Additionally, tax benefits and other financial incentives are implemented by 6 countries, while 3 countries opt for non-economic benefits as a means of support. An overview of the types of support schemes offered to FCEVs by country is given in Table 6.

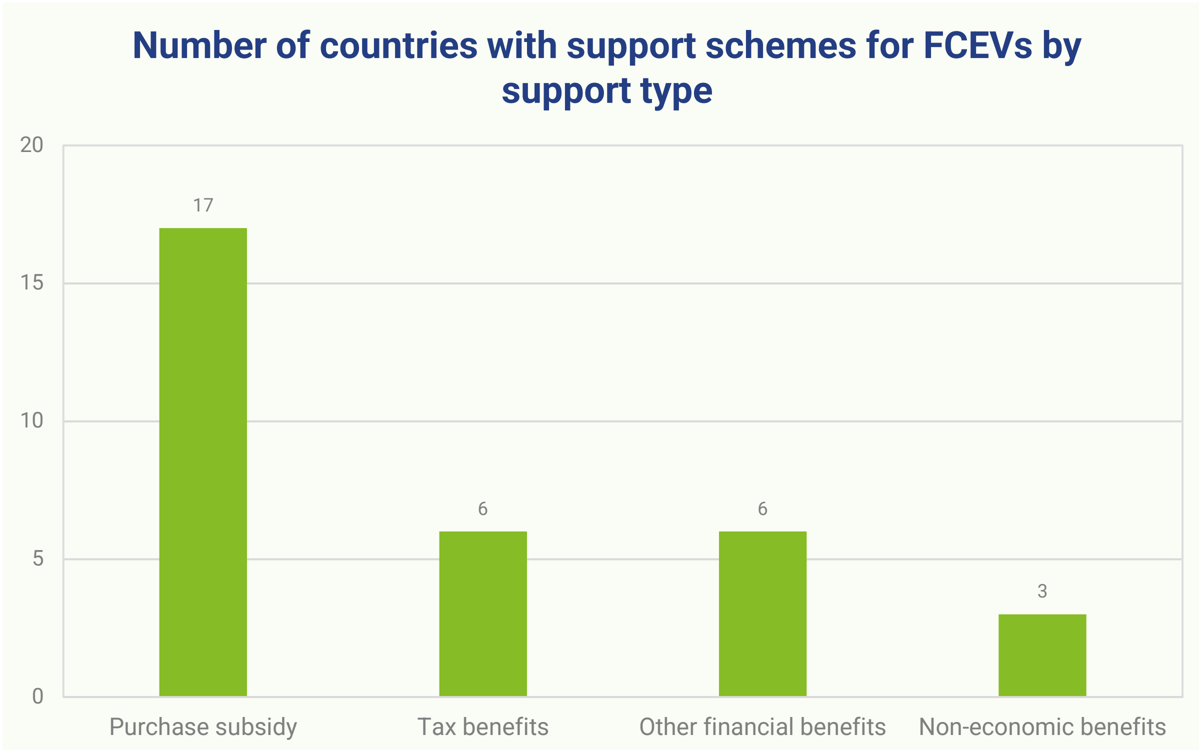

Figure 17. Number of countries with support schemes offered to FCEVs by support type

Table 6. Overview of the types of support schemes offered to FCEVs by country

Country	Purchase subsidy	Tax benefits	Other financial benefits	Non-economic benefits
Austria	√	√		√
Belgium	√	√		√
Croatia	√			
Czech Republic	√		√	
Denmark		√		
Estonia	√			
France	√		√	
Germany	√			
Ireland	√	√	√	
Italy	√			
Lithuania	√			
Luxembourg	√			
Netherlands	√			
Norway	√	√	√	
Poland	√			
Portugal	√	√		
Slovakia	√	√		
Slovenia	√		√	
Spain	√			√
United Kingdom			√	

Figure 17, illustrates the distribution of support schemes for Fuel Cell Electric Vehicles (FCEVs) across various vehicle types. The data reveals a notable focus on passenger cars/vans (M1/N1), which emerge as the primary vehicle type covered by the support schemes. Specifically, these schemes are implemented in 20 European countries. Following closely are light-duty vehicles (M2/N2), heavy-duty vehicles and buses encompassing support in 16, 15 and 14 countries, respectively.

Support schemes for non-road mobile machinery are observed in only 3 countries, while those for trains and light rail are applicable in just 2 countries. Table 7 gives an overview of the different vehicle type applications of support schemes offered to FCEVs by country.

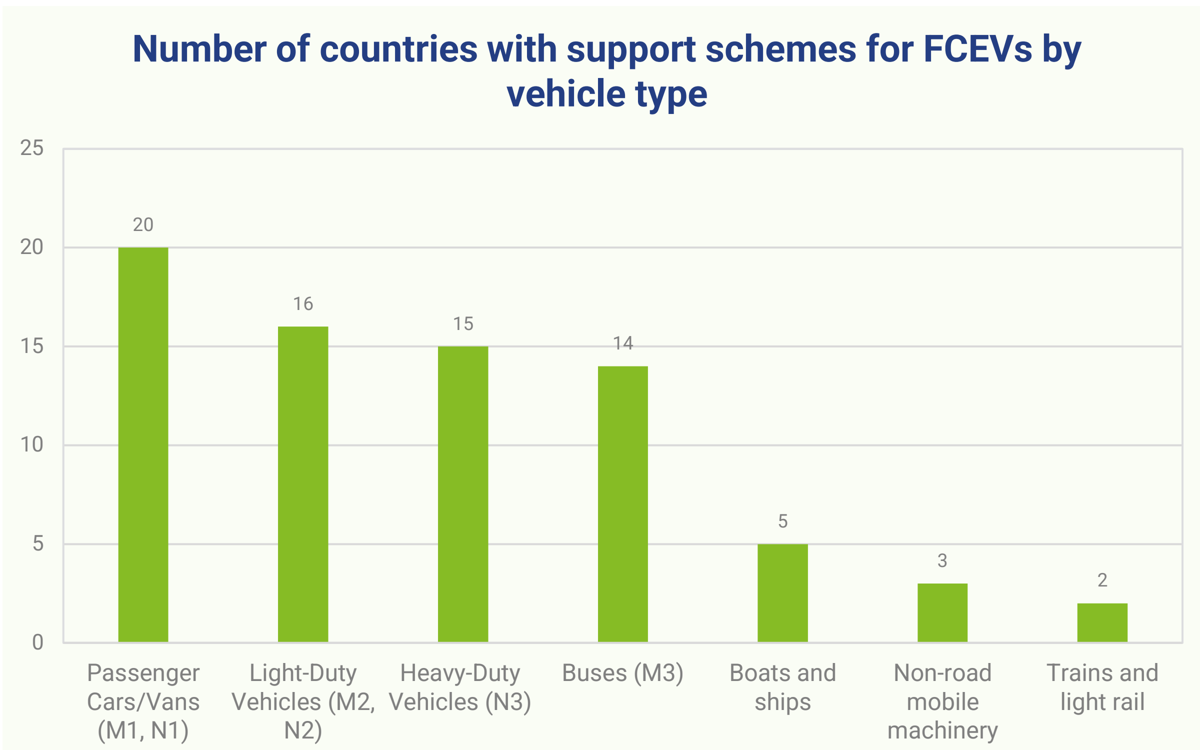

Figure 17. Number of countries with FCEVs support by vehicle type

Table 7. Overview of the different vehicle type applications of support schemes offered to FCEVs by country

Country	Passenger Cars/Vans (M1, N1)	Light-Duty Vehicles (M2, N2)	Heavy-Duty Vehicles (N3)	Buses (M3)	Boats and ships	Non-road mobile machinery	Trains and light rail
Austria	√	√	√	√	√	√	
Belgium	√	√	√	√			
Croatia	√	√	√	√			
Czech Republic	√	√					
Denmark	√	√					
Estonia	√						
France	√						
Germany	√	√	√	√	√	√	√
Ireland	√	√	√	√			
Italy	√	√					
Lithuania	√	√	√	√			
Luxembourg	√	√	√	√			
Netherlands	√		√	√			
Norway	√	√	√	√	√		
Poland	√	√	√	√			
Portugal	√	√	√	√			
Slovakia	√	√	√	√			
Slovenia	√	√					
Spain	√						
Switzerland				N/A			
United Kingdom	√	√	√	√	√		

HRS

Figure 18 shows the responses from the EU countries regarding policies and legislation for hydrogen refuelling stations (HRS) deployment. Out of 29 questioned countries, 14 have reported to provide support for HRS deployment, 12 have set national targets for it, 5 impose taxes on hydrogen fuel usage, and 8 have official guidelines for HRS permitting.

