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HYPAT Discussion Paper 05/2023

Mobilizing Europe's Full Hydrogen Potential: Entry-Points for Action by the EU and its Member States

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Funding

The HYPAT – H_2 POTENTIAL ATLAS – project is funded by the German Federal Ministry of Education and Research BMBF as part of the "Hydrogen Republic of Germany" ideas competition in the basic research module on green hydrogen. The project runs for a period of three years, March 2021 - February 2024.

SPONSORED BY THE

Federal Ministry of Education and Research

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https://hypat.de/hypat-en/

Recommended Citation

Quitzow, R.; Triki, A.; Wachsmuth, J.; Fragoso Garcia, J.; Kramer, N.; Lux, B:; Nunez, A. (2023): Mobilizing Europe's Full Hydrogen Potential: Entry-Points for Action by the EU and its Member States. HYPAT Discussion Paper No 5/2023. Karlsruhe: Fraunhofer ISI (Ed.)

Published

Date	Version	Amendment
September 2023	01	

Acknowledgements

The author team would like to thank the members of the HYPAT consortium who helped improve the quality of the working paper by providing their valuable comments to a previous draft of the paper. This includes Friederike Altgelt (dena), Vasilios Anatolitis (Fraunhofer ISI), Natalia Pieton (Fraunhofer IEG), Eva Schmid (dena), Zarah Thiel (Ruhr-Universität Bochum), Martin Wietschel (Fraunhofer ISI).

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Executive Summary

This policy paper takes stock of ongoing hydrogen policy developments in Europe, placing particular attention on how the European Union (EU) can most effectively mobilize its domestic hydrogen potential. While the paper acknowledges that hydrogen imports from countries outside the EU are likely to play a significant role, it departs from the premise that the large-scale mobilization of cost-competitive domestic resources is an essential element for ensuring the EU's energy security and industrial leadership in the sector.

It begins with an overview of future renewable energy demand in Europe within the context of decarbonization, on the one hand, and potentials for renewable hydrogen production and their distribution across the EU, on the other. It then contrasts this with hydrogen-related targets and announced investments in the Member States. Against this background, the paper provides a review of key EU-level policies, focusing on the promotion of hydrogen production and use. Questions related to infrastructure for storage and transport of hydrogen are beyond the scope of the paper and are not considered. Building on the policy review, the final section proposes five recommendations for further development of EU hydrogen policy and funding schemes.

Section 1: Meeting European hydrogen demand with domestic supply: potentials and mismatches

The short review of renewable energy potential reveals that meeting future hydrogen demand poses significant challenges as well as key trade-offs between intensifying and accelerating renewable energy deployment, on the one hand, and increasing dependence on future hydrogen imports, on the other. Against this background, **prioritizing the use of hydrogen in hard-to-electrify sectors has clear benefits.**

That said, **there is significant renewable energy potential within Europe** that could be mobilized to meet a large share of domestic hydrogen demand. However, this potential is not only spread unevenly across countries. There is also a significant **mismatch between those countries with significant renewable energy potential and those investing most actively in the development of the hydrogen sector**. Rather, a key factor in driving policy ambition and related project pipelines is the fiscal capacity to support hydrogen investments. In this vein, current trends indicate that the **EU is failing to leverage its full potential** for meeting its ambitious renewable hydrogen targets. Moreover, investments in both hydrogen production and use are **leaving behind some of the most promising regions** in terms of long-term potential to generate surplus renewable energy.

Section 2: EU hydrogen policy and governance: the state-of-play and key challenges

A subsequent review of EU hydrogen policy and governance reveals that the EU's approach to promoting its hydrogen sector suffers from an excessive degree of complexity. The simplicity of the new tax-based incentive schemes under the US Inflation Reduction Act represents a stark contrast to the complex regulatory and administrative landscape in the EU. This reduces the overall attractiveness of the EU as a destination for investment in hydrogen-related technologies and infrastructure. **In addition, current EU policy risks reinforcing the bias towards investments in those Member States that can**

offer national funding schemes, such as subsidies granted under the Guidelines on State aid for climate, environmental protection and energy.

