Clean Hydrogen Partnership

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Synergies with Members States and Regions

Hydrogen Policies and funding strategies from European countries' national practitioners

WHITE RESEARCH

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Introduction

Task 1 of the tender "Technical Assistance to Generate Synergies with Members States and Regions" is dedicated to the assessment of various policy and funding initiatives to identify gaps and potential for synergies between national and/or local hydrogen strategies with the current Clean Hydrogen Partnership Strategic Research and Innovation Agenda[1] (SRIA). This analysis uses as a basis the currently available version of the SRIA, which was published in February 2022, and covers the programming period 2021-2027. However, the consortium is aware that the SRIA is currently under revision with an update expected by the end of 2023.

The report covers national and regional/local hydrogen (H2) strategies of the EU-27, as well as of the HE associated countries with representatives in the Clean Hydrogen Joint Undertaking State Representatives Group (SRG), namely Norway, Iceland, Türkiye, Israel and Georgia. Moldova was finally not included in the analysis, since no contacts are available in the SRG.

Scope of the report

For this report, the first activity focused on collecting publicly available information on national H2 policies and funding strategies of the EU-27, as well as of the HE Associated countries with representatives in the Clean Hydrogen Joint Undertaking SRG, namely Norway, Iceland, Türkiye, Israel and Georgia.

The second activity focused on making contact with the representatives of the Clean Hydrogen Partnership State Representatives Group (SRG), to ensure that the previously collected information is up-to-date, and to retrieve additional information, which was not publicly available via literature search.

Activity 2 is then broken down into the following steps:

- Step 2.1: *Drafting and circulating the questionnaire to Public Authorities*. The questionnaire (Annex 2) was circulated at the beginning of April 2023 to the SRG representatives
- Step 2.2: *Follow-up interviews with Public Authorities*. The interviews with those MAs, which expressed interest for a follow-up to provide additional information, were performed in May 2023.
- Step 2.3: *Elaboration of the first draft*. The first draft was circulated for comments on 21st June 2023.
- Step 2.4: *Integration of inputs* is planned to be performed by mid-July 2023.
- Step 2.5: *Publication of the final report "* now made publicly available.

[1] https://www.clean-hydrogen.europa.eu/about-us/key-documents/strategic-research-and-innovation-agenda_en

The consultation with the SRG was performed in a two-step approach:

- ***Use of questionnaire.*** The questionnaire was circulated in the first half of April asking for feedback up to end of April/first half of May. It is available in Annex 2.
- ***Conduct of Interviews.*** The information collected via the questionnaire was further complemented, whenever needed, by the interviews scheduled within the first half of May.

Content of the report

This document collects and presents in a structured way relevant information related to national H2 strategies, as available at the time of publication (June 2023).

A short summary with the main features of relevant regional strategies, which were mentioned by the SRG, is also available in Chapter 33.

Each selected country has dedicated a specific chapter, which summarises the main points of its national strategy, divided into the following paragraphs:

- **Governance:** ***Identification of authorities in charge of the development of national and regional H2 strategies.*** Relevant Ministries, National Agencies, Local Agencies, and other relevant public stakeholders are mapped. The objective is to identify which authority oversees the development and implementation of the hydrogen strategy, both at national and local levels. The contact points are expected to be found in the relevant hydrogen strategies at national and local level. Often, they coincide with already named representatives in the Clean Hydrogen Partnership State Representatives Group (SRG). However, in some cases, they differ.
- **Targets**: ***Listing of main targets, as identified in national hydrogen strategies.*** Relevant information will be collected on the main hydrogen targets, as identified in each national H2 strategy. The objective is to identify and list the main targets, with a focus on those with a clear quantification. This information provides a clear the direction and orientation of the national H2 strategy. A table summarissing the main national H2 targets with respect to EU startegies related to H2 is available as Annex 1.
- **Research and innovation priorities:** ***Correlation of research and innovation priorities in the Clean H2 SRIA with the ones identified in national hydrogen strategies.*** Research and innovation priorities identified at national level are listed according to the pillars of the Clean H2 SRIA[2]:
  - Renewable H2 production.
  - H2 transport, distribution and storage.
  - H2 end-uses:

[2] Strategic Research Challenges have not been included in the analysis, since none could be identified.

- Mobility application.
- Heat and power.
- Cross-cutting.
- H2 Valleys.
- Supply chain.

The objective being to provide an immediate overview of areas where synergies between the EU and national level are possible, and areas where gaps exist.

- **Funding instruments**: ***Identification of research and innovation programmes at national level available for H2 projects, and related budget envelop.*** A table per country will be prepared summarising available national funding programmes and, whenever possible, related budgets classified according to the previously defined research and innovation priorities. The objective is to provide an easily readable overview of the R&I funding programmes that national authorities are setting aside for the identified priorities This analysis will focus on national funding programmes, as well as EU funds, which are managed at national and/or local level, such as: structural and regional funds, Joint Transition Fund (JTF), Recovery and Resiliency Facility (RRF). Whenever available, specific regional funding programmes will also be listed.
- **Projects**: ***List of ongoing and planned projects at national level***. A list of projects, both ongoing and planned, funded by the previously mentioned programmes, will be provided per country. A short explanation will also be provided. Eventual issues arising from projects' implementation are also presented.
- **Overall framework: NECPs and other relevant strategies**: Identification of links and implications of the National Hydrogen Roadmaps in the revision process of NECPs (National Energy and Climate Plans), and other structural initiatives such as the AFI (Alternative Fuels Infrastructure) Plans, the Island Clean Energy Transition Agendas, the TJT (Territorial Just Transition) Plan. This paragraph identifies other energy policy and financing strategies where hydrogen is mentioned. The final objective being to ensure that a coherent policy and financing framework is in place at national level to support the deployment of hydrogen technologies.

This information collection exercise aims at providing relevant information, which will be further analysed and elaborated in Deliverable 1.3 with a view to identifying potential synergies and existing gaps with the Clean H2 SRIA.

Methodology

The document has been developed by complementing the information retrieved via literature review with the information provided by the SRG representatives both via the tailor-made questionnaire (Annex 2) and Teams' interviews.

Not all national hydrogen strategies are available in English or in a language spoken within the consortium. This has made it difficult to reach full understanding of the strategy. However, in this case, the authors have used translation software to be able to understand at least the main points.

Concerning regional strategies, at the moment, the document reports the most relevant ones which could be found via open Internet search, and which were pointed out by the SRG for their relevance.

Annex 3 details the focus areas of the tailor-made questionnaire, corresponding to the areas where limited or no information was collected via the literature review.

The information collection is, in some cases, partial:

- Not all contacted countries have replied to the questionnaire. For six countries (EE, FI, FR, GR, LT, MT), only literature review is available. This might make the chapter related to these countries incomplete.
- Not all contacted countries have replied approving the final draft of their chapter. This might leave some doubts about the completeness of the reported information.
- Some countries are in the process of finalising or updating their strategy. As a result, the collected information risks not being up-to-date.

Moreover, the information collection needs to be better streamlined, and additional guidance needs to be provided to SRG representatives to make sure that the collected information is as homogeneous as possible:

- ***Not all countries have the same targets included in their strategies***. A majority has electrolyser capacities as quantified target, since this is the main target included in the EU hydrogen strategy[3], adopted in July 2020. However, other targets categories differ: some countries use the percentage of H2 in the energy mix, others the number of H2-fuelled vehicles, or the percentage of hydrogen in the gas grid. This information provides an important indication on the areas where the country mainly wants to focus its hydrogen investments (H2 production, H2 use in mobility applications, in industry…).
- ***In most cases, research and innovation priorities are not included in the hydrogen strategy***, and in limited cases, they are listed according to the structure of the Clean H2 Partnership SRIA. In order to receive homogeneous information, therefore, we structured the questionnaire sent to the SRG according to the Clean H2 Partnership pillars.
- It is ***difficult to be exhaustive on the existing funding programmes*** at national and regional level, since, in some cases, there are quite a few. In the document, we have reported those that focus to research and innovation, excluding funding programmes that finance infrastructure development. However, in some cases, there is not such a clear cut. Moreover,

[3] https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/key-actions-eu-hydrogen-strategy_en

not all countries have specific programmes dedicated to hydrogen, but rather programmes funding energy research. In these cases, the amounts of available budgets for hydrogen research might not be clearly stated.

- ***It is difficult to be exhaustive on the ongoing and planned projects***, at national and regional level, since, in some cases, there are quite a few. In the document, we have reported the most relevant ones funded at national level, and those that are relevant for the Clean H2 Partnership, such as H2 Valleys and IPCEIs. We have also focused on research and innovation projects, excluding those which are mainly focused on infrastructure development.
- The last chapter presents ***other relevant energy strategies*** where H2 is mentioned, and that are relevant when defining a supportive policy and financing framework at national level. In this case, more precise information should be included in the questionnaire on the type of policies and strategies that should be included. Moreover, adoption and updates of new/existing policies can modify targets and related priorities. For instance, the NECP revision, expected by end of June 2023, should provide important additional information on national hydrogen targets, policies and funding strategies. However, this could not be taken into account in this document, due to timing.

Next steps

The information on national H2 strategies will be analysed and elaborated into Deliverable 1.3 “Report on the gaps and potential for synergies from around 30 European Countries Hydrogen strategies and the 2021-2027 SRIA of the JU”.
The scope and focus of this report was discussed at the TA4Synergies Steering Committee meeting, which took place on 1st June 2023.
One chapter will be prepared for each country, including the following information:

- ***Overall analysis***, in terms of:
  - Governance around three level:
    - Coordination between responsible Ministries and agencies.
    - Coordination between national and regional level.
    - Other stakeholders' involvement.
  - Targets:
    - Level of detail of the hydrogen strategies and/or roadmaps (comprehensiveness).
    - Targets coverage (electrolyser capacity, HRS, other infrastructure).
    - Other non-quantified targets.
  - Research and innovation priorities:
    - Areas of synergies with the pillars of the Clean Hydrogen Partnership SRIA.

        - Extent to which R&I priorities are contributing to (previously defined) targets' achievements.
    - Funding instruments:
        - Identified national/regional and EU funding instruments to support R&I priorities, and possibility for co-funding.
            - Readiness and experience of projects' co-funding.
        - Projects:
            - Ongoing (and planned) projects' coverage with respect to R&I priorities.
            - Awareness of difficulties related to projects' implementation and proposed measures.
        - Overall framework:
            - Identification of a revision process to ensure that new policy developments related to hydrogen are taken into consideration and vice versa.
            - Additional measures to support H2 economy.
- ***Identification of areas for synergies***, covering:
    - R&I priorities where further cooperation between national and EU levels can be strengthened.
    - Potential for synergy of national funding programmes with the Clean H2 SRIA.
    - Identification of best practices.
    - Technical Assistance for those countries which are in the H2 capacity building phase.
- ***Identification of existing gaps***, for instance, in cases where not enough projects are being funded under a given priority to reach the quantified target, as identified in the national H2 strategy.
- ***Recommendations*** in terms of national H2 strategy comprehensiveness and coherency, its links with other relevant strategies in the field of energy and mobility; coverage of national R&I priorities by existing funding programmes; areas for improvement.

The final Deliverable 1.3 is planned to be available in September 2023.

1. Austria

Climate-neutral hydrogen is an important enabler for the Austrian goal of climate neutrality by 2040 and for reaching a 100% of the national electricity consumption from renewable sources by 2030. Due to its wide range of applications, hydrogen can both help to ensure climate neutrality in sectors that are difficult to decarbonise – such as energy-intensive industry – and support the path towards a renewable energy system with decreased dependency on imported fossil fuel.

The **Hydrogen Strategy for Austria**[4] adopted in 2022 enables the targeted and efficient use of climate-neutral hydrogen in **strategic consumption sectors** based on concrete fields of action. The aim is to drive investments in **renewable hydrogen production** and at the same time promote sustainable business models.

The Strategy also includes an analysis to understand where hydrogen use is better suited, and where efforts should be concentrated upon:

- **Use in energy-intensive industry**:
  - As a feedstock in the chemical industry.
  - In the steel industry.
- **Mobility applications**:
  - In aviation.
  - In shipping.
- **In the energy systems**:
  - For peak load balance.
  - For storage and flexibility options.

Austria considers climate-neutral hydrogen in its strategy: both the one produced from renewable energy (“green hydrogen”) and the one produced from fossil fuels with complete CO2 capture (“blue hydrogen”), or through pyrolysis (“turquoise hydrogen”) from natural gas.

1.1. Governance

The two Ministries responsible for the “Hydrogen Strategy for Austria” are the one on **Climate Protection, Environment, Energy, Mobility, Innovation and Technology** (BMK- also in the

[4] *Wasserstoffstrategie für Österreich (Hydrogen Strategy for Austria), Federal Ministry Republic of Austria- Climate Action, Environment, Energy, Mobility, Innovation and Technology, AND Federal Ministry Republic of Austria- Labour and Economy, 2022:* [Wasserstoffstrategie für Österreich (bmk.gv.at)]

States Representative Group of the Clean Hydrogen Partnership), and the one on **Labour and Economy** (BMAW).

A **task force** consisting of representatives of the responsible ministries will be set up to implement the Austrian hydrogen strategy. For the greatest possible transparency and integration of relevant stakeholders in the implementation process, the work of the task force will be supported by an Advisory Board of experts of the national hydrogen **Platform H2Austria**. It will ensure communication and dialogue while compiling the competences and activities of research, academia, energy industry and civil society to promote cooperation, synergies, and awareness. The task force will coordinate and ensure the implementation of the Hydrogen National Strategy and will meet at least once a year.

The forementioned national hydrogen Platform H2Austria provides a platform for exchange between private and public stakeholders and between managing authorities to bundle the perspectives, competencies and activities of research, industry, the energy sector and civil society in a dialogue process.

The Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology will submit to the Austrian Parliament from 2023 and every two years thereafter an evaluation report on the implementation of the strategy and its individual measures.

The **Austrian Research Promotion Agency (FFG)** is the national funding agency for industrial research and development in Austria. It is owned by the Republic of Austria, represented by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) and the Federal Ministry for Labour and Economy (BMAW).

No specific regional strategies are being developed in Austria. However, regional governments can decide to fund some H2 projects with regional funds. In order to increase consistency in the use of national and regional funds, and avoid overlapping whenever possible, the Austrian government is launching the H2 Platform Austria.

Some relevant Managing Authorities:

- **Office of the Austrian Conference on Spatial Planning** for Programme ERDF/JTF 2021-27: Investments in employment, growth and the transition to a low-carbon economy in Austria 2021-2027.
- **Office of the Government of Lower Austria** for (Interreg VI-A) Austria-Czechia.
- **State Government, Department of Regional Planning**, Coordination Office for EU Regional Policy for (Interreg VI-A) Austria-Germany/Bavaria.
- **City of Vienna**, Department for European Affairs for (Interreg VI-B) Central Europe.

1.2. Targets

The main targets of the Hydrogen strategy for Austria are:

- Replacing fossil-based hydrogen with climate neutral hydrogen in energy intensive industries: 80 % until 2030.
- Deployment of 7,5 TWh of renewable gases including hydrogen by 2030 through a green gas quota.
- Installation of **1 GW electrolysis capacity** by 2030.
- Creation of a supporting framework to produce renewable hydrogen.
- Establishing the production of hydrogen as an integral part of the energy system.
- Development of a targeted hydrogen infrastructure.
- Enhancing international partnerships for climate neutral hydrogen.
- Strengthening the innovation and technology potential in Austria through focused development of hydrogen technologies.
- Establish an integrated market for renewable hydrogen.

Regarding infrastructure, an extensive analysis on adaptation of pure natural gas pipelines and locations for renewable gas production will be made as part of the integrated Austrian network infrastructure plan (NIP, Draft to be published in June 2023).

1.3. Research and innovation priorities

When compared to the research and innovation priorities of the Clean H2 Partnership for the period 2021- 2027, Austria focuses on:

- **Renewable H2 production**:
  - Electrolysis
  - Biogenic hydrogen production through biomass-gasification- processes
  - Methanation
- **H2 storage and distribution:**
  - H2 in large scale storage in underground gas reservoirs
  - H2 in natural gas grid
  - H2 refuelling stations
- **H2 end-uses**:
  - Mobility applications (mainly focus on trucks and buses)
  - Clean heat and power (focus on decarbonisation of hard-to-abate sectors)
- **Cross-cutting issues**:
  - Safety, Pre-Normative Research and Regulations, Codes and Standards

- **Hydrogen Valleys*: Wasserstoffinitiative Vorzeigeregion Austria Power&Gas (WIVA P&G)*** It pursues demonstrating the conversion of the Austrian economy to a largely CO2-neutral structure with the production and use of renewable hydrogen as an important component.
  WIVA P&G now supports and accompanies eight cross-sector projects with a total investment of around 79 million Euros. (www.wiva.at)

In the area of **mobility**, links will be made through R&D and demonstration funding programs for zero-emission technologies (including hydrogen) in the mobility sector (e.g., **RTI Agenda Mobility 2040, Zero-Emission Mobility, European Strategic Research & Hydrogen Agenda "Green Hydrogen"**). Focus on trucks and buses by the programs EBIN (emission-free buses and infrastructure) and ENIN (zero-emission commercial vehicles and infrastructure) in 2022.

1.4. Funding instruments

An overall investment of 937 million euros is foreseen in the strategy to reach the target related to the electrolyser capacity.

Austria participates actively in the implementation of EU hydrogen value chains. It has deployed a budget of **125 million euros** for the first *Important Projects of Common European Interest (IPCEI)* and is part of the "European Clean Hydrogen Alliance" and of the "Clean Hydrogen Partnership".

Austria has already implemented through the Renewable Energy Expansion Act package the legal simplified framework enabling of **electrolysis plants for grid integration** in the ElWOG, this act is under the Renewables Deployment Act (EAG) which subsidises electrolysis facilities producing renewable hydrogen (minimum of 1 MW capacity) with a **fund of 40 million euros per year,** and enables exemptions for hydrogen from renewable energy subsidy fees, grid fees for electricity and grid fees for natural gas used for blending purposes.

Additional funds deployed by the Austrian government include:

- "**Transformation of the Economy**" program of the Climate and Energy Fund supports companies in emissions trading, in avoiding process-related emissions (2022-2026, 100 million euros) and also by training opportunities for job creation.
- **Industry transformation** (if not funded in the EAG) - 2,975 billion euros by 2030 (175 million euros in 2023, 400 million euros per year thereafter).
- "**Umweltförderung im Inland**" (UFI): Promotion of climate protection measures by companies, municipalities and associations with an annual commitment framework of 150 million euros. The focus is on the use of renewable heat, waste heat recovery, energy efficiency measures and resource efficiency.
- Funding programme on **emission-free buses and infrastructure** to support additional investment costs for vehicles and infrastructure (2022-2026, 406 million euros).

- Funding program on **emission-free commercial vehicles and infrastructure** (2022-2026, 455 million euros).
- **Clean Energy Transition Partnership TRI 3:** Implementation of the SRIA of the Green Hydrogen Agenda Process through transnational tenders with European/international partner countries (2022-2023: budget of 3,5 million euros).
- **R&I Mobility Strategy** (2023: up to 4.8 million euros for fuel cells and hydrogen activities).

The Table below summaries the existing funding programmes, the available budget and the priorities.

Programme Name	Level	Budget	Priorities
N.A.		937 million euros up to 2030	Electrolyser capacity (1 GW)
IPCEI	National	125 million euros up to 2022	Hydrogen generation; Fuel cells; Transport, distribution and storage; Application in industry
Transformation of the Economy	National	100 million euros (2022- 2026)	Industry decarbonisation
Industry Transformation	National	2,975 billion euros up to 2030	Industry decarbonisation (not covered by previous fund)
Umweltförderung im Inland (UFI)	National	150 million euros	Renewable heat, waste heat recovery, energy efficiency measures and resource efficiency
Emission-free buses and infrastructure	National	406 million euros (2022- 2026)	Investment costs for vehicles and infrastructure
Emission-free commercial vehicles and infrastructure	National	455 million euros (2022- 2026)	Investment costs for commercial vehicles and infrastructure
CETP/TRI3	Trans-national	3,5 million euros (2022-2023)	Implementation of the SRIA of the Green Hydrogen Agenda Process
R&I mobility strategy	National	Up to 4,8 million euros (2023)	Fuel cells and hydrogen activities

Table 1. Austria's available funding programmes and description.

Both IPCEIs and a part of the Transformation of the Economy programmes (100 million euros) are using funds from the Recovery and Resilience Fund (RRF). As part of the European Project of Common Interest (PCI) process three transmission system operator projects in the hydrogen infrastructure category are pending on selection to receive funds from the Connecting Europe Facility funds.

An overview of the numerous hydrogen programs and funding lines can be found under the online national official platform *Förderungen: H2Austria.*

Austria has experience in the synergetic management and coordination of European and national/regional H2 funding as it is part of the Clean Energy Transition Partnership (CETP) of the Horizon Europe programme. More specifically, the related action correspondent to hydrogen

is part of the Transition Initiative 3 (TRI 3) which addresses enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS. It is believed that more synergies could be implemented between CETP/TRI 3 and the Clean Hydrogen Partnership in co-funding some projects.

1.5. Projects

At present Austria has the following demonstrations and deployment of hydrogen projects:

- **IPCEI** along the value chain:
  - Hydrogen generation and storage: AVL and Christof industries.
  - Fuel cells technology: Plastic Omnium AT.
  - End-user technology: Plastic Omnium AT and Bosch AT
  - Hydrogen applications in industry: Borealis and Verbund.
- **HiPoLiq:** Demonstration of highly efficient Power to Liquid Plant (AVL)
- **Hydrogen Valley** (funded with national and private funds)**:**
  - WIVA P&G (WASSERSTOFFINITIATIVE VORZEIGEREGION AUSTRIA POWER & GAS):
    - ***HyWest***: regional green hydrogen economy in Tyrol (FEN Sustain Systems, MPreis, Zillertaler Verkehrsbetriebe, TIWAG, TIGAS).
    - ***H2Real***: first industrial demonstration of up to 15 vol.% hydrogen at an existing gas turbine in Donaustadt, Vienna and installation of a 2.5 MWel PEM-electrolysis-system demonstrating gas grid injection, use of green hydrogen in the public and heavy-duty transport as well as use of process waste heat (Wiener Stadtwerke)
- **HyGrid^2:** natural gas steel pipeline section re-purposed for hydrogen transport (Energienetze Steiermark and Bilfinger Industrial Services).
- **HyFor:** Hydrogen-based fine-ore reduction pilot plant at the Donawitz site in Styria (Primetals Technologies and voestalpine).
- **SUS-F:** follow-up of SuSteel (Sustainable Steelmaking) at the Donawitz site in Styria.
- **H2Pioneer:** onsite PEM electrolysis plant, operated with renewable electricity, demonstrated in Villach (Infineon and Linde).
- **Renewable Gasfield**: green hydrogen production via electrolysis and load-flexible, double stage catalytic methanation on a large scale, and distributes the produced SNG in the existing gas grid (Energie Steiermark).
- **UpHy I & II**: developing solutions for official calibration of gas quality and dispensed hydrogen mass and construction of a 10MW PEM electrolyzer to substitute grey hydrogen in the refinery.
- **Underground Sun Storage 2030**: large-scale storage of renewable hydrogen in pure form in an underground gas reservoir in the municipality of Gampern, Upper Austria (RAG

Austria AG, Axiom Angewandte Prozesstechnik GmbH, Energie AG Oberösterreich, EVN AG, VERBUND, voestalpine Stahl GmbH).

Projects have experienced delays in their implementation timeline mainly due to the current inflation in the energy market, and due to the difficulty in the supply of some fundamental components and materials for the production of electrolysers.

1.6. Other policies and measures

Hydrogen is considered in several aspects in the **Austrian NECP** of 2019, since it is envisaged as a renewable key energy source to achieve its goal of consuming 46-50% of renewable, and source 100% of electricity. In terms of taxes, advantages like exemptions are established. The Austrian NECP is currently under revision, and its draft should be made available by June 2023. However, it is not available at the time of drafting this document, and its updates cannot be included.

Austria takes part in the **Pentalateral Energy Forum**, a regional cooperation framework made up of energy ministers from the Benelux nations (Belgium, Netherlands, Luxembourg), Austria, Germany, and Switzerland created in 2005 to facilitate cooperation on European energy policy.

Austria is amongst the Member States which address hydrogen infrastructure in their national policy frameworks (NPFs). Austria will revise the regulation on the establishments of the Infrastructure of Alternative Fuels (AFIR) for a rapid standardization of hydrogen refuelling for heavy vehicles. Moreover, for aviation, a blending commitment is being negotiated to encourage sustainable aviation fuels. Moreover, an Austrian Network Infrastructure Plan (NIP) is expected to be published in June 2023[5], and should include an extensive analysis on adaptation of pure natural gas pipelines and locations for renewable gas production.

The **Austrian Recovery and Resilience Plan (RRP)**[6] also supports the following investments related to hydrogen:

- ***Charging infrastructure*** (which should be in place by 2026):
  - Installation of the charging infrastructure (overnight/deposit and occasional loading at stops), overhead contact lines and hydrogen refuelling points necessary for the operation of at least 682 zero -emission buses.
  - Installation of the charging infrastructure and hydrogen refuelling points necessary for the operation of at least 2 767 zero -emission utility vehicles.
- ***Hydrogen production capacity*** from renewable sources of at least 200 MWh to be installed by end of 2025.

[5] Not known at the time of wiriting this Document.
[6] ANNEX to the Council Implementing Decision on the approval of the assessment of the recovery and resilience plan for Austria, July 2021: https://data.consilium.europa.eu/doc/document/ST-10159-2021-ADD-1/en/pdf

- ***Support to IPCEI Hydrogen***: The general objective of the planned investment is to help building a national and European hydrogen ecosystem to contribute to the achievement of Austria's and the EU's climate objectives. Austria's ambition is to be firmly anchored in the renewable hydrogen value chain. The planned investment aims to promote integrated projects along the hydrogen value chain, especially covering hydrogen production, storage and applications. Following a call for interest, the investment shall provide funding to selected projects, focusing in particular on energy-intensive industrial and mobility sectors that are difficult to decarbonise as well as on R&D/FID of components. The implementation of the investment shall be completed by 31 August 2026.

Austria will receive in total €136 million (in current prices) under the **Just Transition Fund** to ensure that the transition to climate neutrality does not leave anyone behind in the Austrian local economy and society. No specific information was found on whether some of these funds are going to be dedicated to hydrogen.

Austria, jointly to other 24 EU Member States participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen** (18th March 2022)[7]. Austria's role focused on the participation to national expert groups and task forces as well as on the coordination of the pan-European and transdisciplinary workshop on hydrogen market stimulation.

[7] Expert groups of the agenda process (2022). Strategic Research and Innovation Agenda. Key findings and conclusions of the agenda process for the European research and innovation initiative on green hydrogen. Final version. *https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/en/green-hydrogen-for-a-sustainable-future.html*

2. Belgium

Within Belgium, the hydrogen competences are split between the federal government (**SPF Economie department of Energy**) and the three regions of Wallonia, Brussels and Flanders.

All federated entities (except for the Brussels region) have hydrogen strategies in place and they work together through the hydrogen workgroup ENOVER/CONCERE.

In addition, the Belgian Hydrogen Council, an industry-led council, was set up to advise all governments in Belgium on hydrogen related matters. The Belgian Hydrogen Council is co-ordinated by WaterstofNet (Flanders) and Cluster Tweed (Wallonia).

The two representatives in the States Representative Group of the Clean Hydrogen Partnership come from the regional governments (Flanders and Wallonia).

2.1. Governance

Federal government

The Belgian federal government adopted its first hydrogen strategy in October 2021, which was updated in October 2022[8] to align it to the REPower EU ambitions.

The federal government identifies four sectors where renewable H2-molecules and H2-derivatives will help to make climate neutral by 2050:

- The **industry** and the **heavy transport** will drive the initial increase in demand for H2-molecules and H2-derivatives.
- The **power sector** will follow with its flexibility needs and for coping with longer periods with little wind and sun.
- The **building sector** could partially rely on H2-molecules and/or H2-derivatives on the longer run.

The total domestic demand for both H2-molecules and H2-derivatives is expected to raise to 125 – 200 TWh/year in Belgium by 2050 (bunkering fuels included).

The Belgian Hydrogen strategy has four pillars that overview the general objectives:

- Positioning Belgium as an import and transit hub for renewable molecules in Europe.
- Expanding Belgian leadership in hydrogen technologies.

[8] *Vision and Strategy Hydrogen, SPF Economie department of Energy, update 2022 (first verion in October 2021): Stratégie fédérale belge pour l'hydrogène | SPF Economie (fgov.be).*

- Establishing a robust hydrogen market.
- Investing in cooperation as a key success factor.

The main **barriers** identified by Belgium to meet these objectives relate to the uncertainties of the energy **price levels**.

Other relevant federal Managing Authorities are:

- Walloon Government, represented by the **Minister-President responsible for coordinating the Structural Funds** for ERDF 2021-2027 Wallonia.
- **Flemish Agency for Innovation and Entrepreneurship** for ERDF 2021-2027 Flanders and other regional funding programmes Research and innovation priorities

2.2. Targets

- Belgium expects to develop **100 to 160 km of additional H2 pipelines** by 2026 and to interconnect with Germany, France, and the Netherlands by 2028 under non-discriminatory third-party access conditions and has for this aim invested **95 million euros** from the National Recovery and Resilience Plan [9].

- To position Belgium as an **import and transit hub** for renewable gases (H2-molecules and H2-derivatives: estimated imported amount of **20 TWh in 2030** and between 200 and **350 TWh in 2050**), three routes are envisaged:
    - **North Sea pipeline**. In 2022, Belgium, Denmark, Germany and The Netherlands committed themselves to develop 65 GW of offshore wind, **20 GW of renewable hydrogen in the North Sea by 2030** and 150 GW of offshore wind by 2050.
    - **Southern route (pipeline)**. The European Hydrogen Backbone initiative foresees a pipeline connection between the North of Spain and Belgium already by 2030, passing through France and Germany before arriving to Belgium via Liège.
    - **Shipping route**. The shipping route is expected to become the most competitive and thus the preferred solution for supplying H2-derivatives to Belgium. The federal government is committed to facilitating the opening of the shipping route. It has therefore concluded MoUs with Oman and Namibia and is launching a call for project for the demonstration of technologies allowing for the import of H2-molecules or H2-derivatives and the injection of gaseous H2-molecules in the hydrogen transport network.

[9] *Plan national pour la reprise et la résilience en Belgique, June 2021: https://dermine.belgium.be/sites/default/files/articles/FR%2020Plan%20national%20pour%20la%20reprise%20et%20la%20re%CC%81silience.pdf*

- At least **150 MW of electrolysis capacity** are expected to come into operation by 2026. Though, overall, Belgium believes that electrolysis capacity will remain limited in Belgium because of the limited local renewable energy potential.

2.3. Research and innovation priorities

The Belgian Hydrogen Strategy highlights the importance to support a strong research and innovation environment related to hydrogen technologies, given that a wide community is already working on the different technological paths related to hydrogen.

A **Research Platform for Energy Transition**, supporting universities and research centres from the regions of Brussels and Wallonia, is also being set up, and should be fully operational in 2025.

Regions

Flanders (BE)

In the Flemish coalition agreement 2019-2024, the Flemish government has included a strong Flemish ambition for hydrogen: “We continue to invest in research and development into sustainable energy and climate solutions. Our ambition in this respect is to become a European leader in, among other things, hydrogen”.

Moreover, a **Flemish Hydrogen Vision** was adopted in 2020[10]. The Flemish Hydrogen vision does not contain any concrete targets or numbers, but it identifies five strategic objectives:

- Supporting excellent research in hydrogen in Flanders knowledge centres (universities and strategic research centres). It also includes the **Moonshot program** (launched in 2019), a future-oriented industrial innovation program that aims to achieve a CO2-neutral industry by 2050. The yearly inventory can be found here.
- ***Strengthening the Flemish industrial ecosystem***. The goal is to strengthen the technological supply side through the use of existing instruments, improvement of these instruments, use of the new opportunities offered by European initiatives, and the optimal combination of Flemish and European funding channels such as the programmes from the Flemish Agency of Innovation and Entrepreneurship and the Spearhead Clusters. The Hydrogen Industry Cluster is co-ordinated by WaterstofNet, the Flemish knowledge and Network Platform, supported by the Flemish Government. Flanders supports this ecosystem with several R&I programmes (co-ordinated by the Flemish Agency Flanders Innovation and Entrepreneurship) and in addition supports R&I activities of the Spearhead Clusters, including the Hydrogen Industry Cluster.

[10] *A Flemish Hydrogen Strategy 2025-2030. Waterstof Industrie Cluster.* *http://www.waterstofnet.eu/_asset/_public/WIC/2020-12-7-Flemish-Hydrogen-Strategy_Hydrogen-Industry-Cluster.pdf*

- ***Stimulating the use of hydrogen and the application of H2 technologies***. The Flemish Government is providing 106.3 million euros to support the first five projects. Flanders supports the implementation of hydrogen technologies and the use of hydrogen, especially in view of the sustainable transition of the industry, which is a priority in Flanders. Several instruments are in place, e.g. economic support instruments, co-ordinated by the Flemish Agency Flanders Innovation and Entrepreneurship.
  In addition, the European IPCEI on Hydrogen Technologies and Systems also has a focus on the support to implementation of hydrogen and hydrogen technologies in general.
- ***Facilitate international partnerships***. Flanders wants to expand its international cooperation with neighbouring countries/regions such as the one with the Netherlands (High Tech cooperation) and with Germany (signed MoU) with regard to both policy formulation and investment opportunities. This includes the further development of innovation cooperation with the Netherlands to seize the opportunities of a cross-border ecosystem.
- ***Flanking policy to stimulate and support***. Flanders will continue to develop a favourable framework for hydrogen through a coordinated approach among all relevant policy fields in Flanders and through a constructive dialogue and cooperation with the federal government and the other regions in Belgium.

WaterstofNet is the Flemish knowledge and collaboration platform that advises the Flemish government and gives support to the implementation of the Flemish hydrogen strategy. WaterstofNet also coordinates the **Flemish Waterstof Industrie Cluster (Hydrogen Industry Cluster)**, a cluster of more than 150 members from all parts of the hydrogen value chain. The cluster has members from the whole Benelux (Flanders, Wallonia, Brussels, the Netherlands and Luxembourg.

WaterstofNet and the Flemish Hydrogen Cluster have a close collaboration with the Netherlands and Flanders. This collaboration started as an Interreg project -collaboration in the period 2009-2021 (**Interreg project Hydrogen Region 2.0**.)

Wallonia (BE)

The Walloon government is still working on its regional hydrogen strategy expected to be approved by June of 2024. As a result, there are no official targets for 2030 or 2050 yet for Wallonia. References have been included in the Regional Energy and Climate Plan (RECP), where there has been established a policy to “develop a Walloon low-carbon hydrogen industry”. By this measure five objectives are stated:

- Establish a legal, administrative and juridic framework for certification, guidance and clarification of competences.

- Write a plan together with the gas distributors of the region (GRD) to inject gas in the network and study the feasibility of alternative transport vectors.
- Name a consortium with the public stakeholders of Wallonia to write a plan to identify final clients and synergies with programmes with limiting regions to plan pilot projects.
- Reinforce the research and innovation in the hydrogen sector. Wallonia has an industrial cluster who has developed a vision document on hydrogen. The mission of the **Cluster TWEED** is to pave the way for the setting up of high quality and industrial-size projects in the fields of production and exploitation of sustainable energy. The Cluster animates six different ecosystems, of which a club dedicated to hydrogen called the "**H2Hub Wallonia**". Cluster Tweed has drafted a Walloon Hydrogen Roadmap ("H2 Roadmap pour la Wallonie") in 2018. This study, validated by the Walloon industry, analysed the role of hydrogen in the region by 2030 and 2050. Additionally, a **Research Platform for Energy Transition** is being set up to support universities and research centres from the regions of Brussels and Wallonia by 2025.

The forementioned objectives are specified by the following quantitative targets:

- **Production**: High power electrolysers (100 MW), plasmolysis (to prevent the release of methane coming from the former Walloon coal mines to reach the atmosphere), CO2 capture and conversion into fuels.
- **Transport**: develop jointly HRS and electric refill on the same localization. Use HRS both for heavy road traffic and for inner waterways freight traffic.
- **Skills**: develop professional skills at every level in hydrogen-linked sectors.

Belgium's Walloon Region has co-funded H2-related projects in the field of research as well as in industrial applications of hydrogen jointly with other European and national budgets. Some delays have been experienced due to the uncoordinated timing of allocation of funds from the different programmes managed by independent governance bodies. The priorities of the region in terms of hydrogen are to develop high power electrolysers (at least 100 MW being done by IPCEI project), investigate the plasmolysis (prevent methane release from coal mines) and the CO2 capture and conversion into fuels technologies, heavy road (hydrogen target of 1 % by 2030 in personal vehicles and 5 % in bus and autocar) and inner waterways freight transport as well as the instalment of necessary refilling stations (target of 10 HRS by 2025 and 20 by 2030).

2.4. Funding instruments (federal and regional)

Several funds at the federal level and at the level of the regions are available to support the development of research and innovation related to hydrogen technologies, as well as to establish a strong hydrogen value chain in Belgium. Federal funding includes the following programmes:

- The **Energy Transition Fund** supports, among other things, research and development on the production, transport and storage of hydrogen and its derivatives. It has been active since 2017, will operate until 2025 and subsidises various projects following an annual call for projects for a total amount of **20 to 30 million euros per year**.
- Hydrogen is included in the Belgian RRP with the following foreseen investments:
  - **Network for H2 and CO2 transport**: 95 million euros from the federal level.
  - **Industrial value chain for hydrogen transition**: 50 million euros from the federal level; 125 million euros from the Flemish level; 117,20 million euros from the Wallonia region.
  - The call for projects **Clean Hydrogen for Clean Industry (CHCI)** is organized within the framework of Belgium's National Recovery and Resilience Plan (RRP). It focuses on the development of promising technologies for the production and use of hydrogen and its derivatives with a relatively high maturity level. A first call was launched in April 2022 for a total support of maximum **50 million euros**. A second one will be launched in 2023 for a total support of **10 million euros**.
- The **H2 Import Call** focuses on the development and demonstration of technologies that enable the import of hydrogen, and its injection on a hydrogen transport network. This call will be launched in early 2023, with an envelope of **10 million euros**.
- The federal government has foreseen an envelope of **300 million euros** to accelerate the interconnection with Germany to be operational by 2028.

The Table below summarises the existing funding programmes, the available budget and the goals.

Programme Name	Level	Budget	Priorities
Energy transition Fund	Federal	20 to 30 million euros/year (2017- 2025)	Research and development on the production, transport and storage of hydrogen and its derivatives
Network for H2 and CO2 transport	NextGenEU/Federal	95 million euros until 2026	To develop 100 to 160 km of additional H2 pipelines and reinforce the hydrogen infrastructure
NextGen EU (RRP)	NextGenEU/Federal	50 million euros	Industrial value chain for hydrogen transition
	NextGenEU/regional	≥ 125 million euros (Flanders) 117,20 million euros (Wallonia)	
H2 import call	Federal	10 million euros (call to be launched in 2023)	To support development and infrastructure to facilitate H2 import
N.A.	Federal	300 million euros up to 2028	Hydrogen infrastructure for interconnection with Germany
Hydrogen research infrastructures RRP programme	Regional (Flanders)	4,56 million euros (2022)	hydrogen research infrastructures
The Flemish Moonshot R&I programme.		20 million euro yearly (including hydrogen production technologies)	hydrogen production technologies
Spearhead Clusters		Dedicated financing envelope/cluster	Cluster and interclusterprojects
Research Foundation Flanders (FWO)		Bottom-up programme	fundamental and strategic academic research at universities and scientific research institutes in Flanders

Flanders Innovation and Entrepreneurship		Bottom-up programme	R&I and investments for companies in Flanders
SPW Research (IPCIE)	Regional (Wallonia)	103 million euros (2021)	Decarbonization industry
SPW Energy		34,8 million euros (2021)	Decarbonization transport/Production H2
SPW Mobility and Infrastructures		500, 000 euros (2021) 8,520 million euros	Study on alternative fuels for inner water transport Refill pilot station for alternative fuels (H2 included) for inner water transport

Table 2. Financial mechanism available for Belgian (federal and regional) Hydrogen Projects.

Belgium's Walloon Region has some experience in co-funding H2-related projects in the field of research and deployment.

Some research projects are directly supported by regional funding, some by ERDF or RRF (in the case of IPCEI). Development nd deployment projects are supported by Kyoto funding as well as RRF[11].

2.5. Projects (federal and regional)

Some important Belgian projects (both regional and federal) are listed. This is a non-exhaustive list.

- The federal government supports the development of the **VKHyLab**, a test infrastructure which will help research institutes and companies to scale up their H2technologies. The government invests 1.5 million euros in the acquisition of the site and subsidies the Von Karman Institute of fluid dynamics with an additional 14.7 million euros to develop this project. This test facility will be operational by 2025.
- Belgium (both federal and regions) participate in the IPCEI Hydrogen. Proposed participation in 15 **IPCEI** projects[12]. Those so far approved under Hy2Tech and Hy2Use being**:**

[11] *https://www.agoria.be/en/market-development/relance/call-for-hydrogen-projects*
[12] Full list of proposed IPCEIs available here: Microsoft Word - 20210930_Update_List_BE_Direct participants.docx (fgov.be)

  - ***Cummins*** to expand its PEM electrolyzer manufacturing capacity at its Oevel factory to 1 gigawatt (GW)
  - ***John Cockerill Hydrogen***: research and innovation project dedicated to the design of a 5 MW, 1000 Nm³/hr alkaline electrolyzer at 30 bar and the industrialization of its large-scale production in Belgium and France.
  - ENGIE Belgium, and TechforLime are involved in the ***COLUMBUS project***: an innovative carbon capture and utilization project in Wallonia. This project will concentrate CO_2 from an innovative type of lime kiln, and combine it with green hydrogen to produce synthetic methane, a renewable gas that will be injected into the gas grid or used in the transport or industrial sectors.
- **Hydrogen Valley: Ports of Flanders** (EU, national, regional and private funding). Cross-sectoral collaboration between the Port of Antwerp-Bruges, North Sea Port, Port Oostende, several industrial players located in the area and the national gas TSO. Here, international import is combined with local production of green and blue hydrogen, facilitating the decarbonisation of several industrial off-takers, both locally as well as in the hinterland of Belgium and beyond through its connection with the European Hydrogen Backbone. This is part of the larger **Green Octopus**, which aims at creating a hydrogen backbone and ecosystem and hydrogen ecosystem between Belgium - The Netherlands – Germany, with links to France and Denmark, serving clean hydrogen supply and demand, facilitated by the ports. Green Octopus is implemented through several projects funded by all governments in BE (IPCEI, additional federal and regional funding).
- According to the EHB initiative, perspectives for **hydrogen infrastructure development**: The Belgian national backbone is expected to emerge through developments mainly in and around the industrial clusters of Antwerp and Ghent, and along the industrial valley in Wallonia. Given the proximity between Antwerp and Rotterdam, port-to-port interconnections with the Netherlands are likely. In addition, interconnections with France and Germany will provide Belgium access for import/export of hydrogen from/to neighbouring countries. Hydrogen demand in Belgium in 2040 is expected to exceed production capacity, so imports and exports with all neighbouring countries including the UK – if technical and economic conditions are right – and imports through the Zeebrugge terminal could be paramount in shaping the North-Western European Hydrogen infrastructure development. As such, thanks to all the interconnections and import facilities, Belgium will have become a true hydrogen hub importing and transiting H2 to neighbouring countries.

Some of hydrogen projects in Wallonia have been suspended or delayed due to the difficulties to respect some rules for the use RRF, mainly related to timing. Other problems have emerged from a misunderstanding of certain GBER (General Block Exemption Regulation) articles resulting in an unappropriated decision by the competent authorities. Solutions to both problems are currently being sought and are on the way to be solved.

2.6. Other policies and measures

Hydrogen is recognised in the Belgian NECP (2019) as being a vital technology in the energy transition as it enables the decarbonisation of certain market segments that have few other alternatives.

Both the federal government and the regions have hydrogen strategies in place, in line with their competences.

The Flemish Hydrogen strategy (November 2020) is supported by WaterstofNet, the Flemish knowledge platform in hydrogen and coordinator of the Hydrogen industry Cluster in Flanders. This strategy and priorities will be integrated in the updated NECP.

From the regional perspective, the Walloon Region has included references to H2 in the update of its RECP (Regional Energy and Climate Plan) and is now elaborating its Regional Strategic Plan for H2 (expected by June 2024).

Belgium participates as an active member in the **North Seas Energy Cooperation (NSEC)** along with Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden and the UK. The governance focuses on the development of the offshore grid development and the large renewable energy production (76 GW by 2030, 193 GW by 2040) in the region. Plans for hydrogen connections are underway.

Belgium jointly to other 24 EU State Members participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

3. Bulgaria

Bulgaria produces about 5 % of Europe's hydrogen, mostly of grey category for industrial use.

At the meeting held on 26/04/2023, the Council of Ministers of the Republic of Bulgaria adopted the „***National Roadmap for improving the conditions for deploying the potential for the development of hydrogen technologies and mechanisms for the production and supply of hydrogen*** ".[13]

The **Ministry of Innovation and Growth** was responsible for the preparation of the document in relation with the implementation of Reform C4.R7 "Developing the potential of hydrogen technologies and hydrogen production and supply" in the National Recovery and Resilience Plan."