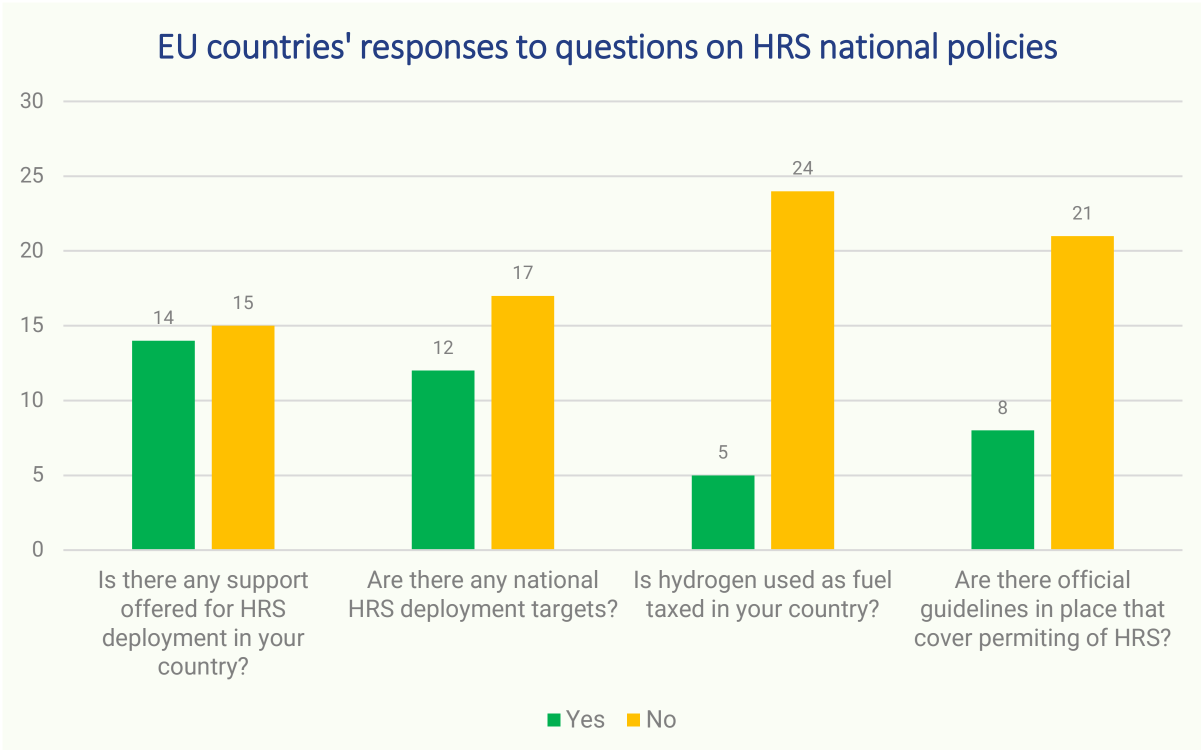

Figure 18. EU Countries' Responses to Key Questions on Hydrogen Refueling Station (HRS) Policies

3.2.4.

End-uses: stationary power & heating

This section covers the questions answered by country specialists related to national policies and legislations support for stationary fuel cells providing electricity and/or heat.

The questionnaire sought to answer whether the policies are in place, their economic value (in EUR or as % of the investment or tax due), and any other relevant details about the policy.

The main questions covered in the questionnaire concerning policies and legislation related to support for stationary fuel cells providing electricity and/or heat included:

- Is there any support offered to stationary fuel cell applications?
- Is there any support offered to deployment of residential/commercial heating with hydrogen?

Stationary fuel cell applications

Figure 19 presents the share of countries providing support for stationary fuel cell applications. Only 2 countries out of 29, Ireland and Sweden, offer support to stationary fuel cell applications.

In Ireland the scheme provides grants for projects, up to 3 MEUR per project, following the EXEED standard to enhance energy efficiency, reduce operational costs, and demonstrate sustainability. While prioritizing energy efficiency, it also supports renewable energy and sustainable heating, given compliance with specified conditions in the scheme guidelines.

In the case of Sweden, from 1 January 2021, individuals can receive support when investing in renewable technology such as stationary fuel cell applications. The support is a maximum 50% tax reduction for individuals on the cost of labour and materials. The tax reduction is solely for individuals.

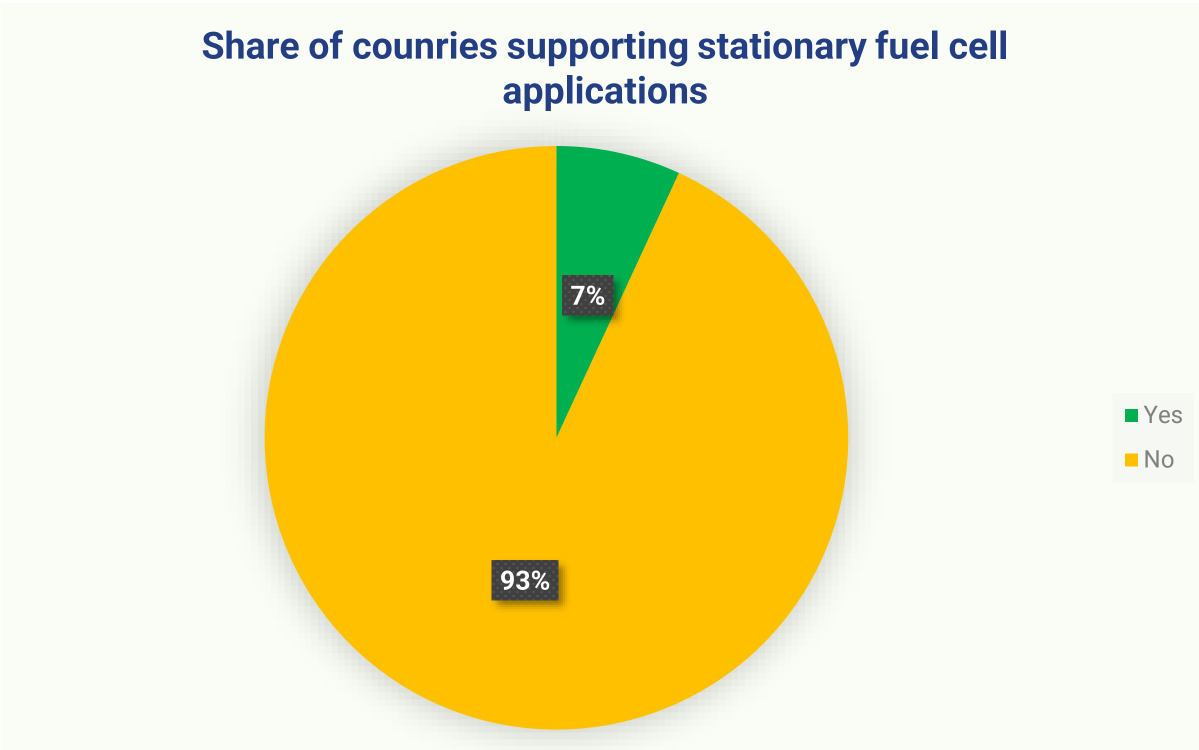

Figure 19. Share of Countries Supporting Stationary Fuel Cell Applications

Residential/commercial heating

Figure 20 presents the share of countries that offer support for the deployment of residential/commercial heating with hydrogen. Only 4 countries out of 29, namely Germany, Ireland, Italy and Netherlands, offer support for the deployment of residential/commercial heating with hydrogen.

In Germany, a 25% subsidy for installations in 5+ year-old residential and non-residential buildings, with a 35% heating exchange bonus is offered. New BEG guidelines require exclusive operation with renewable hydrogen or biomethane, meeting efficiency standards, and a 10-year maintenance contract for reliable operation.

In Italy, the Ecobonus for micro co-generators, extended through 2022, offers a 65% deduction, up to 100,000 EUR, for fuel cells replacing existing plants with a primary energy saving (pes) ≥ 20%.

In Netherlands, a subsidy of 39.4 MEUR facilitates new approaches in residential or commercial construction that aid in reaching the climate targets. Heating buildings with hydrogen falls under that scope.

In Ireland the support offered to deployment of residential/commercial heating with hydrogen, falls within the same scheme offered to stationary fuel cell applications, described in the section above.