EU-level funding schemes could provide a counterweight to this trend. **However, to date, the volume of the EU's hydrogen-specific funding schemes is relatively small compared to the funds allocated in important Member States like Germany and France**. Moreover, to date, the Innovation Fund, the largest EU-level scheme for allocating hydrogen-related investment, has favoured high-capacity states, i.e. Sweden, the Netherlands, Germany and Finland. The Recovery and Resilience Facility currently offers the most substantive EU-level scheme in terms of funding volume. However, given its nature as a vehicle primarily for channelling debt to Member States, it does not substantively enhance the fiscal space for pursuing hydrogen-related investments.

Cohesion policy funds do offer a well-established vehicle that could channel support specifically to regions with high renewable energy potential but relatively low fiscal capacity. However, for now, **regional hydrogen valley initiatives are also concentrated in high-capacity Member States**, indicating that the overall enabling environment in Eastern and Southeastern Europe is not yet in place to stimulate more ambitious hydrogen-related activities.

Section 3: Policy Recommendations: Enabling hydrogen investments in Member States and regions with high renewable energy potential, while reducing regulatory complexity

Based on the review of developments in sections 1 and 2, the following section proposes five policy recommendations.

Recommendation 1: Scale-up dedicated EU-level funding for renewable hydrogen production and use

An obvious entry-point for counterbalancing the current bias in favour of renewable hydrogen investments in countries with high fiscal capacity rather than high renewable energy potential would be the **introduction of consolidated, large-scale EU-level funding schemes, both in support of hydrogen production and use.** Specifically, this could come in the form of the planned renewable hydrogen auctions (on the supply-side) and Carbon Contracts for Difference (CCfDs) (on the demand-side). This could also include dedicated auctions for structurally disadvantaged regions.

To be effective, the funding volume of EU-level schemes would have to approach the level of state-aid being provided at the national level. One way of doing so could be via a dedicated fund, as originally envisaged with the EU Sovereignty fund. Moreover, to avoid a bias in favor of richer Member States, such **EU-level schemes should pose strong restrictions on cumulation with state aid for the same hydrogen projects**. This is particularly crucial when it comes to auction-based schemes. Conversely, exempting the cumulation with cohesion policy funds could offer an additional incentive for investments in less-developed regions.

Recommendation 2: Introduce cross-border renewable hydrogen auctions

Another option for channelling investment to Member States and regions with high renewable energy potential but a relatively constrained fiscal capacity could be the use of cross-border renewable hydrogen auctions. In the upcoming revision of the EU's Governance Regulation,

which already includes the Renewable Energy Financing Mechanism for cross-border renewable electricity financing, a corresponding scheme could be established for renewable hydrogen. Among other things, **Member States could operate cross-border auctions with other EU Member States in order to fulfil their national RFNBO quotas**.

Recommendation 3: Introduce national renewable electricity targets to identify priority areas for hydrogen investment

Not only is it crucial that investments are channelled to countries with high potential for renewable energy. But it is equally important that investments in renewable hydrogen accelerate in tandem with investments in renewable energy more broadly. To ensure this, **the EU could introduce a system of national renewable electricity targets, including yearly interim targets, that are compatible with the EU's pathway to climate-neutrality by 2050.** In a first step, such a harmonized target system could remain voluntary and could be utilized as the basis for granting exemptions from additionality requirements for those countries that meet or exceed their interim renewable energy targets. If sufficiently ambitious, such targets would offer a more effective safeguard than additionality requirements alone against the risk of renewable hydrogen investments undermining the decarbonization of the power sector. Such an approach would allow countries that have ensured that the decarbonization of the electricity sector remains on track to reduce regulatory complexity and boost their attractiveness for investments in renewable hydrogen as well as the related downstream industries. At a later stage, such targets could be made mandatory in the context of a further revision of the Renewable Energy Directive (RED).