The adopted hydrogen roadmap defines several operational goals for the development and use of potential hydrogen technologies:

- Promotion of the consistent and effective introduction of technologies for the production, transportation and use of green hydrogen in industry, energy and transport.
- Intensification of research and innovations.
- Creating conditions for education and training for new professions and jobs and for an informed consumer and administrative environment related to hydrogen technologies.
- Promotion of European and international cooperation.

Moreover, the **Energy Strategy** is a fundamental document of the national energy policy that is approved by the Council of Ministers and passed by the National Assembly of the Republic of Bulgaria. The present National Energy Strategy till 2020 reflects the political vision of the government on the European development of Bulgaria according to the up-to-date European energy policy framework and the global trends in the development of energy technologies.

The main priorities in the Energy Strategy can be summarized along the following five directions:

- To guarantee the security of energy supply.
- To attain the targets for renewable energy.
- To increase the energy efficiency.
- To develop a competitive energy market and policy for the purpose of meeting the energy needs.
- To protect the interests of the consumers.

[13] *Национална пътна карта за развитие на водорода (2023). Министерство на Иновациите и растежа. naczionalna-patna-karta-za-podobryavane-na-usloviyata-za-razgrasthane-na-potenczziala-za-razvitie-na-vodorodnite-tehnologii-i-mehanizmite-za-proizvodstvo-i-dostavka-na-vodorod.pdf (government.bg)*

These priorities also determine the Government's vision for the development of the energy in the coming years, namely:

- Maintaining of a safe, stable and reliable energy system.
- The energy sector remains a leading branch of the Bulgarian economy with definite orientation to foreign trade.
- Focus on clean and low-emission energy – nuclear and renewable sources.
- Balance between quantity, quality and prices of the electric power produced from renewable sources, nuclear energy, coal and natural gas.
- Transparent, efficient and highly professional management of the energy companies.

3.1. Governance

The Energy strategy (NCEP) of 2020 was written by the **Ministry of Economy, Energy and Tourism** and approved by the Council of Ministers in accordance with Art. 4, Paragraph 2, Point 1 of the Energy law.

The **Ministry of Innovation and Growth** is in charge of the development and implementation of the hydrogen strategy. It coordinates the development and implementation of the hydrogen road map.

The work of the **Advisory Council for the European Green Deal** to the Council of Ministers has started. The Advisory Council is the body that is expected to set the framework for the upcoming reforms and investments for decarbonisation and modernization of the Bulgarian economy. Departmental committees are created for the Advisory Council including a Commission for sustainable mobility and a Commission for the presentation and discussion of the national negotiating positions on the legislative package of the EU "Fit For 55".

A representative of the **Ministry of Education and Science** seats in the SRG of the Clean Hydrogen Partnership.

An **Innovation Board** is also going to be established. The Board will be an advisory body to the Ministers of Education and Science and of Innovation and Growth. Its members will be leading experts in various scientific fields from the country and abroad, from public and private scientific organizations, innovators and business leaders. The Board will be permanent and will meet at least once a year. It will propose long-term policies for the development of innovation and related research. The Board will support coordination with other national or sectoral strategies, such as the Integrated Energy and Climate Plan, the Higher Education Strategy, the National Roadmap to improve the conditions for unlocking the potential of hydrogen technologies, the Industry 4.0 Strategy, etc.

Other relevant Managing Authorities are:

- Coordination of Programmes and Projects Directorate, **Ministry of Transport and Communications** for Transport Connectivity.
- Directorate General "**Strategic Planning and Regional Development Programs**", MRDPW Contact for the Development of Regions.
- Ministry of Innovation and Growth, Directorate General "**European Funds for Competitiveness"** for Research, Innovation and Digitalisation for Smart Transformation.

3.2. Targets

- The Integrated Energy Strategy Plan provides mainly for the development of the transportation sector in Bulgaria where the target is to introduce **34 GWh of hydrogen fuelled vehicles by 2030**.
- The recently published hydrogen roadmap has set needs for industrial use of **H2 production of 150 thousand tonnes/year** and a target to reach an **electrolyser total capacity of 55MW** by 2026.
- Currently, there are no **hydrogen powered vehicles**, but the aim is that, by 2026, this figure will increase to **65 hydrogen vehicles and 5 Hydrogen Refuelling Stations**. This target is expected to increase substantially by 2030 and reach an additional **120 hydrogen vehicles and 14 HRS by 2030** according to the National frame for alternative fuels. These numbers are based on the forecasted low scenario, but with the high scenario these numbers could double, especially when including the retrofitting of truck, rail, and maritime vehicles.

3.3. Research and innovation priorities

Concerning research and innovation priorities in the hydrogen sector, Bulgaria aims at investing in the whole value-chain from production to end-use in industry and transport. Special attention is given to investments into research infrastructures (creation and launch of a Competence Centre). More specifically, Bulgaria has a specific focus on these ones:

- **H2 production technologies**:
  - Biological production of hydrogen and photo-(electro) catalysis.
- **H2 end-use technologies**:
  - *Transport applications*: Focus on the development of a retrofitting approach for waterborne and rail transport.
  - *Clean heat and power applications* planned under ZAHYR hydrogen valley.
- **Cross-cutting topics**:
  - *Sustainability, LCSA* (Life-Cycle and Socia Assessment)– included in the hydrogen valley development.

- *Education and public awareness* – participation in two European projects – Sustainable Hydrogen Uptake through Innovation and Education "KICstartH2" and "GreenSkills4H2" - The European Hydrogen Skills Alliance.

3.4. Funding instruments

As stated in the recent Bulgarian Hydrogen Roadmap, the country could expect an overall **total budget of 3.2 billion euros,** including 0.5 billion euros of own funds, over the next 10 years.

The different programmes are depicted in the Table below. In the implementation plan of the stated Hydrogen Strategic Roadmap the budget sources are identified including the co-funding possibilities with European incentives. The most remarkable synergies are with Horizon Europe which normally co-funds 50 % of the deployed Hydrogen Bulgarian projects. Other European instruments that can be used for co-funding projects of interest in the area of hydrogen are Resilience and Recovery Plan, Modernisation Fund, and the Just Transition Fund, where regional plans are drafted[14].

Programme Name	Level	Budget	Priorities
The Competitiveness and Innovation in Enterprise Programme (CIP) 2021-2027	National	Approximately €320 M	Thematic area 5 "Clean technologies, circular and low carbon economy". Transformation of energy consumption and use in the private industry
The Research, Innovation and Digitalisation for Intelligent Transformation (RIDIT) programme	European and national (co-financed by the ERDF and the Bulgarian state budget)	1.093.446.112 EUR (885.510 000 European and national co-financing of EUR 207.936.112)	Development of Hydrogen technology
	National		Investment 5: "Support scheme for pilot projects for green hydrogen and biogas production". Economic Transformation Programme (ETP). Reform 5: Electric mobility. Investment 7 Green

[14] *Partnership Agreement with Bulgaria, August 2022:* https://commission.europa.eu/publications/partnership-agreement-bulgaria-2021-2027_en

			Mobility - a pilot scheme to support sustainable urban mobility through environmentally friendly development measures, Safe, functional and energy-efficient transport systems
2021-2027 Regional Development Programme. Fair Transition Fund (FTTF).	Regional	1,178 million euros for Bulgaria, of which 505 million euros from the Multiannual Financial Framework and 673 million euros from the "Next Generation EU" Instrument	Territorial Plans for a just transition (TPSP) of the regions of Stara Zagora (and adjacent municipalities), Kyustendil and Pernik. Developed by the Ministry of Regional Development and Public Works in synergy with national governance Hydrogen bodies.

Table 3. Bulgaria' s funding mechanisms

Moreover, Bulgaria includes in its Hydrogen roadmap support measures in the form of investment risk mitigation policies (*e.g.*, grants, loans, tax incentives or CCfD (Carbon Contracts for Difference)), to reduce the risks related to early innovative projects and to further attract private investment.

3.5. Projects

The current stage of ongoing and future projects of Bulgaria include:

- The first registration of a **hydrogen fuel cell vehicle** in Bulgaria took place in March 2023. This work has financial support from the project No BG05M2OP001-1.002-0014 „Center of competence HITMOBIL", which also covers the realization of the first hydrogen refuelling station (mobile design) expected to be commissioned in September-October 2023.
- **National Demonstration projects**: The first hydrogen refuelling station (mobile design) hydrogen is under realization. The estimated date of commissioning is September-October 2023. This work has financial support from project Nr. BG05M2OP001-1.002-

0014 „Center of competence HITMOBIL". Conditions and procedure for the design, construction, commissioning, and control of refuelling stations for hydrogen fuelled vehicles have been developed and promulgated at national level (Regulation No. RD-02-20-2 of 2020).

- Preparation of a conceptual project at national level for the application of hydrogen and technologies in the historical railway along the Septemvri-Dobrinishte route (**BGH2A**).
- Preparation of **Li-ion batteries project (bLion)** under the Hydrogen Europe's Lighthouse Initiative, which aims to support the speed up and the implementation of large-scale hydrogen projects in Europe and generate momentum around them. The Initiative will also foster synergies and build upon complementarities that aim to accelerate hydrogen roll out efforts.
- **Hydrogen Valleys:**
    - **Stara Zagora** (5 MW) with the aim to produce at least 500 tonnes of hydrogen per year each. Its funding of ***8 million euros*** was recently announced by the Clean Hydrogen Partnership. Another ***8 million euros*** were provided locally by the Ministry of Innovation and Growth and approximately ***4 million*** by private investors The estimated overall needed budget for the completion of the Valley is estimated at ***50 million***.
    - Bulgaria is also planning to develop and implement two more Hydrogen Valleys: in the region of Burgas (Black sea Port) and Ruse (Danube port).

The difficulties related to the implementation of hydrogen projects in Bulgaria are mainly due to the fact that these are large scale projects, in general too risky for investors. This is the main reasons why the Bulgarian Hydrogen Strategy foresees specific supporting measures to de-risk investments into hydrogen projects. Moreover, Bulgaria needs to further develop its national value chain and establish a hydrogen industry.

3.6. Other policies and measures

According to its NECP (2019), Bulgaria intends to enable the integration of hydrogen in its energy and mobility systems. It expects by 2030 an annual final hydrogen consumption of 32GWh (now updated to 34 GWh) in the transport sector, which will be facilitated by the planned deployment of hydrogen refuelling stations. The hydrogen will be produced with electrolysers using renewable electricity. The updated revision of the NECP (with a draft expected to be submitted by June 2023) foresees increased targets for hydrogen production and export through the European gas grid pipeline network.

The **Bulgarian RRP** envisages tripling power generation from renewables, accelerated deployment of alternative energy sources, such as renewable hydrogen, geothermal and sustainable biogas, building up large electricity storage capacities, increasing electricity interconnection capacities, improving the energy efficiency of buildings, and liberalising the wholesale and retail electricity markets.

Bulgaria's Minister of Economy launched the process to prepare a **new Innovation Strategy for Smart Specialisation 2021-2027**, with the aim to further explore the deployment of electrochemical sources such as hydrogen and fuel cell technologies. Coherency and synergies with the Bulgarian Hydrogen Strategy should be ensured.

The Hydrogen Valley "Stara Zagora" is located in the South-East of Bulgaria, where coal mines and power plants constitute the basis of their economic development. Possibility to exploit **synergies with the Just Transition Plan** should be evaluated.

The Partnership Agreement[15] foresees several actions, in accordance with the goals for carbon neutrality: deployment of infrastructure for alternative fuels in the port of Burgas and port of Varna, *introduction of transport using hydrogen for fuel in the port of Burgas*, and production of green energy in the port of Vidin.

Bulgaria is also committed to full use the opportunities for synergy between the **ERDF and the Horizon Europe Framework Programme** by financing projects that have received "Seal of Excellence" certificates and/or passed the evaluation threshold, as well as providing co-financing for participation in European partnerships. It will also exploit **complementarity and synergy with the initiative for interregional innovation investments** (I3) under the European programme INTERREG, aimed at helping participants in smart specialization strategies (S3) to bring innovations to the European market, in projects of common European interest in the field of hydrogen technologies, microelectronics and others for the inclusion of the Bulgarian industry in the value chains included in the new EU Industrial Strategy.

Bulgaria jointly to other 24 EU Member States participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**. Bulgaria's role focused on the participation of national expert groups and task force meetings as well as the coordination of the pan-European and transdisciplinary workshop on hydrogen production together with Italy.

[15] It covers the European Regional and Development Fund – ERDF, the European Social Fund Plus - ESF+, the Cohesion Fund – CF, the Just Transition Fund – JTF, and the European Maritime Fisheries and Aquaculture Fund - EMFAF

4. Croatia

The implementation of a **Croatian Hydrogen Strategy from to 2050**[16] has been initiated.

The Hydrogen Strategy is fully aligned with the ***Energy Development Strategy* (2030-2050)** of the Republic of Croatia, where hydrogen is mentioned as an alternative fuel, and with **Strategy for Transport Development of the Republic of Croatia** for the period 2017-2030, where hydrogen is mentioned as a potential option for mobility.

Croatia still has not set up a hydrogen economy yet (only production of grey hydrogen for refinery use), but is working to establish a low-carbon hydrogen production to ensure the gradual uptake of hydrogen in the energy system.

The Strategy mentions that hydrogen is not yet price competitive (2,5-5,5 EUR/kg) with fossil fuels (2 EUR/kg), but forecasts predict that appropriate measures to reduce RES electricity prices will allow higher profitability of green hydrogen (1.5-3 EUR/kg in 2030).

The Strategy is based on four pillars, setting out the main orientations for the development of a hydrogen economy as follows:

- **Hydrogen production** — enable the production of low-carbon hydrogen that will focus primarily on renewable hydrogen with the aim of producing products with low or zero CO2 emissions.
- **Storage and transport of hydrogen** — the repurposing of existing infrastructure to transport hydrogen from the production site to the place of consumption in the long term. In the short term, production sites are expected to be in places of consumption for the purposes of industrial processes.
- **Use of hydrogen** — enabling the use of hydrogen in industrial processes, agriculture, etc., as well as developing the use of hydrogen in transport by providing incentives for the purchase of hydrogen vehicles and vessels.
- **Education, research and innovation** — ensuring the development and commercialisation of new technologies in the production and safe use and transport of renewable hydrogen.

[16] Hydrogen strategy of the republic of Croatia until 2050 (2022). Ministry of economy and sustainable development. Croatian Hydrogen Strategy ENG FIN 22 8.pdf (gov.hr)

4.1. Governance

The **Ministry of Economy and Sustainable Development** was in charge of developing the Hydrogen Strategy and shall submit a report on the implementation of the Strategy in accordance with the prescribed modalities and deadlines.

To implement and monitor the implementation of the Hydrogen Strategy, the Ministry in charge of the energy sector will, in cooperation with the **Regional Hydrogen Centre**, ensure the adoption of the necessary legislative framework for the purpose of implementing the priorities and monitor the fulfilment of the set objectives. The Centre would be run by the scientific community and will become a generator of ideas and innovative solutions.

4.2. Targets

Figure 1 below graphically presents the main targets included in the hydrogen strategy:

- Croatia has the objective to connect **1.500 MW** of new RES electricity sources to the energy system by the end of 2024, and to build around 2 500 MW of installed capacity by 2030, with the aim of ensuring clean energy production that should meet its own needs.
- To install **70 MW of electrolyser capacity** by 2030, and **2.750 MW** by 2050.
- To increase the hydrogen share in the energy mix to **0,2%** by 2030, and **11%** by 2050.
- To increase the number of **hydrogen refuelling stations (HRS)**: **15** by 2030, and **100** by 2050.
- To increase the **number of patents** related to hydrogen research: **5** by 2030, and **50** by 2050.

STRATEGIC OBJECTIVE	PERFORMANCE INDICATOR	INITIAL VALUE	TARGET VALUE	
		2021/2022	2030	2050
Increase of renewable hydrogen production	Electrolyser capacity Unit of measurement: MW Code: II.02.6.48	0	70	2750
Increase of the exploitation of the potential of RES for the production of renewable hydrogen	Share of hydrogen in total energy consumption Unit of measurement: % Code: II.02.6.49	0	0,2	11
Increase of the use of hydrogen	Number of hydrogen charging stations Unit of measurement: number Code: II.02.6.50	0	15	100
4Encouragement of the development of science, research and development of hydrogen technologies.	Number of patents related to the hydrogen economy Unit of measurement: number Code: II.02.6.51	0	5	50

Figure 1. Main targets of the Croatian Hydrogen Strategy

4.3. Research and innovation priorities

The main research and innovation priorities included in the Croatian strategy are:

- **H2 production**: electrolysis, waste gasification and other low-carbon hydrogen production technologies.
- **H2 end-uses**:
  - *Mobility applications:* to substitute conventional transport fuel with low-carbon hydrogen with special emphasis on waterborne and rail applications.
- **Cross-cutting issues**:
  - *Standardisation*: to standardize hydrogen use in transport.
  - *Legal framework:* to develop a better framework to encourage innovation and demo projects.
- **Hydrogen Valleys**: The North Adriatica Hydrogen Valley covers the whole territory of Croatia. Therefore, no other Hydrogen Valleys are currently planned. However, if additional regional and/or local initiatives emerge, they would be supported at national level.

4.4. Funding instruments

In terms of financial investment, Croatia's national public funding is showed in the Figure below. On top of these national funds, Horizon Europe, the European Structural and Investment Funds (ESIF), the National Recovery and resilience Plan, the Modernisation Fund, etc. are expected to support research hydrogen projects.

The possibility to attract private investments, which are increasingly oriented towards the green transition, will largely depend on the existence of business models, also based on co-financing, and the cost-effectiveness of such projects.

Figure 2.Funds available for hydrogen projects in Croatia

Additional funds are also available for specific project lines:

- Installation of a 30 MW electrolyser for production of renewable hydrogen. 27.150.500 euros (from RRF and ERDF).
- Installation of HRS for road transport 21.272.281 euros (for 10 HRS from RRF and ERDF).

The Table below summarises the existing funding programmes, focusing on research and innovation, the available budget and the priorities.

Programme Name	Level	Budget	Priorities
Generation	National	15 million euros	Renewable H2 production Development and investment in H2 technologies
Research and innovation	National	15 million euros	Regional Hydrogen Centre R&D in the field of renewable hydrogen

Table 4 Financial programmes for Croatian Hydrogen.

4.5. Projects

- Croatia has established the project of **North Adriatic Hydrogen Valley (NAHV)** together with Slovenia and the Italian Autonomous region Friuli–Venezia–Giulia. It is a transnational project led by the Slovenian energy company HSE and supported by the Clean Hydrogen JU with an allocation of a 25 million euros grant. It consists of pilot projects to produce more than 5,000 tonnes of green hydrogen per year and its storage, distribution, and use. The final goal of the project is the decarbonisation of major industrial sectors, such as steel and cement production, as well as sustainable transport solutions related to reducing the carbon footprint. Croatia has no experience of co-funding projects with EU funds yet. However, part of the NAHV projects budget for Croatia is also funded with national funds.
- Several other H2 projects are also ongoing in the areas of construction of RES plants with hydrogen production on spot; refitting train locomotives to hydrogen; production of electrolysers; construction of hydrogen filling stations; switch of the public transport to hydrogen powered vehicles etc.

The most relevant obstacle for the successful projects' implementation is the investment risk, since there is no H2 economy developed in Croatia yet. Another important obstacle is the capability to obtain enough financing for the development and fulfilment of the project. In addition, there are various obstacles regarding administrative processes such as acquiring land, special planning difficulties, and impact assessment process that represent bottleneck for the

development of such projects. Linked to this is the lack of people working in the administrative bodies with the necessary competences.

There are also some technical difficulties, which are currently limiting the implementation of renewable energy sources into the Croatian electricity system, that will be successfully solved upon completion of the planned investment through the National Recovery and Resilience Plan.

4.6. Other policies and measures

According to its NECP (2019), Croatia intends to enable the integration of hydrogen in its energy and mobility systems. It expects by 2040 a final hydrogen consumption of 0.01PJ or 2.8 GWh in the transport sector and has the intention to build hydrogen refuelling stations and to develop technical standards to facilitate market uptake.

According to Croatia's NECP, the role of hydrogen in its energy and transport systems is expected to gradually uptake by 2030. The NECP also mentions that incentive measures for the procurement of vehicles primarily fuelled by alternative fuels need to be implemented.

Croatia, together with other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

Some Croatian islands are also developing Clean Energy Transition Agendas, including hydrogen as an option, with the support of the Clean Energy for EU islands secretariat:

- The ***Island of Zadar*** submitted a Clean Energy Transition Agenda (CETA)[17]. Its CETA includes a strategic point dedicated to fleet conversion for coastal liner maritime transport (hydrogen/gas), highlighting that it is necessary to invest in fleet conversion, propulsion systems using environmentally friendly energy sources, i.e. alternative fuels (electric energy, natural gas including biogas, biofuels, liquefied petroleum gas, hydrogen...). However, no further information is mentioned in the document.
- The ***Island of Lavdara*** also includes the decarbonisation of maritime transport in its CETA [18], and mentions hydrogen as an option. However, no further information is mentioned in the document.

[17] *CETA for the City of Zadar Islands, January 2023.* https://clean-energy-islands.ec.europa.eu/countries/croatia/zadar-islands
[18] *CETA for Lavdara, January 2023,* https://clean-energy-islands.ec.europa.eu/countries/croatia/lavdara

5. Cyprus

Currently, the Ministry of Energy, Commerce and Industry (MECI) is developing a National Hydrogen Strategy. Technical Support was obtained in May 2022 from the European Commission in order to develop the strategy. The study was completed in December 2022 and is currently under review by MECI.

With the rising interest towards hydrogen related initiatives and proposals across Europe, various private initiatives are promoted across the island as well. These include the recent award of a EU Innovation Fund project, in addition to various other initiatives that are currently seeking either EU funding of various forms, or funding via other means, including the Research and Innovation Foundation (RIF), the national authority in charge of supporting and promoting research, technological development and innovation in Cyprus.

5.1. Governance

The energy competences fall under the **Ministry of Energy, Commerce and Industry** (MECI) which also receives support from various stakeholders, including the Cyprus Energy Regulatory Authority (Internal market, interconnection, further integration of renewable energy sources), the Cyprus Institute of Energy, Environment and Water Research, and the Centre for Climate change Projection, Air Quality, and Renewable energy.

The representatives to the States Representative Group of the Clean Hydrogen Partnership are nominated by Ministry of Energy, Commerce and Industry, as well as by the **Ministry of Research, Innovation and Digital Policy.**

Other relevant Managing Authorities:

- Directorate General for Growth, **Ministry of Finance (DG GROWTH) for Cohesion Policy Programme** “THALIA 2021-2027”.

5.2. Targets

Not available yet, but currently under development as part of the national hydrogen strategy.

5.3. Research and innovation priorities

There are not priorities set for Hydrogen technologies because they have not been contemplated in the national energy policies.

However, the technical study has highlighted potential for the development of hydrogen applications in two areas:

- Industrial applications: Cement, bricks and tiles production.
- Transport sector with a focus on logistics of goods and public transport.

The study further supported the development of a number of refuelling stations across the island and the funding of various heavy-duty vehicles for the transport of goods.

5.4. Funding instruments

Currently there are no national funding programs for the development of hydrogen initiatives in Cyprus.

Currently Cyprus is not in the process of co-funding H2-related projects, as it is still developing its National Strategy. Depending on the strategy aims and outcomes, the Ministry will carry out the necessary steps to review options for the funding and development of H2-related projects.

5.5. Projects

Cyprus has been granted in December 2022 its first Innovation Fund project (**62 million euros** total IF budget), the **GreenH2CY** (Green Hydrogen Project for Transport in Cyprus), by which the green hydrogen production and refuelling station installation and operation of a 2 MW PEM-type electrolyser and a refuelling station adjacent to the electrolyser will be developed to be implemented in energy-intensive industries.

The hydrogen plant is expected to produce by 2025, 150 tonnes of hydrogen fuel per year, which is equivalent to 627 tonnes of diesel fuel per year. The energy will be supplied by a local renewable energy supplier using Guarantees of Origin (GOs) to demonstrate the use of only renewable energy sources, so that the final product can be classified as green. The water used will come from tertiary wastewater treatment by the Larnaca water development department, thus contributing to circular economy actions. For the first step, the final product will be used in the transport sector, more specifically for light and heavy-duty vehicles, to replace diesel vehicles.

Further projects dedicated to research on hydrogen production and storage are currently seeking European funding and private investments. Moreover, the Ministry of Energy, Commerce and Industry is encouraging private initiatives for the development of Hydrogen Valleys in Cyprus, while the Deputy Ministry of Research, Innovation and Digital Policy currently exploring the potential of Cyprus to support new hydrogen valleys.

5.6. Other policies and measures

In the upcoming NECP revision, hydrogen targets will be added based on the projected results from the scenario analyses developed by the Ministry of Energy, Commerce and Industry (MECI). As the AFI Cyprian Plan is being revised in light to the updated alternative fuels' directive by the

Ministry of Transport, Communications and Works, it could further mention H2 infrastructure deployment.

The private sector launched, in March 2021, the **Cyprus Hydrogen Association** whose chairman is Makis Ketonis of Ketonis Developments Ltd with the objective to contribute to energy diversification sources, to promote business and technological innovations and economic growth and reduction of conventional fuels.

The **Just Transition Fund** (JTF), with a dedicated budget of **101 million euros**, will help Cyprus with its energy transition process towards the 2030 and 2050 targets. Investments from the JTF will strengthen the energy transmission and distribution systems to allow for storage technologies and transition towards renewable energy. The JTF will also support measures for small and medium-sized businesses to apply new technologies and increase the use of renewable energy sources. However, no information is currently available on their use for hydrogen-related projects.

Cyprus, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

6. Czech Republic

The Czech **Hydrogen Strategy** [19] was developed by **the Ministry of Industry and Trade** and adopted in 2021.

Czech Republic's goal is to focus primarily on the development of **low-carbon hydrogen** (blue hydrogen), defined as generating a maximum of 36.4 g CO2/MJ.

The Hydrogen Strategy is based on four pillars:

- Low-carbon hydrogen production.
- Low-carbon hydrogen use.
- Hydrogen transport and storage.
- Hydrogen technologies.

The strategy also defines and analyses current barriers for reaching these objectives, and foresees the implementation of **Task Cards**, which describe the measure, responsible body and deadlines for the actions to remove removing them.

The Strategy includes a thorough SWOT analysis, which analysis the most suited technologies and end use areas for the development of a hydrogen economy in the Czech Republic.

6.1. Governance

The development of hydrogen technologies and their introduction into practice is within the competence of the **Ministry of Industry and Trade**, under the responsibility of the **Plenipotentiary of the Minister of Industry and Trade for Hydrogen Technologies**. This Minister will manage the **Hydrogen Coordination Group** and will be supported by the **Hydrogen National Council**. The governance will then involve the following bodies:

[19] The Czech Republic's Hydrogen Strategy (2021). Ministry of Industry and Trade. Hydrogen-Strategy_CZ_2021-09-09.pdf (mpo.cz)

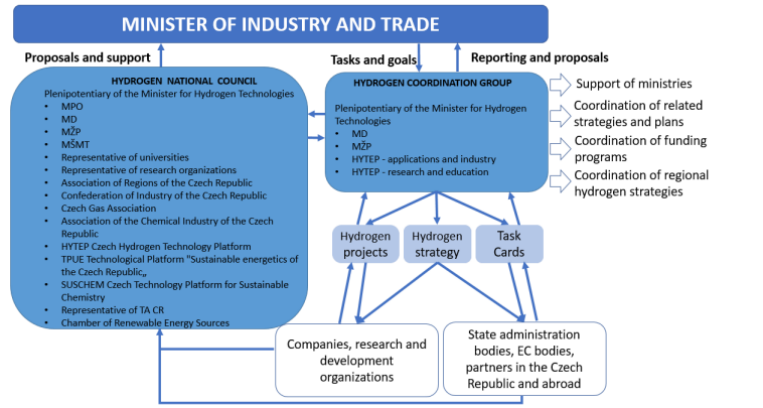

Figure 3.Governance of the Czech Hydrogen Strategy

The Strategy recognizes the importance of other cross-cutting areas that include education and awareness raising, a supporting regulatory framework and a plan for hydrogen safe handling. The measures contemplated for public awareness are in the Task Cards 24 “Support for a degree programme focused on hydrogen technology at universities”, 25 “Accreditation of retraining in hydrogen technology” and 26 “To raise awareness of hydrogen technology at secondary schools by including it in curricula (physics, chemistry, etc.)”.

Other relevant Managing Authorities:

- **Ministry of the Environment, EU Funds Department** for Environment 2021-2027 programme.
- **Ministry of Transport of the Czech Republic - EU Funds Department** for Transport 2021-2027 programme.
- **Ministry of the Environment, Department of Support for the Transformation to a Low-Carbon Economy** for Just transition 2021-2027 programme.
- **Ministry of Industry and Trade of the Czech Republic / EU Funds Section** for Technologies and Applications for Competitiveness programme.
- **Ministry of Regional Development – Department of the Managing Authority of the Integrated Regional Operational Programme** for Integrated Regional programme 2021-2027
- **Ministry of Regional Development of the Czech Republic Department of European Territorial Cooperation Czech Republic** for (Interreg VI-A) Czechia-Poland.

6.2. Targets

A series of scenarios have been developed with specific targets:

- Number of hydrogen **buses: 900 by 2030**, and 4.600 by 2050.
- Number of hydrogen **passenger cars: 45.000 by 2030** and 600.000 by 2030.

- Number of hydrogen **trucks: 4.000 by 2030** and 60.000 by 2050.
- Percentage of electricity and heat produced by hydrogen: **3% by 2050**.
- Volume of **low-carbon hydrogen production: 101 kt/year by 2030**.

6.3. Research and innovation priorities

The main priorities for hydrogen production and consumption, developed in the Czech Hydrogen Strategy, are:

- **Renewable H2 production**: Hydrogen production equipment (electrolysis and pyrolysis).
- **H2 end-uses:**
  - *Mobility applications*: Components for hydrogen vehicles and transport infrastructure; Hydrogen vehicles (buses, trucks and cars).

6.4. Funding instruments

To ensure that the Hydrogen Strategy goals are accomplished, financial support schemes that are already in place for related programmes will be linked to reach the objectives.

The analysis made by the Czech Republic includes the identification of national and European resources that can be allocated to the four hydrogen pillars established by the country and to find gaps to align the corresponding plans and amend them.

Some of them are summarised here:

- **Modernisation Fund**: it finances projects on carbon reduction, energy efficiency and security, the internal energy market and research, innovation and competitiveness. **150 billion CZK** for the period 2021- 2030. The financial measures have been divided into 9 programmes with specific conditions on their respective call for project intentions: HEAT (26 %), RES + (38,7 %). ENERG ETS (13,3 %), TRANSGov, LIGHPUB, KOMUNERG, ENERGov, ENERG, TRANSCom.
- **Operational Programme Just Transition**: it focuses on mitigating the negative impacts of the shift away from coal in regions that will face serious socio-economic problems because of the transition to a climate-neutral economy in the European Union by 2050. **1,58 billion euros** for the period 2021- 2027.
- The **Country for the Future:** to increase the international competitiveness of companies by linking cooperation between academia, the business sector, the innovation environment and a larger use of R&D results in practice, including facilitating entry into new markets or moving up global value chains. **300 million CZK** for the period 2019-2027.

The Czech Republic uses cohesion funds and EU ETS to finance various activities including hydrogen. Various funds are managed by different ministries. Some examples applicable for hydrogen projects are listed below:

Programme Name	Level	Budget	Priorities
Modernisation Fund	EU	Around 6 billion euros (2021-2030)	Operated by The State Environmental Fund of the Czech Republic (SEF): carbon reduction, energy efficiency and security, the internal energy market and research, innovation and competitiveness Program RES+, Ministry of Environment: construction of photovoltaic, electrolyzers, cleaning and storage systems.
Operational Programme Just Transition	EU	1,59 billion euros (2021- 2027)	Mitigating the negative impacts of the shift away from coal in regions. The Ministry of Environment is responsible to fund the use of hydrogen for green transition in specific regions.
Country for the Future	National	Around 12,5 million euros (2019- 2027)	Support to international cooperation.
Recovery and Resilience Facility (RRF)	EU	(2021-2026)	Ministry of Industry and Trade: production and consumption of hydrogen.
European Regional Development Fund (ERDF), Cohesion Fund (CF)	EU	2.4 billion EUR (2021- 2027)	Program OP TAK, Ministry of Industry and Trade: support for technology development and innovations. Program OPE, Ministry of Environment: energy savings, the development of renewable energy sources.

Table 5. Available budget of the Czech Republic for hydrogen projects.

6.5. Projects

- The **ORLEN Benzina filling station** located in Prague's Barrandov district is a state-of-the-art, unmanned facility that is open to the public 24/7. The station features two dispensers that come equipped with specially designed gun noses that offer a pressure of 700 bar for cars and 350 bar for larger vehicles. This impressive facility was made possible with the financial support from the Ministry of Transport of the Czech Republic under the Sectoral Operational Programme Transport. ORLEN Unipetrol has set ambitious goals to provide up to 28 hydrogen filling stations across the Czech Republic by 2030, along with two hydrogen distribution terminals for rail transport in Litvínov and Neratovice. This is part of the **IPCEI Hydrogen Eagle**, an investment program to develop an international chain of hydrogen hubs powered by renewable energy sources, such as photovoltaic powerplants, and to build innovative facilities to convert municipal waste into zero- and low-emission hydrogen with installation of electrolysers and development of PEM membranes. The project also provides for the construction of more than 100 hydrogen refuelling stations for individual, public and cargo transport (54 in Poland, 22 in Czech Republic and 26 in Slovakia). Hydrogen city buses in Ústí nad Labem and Ostrava are being implemented as well as intercity hydrogen buses.
- An interactive map of Czech Republic's hydrogen projects can be found in https://www.cistadoprava.cz/mapy/h2/ *(only available on the Czech's website)*.

Some challenges that have hampered the implementation of projects include the fragmented and uncoordinated funding for the different components of the hydrogen supply chain needed for a whole project. This is the case of some IPCEI projects, which were not fully funded, since structural funds could not be used. In other cases, like for the use of RRF, the timeline between the project duration and the time of disbursement of the funds does not match (the results need to be available by 2026, which is not possible in the case of H2 projects). The different Ministries are currently discussing some approaches to make sure that the whole project value chain is covered.

6.6. Other policies and measures

In the Czech NCEP (2019), hydrogen is extensively studied with a focus on its application in mobility where a **National Action Plan for Clean Mobility** has been detailed with an individual analysis for Hydrogen mobility. Hydrogen will be produced from natural gas by pyrolysis, by electrolysis of renewable sources and adapted to the present gas infrastructure for transport and storage, distribution and final consumption.

Both NECP and the Hydrogen Strategy of the Czech Republic are prepared by the Ministry of Industry and Trade, which ensures interconnection and consistency between both documents.

The Czech **Just Transition Fund** chapter includes reference to using this fund to support the development of new renewable energy sources, with a focus on the green hydrogen and battery product chain, as well as the infrastructure necessary for industrial electrification.

The region of Usti, which is a coal region, has also developed a regional hydrogen strategy, which highlights some specific priorities for the region transition that are, however, in line with those at national level.

Czech Republic, jointly to other 24 EU Member States, participated to the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

7. Denmark

In December 2021, the former Danish government published its proposal for the "**Strategy for power-to X**"[20]. Currently, the strategy has four specific objectives:

- Power-to-X must be able to contribute to the realization of the objectives in the Danish Climate Act.
- The regulatory framework and infrastructure must be in place for Denmark to utilize its strengths and allows power- to-X to perform on market terms in the long run.
- The integration between power-to-X and the Danish energy system must be improved.
- Denmark must be able to export power-to-X products and technologies.

PtX is a comprehensive term for a number of technologies that are all based on using green electricity to produce hydrogen. This hydrogen can subsequently be used directly as a fuel for road transport or industrial purposes or further converted into other fuels, chemicals and materials.

7.1. Governance

The Strategy is developed by the **Ministry of Climate, Energy and Utilities,** while the representative on the States Representative Group of the Clean Hydrogen Partnership comes from the Danish Agency for Higher Education and Science.

As part of the political agreement Development and promotion of hydrogen from March 2022, a the **PtX-secretariat** (ptx@ens.dk) has been established in the Danish Energy Agency. It will contribute to the coordination across public authorities regarding environmental, safety and risk assessments and permitting processes for hydrogen and PtX-plants and it will ensure a continuous dialogue with actors in the PtX sector (including CCU). One of the tasks for the secretariat is to identify any regulatory and legislative barriers for developing and utilizing PtX in Denmark and to ensure the correct framework conditions for the successful integration of PtX-technologies into the energy system as a whole. Furthermore, the secretariat should work towards uniform rules for documentation of green hydrogen and develop tools that promote appropriate placement of PtX facilities and possible utilization of excess heat. Moreover, a Public-Private Partnership called the *Triangle Energy Alliance* has been established between municipalities, private sector companies and the government to support the development of large-scale demonstration projects in the triangle region.

[20] The Government's strategy for Power-to-X (2021). Danish Ministry of Climate, Energy and Utilities. Strategi for Power-to-X (ens.dk)

Other relevant Managing Authorities in hydrogen matters include:

- **The Danish Business Authority, Development throughout Denmark, Decentralized business promotion** for National programme for the ERDF in Denmark: Strong enterprises through innovation, digitalization and green transition.

To further continue collaboration for PtX deployment, in 2022, the InnoMission number 2 "Green fuels for transportation and industry (Power-to-X, etc.) of the country" launched the **GreenFuels partnership**. The partnership will focus on commercial scale-up of already known technologies, the realization of large demonstration projects and the construction of new value chains targeted at buyers in the transport sector in the relatively short term. The partnership has 60 partners with a budget of **37,57 million euro** and is expected to have a duration of 5 years.

7.2. Targets

The political agreement of 15th March of 2022 of the Danish Parliament on development and promotion of hydrogen and green fuels (the PtX Agreement) set several targets:

- **4-6 GW electrolysis capacity** by 2030 of green hydrogen.
- To dedicate **1.25 billion DKK to support of production** of PtX in Denmark. The money will be implemented as a market-based competitive bidding process.
- Enabling the build-out of **infrastructure for hydrogen** in Denmark.
- Appointment of a **PtX Taskforce** to support developing a market and infrastructure for hydrogen in Denmark earmarked with €7.5 million in 2022-2026 and with responsibility to provide guidance to project developers and authorities.

7.3. Research and innovation priorities

Denmark's Strategy for investments in green research, technology and innovation from 2020[21] introduced the instrument **Green research and innovation partnerships**, funded by NextGenerationEU. The partnerships are centred around four missions, where one of them is green fuels for transportation and industry (Power-to-X etc.). The expectation is that roadmaps lay out a pathway to accelerate the development of cutting-edge green solutions through strategic and coherent green research ranging from strategic research to commercialization.

Hydrogen R&I priorities include:

- **Hydrogen transport, storage and distribution**:

[21] Green solutions of the future - Strategy for investments in green research, technology, and innovation, 2020: https://ufm.dk/en/publications/2020/green-solutions-of-the-future-strategy-for-investments-in-green-research-technology-and-innovation-1

  - The main goal is to develop hydrogen infrastructure that can support flexible operation of the PtX plants and transport hydrogen over long distances, which is important as Denmark aims to be a PtX exporter.
  - **Storage**: Gas Storage Denmark investigates the possibility to store hydrogen in underground gas storage facilities. In addition, storage through line packing is expected to be available already in the early phase of hydrogen infrastructure.
  - In **natural gas grid**: in the short term, a few pipelines are expected capable of being repurposed (including one linking with Germany); in the long-term further methane gas pipelines may be retrofitted, as production and demand of methane in Denmark reduces.
  - **Liquid Hydrogen carriers**: investment in PtX products such as ammonia, methanol, or e-kerosene.
  - **Hydrogen Refuelling Stations**: maritime and aviation refuelling.

- **End-use sectors:**
  - **Transport applications:** The Pioneer Center CAPeX will develop and implement a new powerful Materials Acceleration Platform (MAP) for rapid development of materials and a closed-loop data infrastructure where new catalysts and other materials for power-to-X are discovered, synthesized and designed directly for their intended operating conditions. PtX will be prioritized in heavy road transport, long distance flights (carbonaceous fuels), shipping.
  - **Clean power and heat**: surplus heat generated from PtX-plants will be studied to be used in local district heating grids and in industrial contexts for process heating.
- **Cross-cutting:** safety standards in terms of health and environment, approval procedures for PtX plants and hydrogen infrastructure.

Moreover, overall support to **techonolgy development** in the form of R&D to optimise the current technology to make it more technology cheaper, efficient and more energy effective, is also available.

The agreement on the development of hydrogen and green fuels from 15 March 2022 sets a target of establishing **4 - 6 GW of electrolysis capacity** by 2030. However, in Autumn 2022, the Danish gas network operators Energinet and Evida have carried out a market analysis estimating an interest in electrolysis production capacity of up to 14 GW in 2030, if all projects are realized.

A main objective of the Danish PtX strategy is for Denmark to become a net exporter of hydrogen and PtX products. These objective needs, as a prerequisite, the development of a hydrogen infrastructure connected to Europe. Nationally, the priority is to use PtX for areas where direct electrification is not possible or associated with very high costs.

7.4. Funding instruments

- The **Energy Technology Development and Demonstration Program (EUDP)** co-finances the development and demonstration of new solutions within energy technology. This is to support Denmark's energy and climate policy objectives of a 70% reduction in CO2 equivalent emissions by 2030 and climate neutrality in 2050. The fund has dedicated 204M DKK for projects in 2022. EUDP can support energy technologies, such as renewable energy technologies, energy efficiency technologies, conversion technologies such as fuel cells and hydrogen, integration of energy systems including storage, more efficient methods for recovery of oil and gas and storage of CO2. Currently, there has not been any experience of co-funding with European schemes, but it is possible to do so.
- In 2021, the Government allocated **DKK 850 million** to the development of the green fuels of the future through the pan-European project on green hydrogen (IPCEI). DKK 600 million have been ear-marked to support the project Green Fuels for Denmark, and aprox. DKK 250 milion to the project HySynergy.
- The Government will also invest **DKK 1.25 billion** via a PtX tender, which is expected to be settled in the fall of 2023.
- The Government has prioritised **DKK 1.3 billion** from 2021-2023 to four green missions aimed at contributing to research and development of green technologies, including a mission on green fuels for transport and industry (PtX, etc.).
- **DKK 500 million** from **REACT-EU** has been allocated to act on the recommendations from the regional growth teams to establish eight local commercial lighthouses in Denmark, including a commercial lighthouse revolving around green energy and sector coupling (with an initial financial support of approx. 15 mio. EUR).
- The *Denmark can do more I* (Danmark kan mere I) reform envisages allocating an additional **DKK 500 million** in EU funds towards 2027, thereby reaching a total of DKK 1 billion for the development of the local commercial lighthouses.
- It has been decided to allocate **DKK 6 billion** as a capital injection into the newly established Export and Investment Fund of Denmark **(EIFO)**, of which 1.7 billion will be targeted for funding companies engaged in commercial large-scale demonstration projects in fields such as PtX.

The Table below summarises some of the existing funding programmes, the available budget and the priorities.

Programme Name	Level	Budget	Priorities
IPCEIs	National	Around 114 million euros	Generation; transport, storage and distribution; end-user; fuel cell technologies.
PtX tender	National	Around 170 million euros	Production of green hydrogen in Denmark.
Green Missions	National	Around 130 million euros	Four green missions (one dedicated to Green Fuels for transport and industry).
REACT- EU	EU	Around 80 million euros	Green energy and sector coupling (apr. 15 mio. EUR).
Denmark can do more I (RRF)	EU	Around 66 million euros	Lighthouse projects.
Export and Investment Fund of Denmark (EIFO)	National	Around 230 million euros	Large-scale demonstration projects also on PtX.

Table 6. Danish Funding Hydrogen programmes.

7.5. Projects

More than **20 projects** are ongoing across the whole country. Some of the most relevant funded projects are listed below:

- **H2RES-project:** demonstration of hydrogen production from 2 MW electrolysis connected directly to offshore wind turbines. The production of 1,000 kg. of green hydrogen per day for utilization in the transport sector.
- **Nature Energy- e-methane**: Demonstration of methanation from biogas (0.01 MW electrolysis). Injecting hydrogen in the production of biogas enables higher output of methane. Next phase of demonstration will from 6 MW electrolysis by 2023.
- **Green Hydrogen Hub**: Production of green hydrogen (350 MWe in 2025 and 1 GWe in 2030) and long-term underground hydrogen storage (200 GWh in 2025 and 400 GWh in 2030). The facility will be near where the salt caverns are located.
- **HØST PtX Esbjerg**: Production of green ammonia for fertilizers and shipping fuels. The developers expect to have 1 GW electrolysis operating by 2026 and produce 600,000 ton of ammonia per year.