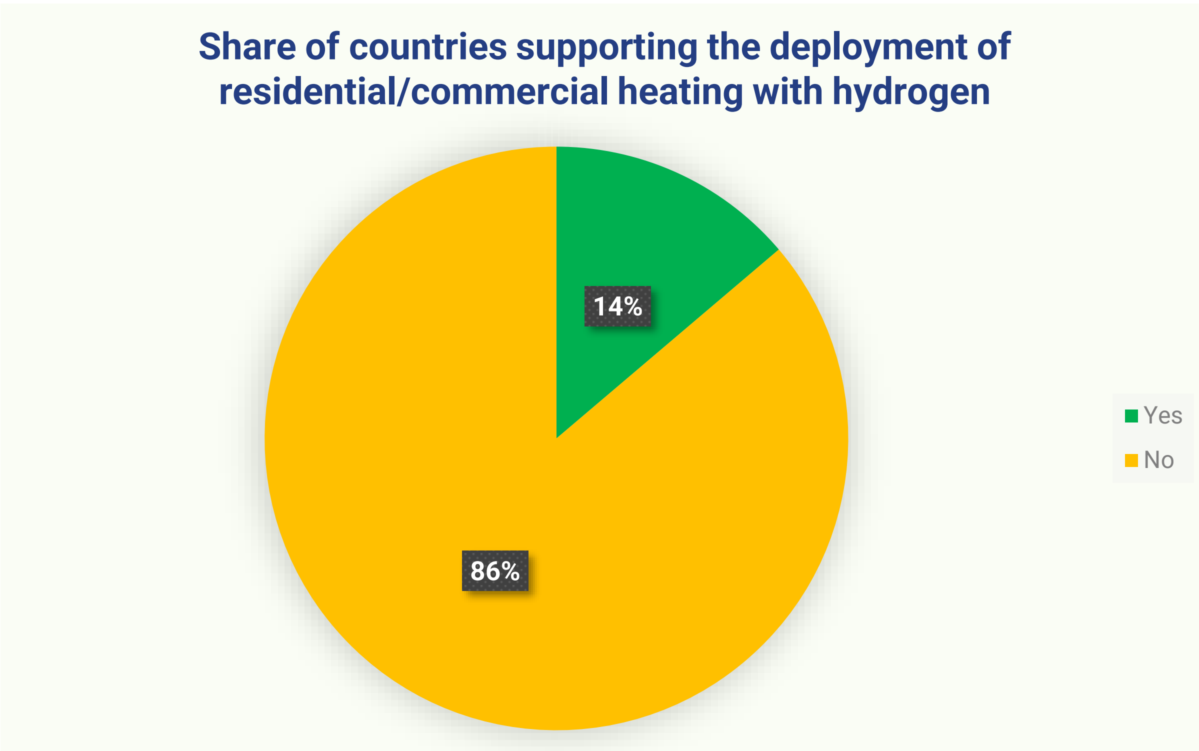

Figure 20. Share of countries supporting the deployment of residential/commercial heating with hydrogen

3.2.5.
End-uses: industry

Even though hydrogen has been used in the industry for decades, the future use of renewable or low-carbon hydrogen for heat, as a feedstock, or as a chemical agent are some of its most promising use cases. This section explores policies supporting increased usage of clean hydrogen in industry.

The questionnaire sought to answer whether the policies are in place, what is their economic value, what industries they cover, and any other relevant details about the policy.

The main question covered in the questionnaire concerning policies and legislation related to the hydrogen industry was:

- Are there any deployment support schemes for the use of renewable/low-carbon hydrogen in industry?

Support schemes in Industry

Figure 21 presents the share of countries offering support schemes for the use of renewable/low-carbon hydrogen in industry. In total 9 countries out of 29, namely Austria, Estonia, Ireland, Lithuania, Netherlands, Slovenia, Spain, Sweden, and United Kingdom, provide deployment support schemes for the use of renewable/low-carbon hydrogen in industry.

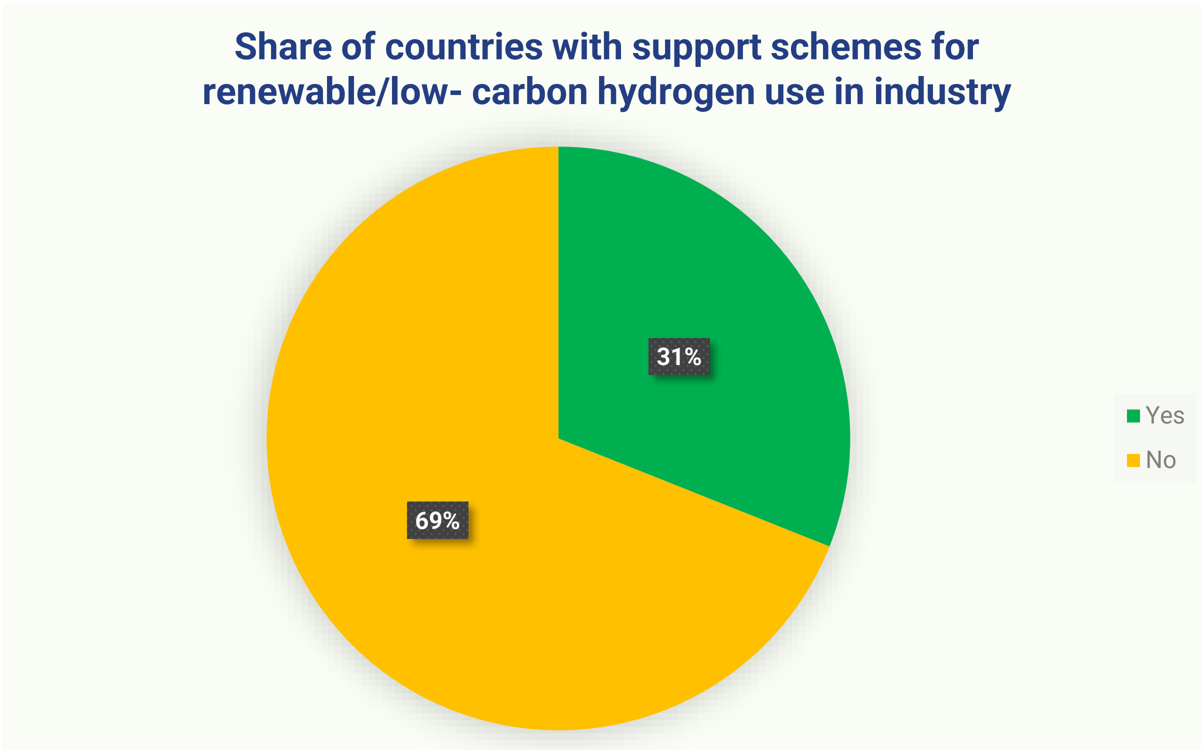

Figure 21. Share of countries with support schemes for renewable/low-carbon hydrogen use in industry

Figure 22 illustrates the value (in MEUR) of support mechanisms for the use of renewable/low-carbon hydrogen in industry by country. The values presented are summing up all the monetary values that were provided in the questionnaire. Spain leads with the highest investment, allocating 150 MEUR, on adapting or replacing existing equipment to achieve a 30% reduction in the volume of current fossil fuel consumption per equipment. Following closely, Lithuania provides significant funding of 122 MEUR from the government. The investment is directed towards increasing electrolyser capacity by 213 MW by 2027, aiming to contribute approximately 16% of annual hydrogen production.

In contrast, Austria demonstrates the lowest investment among the selected countries, totalling 30 MEUR. The investment is primarily targeted at hydrogen production plants within the framework of pilot and demonstration plants or industrial facilities.

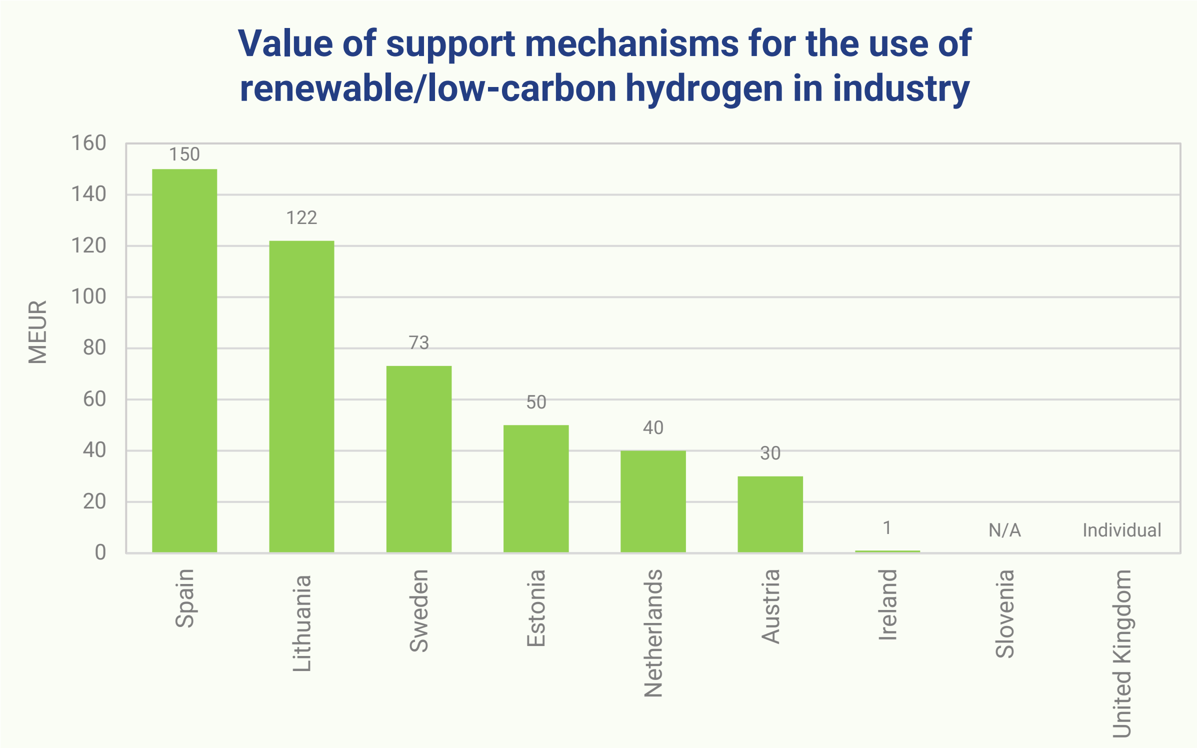

Figure 22. Value (in M€) of support mechanisms for the use of renewable/ low-carbon hydrogen in industry by country
** In the case of Ireland, the value of investment refers to the amount given for each project.*

Figure 23 gives an overview on the number of countries providing support schemes for the deployment of renewable/low-carbon hydrogen, categorized by the industry they target. The majority of countries apply these support schemes to ammonia production industries, totalling 8. Following closely is the chemicals industry, where support schemes are observed in 7 countries. In contrast, the deployment of support schemes for renewable/low-carbon hydrogen in steel production industries is observed in the fewest countries, totalling 6.