Recommendation 4: Develop bilateral or regional hydrogen partnerships between potential surplus and deficit countries in the EU

EU-level coordination and exchange on national hydrogen policy is limited. The EU Hydrogen Energy Network, the only platform targeting inter-governmental exchange, facilitates only basic information exchange. **Establishing bilateral or regional hydrogen partnerships could help deepen inner-European cooperation, in particular between potential surplus and deficit countries.** Firstly, such partnerships could facilitate knowledge exchange and mutual learning. This could help align national hydrogen strategies and goals with enhanced EU hydrogen targets and facilitate early alignment of positions on EU-level hydrogen dossiers as well as their harmonized transposition into national law. The latter might help accelerate the completion of the European regulatory framework for the hydrogen sector, which is needed to provide basic regulatory certainty for investors. Secondly, such **partnerships could be used as the basis for agreeing on a split between importing and exporting countries when accounting for the use RFNBOs towards the fulfilment of renewable targets.** Such agreements would allow Member States with high renewable energy potential to contribute to the EU-wide ramp-up of hydrogen, while also supporting the fulfilment of their national quota. This could be further enhanced by introducing cross-border auctions, as mentioned in recommendation 2.

Recommendation 5: Focus support for hydrogen use on hard-to-electrify sectors, in particular in countries with a future deficit in renewable energy generation.

The comparison of renewable energy potentials with the potential electricity demand for supplying energy-intensive industries, aviation and the maritime sector has shown that some

Member States will not be able to meet the demand of these hard-to-electrify sectors domestically at reasonable hydrogen production costs. Hence, their deficit will increase substantially if hydrogen is allocated to sectors with cheaper mitigation options, such as residential heating and road transport. In other words, in these countries in particular there is a clear benefit in focusing hydrogen use on hard-to-electrify sectors, as this will limit their future need for hydrogen imports and strengthen the resilience of their energy sector.

Therefore, countries with a future renewable energy deficit should restrict national support schemes to the hard-to-electrify sectors. To ensure that hydrogen is allocated to these sectors, demand-side schemes focusing on energy-intensive industries and the maritime and aviation sectors should be prioritized over supply-side support schemes. Alternatively, supply-side schemes can be designed for use in the hard-to-electrify sectors by requiring offtake agreements from the hard-to-electrify sectors for at least a substantial share of the production. The German H2 Global scheme, for instance, where the government conducts auctions for the supply with renewable hydrogen or its derivatives as well as its subsequent offtake, offers a suitable framework for this. In this case, the auctions for hydrogen use could be restricted to selected end-uses.

From an EU-level perspective, it is also sensible to reduce overall demand for hydrogen. This in turn will lead to lower overall demand for renewable energy, thereby alleviating the need to navigate trade-offs between large-scale domestic deployment and dependency on imports from non-EU countries. **Hence, EU-funding should also clearly prioritize hydrogen use in hard-to-electrify sectors to ensure that domestic resources will be able to meet a significant share of internal demand.**

Introduction

With its hydrogen strategy, the European Union (EU) has identified renewable hydrogen as a key for the decarbonization of so-called hard-to-electrify sectors as well as a medium for storing and transporting energy within a carbon-neutral energy system. It also aims to position the European hydrogen industry as a leader in related technologies and supply chains. Since the invasion of Ukraine, hydrogen has also been identified as an avenue for reducing Europe's dependence on Russian natural gas. In this vein, the EU targets the deployment of 100 GW of electrolyzer capacity and the domestic production and import of up to 20 million tonnes of hydrogen by 2030 (EC, 2022c, 2023f).