- **H2 Energy Europe**: Production of 90,000-ton hydrogen (1 GW electrolysis by 2025). The hydrogen should be used to fuel trucks and be used for production of methanol.
- **SOEC production**: A Danish company has announced it will build the world largest electrolysis facility for Solid Oxide Electrolysis Cells. It will have a production capacity of 500 MW a year with the option for extension to up to 5 GW. The facility will create 170 jobs.
- **Hydrogen for industry and transportation**: Power-to-X production centre and hub in Jutland to facilitate PtX products for Northern Jutland. The project consists of a testing and a construction phase with a planned 100 MWe electrolysis cell, a hydrogen terminal for cars and lorries, a distribution centre. It aims at promoting sector coupling etc. It is a regional lighthouse whose funds have been allocated regionally. To this extent, a public-private partnership between industry, and the regional government has been created.
- **H2 Interconnector Bornholm-Lubmin** is scheduled to bring hydrogen from the Danish island Bornholm to Lubmin from 2027. The cross-border hydrogen infrastructure aims to support and enhance an accelerated development of offshore wind in the region and wider Baltic Sea, while securing a reliant and cost-efficient decarbonization pathway for the north-eastern European energy system. The project is being developed by GASCADE together with Copenhagen Infrastructure Partners' (CIP) dedicated CI Energy Transition Fund as a potential financial investor. It is a regional lighthouse identified as the green transport hub whose funds have been allocated regionally.
- **H2 Valley**: ***HyBalance*** (EU, national and private funding) demonstrates the use of hydrogen in the energy system. The hydrogen is produced from water electrolysis, enabling the storage of renewable electricity from wind turbines. It balances the grid, and the hydrogen is used for transport and in industry. It was one of the first Valleys launched in 2014 and is currently fully implemented.
- **IPCEI**:
    - **Green Fuels for Denmark** aims at producing large quantitates of sustainable green fuels for road, maritime and air transport. When fully developed the project aims at a total capacity of 1,3 GW electrolysis.
    - **HySynergy 2.0:** Production of green hydrogen to be used in industrial processes and transport. The Crossbridge Energy refinery will be the recipient of large parts of the green hydrogen. In 2025 HySynergy 2.0 will have established 300 MW of electrolysis capacity and will undergo a transition to convert green electricity to liquid green fuels.
    - ***Green Fuels for Denmark*** is being developed by Ørsted in partnership with leading off-takers in heavy road transport (DSV), shipping (Maersk and DFDS),

and aviation (Copenhagen Airports, SAS). The funding will help enable the consortium behind Green Fuels for Denmark to develop the first phases of the project as part of the industrialisation of renewable hydrogen and green fuels needed to compete with fossil-based alternatives. The funding will go towards realising Green Fuels for Denmark's first phases of 10 MW, 100 MW and 300 MW megawatt, respectively. A share of the IPCEI funds will be used to part-finance two Everfuel fuelling stations which will offtake green hydrogen produced by Green Fuels for Denmark. Green Fuels for Denmark ultimately targets 1,300 MW of electrolysis capacity in Copenhagen.

The delays experienced by the projects are mainly due to unexpected technical obstacles, challenges in the supply chain (longer lead-time), changes in commercial collaboration between partners and Covid-19 restrictions. For these reasons, higher TRL projects might experience more problems than basic research ones.

7.6. Other policies and measures

Denmark's current NECP (2019) does not include specific objectives or targets for the production or use of hydrogen. However, it recognises that new solutions will have to be developed in the power and gas sectors, in road transport, aviation and navigation as well as in the agricultural sector. Power-to-X is one of the technologies that can contribute to fully decarbonizing the Danish economy. Regarding mobility, the Government wants to speed up the development of green transport in Denmark towards 2030, e.g. by promoting electrification and green fuels. The upcoming updated NECP will include information on the Danish ambitions for electrolysis capacity.

The national strategy *"Green solutions of the future - Strategy for investments in green research, technology, and innovation"* (2020) describes the main priorities for the Danish green research and innovation efforts. Seven main topics are identified, the first one on *Energy production*, includes hydrogen and it is then linked to two of the four missions: Carbon capture and storage or utilisation and Green fuels for transportation and industry (Power-to-X etc.)

Denmark participates as an active member in The **North Seas Energy Cooperation** (NSEC) along with Belgium, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden and the UK. The governance focuses on the development of the offshore grid development and the large renewable energy production (76 GW by 2030, 193 GW by 2040) in the region. Plans for hydrogen connections are underway.

Denmark, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

8. Estonia

In October 2020, the Parliament of Estonia delivered a proposal to the government for the development of a **hydrogen strategy**[22]. The strategy will cover a variety of sectors, such as transport, energy production and buildings. Moreover, it will address the entire value chain, from production to end use. The strategy is still under development.

In the meantime, a **Hydrogen Valley Estonia** has been launched, based on the cooperation between three regions, one university and five of the largest companies in energy and industry. These partners have formed a Management Team and a Steering Group to build up the strategy, the governance, and the European recognition of the Valley.

A Work Programme has been approved for the period 2023- 2028. In the six coming years, hydrogen production will be developed in at least six regions in the country. Parallel to that, transport and storage infrastructure is being developed, including import and export terminal infrastructure, fuelling stations and storage facilities.

8.1. Governance

The actual responsible public representative authority is the **Ministry of Environment**, who is also representative in the States Representative Group of the Clean Hydrogen Partnership.

The Estonian Hydrogen Association (Tiit Kallaste) has joined the international hydrogen initiative, which has the objective of achieving the decarbonisation potential of hydrogen technology-based economic sectors, the energy system and the EU's long-term energy supply.

Other relevant Managing Authorities:

- **State Support Services Centre** for Programme for Cohesion Policy Funds 2021-2027.

8.2. Targets

- In the short term there are at least **five sites** planned for large scale onshore solar energy production, where partly converting energy to hydrogen will make sense, as delivering the amounts of energy to the grid will be either very costly or not doable at all.
- In the long term, at least part of the (7GW) offshore potential will be converted to hydrogen from 2029 onwards.

[22] Proposal to the Government for the Development of a Hydrogen Strategy, December 2020: https://h2est.ee/en/estonian-hydrogen-strategy/

8.3. Research and innovation priorities

No specific information on research and innovation priorities for hydrogen was found.

8.4. Funding instruments

- Estonia has considered Hydrogen technologies in its 2021 **Recovery and Resilience Plan** with a projected investment of **50 million euros.**
- **Accelerating the green transition in enterprises** (**220,2 million euros**) aims at speeding up the green transition in the business sector in Estonia. It includes measures on change of business models and uptake of efficient green technologies for which Estonia has provided information on the eligibility criteria. This component also includes a measure to test setting up and piloting integrated green hydrogen value chain and provides assurances that if hydrogen is produced from biomass, sustainability criteria defined in Article 29-31 of Directive 2018/2001 will apply.

The Table below summarises the existing funding programmes, the available budget and the priorities.

Programme Name	Level	Budget	Priorities
RRP	EU	50 million euros (2021)	Hydrogen technologies
Accelerating the green transition in enterprises	National	220,2 million euros	Including test setting up and piloting integrated green hydrogen value chain

Table 7. Estonian Funding Hydrogen programmes.

8.5. Projects

As a result of the preliminary scoping of the Valley, **thirty projects** to be included into the scope have been identified. Almost every single project is initiated by one of the partners in the Steering Group. They range from generation of renewable energy to use cases, across the country. By far most of the projects are in the idea and feasibility phase.

Hydrogen use cases under development range from fuelling public transport, heavy duty vehicles, rail, shipping, aviation, and other transport modalities to feedstock for industry, net balancing and even heating cases in the built environment.

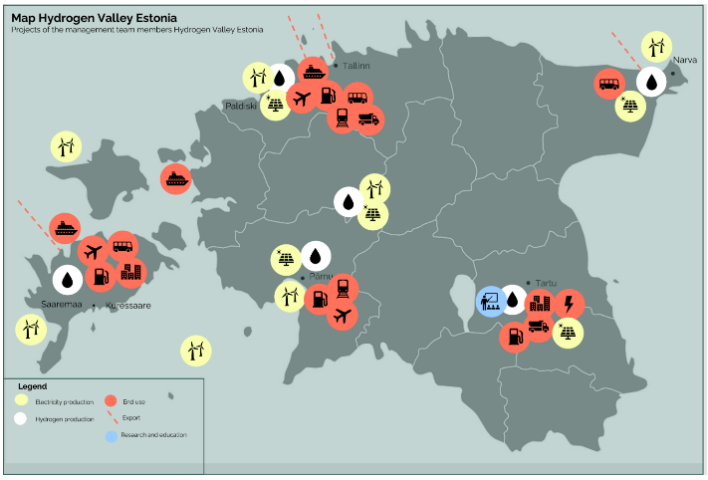

Figure 4. Projects identified in the Hydrogen Valley Estonia

- **IPCEIs:**
  - ***Elcogen***, a fuel cell and electrolyser manufacturer, is amongst the world's most advanced solid oxide specialists, with lower than-normal operating temperatures and superior economics. It has received €24 million investment from HydrogenOne (an equity fund), as well as under IPCEI.
  - **Hydrogen infrastructure development**: Until the Estonian renewable energy production capacity ramps up, Estonia could act as an onshore transit corridor from Finland to other Baltic states and Poland. However, building hydrogen pipelines would be a great undertaking for a small country like Estonia. For this hydrogen transit pipeline to be possible in 2030, strong incentives from both EU, regional and national level are needed, in the form of rapid planning, permitting, securing appropriate funding and agreement on tariffing.

8.6. Other policies and measures

Estonia plans to address the transport, building, electricity generation and gas networks sectors, addressing the entire value chain from generation, over storage, transport and distribution to end use. Estonia's NECP (2019) emphasizes that the lack of regulation is a major obstacle to the development of clean hydrogen.

Estonian partners in the HVE want to optimally respond to European programs: **Hydrogen Valleys** (accelerating Valley learning curve), **TEN-T** (investing in hydrogen-driven transport corridors), **Hydrogen Backbone**.

The recovery and resilience plan (**RRP**) includes measures to incentivise the uptake of renewable energy, pilot hydrogen and energy storage, help introduce green business models in companies, improve energy efficiency of buildings, and invest in sustainable transport.

Estonia, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen.**

9. Finland

The **National Climate and Energy Strategy** (2022) outlines measures by which Finland will meet the EU's climate commitments for 2030 and achieve the targets set in the Climate Change Act for reducing greenhouse gas emissions by 60 per cent by 2030 and being carbon neutral by 2035. It includes a **section on hydrogen**, which also sets quantitative targets for hydrogen electrolysis capacity.

This strategy was based on the extensive Hydrogen economy – Opportunities and limitations report 1 (March 2022)[23], and reviews the state of art of hydrogen in terms of policy and value chain (production, storage, distribution, and application) in Europe and Finland. In the economic report, an analysis of European countries, their roadmaps, strategies and projects were made.

9.1. Governance

The **Ministry of Economic Affairs and Employment (MEAE)** is the main decision maker for hydrogen matters. It is also the representative in the States Representative Group of the Clean Hydrogen Partnership.

In February of 2023[24], the principal decision on hydrogen was released, including 20 measures that will contribute to the development of hydrogen and the hydrogen economy. They are grouped in three categories:

- Actions on the policy environment and regulation.
- Actions on knowledge and cooperation.
- Actions on innovation and investment.

These measures are set to continue the guidelines of the Climate and Energy Strategy and to be the based to an official separate Hydrogen Strategy. Moreover, in this document, the competences for Hydrogen have been distributed along the ministries and stakeholders.

In terms of national cooperation networks, Finland has created hubs, such as the **National Hydrogen network** around the Gulf of Bothnia in Spring of 2021. By October 2021, approximately 50 hydrogen companies had joined it. The hydrogen network aims to be a global leader in developing and offering hydrogen solutions globally. The hydrogen network published a white paper on the promotion of the Finnish hydrogen economy in September 2021.

[23] Hydrogen economy -Opportunities and limitations. Publications of the Government´s analysis, assessment and research activities (2022). Publications of the Prime Minister's Office. ISBN pdf: 978-952-383-068-4
[24] Government resolution on hydrogen. Publications of the Finnish Government 2023:19. Government resolution on hydrogen (valtioneuvosto.fi)

In the international landscape, Finland participates in partnerships for hydrogen such as those built within the framework of the International Energy Agency (IEA), the Clean Energy Ministry and Mission Innovation.

9.2. Targets

Finland has set a target for the **electrolysis equipment** for hydrogen production to be at least of 200 MW in 2025 (9 MW in 2021) and **1.000 MW** in 2030, considering the commercialisation of hydrogen technology.

Moreover, the country will pilot the use of hydrogen in transport, especially in heavy-duty road and waterborne transport. The goal is that **electrofuels** will amount to **3 per cent** of all transport fuels by 2030.

9.3. Research and innovation priorities

The preliminary priorities include:

- Development and use carbon capture and utilization (CCS/CCU) technologies.
- Solutions to reduce CO2 emissions caused by waste incineration.

Further guidelines on R&D goals on hydrogen will be set by the upcoming national hydrogen strategy.

9.4. Funding instruments

- Research and development activities related to hydrogen solutions will be promoted with **Business Finland's competitive RDI funding**, in which the green transition is one of the focus areas (**326 million euros**).
- Meanwhile, pilot, scaling and full-scale investment projects in the hydrogen economy are aligned with the current funding focus of **Finnvera, Tesi and the Finnish Climate Fund**.
- In the **Sustainable Growth Programme for Finland**, **150 million euros** have been allocated to low-carbon hydrogen and carbon capture and utilisation for 2023-24. The programme also promotes research and development activities, and investments in energy infrastructure and new energy technology. The programme provides a highly significant funding package that enables the promotion of hydrogen solutions at different parts of the value chain.
- In addition, hydrogen projects can be financed continuously with the **energy aid** of the Ministry of Economic Affairs and Employment.

The Table below summarises the existing funding programmes, the available budget and the priorities.

Programme Name	Level	Budget	Priorities
Business Finland's competitive RDI funding	National	326 million euros	Green transition is part of it
Sustainable Growth Programme for Finland	National	150 million euros (2023- 2024)	Low-carbon hydrogen (different parts of the value chain) and CCU

Table 8. Finnish financial hydrogen mechanisms.

9.5. Projects

In Finland, there are currently (at the beginning of 2023) over **20 hydrogen projects** in different phases. Most of the projects are in a preliminary planning phase, which represents the basis for organising funding and making investment decisions. The projects mainly focus on the production of clean hydrogen and using wind power as the source of energy.

They aim to produce electric fuels for the needs of industry and transport are carried out in different parts of Finland, mainly in the largest industrial regions on the south and west coasts. These include:

- The one the **city of Kerava** with 20 fuel cell buses for public transport, being powered by hydrogen produced from a PV plant.
- **19 publicly accessible hydrogen refuelling points.**
- **Gasgrid Finland** is investigating the possibilities of developing Finland's hydrogen network and the hydrogen market in the Baltic Sea region and has therefore initiated three major infrastructure development projects in cooperation with infrastructure players in neighbouring countries and international industry players.
- The industrial-scale research project at the **SSAB steel mill** seeks to manufacture fossil-free steel by means of hydrogen reduction and clean electricity.
- **Southern Finland** is home for several demonstration hydrogen projects on the production of synthetic natural gas (Q Power and Wärtsilä); production of clean hydrogen and utilisation in ferry transport (Flexens); synthetic methanol (Joutseno business consortium) and the production of clean and lowcarbon hydrogen for the manufacture of oil and liquid biofuels (Neste).

Figure 5. Examples of Finnish hydrogen projects in 2021.

- **IPCEIs**:
  - ***P2X Solutions' green hydrogen and synthetic methane production plant*** project. P2X Solutions will construct 70 MW of green hydrogen production capacity and a methanation plant to produce renewable synthetic methane. According to the schedule, the Harjavalta plant will be completed in 2024. As part of the IPCEI project, the company is currently investigating the construction of a hydrogen and e-fuel production facility in Joensuu together with Savon Voima. P2X Solutions' goal is 1,000 MW of electrolysis capacity in 2031.
  - ***Solar Foods*** is currently building its first hydrogen fermentation factory in Vantaa, Finland, which will move the company forward to the final investment decision (FID) stage aiming at a large-scale factory investment during the IPCEI project.
  - The hydrogen projects at ***Porvoo refinery*** will become an integral part of the European value chain for the production and use of clean hydrogen. The production of clean hydrogen will play a key role in developing responsible, commercially viable solutions for low-carbon traffic and industry.

9.6. Other policies and measures

The Finnish NECP of 2019 does not comprise specific hydrogen related measures nor objectives.

The **Finnish RRP** includes the provision to launch calls for applications for four large investment measures focusing on: renewable energy and related infrastructure, renewable hydrogen and carbon capture and storage and utilisation, as well as investments in the decarbonisation of industry. More specifically, it targets investments along the hydrogen value chain as well as in carbon capture, storage and recovery for a total of 156 million euros.

The Clean Energy Transition Agenda for the ***island of Kökar*** includes reference to zero-emission ferry and the possibility to choose between battery-driven ferries, and ferries powered by hydrogen. For long distances, hydrogen could be the best alternative. For a ferry like Gudingen, which is in use today, approximately 800 kg of hydrogen would be needed every day. To produce this amount of hydrogen almost 5 MW of installed wind power is required. To put the numbers into perspective, 0,5 MW of wind power is installed as of today and this turbine produces approximately 50 % of the yearly electricity demand. A project like this is more likely to be realizable in the timespan of 2030-2050 when efficiencies have increased, and prices decreased. A first step would be to go through with small scale pilots for battery driven and hydrogen driven marine vessels before advancing to larger ferries. For a hydrogen demo, a boat from Sjötrafik AB could be used.

Finland, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen.**

10. France

France adopted a **National strategy for the development of decarbonised and renewable hydrogen in France** in September 2020[25].

The strategy has three main objectives:

- To install enough electrolysers to make a significant contribution to the decarbonisation of the economy.
- To develop clean mobility, in particular for heavy-duty vehicles.
- To build a French industrial sector that creates jobs.

The Government has selected three priorities for intervention, which correspond to the main hydrogen markets and enable their development on the French territory to be rooted in a sustainable and long-lasting dynamic, so that this strategy contributes fully to France's goal of carbon neutrality by 2050:

- Decarbonising industry by developing a French electrolysis sector.
- Developing the use of decarbonised hydrogen for heavy-duty mobility.
- Supporting research, innovation and skills development to promote the uses of tomorrow.

An update of the national strategy for the development of hydrogen is currently being developed, and it is foreseen by the end of June 2023[26].

10.1. Governance

A **National Council for Hydrogen** (CNH), composed of the Ministry of Ecological Transition, the Ministry for Economy, Finances and Recovery, and the the Ministry for Higher Education, Research and Innovation, has been created with a view to ensuring the implementation of a national hydrogen strategy for France. The coordinator for the implementation of the national hydrogen strategy is Hoang Bui (General Secretariat for Investment).

The main representative in the States Representative Group of the Clean Hydrogen Partnership comes from the Ministry for Higher Education, Research and Innovation.

Other relevant Managing Authorities:

- **Région Provence- Alpes-Côte d'Azur** for the Programme Programme Sud - Provence-Alpes-Côte d'Azur and Massif des Alpes ERDF-ESF+-JTF 2021-2027.
- **Conseil régional de La Réunion** for the Programme Réunion ERDF-ESF+ 2021-2027.

[25] Stratégie nationale pour le développement de l'hydrogène décarboné en France.
[26] This is not yet known at the time of writing this Document, and could not be included in the analysis.

- **Région des Pays de la Loire** for the Programme Pays de la Loire ERDF-ESF+-JTF 2021-2027.
- **Région Occitanie** for the Programme Occitanie ERDF-ESF+ 2021-2027.
- **Conseil Régional de Nouvelle-Aquitaine** for the Programme Nouvelle-Aquitaine ERDF-ESF+ 2021-2027.
- **Conseil Régional de Normandie** for Programme Normandie ERDF-ESF+-JTF 2021-2027.
- **Région Hauts de France** for Programme Hauts de France ERDF-ESF+-JTF 2021-2027.
- **Collectivité Territoriale de Guyane** for Programme Guyane ERDF-ESF+ 2021-2027.
- **Conseil régional de la Guadeloupe** for Programme Guadeloupe ERDF-ESF+ 2021-2027.
- **Région Grand Est - Délégation aux Fonds Européens** for Programme Grand Est and massif des Vosges ERDF-ESF+-JTF 2021-2027.
- **Conseil régional de Bourgogne-Franche-Comté** for Programme Bourgogne-Franche-Comté and massif du Jura ERDF-ESF+ 2021-2027.
- **Prefecture de Mayotte** for the Programme Mayotte ERDF 2021-2027.
- **Région Hauts-de-France - Direction Europe** for the Programme (Interreg VI-B) North-West Europe.

10.2. Targets

- To install **6,5 GW of electrolysers by 2030**, able to produce 60 kt/year of hydrogen.
- To abate more than 6 Mt of CO2 emissions by 2030.
- To create between 50,000 and 150,000 direct and indirect jobs in France.

10.3. Research and innovation priorities

The **Priority Research Programmes and Equipments** (PEPR- Programmes et Equipements Prioritaires de Recherche) in the area of hydrogen, led by CEA and CNRS, have been granted 80 million euros up to 2030.

- **H2 storage and distribution**: hydrogen can be used to facilitate the deployment of renewable energies by improving the stability of energy networks. Hydrogen represents a definite potential in the medium term for the decarbonisation of the gas sector (liquid H2, reuse in the gas network).
- **H2 end-uses:**
  - *Mobility applications/Tomorrow's heavy-duty mobility:* this is particularly the case for decarbonised aircraft and ships. In particular, some R&D financing dedicated to research on hydrogen plane is available via CORAC (Civil Aviation Research Council).

- *Clean heat and power* (focus on decarbonisation of hard-to-abate sectors): the use of decarbonised hydrogen can be integrated into certain industrial processes to reduce CO2 emissions. Hydrogen could, for example, be used in the steel industry for the reduction of iron ore, or in the chemical industry for the manufacture of fertilisers.

- **Hydrogen Valleys**: Normandy Hydrogen; Regional Hydrogen Roadmap; ZEV- Zero Emission Valley.

10.4. Funding instruments

The strategy foresees an overall investment to develop and implement hydrogen technologies for a total of **9 billion EUROS** up to 2030, as part of "*France Relance*" and "*Investissements d'Avenir*".

10.5. Projects

- **Arcelor Mittal**, in its Dunkirk steel production site, foresees the replacement of one of its furnaces with a new technology based on Direct Reduction of Hydrogen (DRI). The first project phase (2022-2026) aims at producing 4 Mt/year of decarbonised steel.
- **12 hydrogen trains** produced by ALSTOM. They will focus on four regions: Occitanie, Bourgogne-Franche-Comté, Auvergne-Rhone Alpes, and Grand-Est.
- **IPCEIs**. France is investing 3 billion euros via RRF.
  - ***Alstom*** wins a grant for a hydrogen plan based on 3 structuring innovations:
    - The development of hydrogen bricks.
    - The development of a hydrogen shunting locomotive.
    - The development of a high-power hydrogen fuel cell generator wagon for freight.
  - ***Arkema*** will be funded as part of the M2H2 project aimed at developing and then industrially deploying high-performance sustainable materials (polymers and composites) to produce, store, transport and use hydrogen for mobility.
  - ***Elogen***'s project consists in increasing the intensity of its R&D to develop innovative stacks of electrolysers with proton exchange membranes. It also includes building, in Vendôme (Loir-et -Cher), a factory allowing the mass production of these stacks. The Elogen gigafactory will start its production in 2025 and will have a production capacity of one gigawatt.
  - ***John Cockerill Hydrogen***'s project revolves around research and innovation dedicated to the design of a 5 MW, 1000 Nm^3/hr alkaline electrolyzer at 30 bar and the industrialization of its large-scale production in Belgium and France. John Cockerill's ambition is to develop an electrolyzer production capacity of 1 GW by 2030. This ambition entails, on the one hand, developing large-capacity alkaline

electrolyzers (from 5 MW, 1000 Nm³/h at 30 initially, then 10MW and up to 20MW in the long term by increasing the diameter of the cells and/or increasing the current density), and on the other hand, starting up a large-scale electrolyzer production chain in Europe: by 2030, a capacity of 1 GW. This industry will be based on mainly French and exclusively European solutions (intellectual property, technologies, production, etc.) and will be located near the major industrial regions of France, Belgium, Luxembourg and Germany.

- ***McPhy's Gigafactory project*** aims to develop new generation electrolyzers and to deploy their industrial production in series. The Belfort site has been pre-selected by McPhy for the implementation of this Gigafactory. With this project, McPhy is targeting 3 objectives:
  - Innovation, through the development of new generation alkaline electrolyzers, in terms of size, components and integration within platforms;
  - Industrialization of large-scale production to meet the needs of the European market, in particular, to contribute to the decarbonization of industry, mobility and energy;
  - Collaboration with numerous partners of the Hydrogen ecosystem in Europe and dissemination of knowledge with academic, industrial and research stakeholders.
- ***Genvia***'s project will develop a new generation of electrolyser to produce clean hydrogen. The technology aims to achieve the highest level of electrical efficiency by boosting the electrolyser with the thermal energy of waste industrial heat. This will significantly reduce the electricity consumption required per kilogram of hydrogen produced making it possible to produce carbon-free hydrogen at an affordable price and expand its use in industrial decarbonisation and other applications. The project will scale up the manufacture of these thermally-boosted electrolysers at Genvia's factory, located in Béziers, in the Occitanie Region of France. Genvia's Technology Transfer Centre based at CEA-Grenoble will help ensure that cutting-edge scientific understanding is leveraged in the design.
- ***HYVIA*** Hyvia will be supported to develop the industrialization in France of hydrogen commercial vehicles and fuel cells. The project will enable the marketing of hydrogen vans for professional and institutional customers, starting in the second half of 2022.
- ***Faurecia's "Historhy Next"*** project aims to develop new generations of hydrogen tanks, both gaseous and liquid, by the end of 2027. Production would start in 2024 at its Allenjoie plant in France's Bourgogne-Franche-Comté region, with a goal of producing more than 100,000 units per year.
- ***Symbio's project HyMotive*** consists in a large-scale transformation project that will enable to accelerate the mass-production of its last-generation fuel cell

systems and develop Saint-Fons, and to develop and industrialize a new generation of fuel cells that are more efficient and at a drastically reduced cost.

- ***Plastic Omnium*** will be supported in the creation of the largest tank manufacturing plant on its Compiègne site.

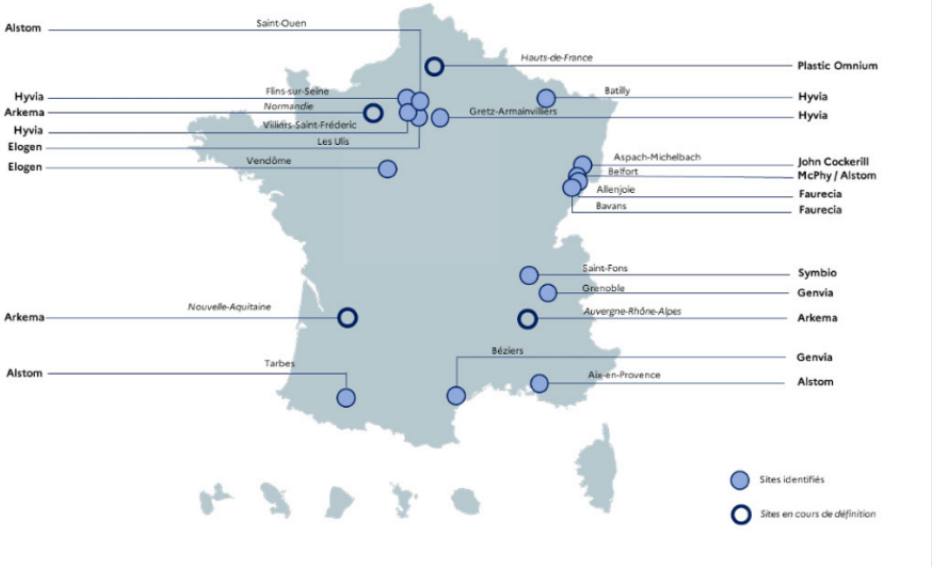

Figure 6. Map of French IPCEI projects

- Seven projects financed by ADEME (French agency for the environmental transition) in the context of the 2021 call dedicated to "**territorial ecosystems**".
- In January 2023, GRTgaz launched a call for interest in order to deepen knowledge of the needs and thus confirm the economic interest of a hydrogen transport infrastructure by pipeline linking the industrial and port area of Fos-sur-Mer and storage capacities located in Manosque, named **HYnframed**.
- **Three H2 Valleys**:
  - ***Regional Hydrogen Roadmap*** (Dijon Métropole Smart Energy). The BFC (Bourgogne-Franche-Comté) region has decided to make a commitment by funding projects that meet these priorities. Its financial commitment is 90 million euros for the next 10 years.
  - ***Normandy Hydrogen*** (Normandy region) aims to strengthen the role of hydrogen within the energy transition in Normandy with priorities in mobility, logistics, industry and the production of renewable hydrogen while developing a fully-fledged industrial sector.

- ***ZEV - Zero Emission Valley*** (Auvergne-Rhône-Alpes Regional Council). This project aims to deploy 20 hydrogen stations and 1,200 vehicles in the Auvergne-Rhône-Alpes Region before the end of 2024.

10.6. Other policies and measures

Hydrogen is thoroughly considered in the French NECP 2019.

It includes the following targets:

1. To have by 2028 20 000 - 50 000 light duty and 800 - 2 000 heavy duty fuel cell vehicles.
2. To have by 2028 400 - 1 000 hydrogen refuelling stations.
3. To switch from 20 to 40% of fossil-based hydrogen in industry to hydrogen produced in electrolysers using low carbon electricity is foreseen by 2028.

France is also part of the the **Pentalateral Energy Forum**, composed of Energy Minsters from Austria, Belgium, Switzerland, Germany, France, the Netherlands and Luxembourg. It is a framework for regional energy cooperation that has initiated several actions for greater electricity market integration and improved security of supply in Europe. Some ongoing work also focuses on hydrogen certification.

The **French Recovery and Resilience Plan** has a chapter specifically dedicated to hydrogen, which refers to the activities of the French National Hydrogen strategy.

Some French islands have also developed Clean Energy Transition Agenda (CETA) with reference to hydrogen:

- The ***Île de Sein*** CETA makes reference to the drafting of a study to evaluate medium term storage solution, including hydrogen, to support the transition to 100% renewables[27].
- The ***Île de Molène*** CETA makes reference to the drafting of a study to evaluate medium term storage solution, including hydrogen, to support the transition to 100% renewables[28].
- The ***Île de Ouessant*** CETA makes reference to the drafting of a study to evaluate medium term storage solution, including hydrogen, to support the transition to 100% renewables[29].

France participates as an active member in The **North Seas Energy Cooperation (NSEC**) along with Belgium, Denmark, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden and the UK. The governance focuses on the development of the offshore grid development and the

[27] Programme de transition vers l'énergie propre, Île de Sein, March 2020: https://clean-energy-islands.ec.europa.eu/countries/france/ile-de-sein-iles-du-ponant
[28] Programme de transition vers l'énergie propre, Île de Molène, March 2020: https://clean-energy-islands.ec.europa.eu/countries/france/molene-iles-du-ponant
[29] Programme de transition vers l'énergie propre, Île de Ouessant, March 2020: https://clean-energy-islands.ec.europa.eu/countries/france/ouessant-iles-du-ponant

large renewable energy production (76 GW by 2030, 193 GW by 2040) in the region. Plans for hydrogen connections are underway.

France, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen.**

11. Georgia

Georgia will release its first Hydrogen Concept/Roadmap by 2024, its development is being supported by the European authorities and will include objectives, targets and analysis of scenarios for the hydrogen deployment in the country. The Ministry of Economy and Sustainable Development of Georgia and its subsidiary institution Georgian Oil and Gas Corporation (GOGC) is actively cooperating with KfW (German Development Bank), under EU funding, to conduct a strategic, market and financial assessment of Green hydrogen across Georgia, including a resource mapping of solar and wind resources across the country, Already in 2021, KfW performed a preliminary feasibility study on a Green Hydrogen including a proposal for a transport-related demonstration project. Moreover, ADB (Asian Development Bank) is currently undertaking a gas sector analysis, making storage and decarbonisation proposals, proposing capacity building activities, as well as a review of technical standards.

KFW's "Assessment of potential for a Green Hydrogen economy in Georgia – Demand, Supply, Legal and Regulatory Analysis" comprises an analysis of potential hydrogen production, assessing the potential demand for hydrogen, assessing storage, conversion and transportation of hydrogen and its derivatives, solar and wind resource mapping (LCoE across the country), TIMES-Georgia and levelized Cost of Hydrogen (LCoH), Supply Chain modelling, analysis of legal, policy and regulatory gap analysis, as well as drafting and developing a Hydrogen Concept/RoadMap that builds on the National Energy Policy (NEP) and its annex National Energy and Climate Plan (NECP) which are planned to be approved by the end of 2023.

ADB's *"Preparing Energy Storage and Green Hydrogen Sector Development Program"* will cover:

- Clean Hydrogen Gas Action Plan (taking its direction from the a.m. Concept).
- Proposal to include H2 in the National Determined Contribution Agreement.
- Environmental, social and health safeguards regulatory frameworks.
- H2 Certification.
- Hydrogen regulatory sandbox.
- Decarbonization strategy for GOGC and GGTC, including hydrogen, hydrogen network.
- Potential CCS and a pilot project design and investment strategy.

The support from KFW and ADB, the drafting of a National Concept and subsequent Action Plan, are expected to provide guidance to the Government on the future role and development of hydrogen and/or its derivatives in Georgia.

11.1. Governance

The Hydrogen Energy Development Support committee for promoting the development of hydrogen energy was established in July 2022 with the support of the **Minister of Economy and Sustainable Development** (MoESD). The main goals of the committee are to:

- Evaluate the prospects of hydrogen energy development in Georgia and the socio-economic impact of hydrogen projects, according to which recommendations will be made for the country's energy development.
- Support development of the national strategy.
- Develop the roadmap for hydrogen national strategy.
- Define additional framework for hydrogen promotion.
- Support an increase of renewable electricity capacities for hydrogen production.

The Chairman of the committee is hold by the Georgian Energy Development Fund, which is under MoESD. MoESD is also representative in the States Representative Group of the Clean Hydrogen Partnership.

Furthermore, as long as the Georgian Energy Development Fund JSC (hereinafter “GEDF”) holds the position of the chairperson within the Committee, it has already taken the necessary steps to join the European Clean Hydrogen Alliance as GEDF, and submitted the Application for membership on 30th May 2023.

11.2. Targets

At this stage, Georgia does not have specific target indicators for hydrogen. With the development of relevant policy and the transposition of EU directives, it will be possible in the future to have specific indicators. The country’s goal, at this stage, is to develop a relevant policy framework for further promoting the hydrogen economy.

11.3. Research and innovation priorities

Georgia is currently focusing on the definition of a vision to develop a hydrogen economy, and on capacity building. It has not reached the state of developing a research and innovation roadmap for hydrogen yet.

11.4. Funding instruments

The **Georgian Energy Development Fund (GEDF)** is a state-owned joint-stock company subordinate to the MoESD. It was created in 2010 to seek out prospective renewable energy projects and promote their development. The GEDF is engaged in preliminary research, feasibility assessments, environmental impact assessments and finding investors and attracting their

interest to existing projects. Investors can sign memorandums or agreements with the GEDF (and eventually a third party) that define the mutual responsibilities of the GEDF and the investor. Depending on the investor's needs, the GEDF can provide various services to facilitate project preparation and implementation. The Public-Private Partnership Agency is a new body created following the adoption of the Public-Private Partnership Law in May 2018. The agency's mandate is to lead the development and implementation of public and private co-operation projects.

There are no specific national nor regional public budgets and financing mechanisms, but, as forementioned, there are several active support donor organizations and generally available funds for innovation. An ongoing, 8,44 million euros EU-funded technical assistance for the "Georgian Energy Sector Reform Project" (GESRP) is working closely with the Government to help Georgia promoting further renewable energy investments, strengthen the country's energy security and enhance opportunities for future energy trading with the EU.

11.5. Projects

The Georgian Oil and Gas Corporation is actively working on the development of a pilot project, which will provide the first production of green hydrogen in Georgia.

In May 2023, the Government of Georgia, represented by the Ministry of Economy and Sustainable Development, the Georgian Oil and Gas Corporation, the City of Batumi and KfW signed a Memorandum of Understanding on deepening the cooperation in this area and work together on the realization of an investment project. The MoU is a further concrete step towards the realization of a demonstration project after KfW and the Government of Georgia signed a Declaration of Intent on Green Hydrogen in November 2021. Substantial preparatory grant funds were committed by the German Government and investment grants are also under preparation.

12. Germany

Germany adopted its first **National Hydrogen Strategy**[30] in June 2020.

The priorities of this strategy to 2026, which includes a dedicated budget of **19,9 billion euros**, are the following ones:

- Take global responsibility.
- Establishment of climate-friendly produced hydrogen, especially from renewable energies, and its downstream products.
- Creation of the regulatory conditions for market ramp-up of hydrogen technologies.
- Reduction of the costs of implementing hydrogen technologies to trigger global markets and make hydrogen competitive as an alternative energy source with highlight in the steel and chemical industry as well as in certain parts of the heating market.
- Making hydrogen sustainable as a raw material for industry
- Strengthen German companies and their competitiveness by pushing research, development, training and technology export for innovative hydrogen technologies.
- Secure and shape the future national supply of hydrogen from renewable energies and its derived products by paving the way for future imports

Given the changes in the policy and regulatory framework at EU level, as well as of the changed energy situation worldwide, it was decided to update the 2020 Hydrogen Strategy. Therefore, the German Hydrogen Strategy is currently under revision and will include:

- No specific target for fuel cell vehicles (global national target of 15 mil. electric vehicles, including FCEV, until 2030)
- Construction of more than 100 HRS for trucks and buses with the current and upcoming calls

12.1. Governance

The governance of the current strategy is composed by the **State Secretaries' Committee on Hydrogen** (Ministries) that cooperate with the Federal Cabinet in matters related to changes of the Strategy. The Federal Government will appoint a **National Hydrogen Council**. The Council is made up of 26 high-level experts from business, science, and civil society who are not part of the public sector. The task of the National Hydrogen Council is to advise and support the State Secretaries' Committee through proposals and recommendations for action in implementing and

[30] The National Hydrogen Strategy. The Federal Government. Federal Ministry for Economic Affairs and Energy Public Relations Division (June 2020). Nationales Reformprogramm 2020 (bmbf.de)

enhancing the Hydrogen Strategy. The National Hydrogen Council meets at least twice a year and invite members of the Committee as guests.

The **'Green Hydrogen' Innovation Officer** of the Federal Ministry of Education and Research (BMBF) is a permanent guest of the State Secretaries' Committee and the National Hydrogen Council and oversees and coordinates the organisation of research and development activities.

On behalf of the Federal Government, the secretariat of the **Coordination Office** assists the Ministries in implementing the Hydrogen Strategy, and the Hydrogen Council in coordinating and drafting recommendations for action. The Coordination Office is also responsible for monitoring the National Hydrogen Strategy. Furthermore, it actively supports the ministries in the implementation of the Strategy by providing a flexible project management structure. Ultimate decisions and responsibility are accounted to the **Federal Ministry for Economic Affairs and Climate Action (BMWK)**.

The German main representatives in the States Representative Group of the Clean Hydrogen Partnership are nominated from BMBF and BMWK.

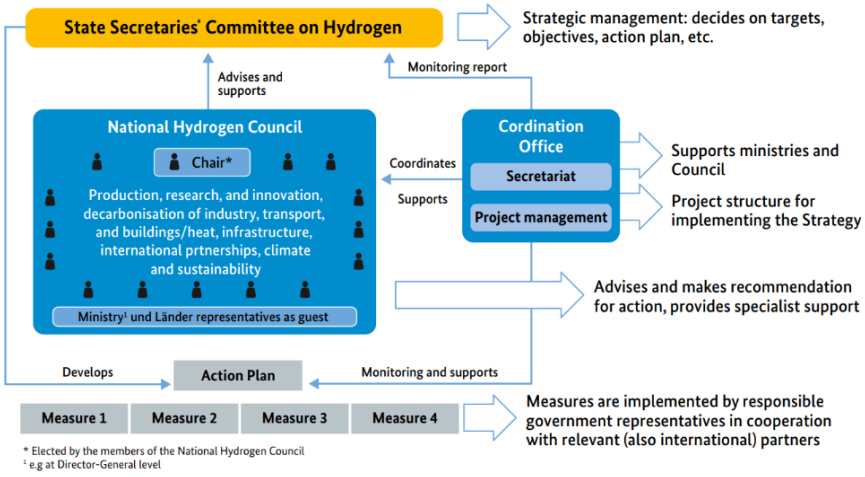

Figure 7.Governance structure of the German National Hydrogen Strategy

Aside from the measures taken at federal level, the Länder have also been planning and implementing their own hydrogen-related measures that are just as important in terms of the creation of a hydrogen economy and the leadership of German companies. Close cooperation between the federal and state levels helps to coordinate activities, use synergies, avoid path dependencies, share valuable experience, and define further steps of action. For this purpose, the Federal Government aims at establishing a suitable platform format (e.g. in the form of a **Federation-Länder Working Group on Hydrogen**), which would make sure that the Länder governments are kept informed about the activities of the Hydrogen Council.

Other relevant Managing Authorities managing regional budgets are listed below:

- **Ministry of Economic Affairs, Labour and Energy of the State of Brandenburg** for the Programme ERDF/JTF 2021-2027 Brandenburg.
- **Ministry of Economic Affairs, Innovation, Digitalization and Energy of the State of North Rhine-Westphalia Department** for the Programme ERDF/JTF 2021-2027 North Rhine-Westphalia.
- **Saxon State Ministry of Economic Affairs, Labour and Transport; Unit "Managing Authority ERDF / JTF**" for the Programme ERDF/JTF 2021-2027 Saxony.
- **EU Managing Authority ERDF/ESF** for the Programme ERDF/JTF 2021-2027 Saxony-Anhalt.
- **Lower Saxony Ministry of Federal and European Affairs and Regional Development Unit** for the Programme Lower Saxony 2021-2027 ERDF-ESF+.
- **Ministry of Food, Rural Affairs and Consumer Protection** for the Programme ERDF 2021-2027 Baden-Württemberg.
- **Bavarian State Ministry of Economic Affairs, Regional Development and Energy / ERDF Managing Authority** for the Programme ERDF 2021-2027 Bavaria.
- **The Senator for Economic Affairs, Labour and Europe** for the Programme ERDF 2021-2027 Bremen.
- **Ministry of Economy and Innovation, Office of Economy** for the Programme ERDF 2021-2027 Hamburg.
- **Hessian Ministry of Economic Affairs, Energy, Transport and Housing** for the Programme ERDF 2021-2027 Hesse.
- **State Chancellery of Mecklenburg-Western Pomerania, Joint Managing Authority for ERDF and ESF (GVB)** for the Programme ERDF 2021-2027 Mecklenburg-Vorpommern.
- **ERDF Managing Authority Rhineland-Palatinate** for the Programme ERDF 2021-2027 Rhineland-Palatinate.
- **Ministry of Economy, Innovation, Digital and Energy** for the Programme ERDF 2021-2027 Saarland.
- **Ministry of Economic Affairs, Transport, Labour, Technology and Tourism of Schleswig-Holstein** for the Programme ERDF 2021-2027 Schleswig-Holstein.
- **Thuringian Ministry of Economics, Science and Digital Society** for the Programme ERDF 2021-2027 Thuringia.
- **Saxon State Ministry for Regional Development** for the Programme (Interreg VI-A) Germany/Saxony-Czechia.

12.2. Targets

The 2020 Strategy includes the following targets:

- The Federal Government expects that around **90 to 110 TWh** of hydrogen will be needed by 2030.
- Germany plans to establish up to **5 GW of generation capacity** including the offshore and onshore energy generation facilities needed for this. This corresponds to **14 TWh of green hydrogen production** and will require 20 TWh of renewables-based electricity.
- An additional **5 GW of capacity** are to be added, if possible by 2035, and no later than 2040.
- National target of 15 million electric vehicles, including Fuel Cell vehicles until 2030 and construction of more than 100 hydrogen refuelling stations for trucks and buses

The Federal Government has included a monitoring mechanism in the National Hydrogen Strategy which will be used to track the development of green hydrogen demand in detail.

The implementation report published in April 2022[31] states the progress achieved by the Strategy till end of 2021:

- More than 2 GW of electrolysis capacity and 1.700 kilometres of hydrogen pipeline network were launched with the 62 German IPCEI hydrogen projects.
- With the amendment of the Energy Industry Act (EnWG) and the associated Hydrogen Network Charges Ordinance, the first regulatory framework conditions were enacted.
- Decarbonisation in transport and industry has been stimulated by the Act on the Further Development of the Greenhouse Gas Reduction Quota (Gesetz zur Weiterentwicklung der Treibhausgasminderungsquote) and a reduction in the quota to 25 percent by 2030.

12.3. Research and innovation priorities

Hydrogen research focuses on key technologies along the entire hydrogen value chain. This includes research into completely new technologies as well as the upscaling of hydrogen technologies. In application-based research, pre-competitive cooperation between science and industry is strengthened.

The German Kopernikus projects or Carbon2Chem are lighthouse projects for pre-competitive cooperation between science and industry.