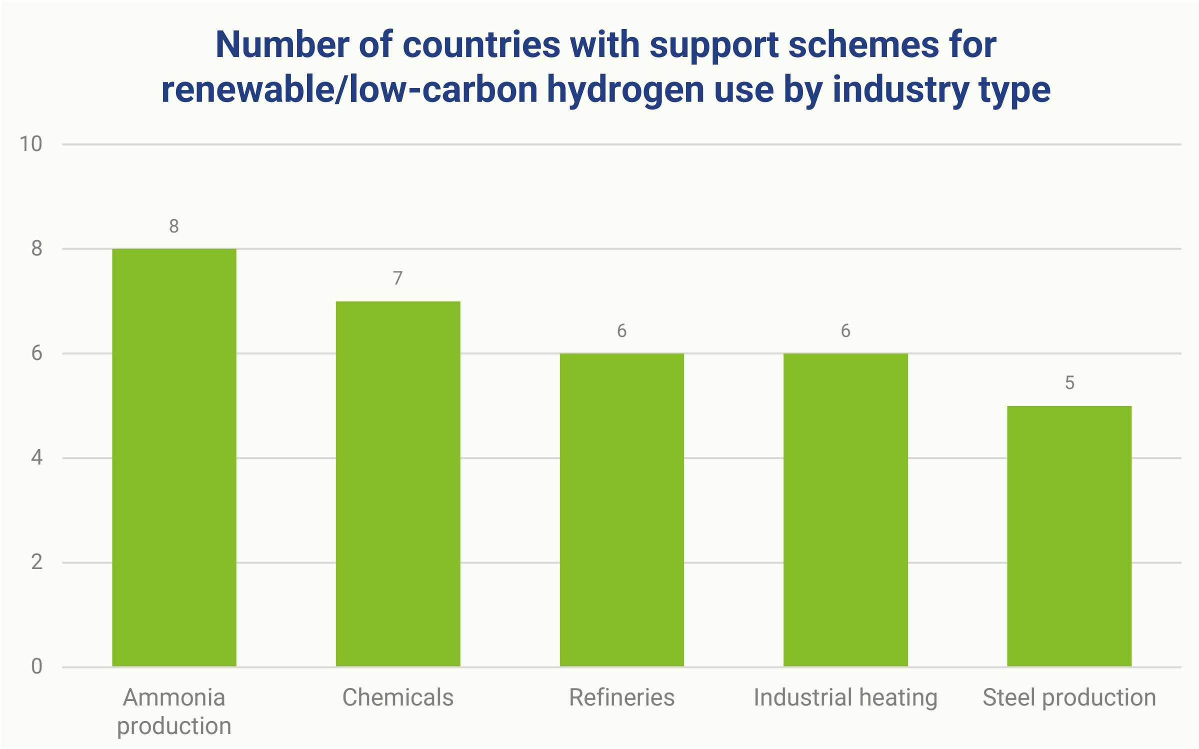

Figure 23. Number of countries with support schemes for the use of renewable/low-carbon hydrogen in industry

3.2.6. Equipment manufacturing

This section covers the questions answered by country specialists related to national policies and legislations for electrolyser (and components) manufacturing.

The questionnaire sought to answer whether the policies are in place, their economic value (in EUR or as %), the type of support schemes (e.g. grant, tax benefits etc.), and any other relevant details about the policy.

The main question covered in the questionnaire related to policies and legislation supporting electrolyser (and components) manufacturing was:

- Are there any support schemes for electrolyser (and components) manufacturing?

Figure 24 illustrates the share of countries offering support schemes for electrolyser (and components) manufacturing. In total 7 countries out of 29, namely Belgium, Czech Republic, Estonia, Germany, Latvia, Spain, and Sweden provide deployment support schemes for the manufacturing of electrolysers and their components.

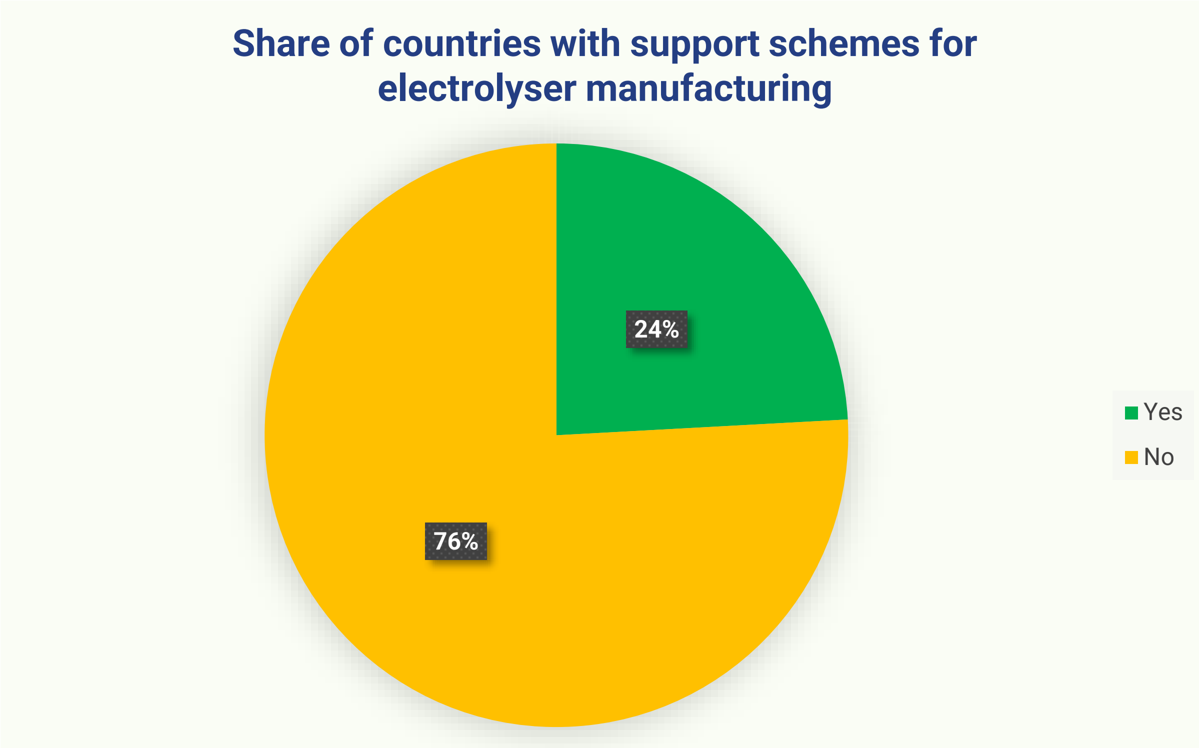

Figure 24. Share of countries with support schemes for electrolyser (and components) manufacturing

Figure 25 presents the different applications of support schemes for electrolyser (and components) manufacturing in European countries. Grants appear to be the most common method of the different support schemes that is applied, used in 4 out of the 7 identified countries. Tax benefits are only applied in the Czech Republic. Latvia combines grants and capital loans in its support schemes, while Estonia's specific approach is not specified.