To achieve these ambitious targets, the EU has begun to launch a range of measures to support investment in renewable hydrogen production, to accelerate the uptake of renewable hydrogen and its derivatives in hard-to-electrify sectors, to promote investments in hydrogen transport and storage infrastructure as well as research and innovation. These efforts have received further urgency following the passage of the US Inflation Reduction Act in August 2022, a large-scale support scheme that introduces attractive tax credits for investments in low-carbon and renewable hydrogen. Under pressure to match US ambition, the EU has further accelerated policy development to ensure a more rapid roll-out of hydrogen-related technologies (EC, 2023f).

This policy paper takes stock of these policy developments. In doing so, it focuses its primary attention on whether and how the EU can effectively mobilize its domestic hydrogen potential. While the paper acknowledges that hydrogen imports from non-EU countries are likely to play a significant role, it departs from the premise that the large-scale mobilization of cost-competitive domestic resources is an essential element for ensuring the EU's energy security as well as industrial leadership in the sector.

In this vein, this paper identifies key challenges and gaps in the EU's enabling environment for the realization of its domestic hydrogen potential. It begins with an overview of its potentials for renewable hydrogen production as the well their distribution across EU Member States. It then compares them to hydrogen-related targets and announced investments in the Member States, highlighting important discrepancies between hydrogen potentials, on the one hand, and ambitions, on the other. Against this background, the paper provides a review of key EU-level policies, focusing on policies for the promotion of hydrogen production and use. Questions related to infrastructure for storage and transport of hydrogen are beyond the scope of the paper and are not considered. Finally, building on the policy review, the final section proposes a number of recommendations for the further development of EU policy and funding mechanisms for the mobilization of domestic hydrogen resources and for supporting the hydrogen ramp-up in the EU more broadly.

1 Meeting European hydrogen demand with domestic supply: potentials and mismatches

This section provides a short review of possible future European hydrogen demand as well as the potential to meet this demand with domestic renewable hydrogen supply. In a first step, it provides an aggregate perspective of demand and supply in countries in the European

Economic Area and the UK. In a second step, it reviews the distribution of potential demand and supply across European countries. It contrasts this with current hydrogen supply targets and planned renewable hydrogen projects in the respective countries.

1.1 Estimating European hydrogen supply and demand: an aggregate perspective

To provide an estimate of Europe's ability to meet its future hydrogen demand with domestic supply depends on the following variables:

- the availability of renewable energy resources for electricity generation
- estimated future demand for renewable electricity, including for the decarbonization of the power sector and for the decarbonization of end-use sectors via direct electrification,
- estimated demand for renewable electricity to generate renewable hydrogen to meet the requirements for decarbonization of domestic end-use sectors

To provide such an estimate, we provide calculations of renewable energy potential and electricity demand, distinguishing between demand for direct electricity use and for the production of renewable hydrogen. Renewable potentials were calculated using the renewable potential calculator 2.0 from the model Enertile[1]. Estimates of electricity demand are based on data from the Transhyde project. The Transhyde project provides demand estimates for a range of scenarios for achieving carbon neutrality in the EU, Norway, Switzerland and the UK, including renewable hydrogen demand in industry, transport and buildings. [2]

In the following, we consider results from two scenarios. The first is referred to as the S2 ChemSteel scenario. This only considers hydrogen demand for sectors with no alternative or only very expensive alternative mitigation options. In the industrial sector, this includes hydrogen demand in the steel and chemical industry (hydrogen as feedstock) as well as

[1] The model calculates the potential for five different generation technologies, including rooftop solar photovoltaics, utility-scale solar photovoltaics, onshore wind, offshore wind and concentrated solar power. The calculations are based on a 6.5 by 6.5 km grid. Land-use criteria are allocated to these tiles according to the GlobCover 2009 dataset. A usage factor is allocated to each land category, to calculate the available land to install the different renewable energy sources. Natural protected areas categories I and II according to the International union for Conservation of Nature and Natural Resources are excluded from the calculation. Further details in the calculation are found in Sensfuß, Frank (2021): Langfristszenarien für die Transformation des Energiesystems in Deutschland. Treibhausgasneutrale Szenarien. Kurzvorstellung. Edited by Fraunhofer ISI, BMWi. Available online at https://www.langfristszenarien.de/enertile-explorer-wAssets/docs/LFS3_TN_Szenarien_2021_06_25_v6__.pdf, accessed on 5/13/2022.