[31] Progress Report on the Implementation of the National Hydrogen Strategy. Federal Ministry for Economic Affairs and Energy Public Relations Division (April 2022). Fortschrittsbericht zur Umsetzung der Nationalen Wasserstoffstrategie (bundesregierung.de)

In addition, ongoing research initiatives on hydrogen production, storage, transport and application in industry and infrastructure are intensified and further developed, such as the hydrogen flagship projects H2Giga (hydrogen production), H2Mare (offshore hydrogen production) and TransHyDe (hydrogen transport and infrastructure, incl. H2 readiness). At the same time, efficiency improvements along the entire value chain are promoted.

More specifically, the priorities from the energy research program focus on:

- Development of innovative technologies for **hydrogen production**:
  - Germany focuses on providing technologies for industrialization, especially series ***production of large-scale electrolysers***, as well as ***offshore electrolysis***. To this end, nearly all early-stage research and development research topics mentioned are pursued in ongoing research projects, as well as most topics mentioned under "demonstration actions". There are first demonstration actions at scale as well as projects in the steel sector. The most relevant R&I topics for hydrogen production technologies constitute the following:
    - Serial and automated production of electrolysers.
    - Offshore electrolysis.
    - Reduction of cell degradation and increase in efficiency.
    - Reduced use of critical raw materials (e.g. platinum, iridium).
    - Improving electrolysis system performance.
    - Flexible operation of electrolysis with renewable energies.
  - Other routes of renewable hydrogen are also pursued, but on a much smaller scale.
- ***Manufacturing technologies*** for components and systems for hydrogen production.
- ***H2 storage and distribution technologies:***
  - *(Long-term) storage of hydrogen*. Focus is on providing technologies for industrialization, especially R&D of transportation technologies.
  - *H2 in natural gas grid:*
    - Develop testing methods to identify the influence of hydrogen on different pipeline materials.
    - Qualify the effects of hydrogen on steel in pipes etc.
    - Identification and development of new materials optimised for hydrogen transport.
    - Construct local demonstration projects both for hydrogen blending and pure hydrogen pipelines with cross border participation, aiming to a gradual shift to pure hydrogen pipelines.
  - *Liquid Hydrogen Carrier*:
    - To increase the efficiency and reduce the costs of hydrogen liquefaction technologies.

        - Develop a range of hydrogen carriers that will be used commercially to transport and store hydrogen while improving their roundtrip efficiency and lowering their cost.
        - Hydrogen Liquefaction.
        - Upscale from the prototype to large-scale plants
    - *Hydrogen Refuelling Stations*:
        - The Federal Government supports investments for HRS with a quota of 80 %. One call for proposals was launched in spring 2023 and a second call is planned later this year.
        - Focus of funding is expanding the HRS infrastructure for heavy-duty vehicles.
        - The difficulties projects in this area are currently facing comprise a lack of standardized refuelling protocols for some technologies with the effect that the government is incapable of defining standards/norms.
- ***H2 use in mobility applications***:
    - *Heavy-duty vehicles*: The focus of R&I in the sector of HD application lays especially on the increase of lifetime, efficiency, durability, cost parity and usability of not only the FC system but the entire vehicle. Therefore, projects ending at a higher TRL including demonstration and validation are pushed forward. Furthermore, major significance is held by projects in the category of storage systems of all state of aggregation (CGH2, CcH2, sLH2). These projects focus on the optimisation of the tank –technology and the standardisation and improvement of the refuelling process.
    - *Waterborne applications*: R&I focus is on further development of power density, increasing efficiency and lifetime. R&I will be focused on all different fuel cell technology (LT/HT PEM, SOFC) regarding the use in inland and deep see applications. Especially the demonstration and validation of those fuel cell technologies in combination with hydrogen and hydrogen-based fuels in real operation is driven forward in current national projects.
    - *Rail applications*: As of 2023, Germany has two completed R&I projects for hydrogen passenger trains with PEM fuel cells: BetHy, which was led by Alstom, and H2goesRail, led by Siemens Mobility. Current project ideas also focus on the hydrogen combustion engine for conversion solutions for shunting traffic and track work vehicles.
    - *Aeronautic applications*: With respect to fuel cell systems in aeronautic applications, the focus is currently on:
    - Demonstration of a fuel cell system under aeronautical conditions (at ground)
        - Development of a testing infrastructure
        - Scaling of the power class into megawatt range

- Increasing power output with simultaneous weight reduction
- Long service life (target: 30,000 operating hours)
- Thermal management in the aircraft

And with respect to tank and LH2:

- Handling of LH2 at the airport
- Refuelling process LH2 (quantities and speed)
- Development of reliable LH2 tanks for large quantities in lightweight design.

- ***H2 uses in clean power and heat:***
  - *Improving existing applications* for scaling up production, reducing costs and enhancing service life.
  - *Developing and testing of new applications* with demonstration projects with >100 kW-performance and integration into complete systems, supply with clean energy for recharging points without grid-connection, digital monitoring systems for remote maintenance.
  - *Stationary fuel cells*:
    - Early-stage research actions.
    - Material, components and systems.
    - Stationary applications and integration into the energy system-industrialization.
    - Hydrogen components.
    - Turbines, boilers and burners:
    - Safety concepts.
- ***H2 cross-cutting issues***: some of the most important topics, currently pursued, are:
  - Implementing RED III in national law and allowing GHG trading quota for renewable hydrogen.
  - Taxation of hydrogen.
  - Planning and implementing the goals for creating a comprehensive HRS network as stipulated in the AFIR.
  - Standardisation of refuelling protocols.
  - Funding of an R&I project which will enable the acceptance for heavy-duty which is required by EN 17127/ISO 19885-1.

- R134 – Homologation.
- Adaptation of the ADR (Agreement concerning the International Carriage of Dangerous Goods by Road) such that FCEV may transport and carry dangerous goods.

- ***H2 Valleys***: On 26th April 2023 three hydrogen valleys were selected for funding under the Hyland programme (https://www.hy.land/). A decision on whether further calls will be launched is still pending.
- **H2 supply chains** are also supported, mainly in the framework of IPCEIs.

12.4. Funding instruments

In the national landscape there are several funds that cover hydrogen deployment in Germany:

- ***The Federal Government's 7th Energy Research Programme***, entitled "***Innovation for the Energy Transition***", sets out guidelines for energy research funding over the coming years. The Federal Government lays down a new strategic approach and puts the programme's focus on technology and innovation transfer. This includes the use of living labs to bring new, promising technological solutions to the market, and to explore and master the challenges under real-life conditions. The experience gained will set the course for implementing the technologies tested on a large scale later on. Greater involvement by young, creative start-ups will also play an important role in this process. The programme strengthens technology and innovation funding in the energy sector and also adds a focus on systemic and societal questions. This involves placing a greater focus on the major, overarching trends in the energy sector. One of these is sector coupling, which enables interaction between the heat, transport and industrial sectors and is crucial for the development of the system as a whole. Another is digitisation, which plays a key role in modernising the energy system.

  Within the 7th Energy Research Programme there are several calls covering hydrogen technologies:

  - With the *Living labs on sector coupling and hydrogen technologies*, the Federal Ministry for Economic Affairs and Climate Action (BMWK) is supporting research on the verge of being put into practice in the energy industry (green hydrogen production, underground storage and industrial usage) --> Energiepark Bad Lauchstädt, H2Stahl, H2-Wyhlen, NRL – Norddeutsches Reallabor
  - *Competition of Ideas "Hydrogen Republic of Germany*": Launched 2020 by the Federal Ministry for Education and Research (BMBF) as an immediate initiative to

implement the National Hydrogen Strategy. Funding for research and innovation as enabler for long-term market and technology leadership of German technology suppliers and service providers in solutions related to green hydrogen. Comprises both large-scale, industry-led Flagship Projects (see below) as well as Basic Research on Green Hydrogen along the whole value chain.

- *Hydrogen Flagship Projects*: Three hydrogen flagships projects are a central contribution by BMBF to the implementation of the National Hydrogen Strategy. Taken together, they represent the largest funding initiative of the Federal Ministry of Education and Research on the subject of the energy transition. Bundling the expertise for hydrogen technologies in science, industry and civil society throughout Germany, they provide a decisive impetus for Germany's entry into the hydrogen economy.
  - The H2Giga project is dedicated to the mass production of water electrolysers.
  - The H2Mare project explores ways to produce hydrogen and its derivatives directly at sea using wind turbines.
  - The TransHyDE project develops, evaluates and demonstrates hydrogen transport technologies.
- *Technologieoffensive Wasserstoff* --> on H2 production, H2 infrastructure, H2 end use, H2 standards and H2 systems in 2021 (R&D projects started 2021 and 2022)
- *Electrochemical materials and processes for green hydrogen and green chemistry (ECCM)*: Call from the Netherlands and Germany on materials and processes for green hydrogen and green chemistry. Pre-proposals can be submitted until 07.02.2023. The planned funding on the German side is 5 million euros, and the same amount on the Dutch side.

- ***Nationales Innovationsprogramm Wasserstoff und Brennstoffzellentechnologie (NIP)***: The German government, and in particular the Federal Ministry for Digital and Transport (BMDV), has been promoting the development of hydrogen technology for over 15 years as part of the National Hydrogen and Fuel Cell Technology Innovation Program (NIP). The NIP is currently in its second phase, ranging from 2016 to 2026. The funding guideline on Research & Development (R&D) within the NIP II is setting the technological basis for hydrogen technologies to advance R&D and enhance readiness for series production by providing funding for:
  - Component, system and prototype development for a wide range of mobility end use applications.
  - Refuelling systems.

- FC systems for power supply to critical infrastructure.
- Pre-normative research projects.

The funding guideline Market Activation NIP II is focussing on the market ramp-up of technologies and achieve cost reductions so that they become competitive. Funding includes:

- Road Vehicles.
- Industrial trucks.
- FC-based, self-sufficient power supply for critical infrastructures.
- Public and private refuelling infrastructure

Within the NIP II, the ***Hyland Competition - Hydrogen Regions in Germany*** supports municipalities in developing regional hydrogen economies/valleys and acknowledges individual levels of expertise. In this way, the needs of different regions can be addressed by establishing three categories: HyStarter (initial formation of local actor networks), HyExpert (detailed analysis and roll out plans) and HyPerformer (realization of hydrogen economies).

Other funding programmes include:

- **Sondervermögen „Klima- und Transformationsfonds**“(KTF). **3,785 billion euros** in grants for the construction of refuelling and charging infrastructure and **715 million euros** in grants for the purchase of commercial vehicles with alternative, climate-friendly drive systems.
- **Clean Energy Transition Partnership (CETP)**. Funding opportunities for storage technologies, hydrogen and renewable fuels, CCS (Carbon Capture and Storage) and CCU (Carbon Capture and Utilisation).
- **International hydrogen projects within the framework of the National Hydrogen Strategy and International research cooperation on Green hydrogen calls** with the focus on research cooperation of the German research landscape with potential partners in other European and non-European countries in the field of green hydrogen. Aside this cooperation, international links with Morocco, South Africa and Brazil have been established and resources allocated.
- The **Export Initiative Environmental Protection** funds projects from German companies and research institutes to conduct pilot/demonstration projects for off-grid and decentralized power supply based on fuel cell technology at international level.
- **Renewable Fuels (RK)**. To promote eFuels, BMVI has funded, one side, 640 million euros in application-oriented development and demonstration projects and for innovation

clusters on renewable fuels, and, on the other side, 900 million euros for the production and market ramp-up facilities further than .

- **Important Projects of Common European Interest (IPCEI)** 11 billion euros from the federal and state governments. Large hydrogen RDI projects and FID projects.
- **Procurement activities in the transport sector by BMDV**. There are several funding activities with ascend to a total of approximately 4,3 billion euros such as the Funding program “Climate-friendly commercial vehicles and infrastructure (KsNI)”.
- A Programme should be set up in 2023 to **retrofit coal-fired power stations for gas**, so that these can then operate using green hydrogen. From this funding, **900 million euros** will be directed to the Flagship-Program 11: H2Global (01/2022–12/2033), which is aimed to international and European cooperation (production facilities for green hydrogen and its derivatives, as well as for the storage, transport and integrated use of hydrogen, and accompanying research projects).

In several federal states, there are additional **hydrogen regional funding** programmes for the implementation of the national and European directives, which might also be combined with the European Regional Development Fund or Just Transition Fund. These can be found in the regional governmental websites. Some examples include:

- Building a sustainable hydrogen economy - Hydrogen Directive, Schleswig-Holstein for production, storage and use of green hydrogen.
- Climate protection funding guideline for municipalities, Mecklenburg-Vorpommern, grant for *e.g.,* investment measures for the use of alternative non-fossil fuels and drives, fuel cell technology and electromobility
- The region of Bavaria has the Collaborative Research Program (BayVFP) “Mobility, promotion of research in the field of engine technology”, with highlight on hydrogen and electric engines and a call for funding hydrogen refuelling stations

Several EU funding mechanisms are adopted by Germany to support RDI into hydrogen technologies: **German Recovery and Resilience Plan** (1.5 billion euros), the **Temporary Crisis Framework** (introduces the possibility of supporting investments into electrolysis technology and other hydrogen-related technology (key technologies for the energy transition), the **European Regional Development Fund** (ERDF), used at regional level, and the **Just Transition Fund** (JTF) (regions eligible for funding through JTF are located in the West and the East of Germany, as these will be affected by coal phase-out: North-Rhine Westphalia, Saxony-Anhalt, Saxony, Brandenburg).

The **German recovery and resilience plan (RRP)** includes significant measures to decarbonise the economy, especially industry, with a focus on renewable hydrogen. It provides for Germany’s

participation in an EU-wide initiative (important project of common European interest – IPCEI) to help the economy make the leap towards renewable hydrogen at all stages of the value chain.

In Germany, three main RRP measures have been identified for the ERDF, which overlap in content with planned measures of the Länder. This involves the promotion of energy efficiency, electromobility and hydrogen technology. In the field of electromobility and hydrogen technology, the Federal Ministry of Economics and climate action and the relevant ERDF managing authorities will coordinate on synergies and complementarities between RRP and ERDF. However, a specific cooperation mechanism seems not to have been established yet.

The Table below summarises the existing funding programmes, the available budget and the priorities.

Programme Name	Level	Budget	Priorities
Sondervermögen „Klima- und Transformationsfonds (KTF)	National	3, 785 billion euros	Construction of refuelling and charging infrastructure
		715 million euros	Purchase of commercial vehicles with alternative, climate-friendly drive systems
Clean Energy Transition Partnership (CETP)	European	278 million euros	Hydrogen is identified as a main technology, including its storage, use in industry, transportation…
Important Projects of Common European Interest (IPCEI)	European	11 billion euros from the federal and state governments	Energy transition including hydrogen, projects of large scale that would not be able to execute by a single EU member
International hydrogen projects for cooperation on Green Hydrogen	International	€15 million per applicant and project	International cooperation for the construction of green hydrogen production plants
H2Global	National	900 million euros	Procurement of green products from partner countries outside the European Union (EU) and the European Free Trade Association (EFTA)

Export Initiative Environmental Protection (EXI)	National	56 million euros already deployed since 2016	Green hydrogen technologies
7th Energy Research Programme of the Federal Government	National	1.3 billion euros	Living labs, hydrogen in the industry (hard to decarbonize sectors)
Nationales Innovationsprogramm Wasserstoff und Brennstoffzellentechnologie (NIP)	National	25 million annually	Hydrogen production and cost reduction of hydrogen technologies and infrastructure in the value chain
Renewable Fuels (RF)	National	1.54 billion euros from the Energy and Climate Fund (EKF) and from the National Hydrogen Strategy	640 million euros development and demonstration projects, 900 million euros production and market ramp-up
Mobility and Fuels Strategy (MFS)	National	Does not specify	Hydrogen vehicles, HRP, infrastructure for hydrogen transport (liquified or compressed gaseous hydrogen)

Table 9. German Hydrogen Funding programmes.

12.5. Projects

- Project **H2 Kompass** (“A tool for creating Germany's hydrogen economy roadmap”).
- Living labs on sector coupling and hydrogen technologies (e.g., **Trans4Real** project involving different German regions that aims to collect and transfer the knowledge of the laboratories regarding generation, distribution, and application of hydrogen technologies to the market).
- **Three Hydrogen Flagship Projects** (H2GIGA for the serial production of water-electrolysers, H2MARE for the the production of hydrogen directly at sea based on offshore electricity , TRANSHYDE for the the development of transport technologies for hydrogen).
- **Technologieoffensive Wasserstoff**.

- Electrochemical materials and processes for green hydrogen and green chemistry (ECCM).

- **CEO-Alliance Cross-Border-European Green Hydrogen Value Chain (CICERONE)**. CB RES project under CEF. The core of the project is to build new, additional renewable power plants in Italy, Spain and Germany and then convert the green power produced to green hydrogen and/or ammonia. Part of the ammonia will be used for off-takers directly in the Netherlands, but the bulk part will be converted to hydrogen and transported to Germany. Construction should start in June 2025.

- **Hydrogen Valleys**:
  - ***EFARM- Hydrogen Valley in Schleswig-Holstein*** is the biggest green hydrogen mobility project in Germany to date. The project is realised by GP JOULE and addresses the complete value chain of green hydrogen on the mobility path from production over logistics to distribution via HRS.
  - ***NDRL (Norddeutsches Reallabor - Living Lab Northern Germany)*** is a project that intends to test the overall transformation of the energy system in order to demonstrate a rapid decarbonisation of all energy consumption sectors in Northern Germany.
  - ***HyWays for Future***. Hydrogen model region in the Northwest of Germany that focuses on the transport and industrial sectors.
  - ***H2Rivers***. Establishment of hydrogen generation and distribution with a focus on mobility applications. Sub-projects form the cornerstone for the transformation of the Rhine-Neckar metropolitan region towards CO2 neutrality.
  - ***HyBayern***. Compilation of three admin. districts (LA-EBE-M), transport companies, energy providers, industry, trade and crafts. Implementation of closed hydrogen cycle generating, distributing and using emission-free "green hydrogen".
  - Moreover, three regional hydrogen valleys were recently selected for funding under the Hyland programme (https://www.hy.land/).
- **IPCEIs**:
  - ***Sunfire:*** industrialisation of its alkaline electrolysis increasing production capacity to 500 MW/year by 2023.
  - ***BoschPowerUnits:*** to take the final R&D steps on the path to series production of its stationary solid oxide fuel cell systems.
  - ***NextGen HD Stack***: EKPO Fuel Cell Technologies intends to develop a new generation of stacks and drive their commercialization forward. At the same time, the carbon footprint during the production of these stacks conceived for commercial vehicles, ships and trains as well as for stationary power generation is to be reduced.

- ***Daimler Truck***. The development objective of the series- ready GenH2 Truck is a range of up to 1,000 kilometers and more without refueling. This makes the truck suitable for particularly flexible and demanding applications, especially in the important segment of heavy-duty long-haul transport. The start of series production for hydrogen-based trucks is planned for the second half of the decade.

- According to EHB initiative, the **German hydrogen network 2030** will connect different demand clusters like Ruhr Area, Rhine-Main Area, Eastern Germany, Central German chemical triangle and Bavaria with hydrogen sources in Germany, especially in the North, and with important import routes. As such, pipeline connections to the Netherlands, the North Sea and to Denmark and to Poland and the Baltic Sea for integrating offshore pipelines and possible imports are foreseen. While in the Southeast import connections to Austria and the Czech Republic emerge. In the West, connections to Belgium and France occur, while a new connection to Poland in the East will be available for imports to meet growing national demand in different regions.

The main difficulties encountered by ongoing projects relate to:

- German Living Lab format needs to comply to the rules of the General Block Exemption Regulation (GBER).
- Hydrogen IPCEI Projects have been delayed due to long pre-notification procedure.
- Delays due to supply difficulties in both special materials and H2 testing equipment. Some delays in acquisition of suitably trained personnel as there is a lot of demand in the H2 sector. (Some are results of COVID pandemic).
- Almost all projects suffered from increasing commodity prices and costs for parts and plants. Also, significant delays along the whole supply chain led to delays up to 12 months or even longer.
- Concerning maritime projects, a partly missing regulatory framework at international and European level is responsible for delays, because the projects must go through extensive individual approval procedures.

12.6. Other policies and measures

Hydrogen is extensively mentioned in the German NECP (2019) with a highlight on mobility applications. According to its NECP, Germany expects to cover about 0,1% of its transport needs with hydrogen by 2030, and around 0,2% by 2040. Germany is planning to add targets in the upcoming NECP revision, as well as in the requested plan by AFIR.

Germany is a member of the **Pentalateral Energy Forum** cooperation, managed by the Minister for Energy.

The **German recovery and resilience plan (RRP)** includes significant measures to decarbonise the economy, especially industry, with a focus on renewable hydrogen. It provides for Germany's participation in an EU-wide initiative (important project of common European interest – IPCEI) to help the economy make the leap towards renewable hydrogen at all stages of the value chain.

Germany participates as an active member in The **North Seas Energy Cooperation (NSEC)** along with Belgium, France, Denmark, Ireland, Luxembourg, the Netherlands, Norway, Sweden and the UK. The governance focuses on the development of the offshore grid development and the large renewable energy production (76 GW by 2030, 193 GW by 2040) in the region. Plans for hydrogen connections are underway.

Germany, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**. Germany was involved in several national expert groups and task force meetings, and coordinated the pan-European and transdisciplinary workshop on hydrogen transport and Infrastructure.

13. Greece

The **National Strategy for the Promotion of Technologies – Applications of Hydrogen and Renewable Gases** was presented at the end of 2022. The proposed strategy contains measures regarding the production and distribution of hydrogen and renewable gases, the use of hydrogen and biogas in several applications, the legal / institutional framework (that is currently under development) as well as research and innovation issues.

In the next 5-10 years, Greece could increase substantially its RES capacity and produce significant quantities of hydrogen for various applications (including actions relevant to islands). The ultimate goal is to create a hydrogen supply chain in the country for use in transportation (heavy vehicles, shipping, etc) and industry.

The sectors of development of the hydrogen market in Greece, according to the plan of the National Strategy, will be, as a priority, the substitution of grey hydrogen in refineries and ammonia, as well as the supply of means of transport for which hydrogen presents a comparative advantage, either directly or through use of synthetic fuels produced from hydrogen. Synthetic fuels will primarily fuel air and maritime transport.

Greece is in the process of starting the meetings on the implementation of their national H2 strategy.

13.1. Governance

A dedicated 20-member committee has been created in the country (with members from different stakeholders like industry, public authorities, research, and academia) with the task of developing the national strategy on hydrogen.

It is expected that hydrogen policies would be drawn by the **Ministry of Environment and Energy (YPEN)**, with the involvement also from the **Ministry for Infrastructure and Transport (YME)**.

The main representative in the States Representative Group of the Clean Hydrogen Partnership comes from the National Centre for Scientific Research “Demokritos”.

13.2. Targets

- Domestic production of 3,500 GWh of hydrogen by 2030 from electrolysis, with a total capacity of **750 MW**, which will be powered by RES projects (80% photovoltaic and 20% wind power). The green hydrogen produced will mainly replace natural gas and partly petroleum in refineries, industry and transport sectors.

- Expected green hydrogen production of around 3 Mtoe and exports for around 1 Mtoe by 2040.
- Expected green hydrogen production of around 7.4 Mtoe and exports for around 2.3 Mtoe by 2050.
- About 30 GW RES for the supply of electrolysis units by 2030 and 60 GW by 2050.
- **Buses**: In the first phase, 120-250 city buses could help reduce pollution in the centers of large cities, while an installation facility could be set up, possibly in the areas under energy transition (Western Macedonia). The technology is mature and approaches the costs of buying and using conventional vehicles. In the first phase, it is proposed to launch 30-50 intercity buses.
- **Light distribution trucks**: Possibility for traffic of 5,000-10,000 in the cities. Some of them could be modified in Greece.
- **Heavy-duty trucks**: Provision number 80-160 for noise-free or polluting waste collection.
- **Private cars**: 30,000-60,000 vehicles.
- **Trains**: 3 to 12 trains for main traffic in parts of the network that are not profitable to electrify and 2 to 5 manoeuvring machines at stations.
- **Shipping:** A certain number of passenger-vehicle ferries of closed type ships that run on H2 or ammonia for transports from the mainland to the island country. This type of ship could be designed and built in Greece in one of the existing shipyards. Supply infrastructure in selected ports could include H2 and / or ammonia production. A similar possibility exists for an open-type passenger car-vehicle running on H2 or ammonia for local lines.
- **Refuelling stations**, estimated at around 100 in the first phase, capable of supplying 0.1-1 tons of hydrogen per day for catering to private vehicles or fleet vehicles, trucks or buses.

13.3. Research and innovation priorities

The thematic intervention area "**Technologies and Systems of Hydrogen and Climate Neutral Fuels**", developed in the framework of the smart specialization strategy of the 2021-2027 Programming Period, prioritizes technologies for production, storage, purification, and compression of hydrogen as well as its distribution systems.

Hydrogen RTDI actions are foreseen in the design of the **Just Development Transition Fund**:

- Creation of a Hydrogen Competence Center.
- Creation of a Hydrogen Hub but also the direct interconnection of the Greek Innovation System with the European Innovation Council.
- Support to start-ups, spinoffs etc in the field of hydrogen technologies is also considered presently in possible coordination with EIC activities.

Other RTDI priorities focus on:

- **Production of synthetic fuels for use on conventional ships**. Green hydrogen could be combined with green CO2 (retained *e.g.,* in biomass / waste gasification plants) in a synthesis plant to produce liquid synthetic fuels. They could use existing liquid fuel transport and distribution infrastructure for ships as well as power conventional ships. Production should be central, close to a green CO2 holding unit.

13.4. Funding instruments

The strategy foresees total investments in the hydrogen supply chain of about **3-4 billion euros** up to 2050.

The Hydrogen Committee proposes to facilitate investment to benefit domestic added value and employment by supporting the financial sector to meet the capital requirements of new investments in industrial production, construction and the provision of services related to hydrogen development. As the relevant investments will be innovative and surrounded by uncertainty, support through government guarantees and grants is proposed.

Concerning investments, the Greek strategy includes four stages:

- The first concerns the period 2022-2027, where there will be uncertainty in investments, due to the high costs. In these five years, **state aid** will be needed for infrastructure development.
- The second phase concerns the period 2025-2030, when the pilot projects will begin, as well as upgrades and adaptation of gas pipelines, hydrogen storage planning, with the role of the state remaining giving aid and tax incentives.
- The third phase focuses on the creation of the market in the period 2027-2035, with the first hydrogen-only networks to facilitate mainly cross-border transactions, development of large-scale hydrogen storage, etc.
- The fourth phase of industrial maturation concerns the period 2030-2045, when completion of the pan-European hydrogen and synthetic fuel infrastructure is expected, conversion of large sections of existing gas networks to hydrogen, storage systems, medium and large-scale compression and liquefaction, as well as national interoperability with the European system.

13.5. Projects

- Nationally funded project results have led to the development of **pilot scale facilities for production, storage and use of hydrogen in Northern Greece and Attica** (e.g., the first pilot HRS). A few companies are also active in the field (ADVENT, HELBIO and new spinoffs / start-ups like CYRUS).

- All energy majors in the country are preparing plans for developments/investments in hydrogen technologies. Large companies in the sectors of cement, metals, etc are also proceeding with plans to engage in hydrogen projects. The **maritime sector** (very important for Greece) is investigating possibilities for employing hydrogen and other alternative fuels in their activities. Regions and local authorities examine the potential for applications in their areas and interests.
- Recent strategic deal of the **Public Electricity Company** (Public Power Corp. SA) with the energy industry major MOH establishing a synergy scheme in view of investments of the order of billions in hydrogen technologies. The goal is the development of green hydrogen production and storage projects, thus facilitating the energy transition of Greece to an environment of low to zero carbon emissions.
- **IPCEIs**:
    - ***White Dragon*:** it aims to replace the coal-fired power plants across the region of Western Macedonia and transition to clean energy production and transmission, with the ultimate goal of fully decarbonizing Greece's energy system. The project plans to use large-scale renewable electricity to produce green hydrogen by electrolysis in the region. It also aims to develop an integrated Hydrogen Industrial Research Center within the **Hydrogen High Technology, Research, Development & Innovation Center** that is anticipated to be created in Western Macedonia.
    - ***Green HiPO***: it concerns the development, design, and manufacturing of HT-PEM fuel cells for the production of heat and power.
    - ***H2CAT***: B&T Composites seeks to develop novel pressurized hydrogen storage tank products that will eventually form a new market standard for stationary, and transportation-related hydrogen storage.
    - ***H2CEM***: a project for the production, storage and use of green hydrogen for combustion to produce energy in furnaces with the aim of carbonizing the cement plants of the Greek firm TITAN.
- **Hydrogen Valleys**: Crete and Corinthia- Trieres (recently awarded).

Concerning the **development of hydrogen infrastructure**, by 2035, Greece's main industrial clusters in Athens, Corinth and Thessaloniki would be connected, with new dedicated hydrogen pipelines following the existing natural gas route. The potential hydrogen cluster in West Macedonia will also be connected to Thessaloniki, near the existing connection to TAP, through the new, hydrogen-ready pipeline in the region, which is currently under development. By 2040, the dedicated hydrogen pipeline could be interconnected with adjacent systems, so that hydrogen can flow from Greece towards South-East, South-West and Central Europe.

13.6. Other policies and measures

According to its NECP (2019), Greece's approach to develop hydrogen as low-carbon solution comprises the following pillars:

- Hydrogen production from renewable electricity.
- Hydrogen use to decarbonize the transport sector (mainly shipping).
- Long term hydrogen storage for power generation.
- Use of existing gas infrastructure for hydrogen transport.
- Stimulate hydrogen related RD&I.

As stated in its NECP, "*Hydrogen is a future solution, although it is currently at an early stage of development. It is noted that Greece has a significant track record in scientific investigation and research in the field of hydrogen production from RES*".

Greece also participates in discussions for the potential establishment of a **Mediterranean Green Hydrogen Partnership**, encompassing hydrogen trade between Europe, Africa and the Gulf.

The **Greek RRP** includes reference to the development of hydrogen infrastructure as an important tool to reduce the country's dependence on fossil fuels.

The following islands are explicitly including hydrogen in their CETA:

- ***Chalki***: It could be possible to partially replace maritime transport to and from the island with a hydrogen-powered passenger ship between Chalki and the nearest ports of Rhodes (central port of Rhodes and Kamiros Skala), especially during the winter months, when the frequency of maritime transport generally becomes sparser.
- ***Sifnos:*** The Sifnos Hybrid Station project aims at 100% Renewable Energy Sources electricity generation and gradually replacing oil for heating and transport (electric vehicles, boats, hydrogen fuelled ferry) rendering Sifnos 100% RES self-sufficient by 2030[32]. The hydrogen fuelled ferry will operate inside the Cyclades Islands which will connect Sifnos to the international airports of the surrounding islands of Paros, Mykonos and Santorini.

Support to the development of hydrogen technologies is also explicitly included as one of the JTF priorities.

Greece, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

[32] CETA for Sifnos, October 2019. https://clean-energy-islands.ec.europa.eu/countries/greece/sifnos1_Clean.pdf (europa.eu)

14. Hungary

Hungary adopted its **Strategy for the introduction of clean hydrogen and hydrogen technologies to the domestic market and for establishing background infrastructure for the hydrogen industry**[33] in May 2021.

On the long term, the Strategy focuses on "green" hydrogen, but in addition to hydrogen based on electricity generated using renewable resources, primarily solar energy, Hungary does not ignore opportunities for hydrogen production based on carbon-free energy accessed either through a nuclear basis or from the network. Additionally, in the short and medium term, a rapid reduction in emissions and the establishment of a viable hydrogen market will also require low-carbon hydrogen.

In this strategy, Hungary makes specific reference to the importance of "*enhancing coordination between EU, multilateral and national programmes in order to avoid any duplication of supported activities and to exploit potential synergies*".

A review of the strategy is foreseen in 2025.

14.1. Governance

From 1st December 2022 the newly established Ministry of Energy oversees energy related issues. The nomination of a new representative for the SRG is under process.

Other relevant Managing Authorities:

- **Undersecretary of State for Transport, Environment and Energy Efficiency Operational Programmes** for the Environmental and Energy Efficiency Operational Programme Plus.
- **Ministry of Finance** for the Programme (Interreg VI-B) Danube.

14.2. Targets

The strategy details some priority objectives and targets to 2030:

- **Production of large volumes low-carbon and decentralized carbon-free hydrogen**:
  - 20 thousand tons / year low-carbon hydrogen
  - 16 thousand tons / year "green" and other carbon-free hydrogen

[33] Hungary's national hydrogen strategy (May 2021) https://cdn.kormany.hu/uploads/document/a/a2/a2b/a2b2b7ed5179b17694659b8f050ba9648e75a0bf.pdf

- 240 MW electrolyser capacity

- **Decarbonisation of industrial consumption, partly with hydrogen**:
  - 20 thousand tons / year low-carbon hydrogen
  - 4 thousand tons / year “green” and other carbon-free hydrogen
  - Avoiding the emission of 95 thousand tons of CO2
- **Green transport**:
  - 10 thousand tons / year “green” and other carbon-free hydrogen
  - 20 hydrogen refuelling stations / 40 refuelling points
  - 4.800 HFC vehicle
  - Avoiding the emission of 130 thousand tons of CO2
- **Electricity and (natural) gas support infrastructure**:
  - 60 MW average cut-off capacity
  - Min. 2% per year volume blending ratio in the natural gas system (where appropriate)

Some support objectives are also highlighted, in terms of:

- Taking advantage of industrial and economic development opportunities.
- Establishing a stimulating operational environment.
- RDI and education to promote the success of hydrogen during the transition.

14.3. Research and innovation priorities

In its strategy, Hungary identifies R&D potential along the value chain in the following domains:

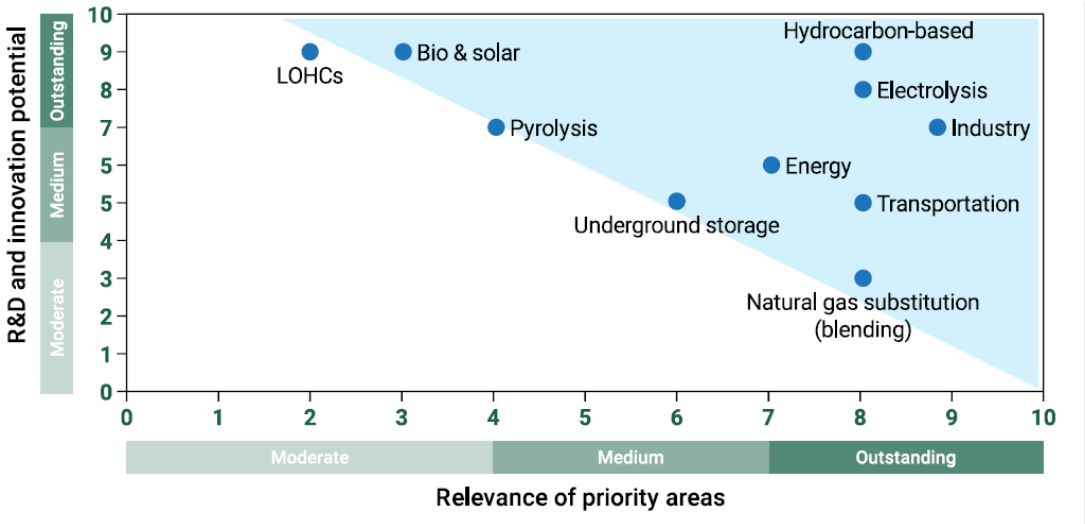

Figure 8. Priority8 areas based on domestic R&D and innovation relevance and potential.

With this respect, the following concrete priorities are identified:

- Foundation of the **National Hydrogen Technology Laboratory** as part of the National Renewable Energy Laboratory. Endeavouring to create a "Horizon Europe Teaming" project in cooperation with a leading foreign partner institution.
- Pilot programmes produced by the National Laboratory and pilot projects by members of the **Hungarian Hydrogen Technology Association** within identified focus areas. Typically, as part of cooperation between industrial and higher education actors.
- Research and development of **carbon dioxide capture and utilisation solutions** and testing within the framework of pilot programmes in the petrochemical and chemical industry (RDI project before 2030).

14.4. Funding instruments

- **Green Truck Programme** for making freight traffic greener (HUF 35-40 bn).
- **Green Bus Programme Plus** for making public service transport at local level greener (HUF 10-20 bn).
- Establishment of **hydrogen valleys** in Hungary to promote the establishment of interconnected networks of the hydrogen value chains within the given geographical regions (HUF 10-15 bn).
- **Research, development and innovation** in service of the establishment of a hydrogen economy (HUF 10 bn).

The Table below summarises the existing funding programmes, the available budget and the priorities.

Programme Name	Level	Budget	Priorities
Green Truck Programme	National	Around 100 million euros	To make freight traffic greener
Green Bus Programme Plus	National	Around 50 million euros	To make public service transport greener
Hydrogen Valleys	National	Around 25 million euros	Support to create H2 Valleys
Hydrogen Highway Project	National	Around 75 million euros	Support to carbon-free hydrogen production, transportation and storage
Blue Hydrogen Project	National	Around 50 million euros	Reduce carbon footprint of industrial hydrogen use

Research, development and innovation	National	Around 25 million euros	Support to RD&I for the hydrogen economy

Table 10. Hungarian financial instruments for hydrogen.

14.5. Projects

Hungary plans to establish two new hydrogen valleys by 2030:

- **Hydrogen ecosystem of the Transdanubia** around the ammonia and refinery industry in the area of Pétfürdő, Százhalombatta. Moreover, in the same area, there are several sectors that may potentially become new hydrogen users: iron and steel works (Dunaújváros), cement production (Beremend, Királyegyháza). The Paks nuclear power plant may supply a significant amount of carbon-free electricity for the establishment of the hydrogen value chain.
- **North-eastern hydrogen valley**: a region with a well-developed industry, with a significant demand for hydrogen in a concentrated area (Miskolc, Tiszaújváros, Kazincbarcika, chemical and petrochemical industry, with significant existing hydrogen usage).

Other projects are also envisaged:

- "**Green Truck**" project and establishment of refuelling infrastructure along corridors (TEN-T corridors, Helsinki corridors).
- Examining the possibility of introducing hydrogen into the natural gas infrastructure, implementing a pilot project. (As part of this measure, implementing the prioritised **Hydrogen Highway Project** for creating a foundation for carbon-free hydrogen production, transportation and energy storage).
- Initiating combination **pilot programmes** (co-firing of natural gas and hydrogen) for closed-cycle gas turbines in order to gain experience in the field of hydrogen technologies, and thus be able to make well-founded decisions concerning later large-scale investments.
- **Defense industrial applications** within the framework of the Zrínyi2026 plan.
- Launching of a priority project at the intersection of CCU/petrochemistry (**Blue Hydrogen Project**).

Concerning the **development of hydrogen infrastructure**, in case there is enough hydrogen production by 2035, Hungary could already have a mature - mostly repurposed - hydrogen network with a total of seven interconnections to Ukraine, Austria, Slovakia, Serbia, Romania, Croatia and a new one with Slovenia.

The challenges the projects have been facing mainly relate to the recent inflation spike following the war in Ukraine.

14.6. Other policies and measures

According to its NECP (2019), Hungary intends to enable the integration of hydrogen in its mobility, industry, building, gas and power systems. The NECP states that "*hydrogen can play a significant role in integrating renewable electricity generation, strengthening domestic security of supply and achieving Hungary's decarbonisation goals*".

The NECP comprises the 2030 concrete target of a renewable electricity-based hydrogen consumption of 51ktoe in the heating and cooling sector.

15. Iceland

A specific hydrogen strategy of Iceland is expected to be published in 2023, and it is not known at the moment of writing.

The Government of Iceland aims to achieve the national goal regarding greenhouse gas emissions set by the Paris Agreement in 2016: a 29% emission reduction by 2030 compared to 2005 levels. Already more than 80% of the total energy consumption in the country is based on renewables: geothermal and hydro. The remaining sources of GHG emissions are fossil fuels for passenger vehicles and ships, industrial processes and agriculture.

To reach this goal, a number of initiatives have been taken:

- Tributary incentives are in place: no VAT for zero emission vehicles, reduced annual tax, 100% depreciation in 1st year.
- The national fund to support zero decarbonizing of transport was doubled in 2022, up to 8 million euros:
    - The first potential deployment of H2 trucks was specifically funded. Two projects got 0,8 million euros.
    - First methanol marine project for a fishing vessel.

Furthermore, the government has been working with Roland Berger on preparing a road map for H2/e-fuels. This document was originally introduced at a stakeholder meeting in late 2021 but was delayed in publication due to changes in the government[34].

Finally, Icelandic New Energy (INE), a research and development company working on projects related to hydrogen and fuel cells, published ***A 2030 vision for H2 in Iceland,***[35] which reviews the context of hydrogen in the country, the potential production, applications, and barriers and sets an action plan as predecessor of a **2050 Hydrogen Roadmap for Iceland** planned to be completed by 2025.

15.1. Governance

The competences on Energy matters rely on the **Ministry of Environment, Energy and Climate**, but it has been working in accordance with the provisions of the new regulation on monitoring and governance systems concerning climate obligations.

[34] References to this document are made in the document of The State and Challenges of Energy Issues (Ministry of the Environment, Energy and Climate 2022). https://www.stjornarradid.is/library/02-Rit--skyrslur-og-skrar/URN/URN_State_of_Energy_Issues_EN_Web.pdf

[35] A 2030 vision for H2 in Iceland (2020). Icelandic New Energy (Íslensk NýOrka). https://newenergy.is/wp-content/uploads/2020/06/A-2030-vision-for-H2-in-Iceland-released.pdf

15.2. Targets

According to INE:

- **70 k tonnes of hydrogen** would be needed to replace fossil fuels,
- **3.850.000 MWh** are needed to reach carbon neutrality and the national target by 2030.
- Locally made e-fuels, or hydrogen, should become at least **5% of marine fuel** in Iceland before 2030 and by 2040, the fishing fleet will evolve to use direct hydrogen or electric fuel whereas small boats will run on electricity.

15.3. Research and innovation priorities

Specific research and innovation priorities from the Icelandic government regarding hydrogen have not been set but, given the general needs of the country and the current deployment of renewable energy, advances in the utilisation of hydrogen in mobility in the road, maritime and aviation, are the main research focus.

15.4. Funding instruments

Currently, funds available in Iceland (6 M€) are mainly focused to support the energy shift in transport from fossil fuels to alternative fuels, which include hydrogen solutions. However, it is technology neutral, and covers other solutions than hydrogen.

Another 8 M€ is made available for direct investments in zero emissions car rental vehicles and trucks. Also in this case, there is no specification whether they should be BEV or H2.

The largest support mechanism in Iceland is that there is no VAT on zero emission vehicles.

The government is planning to change the funding mechanism at the beginning of 2024, but details are not available yet.

15.5. Projects

There are several hydrogen projects deployed in Iceland:

- **Production**: Hydrogen wagons in public traffic in Reykjavik and the first hydrogen station was built to extract hydrogen from water in the European Union project ECTOS (Ecological City TranspOrt System). Moreover, hydrogen is produced in the ***Orka natturunnar*** at the Hellisheidi power plant and driven in a tanker to sales outlets. Additionally, two related projects have been in the pipeline:
    - Landsvirkjun is examining hydrogen production at ***Ljosafossstod*** (power requirement of 10 MW).

- ***Finnafjardarhofn***'s project envisages the production of hydrogen by electrolysis of water and possibly the production of more types of E-fuel.
- Ideas for hydrogen production also consider activities by e.g., Þorlakshofn and in Husavik. There, ***Green Energy/Atome Energy*** intends to produce hydrogen and ammonia with a 30–100 MW power requirement. Moreover, hydrogen production by electrolysis has been coupled to generate methanol.

- **Transport**: The largest demonstration is the ***H2ME 1&2*** (Hydrogen Mobility Europe) project, funded by the Clean Hydrogen Partnership. In Iceland, it involves 22 cars (from which 1 taxi) and two refuelling stations (Reykjavik operated by Orkan by Vesturlandsvegur and another by Fitjar in Reykjanesba). A handful of vehicles are in service which are not part of the of the H2ME project. The momentum of hydrogen is though growing very fast ,and several demonstration activities are in the planning. None have materialised yet – but the goal is to increase the fleet of hydrogen vehicles and stations no later than early 2024.
- **Strategic research:**
  - ***EURO-HYPORT***, investigates the feasibility of exporting hydrogen.
  - ***HyApproval,*** manual for hydrogen station certification, designed for hydrogen refuelling station operators and town authorities.
  - ***HySociety***, socio-technical and economic barriers that stand in the way of using hydrogen.

The main issues related to projects' development relate to the high failure rate of the HRS´s. There are only 2 stations 30 km apart and the downtime has been too high resulting in negative feedback from the customers. Also, there is only one electrolyser and, if that fails, the whole system fails. It is of utmost importance to expand the operation and get large scale projects off the ground to increase hydrogen production, and to attract more customers.

Iceland is also interested in developing Hydrogen Valleys, especially related to maritime applications.

Iceland, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

16. Ireland

Ireland is currently working on a **National Strategy for Hydrogen** that will be part of Ireland's Climate Action Plan in the second half of 2023. This is not known at the time of writing this Document.