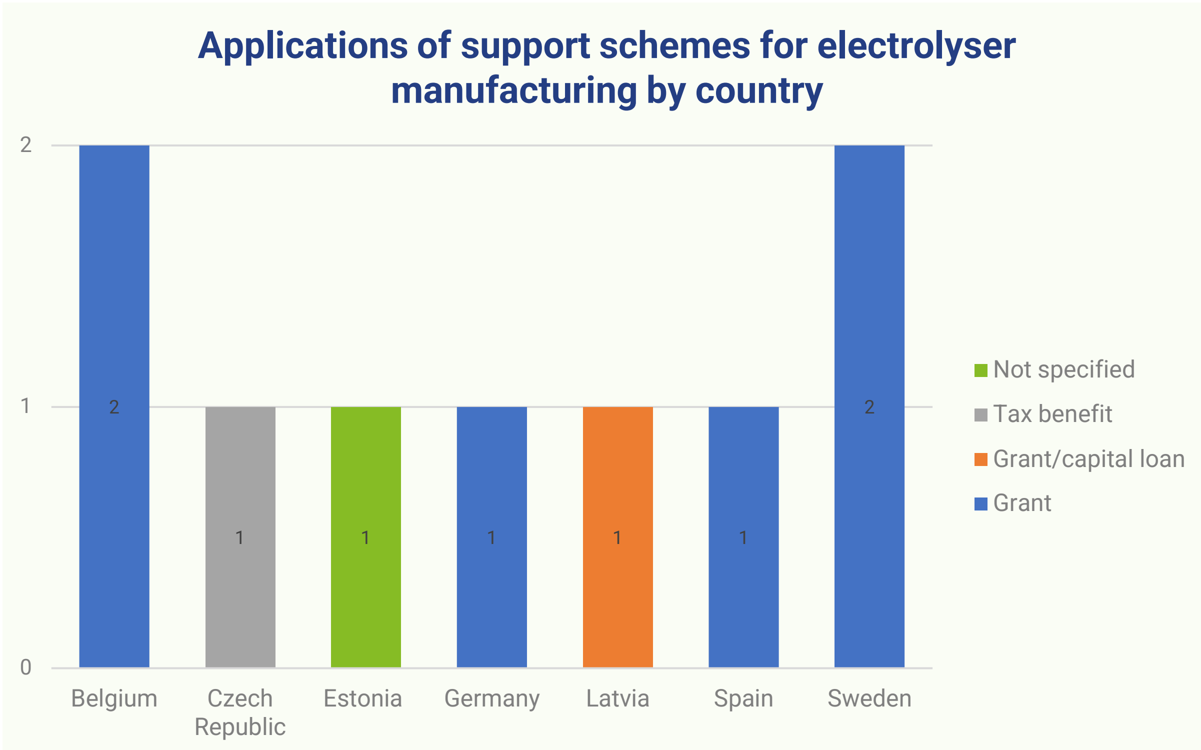

Figure 25. Applications of support schemes

04 Codes and standards

Introduction

This chapter provides an overview of the key European standards that are relevant for the facilitation of the emerging clean hydrogen market.

The dataset of the European Hydrogen Observatory builds on the data that was included in the previous Fuel Cells and Hydrogen Observatory. This dataset has been updated with new standards that were published between January 2022 and September 2023, which were identified by searching the activities of key standardisation technical committees.

This chapter provides an overview of the standards that are included in the database, how they are categorised, and which new standards have been added in the years 2022 and 2023. Moreover, it also gives some context, explaining the importance of standards in facilitating the large-scale deployment of hydrogen and fuel cells.

Interactive data dashboards on codes and standards can be accessed on the European Hydrogen Observatory website.

4.1. Overview

The EHO includes a searchable database including 104 standards that are relevant to the facilitation of the emerging clean hydrogen sector. This is not a fully exhaustive list of relevant standards, but rather an overview of some of the most important and directly relevant standards in place covering key components of the hydrogen value chain. The database includes 11 new or updated standards that were published between January 2022 and September 2023. Furthermore, a list of standards published between October 2023 and January 2024 has been included at the end of this chapter. These standards will be incorporated into the next update of the EHO.

The standards included in the database were published by 23 different technical committees of standardisation bodies, which are explained in more detail in the next section. Of these 23 technical committees, 5 are responsible for publishing around 75% of the standards included in the database, as illustrated in Figure 26. These technical committees cover the following topic areas:

- Road vehicles (ISO/TC 22)
- Hydrogen technologies (ISO/TC 197)
- Fuel cell technologies (IEC/TC 105)
- Gas cylinders (ISO/TC 58)
- Independent gas-fired space heaters (CEN/TC 62)

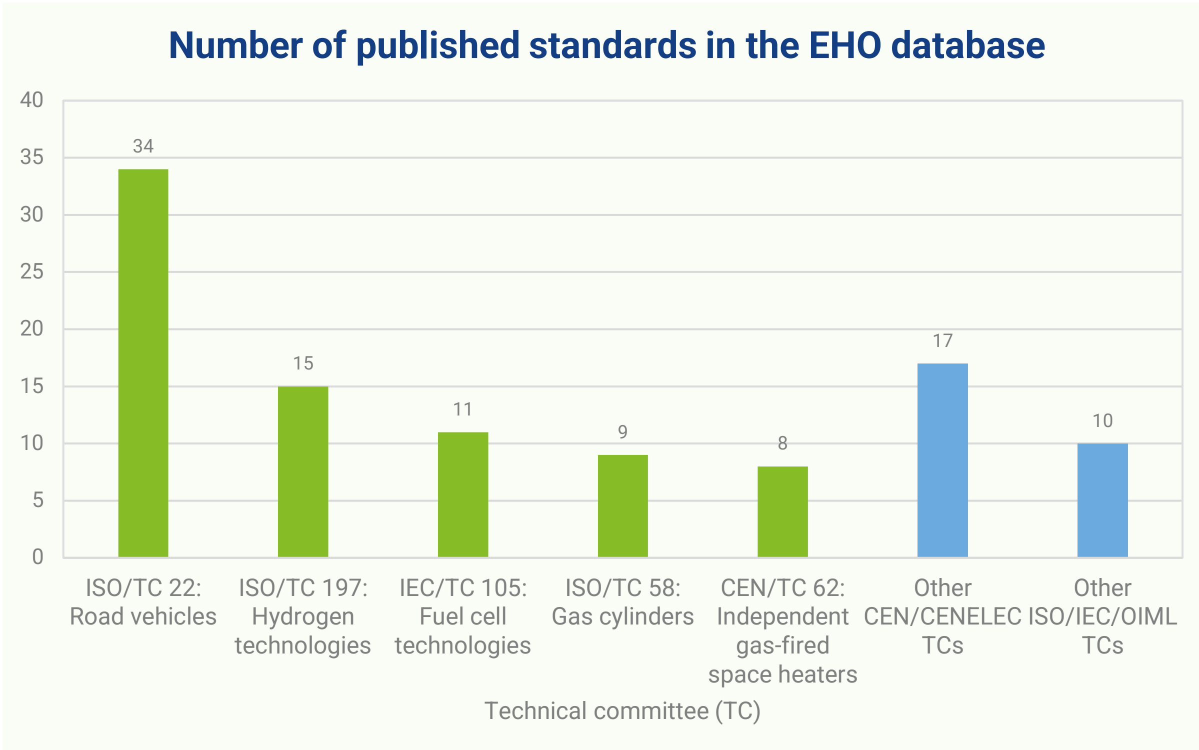

Figure 26. Number of published standards in the EHO per technical committee

The standards are categorised in the EHO according to the different stages of the hydrogen value chain, as shown in Figure 27. This is a new categorisation structure compared with the previous observatory, which is also aligned with the categories used in other EHO datasets.

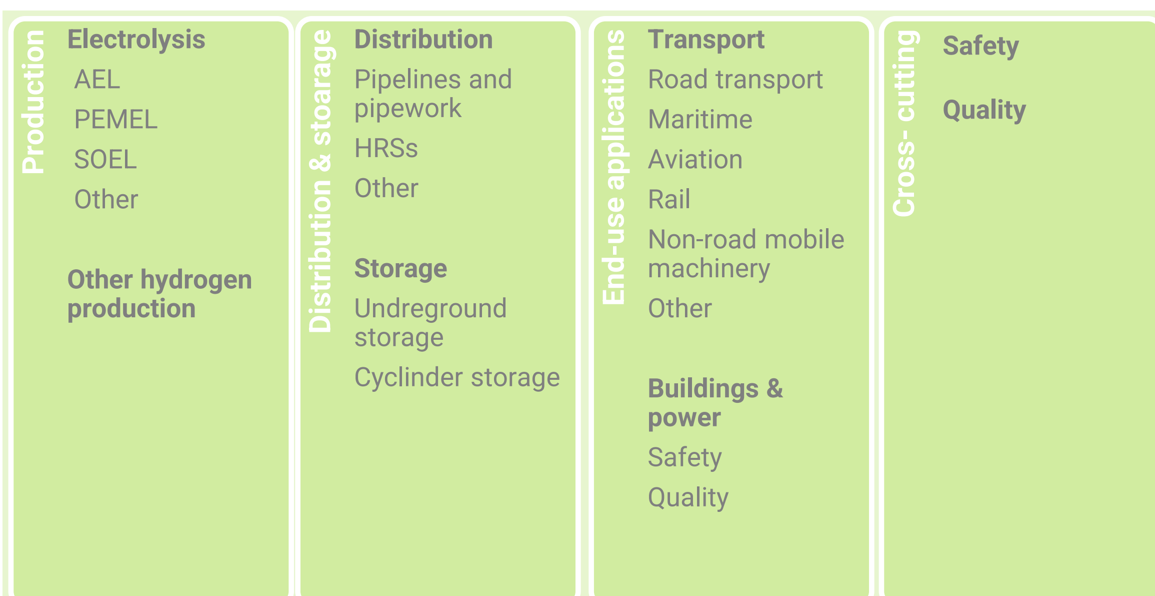

Figure 27. Categorization of standards in the EHO according to the different stages of the hydrogen value chain

4.2.
Standardisation in the hydrogen sector

4.2.1.
Context

A 'standard' is a technical document, developed by consensus, that can be used as a rule, guideline or definition. It should define a repeatable way of doing something[41]. Within the European Union, standards are a core component that enable the functioning of the single market. For example, harmonised standards enable companies to demonstrate EU law compliance. Standards also give consumers confidence in relation to safety and quality, and enable interoperability and cross-border trade.

Standards have already played an important role in facilitating research and innovation in hydrogen generation and applications. However, standardisation activities will need to be accelerated to facilitate the rapid development of the hydrogen market[42]. This fits into a wider challenge, addressed in the EU's Strategy on Standardisation, to respond to an increasingly rapid innovation pace whilst maintaining quality, and also to ensure that the EU can influence global standardisation.[43.]

The need to keep pace with the constantly developing policy and technological developments is illustrated in Figure 28. This figure shows the expected pace of change of the European renewable hydrogen market in the top arrow, with targets to accelerate production over the next decade and to 2050. This will be underpinned by policy and legal frameworks and technological developments, illustrated in the second arrow in the figure. Finally, as illustrated in the bottom arrow, in order for hydrogen technologies to be deployed on the market, standards need to be developed, to facilitate safety, quality and compliance. Standards can then also be used to certify products as safe and fit to be placed on the European market.

[41] European Standards - CEN-CENELEC (cencenelec.eu)
[42] 20230301_ech2a_roadmaphydrogenstandardisation.pdf (cencenelec.eu)
[43] 20230301_ech2a_roadmaphydrogenstandardisation.pdf (cencenelec.eu)

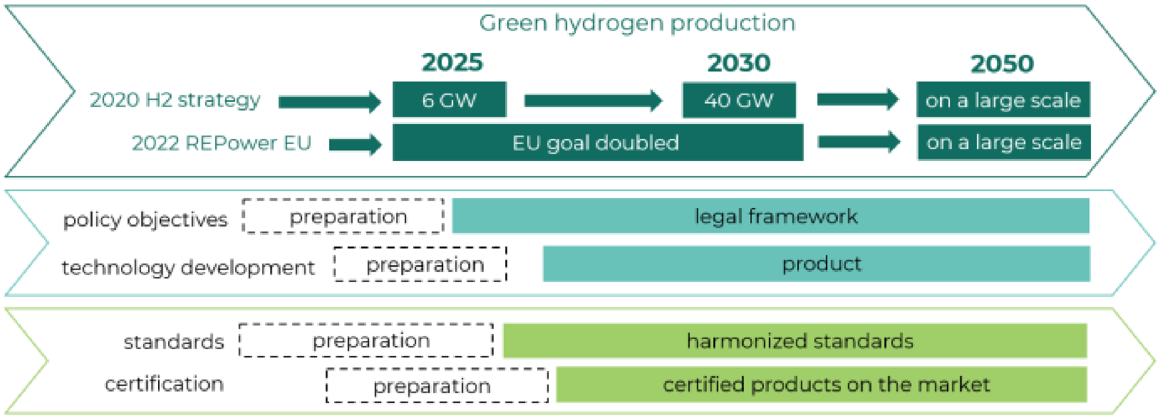

Figure 28. Interlinkages between policy objectives, technology development, standard-setting, and certification[44]

4.2.2.

Standardisation bodies

The codes and standards module covers hydrogen standards developed by the following bodies: ISO, IEC, OIML, CEN, CENELEC. These are described in more detail in this section. Within each organisation, technical committees bring together key stakeholders to develop standards.

Global bodies: ISO, IEC and OIML

ISO (the International Standardisation Organisation) and IEC (the International Electrotechnical Commission) bring together experts from approximately 170 countries globally to develop voluntary, consensus-based standards.

One of the key ISO Technical Committees that deals with Hydrogen is ISO/TC 197: Hydrogen Technologies. The scope of this committee is standardisation in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen. The committee has recently established a sub-committee: (ISO/TC 197/ SC1), focused on standardization of large-scale hydrogen energy systems and applications including aspects of testing, certification, sustainability and placement, and coordination with other relevant standardisation bodies and stakeholders[45]. This will help to facilitate, for example, applications where overlap or blending with other fuels and energy carriers and systems is considered.

One of the key IEC Technical Committees that deals with Hydrogen is TC 105: Fuel Cell Technologies. The scope of this committee is to prepare international standards regarding fuel cell (FC) technologies for all FC types and various associated applications such as stationary FC

[44] 20230301_ech2a_roadmaphydrogenstandardisation.pdf (cencenelec.eu)
[45] ISO/TC 197/SC 1 - Hydrogen at scale and horizontal energy systems

power systems for distributed power generators and combined heat and power systems, FCs for transportation such as propulsion systems (excluding road vehicles, coordinated by ISO/TC 22 which have also published several relevant standards, as shown in Figure 28 range extenders, auxiliary power units, portable FC power systems, micro FC power systems, reverse operating FC power systems, and general electrochemical flow systems and processes[46]. This committee is currently developing many standardisation projects, including in the emerging applications of electrically powered industrial trucks, unmanned aircraft systems, and railways.

The EHO also includes some standards from the OIML (International Organisation for Legal Metrology). This is an international standard-setting body linked to the World Trade Organization's Technical Barriers to Trade Agreement. OIML standards should therefore be applied, when appropriate, by all signatories of the WTO Technical Barriers to Trade (TBT) Agreement when developing technical regulations, in application of Article 2.4 of that Agreement.

European bodies: CEN and CENELEC

CEN (The European Committee for Standardization) and CENELEC (European Committee for Electrotechnical Standardization) are two organisations that bring together members from 34 countries to develop European standards and are able to work on standardisation requests issued by the European Commission.

Both organisations have the goal to pursue one standard, one test, accepted everywhere[47]. In support of this, they actively support the activities of ISO and IEC, including through technical cooperation facilitated by the Vienna Agreement (between CEN and ISO) and the Frankfurt Agreement (between CENELEC and IEC).

CEN and CENELEC have recently established the CEN-CENELEC Joint Technical Committee 6: Hydrogen in energy systems, which is looking into standardisation in devices and connections for the production, storage, transport and distribution, measurement and use of hydrogen from renewable energy sources and other sources[48]. In addition, the two organisations have established a Joint Task Force on hydrogen in natural gas systems with the intention to support the timely provision of coherent deliverables in the different CEN and CENELEC Technical Committees, which will allow a safe and reliable use of hydrogen in a decarbonizing energy system[49]. The EHO also includes relevant standards from technical committees that have a broader topic focus. For example, there are 8 standards in the database that were published by

[46] IEC - TC 105 Dashboard> Scope
[47] CEN and CENELEC - CEN-CENELEC (cencenelec.eu)
[48] Hydrogen - CEN-CENELEC (cencenelec.eu)
[49] Ibid.

CEN/TC 62, which sets standards for independent gas-fired space heaters.

Figure 29 shows an illustration developed for the European Clean Hydrogen Alliance roadmap on standardisation of the known technical committees that are dealing with hydrogen topics across the hydrogen value chain, with global standards in the outer circle and European standards in the inner circle. This includes some committees that have been set up specifically to tackle hydrogen topics, such as the 'ISO/TC 197: Hydrogen Technologies', as well as broader technical committees that cover some standardisation topics that are also relevant to hydrogen deployment, such as 'CEN/TC 15: Inland navigation vessels'. The figure illustrates the fact that many technical committees cover topics across the hydrogen value chain. It is expected that this landscape will continue to develop over coming years, with additional technical committees being set up to tackle specific issues. Against this backdrop, it will be increasingly important to coordinate efforts between standardisation bodies and committees.

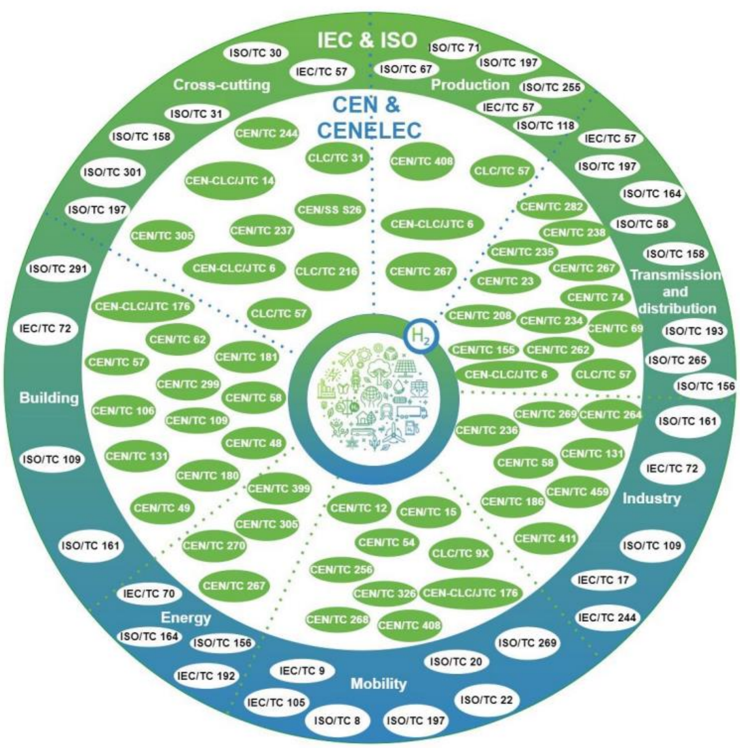

Figure 29. European and International hydrogen standardisation landscape[50]

[50] 20230301_ech2a_roadmaphydrogenstandardisation.pdf (cencenelec.eu)

4.2.3.