The **Climate Action Plan 2023**[36] sets out the potential green hydrogen has to support decarbonisation across several sectors, including heavy goods transport, high-temperature heat for industry, and electricity generation. Green hydrogen could play a significant role in sector coupling (the increased integration of energy supply and end-use sectors), and in minimising the overall cost of decarbonisation across all sectors.

Specific actions relating to hydrogen are set out in the Annex of Actions to the Plan and include:

- Testing the technical feasibility of safely injecting green hydrogen blends in the gas grid.
- Assessing the potential for system integration between the electricity and gas networks, which will include the production, storage and use of green hydrogen.
- Progressing research and pilot studies regarding the use of hydrogen in the transport sector.

There are also a number of other actions, such as those concerning renewable energy in the heat sector, where hydrogen is a relevant factor.

Further measures set out in the Plan include incentivising electrolyser production, developing storage capacity for long duration and seasonal storage of renewable energy, and co-location of electrolysers with renewable energy production infrastructure.

16.1. Governance

The text for the consultation on the Irish Hydrogen Strategy was developed by the **Department of the Environment, Climate and Communications**.

The Irish representative on the States Representative Group on the Clean Hydrogen Partnership is **Ireland Enterprise**, the government organisation responsible for the development and growth of Irish enterprises in world markets.

Othe relevant Managing Authorities:

- **Northern and Western Regional Assembly** for the Northern and Western Regional Programme 2021-2027.

[36] Climate Action Plan 2023. Department of the Environment, Climate and Communications. https://www.gov.ie/en/publication/7bd8c-climate-action-plan-2023/

- **Southern Regional Assembly** for the Southern, Eastern and Midland Regional Programme 2021–2027.

16.2. Targets

Ireland has considerable potential to produce green hydrogen from renewable electricity given its offshore and onshore wind potential. With a sea area approximately seven times the size of its landmass, Ireland has one of the best offshore renewable energy resources in the world.

Concerning specific targets related to hydrogen, one was found related to the installation of **2GW** electrolyser capacity for green hydrogen from dedicated offshore wind by 2030.

16.3. Research and innovation priorities

There is significant research underway concerning hydrogen and its future role in Ireland's energy mix. The **Sustainable Energy Authority of Ireland (SEAI)** is developing several initiatives on the role of green hydrogen in decarbonisation.

The main research interest on hydrogen from Irish organisations focuses on:

- Hydrogen from offshore wind.
- Electrolyser development.
- Storage mechanisms.

16.4. Funding instruments

There is no specific hydrogen-related programme, but several National Bodies include Hydrogen under their areas of research interest:

- **Disruptive Technologies Innovation Fund**: Call 6 is an open call and the type of eligible research include both “industrial research” and/or “experimental development”.

SEAI RD&D call 2023 also includes topic areas for Developing electrolysers for offshore deployment Up to €650,000 available.

16.5. Projects

At present, Ireland has no dedicated hydrogen networks and current uses of hydrogen are relatively limited and dispersed.

- The **Whitegate refinery** in Cork produces hydrogen for internal use.
- **BOC**, a provider of industrial, medical, and special gases, produces hydrogen which is used by a range of industry sectors, such as aerospace, electronics, pharmaceutical and

medical. BOC also supplies the green hydrogen used for the three Bus Éireann hydrogen buses.

- **Intel** is one of the biggest users of hydrogen in Ireland with a sizable internal hydrogen network to supply hydrogen to various processes.
- In the transport sector, the National Transport Authority and Bus Éireann are using **three hydrogen-fuel-cell-electric double-deck buses** on commuter services in the Greater Dublin Area as part of the Department of Transport's Low Emission Bus Trial.

Since 2021 a growing number of projects has been funded:

- **Indaver** has been granted planning permission for a 10MW hydrogen generation unit.
- **Bord Na Mona & BOC** are building a 2MW electrolyser and **Mercury** are applying for planning permission for an 80MW electrolyser.
- **HyFloat1**: Concept development of floating offshore wind foundations coupled with hydrogen storage. Two-year project with a total cost of 387.683 euros, led by the University College York.
- **Developing an economically viable dark fermentation process for biohydrogen production from Irish whiskey distillery and dairy industry wastes.** This two-year project will develop economic solutions for the dark fermentation process using waste products from the whiskey and dairy industries to maximise the production of biohydrogen. This will guide full-scale applications for energy recovery towards a low carbon economy and assess the economic and environmental benefits for future industry pathways. Two-year project with a total cost of 212.889 euros, led by the University College Cork.
- **HyLIGHT** is a 3-year project funded by Science Foundation Ireland (SFI) and a 25-strong industry consortium through MaREI the SFI Research Centre for Energy, Climate and Marine, UCC, DCU & NUIG.
- The **GenComm** project funded by **Interreg North-West Europe** aims to address the energy sustainability challenges of North-West Europe, by technically and commercially validating renewable hydrogen technologies. The project will develop three pilot plants, in Northern Ireland (wind power), Scotland (bioenergy) and Germany (solar power), linking the three main renewable sources, solar power, wind power and bioenergy, with energy storage and the main forms of demand - heat, power and transportation fuels. Based on the pilot plants, technical and financial models will be developed, with the overall aim of developing a decision support tool.
- Under the **HWind project**, SFI MAREI & University College Cork are seeking to support the development of green hydrogen as the means of more efficiently providing energy by bringing the electricity network and gas network together to make optimal use of Ireland's offshore wind resources. The project will seek to identify new markets for green hydrogen and ensure that Ireland delivers on EU strategy in energy system integration.

- The number of **Irish SMEs focused on hydrogen** has grown and is supported by the National Support Agency Enterprise Ireland.
- **Hydrogen Valley Shamrock** in Galway (recently awarded).
- Concerning the development of a **hydrogen infrastructure**, by 2035, a hydrogen "valley" network could emerge around the city of Cork, on Irelands' south coast. Supply resilience for this mainly green hydrogen cluster would be assured with supplementary imported hydrogen which could be either tanker or interconnector sourced (via a hydrogen pipeline direct to the continent). By 2040, one of the 2 Moffat interconnectors from the UK could be converted for 100% hydrogen transport and some relatively small-scale reconfiguration of the Dublin gas transmission network could enable local, scale, hydrogen – fired power generation. The other Moffat interconnector could sustain resilient supply to the remaining unconverted network, it no longer having to serve the Cork cluster and Dublin power generation loads.

16.6. Other policies and measures

The Climate Action Plan 2021 sets out the potential green hydrogen has to support decarbonisation across several sectors, including heavy goods transport, high-temperature heat for industry, and electricity generation. Green hydrogen could play a significant role in sector coupling (the increased integration of energy supply and end-use sectors), and in minimising the overall cost of decarbonisation across all sectors.

Aran islands, located at the mouth of Galway Bay Special Area of Conservation, Natura 2000, have developed a CETA which includes, amongst the different decarbonisation options, the set-up of hydrogen fuelled ferries.

Ireland participates as an active member in The **North Seas Energy Cooperation (NSEC)** along with Belgium, France, Denmark, Germany, Luxembourg, the Netherlands, Norway, Sweden and the UK. The governance focuses on the development of the offshore grid development and the large renewable energy production (76 GW by 2030, 193 GW by 2040) in the region. Plans for hydrogen connections are underway.

Ireland, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen.**

17. Israel

17.1. Governance

No specific hydrogen strategy is available for Israel at the time of writing this Document.

Energy responsibility is under the **Ministry for Energy**.

The Israeli representative in the States Representative Group of the Clean Hydrogen Partnership comes from Israel Innovation Authority (IIA).

17.2. Targets

No specific targets were found.

17.3. Research and innovation priorities

- **Renewable H2 production**: ongoing research on technologies to reduce emissions and related regulation.
  - Other modes of H2 production: focus on pyrolysis.
- **H2 storage and distribution**: ongoing RD&D to evaluate which type of infrastructure will be needed in the future.
  - *H2 storage*. Ongoing research on underground storage.
- **H2 end-uses:**
  - *Transport applications*: ongoing investments in RD&D with a view to select the most suitable technologies for development and demonstration projects.
  - *Clean heat and power/Characterization of Hydrogen Hub site(s):* Which technologies could replace fuels and reduce emissions in all industry sectors.

17.4. Funding instruments

The **Israeli Ministry of Energy** is planning a call for proposals dedicated for hydrogen technology. The estimated public funding for the call is approximately **6.1 million euros**.

The Israel Innovation Authority (IIA), an independent publicly funded agency, offers grants via bottom-up calls open to all technologies, including for H2-related projects with different maturity, and it can also fund large infrastructure with other two entities.

17.5. Projects

- At the moment there is a **small hydrogen valley** planned in **southern Israel**, the public funding estimated for the project is about **10 million euros**. However, the project timeline and target date of launch into operations are not clear yet. In addition, the chief scientist of the Israeli Ministry of Energy is working on a strategic plan for hydrogen that will include a recommendation for public funding of R&D and demonstration projects such as a hydrogen valley.
- An Israeli group with different stakeholders (Academia, Industry, Municipality) submitted a proposal in a consortium for **H2 Valleys (large-scale) call**.
- There are a few local industry initiatives and collaborations:
    - **Pilot test with fuel cell trucks** that will be fuelled at a new pilot hydrogen fuelling station.
    - **Pilot test for independent EV charging stations** powered by GenCell small fuel cells.
    - A strategic agreement for **200 MW electrolysers** for green hydrogen projects between an H2Pro and Doral, an Israeli renewable energy company.
    - A project of a **pilot system of 0.4 MW** scheduled for 2023 in Israel. (The project is supported by the Israeli Ministry of Energy). Green hydrogen will be produced by H2Pro's E-TAC technology. Doral develops a photovoltaic plant which will produce electricity for the project. The hydrogen will be blended with natural gas to be used in the a nearby dairy factory.
    - **One fuelling station** opened for experimental use with two Hyundai trucks that were imported to Israel for a pilot.

The main issue faced by Israel in developing hydrogen projects is related to the lack of awareness in the area about its opportunities. The implementation of more hydrogen projects could give a boost to the development of a hydrogen economy in the area, including in countries such as Egypt and Jordan.

Israel participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

18. Italy

Italy launched a Hydrogen Roundtable (Tavolo sull'idrogeno[37]) in 2019 with a view to adopting a comprehensive strategy on hydrogen. Some guidelines[38], developed by MISE (today known as Italian Ministry for Enterprise and Made in Italy) were proposed and sent for consultation in 2020.

The focus areas include:

- **Trucks** for long-run mobility, linked to the development of an extensive network of refuelling stations.
- **Trains**. In Italy, there is still an elevated presence of diesel trains in some regions (e.g. Sardinia, Sicily, Piemonte), and the target is to convert half of the national lines, currently running on diesel, to hydrogen by 2030.
- **Chemicals and petrochemicals industry**, where H2 is already produced from natural gas. It represents, therefore, an ideal sector where to start investing into the production of H2 also from renewables.
- **Mixing H2 in the natural gas grid**.

These guidelines represent the Italian H2 industrial strategy.

A strategy focused on H2 research was also developed and approved in October 2020: Strategia Italiana Ricerca Idrogeno (SIRI)[39].

18.1. Governance

MISE (**Italian Ministry for Enterprise and Made in Italy**) is one of the Ministries in charge of the hydrogen strategy and development. It is also supported by **MIUR (Italian Ministry for University and Research)** with respect to the identification of research and innovation priorities.

Other Ministries, such as the one for Environment and Energy Security (MASE) and the one for Transport and Sustainable Mobility are also involved in disbursing funds for H2 projects in particular within the NEXT GENERATION EU Program (PNRR). There is a proper interface between MASE Ministry and the **Italian association on hydrogen** (H2IT), which is mainly formed

[37] Report proposte pervenute al tavolo idrogeno (2019) Ministero dello Sviluppo Económico. https://www.mimit.gov.it/images/stories/documenti/Report_Tavolo_Idrogeno.pdf

[38] Strategia Nazionale IdrogenoLinee Guida Preliminari. Ministerio dello sviluppo economico (2020). Preliminary guidelines_IT H2 strategy.

[39] Strategia italiana Ricerca Idrogeno (2020). Ministerio dell Università della Ricerca https://www.miur.gov.it/-/prime-linee-guida-per-la-ricerca-italiana-sull-idrogeno

by the industrial stakeholders that are active on the hydrogen sector in Italy, together with research centres (FBK, ENEA and CNR), and several universities.

Some prominent research centres in the area of energy (**CNR** is the representative in the States Representative Group of the Clean Hydrogen Partnership, and **ENEA** is strongly involved in the Clean Hydrogen Alliance) are mainly in charge of developing the Italian research and innovation strategy supporting MIUR.

Other relevant Managing Authorities:

- **Molise Region - I Department of the Presidency of the Regional Council** for the RP Molise ERDF ESF+ 2021-2027.
- **Cabinet of the President - Special structure for program implementation - Unitary Programming Section** for the RP Puglia ERDF ESF+ 2021-2027.
- **Department of Unitary Programming** for the RP Calabria ERDF ESF+ 2021-2027.
- **Managing Authority of the Basilicata ERDF/ESF+ Regional Programme** for the RP Basilicata ERDF ESF+ 2021-2027.
- **Single Managing Authority Service ERDF – ESF** for the RP Abruzzo ERDF 2021-2027.
- **Campania Region** for the RP Campania ERDF 2021-2027.
- **Directorate-General for the Knowledge, Labour and Enterprise Economy** for the RP Emilia-Romagna ERDF 2021-2027.
- **Autonomous Region of Friuli Venezia Giulia - Community funds management service** for the RP Friuli-Venezia Giulia ERDF 2021-2027.
- **Regional Directorate for Economic Development, Productive Activities and Research** for the RP Lazio ERDF 2021-2027.
- **Competitiveness Sector functionally integrated in the Economic Development Department** for the RP Liguria ERDF 2021-2027.
- **Directorate General for Education, University, Research, Innovation and Simplification** for the RP Lombardia ERDF 2021-2027.
- **Directorate for Integrated Programming of Community and National Resources** for the RP Marche ERDF 2021-2027.
- **Autonomous Province of Bolzano, Europe Division, Office for European Integration** for the RP AP Bolzano ERDF 2021-2027.
- **Strategic Planning and European Programming Service** for the RP AP Trento ERDF 2021-2027.
- **Regional Planning Centre - Department of Planning, Budget, Credit and Territorial Planning** for the RP Sardegna ERDF 2021-2027.
- **Presidency of the Sicilian Region – Department of Programming** for the RP Sicilia ERDF 2021-2027.

- **Tuscany Region – Directorate General for Territorial Competitiveness of Tuscany** for the RP Toscana ERDF 2021-2027.
- **Directorate for Resources, Planning, Culture and Tourism** for the RP Umbria ERDF 2021-2027.
- **Structure Regional Development Programmes** for the RP Valle d'Aosta ERDF 2021-2027.
- **Unitary Planning Directorate**, which is part of the Economic Policies, Human Capital and Community Planning Area for the RP Veneto ERDF 2021-2027.
- **Emilia-Romagna General Directorate Resources, Europe, Innovation and Institutions** for the Programme (Interreg VI-B) Adriatic-Ionian.
- **Autonomous Region Friuli Venezia Giulia, Central Directorate for Finance, Accounting Unit** for the programme (Interreg VI-A) Italy-Slovenia.
- **Veneto region Area for Economic Policies, Human Capital and Programming of European Funds** for the Programme (Interreg VI-A) Italy-Croatia.

18.2. Targets

The main targets to 2030 with respect to hydrogen development, as identified in the preliminary guidelines, refer to:

- **2%** of hydrogen penetration in the final demand. The provisional target to 2050 foresees a 20% penetration of H2 in the energy demand.
- Contribution to a reduction of 8 Mtons of CO2.
- **5 GW** of hydrogen production via electrolysis.
- Estimated contribution to the GNP of 27 billion EUR.
- Creation of 200.000 temporary jobs, and at least 10.000 permanent jobs.

18.3. Research and innovation priorities

Some guidelines focusing on research into hydrogen[40], prepared by the Ministry of University and Research (MIUR), were adopted in 2020. The document focuses on these topics:

- **Production of green hydrogen**:
  - Electrolysis
  - Other H2 production technologies (from biomass).
- **Transport, storage and distribution**:
  - *Transport, storage and distribution network*: ammonia been identified as a potential liquid carrier.

[40] Microsoft Word - Prime.indicazioniSIRI.docx (miur.gov.it)

- *Low-cost hydrogen fuelling stations*: Compressed hydrogen is the main option for refuelling stations for road and rail transport at pressures of 350 and 700 bars.
- *Blending hydrogen into natural gas:* injection studied up to 20 % (current legislation limits to 2 %). It is widely considered that the Italian NG infrastructure needs proper upgrade to allow uptake of large hydrogen concentrations.

- **Final uses**:
  - *Mobility*: heavy duty vehicles, ships, trains and aviation with liquid hydrogen carriers, synthetic fuels (renewable hydrogen as process enabler) and e-fuels.
  - *Stationary applications* (mainly co-generation in the built environment): replace natural gas boilers with renewable hydrogen fed CHP units using stationary fuel cells. Internal combustion of hydrogen is also considered.
  - *Electricity production*.
  - *Applications in industry*.
- **Cross-cutting issues**:
  - Security, safety, pre-normative research.
  - Regulatory criteria and authorisation procedures.
  - System of guaranteed of origin, traceability of hydrogen supply, standardisation, codes and standards.
  - Education and training (to a lesser extent).

The Italian guidelines refer to several EU documents, such as the EU Communication on “A hydrogen strategy for a climate-neutral Europe”, the Clean Hydrogen Partnership SRIA, the European Hydrogen Backbone (EHB), and the “Ten-Year Network Development Plan (TYNDP) – ENTSOG & ENTSOE (July 2020).

18.4. Funding instruments

The preliminary guidelines foresee an overall investment of **10 billion euros** from 2020 to 2030 in order to achieve the above-mentioned targets, distributed as follows:

- **H2 production: 5-7 billion euros**
- **H2 infrastructure: 2-3 billion euros**
- **Research: 1 billion euros**

This investment should come from several funds, both at EU and national level:

- **Next Gen EU** (Recovery and Resilience Facility, REACT-EU, Horizon Europe).
  - The Italian RRP (PNRR- Piano nazionale di ripresa e resilienza) provides **3,64 billion euros** for the development of hydrogen.
    - 160 million euros dedicated to research and development of new technologies, including the drafting of an ***Operational Plan for Research***

(POR- Piano Operativo di Ricerca) designated by the investment 3.4 of the RRP. This document stems from an agreement between the Italian Ministry for Environment and Energy Security with ENEA, CNR and RSE (the three main Italian research centres in the area of energy). 40 million euros will be dedicated to green H2 production; 30 million euros for storage, distribution and e-fuels; 30 million euros for fuel cells for stationary and mobility applications; 20 million euros to intelligent energy systems to improve security of H2 infrastructure.

- 530 million euros dedicated to the use of H2 in trains and trucks (Ministry of Infrastructure and Sustainable Mobility) designated by the investment 3.2 and 3.3 of the RRP, including 10 HRS for trains, and 40 HRS for light and heavy-duty vehicles.

The Figure below summarises the Italian RPP investments into different areas:

Hydrogen in PNRR – 3,64 billion

M2C2.3 Promote the production, distribution and end uses of hydrogen : 3,19		
Investment 3.1: Production in abandoned industrial areas	Hydrogen Valleys with local production and consumption, enhancement of nearby SMEs	500 M€
Investment 3.2: Use of hydrogen in hard-to-abate sectors	Chemicals and petroleum refining, Other hard-to-abate sectors include steel, concrete, glass and paper.	2 B€
Investment 3.3: Hydrogen charging stations for road transport	Priority for refueling infrastructures, 40 on corridors and strategic nodes	230 M€
Investment 3.4: Hydrogen charging stations for rail transport	Conversion of non-electrified railway lines to hydrogen, 9 refueling stations	300 M€
Investment 3.5: Research and development on hydrogen	Technologies for storage and transport of hydrogen and for transformation into other derivatives and green fuels;	160 M€
M2C2.4 Developing more sustainable local transport		
Investment 4.4:	Renewal of the regional public transport bus fleet and railways with clean fuels vehicles	10,18 B€
M2C2.5 Support for the industrial value chain		
Investment 5.2: Hydrogen	Installation of 1GW of electrolysers (5GW by 2030) + fuel cells	450 M€

- **Cohesion and Development Fund (2021- 2027) details cooperation priorities,** mainly funded via the EU cohesion fund. Energy is included amongst the priorities, with specific reference to support to the development of green hydrogen and electrolysers in the South of Italy. No reference to a dedicated budget could be found.
- **IPCEI fund** from August 2021 makes 95 million euros available to companies applying to IPCEIs (not necessarily in the area of hydrogen).
- **Sustainable Development Fund** finances projects with a significant impact at national level on industry competitiveness of the productive apparatus, with a special focus on:
  - *Promotion of research, development and innovation projects of strategic importance* for the relaunch of the competitiveness of the production system, also through the consolidation of research and development centers.
  - *Strengthening of the manufacturing* structure, the reuse of production facilities and the relaunch of areas facing complex crisis situations.

- Promotion of the international presence of Italian companies abroad and attracting investments from abroad.

- **National fund for research on the electric system** focuses on three priorities: smart grids, hydrogen, and innovative energy materials (low TRL). Concerning hydrogen, the supported priorities are:
  - *Hydrogen production*: development of processes and technologies, alternative to alkaline electrolysis and PEM, based on the combination of different types of renewable energy sources and on the use of non-CRM and recycled raw materials. The goal is to achieve gradually decreasing production costs.
  - *Hydrogen transport and storage*: analysis and development of different integration strategies.
  - *End- uses* with a focus on the development of innovative materials.

The available budget for hydrogen is **18,15 million euros** for the period 2022-2024. The funds are available to recognized research centres to cooperate on the identified priorities.

18.5. Projects

Italy has several on-going H2 projects co-funded by the aforementioned schemes:

- Project by ENEA (14 million EUR) to support the creation of an **H2 incubator** in around the ENEA headquarter in Italy. Project financed by Mission Innovation.
- Creation of a **high technology centre for H2** in Sicily from the cooperation of the Region, together with universities and some stakeholders located in Siracusa, Milazzo and Gela.
- Techno-economic feasibility study for the installation of an H2 production plant based on PV, as part of the **Green ports** priority in the Italian RRF, around the area of Genoa.
- **IPCEI**:
  - ***Electrolyser gigafactory*** by De Nora in partnership with Snam. Production of components and systems for water electrolysis and fuel cells. It aims to contribute to the development of alternative energy sources necessary to achieve the decarbonization of industrial supply chains, starting with those related to mobility. The Gigafactory will be located in the area of Cernusco sul Naviglio (Milan). The start of the construction works is expected by half 2023.
  - ***Hydrogen Industrial Lab*** by ENEL. Industrial-scale innovation laboratory that will be built in Sicily and will allow Enel Green Power to collaborate with start-ups and global players to develop, test and validate new green hydrogen production and storage technologies in a controlled environment, already integrated into the business.
  - ***Electrolyser Gigafactory*** by Ansaldo. The factory will have a production capacity of about 800 MW and will be fully operational by the end of 2026.

- ***IFuture Hydrogen*** by Fincantieri. A programme that will lead to the creation of two distinct marine products powered by hydrogen: a family of internal combustion engines and a modular fuel cell platform. Both will be dedicated to a power range between 500 and 4,000 kW and will reduce CO2 emissions to values close to zero.
- ***Iveco***: to build and promote hydrogen-powered heavy-duty mobility in Europe.
- ***Hydrogen Valley of Rome*** by NextChem. The project sets up the first industrial-scale technological hub for the development of the national supply chain for the production, transport, storage and use of hydrogen for the decarbonization of industrial processes and for sustainable mobility.
- ***RINA-Centro Sviluppo Materiali*** for materials' development.
- ***SardHy Green Hydrogen***, the company established on the basis of a joint project of Enel Green Power and Saras related to the development of green hydrogen in Sardinia.
- ***South Italy Green Hydrogen***. Two joint projects between ENEL Green Power and Eni. One of the projects is to be implemented at the biorefinery in Gela, Sicily, where a 20 MW electrolyzer will be installed. The other will be near Eni's refinery in Taranto, in the Apulia region, where a 10 MW electrolyzer will be installed. Both will use PEM (polymer electrolyte membrane) technology. The two corporations have found that green hydrogen, produced using only renewable energy, is the most appropriate solution to drive the decarbonization of these two plants.

- **Hydrogen Valleys (500 M until 2023)**:
  - ***Hydrogen Valley South Tyrol*** aims to decarbonise the mobility sector and to connect the region with the main Italian and European economic areas along the Brenner Corridor.
  - ***H2iseO: an italian hydrogen valley for sustainable mobility***. Jointly implemented by FNM and Trenord, aiming at decarbonising public transport services and at supporting the transition towards a more sustainable transport systems.
  - ***Lombardy***. Smaller scale hydrogen valley, recently approved, which aims at decarbonising the area around the Malpensa airport.
  - ***Puglia Green Hydrogen Valley*** by Edison, Snam, Saipem and Aldoran. Creation of three H2 production plants, connected to PV generation, in the area of Brindisi, Taranto e Cerignola. Once set up, the project should be able to produce around 300 million m3 per year. It has not received EU funds yet.
  - ***North Adriatic Hydrogen Valley.*** Managed by Presidency and Regionale Government of the Friuli Venezia Giulia Autonomous Region (RAFVG) together with the relevant governments of Croatia and Slovenia.
  - In terms of **development of hydrogen infrastructure**, by 2030, the Italian backbone may stretch from Sicily till the hydrogen valley of Emilia Romagna

supporting an accelerated development of hydrogen in the country. These developments will be coupled with the potential to import hydrogen from Tunisia, fully exploiting the cost advantage of solar production and land availability in Northern Africa.

The Autonomous Region of Friuli Venezia Giulia (RAFVG) cooperates with the Central European Initiative (CEI)- Executive Secretariat (ES) (https://www.cei.int/Secretariat) through agreed Joint Work Programmes (JWPs), which include several activities and initiatives based on common priorities. This collaboration has been taken as an example to be translated to other local and regional authorities.

The main issues encountered until now related to co-funding between the RRP program and others are mainly due to the need of traceability of the employed funds, financial reporting, and absence of a clear legal framework. Moreover, the main challenges for national projects regard financing conditions, in particular the pre-financing of RRP projects does not exceed 10%, and interim financing may occur after one year or even after 18 months. This hampers the participation of SMEs as well as of universities and research organisation that cannot advance the requested investments. Finally, since the supply chain is not yet well developed, there might be delays in projects' implementation and even low interest and capability in participating in hydrogen tenders.

18.6. Other policies and measures

The Italian Integrated Plan for Energy and Climate (PNIEC- Piano nazionale integrato per l'energia e il clima), in its version published in January 2020 by MISE (now Italian Ministry for Enterpise and Made in Italy), makes some general references to the role of hydrogen, mainly in reference to the decarbonisation of energy-intensive industries, and to long-run commercial transport.

The MEHRLIN project in northern Italy, for instance, has integrated different funding sources, namely CEF, H2020 and LIFE. It will finance (through CEF) the construction of H2 stations for buses, whilst the LIFE programme is financing the deployment of a fleet of 28 hydrogen fuel-cell cars (Zero Emission LIFE IP). Through the H2020 JIVE project, 27 fuel-cell buses for the same location will also be supported.

Italy is removing barriers to the development of renewable energy, and it is using the **RRP** to support investments in energy efficiency. According to its RRP, Italy will adopt a new law with environmental tax incentives to support the production and use of renewable hydrogen and remove administrative barriers to hydrogen deployment (security provisions and simplification of measures to install small structures and re-charging stations). Moreover, it is going to publish tenders for key railway infrastructure investments, including high-speed rail services to the South, based on hydrogen.

Concerning Islands CETAs, the following one makes a direct mention on hydrogen:

- ***Pantelleria*** [41]**:**
  - Increase of the share of alternative traction vehicles (electric, hydrogen, biogas) in the total number of vehicles registered in Pantelleria.
  - Equip the island's electricity grid with adequate storage systems that can accumulate energy in times of overproduction from variable RES and can return it during peak demand (e.g. hydrogen, flow batteries).

The Italian cohesion strategy includes, amongst its priorities, the support to innovative and experimental technologies, such as green hydrogen.

Italy, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**. Italy was involved in several national expert groups and task force meetings, and coordinated the pan-European and transdisciplinary workshop on hydrogen production together with Bulgaria.

[41] Agenda per la Transizione Energetica, Isola di Pantelleria, October 2020: https://clean-energy-islands.ec.europa.eu/countries/italy/pantelleria

19. Latvia

No hydrogen strategy has been developed in Latvia so far. Efforts to help the development of a hydrogen economy in the country are being carried out by researchers and businesses within the framework of associations, such as the Latvian Hydrogen Association.

Various actors in the industry have joined efforts and created the **Hydrogen Alliance Latvia** that focuses on joint effort and collaboration to facilitate new innovation, collaboration efforts and a unified goal of promoting hydrogen as way of energy independence and as possible future technology that will lead the way towards net zero emissions. The alliance features stakeholders of all levels – SMEs, public bodies and universities with state-of-the-art R&D institutes and laboratories.

Latvia has recently announced that it is currently focussing on large scale wind projects as an important precondition for developing H2 generation facilities. The strategic focus, therefore, seems first to be on expanding Latvian capacities to produce renewable energy, before moving to green H2 production.

19.1. Governance

The key actors for the development and implementation of a national hydrogen strategy seem to be the **Investment and Development Agency of Latvia** (direct administrative organisation subordinated to the Minister of Economics of the Republic of Latvia) and the Green and Smart Technology Cluster (co-financed by the European Regional and Development Fund), which manages the Hydrogen Alliance Latvia.

The website of the Latvian Hydrogen Association provides links to some relevant stakeholders, namely:

- Ministry of Education and Science, Republic of Latvia (main representative in the States Representative Group of the Clean Hydrogen Partnership)
- Ministry of Economics of Republic of Latvia
- Ministry of Environmental Protection and Regional Development
- Latvian Academy of Science
- Latvian Council of Science
- Patent Office of the Republic of Latvia
- Investment and Development Agency of Latvia
- State Education Development Agency

Other relevant Managing Authorities:

- **Ministry of Finance** for the European Union Cohesion Policy programme 2021-2027.

19.2. Targets

Latvia's objective for **public hydrogen refuelling infrastructure** is to comply with the requirements of the AFIR Regulation, i.e. currently it is stipulated that the hydrogen station must have a capacity of 1t/day, as well as the distance between hydrogen refuelling stations along the TEN-T road network must not exceed 200km. Latvia intends to meet these requirements by the end of 2030.

19.3. Research and innovation priorities

Latvia aims to promote the development of a strong and cohesive hydrogen ecosystem and related technologies, as well as to accelerate the uptake and capacity of hydrogen innovation, infrastructure, production and applications, enabling the hydrogen industry to develop in line with the objectives set by the EU, contributing both to the Latvian economy and to the achievement of climate goals.

The R&I priorities of Latvia are currently focused on:

- **H2 production**: innovative technologies for electrolysis (amphoteric decoupled electrolysis method).
- **H2 storage and distribution**: feasibility studies of adaptation of the gas grid to H2 (e.g., in the residential sector); compliance of the public hydrogen refuelling infrastructure with the requirements of the AFIR Regulation before 2030; analyse the best-fitted spots for storage.
- **H2 Valleys**:
    - *BalticSeaH2* implements a large-scale, interregional hydrogen valley across country borders in the Baltic Sea region, with a main valley between Finland and Estonia. Two Latvian companies are involved.
    - Ports are centre pieces of hydrogen valleys for Latvia. With three key ports in Latvia – Riga, Liepaja and Ventspils, this offers excellent development opportunity and innovation capacity.

19.4. Funding instruments

At the moment there is no specific national funding programme for the development of the H2 economy in Latvia.

Latvia has designated national R&I representatives knowing the HE priorities and actions (such as new missions, partnerships, cohesion programmes) and regional smart specialisation priorities

to create synergies and implement strategic plans to exploit smart growth-related instruments. To this end. Latvia uses the bottom-up S3 priority-setting to find partners and set R&I priorities and targets.

19.5. Projects

- In Riga, as part of the **H2Nodes** project, the public transport operator "Rīgas satiksme" in the Latvian capital has introduced hydrogen fuel cell range extenders in its unified electric trolleybus system. With this pilot project of the innovative concept of "HyTrolley" trolleybuses provide greater flexibility in the transport system, less noise, zero tailpipe emissions and better energy efficiency. The trolleybuses are powered by hydrogen produced by the only hydrogen fueling station in the Baltics with a 300 kg daily output and a storage capacity of 600 kg – enough to power the 10 trolleybuses implemented within the project and several other hydrogen powered vehicles. This project kicked off practical use of hydrogen as a fuel in Latvia and the trolleybuses move daily commuters throughout Riga. However, the hydrogen station produces grey hydrogen from natural gas.
- The Latvian startup **Naco** plans to build a manufacturing station to provide its clients with ready-to-use coated parts for hydrogen production.
- Latvia participates in the **Baltic Sea Hydrogen Network** project (financed by the Swedish Institute), with as aim to "build an extensive, multinational, multilevel and cross sectoral network/partnership regarding Hydrogen around the Baltic Sea, which subsequently will mobilize early users and increase awareness of Hydrogen as an energy carrier in the Baltic Sea Region".
- Cross-border Hydrogen Valley project **BalticSeaH2** (33 million euros) will research production and mining potential, prototype technologies and their applications, develop basic infrastructure and promote systematic intersectoral cooperation. The Freeport of Riga will focus on end h2 application in the maritime sector, such as vessel refuelling, shipping, hydrogen storage, redistribution, transfer and distribution. It is also planned to convert and pilot a hydrogen-powered vessel.
- "Supporting the Regional Development of the Green Hydrogen Fuel Value Chain for Transportation in Estonia and Latvia" (**H2Value**) project. First inter-regional green hydrogen value chain in South Estonia (Tartu) and Northern Latvia (the Vidzeme region). Its main goals are to establish a small-scale solar-powered green hydrogen production plant in the Tartu region, establish a green hydrogen refuelling station and test the feasibility of transporting green hydrogen by road to be used as a fuel source for specially adapted cars.
- **HydroG(re)EnergY-Env** project's objective is to develop and validate an efficient hydrogen production technology where hydrogen is generated from renewable energy sources with AI assistance for control, management and optimization.

- Concerning the **development of hydrogen infrastructure**, the gas TSOs of Estonia, Finland, Latvia, Poland, Germany and Lithuania have signed a cooperation agreement to develop hydrogen infrastructure from Finland through Estonia, Latvia, Lithuania and Poland to Germany to meet the REPowerEU 2030 targets.

19.6. Other policies and measures

Latvia seems to consider hydrogen applications as a long-term perspective. Its NECP (2019), covering 2021-2030, does not include specific objectives or targets for the production or use of hydrogen, nor hydrogen specific policies and measures.

According to its NECP, Latvia plans to retrofit its gas infrastructure to improve its efficiency. In this frame, it will assess the possibility to adapt the natural gas infrastructure enabling it to transport hydrogen.

Latvia foresees to develop an action plan for the deployment of hydrogen infrastructure, while also taking actions to set up adequate market conditions, if and where applicable. It could, therefore, be included in the Alternative Fuel Infrastructure Plan.

Latvia, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

20. Lithuania

In June 2022, a dedicated study for the hydrogen sector in Lithuania, referred to as **Guidelines and their implementation action plan for the development of the hydrogen sector in Lithuania**[42], was completed. It is composed of four main sections:

- Policy review
- SWOT analysis
- Scenario modelling
- Strategy and implementation

This document mentions, amongst its objectives, "*To establish MoUs with neighbouring EU member states on areas of collaboration to increase regional security of supply and coordinate on transmissions / storage / import / and export infrastructure*".

20.1. Governance

The main responsible for the Lithuanian hydrogen strategy is the **Ministry of Energy**, which is also the main representative in the States Representative Group of the Clean Hydrogen Partnership).

The figure below summarises the actions foreseen in the strategy and the responsible Ministry.

[42] https://enmin.lrv.lt/uploads/enmin/documents/files/AmberGrid_Draft_Lithuania_Hydrogen_Strategy_vFinalPresIndustry.pdf

Action			Assumed responsible	Timeframe for completion	Time to complete
Mid 2020s targets	1	Take ownership of strategy and lead governance	Ministry of Energy	2022	< 1 year
	2	Develop a pilot use cases in HGVs that supports the minimum EU target for refueling network on TEN-T	Ministry of Energy	2025-26	3 – 4 years
	3	Rollout of hydrogen buses across 5 largest cities	Ministry of Transport & Comms.	2025-26	3 – 4 years
	4	Enable projects through establishment of clear health and safety regulation and environmental planning	Ministry of Environment	2023-24	0.5 – 2 years
	5	Develop a pilot use case in rail	Ministry of Transport & Comms.	2025-26	3 – 4 years
2030 targets	6	Deliver scaled up project delivery in fertilizers and establish first hydrogen valley around fertilizer production	Ministry of Energy	2028-30	3 – 4 years
	7	Begin testing hydrogen blending in the gas network	Ministry of Energy	2028-30	3 – 4 years
	8	Prepare for market-based scale up	Ministry of Energy	2028-30	3 – 4 years
	9	Invest in seasonal storage for hydrogen	Ministry of Energy	2028-30	3 – 5 years
	10	Build capability and human capital in hydrogen	Ministry of Economy and Innovations	2028-30	5 – 10 years
	11	Assess pilots for aviation and shipping deliverable by 2030 (but not earlier than late 2020s)	Ministry of Energy	2030	3 – 4 years
Beyond 2030	12	Establish a business model for low carbon flexibility in power system to deliver net zero power by 2035	Ministry of Energy	2030	1 – 3 years
	13	Long term planning for role of hydrogen in fuel mix	Ministry of Energy	2030	0.5 – 2 years
	14	Long term planning for hydrogen transmission and storage	LitGrid / AmberGrid	2030	0.5 – 2 years

Figure 9. Actions and responsible Ministry in the Lithuanian National Hydrogen Strategy

Other relevant Managing Authorities:

- **Ministry of Finance of the Republic of Lithuania** for the Programme for the European Union funds' investments in 2021–2027.

20.2. Targets

The targets presented in the strategy include:

- Target **300 - 350 MW of electrolyser production capacity** (or equivalent through other technologies) by 2030 and 30 kt of low-carbon hydrogen production, representing approx. 1% of target 2030 EU capacity and 0.3% of production respectively 15% of domestic ammonia production enabled by low-carbon hydrogen
- **Hydrogen buses** in place wherever they are the preferred zero emissions solution in 5 major cities.
- **1 pilot hydrogen train**.
- Approximately 2% of demand in seasonal storage by 2030.
- **50 – 100 HGVs** powered by hydrogen by mid-2020s and at least **5 refuelling stations** in place to accommodate roll out of hydrogen across TEN-T network.

20.3. Research and innovation priorities

Lithuania's research in hydrogen technology and applications is well developed and active, with, among others, the Lithuanian Energy Institute (LEI) and the Vilnius Gediminas Technical

University (this University has together with the company „SGdujos“ established the **Laboratory for Experimental Research of Hydrogen as Fuel or Fuel Additive** in Lithuania).

The very first laboratory of such type in Lithuania and the Baltic states is engaged in studying of the opportunities related to the use of a **new type of ecological fuel – mixture of hydrogen and natural gas (hydro-methane) – in vehicles.** The laboratory also contributes to the development of programs related to climate change mitigation and collaborates with the major European motor vehicle manufacturers. This laboratory employs a team of scientists from VilniusTech University, which successfully studies the possibilities of hydrogenation of natural gas, cooperates in the field of scientific research and develops technologies for a major Swedish manufacturer Scania AB. As a result of the achievements of the abovementioned laboratory, the Lithuanian cities of Marijampole, Telsiai and Ukmerge bus fleets use up to 10% of hydrogenated natural gas.

20.4. Funding instruments

Nearly €1bn will be required up to 2030 through a combination of public and private sector investment.

- For the manufacturing and instalment of 65 MW electrolysers, support in the form of subsidies is foreseen from 2 instruments: EU's Recovery and Resilience Facility (RRF) and EU's Modernisation Fund.
    - From **RRF, 20 million euros** will be dedicated to "green" hydrogen production, with a special focus to its use for transportation purposes (especially in public transport). To this extent, a call for proposals was open in Q4 2022.
    - From **Modernization Fund, 50 million euros** will also be dedicated to "green" hydrogen production capacities' enhancement, but for a much wider variety of uses: in transport, industry, energy, natural gas infrastructure. A call for proposal is planned to be announced by the end of 2022.
- For the fuelling stations and hydrogen vehicles: support in the form of subsidies is foreseen from EU's Recovery and Resilience Facility (***RRF***): **2,4 million euros** is foreseen for 4 public hydrogen refuelling stations and of **160 million euros** for light vehicles, heavy duty transport vehicles, low-floor and high-floor buses running on alternative "green" fuels or electricity (the exact number of hydrogen vehicles is not specified, but an estimate is 34 units). The calls for proposals' documentation are being prepared.

Programme Name	Level	Budget	Priorities
EU's Recovery and Resilience Facility (RRF)	EU	Around 180 M	Hydrogen production for transport application
EU's Modernisation Fund	EU	50 M	Transport, industry, energy, natural gas infrastructure

Table 11. Available budget for hydrogen Lithuanian projects.

20.5. Projects

- A hydrogen valley centred on colocation of electrolyser production and demand could be created in the **Kaunas-Vilnius region**.
- A valley can also be created around the **Klaipeda region** capable of eventually linking hydrogen supply in this region with hydrogen demand at any point along the pipeline. This valley may include the port of Klaipeda if import and export infrastructure are to be built in the longer term. This valley could optionally extend out to the Northern part of the country where further demand will come from the refinery and the cities of Panevėžys and Šiauliai for transport use cases.

20.6. Other policies and measures

According to its NECP (2019), Lithuania considers hydrogen as “a promising area for energy innovation and an opportunity to acquire new energy competences”. Launching a hydrogen market would allow “the capitalization of research efforts, the creation of new businesses, economic growth and exportation opportunities”.

The National Energy Development Programme 2021-2030 (NEDP) was approved by the Government of the Republic of Lithuania in December 2021. The purpose of the NEDP is to determine the main changes to be made in the country in the coming decade, ensuring progress in the field of energy. One of NEDP’s measures is to *"Implement advanced technologies, gradually reducing the use of fossil fuels, giving priority to hydrogen technologies*”.

The **Lithuanian RRP** promotes sustainable transport by supporting the replacement of polluting road transport vehicles, improving public transport services, installing charging/refuelling infrastructure for vehicles using alternative fuels, and developing an alternative fuels sector (sustainable biomethane, second generation liquid biofuels, hydrogen).

Lithuania, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

21. Luxembourg

The **Luxembourg's hydrogen strategy** [43] was published in September 2021.

This strategy describes the context of decarbonisation and the role of hydrogen as part of the ambition to achieve climate neutrality at latest until 2050, Luxembourg's priority goes to energy efficiency and direct electrification. Renewable hydrogen can play a role in the integration of energy sectors in the long term. Initially, however, its use will be limited to sectors that are difficult to decarbonize by direct electrification, such as heavy industry.

The Strategy is based on seven measures:

- To contribute to the definition of the legal and regulatory framework at EU level.
- To cooperate with EU Member States and third countries.
- To identify opportunities in Luxembourg - Research and innovation.
- To materialise flagship projects.
- To prioritise actions - Towards targeted decarbonisation by renewable hydrogen.
- To develop instruments to support a developing renewable hydrogen market.
- To implement and continuously improve the strategy via a specific Taskforce H2 Luxembourg.

21.1. Governance

The **Ministry of Energy** is the main responsible body for hydrogen competences, which are managed in a national level lacking from regional specific roadmaps and initiatives.

The Luxembourg representative in the States Representative Group of the Clean Hydrogen partnership comes from Luxinnovation, which is the Luxembourg innovation agency.

An informal governance structure is established to ensure the implementation of the strategy. Two levels will be complementary in the so-called "**Taskforce H2 Luxembourg**":

- A permanent steering committee under the lead of the Ministry of Energy with representatives of the various ministries.
- Expert groups will allow to regularly assess the measures taken, to quantify the budgetary requirements, to refine the objectives and ensuring continuous improvement. This governance structure is formalised with the adoption of the strategy by the government.

[43] Stratégie hydrogène du Luxembourg (2021). Le gouvernement du gran duche de Luxembourg. https://gouvernement.lu/dam-assets/documents/actualites/2021/09-septembre/27-turmes-hydrogene/Strategie-hydrogene-LU-fr.pdf

Other relevant Managing Authorities:

- **Ministry of the Economy - Directorate for Regional Policy** for the Programme Investing in a smarter and greener Europe.
- **EGTC – Managing Authority Interreg VI Greater Region** for the Programme (Interreg VI-A) France-Belgium-Germany-Luxembourg.

21.2. Targets

- An **annual consumption** of fossil hydrogen in industry of around **450 tonnes**.
- Against the background of the target climate neutrality by 2050, renewable hydrogen and its renewable derivatives can help **cutting GHG emissions by 1 to 2 million tonnes of CO2 equivalent per year**.
- **Potential demand for hydrogen**, which could exceed 125,000 and **reach 300,000 tonnes per year**, in Luxembourg.

21.3. Research and innovation priorities

In terms of research and innovation priorities, Luxembourg focuses on:

- **H2 production:** mainly electrolysis. Moreover, Luxembourg is also focusing on strengthening its renewable energy production capacity with the implementation of some agri-PV projects and coupling hydrogen with methane generation.
- **H2 storage and distribution technologies**: mainly development of HRS, and H2 transport infrastructure, as part of the MosaHYc project.
- **H2 use**:
    - Transport applications: heavy duty vehicles, and rail applications.
    - Clean and Power: applications in hard-to-abate industries.

21.4. Funding instruments

Luxembourg has a fully bottom-up strategy in terms of projects' support. Therefore, organisations developing projects in several areas and with different TRLs can apply when calls are lunched for national funds, especially by the Ministry of Economy.

The Ministry also aims at introducing a more targeted approach for projects' funding. However, this is currently being discussed as part of the revision of the Research and Innovation Law, which would also need to take into account the new provisions of the Global Block Exemption Regulation (GBER).

In terms of co-funding, Luxembourg focuses on the EU Innovation Fund, the Research Fund for Steel and Coal (RFSC), and instruments from the European Innovation Bank (EIB). While only

limited funds are available from ERDF and RRF, which are, normally, devoted to other priorities than hydrogen.

21.5. Projects

- The **first hydrogen fuel station in Luxembourg**. The first public hydrogen station in Luxembourg is planned to be commissioned in 2023 by TotalEnergies. This first station in the Grand Duchy provides for the supply of hydrogen to light vehicles, commercial vehicles and heavy goods vehicles and will be created in ZAE Wolser A in Bettembourg, a multi-modal logistic centre to complement the hydrogen valley infrastructure.
- With the infrastructure project **MosaHYc** (moselle-saar-hydrogen-conversion), the distribution network operators Creos (Germany) and GRTgaz (France), in cooperation with the energy company Encevo (Luxembourg), want to establish an approximately 100-kilometre-long hydrogen pipeline in the SaarLorLux Grande Région. About 70 kilometres of existing gas pipelines, some of which are out of service, are to be converted into hydrogen pipelines. An additional construction of about 30 kilometres of hydrogen pipelines will create a first hydrogen island network. Specifically, existing pipelines in the area of Völklingen (Germany), Carling (France), Bouzonville (France) and Perl (Germany) will be examined for their suitability as hydrogen pipelines. A major new construction will be built from Bouzonville in the direction of Dillingen. The island network will provide a capacity of up to 120,000 m3/h, depending on the maximum operating pressure. The pipeline network is scheduled to be commissioned in 2026. In 2030, the transport of about 60,000 t of hydrogen per year is expected. In the long run, the project paves the way to accelerate the development of an interregional market for hydrogen. As a project between France, Germany and Luxembourg, mosaHYc considers itself as a European and cross-border pioneer project in the Grande Région within Saarland, Grande Est and Luxembourg to provide a first and exemplary infrastructure for the cross-border transport of hydrogen.
- **Haesaerts**: Dual fuel diesel-hydrogen lorries from Luxembourg. Haesaerts Luxembourg, a road and multimodal transport company based in Livange, which is member of the Altrea Logistics group, is specialised in tanker transport of liquid chemicals, gases and cryogenic products. After four years of research and development by CMB Tech, Haesaerts is now about to put a dual fuel lorry, fuelled by a mixture of traditional diesel and hydrogen, on the road. Equipped lorries have a range of 450 km in dual fuel mode. When the hydrogen reserve is exhausted, they continue to run on diesel alone.
- **Grande Region Hydrogen Valley**: it aims to develop and support a hydrogen ecosystem in the Greater Region of Saarland (Germany), Lorraine (Grand-Est, France) and the Grand Duchy of Luxembourg promoted by Encevo and among the partners there are two other participants of the MosaHYc project. It offers a forum for interlinking hydrogen projects in this region and jointly exploiting synergies. In the long term, the aim is to establish a hydrogen economy in this region and an infrastructure to transport hydrogen (70 km) with

a private investment of 117 million euros. Since the project does not include a Luxembourg location there has not been national public investment. It has been included in the Mission Innovation Hydrogen Valley Platform and adopted as a European Economic Interest Grouping (EEIG).

- **Luxembourg Hydrogen Valley (LuxHyVal),** funded by the CH Joint Undertaking, coordinated by The University of Luxembourg, and developed within the framework of the European Hydrogen Backbone (EHB), with the support of the company Creos to serve as a cross-border hydrogen carrier.
- According to the EHB initiative, concerning the deployment of **hydrogen infrastructure**, in the medium term, priority is put on the potential hydrogen supply of industrial clusters connected to a cross-border hydrogen infrastructure. By 2040 a full connection to the European hydrogen backbone via Belgium and Germany can be envisaged, requiring a new pipeline between the Belgian and German hydrogen networks at Bras, which is being developed with the MosaHyc project near Remich.

Even if Luxembourg has only recently started developing a hydrogen ecosystem, the sector is growing fast, given the existence of a strong financial, technical and industrial ecosystem.

21.6. Other policies and measures

According to its NECP (2019), Luxembourg wants hydrogen to be part of its energy transition to a low carbon economy, especially in the mobility sector, in the industry and as energy storage vector. Luxembourg also considers hydrogen as an interesting opportunity for its industrial companies and research institutions.

Luxembourg is member of the **Pentalateral Energy Forum**, which develops studies and joint political declarations, and of the **North Seas Energy Cooperation**, which analyses of the optimal use and landing of offshore energy.

The **RRP** mentions renewable hydrogen as a viable option to replace gas consumption in heavy industry.

Luxembourg participates as an active member in the **North Seas Energy Cooperation (NSEC)** along with Belgium, France, Denmark, Germany, Ireland, the Netherlands, Norway, Sweden and the UK. The governance focuses on the development of the offshore grid development and the large renewable energy production (76 GW by 2030, 193 GW by 2040) in the region. Plans for hydrogen connections are underway.

Luxembourg, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

22. Malta

There is no national strategy for hydrogen in Malta; moreover, no plans to develop one in the nearest future have been announced.

In 2018, the Minister for Energy and Water Management, Joe Mizzi, signed **The Hydrogen Initiative**. The Hydrogen Initiative aims to advance policies, programmes and projects that accelerate the commercialization and deployment of hydrogen fuels and technologies across all aspects of the economy. Building on recommendations from the Hydrogen energy Ministerial meeting in 2018 in Japan, and in partnership with other coalitions like the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) and Mission Innovation, the initiative focuses on how hydrogen can contribute to cleaner energy systems, while promoting sustainability, resilience and energy security. However, Malta is not listed anymore amongst the participating countries.

Malta seems to consider hydrogen as a longer-term option. Its NECP (2019) does not provide concrete hydrogen targets nor hydrogen specific policies and measures.

22.1. Governance

The **Ministry for Energy and Water Management** signed the “Hydrogen Initiative”, and it could be considered as being the main responsible related to the definition and implementation of a hydrogen strategy in Malta.

The **Ministry of Transport and Infrastructure** also plays an important role in defining projects of interest in this area.

Other relevant Managing Authorities:

- **Planning and Priorities Coordination Division within the Ministry responsible for EU Funds** for the Programme “Towards a smarter, well connected and resilient economy, a greener environment and an integrated society”.

22.2. Targets

No information was found on this point.

22.3. Research and innovation priorities

The main research focus areas are:

- **H2 uses: Mobility application**:

- Mainly related to the use of H2 to power larger electric drive trains used for trucks and buses. In this regard, the Ministry for Transport and Infrastructure together with Transport Malta will pursue future technology developments and facilitate demonstration and lighthouse projects.
- Maritime transport could also become a focus of interest, given the importance that the maritime sector has for Malta.

- **H2 transport** via underground sea pipelines.

22.4. Funding instruments

No information was found on this point.

22.5. Projects

The Maltese government is exploring the possibility of having hydrogen and blends of other renewable fuels, including bio-methane, delivered to Malta through a **gas pipeline from Gela** in Sicily from 2030 onwards. A tender for a market research survey issued by Melita TransGas, the national company entrusted with the pipeline project, aimed at gauging the interest of potential investors in hydrogen production, storage and transportation. The final objective would be to attract EU funds for this project.

22.6. Other policies and measures

Malta's National Electromobility Action Plan (MNEAP) is being updated to reflect the National Transport Strategy and National Operational Transport Master Plan, including a new action plan up to 2025 and a long-term strategy (2050). This could feed in the Alternative Fuel Infrastructure Plan (AFI Plan) to be submitted to the European Commission by 2024.

The **Malta National Hydrogen and Fuel Cell Technology Innovation Programme** (MNHFCTIP) will be part of the Malta National Electromobility Action Plan, which will step up its efforts to promote battery and all-electric drive technologies. The Maltese authorities will also follow technological developments in Hydrogen Fuel Cell Technology applications for the maritime sector.

23. Netherlands

A **Government Strategy for Hydrogen**[44] was published in 2020 by the Ministry of Economic Affairs, and Climate Policy.

Furthermore, a **National Hydrogen Programme** (Nationaal Waterstof Programma), as part of the National Climate Agreement, was published in November of 2022. The roadmap establishes two distinct phases from 2022 to 2025 and from 2025 to 2030 in the identified priority areas of production, import, industry, mobility, infrastructure, innovation, social acceptance, building application, security, legal framework, gas infrastructure adaptation.

In cooperation with the Ministry of Economic Affairs and Climate Policy, the Dutch employers' organisation in the technology industry (FME) has mapped out the current position of the Dutch manufacturing industry in the area of hydrogen, which is available in the **Hydrogen Guide:** https://www.nlplatform.com/hydrogen-guide

23.1. Governance

The **Ministry** responsible for the Strategy is the one of **Economic Affairs and Climate Policy (EZK)**, which is the same one represented in the States Representative Group of the Clean Hydrogen Partnership. It is responsible for policy making and drawing the necessary instruments and subsidies as well as the representant of European affairs.

Other governmental bodies are consulted to effectively implement the Hydrogen Roadmap:

- ***RVO*** is the executor of the funding instruments on applied research and development.
- ***NWO*** is the point of contact for (the implementation of) the funding instruments (but not exclusively) on fundamental research.
- The board of ***GroenvermogenNL*** is responsible and point of contact for this program.
- The implementation of the associated ***subsidy schemes*** lies with RVO and NWO and it comes about in consultation with the Ministry of Economic Affairs.
- The Energy Top Sector, ***TKI Nieuw Gas*** (in close cooperation with the other missions and Multiyear Mission Driven Innovation Programmes (MMIPs)) has the responsibility to establish and keep the strategy up to date. Additionally, it provides an innovation network for cooperation as well as advises policymakers.
- The ***Ministries of the Interior and Kingdom Relations (BZK) and EZK*** are jointly responsible for innovation policy and instruments for hydrogen in the built environment.

[44] Routekaart Waterstof (2022). Nationaal Waterstof Programma. https://www.rijksoverheid.nl/documenten/rapporten/2022/11/30/routekaart-waterstof

- The ***Ministry of Infrastructure and Water Management*** (IenW) is responsible for innovation policy and instruments for hydrogen in the mobility sector. Rijkswaterstaat (RWS) is the main executing body for IenW policies.
- The ***Ministry of Agriculture, Nature and Fisheries (LNV)*** is point of contact for innovation policy and instruments for hydrogen in the agricultural sector.
- The Ministry of EZK is point of contact for European schemes together with IenW which collaborates with CEF Transport.

Other managing authorities that participate in the development of hydrogen projects include the ***Interprovincial Consultation (IPO),*** which is composed of twelve Dutch provinces.

Furthermore, an informal community of government officials of all branches and organisations dealing with H2-issues is created under the organization ***HyUp*** for information sharing and cooperation establishment.

23.2. Targets

The goals and actions are listed around 3 phases: the short (2022-2025), medium (2025-2030) and long term (after 2030). From these, the highlighted targets are:

- The National Hydrogen Programme includes an ambition to scale up **electrolysis** to approximately **600 MW** of installed capacity coupled with renewable sources by 2025 and **6-8 GW** of installed capacity by 2030.
- By 2025 have ten electrolysis projects realised of different scale; both <20 MW and >100 MW and for different (industrial) applications, and in different regions.
- Investment decisions taken for about 2000 MW of electrolysis capacity by 2025.
- **Physical blending** up to 2% is already achievable with minor adjustments, and with further adjustments, the percentage could gradually be increased to approximately **10-20%**.
- 50 refuelling stations, 15.000 fuel cell vehicles and 3.000 heavy-duty vehicles by 2025; 300.000 fuel cell vehicles by 2030.
- Aviation Agreement with the sector included the commitment to reach **14% blending of sustainable fuels by 2030 and 100% by 2050.** Given the limited availability of biomass, this is expected to consist largely of synthetic fuels. Sufficient availability of hydrogen for the aviation sector is a prerequisite in this regard. Blue hydrogen will also be considered as a stepping-stone to a fully sustainable synthetic fuel based on green hydrogen. Goal of 150 zeroemission inland vessels by 2030 by which hydrogen-carrying fuels are considered to be used.
- After 2030, renewable hydrogen production in the Netherlands can take place without operational support because successful policies have led to robust demand for renewable hydrogen.

- Scaling up of both centralised electrolysis (on platforms) and decentralised electrolysis (in turbines) at sea by 2030.

23.3. Research and innovation priorities

Two main research and innovation programmes are ongoing in the Netherlands:

- The **Electrochemical Conversion & Materials (ECCM) programme** connects strong knowledge positions in the Netherlands in the fields of chemistry, energy and high-tech manufacturing.
- The **Multi-year Programmatic Approach for Hydrogen** (hydrogen MMPI), drafted by TKI New Gas, provides a solid basis for organising and stimulating the necessary innovations. The principal focus is on the industrial production and application of hydrogen and the development and landing of offshore wind energy through sustainable gases.

There are five main R&D priorities identified in the Hydrogen National Programme:

- **H2 production: Making carbon neutral H2 and direct use.** Development of sustainable hydrogen chains in industry, consisting of hydrogen production linked to offshore wind, infrastructure and storage, and application in industry for energy purposes and as a raw material, including the necessary system integration.
- **Transport and storage of H2.** Import of hydrogen-containing energy carriers, such as derivatives and LOHCs, and hydrogen in gaseous and liquid form
- **H2 application** in mobility focusing on heavy transport.
- **Regional, decentralised production and use of hydrogen in congested regions** where the energy grid hinders the realization of sustainable energy projects. Or where local use of hydrogen can be operated efficiently.
- Development of technology clusters for hydrogen components and **supply chains**, including link with the manufacturing industry.

In addition to the topics mentioned, various overarching themes such as the Human Capital Agenda (HCA), social impact and digitalisation are part of the Innovation Agenda.

23.4. Funding instruments

According to government's own calculations, the scaling up of green hydrogen production capacity to 3 to 8 GW by 2030 will require **5 billion euros**.

Several funding schemes are available:

- The government supports **applied research and development of hydrogen production in the various MOOI** (Mission-oriented Research, Development and Innovation) tender.

- Innovative pilots in the field of hydrogen are encouraged through the **DEI+ (Energy Innovation Demonstration Scheme**). Within the DEI+, these projects will in any case be eligible to receive a subsidy for 25% of the eligible costs. Depending on the type of company, this amount may be up to 45%, up to a maximum of **15 million euros per project**.
- The government aims to facilitate the scaling-up process by making use of the existing **Climate Budget funds** available for temporary operating cost support as of 2021. The government will be allocating approximately **35 million euros** per year for this purpose.
- Production of hydrogen by electrolysis is included in the **new support scheme for cost-effective carbon emissions reduction (the SDE++)**.
- The new allocation of existing funds is complementary to the DEI+, **HER (renewable energy subsidy module**) and the SDE++. The aim is to accelerate cost reductions, so that a cost-effective roll-out of green hydrogen can take place sooner to ensure a reduction in CO2.
- **338 million euros** has been allocated to finance the production of green hydrogen projects from the National Growth Fund.

Programme Name	Level	Budget	Priorities
National Growth Fund (GroenvermogenNL), specific programme of DEI+: Hydrogen and green chemistry	National	€838 million, of which around €100 million will be allocated through NWO in seven calls	Production of green hydrogen and R&D
IPCEI (Hy2tech, Hy2Use, Hy2Infra, Hy2Move)	National	€ 35 million euro for granted projects of Hy2tech, € 783.5 million for granted projects of Hy2Use, € 600 million for granted projects of Hy2Infra and e 200 million are expected for Hy2Move	R&D projects, build electrolysers, import and storage projects, mobility
Regio Noord: Groningen, Friesland en Drenthe	Regional	€ 2 million euro	R&D projects
Flevoland	Regional	€ 940.800 euro	R&D projects
Noord-Holland	Regional	€ 6,6 million euro	R&D projects
Utrecht	Regional	€ 2.4 million euro	R&D projects

Gelderland	Regional	€ 3.7 million euro	R&D projects
Overijssel	Regional	€ 3.1 million euro	R&D projects

Table 12. Hydrogen funding for Netherlands hydrogen projects.

The Netherlands have experience in co-funding, one example is the project Djewels, where European (11 million euro from the FCHJU), national (DEI funds) and regional (5-million-euro Waddenfonds) funding has been devoted. However, the national mechanism has been stopped and analysis for the replacement of funds is underway.

One other example is the Hydrogen Valley HEAVENN, which has received 20 million euros from the FCHJU through H2020 programme, and an additional public-private 70-80 million euros from public bodies at national and regional scale (Province of Drenthe Province of Groningen, Province of Drenthe, The Netherlands Ministry of Economic Affairs and Climate, The Netherlands Ministry of Infrastructure and Water Management).

23.5. Projects

There are several ongoing projects in hydrogen. Some of the most relevant ones are listed below:

- The **WAviatER** project in the Northern Netherlands is developing green hydrogen production technology for the aviation sector and other energy applications.
- **Hydrogreenn** (HYDROGen Regional Energy Economy Network Northern Netherlands) is a triple helix initiative. It's focused on business development for hydrogen applications. One of the network's pilot projects uses hydrogen for residential heating instead of natural gas.
- In the private sector, a consortium of Shell, RWE, Groningen Seaports, Equinor & Gasunie called **NortH2** is combining all aspects of the supply chain to achieve large-scale supply of green hydrogen. Its goal is to produce four gigawatts of green hydrogen by 2030, upscaling to more than 10 gigawatts by 2040.
- The **Dutch-Flemish North Sea Port cluster** is an important harbour to secure the long-term competitiveness of European industry in a green economy. Denmark-based Ørsted, a world leader in offshore wind energy, has the ambition to develop the world's largest renewable hydrogen plant here with its '**SeaH2Land**' project.
- Vattenfall, part of the Dutch Hydrogen Coalition, is converting an **existing power plant in the Eemshaven to hydrogen**. The first of the plant's three 440 MW units will run on low-carbon hydrogen by 2023.
- The project **Djewels** located in Delfzijl, counts with private funding from 6 companies including the gas grid operators Gasunie and HyCC/Nobian and from the Clean Hydrogen Partnership as well as from the regional fund The Wadden Fund. The aim is to build an electrolyzer (20MW) that will produce up to 3,000 tonnes of green hydrogen each year.

They are also options under study to expand its capacity to 60MW to produce sustainable jet fuel.

- Additional Demonstration Energy and Climate Innovation pilot projects funded by the DEI + are: Sinnewetterstof, Hysolar, PosHYdon - Topsector Energie, H2Hollandia, DUWAAL, Emmen Electrolyser test centre. Another demo unit is the project AmpHytrite funded by the MOOI Hern subsidy.
- **IPCEIs:**
  - The **Nedstack Fuel Cell Giga Factory (FCGF**) (21 million euros from RVO funding) will be accommodated next to Nedstack current operations in Arnhem, at the IPKW business park. The project will help to lift the regional hydrogen eco-system into a new era of industrialized and green fuel cell production. A first phase of the production system is expected to see start-of-production in 2023, whereas the full line should be able to meet the gigawatt capacity rate by 2026.
  - **ELYgator** (150 million euros from RVO funding) and **CurtHyl** (141 million euros from RVO funding) by Airliquide NL. The two projects will produce a total of around 30,000 tonnes of renewable hydrogen per year. The ELYgator project will be located in Terneuzen. The CurtHyl project will be located at the Maasvlakte 2 conversion park in Rotterdam. Those two-world scale electrolyzers will be integrated into the existing Air Liquide portfolio of assets and enable the supply of low-carbon hydrogen to multiple customers of the industry and the mobility markets.
  - **HyNetherlands** (113 million euros from RVO funding) The first phase of the project involves a new 100MW electrolyser at the ENGIE Ems site. This electrolyser will produce hydrogen for e-methanol production, the local mobility sector and industry. HyNetherlands wants to develop, build and operate one of the first large-scale industrial value chains in Europe for the production of e-methanol based on renewable hydrogen and biogenic CO2 in the Northern Netherlands (Province of Groningen).
  - **H2-Fifty** (103 million euros from RVO funding) proposes to produce green hydrogen that will be used to help decarbonize industry and heavy transport in the region, including BP's Rotterdam refinery.
  - **Haddock** (110 million euros from RVO funding): 100 MW renewable hydrogen production facility, offshore wind from wind farms Borssele 1+2 or Hollandse Kust West ,and will provide energy for the production of ammonia for the fertilizer producer Yara in the city of Sluiskil.
  - **H2ermes** (14,3 million euros from RVO funding): use of green hydrogen in the production of steel by Tata Steel and the production of sustainable fuels and chemicals in the port of Amsterdam with 100 MW electrolyser plant.

- **Uniper and the Port of Rotterdam Authority** (150 million euros from RVO funding) have entered into an agreement for developing the production of green hydrogen at the Uniper location on Maasvlakte. Uniper location on Maasvlakte is ideally suitable for large-scale production of green hydrogen with the use of power generated by North Sea wind farms.
- **Holland Hydrogen I** (150 million euros from RVO funding) by Shell will be the Europe's largest renewable hydrogen plant, once operational in 2025. The 200MW electrolyser will be constructed on the Tweede Maasvlakte in the port of Rotterdam and will produce up to 60,000 kilograms of renewable hydrogen per day. The renewable power for the electrolyser will come from the offshore wind farm Hollandse Kust. The renewable hydrogen produced will supply the Shell Energy and Chemicals Park Rotterdam, by way of the HyTransPort pipeline1, where it will replace some of the grey hydrogen use in the refinery.

- **Hydrogen Valleys**:
  - ***HEAVENN*** (Northern Netherlands) is a large-scale demo project which brings together production, distribution, storage and local end-use of hydrogen into a fully-integrated and functioning Hydrogen Valley.
  - ***Europe's Hydrogen Hub: H2 Proposal Zuid-Holland/Rotterdam***. Zuid-Holland has the industry, knowledge institutes and transportation capabilities to be the European Hydrogen Hub, and supply Europe's hydrogen demands.
  - ***Hydrogen Delta*** represents a Dutch-Belgium cross-border industrial cluster focused on the implementation of large-scale green (and blue) hydrogen as a feedstock material in the chemical, refinery and steelmaking industry.

According to the EHB initiative, concerning the development of **hydrogen infrastructure**, by making maximum use of the existing natural gas transport infrastructure, the Dutch hydrogen backbone can have a capacity of approximately 10-15GW by 2030. The national hydrogen Dutch transport network will be developed in phases, following and facilitating the hydrogen market development. The aim is to connect the Rotterdam-Rijnmond region with the area 'Noordzeekanaalgebied' (steel-production) and the Northern Netherlands first. With this first step, these regions will also gain access to underground hydrogen storage at Zuidwending and to Germany. The Schelde-Delta region, including a connection with Belgium, will also be developed at an early stage. Gasunie and partners will also be working together to develop the ACE ammonia import terminal. The terminal will operate on the Maasvlakte near Rotterdam (connected to the Holland Hydrogen I project).

The main problem that faces hydrogen projects in the Netherlands is that the production of green hydrogen is not competitive yet. This makes investments vulnerable as they are perceived as risky by companies. Moreover, the uncertainty of the legal framework as well as the concerning

environmental aspects of some hydrogen applications (NOX emissions) further negatively impact the deployment of this technology.

23.6. Other policies and measures

The Netherlands has the ambition to become a European leader in the deployment of hydrogen, as “hydrogen is considered to play an essential role in the transition, to achieve the 2050 climate goals”. In its NECP (2019) and National Strategy to achieve the 2030 GHG emission reduction targets, the Netherlands is committed to launch a hydrogen programme, which would support the ambition to have an installed electrolyser capacity of 3-4 GW in 2030.

The Netherlands is part of the **Pentalateral Forum**.

The regions play a pivotal role in the further roll-out of hydrogen in The Netherlands. The **Northern Netherlands** is an example of a region where new economic prospects are being developed, building on the existing infrastructure and knowledge of gas. Regional authorities and organisations will be able to play a key role in developing and facilitating local infrastructure and projects in the built environment, in mobility and industry. Actively demonstrating and bringing the opportunities to the fore also contribute to creating social support for hydrogen and getting citizens involved with the energy transition. The drafting of **Regional Energy Strategies** would be a good occasion for these local opportunities to be identified.

According to its **RRP**, The Netherlands is taking measures to increase the supply and use of sustainable bio-methane and hydrogen. There are plans to invest into electrolysis capacity for hydrogen production as well as to transform part of the existing gas transmission network into a hydrogen backbone by 2027, covering the main industrial clusters and including interconnections with Antwerp and the Ruhr area in Germany.

ERDF makes reference to the importance of investing in technological development in the field of dual fuel and hydrogen, including for making shipping more sustainable.

The Netherlands participates as an active member in the **North Seas Energy Cooperation (NSEC)** along with Belgium, France, Denmark, Germany, Ireland, Luxembourg, Norway, Sweden and the UK. The governance focuses on the development of the offshore grid development and the large renewable energy production (76 GW by 2030, 193 GW by 2040) in the region. Plans for hydrogen connections are underway.

The Netherlands, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

24. Norway

The Norwegian Government launched a **Hydrogen strategy**[45] in 2020.

The conditions for the development of a hydrogen economy in Norway are ideal, and Norwegian businesses are well positioned to participate in this potentially growing market:

- Norway has many years of industrial experience across the entire hydrogen value chain, and conditions for the production and use of clean hydrogen are ideal. Many Norwegian companies and technology communities are already developing and supplying equipment and services for the production, distribution, storage and use of hydrogen for various sectors.
- Norway has large gas reserves and the potential to increase energy production from renewable energy.
- Converting natural gas to clean hydrogen requires the capture and storage of CO2. The Norwegian continental shelf could potentially act as a CO2 storage site.
- Through the petroleum industry, Norway has robust expertise from processing gas to tackling major industrial projects.
- Norway has competitive knowledge and technology communities and a maritime industry that includes large segments of the maritime value chain. The industry already has experience in developing and implementing new high-technology solutions in maritime transport, including the use of batteries and liquefied natural gas (LNG).

On the road towards a low-emission society in 2050, Norway has pledged to reduce the GHG-emissions by at least 50 and up to 55 percent by 2030. The role of hydrogen has been highlighted by the government stating that it aims to build value chain in hydrogen where production, distribution and use are developed in parallel.

24.1. Governance

The Norwegian Government launched a Hydrogen strategy in 2020. The **Ministry of Petroleum and Energy** and the **Ministry of Climate and Environment** were responsible for the strategic process behind. The government launched the Norwegian Hydrogen Roadmap in Spring 2021. The government will support technology development through piloting and demonstration of production and use of clean hydrogen in maritime transport, heavy vehicles and industry.

[45] The Norwegian Government's hydrogen strategy (2020). Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment. https://www.regjeringen.no/en/dokumenter/the-norwegian-governments-hydrogen-strategy/id2704860/

24.2. Targets

Ambition towards 2025:

- To establish five hydrogen hubs for maritime transport with possibilities for further developing of connected land transport solutions based on hydrogen.
- To establish one to two industrial projects with associated hydrogen production facilities.
- To establish five to ten pilot projects to develop and demonstrate new and more cost-effective hydrogen solutions and technologies.

Ambitions towards 2030:

- Hydrogen as an energy carrier has been established as a real alternative in the maritime sector and matures further as a good alternative in industry.

24.3. Research and innovation priorities

The main hydrogen research and innovation priorities focus on:

- **H2 production**: Production of both blue and green hydrogen:
  - Electrolysis.
  - National priority on production of clean hydrogen from NG with CCS.
  - Open for other routes for production of hydrogen and hydrogen carriers as well as biofuel.
- **H2 Storage and distribution technologies**:
  - *H2 storage*: LH2, NH3, compressed hydrogen, underground storage
  - *H2 in gas grids*: Focus on research on hydrogen in gas grid (safety (embrittlement), infrastructure).
  - *Liquid hydrogen carriers:* Current portfolio focus on LH2 and NH3; LH2 tanks, safety, demonstration in maritime sector, liquefaction technology.
  - *Improving transportation means*: Pipeline transport, transportation of LH2.
  - Compression purification and metering solutions: metering and compression systems.
- **H2 use in transport applications**:
  - *Building blocks*: Current portfolio on fuel cell stack technology. Support mainly PEM and Alkaline fuel cells.
  - *Waterborne applications*: High priority on waterborne applications, activities include fuel cells for ships, hydrogen in ports.
- **H2 use for clean power and heat**:
  - Utilization of hydrogen and hydrogen carriers in *industry*. Demonstration at hydrogen hubs for industrial sector.

- *R&I action on H2 burners and turbines*.

- **Cross-cutting issues**:
  - Focus on *sustainability, guidelines and environmental impact* of hydrogen and hydrogen carriers.
  - Education and public awareness. Education a natural part of RCN project and centre portfolio. Public awareness part of hydrogen R&I centres.
  - *R&I on safety, regulations and standards*.
- **Supply chain**. Main focus on:
  - Development of new and improved manufacturing technologies and production processes that facilitate the safe and sustainable use of non-critical (raw) materials as well as facilitate the adoption of the circular economy principles.
  - Reducing the use of critical (raw) materials. with sustainability or environmental concerns, such as for instance those deriving from poly/perfluoroalkyls.
- **Hydrogen Valleys**:
  - Currently, there are 5 nationally funded hubs, which can be identified as Hydrogen Valleys. These cover hydrogen production and use for maritime sector and industry.
  - There is also support for a Nordic call on Nordic Hydrogen Valleys as Energy Hubs- by 2030 and 2040.

24.4. Funding instruments

- Public funding mechanisms for hydrogen covers basic research to innovation projects. The **Research Council of Norway, Innovation Norway, Enova and Gassnova** are the funding bodies that provide national public funding for hydrogen projects. A formal collaboration (labelled **Heilo**) between the four organisations has been established and information about funding and collaboration can be found on the Heilo webpage (https://www.enova.no/heilo/).
- Norway does not have specific funding programs on hydrogen. There are both national and regional R&I funding programs under the portfolio Energy, transport and low emission and the strategic area: "Decarbonisation and development of carbon-neutral energy carriers - climate-neutral products and technology with a particular focus on the major emission sources in industry and transport" to which hydrogen projects are eligible. There might be some calls at national and regional level where H2 is prioritised.
- Norway is a part of **Clean Energy Transition partnership (CETP)** and will fund new project within **TRI3 Hydrogen and renewable fuels**. New proposal for call 2023 seems more aligned with Clean Hydrogen JU. However, Norway will not join 2023 call on hydrogen.

- The public funding level for research, demonstration, and market introduction has increased significantly in 2021 and key energy companies and industries in Norway have committed to several large hydrogen projects.

24.5. Projects

Several projects in the industry are already looking closely at hydrogen or ammonia as energy carriers. Significant efforts have been made in developing electrolysis technology, production of hydrogen with CCS from natural gas, hydrogen powered vessels and hydrogen infrastructure. Norway is an energy nation with good conditions to do well in a market for hydrogen.

Norway has a clear strategy and an action plan to demonstrate full scale industrial hydrogen projects over the coming years and several major milestones were achieved in 2021 and 2022.

- In December 2021 the Norwegian Public Roads Administration announced a new **15-year contract for the operation of the two new hydrogen ferries between the Lofoten Islands and Bodø from 2025-2040.**
- At the end of 2021 **three large and important hydrogen projects** were funded from the government, described below.
    - **Production of hydrogen** – Yara is a world leader in fertilizers and will replace parts of today's grey hydrogen with hydrogen produced by electrolysis. This will contribute to emission reductions and hopefully provide the knowledge and experience needed for full-scale production of both green manure and ammonia. The demonstration plant will produce enough green hydrogen to produce 20,500 tonnes of ammonia per year. This corresponds to between 60,000-80,000 tonnes of mineral fertilizer. If the project is successful, it could be the starting point for full scale green ammonia production as the next step. Both green manure and green ammonia as fuel for ships are possible uses.
    - **Replace coal with hydrogen.** At Europe's only smelter for titanium dioxide in Tyssedal, Eramet Titanium and Iron will look at how to replace coal with green hydrogen in the production of titanium dioxide. If the project is successful, the technology can be used on a full scale, both in Norway and internationally, and contribute to significant emission reductions. Through the project, technology will be developed that allows Eramet, in the future, to build a full-scale plant where to replace 85 percent of coal consumption with hydrogen, and thus reduce CO2 emissions from the factory in Tyssedal by approx. 235,000 tonnes of CO2 per year - a reduction of more than 82 percent. It is expected that all or part of the technology can also be used in other parts of the Eramet Group.
    - **Blue hydrogen production**. Through the Barents Blue project, Horisont Energi will establish ammonia production from natural gas with carbon capture near Hammerfest in Finnmark. The project will use new and energy-efficient technology

and will be carried out by a joint venture that is to be established together with Spanish fertilizer company Fertiberia. The plant will produce 1 million tonnes of ammonia per year. CO2 will be transported to a future carbon storage Polaris for permanent disposal.

- **Maritime transport**. Maritime transport has been supported through several projects since 2015. More than 10 hydrogen pilot projects have been funded within Maritime sector focusing on emission-free solutions in shipping. HyShip is cofounded by Clean Hydrogen Partnership. In addition, several projects are funded for development and demonstration of new hydrogen technologies and solutions. Some examples of recently Norwegian public cofounded projects within maritime sector are given below.
    - **Zero emission cargo ship based on hydrogen**. The two cargo owners, HeidelbergCement and Felleskjøpet, aim to establish a sustainable transport system without emissions of greenhouse gases by building a cargo ship powered by hydrogen. The ship is planned to be in operation in 2024. The transport system will combine the cargoes of the two companies, with the cargo ship carrying aggregates from western to eastern Norway and grain in the opposite direction. Egil Ulvan Rederi has been selected to develop, build and operate a zero-emission cargo ship. The ship concept has been developed in close cooperation with Norwegian Ship Design – TNSDC, a Norwegian ship design and engineering company.
    - A **vessel for transport of ammonia that is fuelled by ammonia**. Grieg Edge will build MS Grieg Ammonia, planned for operation from 2025. The vessel is planned to be used for transport of ammonia and it will also be powered by ammonia. The vessel got Approval in Principle in April 2022 based on work from LMG Marin, Wärtsila and Grieg Edge. The tanker is a part of the larger Berlevåg-project in the north of Norway: a group of Norwegian companies that intend to use wind from Raggovidda wind park to produce green ammonia.
- **Five hydrogen Hubs (valleys)**. Funding was given to five productions plants for renewable hydrogen along the Norwegian coast. This will strengthen Norway's position as a driving force for emission-free solutions in shipping. The five hubs that receive funding are: Glomfjord, Rørvik, Hitra, Floro and Kristiansand.
- Concerning the development of **hydrogen infrastructure**, the EHB initiative mentions that in 2030, based on available system capacity, one of the export pipelines downstream the riser platforms Draupner or Sleipner could be repurposed to hydrogen transport. A new pipeline, for instance from Norway to the Netherlands, is also an option, however this would have to be sized for volumes expected in 2040. Blending of hydrogen into the natural gas export stream could also be another option to allow usage of the existing natural gas pipelines from 2030.

Norway participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen.**

25. Poland

The **Polish Hydrogen Strategy until 2030 with an outlook until 2040 (PHS)**[46] is a strategic document of the Polish Government that sets out the main objectives for the hydrogen economy development in Poland and the actions needed to achieve them.

The objectives of the strategy refer to three priority areas:

- Hydrogen use: energy, transport and industry.
- Hydrogen production, distribution and storage.
- The need to create a stable regulatory environment.

On 14th October 2021, the Polish administration, industry, academia and business environment launched the ***Polish Hydrogen Sector Deal***. Up to now, more than 230 entities have signed the Deal and committed to joint collaboration to deliver the objectives defined in the document. The Deal is expected to be the key executive instrument for the implementation of the Polish Hydrogen Strategy.

25.1. Governance

The Strategy was drafted by the **Ministry of Climate and Environment**, which is also directly involved in the States Representative Group of the Clean Hydrogen Partnership.

To provide effective management of the Sector Deal, the **Hydrogen Economy Coordination Council**, consisting of 45 members representing all parties, was established. The Council has already established 7 working groups who will work on providing solutions for the hydrogen economy in Poland and its priorities. The group focuses on 6 strategic topics:

- Implementation of hydrogen technologies in the power and heating sector.
- Use of hydrogen as an alternative fuel for transport.
- Supporting the decarbonization of the industry.
- Hydrogen production in the new installations.
- Efficient and safe hydrogen transmission, distribution and storage.
- Creating a stable regulatory environment.

Other relevant Managing Authorities:

- **Management Board of the Lower Silesian Region** for the programme “European Funds for Lower Silesia 2021-2027".

[46] Energy Policy of Poland until 2040 (EPP2040). Polish Government (2021). https://www.gov.pl/web/climate/energy-policy-of-poland-until-2040-epp2040

- **Board of the Kujawsko-Pomorskie Region** for the programme “European Funds for Kujawy and Pomorze 2021-2027".
- **Management Board of the Mazowieckie Region** for the Programme “European Funds for Mazowsze 2021-2027".
- **Management Board of the Silesian Region** for the programme “European Funds for Silesia 2021-2027".
- **Board of the Świętokrzyskie Region** for the programme “European Funds for Świętokrzyskie 2021-2027".
- **Board of the Warmian-Masurian Region** for the Programme “European Funds for Warmia and Mazury 2021-2027".
- **Board of the Wielkopolska Region** for the Programme “European Funds for Wielkopolska 2021-2027".
- **Board of the West Pomeranian Region** for the Programme “European Funds for Pomorze Zachodnie 2021-2027".
- **Ministry of Development Funds and Regional Policy of the Republic of Poland** for the programme “(Interreg VI-A) Poland-Denmark-Germany-Lithuania-Sweden (South Baltic)”.
- Industrial Development Agency JSC for the coordination of all-Poland hydrogen valleys programme.

25.2. Targets

By 2025:

- **100 to 250 zero-emission buses** powered by hydrogen are expected to be in operation.
- At least **32 hydrogen filling stations** will be built.

By 2030:

- About **800-1000 hydrogen buses** should be in operation, gradually replacing combustion vehicles.
- At least **5 hydrogen valleys**, understood as centers of excellence for the implementation of the hydrogen economy, sector integration, industry climate transformation, and infrastructure construction, are planned.
- To achieve an installed production capacity of **2 GW** from low- and zero-emission sources and processes.

25.3. Research and innovation priorities

The subject of research on the production and use of hydrogen as an energy carrier is one of the priorities of the National Science Policy (adopted by the Polish government in 2022) in the field of energy and climate. The main focus is on the following priorities:

- **Renewable H2 production**: Research and development into low-emission processes and technologies for obtaining hydrogen, as well as launching such installations with a total power of min. 50 MW. Joint production with nuclear power is considered as well as the development of CCS/CCSU technology.
- **H2 end-uses:**
  - *Mobility applications*: focus on Heavy-duty Vehicles, rail and buses.
  - *Clean heat and power:* ongoing research and development in the field of co- and poly-generation systems for residential blocks, office buildings, small estates and public buildings using fuel cells and in the field of P2G and G2P systems. Ongoing analysis on whether the turbines are better fit for these purposes than fuel cells.
- **H2 storage, distribution technologies*:***
  - Explore and analyse possible geological structures to store hydrogen such as salt caverns.
  - Build hydrogen pipelines and terminals in ports.

25.4. Funding instruments

There are few national programs for investments in hydrogen production, hydrogen refuelling stations and R&D. Programs benefit both form EU funding and national funding.

The Ministry of Education and Science, through its implementing agency National Centre for Research and Development (NCBR), has launched several flagship initiatives:

- Joint Undertaking of the NCBR and PKN ORLEN supporting **scientific research and development for the refining and petrochemical industry** – **NEON** with budget of PLN 35 million since 2022.
- Programme "**Technologies for the production and use of hydrogen**" with a budget of as much as PLN 141 million under the new strategic NCBR's programme (one of the flagship programs of science policy) "New technologies in the field of energy" 2021-2029 (hydrogen is one of the 6 priorities of this program).
- The NCBR program "**Hydrogen Storage**" 2018-2022 with a budget of PLN 32 million, the purpose of which is to develop an innovative, mobile hydrogen tank intended for use with fuel cells.

Programme Name	Level	Budget	Priorities
NEON	National	Around 7 million euros since 2022	Scientific research and development for the refining and petrochemical industry
NCBR/Technologies for the production and use of hydrogen	National	Around 30 million euros (2021-2029)	Technologies for the production and use of hydrogen
NCBR/Hydrogen storage	National	Around 7 million euros	To develop an innovative, mobile hydrogen tank intended for use with fuel cells

Table 13. Poland Hydrogen funding programmes.

25.5. Projects

The current on-going projects that are deploying and reaching towards the accomplishment of the research and innovation priorities previously mentioned are:

- Support for **charging and refuelling stations for zero and low emission vehicles** in Poland (22 million PNL from the National Fund for Environmental Protection and Water Management).
- **New Energy** (103 million PNL from the National Fund for Environmental Protection and Water Management).
- **Green Public Transport**: 122 hydrogen-fuelled buses (70.000 PNL from the National Fund for Environmental Protection and Water Management).
- **LOTOS's Green H2 (Climate, Energy and Environmental Aid Guidelines-CEEAG):** reduce greenhouse gas emissions in the energy-intensive and hard-to-abate refinery sector (€158 million). Electrolyser with a capacity of 100 MW, as well as the construction of 50 MW photovoltaic power plant and 20 MWh battery storage to be operative by 2027 and produce up to 13,600 tonnes of renewable hydrogen per year.
- **IPCEIs**:
    - Development and demonstration of hydrogen generation technology based on high-temperature steam decomposition using zero emission energy resources by **Synthos**.
    - **Hydrogen Eagle** an investment program to develop an international chain of hydrogen hubs powered by renewable energy sources and build innovative facilities to convert municipal waste into zero- and low-emission hydrogen. The project also provides for the construction of more than 100 hydrogen refuelling stations for individual, public and cargo transport. The scheme, covering Poland, the Czech Republic and Slovakia, will allow ORLEN Group to achieve annual

hydrogen production capacity of approximately 50,000 tonnes by 2030. The program provides for the construction of six new RES-powered hydrogen hubs: two in Poland, two in the Czech Republic, and one in Slovakia, including plans to build a hydrogen electrolysis plant to which electricity will be supplied from the Baltic Power offshore wind farm.

- **H2 Valleys**: currently, six regional hydrogen ecosystems have been identified in the following areas: West Pomerania, Subcarpathia, Lower Silesia, Silesian-Lesser, Masovia, and Pomerania.

Some difficulties that have emerged in the projects' planning and implementation are due to the long decision-making times for IPCEI and CEEAG (Climate, Energy and Environmental Aid Guidelines) projects allocation. Poland had to wait for the EC decision before granting the State Aid to the projects as identified in the NRRP, while these should be completed until the end of 2026. This approval delay introduces a further risk factor in achieving the planned projects in the NRRF.

Finally, electrolysers production is not developed yet in Poland, and currently the approximate waiting time for ordered electrolyser is 4-5 years, introducing a further delay in developing these capacities.

25.6. Other policies and measures

Poland's NECP (2019) does not include specific objectives or targets for the production or use of hydrogen.

The **Polish RRP** includes reference to sustainable biomethane to be employed in the cogeneration of heat and electricity and of renewable hydrogen, which could be useful to decarbonize hard-to-abate sectors. Moreover, accelerated investment in renewables would enable stepping up renewable hydrogen generation to foster decarbonisation of the transport sector and hard-to-abate industrial sectors.

The Polish **cohesion strategy** envisages to support investments in the expansion, repurposing, conversion or upgrading of gas transmission and distribution networks, provided that such investments prepare those networks for the integration of renewable and low-carbon gases such as hydrogen, biomethane and syngas into the system and allow for the replacement of installations running on solid fossil fuels.

Information on Poland's current Hydrogen statistics and regulations are summarised on the H2poland.eu portal developed by the Industrial Development Agency JSC.

Poland, together to other 24 EU State Members, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

26. Portugal

The **Portuguese National Hydrogen Strategy (EN- H2)**[47] was approved in August 2020.

The main characteristics of the Portugal energy system have determined the selection of a set of strategic configurations for the hydrogen value chain, presented in decreasing order of importance:

- **Power-to-Industry (P2I).** Replacing natural gas with hydrogen in the industrial sector (refining, chemistry, steel, among others) contributes more quickly to reducing your GHG emissions.
- **Power-to-Gas (P2G).** Green hydrogen can be injected directly into the natural gas networks (transport and distribution) or through the conversion of hydrogen to synthetic methane.
- **Power-to-Mobility (P2M)**. Hydrogen is transported, or produced locally, to supply vehicle filling stations. Higher importance on heavy vehicles.
- **Power-to-Synfuel (P2FUEL)**. The use of green hydrogen has great potential to decarbonize the production of fuels, replacing them with synthetic fuels from renewable sources (production of "green" synthetic fuels for aviation).
- **Power-to-Power (P2P)**. Excess renewable electricity can be converted to hydrogen, stored and then converted back to electricity via fuel cells or in properly adapted gas power plants.