Other standardisation initiatives

There are several standardisation initiatives that have been established to assess the state of standardisation development and recommend priorities going forward. These initiatives will be increasingly important as the development of the hydrogen market, and associated standardisation needs accelerates. This section gives a brief overview of some of the key initiatives that have emerged in recent years.

European Clean Hydrogen Alliance (ECH2A) Standards Roadmap

The ECH2A brings together industry, public authorities, civil society, and other stakeholders with the mission to support the large-scale deployment of clean hydrogen technologies by 2030. In support of this, it established a working group on standardisation in February 2022, which published a 'Roadmap on Hydrogen Standardisation' in March 2023[51]. This roadmap includes a comprehensive analysis of current global and European hydrogen standardisation activities, an analysis of the key gaps that need to be addressed, and recommendations to support the streamlining and consolidation of activities going forwards. This roadmap was – and will continue to be - a key data source for the EHO standards database, given its detailed overview of the key technical committees that are developing relevant standards.

Other organisations assessing standardisation activities

The **Hydrogen Council** is a global CEO-led initiative that was established with the mission to advance the role of hydrogen in the energy transition globally. Regarding the topic of standards, the Hydrogen Council is particularly involved with supporting the development of safety standards. As part of this work, it recently performed a gap analysis, identifying 400 standards gaps that need to be filled. This included technical areas such as a systemic approach to interface design in refuelling stations, as well as 'safety culture' topics. As these topics were all rated as highly critical, the Hydrogen Council has also been tracking progress in each topic.

The **International Partnership for hydrogen and fuel cells in the economy (IPHE)** is an inter-governmental partnership that was established with the mission to facilitate and accelerate the transition to clean and efficient energy and mobility systems using hydrogen and fuel cell technologies across applications and sectors. The IPHE has a working group on regulations, codes, standards, and safety, which assesses progress on standardisation, for example through the high-level regulatory gap analysis that it

[51] 20230301_ech2a_roadmaphydrogenstandardisation.pdf (cencenelec.eu)

conducted in 2021[52]. This analysis is helpful to understand the regulatory priorities that will drive future standards development but is not as detailed as the analysis conducted by the ECH2A and Hydrogen Council.

The **International Renewable Energy Agency (IRENA)** – the lead global intergovernmental agency for energy transformation – has conducted projects on hydrogen standardisation, including the following project: "Quality Infrastructure (QI) for Renewable Hydrogen: technical standards and quality control for the production and trade of renewable hydrogen". Projects like this also have the aim of developing roadmaps to be followed by global standard makers in the development of new hydrogen standards.

The results from these initiatives were already used to inform the mapping for the current EHO database. The gap analysis and roadmaps will also support the future development of the database, as it shows in which areas standards are likely to be developed.

4.3.

Recent standards (2022 - 2023)

As set out in the next section, a number of standards have been revised and developed in 2022 and 2023. This includes standards in the following areas:

- Fuel cell technologies
- Gas cylinders
- Road vehicles
- Hydrogen refuelling

Moreover, this report includes standards that have been published since September 2023, which will be added to the EHO in its next update. This includes ISO/TS 19870:2023, which sets a methodology for determining the greenhouse gas emissions associated with the production, conditioning, and transport of hydrogen to consumption gate. This landmark standard, which was unveiled at COP28, aims to act as a foundation for harmonization, safety, interoperability, and sustainability across the hydrogen value chain[53].

[52] IPHE RCSSWG Regulatory Areas for Action Compendium A4FINAL (usrfiles.com)
[53] New ISO standard on hydrogen unveiled at COP28 | European Hydrogen Observatory (europa.eu)

4.3.1.

Newly published standards between January 2022 and September 2023

This section gives an overview of all the standards published between January 2022 and September 2023 that are included in the EHO database. These include standards that already existed in a previous form and have been reviewed and revised. These are organised per technical committee.

ISO/TC 58: Gas Cylinders[54]

Committee scope: Standardisation of gas cylinders and other pressure receptacles, their fittings and requirements relating to their manufacture and use.

Newly published standards:

ISO 11114-1:2020/Amd 1:2023: Gas Cylinders - Compatibility of cylinder and valve materials with gas contents. Part 1: Metallic materials (Published: July 2023). This amends Standard ISO 11114-1:2020 to include an update on the material compatibility of aluminium silicon bronze. ISO 11114-1:2020 provides requirements for the selection of safe combinations of metallic cylinder and valve materials and cylinder gas content. The compatibility data given is related to single gases and to gas mixtures. Note: this standard was developed in collaboration with CEN/TC 23 (Transportable Gas Cylinders).

ISO 11515:2022: Gas cylinders. Refillable composite reinforced tubes of water capacity between 450 l and 3000 l - Design, construction and testing (Published: August 2022). This standard – which replaces ISO 11515:2013/Amd 1:2018 - specifies the minimum requirements for the materials, design, construction and performance testing of

- Type 2 hoop-wrapped composite tubes,
- Type 3 fully-wrapped composite tubes, and
- Type 4 fully-wrapped composite tubes

with water capacities between 450 l and 3 000 l for storage and conveyance of compressed or liquefied gases with test pressures up to and including 1 600 bar and a design life of at least 15 years.

IEC/TC 105: Fuel Cell Technologies[55]

Committee scope: Standardisation of fuel cell (FC) technologies for all FC types and various associated applications such as stationary FC power systems for distributed power generators and combined heat and power systems, FCs for transportation such as propulsion systems (see note below), range extenders, auxiliary power units, portable FC power systems, micro FC power systems, reverse operating FC power systems, and general electrochemical flow

[54] ISO/TC 58 - Gas cylinders
[55] IEC - TC 105 Dashboard> Scope

systems and processes. Note: applications to road vehicles covered by ISO/TC 22).

Newly published standards:

IEC 62282-8-301:2023: Fuel cell technologies - Part 8-301: Energy storage systems using fuel cell modules in reverse mode - Power-to-methane energy systems based on solid oxide cells including reversible operation - Performance test methods (Published: May 2023). This standard specifies performance test methods of power-to-methane systems based on solid oxide cells (SOCs). Water, CO_2, and electricity are supplied to the system to produce methane and oxygen.

IEC 62282-4-102:2022: Fuel cell technologies - Part 4-102: Fuel cell power systems for electrically powered industrial trucks - Performance test methods (Published: December 2022). This standard specifies the performance test methods of fuel cell power systems for propulsion and auxiliary power units (APU). This document covers fuel cell power systems for propulsion other than those for road vehicles. This document applies to gaseous hydrogen-fuelled fuel cell power systems and direct methanol fuel cell power systems for electrically powered industrial trucks.

IEC 62282-4-600:2022: Fuel cell technologies - Part 4-600: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) - Fuel cell/battery hybrid systems performance test methods for excavators (Published: August 2022). This standard covers the requirements for the performance test methods of fuel cell/battery hybrid systems intended to be used for electrically powered applications for excavators. For this purpose, this standard covers electrical performance and vibration tests for the fuel cell/battery hybrid system, as well as performance test methods which focus on vibration and other characteristics for balance of plant (BOP) installed in heavy-duty applications with fuel cell/battery hybrid system.

IEC 62282-4-101:2022: Fuel cell technologies - Part 4-101: Fuel cell power systems for electrically powered industrial trucks – Safety (Published: August 2022). This standard deals with safety of fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU). Specifically, this covers safety requirements for fuel cell power systems intended to be used in electrically powered industrial trucks as defined in ISO 5053-1, with a few exceptions, which are set out in the standard.

IEC 62282-3-201:2017+AMD1:2022: Fuel cell technologies - Part 3-201: Stationary fuel cell power systems - Performance test methods for small fuel cell power systems (Published: February 2022). This standard provides test methods for the electrical, thermal and environmental performance of small stationary fuel cell power systems that meet a set of defined criteria, which includes having a rated electric power output of less than 10 kW.

ISO/TC 22 (Road Vehicles) – Sub-committee 37: Electrically propelled vehicles[56]

Committee scope: Standardisation of specific aspects of electrically propelled road vehicles, electric propulsion systems, related components and their vehicle integration.

Newly published standards:

ISO 21782-1:2023: Electrically propelled road vehicles - Test specification for electric propulsion components, Part 1: General test conditions and definitions (Published: February 2023). This standard – which replaces ISO 21782-1:2019 – specifies the test procedure for performance and operating load for voltage class B electric propulsion components (motor, inverter, DC/DC converter) and their combinations (motor system) of electrically propelled road vehicles.

ISO 23828:2022: Fuel cell road vehicles. Energy consumption measurement - Vehicles fuelled with compressed hydrogen (Published: June 2022). This standard – which replaces ISO 23828:2013 - specifies the procedures for measuring the energy consumption and driving range of fuel cell passenger cars and light-duty trucks that use compressed hydrogen.

ISO 6469-2:2022: Electrically propelled road vehicles – Safety specifications, Part 2: Vehicle operational safety (Published: May 2022). This standard – which replaces ISO 6469-2:2018 - specifies requirements for operational safety specific to electrically propelled road vehicles, for the protection of persons inside and outside the vehicle.

CEN/TC 268: Cryogenic vessels and specific hydrogen technologies applications[57]

Committee scope: Standardisation in the field of insulated vessels (vacuum or non- vacuum) for the storage and the transport of refrigerated liquefied gases, as defined in Class 2 of "Recommendations on the Transport of dangerous goods - Model regulation", in particular concerning the design of the vessels and their safety accessories, gas/materials compatibility, insulation performance, the operational requirements of the equipment and accessories. The preparation of standards for hydrogen refuelling points are also included.

Newly published standards:

EN 17124:2022: Hydrogen fuel - Product specification and quality assurance for hydrogen refuelling points dispensing gaseous hydrogen - Proton exchange membrane (PEM) fuel cell applications for vehicles (Published: September 2022). This standard – which replaces EN 17124:2018 **-** specifies the quality characteristics of hydrogen fuel dispensed at hydrogen refuelling stations for use in proton exchange membrane (PEM) fuel cell vehicle systems, and the corresponding quality assurance considerations for ensuring uniformity of the hydrogen fuel.

[56] ISO/TC 22/SC 37 - Electrically propelled vehicles
[57] CEN Technical Bodies - CEN/TC 268 (cencenelec.eu)

4.3.2.

Newly published standards after September 2023

This section includes a summary of standards that have been published since September 2023. These are not yet in the EHO database, but they will be included in the next update.

ISO/TC 22 (Road Vehicles) – Sub-committee 37: Electrically propelled vehicles[58]

Committee scope: Set out in the section above.

Newly published standards:

ISO/TR 11954:2024: Fuel cell road vehicles - Performance measurement. Vehicles fuelled with compressed hydrogen (Published: January 2024). This standard – which replaces ISO/TR 11954:2008 - specifies test methods for the measurement of performance, such as acceleration, maximum speed and hill climbing ability, of fuel cell hybrid electric vehicles (FCHEV) as passenger cars and light duty trucks with a maximum authorized total mass of 3 500 kg and fuelled with compressed hydrogen.

ISO/TR 17326:2023: Fuel cell road vehicles – Cold start performances under sub-zero temperature. Vehicles fuelled with compression hydrogen (Published: December 2023). This standard describes the test methods for the cold start performances of fuel cell hybrid electric vehicles (FCHEV) under sub-zero temperature conditions. This applies to FCHEV as passenger cars and light duty trucks with a maximum authorised total mass of 3500 kg and fuelled with compressed hydrogen.

ISO/TC 138 (Plastics pipes, fittings and valves for the transport of fluids) – Sub-committee 4: Plastics pipes and fittings for the supply of gaseous fuels[59]

Committee scope: Standardisation of pipes, fittings, piping systems and auxiliary equipment intended for the supply of gaseous fuels and made from all types of plastic materials, including all types of reinforced plastics.

Newly published standards:

ISO 16486-1:2023: Plastics piping systems for the supply of gaseous fuels. Unplasticized polyamide (PA-U) piping systems with fusion jointing and mechanical jointing - Part 1: General (Published: December 2023). This standard – which replaces ISO 16486-1:2020 - specifies the general properties of unplasticized polyamide (PA-U) compounds for the manufacture of pipes, fittings and valves made from these compounds, intended to be buried and used for the supply of gaseous fuels. It also specifies the test parameters for the test methods to which it refers.

[58] ISO/TC 22/SC 37 - Electrically propelled vehicles
[59] ISO/TC 138/SC 4 - Plastics pipes and fittings for the supply of gaseous fuels

ISO/TC 197 (Hydrogen Technologies) – Sub-committee 1: Hydrogen at scale and horizontal energy systems[60]

Committee scope: Standardisation of large scale hydrogen energy systems and applications including aspects of testing, certification, sustainability and placement, and coordination with other relevant standardization bodies and stakeholders.

Newly published standards:

ISO/TS 19870:2023: Hydrogen Technologies – Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate (Published: November 2023). This standard specifies methodologies that can be applied to determine the carbon footprint, or partial carbon footprint of a hydrogen product. The standard covers requirements and evaluation methods for several hydrogen production pathways, including electrolysis, steam methane reforming with CCUS, co-production and coal gasification with CCUS, auto-thermal reforming with CCUS, hydrogen as a co-product in industrial applications, and hydrogen from biomass waste as a feedstock.

IEC/TC 105: Fuel Cell Technologies[61]

Committee scope: Set out in the section above

Newly published standards:

IEC 62282-4-202:2023: Fuel cell technologies - Part 4-202: Fuel cell power systems for propulsion and auxiliary power units - Unmanned aircrafts - Performance test methods (Published: October 2023. This standard covers performance test methods of fuel cell power systems intended to be used to power unmanned aircrafts, including general requirements, start-up, shutdown, power output, continuous running time, electric efficiency, data transmission, warning and monitoring, environmental compatibility, etc.

[60] ISO/TC 197/SC 1 - Hydrogen at scale and horizontal energy systems
[61] IEC - TC 105 Dashboard> Scope

Conclusions

This report provides an overview on the latest advancements of the European hydrogen policies and standards. Since the last policies and standards reports in 2022, of the former Fuel Cells and Hydrogen Observatory, the EU policy and standards landscape has continued to expand covering the whole value chain of hydrogen. On a national level, the scope of the previous reports went beyond the borders of the EU. With the relaunched European Hydrogen Observatory, the scope is now limited to the EU level.

EU policies and legislation

Since 2022, many of the proposed EU legislations revisions of the Fit for 55 package have now been adopted, including Renewable Energy Directive, a EU Emission Trading System, Alternative Fuels Infrastructure Regulation, FuelEU Maritime, ReFuelEU Aviation and CO_2 emissions performance standards for cars, light duty heavy duty vehicles. In addition to many other proposals and funding initiatives of the EU Commission, and the new Green Deal Industrial Plan, including the Net-Zero Industry Act and Critical Raw Materials Act, these newly adopted EU legislations will have an increasing impact on the hydrogen sector throughout the whole value chain, rapidly increase the uptake of renewable hydrogen.

National hydrogen strategies

The previous report of 2022 included 13 European countries that had adopted national hydrogen strategies at the time, which now has increased up to 20. Most of the European national strategies have a strong emphasis on hydrogen production, distribution, storage, and end-use in mobility and industrial sectors, while fewer countries prioritize initiatives related to import/export routes, heating and energy, and technology manufacturing.

National policies and legislation

Compared to the 2022 report, a survey was now conducted across 28 European countries to collect the key national policies and legislations developed along the hydrogen value chain. Regarding hydrogen production, a significant majority of countries now provide support for capital expenditure (CAPEX) in renewable or low-carbon hydrogen plants, while a smaller but growing number of countries offer support for operational expenditure (OPEX).

Support for hydrogen injection in transmission grids is still limited, with only two countries offering schemes. In end-use sectors, a majority of countries support hydrogen adoption in mobility, particularly through purchase subsidies for fuel cell electric vehicles (FCEVs). Additionally, a smaller number of countries also start providing support of hydrogen use in industry. Overall, the survey demonstrates the varying degrees of support among European countries and a growing ambition on hydrogen adoption across the different steps in the value chain.

Codes and standards

Compared to the previous report and the former Fuel Cells and Hydrogen Observatory, the categorization structure of the standards and codes database is now updated. The EHO database now includes 104 searchable standards that are relevant to the emerging clean hydrogen sector, categorised according to the different stages of the hydrogen value chain. On a European level, there has been considerable progress, with 11 published standards that were either revised or newly developed between January 2022 and September 2023.

The standards included in the database were published by 23 different technical committees of standardisation bodies. Of these 23 technical committees, 5 are responsible for publishing around 75% of the standards.

Appendix

A.1.

Qualitative summary of national strategies content along the hydrogen value chain

Country	Production	Trade	Distribution & storage	End-use				Manufacturing	Education, research & development	Cross-cutting
				Mobility	Industry	Heating	Energy & back-up power			
Austria	√		√	√	√					
Belgium	√	√	√	√	√	√		√		
Bulgaria	√		√	√	√		√		√	√
Croatia	√		√	√	√	√	√		√	
Czech Republic	√		√	√					√	
Denmark	√		√							
Estonia	√		√	√				√	√	√
Finland	√		√	√					√	√
France	√			√	√				√	√
Germany	√	√	√	√	√	√	√	√	√	√
Hungary	√		√	√	√		√	√		√

Ireland	√	√	√	√	√		√			√
Luxembourg	√	√	√	√	√	√			√	√
Netherlands	√	√	√	√		√				√
Norway	√	√		√	√				√	√
Poland	√	√	√	√	√	√		√	√	√
Portugal	√	√	√	√	√	√	√	√	√	√
Slovakia	√		√	√	√	√	√	√		√
Spain	√		√	√	√		√	√	√	√
United Kingdom	√	√	√	√	√	√	√		√	√