A number of policy initiatives and programmes associated with hydrogen have been launched, starting from the period 2020-2021, and are reported in the paragraphs below.

26.1. Governance

The Portuguese Hydrogen Strategy was developed by the **Ministry for Environment and Climate Action in 2020.** The highest body is the MAAC-SEEnC (Secretary of State for Energy and Climate) from which the climate policy relies on the APA (National Environmental Agency) and the energy authority in the DGEG (Direção-Geral de Energia).

[47] Estratégia Nacional para o Hidrogénio (EN-H2). DGEG 2020. https://www.dgeg.gov.pt/pt/areas-transversais/relacoes-internacionais/politica-energetica/estrategia-nacional-para-o-hidrogenio-en-h2/

Representation in the States Representative Group of the Clean Hydrogen Partnership is shared between Ministry of Science, Technology and Higher Education (MCTES) and Ministry of Economy, through ANI[48], and MAAC, through DGEG[49] e LNEG[50].

Other relevant Managing Authorities:

- **Climate Action and Sustainability Program Management Authority** for the Thematic Programme for Climate Action and Sustainability.
- **The Agency for Development and Cohesion (AD&C)** coordinates the regional development policy and ensures the general coordination of the European Structural and Investment Funds (ESIF).
- Energy Services Regulatory Authority (ERSE) regulates, throughout the national territory, the electricity, natural gas, liquefied petroleum gas (LPG) in all categories, petroleum-derived fuels and biofuels sectors, and the management of the electric mobility network operations.
- In economic affairs, the ministry collaborated with the IAPMEI (Ministry of Economy and Maritime Affairs) and the Agency for Investment and Foreign Trade (AICEP).
- **Institute for Regional Development** for the Madeira Regional Programme 2021-2027.
- **Regional Directorate of Planning and Structural Funds** for the Azores Regional Programme 2021-2027.
- **Northern Regional Coordination and Development Commission** for the Norte Regional Programme 2021-2027.
- **Regional Coordination and Development Committee** for the Centro Regional Programme 2021-2027.
- **Alentejo Regional Development and Coordination Commission** for the Alentejo Regional Programme 2021-2027.
- **Commission for Coordination and Regional Development of Lisbon and Tagus Valley** for the Lisbon Regional Programme 2021-2027.
- **Algarve Regional Development and Coordination Commission** for the Algarve Regional Programme 2021-2027.

26.2. Targets

The targets to 2030 mentioned in the EN-H2 which are being updated in June 2023:

- **10% to 15 % injection** of green hydrogen into natural gas networks.

[48] ANI – Agência Nacional de Inovação (National Innovation Agency) under shared responsibility of MCTES and Ministry of Economy.
[49] DGEG – Direção-Geral de Energia e Geologia, https://www.dgeg.gov.pt/pt/
[50] Laboratório Nacional de Energia e Geologia, https://www.lneg.pt/

- **2 % to 5 %** of green hydrogen in the **industrial sector**'s energy consumption.
- **1 % to 5 %** of green hydrogen in the **road transport** sector's energy consumption.
- **3 % to 5 %** green hydrogen in the **national shipping sector**'s energy consumption.
- **1,5 % to 2 %** of green hydrogen in the **final energy consumption**.
- **2 GW to 2.5 GW** of installed **electrolysers capacity**.
- Setting up **50 to 100 hydrogen refuelling stations**.

26.3. Research and innovation priorities

The main hydrogen research and innovation priorities include:

- **Production**: diversify the green H2 production technology (electrolysis is the main priorities, but other production routes, such as biomass gasification, are also being investigated), improve scale-up, efficiencies and the LCOH, support the national technology manufacturers on green H2 (different stages in the value chain), increase electrolysis capacity
- **Storage and distribution**: restore Natural Gas (NG) assets (*e.g.,* gas infrastructures like storage, transport and distribution pipelines) to receive hydrogen blends, develop proprietary technology to convert H2 into other carriers (e.g. ammonia, liquid H2, LOHC) and transport them (e.g. ship, container).
- **Market stimulation**: improve system integration, sector coupling and storage strategies, market conditions, business models and financing.
- **Heat and power**: investigate the required adaptations to integrate H2 into current appliances. The main research focus is expected in the power and industrial sectors. While the buildings sector - and residential buildings in particular, are expected to show a limited interest.
- **Cross-cutting**: improve the sustainability of the green H2 along the different stages of its lifecycle; common understanding of concepts, standards, safety and certification; cooperation, collaboration and partnership, education, capacity building and development of a modelling software to simulate business cases associated with renewable H2 throughout the value chain.
- **Valleys**: development of several H2 Valleys.
- **Supply chains**: supply centralised acquisitions in line with the EU Hydrogen Bank.

26.4. Funding instruments

- **Resiliency and Recovery Plan (RRP)**. The RRP established several types of funding schemes, and it is estimated that it allocated in 2021 around **0.52 billion euros** to the hydrogen and batteries value chains.

- **Business Innovation mobilisation Agendas/Alliances** fund projects related to innovation, energy transition, export capacity and creation of skilled jobs with total **558 million euros** allocated across all domains (including energy).
- **Business innovation green agendas** fund projects related to innovation, energy transition, export capacity and creation of skilled jobs. **285 million euros** were allocated to green hydrogen industrial projects. A first call with 60 million euros funding closed in December 2021 and at least 6 green H2 "agendas" were approved (estimated 10 million euros each).
- **H2 and renewable gases** funds renewable gas production projects and tested technologies aiming for 264 MW of renewable gas production capacity till end 2023. Total funding of **185 million euros**. With the first call, 13 projects were approved corresponding to 40 million euros public funds (remaining funding is private).

Programme Name	Level	Budget	Priorities
RRP	EU	520 million euros	Hydrogen and batteries value chain.
Business Innovation mobilisation Agendas/Alliances	National	558 million euros	
Business innovation green agendas	National	285 million euros	Green hydrogen industrial projects
H2 and renewable gases	National	185 million euros	Renewable gas production projects

Table 14. Financing tools for Hydrogen Portuguese projects.

Portugal is aware of co-funding possibilities between the ERDF programmes and projects of European Partnerships (CETP, DUT), and ones from the SME's rewarded with 'seals of excellence'. Moreover, it is open to explore the synergies with Clean for Hydrogen JU to implement this mechanism.

26.5. Projects

Several projects and initiatives are being developed. Here the most relevant ones are listed from the smaller to the larger ones.

- **HyLab** - **Collaborative Laboratory (CoLAB) on Hydrogen**. CoLabs are collaborations between academic organisations and private companies, combining public and private funding, to find solutions to complex transdisciplinary problems that need coordination between business, social society and government. the HyLAB was formally created in 2021 with the main goal of enabling the Portuguese swift implementation of green hydrogen production, storage, transport and utilization at competitive costs. As other

CoLabs (e.g., BIOREF, NET4CO2, SMART ENERGY LAB, and VG COLAB), HyLab implements research and innovation agendas aimed at the creation of economic and social value along the hydrogen value chain.

- **IPCEIs**:
  - **Green hydrogen production development in Portugal (Wave HY2tech).** 1s1 Energy's 300MW/year hydrogen plant would use water electrolysers to make hydrogen, reducing carbon emissions.
  - **H2 Enable (Wave HY2Use)** is a Bondalti project for the production of hydrogen at the Estarreja Chemical Complex. The project mainly aims to decarbonise Bondalti's operations, namely in the production of Aniline. H2Enable will also allow production for direct sale in the market, namely through the national natural gas network and in the mobility sector.

  Further proposals are being prepared and revised with focus on regional green H2 infrastructures.

- Currently the following **Hydrogen valleys** are under different stages of development among other proposed ones and in early agreements:
  - ***Sines Hydrogen Hub*** (including deep water seaport) with: H2 verde@Refinaria de Sines (Petrogal); HEVO Indústria; Moving2Neutrality; H2Sines Windpower.
  - Nazaré Green H2 Valley (hard-to-abate sectors. Expected in 2023).
  - Estarreja H2 valley (under preparation).

According to the European Hydrogen Backbone (EHB) initiative, concerning the **development of hydrogen infrastructure**, by 2030, at least up to two dedicated industrial clusters (at North and South of the country) could be supplied by dedicated 100% hydrogen closed loop integrated network systems with a length of around 20 km.

Portugal has reported various difficulties in the implementation of hydrogen projects. On one side, the duration and complexity of permitting processes for both H2 generation and the associated renewable electricity power generation has delayed the workplans. To mitigate this, recent regulatory updates have been set up to make permitting more flexible and agile (DL 11/2023, DL 30-A/2022, and DL 72/2022). On the other hand, the capacity of the existing grid infrastructure to cope with the major influx of renewable power to feed electrolysers is not enough and thus the extension of such capacity is needed. Finally, the offer to satisfy the demand of electrolysers is low and due to the substantial increase in demand for these equipment, rather long waiting times for electrolysers have been reported (circa 1.5 years between order and delivery).

26.6. Other policies and measures

The National Energy and Climate Plan 2021-2030 (PNEC 2030) defines the policies and measures for the next decade to achieve carbon neutrality in 2050.

Portugal has the ambition to become “EU’s principal green hydrogen producer”. According to its NECP (2019), Portugal is committed to “create a real market for renewable gases”, to develop an industrial policy with the aim to “position Portugal as an important European player in the green hydrogen market, leveraging solar energy as a factor for competitiveness”. In its NECP renewable hydrogen is considered as a key technology to increase the production of renewable electricity and renewable gases in parallel, and to decarbonise sectors with limited low carbon solutions, like the transport and industrial sectors.

The National Strategy for Hydrogen is contributing to the current NECP revision.

The **RRP** also includes reforms and investments to support R&I&D for decarbonisation and to boost the use and production of hydrogen and renewable gases.

The following islands include hydrogen in their Clean Energy Transition Agenda:

- ***Culatra island***. The decarbonisation of the island’s transport system foresees the use of green hydrogen as a ferry fuel converting the actual fleet to green energy carriers. One of the actions includes the creation of a fund for fundraising to build a hydrogen/solar or electricity-powered passenger transport ferry. If hydrogen is to be produced on Culatra by a small-scale electrolyser with a storage unit, this will furthermore impact the local electricity demand[51].
- ***H2PortoSanto*** project aims to transform local residual biomass into clean hydrogen, helping the island become less dependent on foreign and fossil fuel energy. Currently, Porto Santo's waste is sent to the neighbouring island Madeira for incineration, representing environmental and economic costs that ideally could be avoided. Transforming local residual biomass into hydrogen will tackle two island challenges: the need for more clean energy production and the need for a local circular waste management approach.

Portugal, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen.**

[51] CLEAN ENERGY TRANSITION AGENDA. Culatra Island, Portugal. The Clean Energy for EU Islands Secretariat. Agenda-de-Transicao.pdf (culatra2030.pt)

27. Romania

The **Energy Law** was amended on 24th July 2020 to include specific hydrogen production provisions ("Law 155"). In accordance with Law 155, the general regulatory framework on hydrogen "Code for Hydrogen" has been proposed by the energy regulator, ANRE. Other legislations in place that have hydrogen in scope are:

- Governmental Decision no. 87/2018, act transposing AFI Directive
- Law no. 37/2018 the promotion of ecological transport

The Ministry of Energy is expected to publish a national hydrogen strategy and a Strategy Action Plan in the first quarter of 2023. However, it is not known at the time of writing this Document.

It should be set around the following priorities:

- Prioritize clean hydrogen from renewable electricity.
- Target the most promising uses for hydrogen: industry, transport and long-term storage.
- Involve public and private stakeholders to outline a strategic roadmap with targets and potential funding sources.
- Outline measures to develop the hydrogen value chain in Romania, particularly for electrolyser manufacturing.

The reform will remove any legislative and administrative obstacles for the development of the renewable hydrogen technology and contribute to the achievement of the future national and European targets for the production, storage, transport, and use of renewable hydrogen by 2030. By way of regulation, hydrogen-ready appliances (such as boilers) and equipment shall be mandatory as of 1 January 2026 for all new installations.

The Ministry of Energy has already taken two important steps:

- Launched a call for the construction of 100 MW electrolysers in Romania with the aim of obtaining green hydrogen.
- It started the implementation of the National Hydrogen Strategy.

27.1. Governance

The **Ministry** responsible to prepare a Hydrogen Strategy is the one **of Energy**.

The main representative in the States Representative Group of the Clean Hydrogen Partnership comes from the National Research and Development Institute for Cryogenic and Isotopic Technologies. The alternate comes from the Ministry of Research, Innovation and Digitalisation.

Other relevant Managing Authorities:

- **Ministry of Investment and Projects** for the Sustainable Development Programme.
- **Ministry of Transport and Infrastructure** - Directorate-General for European Transport Programmes for the Transport Programme.
- **North-East Regional Development Agency** for the Programme North-East.
- **South-East Regional Development Agency** for the programme South-East.
- **South Muntenia Regional Development Agency** for the Programme South Mutenia.
- **Center Regional Development Agency** for the programme Central Region.
- **Agency for Regional Development South-West Oltenia** for the Programme South-West Oltenia.
- **West Regional Development Agency** for the Programme West.
- **North-West Regional Development Agency** for the programme North-West.
- **Bucharest-Ilfov Regional Development Agency** for the Programme Bucharest-Ilfov.
- **Ministry of Development, Public Works and Administration** for the Programme (Interreg VI-B) Interreg NEXT Black Sea Basin.

27.2. Targets

- Building at least **1.870 km of network for the distribution of green hydrogen** in the Oltenia region that shall carry at least 20% of renewable hydrogen (by volume) when commissioned by 30 June 2026, and 100% renewable hydrogen and/or other renewable gases in 2030.
- Installing **green hydrogen production capacities of at least 100 MW in electrolysers**, producing at least 10.000 tonnes of hydrogen from renewable sources by 31December 2025.
- **12 H-EMU** (Hydrogen Electric Multiple Units) are expected to become operational by Q2 2026.

27.3. Research and innovation priorities

The **National Center for Hydrogen and Fuel Cells** (CNHPC) has defined a series of research directions and priorities, but these cannot be considered as country priorities, even if the Center is a reference hub. As a result, there are no specific country R&I priorities.

27.4. Funding instruments

There are no specific national funding programmes for hydrogen technologies.

However, within the **National RRP,** several budget lines can be dedicated to support hydrogen-related projects:

- Component 10 - Local Fund, C10.I.1.1 *Non-polluting vehicles intended for public transport*, allows the purchase of new non-polluting vehicles with zero exhaust gas emissions: electric/hydrogen buses, including vessels similar to buses that serve public passenger transport on water, electric/hydrogen minibuses.
- Component C 4. *Sustainable transport*, Investment I2 – Railway rolling stock
- Component C6/M ENERGIE, Investment measure I.2 – *Renewable gas distribution infrastructure, as well as green hydrogen production capacities and/or its use for electricity storage.*
- Component C6/M ENERGIE, Investment measure 2.2 - *Supporting investments in building capacities for the production of green hydrogen in electrolysis plant*s.
- The Ministry of Transport through the Railway Reform Authority submitted for publication in SEAP (Sistemul Electronic de Achizitii Publice - Electronic Public Procurement System) the **tender for the first hydrogen trains**, an investment financed by PNRR.

- The Romanian Government has adopted a Memorandum initiated by the Ministry of European Funds and supported by the Ministry of Education and Research. The Memorandum proposes funding in the programming period 2021-2027 for Romania's first hub dedicated to hydrogen, for research and development in respect to the use of hydrogen in transportation, district heating and nuclear energy generation, as the "fuel of the future".

27.5. Projects

- Authorities in twelve cities in Romania tested a hydrogen bus for public transport, the **Solaris Urbino 12**, in a national tour. For two months, the Solaris hydrogen bus was present in twelve cities in Romania along the following route: Cluj-Napoca, Târgu Mureș, Brașov, Sfântu Gheorghe, Iași, Galați, Constanța, Bucharest, Râmnicu Vâlcea, Craiova, Timișoara and Oradea.
- Delgaz Grid, the natural gas and electricity distribution company within the E.ON Romania group, started in November a pilot project to test the compatibility and operation of the use installations and the components of the distribution system with a mixture of natural gas (NG) and hydrogen (H2). The experimental testing infrastructure was officially inaugurated in Medias (Sibiu County) on June 8 (2023).
- Hidroelectrica S.A. (hydroelectricity company), intends to launch two projects for the hydrogen production plants construction. In this sense, the company made progress by launching invitations for feasibility studies and specifications related to project execution.
- **IPCEI**:

  - **Green Hydrogen@Blue Danube**. The project targets the large-scale production of green hydrogen in Southeastern Europe and its subsequent transport via LOHC and ships to industrial off-takers along the Danube river.
- No Hydrogen Valleys have been funded yet:
  - There are plans for the Dobrogea region to become a clean hydrogen valley. There is high potential for local clean hydrogen projects with several industrial off-takers as anchor load and potentially transport off-takers, replacing grey hydrogen supply, or more carbon intensive industrial processes. In the long-term Dobrogea can grow into a larger-scale, international and export-focused hydrogen valley, with the Port of Constanța as its centrepiece.
  - Some concrete steps have also been defined for the development of a H2 Valley around Galati. (Galati Valley)
- According to the EHB initiative, concerning the **development of hydrogen infrastructure**, in 2030 Romania can be interconnected with Hungary, Bulgaria via the current BRUA corridor whereas another connection is envisaged with the Republic of Moldova in north-eastern Romania.

27.6. Other policies and measures

According to its NECP (2019), Romania considers hydrogen deployment mainly in the transport, gas and power sectors. Romania seems to consider hydrogen applications as a long-term perspective. Its NECP does not include specific objectives or targets for the production or use of hydrogen, nor hydrogen specific policies and measures.

The **RRP**'s energy component addresses the challenges of the Romanian energy sector in terms of decarbonisation and air pollution, aiming to accelerate the decarbonisation of the energy sector by phasing-out lignite and coal fired-power plants by 2032, and by facilitating the deployment of renewables and alternative energy sources, such as green hydrogen.

Romania, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

28. Slovakia

The **National Hydrogen Strategy: Preparing for the Future**[52] of Slovakia was approved in June 2021, and it is the basic document that defines the strategic role of the state in the use of hydrogen technologies in the Slovak Republic in the context of current developments in EU countries.

The overall goal of the Slovakian strategy is to increase the competitiveness of the Slovak economy and significantly contribute to a carbon-neutral society in accordance with the Paris Declaration.

The strategy defines the conditions for the implementation of hydrogen technologies in accordance with the long-term strategic view of the development of the Slovak Republic until 2030, and 2050. It establishes a framework for the use of hydrogen throughout its chain. It also recommends the implementation of hydrogen activities in cooperation with other EU countries.

The action plan (until 2030) includes 36 measures to promote, develop and operate hydrogen economy in Slovakia. Measures are divided into several categories and cover: analysis, legislative changes, production, distribution, storage and consumption of hydrogen, marketing and PR activities, personal and financial needs. This action plan will aid investments to develop a hydrogen value chain and introduce an appropriate supportive regulatory framework. The action plan has been provided for public consultation, and it now awaits to be approved by the government.

At regional level, there is the **Hydrogen + Strategy for Kosice Region,** the first regional hydrogen strategy in Slovakia from 2020, adopted by the local governmental council of Kosice Self-Government Region in March 2021.

In 2023, the Kosice Self-Government Region applied for Small Scale Hydrogen Valley project with a proposed budget of 9 million euros. There is also an initiative with the private sector of Kosice waste management industry to build the operation of a hydrogen refuelling station on garbage for heavy trucks and hydrogen buses for the region.

28.1. Governance

There is no specific regulatory body responsible for the implementation of hydrogen projects in Slovakia, but several Slovak ministries, government agencies and local authorities are responsible for the development of hydrogen projects. Finally, the energy policies fall under the **Ministry of Economy** of the Slovak Republic.

[52] National hydrogen strategy Ready for the future (2021). Government of the Slovak Republic No. 356/2021. National hydrogen strategy Ready for the future (2021) - Enviroportal - online environment

The main representative in the States Representative Group of the Clean Hydrogen Partnership comes from the Technical University of Kosice.

Other relevant Managing Authorities:

- **Ministry of Investment, Regional Development and Informatization** for the Programme Slovakia - SK - ERDF/CF/JTF/ESF+.
- **Ministry of Investments, Regional Development and Informatization** of the Slovak Republic, Section of Cross-border cooperation programmes for the Programme (Interreg VI-A) Slovakia-Austria.
- **Slovak National Hydrogen Association** covers all relevant stakeholders working on deployment of future hydrogen economy (industry, academy, local government etc.). Organising workshops, roundtables, negotiations with ministries etc.

28.2. Targets

Slovakia estimates various targets in its Action Plan for the implementation of Hydrogen[53] technologies by 2030:

- **1% of its RES target for the transport sector will be covered by the direct use of hydrogen** (2 ktoe hydrogen out of a total of 229 ktoe renewable fuels). By 2040, this share could be multiplied by more than 20.
- Annual **production** of **45,000 tonnes of hydrogen** from which 25,000 tonnes by electrolysis (installed 300 MW) of RES and nuclear sources and 20,000 tonnes of biomass and waste.
    - 30,000 t for industrial use
    - 5,000 t for other energy conversion
    - 10,000 t for the transport sector: 4,000 t passenger cars, 260 t for buses, 600 t for light vehicles, 600 t for heavy and 12 t for regional trainsets.
- Development of hydrogen infrastructure for transportation and storage and fuelling (**3 HRS**)

28.3. Research and innovation priorities

In the first period, the main research area will be the analysis of the optimal hydrogen production method for the Republic of Slovakia. For this and additional innovation targets, a deadline (1 Quarter 2023), the responsible body (MSVVaS SR), and cooperating institutions and funding sources have been identified in the Slovakian Hydrogen Action Plan. However, no information

[53] ACTION PLAN Measures for successful implementation of the National Hydrogen Strategy mPs9Bk3V.pdf (gov.sk).

has been found, at the time of writing, about this analysis, and it has not been included in the Document.

The Centre for Hydrogen Technology Research of the Slovak Republic (CVVT) has been funded in Košice to lead the education and innovation in the country.

Some mentioned areas of applied hydrogen research (included in Annex 3 of the strategy) involve the innovation in materials, fuel cells, transportation, distribution, storage, risk management, application in the chemical and metallurgical industry and security protection and detection systems in hydrogen value chain.

28.4. Funding instruments

The planned expenditure on implementation of hydrogen projects from the state and direct European funding totalling 955 million euro plus private resources estimated at €1.5 billion euro. These include:

- The total investment in the new network of factories and service stations is estimated at **110 million euros.** BCF Energy plans to start the production and sale of green hydrogen in 2023/2024.
- The Slovakian RRP includes a specific priority on "*Low-carbon transport: supporting the roll-out of charging stations for alternative fuels and the modernisation of railways and new cycling Infrastructure*" for an amount of **712 million euros**. It is not clear how much of it could specifically be dedicated to hydrogen mobility.

Programme Name	Level	Budget	Priorities
BCF	National	110 million euros	HRS network
RRF	EU	712 million euros	Low-carbon transport: supporting the roll-out of charging stations for alternative fuels and the modernisation of railways and new cycling Infrastructure
Investment aid from the state budget	National	137.7 million euros	Research and development tasks in line with SK RIS3 2021

Table 15. Slovakian Hydrogen funding programmes.

28.5. Projects

- **100 hydrogen bikes** in Kosice region: 600.000euros.
- Actions under the support of the Slovak Innovation and Energy Agency (SIEA):
  - 2 cars Toyota Mirai

  - 2 hydrogen fuel stations (1 permanent in Bratislava) and 1 mobile hydrogen fuel station
- BCF Energy plans to establish **4 fuelling stations** with hydrogen through the Benzinol network. The first refuelling station should soon appear between Handlová and Prievidza.
- To produce cleaner hydrogen, BCF Energy plans to build several factories, the daily production of which is estimated at **4.000 kilograms of hydrogen**. Electricity for its production will come from solar power plants, which will cover an area of more than 230 hectares.
- According to the EHB, concerning the **development of hydrogen infrastructure**, by 2030 the Slovak connection between Austria and Czech Republic could be repurposed to supply hydrogen from North Africa towards further towards consumption centers through the interconnection points Baumgarten and Lazhot.

28.6. Other policies and measures

According to its NECP (2019), Slovakia considers the “use of decarbonised gases and hydrogen” as a way to “ensure environmental sustainability”. Slovakia considers hydrogen as a “very promising fuel” and a good option (also regarding air quality) to replace natural gas on the one hand and fossil fuels in the transport sector on the other hand.

On 31st May 2023, the Slovak National Hydrogen Association (NVAS) together with government of Slovakia, President H.E. Zuzana Caputova and French President H.E. Emmauel Macron signed a Memorandum of Cooperation in nuclear energy and the development of clean hydrogen technologies.

Other documents that reference hydrogen are the Low-Carbon Development Strategy of the Slovak Republic until 2030 with a View to 2050 (hydrogen in mobility) and the current NCEP (2019).

Slovakia, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen.**

29. Slovenia

The first hydrogen refuelling station in Slovenia was commissioned in 2013. The project was co-financed by the European Union and coordinated by the Center of Excellence for Low-Carbon Technologies CONOT (CONOT is the key facilitator of hydrogen projects in Slovenia and serves as a point of reference for Balkan countries). In 2017, the Government of Slovenia communicated about its commitment to stimulate alternative fuels, among which hydrogen, to "stop the sales of new gasoline and diesel motor cars by 2030".

However, so far, it does not seem like Slovenia has drafted and implemented a specific hydrogen strategy, but some targets are included in its NECP (2019).

29.1. Governance

The **Ministry for Infrastructure** is responsible for energy-related matters, and it is also directly involved in the States Representative Group of the Clean Hydrogen Partnership.

Other relevant Managing Authorities:

- **Government Development Service and European Cohesion Policy** for the Slovenia's EU Cohesion Policy Programme 2021-2027.

29.2. Targets

Slovenia expects by 2030 a **final hydrogen consumption of 10 ktoe (116 GWh) in the transport sector,** and by 2040 a consumption of 63 ktoe (732 GWh) mainly in the transport, but also progressively in the building and industry sectors.

29.3. Research and innovation priorities

No information was found on this point.

29.4. Funding instruments

No information was found on this point.

29.5. Projects

- **The North Adriatic Hydrogen Valley project**, jointly developed in Slovenia, Croatia and the Italian region of Friuli Venezia Giulia, has been awarded 25 million euros. It is the first European transnational project with the aim to establish a dedicated hydrogen valley. The

three-country partnership, with the Slovenian state-owned power company Holding Slovenske Elektrarne (HSE) as the leading partner, comprises 34 organisations and covers the entire chain, from production to storage and distribution to the end use of hydrogen in various sectors such as industry and transport.

- According to the EHB initiative, concerning the **development of hydrogen infrastructure**, by 2035, there would be hydrogen interconnections from Slovenia to Hungary and Italy which connects the national hydrogen markets, but also major green hydrogen supply sources (e.g., North Africa). The connection to Austria and Croatia would ensure that the European Hydrogen Backbone becomes an integrated hydrogen network stretching from South-Eastern to North-Eastern Europe.

29.6. Other policies and measures

According to Slovenia's NECP (2019), hydrogen can play a role in integrating the production of renewable electricity, strengthening security of gas supply and contributing to reach the decarbonisation targets. Renewable hydrogen can be used to store large amounts of electricity produced during periods of low demand.

The Slovenian cohesion strategy makes reference to the need to invest into the establishment of an infrastructure for the charging of electric or hydrogen-powered vehicles.

Slovenia, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

30. Spain

The **Spanish Hydrogen Roadmap**[54] was approved in 2020 by the Council of Ministries and it constitutes the Measure 9 of the country's RRP (Recovery and Resilience Plan). This Roadmap provides a Vision to 2030 and 2050, establishing ambitious targets, whose achievement will ensure the industrial and technological positioning of the Spanish economy in the European context, the decarbonisation of a relevant volume of grey hydrogen consumed today, and the full introduction of renewable hydrogen in sustainable mobility. An update of this roadmap is expected along 2023. However, it is not known at the time of writing this document.

30.1. Governance

The **Ministry** responsible for the designing of the strategy is the **Ministry for Ecological Transition and the Demographic Challenge (MITECO)**, with the support from different Ministries, such as Ministry of Science and Innovation that is the representative in the States Representative Group of the Clean Hydrogen Partnership.

Spain is divided in Autonomous Communities which have the competences of authorising Hydrogen injection in the grid (maximum of 5%) under the supervision of the System Technical Operator (TSO). The main cooperating body between the Central Government and these Autonomous Communities is the "**Sectorial Energy Conference**" which meets annually to discuss and agree on new funding measures that include hydrogen matters.

Other relevant Managing Authorities:

- **Subdirectorate-General for Management of the ERDF, of the Directorate-General for European Funds. Ministry of Finance and Public Function** for the Just Transition Programme Spain 2021-2027.
- **Subdirectorate-General for Management of the ERDF. Directorate-General for European Funds. General Secretariat of European Funds. Ministry of Finance and Public Function** for the following Programmes:
    - Aragon ERDF 2021-2027.
    - Baleares ERDF 2021-2027.
    - Canarias ERDF 2021-2027.
    - Cantabria ERDF 2021-2027.
    - Castilla y Leon ERDF 2021-2027.
    - Castilla-La Mancha ERDF 2021-2027.
    - Ceuta ERDF 2021-2027.

[54] Spanish Hydrogen Roadmap (2020). MITECO. Hoja de Ruta del Hidrógeno (miteco.gob.es)

- Region of Valencia ERDF 2021-2027.
- Galicia ERDF 2021-2027.
- La Rioja ERDF 2021-2027.
- Community of Madrid ERDF 2021-2027.
- Melilla ERDF 2021-2027.
- Region of Murcia ERDF 2021-2027.
- Navarra ERDF 2021-2027.
- Basque Country ERDF 2021-2027.

30.2. Targets

- **4 GW of installed electrolyzer capacity** (10 % of the total European target) with an intermediary target of 300-600 MW by 2024.
- A minimum share of **25% renewable hydrogen** of total grey hydrogen consumption in the **industrial** sector.
- **The implementation of** a fleet of at least 150 buses, 5.000 light vehicles and 2 trainlines. Following the same proceeding, a minimum of 100 hydrogen plants and machinery fuelled on green hydrogen would have to be installed in 5 airports and harbours.
- An estimated investment of 8.9 billion euros between 2020 and 2030.

30.3. Research and innovation priorities

The priorities for hydrogen are depicted in the calls for proposals of the main Spanish funding agencies, focusing on:

- **Production**: mainly electrolysis, but also innovative production technologies, such as solar-driven hydrogen production using photoelectrochemical cells or hydrogen production based on bioprocesses.
- **Storage and distribution technologies**: habilitate existing gas infrastructure as well as its monitoring and control system; building of hydrogen refuelling stations (HRS) to support the deployment of fuel cell vehicles.
- **Transport**: developing and deploying advanced fuel cell systems and related infrastructure especially for Heavy-duty vehicles.
- **Cross-cutting issues**: pre-normative research to establish standards and regulations to ensure safe H2 production, transport, and use; sustainable and circular hydrogen production pathways.
- **Valleys**: Spain has several H2 Valleys and plans to have additional ones. It is part of the Component 9 (Renewable Hydrogen) of the PERTE EHRA. Its activities include the construction of a high-capacity electrolyser, the supply from renewable electricity generation facilities, the integration of targeted industries, innovation in hydrogen transport

(minimum modes), storage and final supply. Moreover, the professional and vocational training is considered.

- **Supply chain:** support to the development of a robust H2 supply chain that covers the entire value chain from production to end-use.

30.4. Funding instruments

In Spain, there are two main policies or programmes that deploy specific calls for hydrogen projects through national public agencies:

- **Hydrogen Roadmap** (2020-2030) has an estimated budget (investment required) of **8.9 billion euros.** It will cover renewable hydrogen, decarbonisation of industry, fuel cells, and sustainable mobility. It comprises an analysis of the funding mechanisms available at national and European level that include the funding for the Just Transition (JTF), RRP, ERDF (experimentation, demonstration) and ESF+ programs.
- **PERTE ERHA** (Strategic Programme for the Recovery and Economic Transformation of Renewable Energy, Renewable Hydrogen and Storage from European funds of Next Generation EU) (2021-2026) has a public funding support of **6.9 billion euros**, and the total funding (public and private) is 16.3 billion euros. From this amount, **the funding for renewable hydrogen is 1.5 billion euros** and **2.8 billion euros from private capital**. The programme will cover all renewable energies, renewable hydrogen, industry applications or fuel cell vehicle. There has already been a deployment of five grant programmes of 400 M euros. It is implemented by IDAE, a public body under the Secretary of State for Energy in the Ministry of Ecological Transition. IDAE informs regularly competent bodies in the regional governments about foreseen calls and results related to hydrogen. In terms of regulation, there is cooperation with the Autonomous Communities to try to identify barriers and establish the necessary legislation to overcome them through working groups and exchange of documentation.

Programme Name	Level	Budget	Priorities
Promotion of the innovation and knowledge of the Hydrogen value chain at national level and integration in the EU (IDAE)	National	From PERTE ERHA, different calls with ranging budgets of 30 to 150 M euros (under GBER) to fund IPCEI projects	Integrated projects as first-of-a-kind or pioneer projects, encompassing investments such as production of renewable hydrogen, Hydrogen refuelling stations (HRS), heavy transport fleets, storage and distribution, industrial users adaptations. Prototypes development, pilot projects and innovative proofs of concept along the whole value chain for renewable hydrogen. Enhanced capacities on manufacturing or testing lines of key equipment and/or components, such as electrolysers, HRS, tanks, compressors, fuel cells, engines, turbines, refuelling stations.
Science and Innovation Missions Programme "Reinforce the technological capacities for a sustainable, safe, and independent energy supply (nuclear fusion, hydrogen, renewables)" CDTI (Center for the Technological Development and Innovation) Ministry of Science and Innovation	National	Small projects: 1,5 – 3 M€ Big projects: 4 – 15 M€	Innovations in Hydrogen value chain. Bottom-up approach, no priorities.
National R&D Programme AEI (National Research Agency) Ministry of Science and Innovation	National	150.000-200.000 EUR	Innovations in Hydrogen value chain. Bottom-up approach, no priorities.

Table 16. Spanish Hydrogen funding programmes.

Spain is aware of the main European funds dedicated to renewable hydrogen and provides the possibility to complement funding for hydrogen projects with national programmes such as the ***Spanish Recovery, Transformation and Resilience Plan (RRP)*** which has been divided in *Components* to support different subjects and maximize reach avoiding double financing. Moreover, it has designed co-funding schemes taking part in the "Clean Energy Transition Co-Funded Partnership" (CETP) of Horizon Europe. It reunites 35 national and regional R&D funding agencies and its Challenge 3 "Enabling climate neutrality with storage technologies, renewable

fuels and CCU/CCS" encompasses Hydrogen innovation. However, bureaucratic complexity of both European and national/regional requirements makes the application process excessively cumbersome and reduces the interest in applying. For instance, the Spanish Recovery, Transformation and Resilience Plan is complementary to other programmes (national and European), provided that the same cost item is not funded twice, and, therefore, could be used for co-financing some projects. However, so far, no project has exploited this opportunity.

30.5. Projects

- **H2PORTS.** European-scale pilot project located in the Port of Valencia that develops and validates the transformation to H2 of two machines (telescopic crane and truck head) in real operating conditions.
- **SUN2HY.** Pre-commercial full-scale demonstrator (TRL-6) for the direct conversion of solar energy into hydrogen by means of photoelectrochemical PEC cells.
- **Renewable Hydrogen Pioneer Projects**. Projects with commercial viability for Hydrogen production and use in hard to decarbonise sectors like industry or heavy-duty vehicles. 150 million euros from national funding (PERTE ERHA).
- **OCEANH2**. Production, storage and distribution of green H2 offshore.
- **SHINE FLEET**. H2 for heavy-duty smart mobility.
- **CARDHIN**. Inductive dynamic load and using H2 for electric vehicles.
- **NEOSOLAR**. H2 production through Solar Thermal plants, including storage.
- **GREENH2PIPES**. Electrolyser H2 production, injection into the natural gas network and transportation using liquid carriers.
- **UNDERGY**. Storage using H2 in depleted gas fields and integration into a smart grid.
- **ECLOSION**. Materials, technologies and processes for the production, storage and distribution of renewable H2 and biomethane.
- **ZEPPELIN**. Green H2 production and storage technologies based on circular economy.
- **PHOTOHY**. Photocatalytic H2 production
- **SOFC4GREENGRID**. Development and integration of Solid Oxide Fuel Cells in microgrids
- **GREENHYCEL** New PEM Electrolysers using alternative materials.
- **HIDRAM. GREEN** Ammonia as multipurpose fuel to decarbonize maritime transport.
- **EFISOEC**. SOEC technology for H2 production.
- **HY2DEC**. Electrochemical H2 production and decarbonization of industry.
- **VALORH2.**– Production, compression, storage, distribution and use of green H2.
- **ATMOSPHERE**. Technologies for the production, storage, and safety of H2 plants.
- **AD GRHID**. Increase flexibility and resilience of distribution power grids using solid-oxide electrolysis, fuel cells and H2 storage.
- **Hydrogen Valleys**:

- The ***Basque Hydrogen Corridor (BH2C)*** is a large-scale strategic project to promote the transition to a decarbonized economy in the Basque Country through the development of a set of coordinated initiatives deployed throughout the entire hydrogen value chain.
- The ***Green Crane initiative*** aims to pave the way for South to North green hydrogen flows in Europe and boosting local demand in Spain and Italy. Cross-border routes aim to connect with The Netherlands and France.
- ***Green Hysland*** aims to create a replicable Hydrogen Territory in the Balearic Islands by converting solar energy generated in Mallorca into green H2 which will be used in multiple applications: mobility, heat and power and injection into the gas grid. 300 tonnes of hydrogen will be produced yearly. Financial contributions come from the European Commission (approximately 10 million euro) through the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) and partners' own resources. In addition, the project has been declared to be a Strategic Project by the Balearic Regional Government and has support from the National Government through IDAE (The Spanish Institute for Diversification and Saving of Energy) and the Ministry of Industry, Trade and Tourism. The total amount estimated needed for the initiative round about 50 million euro.

Figure 10.IPCEI Spanish projects distributed geographically.

- **IPCEIs:**
  - The **Tecnopropia** project by H2B2, and located in Seville, consists of the development and manufacture of competitive electrolysers of the three main technologies (PEM, AEM and SOEC).
  - The project presented by **SENER**, and located in the Basque Country, consists of the establishment of an electrolyzer factory with the aim of supplying the Spanish market with competitive technology and local manufacturing. The first phase of this project includes the manufacture of electrolyzers using alkaline technology. In a second phase, the development of its own technology is incorporated.
  - The **Nordex** initiative will involve the development and production of hydrogen generation technology using electrolyzers. To this end, it will develop an alkaline electrolyzer between 5 MW and 10 MW, adapted to the variable operation and with direct electrical support of a wind turbine and a photovoltaic installation. It involves an R&D phase, aimed at increasing the flexibility of the operation in alkaline

technologies, and a second phase in which a modular prototype will be developed and will use the existing Nordex facilities in Asturias and Navarra.

- IVECO's '**Poseidon**' initiative foresees the development and production of heavy commercial vehicles with hydrogen propulsion for regional and urban use. To this end, IVECO plans to invest in its headquarters, both in Madrid and in Valladolid and Barcelona, with the aim of developing highly complex R&D processes and new production capacities, including manufacturing and maintenance facilities, in addition to the manufacture of a first series of fuel cell pilot vehicles.
- **Bay of Biscay Hydrogen** (Petronor/Repsol): 100MW electrolyzer project. The plant's construction will start in 2023, and it won't start producing goods until the second half of 2024. Large industrial users around the Port of Bilbao, the Biscayan Left Bank, and the surrounding area will be decarbonized using the output of this facility. Through the infrastructures that will soon be erected at the Energy Intelligence Center of the Ezkerraldea-Meatzaldea Technology Park, it will also deliver renewable hydrogen for mobility and heavy transport decarbonization applications.
- **Cartagena Hydrogen Network** (Repsol) will develop a large-scale electrolyzer (100 MW) to promote the decarbonization of industries in Cartagena.
- **H2 Aboño** (EDP). The company, which has announced that it will stop producing with coal in 2025, plans to convert this strategic location into the Asturian valley of green hydrogen. The technical and market knowledge and the privileged geographical location of the facility would guarantee the production and supply for the Asturian electricity and green hydrogen industry necessary in its manufacturing processes.
- **H2 Los barrios** (EDP). The company EDP will build 100 MW of electrolyzers, later scalable for Los Barrios. It is an initiative that will supply green energy to the industry located in the Campo de Gibraltar. This project aims to transform thermal power plants into sites linked to renewable energies, green hydrogen, energy storage and the flexibility of the electricity system.
- The **Puertollano plant** by Iberdrola is one of the largest industrial hydrogen facilities in Europe. The plant generates 100% green hydrogen using one of the world's largest electrolysis systems and will have zero carbon emissions as it uses renewable energy from the integrated solar plant. The green hydrogen produced at the Iberdrola plant is planned to be used by the ammonia factory in Puertollano, owned by chemical and fertilizer company Fertiberia Group. Fertiberia's ammonia plant will use the green hydrogen to reduce the use of natural gas.
- **H2Med**: The hydrogen pipeline will connect Portugal and Spain with France and Germany to supply about 10% of the European Union's hydrogen demand by

2030. The pipeline under the Mediterranean Sea will carry green hydrogen, made from water via electrolysis using renewable energy.

- **Endesa** plans to install a 7,2 megawatt electrolyser in Alfajarín to supply renewable gas to Industrias Químicas del Ebro (IQE).
- **IAM Caecius project**, in Teruel, with 25 MW of electrolysers, which is part of the projects for innovative uses of green hydrogen, in conjunction with the Térvalis Group.

The main difficulties encountered by ongoing projects can be sum up in:

- High cost of H2 technologies.
- Lack of adequate capacities, human capital and resources.
- Continuous technical challenges, such as such as the need to improve the efficiency and reliability of H2 production, storage, and transport.
- Infrastructure availability.
- Trustworthiness concerning security and safety issues that can have a negative impact on the adoption of the technology by the users.

Finally, the lack of harmonised regulation at European and national level on cumbersome permitting procedures also have a negative impact on the projects' development and implementation.

30.6. Other policies and measures

According to its NECP (2019), Spain considers renewable hydrogen as a key technology to increase the production of renewable electricity and renewable gases in parallel, and to decarbonise sectors with limited low carbon solutions, like the transport and gas sectors. The updated version of the NECP is expected to take into account the targets being assessed at European level for renewable hydrogen production and demand.

The Spanish NECP (PNIE 2020) makes multiple references to hydrogen including its renewable production in the Action 7 of the SET-Plan for stationary energy storage and as part of the objective for transport and the reduction of 23% of its GHC.

Currently, Spain has developed a mechanism for guaranteeing the origin of renewable gases like hydrogen. It is reinforced legally by two laws: the Royal Decree 376/2022 of 17th May by which the sustainability criteria of these energies are described and the TED Order/106/2022 of the 28th of October by which a management proceeding defines the basic regulatory rules for the use and employment of renewable gases. This information is integrated in a platform that will manage the origin guarantees and is expected to be operative in March of 2023.

The **Spanish JTF** highlights, amongst its objectives, the need to support new technologies of generation and energy vectors (such as green hydrogen) that, despite not yet profitable at market price, they are among the developments most promising. With this respect, there is a need to boost the value chain of renewable energy, self-consumption, energy storage and renewable hydrogen, in particular through support for projects that can incorporate a social and employment component.

The following the development of hydrogen in islands, some of them mention hydrogen in their strategy:

- ***Menorca*** has developed a comprehensive vision to 2030 to decarbonise. Hydrogen is mentioned in relation to the decarbonisation of the public transport sector: "*Bolster the renovation of collective transportation vehicle fleets toward cleaner and more efficient vehicles with zero direct emissions, whether electric or with hydrogen fuel cells"*.
- In the CETA of the ***A Illa de Arousa***, some dissemination activities have been taking place to raise awareness on hydrogen technologies. However, no specific plans to adopt it are mentioned.
- The study published by the Clean Energy Island Initiative on "**Virtual Transmission Line for N-1 Security Compliance with Storage: La Palma**", amongst its recommendations mentions "*Power-to-X storage have extensive seasonal to short-term applications tailored for back-up applications and stacking revenue streams, while other consumptions of Hydrogen like gas grid in the system should be also considered*".

Spain, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen.**

31. Sweden

Its **National Hydrogen Strategy**[55] was published in November 2021. The EU strategy was fundamental for developing the Swedish national hydrogen strategy proposal which is divided into:

- Phase 1 until 2030: Expand electrolysis and renewable energy infrastructure, use hydrogen in existing industries and launch pilot projects.
- Phase 2 until 2045: Develop green hydrogen value chains aim for a high degree of decarbonization in industry through green hydrogen, assess the need for more electrolysis capacity to decarbonize heavy-duty transport.

31.1. Governance

The strategy was put forward by the **Swedish Energy Agency**, which is also represented in the States Representative Group of the Clean Hydrogen Partnership.

Other relevant Managing Authorities responsible for regional funding are:

- **Swedish Agency for Economic and Regional Growth** for the following programmes:
  - European Regional Development Fund programme for Skåne-Blekinge 2021-2027.
  - European Regional Development Fund programme for Småland and the islands 2021-2027.
  - European Regional Development Fund programme for West Sweden 2021-2027.
  - European Regional Development Fund programme for East-Central Sweden 2021-2027.
  - European Regional Development Fund programme for Stockholm 2021-2027.
  - European Regional Development Fund programme for North-Central Sweden 2021-2027.
  - European Regional Development Fund programme for Central Norrland 2021-2027.
  - European Regional Development Fund programme for Upper Norrland 2021-2027.
  - European Regional Development Fund National programme 2021-2027.
  - (Interreg VI-B) Northern Periphery and Arctic.

[55] Strategy for Hydrogen (2021). Energimyndigheten. https://www.energimyndigheten.se/remissvar-och-uppdrag/Download/?documentName=F%C3%B6rslag%20till%20nationell%20strategi%2025%20nov.pdf&id=1793

31.2. Targets

- **Green hydrogen production target between 22-42 TWh** by 2030, and 44-84 TWh by 2045.
- Total **electrolyser capacity of 5 GW by 2030** and 15 GW by 2045.

31.3. Research and innovation priorities

The majority of industrial development projects for new value chains based on hydrogen include research partnerships between several Swedish universities and research institutes. Technology and system suppliers also participate in many of the projects. The activities cover the entire value chains, from the development of individual materials and system components, process steps, process integration to system analysis and policy.

More research-oriented projects are also underway within the framework of, for example, **FFI (Strategic Vehicle Research and Innovation Programme)** focusing on hydrogen combustion engines and fuel cells for the propulsion of heavy traffic.

31.4. Funding instruments

- The total private financing for the Rock Cavern storage is 19.4 million euros Vattenfall, SSAB and LKAB and **4,8 million euros** in public financing by the Swedish Energy Agency.
- The total financing needed for the H2 Green Steel project is **2,5 billion euros**.
- To ensure Swedish participation in **IPCEI projects**, the Government proposes an investment of SEK 200 million in 2021, for 2022 an estimated SEK 200 million and thereafter **SEK 70 million per year in 2023-2027**. Companies participating in an IPCEI initiative will have the opportunity to avoid state aid rules if they work together with value chains from other EU countries. On the other hand, they may not automatically receive any allocated funds, but are able to apply for funds only if their own State allocates money.
- There are also significant opportunities for public funding in the area from Swedish sources through, for example, the **Swedish Energy Agency's Green Industry Leap** and their call for the establishment of new so-called Competence Centres, the Swedish Environmental Protection Agency's Climate Leap and the government credit guarantees.

Programme Name	Level	Budget	Priorities
SEA	National	4,8 million euros	Rock Cavern Storage
H2 Green Steel	National	2,5 billion euros	Company founded in 2020 with the aim to build a large-scale green steel production in northern Sweden.
SEA Green Industry Leap	National	Not known	Establishment of Competence Centres such as the SHDC
IPCEIs	National	20 million euros in 2021- 2022 7 million euros/year (2023-2027)	

Table 17. Hydrogen funding instruments for Swedish projects.

31.5. Projects

- **H2 Green Steel**, a company founded in 2020 with the aim to build a large-scale green steel production in northern Sweden, is one of the pioneering companies aiming to use green hydrogen to decarbonise industrial processes. It is building its first mass production plant for emissions-free steel in the town of Boden. By 2026, the plant is to produce 2.5 million tons of steel annually and 5 million tons by 2030. The plant will have an 800-megawatt electrolyser on the ground. The first equity financing of 50 million euros was done by a select group of investors, including Vargas, Scania, SMS group, and BILSTEIN GROUP.
- **Hydrogen for aviation**: The Swedish Energy Agency has awarded funding for hydrogen projects that can lead to fossil-free aviation. There have been two awards- GKN Aerospace for developing engine subsystems in the national H2JET project, which is investigating hydrogen combustion-powered turboprop and the other, RISE SICOMP AB, which is focused on the development of ultralight liquid hydrogen fuel tanks for aircraft.
- **Rock Cavern Storage:** Three companies, Vattenfall, SSAB and LKAB have reached the halfway point in the construction of a rock cavern storage facility in a coastal city in northern Sweden. The 100-cubic-meter facility is being constructed 30 meters below ground and will begin storing green hydrogen next year.
- Since the summer of 2020, the Foundation for Strategic Research, SSF, has supported a research centre in hydrogen research led by the Royal Institute of Technology, KTH, and includes seven research groups at four Swedish universities (Chalmers, KTH, Lund University, and Umeå University) and a research group at RISE. The "**Production, Use**

and Storage of Hydrogen, PUSH" centre will run for five years and covers the entire value chain in a hydrogen-based energy system – production through electrolysis, storage and distribution and end-use in the form of electricity from fuel cells.

- **IPCEI**:
  - Hydrogen application in industry: **HYBRIT Green Steel**: According to the Swedish venture Hybrit, it is the world's first customer delivery of "green steel" produced without using coal. It delivered the green steel to the truck maker VOLVO AB, as a trial run before full commercial production in 2026. SSAB, LKAB and Vattenfall created HYBRIT, Hydrogen Breakthrough Ironmaking Technology, in 2016, with the aim of developing a technology for fossil-free iron- and steelmaking.
- Concerning the **development of hydrogen infrastructure**, Nordion Energi is, together with Gasgrid Finland, jointly developing a greenfield cross-border hydrogen infrastructure in the region of Bothnian Bay (Nordic Hydrogen Route) with the target of having the network operational by 2030. At about the same time, in response to the upgraded domestic hydrogen production ambitions of REPowerEU, offshore hydrogen connections are envisioned from the Bothnian Bay, across the Baltic Sea, through the island of Åland with connections to mainland Finland and Sweden, down through the islands of Gotland and Bornholm, to the European mainland. This infrastructure, known as the Baltic Sea Hydrogen Collector (BHC), is an initiative being explored by Nordion Energi, Gasgrid Finland, OX2 and Copenhagen Infrastructure Partners. These projects together with the Nordic-Baltic Hydrogen Corridor and the Nordic Hydrogen Route are complemented by the BalticSeaH2 initiative which includes 40 partners and involves the whole hydrogen value chain from nine Baltic Sea region countries.

31.6. Other policies and measures

The Swedish NECP (2019) does not comprise specific hydrogen related measures or objectives, but some concrete hydrogen initiatives or projects are mentioned.

Sweden participates as an active member in The ***North Seas Energy Cooperation (NSEC)*** along with Belgium, France, Denmark, Germany, Ireland, Luxembourg, Norway, The Netherlands and the UK. The governance focuses on the development of the offshore grid development and the large renewable energy production (76 GW by 2030, 193 GW by 2040) in the region. Plans for hydrogen connections are underway.

Sweden, jointly to other 24 EU Member States, participated in the co-writing process of the **Strategic Research and Innovation Agenda of the European Research Area (ERA) on Green Hydrogen**.

32. Türkiye

Türkiye ratified the Paris Climate Agreement in 2021 and committed to a zero-emissions target by 2053. Within the scope of the "European Green Deal Action Plan" under the coordination of the Ministry of Trade of the Republic of Türkiye, **Green Growth Technology Roadmap** is carried out in cooperation with the Ministry of Industry and Technology of the Republic of Türkiye and the Scientific and Technological Research Council of Türkiye (TUBITAK) to meet these objectives.

The **Türkiye Hydrogen Technologies Strategy and Roadmap**[56] was published by the Ministry of Energy and Natural Resources on 19 January 2023. It details 13 policies which include the revision of the legal framework and certification the national and international engagement as well as the promotion of research in the different fields of the hydrogen value chain.

32.1. Governance

The **Ministry of Industry and Technology** of the Republic of Türkiye and the **Scientific and Technological Research Council of Türkiye (TUBITAK)** are in charge of achieving the objectives related to the “Green Growth Technology Roadmap” under the management of The **Ministry of Trade**. The **Turkish Energy, Nuclear and Mineral Research Agency (TENMAK)** which is under the Ministry of Energy and Natural Resources, works closely in determining the regulations and incentives with the energy managing authorities including developing the new funding mechanism related to clean energy.

32.2. Targets

- In the national legislation, the goal is to install an **electrolyser capacity** of **2 GW in 2030**, 5 GW in 2035 and 70 GW in 2053.
- Reduce the **cost of green hydrogen production to less than $2.4/kgH** by 2035 and less than $1.2/kgH by 2053.
- **Blend the natural gas with at least 3.5% of hydrogen and synthetic methane** by 2053 (MENR by the “Türkiye National Energy Plan”).

32.3. Research and innovation priorities

As part of the Roadmap, the R&D and innovation priorities have been elaborated and are summarized by the following areas:

[56] https://enerji.gov.tr/Media/Dizin/SGB/en/HSP_en/ETKB_Hydrogen_T_Strategies.pdf

- **H2 production:** development of electrolyser and mass production of hydrogen (boron technologies) in integrated facilities covering safety standards.
- **H2 storage, distribution:** production of storage facilities such as pressurized tanks for land vehicles, metal hybrids, and cryogenic tanks in the aviation, space and defence industries.
- **H2 use:**
    - *Mobility applications*: hydrogen refuelling stations will be installed and expanded in Türkiye to meet the fuel needs. They will be developed domestically through R&I projects and placed on the market by foreign companies. R&D activities will be carried out and project support will be provided to commercial products that can be equipped with sodium borohydride fuel cells, including rail and heavy-duty vehicle applications. Some of these studies are:
        - Storage analysis for pressurized and liquid hydrogen transport vehicle
        - Demonstration studies for hydrogen transport at sea
        - 200-300 kW FC land and sea vehicle applications
        - 100-300 kW FC rail vehicle applications
    - *Heat and power*: the goals are to achieve 1% to a 100% of a hydrogen natural gas turbine, boiler, etc technology and to blend a quantity of 5% to 100% of hydrogen in the natural gas grid for domestic and industrial use.
- **Cross-cutting:** awareness raising by “promotional demonstration” projects will be carried out by TENMAK. Incentives for PhD thesis translation to market.
- **Valleys:** currently Türkiye has one hydrogen valley denominated HySouthMarmara and two under revision for funding.
- **Supply chain:** TUBITAK Industry Innovation Network Mechanism (SAYEM) Program will help and support local stakeholders working on the hydrogen value chain to produce the needed materials domestically.

32.4. Funding instruments

In the national landscape, mainly two organizations are responsible for supporting and developing the H2 economy through the R&D and innovation funding programmes:

- **TUBITAK Industry Innovation Network Mechanism (SAYEM) Program**, will launch specific calls for hydrogen related projects such as the **Productization Program (UPG)** to support proposals that have the target for commercialization of the products with TRL 9 level for H2 production. Moreover, H2 activities are also supported by two national bottom-up programmes: **1001** which aims at funding new knowledge, make scientific comments or solve technological problems, and the **1501** program that supports project-based research-technology development and innovation activities of Small and Medium-

Sized Enterprises (SMEs). There is no specific programme to fund for basic research and lower TRLs.

- **The Turkish Energy, Nuclear and Mineral Research Agency (TENMAK)** has also launched a call (closed at the beginning of May 2023) whose goal is to produce technological products (at TRL 4-8) with high efficiency, low cost, modular and compact, as well as environmentally friendly. It focuses on clean hydrogen production technology (min. 100 kg production capacity), storage and liquefaction technology and fuel cell technology (according to the application area min. 10 kW capacity, a modular design)

Türkiye experience in co-funding projects via its participation to the **CETP**. Moreover, it participates in the EUREKA **Eurogia Programme**, which includes within its priorities fuel cell technologies, production, storage and station of hydrogen.

Finally, Türkiye also has access to the **Instrumental Pre-Accession Funds (IPA III)** whose window number 3 "*Green agenda and sustainable connectivity*" and 4 "*Competitiveness and inclusive growth*" can be used to support the development of the H2 economy. Lastly, for promoting private investment on hydrogen large projects, the loans from the EIB and EBRD have been used. However, this last programme mainly supports infrastructure investments rather than R&D projects.

32.5. Projects

Building a local hydrogen ecosystem integrated with renewable resources has become an energy strategy priority for Türkiye. Several projects are being developed both at national level, and thanks to international cooperation.

The following initiatives are ongoing at national level:

- In January 2022, a protocol for cooperation was signed among key enablers of hydrogen production in Türkiye. These parties are TUBİTAK, Enerjisa Üretim (one of the largest private power generation companies of Türkiye), Aspilsan (Turkish Battery Industry), Eti Maden (world's largest Boron producer), and the South Marmara Development Agency. The main aim of the **Protocol** is to produce green hydrogen, green methanol, and ammonium for research, development and industries. This green hydrogen produced from the site would have the potential to be blended into the gas without extra transportation costs. The site is situated to export green hydrogen to Europe conveniently. In addition, the Trans-Anatolian Natural Gas Pipeline (TANAP) line crosses the site, which will raise the potential to explore the possibility of blending. Turkish companies and institutions are currently brainstorming about the implications of hydrogen for their businesses. The Turkish Petroleum Refineries Corporation (TUPRAS), the largest hydrogen producer of Türkiye, aims to reach an installed green hydrogen electrolysis capacity of approximately 1 GW by 2030, and 2.5 GW by 2035 through greenfield projects and acquisitions. In

addition, Türkiye's largest automotive industry exporters are taking concrete steps towards green hydrogen by developing hydrogen-compressed tanks and fuel cells for trucks.

The following initiatives are ongoing with international partners:

- **Development of Advanced Composite Pressure Vessels for Hydrogen Storage (Adhere)** funded under the ERANET-SES Joint Call 2019.
- **Sustainability development and cost-reduction of hybrid renewable energies powered Hydrogen stations by risk-based multidisciplinary approaches (SUSHy)**, funded under EIG CONCERT-Japan.
- Optimization of a solar and hydrogen energy-based electricity and hot water generation system for off-grid applications (**OPTSOLH2**), funded under Türkiye – Iranian Collaboration Call
- **Hydrogen Valley**: A smaller-scale Hydrogen Valley was recently announced for the area of ***South Marmara***. It has received thirty-six million euros from national funding and an additional 4,45 million euros from European funds. It is intended to have a production and usage of 500 tons of green hydrogen in industry and its derivatives such as methanol and ammonia to phase out the use of fossil fuels. It is coordinated by the South Marmara Development Agency, has sixteen local and foreign partners including TUBITAK and TENMAK as advisory team for the revision of the first draft of the South Marmara Hydrogen Roadmap. A sodium borohydride-based fuel cell emergency power system will be developed by TUBITAK in the project to use in disaster and strategic areas.

The main difficulties related to the projects' implementation are the lack of a comprehensive regulation and dedicated standards.

33. Regional strategies

The **European Hydrogen Valleys Partnership** is an initiative by DG REGIO whose key objectives are to:

- Develop the technological readiness and the commercial availability of FCH applications.
- Overcome the lack of access to information and expertise in the field hydrogen.
- Facilitate matchmaking and co-investment between European regions.
- Strengthen the value chain for FCH technologies via interregional cooperation.
- Contribute to the decarbonization of the EU's economy.
- Green the production of hydrogen.
- Be an active stakeholder on EU policy making on hydrogen.

Several regions are involved in this work, and the full list is available on: https://s3platform.jrc.ec.europa.eu/hydrogen-valleys#fragment-89005-flbc.

Moreover, the Clean Hydrogen Partnership has launched a **FCH-Regions' Hub**, whose objective is to support regional and local authorities and other public bodies across the European Union to develop and turn their concepts for regional hydrogen and fuel cell (FCH) projects into detailed work plans. Raising awareness and providing project development assistance to regional FCH projects will further accelerate the deployment of hydrogen in Europe, contributing to carbon neutrality and zero pollution.

A **Green Hysland's H2 Islands Hub** has also been launched, as part of the Green Hysland project in Mallorca. Several island initiatives have joined it. The supporters can be found on the relevant webpage: https://greenhysland.eu/h2-hysland-hub/.

Notwithstanding the regions' involvement in these initiatives, a limited number of official regional strategies has been identified. Their main features are going to be presented in this chapter. One of the objectives of Activity 2 is to find out whether more regional strategies have been adopted.

The project **Inn2Power**, funded by the Interreg North Sea Region, has also published a status report on green hydrogen: https://northsearegion.eu/inn2power/publications-press/.

33.1. Grand- Est (FR)

The French Region Grand-Est has developed a specific Hydrogen Strategy covering the period 2020- 2030.

This regional strategy introduces some quantitative targets:

- To develop an **electrolyser installed capacity of 600 MW** by 2030.

- To develop **five hydrogen production units** in: Saint-Avold (57), Florange (57), Chalampé (68) ou Marckolsheim (67).
- To deploy **700 buses, 1.200 trucks, 100 canal boats**.
- To develop **five industrial demonstrators** for the use of hydrogen in the regional industrial territory.

33.2. Ile-de-France (FR)

As part of its Regional Strategy for Energy and Climate, the region Ile-de-France adopted, in 2019, a document, detailing actions to promote **Ile-de-France as a hydrogen territory**.

These actions will support local stakeholders in the following fields:

- Hydrogen production via electrolysers; biomass pyrolysis; biogas reforming.
- Accessible and interoperable hydrogen distribution network.
- Installation of Hydrogen Refuelling Stations, taking into account their best localisation.

33.3. North German Hydrogen Strategy (DE)

One example of the regional development of green hydrogen is the **North German Hydrogen Strategy**[57] under the responsibility of the Ministers of Economics of five northern German states (Bremen, Hamburg, Mecklenburg-Vorpommern, Niedersachsen and Schleswig-Holstein) in Germany. Their target: A green hydrogen economy will be established in northern Germany by 2035 to enable an almost complete supply to all customers interested in green hydrogen.

By 2025, at least **500 megawatts of electrolysis capacity** for the production of green hydrogen should be installed in northern Germany, and by 2030 at least five gigawatts. In this way, a regional basic supply of green hydrogen will gradually be made possible, which can be expanded over the entire region in the medium term. In northern Germany, a green hydrogen economy will be established by 2035 to enable an almost complete supply to all customers interested in green hydrogen.

The Northern strategy outlines initial implementation steps in four fields of action:

- Field of action "Hydrogen infrastructure".
- Field of action "Value creation through hydrogen".
- Field of action "Hydrogen in guidelines, regulations and programmes".
- Field of action "Hydrogen acceptance and education".

[57] https://norddeutschewasserstoffstrategie.de/wp-content/uploads/2020/11/norddt-H2-Strategie-final.pdf

Support via IPCEIs is recognised of primary importance, especially in support of the **European Hydrogen Backbone** infrastructure.

33.4. Northern Netherlands (NL)

The Northern Netherlands is acknowledged as the leading hydrogen valley in Europe. Building upon the current momentum, acknowledgement and level of ambition, the region would like to retain this position after 2030 and wants to encompass the entire hydrogen value chain.

They provide some competitive advantages in terms of:

- Access to the European markets for hydrogen with a predicted 400PJ/y (petajoule) requirement in 2030.
- A large offshore wind potential, located north of the Northern Netherlands, with space for more than 20GW, with 4-6 GW being allocated for the production of green hydrogen.
- Strategic location for the production of hydrogen in industrial hubs (Delfzijl, Eemshaven, Emmen) to create a production capacity of 100PJ/y in 2030.
- Expansive and available gas infrastructure; including parallel gas pipelines, salt caverns for storage and strategically located seaports.
- Knowledge about trade, transport and innovation in both the traditional natural gas industry as well as the hydrogen industry.

Their Roadmap is implemented in two phases:

- **Phase 1: Development and scale-up (2020 – 2025)**. From now until 2025, the Northern Netherlands will develop between 5 – 10 PJ capacity per year, and scale up the value chain from production and infrastructure to use-cases. In order to realize this, approximately 850 million euro is required. Besides these private investments, additional political and financial commitments are necessary to guarantee this timeline.
- **Phase 2: Expansion to North-Western Europe (2025 – 2030)**. Starting from 2025, the hydrogen ecosystem capacity in the Northern Netherlands will grow with 100PJ per year. 75% of this will be green hydrogen (6GW), the remaining 25% will be blue hydrogen. The region will increase its demand to supply the hydrogen markets of North-Western Europe with 400PJ per year. Large projects stimulate the integration of hydrogen ecosystems, while domestic and international infrastructure will connect the Northern Netherlands to the North-West European markets. In order to realize these projects, more than 9 billion will be invested.

33.5. Piemonte (IT)

Piemonte adopted its **Regional Hydrogen Strategy** in June 2022. It focuses on four priority areas:

- **Diversification, Research, Development and Innovation,** which helps companies in moving towards hydrogen-related markets, supports research, export and aims at attracting investments.
- **Mobility and transport**, concerning activities to support hydrogen adoption in public transport, freight logistics, and railway transport.
- **Production, distribution and use of hydrogen** concerns activities to produce green hydrogen in the Region, distribution in the natural gas grid, and co-generation in buildings and industry.
- **Transversal activities** support training and education activities, as well as activities to support the participation of regional stakeholders in European and international platforms.

The Strategy details activities, and the funds that can be used to support these activities, such as:

- POR FESR 2021–2027 (Regional Operational Programme of the European Fund for Regional Development).
- PNRR (Italian Recovery and Resilience Fund).
- National Funds by MISE (Italian Ministry for Enterprise and Made in Italy).
- National Funds by MITE (Italian Ministry for Ecological Transition) on air quality.
- POSR FEASR 2021- 2027 (European Agricultural Fund for Rural Development).
- POR FSE 2021 – 2027 (European Social Fund).

33.6. Puglia (IT)

The Region Puglia developed its own Hydrogen Strategy, known as **#H2Puglia2030**, in 2021, mainly with the aim to supporting its candidature to host a Hydrogen Valley, taking into account favourable conditions related to:

- National leader for the production of energy form renewable sources: the share of renewable energy in Puglia in 2019 was 52%, compared to 34% at national level.
- Local know-how and already developed pilot projects.
- Strong academic and research context.
- Puglia is one of the first Italian regions, which introduced specific legislation in the hydrogen sector (Legge n. 34 del 23 luglio 2019).
- Presence of a potentially high demand for green hydrogen, since the biggest Italian steelmaking factory is located in this region.
- Presence of two special economic areas (ZES): Adriatica and Ionica, which will attract important national funds for their development.

Some specific hydrogen targets have also been adopted:

- 40-45.000 tonnes/year of final hydrogen consumption.
- 20-25.000 tonnes/year of hydrogen mix in the natural gas grid.
- Installation of 500 MW electrolysers capacity for the production of hydrogen.

33.7. Sicily (IT)

Sicily adopted the guidelines for the development of a **Hydrogen Strategy- Integration and Development of the Energy and Environment Forecasts in Sicily** in 2021.

As part of this Plan, Sicily has put forward its candidature to host a **High-level National Hydrogen Laboratory**. Moreover, Sicily will be supporting:

- The deployment of electrolysers for hydrogen production with high pressure storage units (up to 10.000 bar).
- The development and purchase of FCEVs and FCHEVs.
- The promotion of research and development activities in the area of mobility.

33.8. Usti (CZ)

Being a coal-rich region, Usti is part of the Joint Transition Mechanism, a key tool to ensure that the transition towards a climate-neutral economy happens in a fair way, leaving no one behind. Amongst the different possibilities, developing hydrogen competences in the region has been recognised as a good tool to move towards a more sustainable energy system.

The Hydrogen Platform of the region of Usti has developed a hydrogen strategy to promote projects in this area and ensure coordination of their the development. Background studies as well as extensive strategic management plan with barriers identification and contingencies have been developed. To this end, it has set the following quantified targets:

- **Production**: 20,000 tonnes of green hydrogen and reduction of 88,000 tonnes of grey hydrogen per year by 2030 and 123,000 tonnes of green hydrogen by 2050.
- **Distribution**: by 2030 5 % of transport of green hydrogen by repurposed gas pipelines (1000 t/year) or newly built modes of transport (19000 t/year) and by 2050 expected to reach 70 %
- **Transport:** float of 3,200 hydrogen vehicles and 65 buses and 285 trucks in 2030 and 42,000 passenger hydrogen vehicles and 330 hydrogen buses in 2050 (current values are on 360 vehicle cars). Development in shipping, rail and freight is also being considered. To ensure the needs of demand for hydrogen filling stations, 6 of them are expected to exist in 2030 and 71 by 2050.
- **Buildings**: implement by 2030 in 50 building hydrogen technology and increase the consumption of the gas to 9 t/year.

- **End-application**: 95 % for the industry (17 000 tonnes/year) with the goal of diversifying the use to electricity and heat generation purposes
- **Education and research:** increase hydrogen R&D related jobs :10 researchers will be working by 2030 and 20 by 2050. By 2030 there would by 50 graduates a year from technical and natural sciences field to adapt the education system to the gradual hydrogen up taking. Research will be also reinforced by the implementation of 15 projects by 2030 and 30 by 2050 as well as by the investment for the obtention of 5 infrastructures for research and for related patents. This will be complemented by the provision of 50 campaigns for awareness and interest rising.

To enhance cooperation within the region, a Memorandum was signed by 23 entities including private companies and institutional bodies such as the leader of the initiative the Economic and Social Council of the Ustecky Region (HSR-U K). On the external side, Ustecky has joined the European “Hydrogen Valleys Smart Specialisation Platform”, highlighting special interest in cooperating with the German region of Saxony and the Polish Lower Silesia.

34. Conclusions

The following points can be highlighted from the information collection exercise:

- Three main levels of ***governance*** can be distinguished:
    - Coordination between different Ministries and agencies to ensure policies and funding consistency.
    - Coordination between national and regional levels to avoid redundancy and overlapping.
    - Coordination between stakeholders to fully mobilise resources.
- In terms of ***targets***:
    - The main focus of the national H2 strategies is on installed electrolyser capacity.
    - A limited number of targets focus on domestic RES H2 production, number of Hydrogen Refuelling Stations, H2-fuelled vehicles...
    - The link with the country RES generation capacity should be stressed.
    - Other modes for renewable H2 production should be better recognised, and their role specified.
- In terms of ***funding instruments***:
    - There is general openness of national programmes towards co-funding. Some details should already be included in the upcoming NECP revision, expected by the end of June 2023.
    - Better coordination should be ensured with CETP (Clean Hydrogen Transition Partnership). For instance, coherence and consistency with respect to the Clean H2 Partnership SRIA should be explored.
    - Some competition related issues need to be clarified. This is ongoing, since the problem has already been identified and discussed within several countries. For instance, it is suggested that Hydrogen Valleys could be granted a IPCEI-type of status, where up to 100% support for the remaining funding gap is possible, or a specific state aid category for Hydrogen Valleys should be created.
    - Some timeline issues have been highlighted with respect to the use of RRF for H2-related projects.
    - The seal of Excellence is particularly suitable for single-beneficiary HE components.

- CEF (Connecting Europe Facility) for refuelling infrastructure could be combined with Clean Hydrogen Partnership funding for industrial or integrated projects and/or ERDF to support local projects.
- The development of Hydrogen Valleys should go hand in hand with existing and yet to be developed energy and transport infrastructure corridors such as TEN-E and TEN-T (AFIR readiness).
- Possibilities of co-funding with ERDF seem to be more complex, since they aslo imply a strong cooperation between national and regional levels.
- Some possibilities for cooperation and co-funding could also be explored with trans-national programmes such as EUREKA and its EUROGIA cluster sepecifically dedicated to sustainable energy.

- In terms of ***other policies and strategies***:
  - The deployment of the necessary infrastructure and incentives should be in line with the REPowerEU target of 10 million tonnes of domestic renewable hydrogen.
  - Objectives and policies to facilitate the manufacturing scale-up of commercially available low-carbon technologies, equipment and components should be put in place.
  - There is a need related to increase manufacturing capacities and industrial value chains in key low-carbon energy technologies, such as the one on hydrogen. The recently published Net-Zero Industry Act (NZIA) already includes important measures to support this.
  - Clear links should be established with: NRRPs, Territorial Just Transition Plans (TJTPs), Partnership agreements and Operational Programmes for ERDF.
  - The Clean Energy Transition Agendas (CETA) for islands seem to play a minor role in hydrogen development, since the H2-related projects are quite often limited in size and rather focusing on deployment than on innovation.
  - Better synergies with the S3 (Smart Specialisation) Platform should be exploited.
  - A link with AFIR (Alternative Fuel Infrastructure Regulation) should be established, since Member States must prepare an HRS deployment plan by 2027 that will satisfy the needs of hydrogen powered road mobility.
  - Supporting measures at national level, such as tax incentives, should be further developed.

- Pilot initiatives, such as the European Research Area (ERA) pilot on Green Hydrogen, should be taken into consideration as a basis to design cooperation models andsynergies.

ANNEXES

List of general consulted references and sources

Reference to the national and regional hydrogen strategies, used as a basis for this report, are directly included in the footnotes.

Additional reference documents are listed here:

National energy and climate plans (NECPs) (europa.eu)

2021 EU and National Policies Report. Fuel Cells and Hydrogen Observatory (FCHO) Chapter_3_Policies_2021.pdf (fchobservatory.eu)

Hydrogen, electrofuels, CCU and CCS in a Nordic context (2022). Nordic Energy Research. nordicenergyresearch2022-02.pdf (norden.org)

Strategic Research and Innovation Agenda of the European Research Area (ERA).

Annex 1- Summary Table on quantified targets with respect to EU-wide targets

Table 18 . Summary Table on Quantified Targets with respect to Clean H2 Partnership SRIA targets.

Country	GW of installed electrolyser capacity by 2024	GW of installed electrolyser capacity by 2030	Production and transportation of renewable H2 by 2030	Share of hydrogen in the final energy demand by 2030	H2 presence in transports by 2030	Number of HRS by 2030
EU-27	*6 GW (10 GW in 2025)*	*40 GW*	*10 million tonnes*			
Austria		1 GW (7,5 TWh of renewable gases)		For hard-to-abate sectors: 80%		
Belgium	150 MW by 2026	20 GW (North Sea)				
Bulgaria	55 MW (2026)		150 t/y		65 hydrogen vehicles (2026) 2,7% / 34 GWh / 120 hydrogen fuelled vehicles	1 pilot: 20MW 5 HRS (2026), 14 (2030)
Croatia		70 MW, 2.750 MW (2050)		0,2% (11% by 2050)		15, 100 (2050)
Czech Republic			101 kt/y (low carbon)	Electricity and heat produced by hydrogen: 3% by 2050.	900 buses, 4.600 (2050) 45.000 cars, 600.000 (2050) 4.000 trucks, 60,000 (2050)	
Denmark		4-6 GW				
Estonia		At least 7 GW offshore energy converted to H2 (2029)				
Finland	200 MW (2025)	1 GW			3 % electro fuels including hydrogen of the overall transport	
France		6,5 GW	60 kt/y			
Germany		5 GW, 10 GW (2035)	14 TWh		15 million electric vehicles	100

					including Fuel Cell ones	
Greece		750 MW	Production: 3 Mtoe (2040) 7.4 Mtoe (2050) Exportation: 1 Mtoe (2040), 2.3 Mtoe (2050)			By 2050: 120-250 city buses, 5,000-10,000 light distribution trucks, 80-160 heavy-duty vehicles, 30,000-60,000 private vehicles, 3-12 trains 100 HRS
Hungary		240 MW	20,000 t/y low-carbon hydrogen, 16,000 t/y "green" and other carbon-free hydrogen		4.800 vehicles	20, 40 refuelling points
Iceland					5 % of hydrogen in marine fuel	
Ireland		2 GW				
Italy		5 GW		2% (20% by 2050)		
Lithuania		300- 350 MW	30 kt/y		Buses in 5 cities 1 train 50-100 HDVs	5
Netherlands	600 MW (2025)	6-8 GW			300.000 vehicles 15.000 light 3.000 heavy duty vehicles (2025) 150 inland vessels including hydrogen fuelled	50 (2025)
Norway					5 hydrogen maritime hubs	
Poland		2 GW	5 hydrogen valleys		800-1.000 hydrogen buses 100-250 (2025)	32 HRS
Portugal		2-2,5 GW		1,5-2 %		50-100
Romania	100 MW (2025)		10.000 tonnes (by 2025)			12 Hydrogen Electric Multiple Units

Slovakia		300 MW	2 ktoe hydrogen, 40 ktoe (2040)	For transport sector: 1% by 2030 20% by 2040	10,000 t hydrogen consumption: 4,000 t passenger cars, 260 t buses, 600 t light vehicles, 600 t heavy, 12 t regional trainsets	3
Spain	30-600 MW (2024)	4 GW		For industry sector: 25% For transport sector: 28%	150 buses, 5.000 light vehicles, 2 trainlines	
Sweden		5 GW 15 GW (2045)	22-42 TWh 44-84 TWh (2045)			
Türkiye		2 GW 5 GW (2035) 70 GW (2053)				

Annex 2- General questionnaire

Table 19 . General questionnaire to prepare the report "Call on "European countries' Hydrogen policies and funding strategies report updated with information from national practitioners from around 30 European countries".

Identifier	Question	Answer
R&I- H2 Targets	What are your country ***targets*** for the development of the H2 economy? (e.g. installed electrolyser capacity, manufacturing of electrolysers; number of hydrogen-fuelled vehicles; number of hydrogen refuelling stations; cost-competitiveness of renewable hydrogen; New applications for hydrogen, including steel making, trucks, rail and maritime transport applications…)	
Identifier	**Question**	**Answer**
BUDGET-National level	Does your country have ***specific national funding programmes*** for the development of the H2 economy? Could you please, give us their names, amount, duration, covered priorities)	
Identifier	**Question**	**Answer**
BUDGET-Local level	Are you aware of any ***specific regional funding programmes*** for the development of the H2 economy? Could you please, give us their names, amount, duration, covered priorities)	
Identifier	**Question**	**Answer**
BUDGET-EU level	What are the ***EU funds utilised by your country*** to support the development of the H2 economy (e.g. Resilience and Recovery Plan (RRP); Modernisation Fund; European Regional Development Fund (ERDF); Just Transition Fund…)?	

Identifier	Question	Answer
BUDGET-Synergies	Does your country have experience in ***co-funding*** H2-related projects using both national/local and EU funds? • If yes, could you, please, elaborate on them? • If not, could you, please, explain why? Are there any hurdles which prevent you to co-fund projects?	

Identifier	Question	Answer
BUDGET-Synergies	Are you aware of the mechanisms provided by the European Commission on synergies between ERDF programmes and Horizon Europe (please see https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022XC1104(02)&from=EN)? • If yes, what are the most appealing to your country regarding H2-related projects?	

Identifier	Question	Answer
PROJ-Success	Can you make a list of the most relevant ongoing and planned H2-related projects?	

Identifier	Question	Answer
PROJ-Challenges	Can you mention the main difficulties your ongoing H2-related projects have faced? Was any of them stopped or significantly delayed? If yes, for which reason?	

Identifier	Question	Answer
SYN-NECPs	Are you planning the inclusion of H2-related targets and information in the upcoming NECP update?	

Identifier	Question	Answer
SYN-Managing Authorities	Is there any structured cooperation in place with Managing Authorities, both at national and regional level? If yes, can you briefly explain how you cooperate with these Managing Authorities?	

Identifier	Question	Answer
SYN-Other policies	Are you planning the inclusion of H2-related targets and information in upcoming reference documents, such as AFI Plan, Partnership agreements?	

Identifier	Question	Answer
R&I- H2	Could you, please, briefly mention what are the main hydrogen research and innovation priorities in the area of hydrogen in your country?	

Identifier	Question	Answer
R&I- H2 PROD	Concerning ***H2 production technologies***, what is the main R&I focus of your country with respect to: • Electrolysis (you can refer to pages 33- 35 of the Clean Hydrogen JU SRIA) • Other routes of renewable hydrogen production (pages 36- 37 of the Clean Hydrogen JU SRIA)	

Identifier	Question	Answer
R&I- H2 S&D	Concerning ***H2 storage and distribution technologies,*** what is the main R&I focus of your country with respect to: • Hydrogen storage (you can refer to pages 39- 41 of the Clean Hydrogen JU SRIA) • Hydrogen in natural gas grid (you can refer to pages 43- 44 of the Clean Hydrogen JU SRIA) • Liquid Hydrogen carriers (you can refer to pages 46- 47 of the Clean Hydrogen JU SRIA) • Improving existent hydrogen transport means (pages 48- 49 of the Clean Hydrogen JU SRIA) • Compression, purifications and metering solutions (pages 51- 52 of the Clean Hydrogen JU SRIA) • Hydrogen Refuelling Stations (pages 54-55 of the Clean Hydrogen JU SRIA)	

Identifier	Question	Answer
R&I- H2 TRANSPORT	Concerning H2 end-use technologies, what is the main R&I focus of your country in the area of ***transport*** with respect to: • Building Blocks (pages 58-59 of the Clean Hydrogen JU SRIA) • Heavy-duty vehicles (pages 61- 62 of the Clean Hydrogen JU SRIA) • Waterborne applications (pages 66- 67 of the Clean Hydrogen JU SRIA) • Rail applications (pages 69- 70 of the Clean Hydrogen JU SRIA) • Aeronautic applications (pages 72- 73 of the Clean Hydrogen JU SRIA)	

Identifier	Question	Answer
R&I- H2 Heat & Power	Concerning H2 end-use technologies, what is the main R&I focus of your country in the area of ***clean power and heat*** with respect to: • Stationary fuel cells (page 79 of the Clean Hydrogen JU SRIA) • Turbines, boilers and burners (page 83 of the Clean Hydrogen JU SRIA)	
Identifier	**Question**	**Answer**
R&I- H2 Cross-cutting	Concerning ***H2 cross-cutting issues,*** what is the main R&I focus of your country with respect to: • Sustainability, LCSA, recycling and eco-design (page 86 of the Clean Hydrogen JU SRIA) • Education and public awareness (page 89 of the Clean Hydrogen JU SRIA) • Safety, Pre-Normative Research and Regulations, Codes and Standards (pages 91- 92 of the Clean Hydrogen JU SRIA)	
Identifier	**Question**	**Answer**
R&I- H2 Valleys	Does your country have plans to develop new/additional ***Hydrogen Valleys***? Covering which activities?	
Identifier	**Question**	**Answer**
R&I- H2 Supply chains	Does your country have plans to support ***H2 supply chains*** (pages 98- 99 of the Clean Hydrogen JU SRIA)	

Annex 3- Focus areas per country of the tailor-made questionnaire

Table 20. Focus areas per country of the tailor-made questionnaire

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Austria	Federal Ministry for Climate Protection (same as SRG)	Well covered	Well covered	Questions focusing on potential synergies with budget and other initiatives	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Belgium	Contact for strategy at Federal level (general email address) Flemish government (SRG)	Not covered. Questions to address thoroughly this point.	Well covered	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about federal and regional level: different strategies?

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Bulgaria	Contact for strategy not clear (likely Ministry of Economy, Energy and Tourism) Ministry of Education and Science (SRG)	Not covered. Questions to address thoroughly this point.	Partially covered. Questions to understand better targets to 2030- 2040- 2050	General amount. Check if more specific budgets have been included in the upcoming strategy.	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Croatia	Ministry of Economy and sustainable development (same as SRG)	Partially covered. Questions to check existence of more specific R&I directions	Well covered	Well covered.	Partially covered. More information on ongoing and planned projects is needed (e.g. small H2 Valley).	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Cyprus	Ministry of Energy, Commerce and Industry (same as SRG)	Not covered. Questions to address thoroughly this point.	Not covered. Questions to address thoroughly this point.	Not covered. Questions to address thoroughly this point.	Well covered.	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Czech Republic	Contact for strategy: Ministry for Industry and Trade (same as SRG)	Well covered	Well covered	Well covered	Partially covered. More information on ongoing and planned projects is needed (e.g. H2 Valley?).	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Denmark	Contact for strategy: Danish Ministry of Climate, Energy and Utilities. Danish Agency for Higher Education and Science in SRG.	Partially covered. Questions to check existence of more specific R&I directions	Partially covered. Questions to understand better targets to 2030-2040- 2050	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Estonia	Ministry of Environment (same as SRG)	Not covered. Questions to address thoroughly this point.	Partially covered. Questions to understand better targets to 2030-2040- 2050	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Finland	Ministry of Economic Affairs (same as SRG)	Partially covered. Questions to check existence of more specific R&I directions	Partially covered. Questions to understand better targets to 2030- 2040- 2050	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
France	Ministry for Higher Education, Research and Innovation (same as SRG)	Well covered	Well covered	Check if there is more precise information concerning budget after 2024.	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Georgia	Minister of Economy and Sustainable Development (same as SRG)	Not covered. Questions to address thoroughly this point.	Not covered. Questions to address thoroughly this point.	General info. Check if more specific budgets have been included in the upcoming strategy.	Not covered. Questions to address thoroughly this point	N.A.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Germany	Responsible for the strategy: BMWK. SRG: BMBF	General statements. Check if updated strategy includes more precise R&I priorities	Check if update targets are expected with strategy revision	Check if updated budget has been included in the upcoming strategy	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Greece	Contact for strategy: Ministry of Environment and Energy Demokritos is SRG contact	Partially covered. Questions to check existence of more specific R&I directions	Well covered	General info. Check if more specific budgets are available	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Hungary	National Office for Research, Development and Innovation (same as SRG)	Well covered	Well covered	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Iceland	Contact for strategy: Ministry of Environment, Energy and Climate SRG: Icelandic New Energy (R&D company)	General. Questions to check existence of more specific R&I directions	Well covered	General budget. Check if more specific budgets have been included in the upcoming strategy	Well covered	N.A.
Ireland	Strategy: Department of the Environment, Climate and Communications SRG: Enterprise Ireland	General. Questions to check existence of more specific R&I directions	Not covered. Questions to address thoroughly this point.	Not covered. Questions to address thoroughly this point.	Well covered.	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Israel	Strategy: Ministry for Energy. SRG: IIA	Well covered	Not covered. Questions to address thoroughly this point.	General budget. Check if more specific budgets are known.	Well covered	N.A.
Italy	Contact for strategy: Italian Ministry for Enterprise and Made in Italy CNR (SRG)	Partially covered. Questions to check more specific R&I directions	Well covered	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Latvia	In charge of strategy: Minister of Economics SRG: Ministry of Education and Science	Not covered. Questions to address thoroughly this point	Not covered. Questions to address thoroughly this point	Not covered. Questions to address thoroughly this point	Not covered. Questions to address thoroughly this point	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Lithuania	Ministry of Energy (same as SRG)	Partially covered. Questions to check existence of more specific R&I directions	Well covered	Well covered	Partially covered. More information on ongoing and planned projects is needed.	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Luxembourg	Strategy: Ministry of Energy. SRG: Luxinnovation	Not covered. Questions to address thoroughly this point	Well covered	Not covered. Questions to address thoroughly this point	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Malta	Contact for strategy: Ministry for Energy SRG: Ministry for Transport	Well covered	Not covered. Questions to address thoroughly this point	Not covered. Questions to address thoroughly this point	Partially covered. More information on ongoing and planned projects is needed	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Netherlands	Ministry of Economic Affairs and Climate Policy (same as SRG).	Partially covered. Questions to check existence of more specific R&I directions	Well covered.	Well covered.	Well covered.	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions (Regional Energy Strategies).
Norway	Norwegian Ministry of Petroleum and Energy (same as SRG)	Not covered. Questions to address thoroughly this point	Partially covered. Questions to understand better targets to 2030- 2040- 2050	General budget. Check if more specific budgets are known.	Well covered	N.A.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Poland	Ministry of Climate and Environment (same as SRG)	Partially covered. Questions to check existence of more specific R&I directions	Well covered.	Well covered.	Partially covered. More information on ongoing and planned projects is needed.	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Portugal	Strategy: Ministry for Environment and Climate Action SRG: MCTES	Not covered. Questions to address thoroughly this point	Well covered	Well covered	Partially covered. More information on ongoing and planned projects is needed.	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Romania	Strategy: National Research and Development Institute for Cryogenic and Isotopic Technologies SRG: Ministry of Energy	Not covered. Questions to address thoroughly this point	Well covered	General info. Check if more specific budgets are available	Partially covered. More information on ongoing and planned projects is needed	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Slovakia	Contact for Strategy: Ministry of Economics. Technical University of Kosice (SRG)	Not covered. Questions to address thoroughly this point	Partially covered. Questions to understand better targets to 2030- 2040- 2050	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Slovenia	Ministry for Infrastructure (same as SRG)	Not covered. Questions to address thoroughly this point	Partially covered. Questions to understand better targets to 2030- 2040- 2050	Not covered. Questions to address thoroughly this point	Partially covered. More information on ongoing and planned projects is needed	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Spain	Contact for Strategy: MITECO CDTI (SRG)	Not covered. Questions to address thoroughly this point	Well covered	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.

Country	Governance/ Contact	R&I	Targets	Budget	Projects	NECPs
Sweden	Swedish Energy Agency (same as SRG)	Partially covered. Questions to check existence of more specific R&I directions	Partially covered. Questions to understand better targets to 2030- 2040- 2050	Well covered	Well covered	Question about inclusion of H2 in NECP update and in AFI Plan in 2025. Question about role of regions.
Türkiye	TUBITAK (same as SRG)	Partially covered. Questions to check existence of more specific R&I directions	Partially covered. Questions to understand better targets to 2030- 2040- 2050	General info. Check if more specific budgets are available	Well covered	N.A.

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