[2] For more information on the Transhyde project and related scenarios, please see https://www.isi.fraunhofer.de/en/competence-center/energietechnologien-energiesysteme/projekte/TransHyDe-Sys.html and Fleiter, Tobias; Al-Dabbas, Khaled; Rehfeldt, Matthias; Alibas, Sirin; Neuner, Felix; Weißenburger, Bastian et al. (in preparation): Szenarien zur zukünftigen Rolle von Wasserstoff im CO2-neutralen Energiesystem. Teil1: Nachfrage und Gesamtsystem.

selected high-temperature industrial processes. In the transport sector, the hydrogen demand is limited to its use for synthetic fuels in aviation and long-distance maritime transport. No hydrogen demand is considered in the buildings sector. The second scenario – the S5 AllSect scenario - considers a number of additional hydrogen applications. In the industrial sector, this includes hydrogen use for mid-temperature process heat. In the transport sector, hydrogen use is extended to long-distance truck transport and a minor share is considered for use in passenger cars. In the buildings sector, hydrogen is used to cover the needs of decentralized heat supply in buildings in areas with less preferable conditions for electrification.

For 2050, the results of these scenarios show that in both scenarios electricity demand would be more than double the current electricity generation in the countries considered (i.e. EU, Norway, Switzerland and the UK), which is slightly over 3000 TWh[3]. The S2 ChemSteel scenario calculates electricity demand of about 6,600 TWh, while the electricity needs in the S5 AllSect scenario are close to 8,000 TWh. In 2021, the EU, UK, Norway and Switzerland produced 1396 TWh[4] of renewable power as well as 769 TWh[5] of nuclear power. Hence, without energy imports and assuming stable amounts of nuclear power generation, renewable energy generation in the considered countries would have to increase by approximately 4500 to 5800 TWh, or a factor of approximately 3 to 4, depending on the scale of hydrogen use. This in turn implies an average increase in renewable energy generation of 160 to 200 TWh per year up to 2050. Between 2017 to 2021, renewable energy generation only expanded by approximately 50 TWh per year in the countries concerned.

These figures clearly indicate the significant trade-offs the EU and its immediate neighbours face in the context of these decarbonization scenarios. They can either choose to prioritize the intensification and acceleration of domestic renewable energy deployment, or they can choose to accept higher levels of dependency on hydrogen imports. By focusing hydrogen deployment on the so-called hard-to-electrify sectors only, as assumed in the S2 ChemSteel sector, overall demand for renewable electricity could be reduced. This would in turn reduce the overall demand for hydrogen, whether domestically produced or imported, alleviating the trade-offs mentioned above. In practice, it is clear that both large-scale renewable energy deployment and hydrogen production in the EU as well as significant amounts of hydrogen imports will be needed.

That said, results from the Enertile model indicate that European countries collectively have the technical potential[6] to meet the overall renewable electricity demand with domestic capacities in both scenarios at levelized costs of €40 per MWh of renewable electricity or less (see Figure 1). This is significantly below average non-household energy prices in the EU, which have increased from €70 in 2020 to €142 in 2022.[7] For the S2 ChemSteel scenario, the

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3 Based on IRENA Renewable Energy Statistics. See https://www.irena.org/Data/Downloads/IRENASTAT

4 Ibid.

5 Based on data provided by the World Nuclear Association, Country Profiles. See https://www.world-nuclear.org/information-library/country-profiles.aspx

6 See footnote 1 for details on how this was calculated.

7 Based on data provided by Eurostat. See https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_205_c/default/table?lang=en

assessment reveals a surplus of renewable electricity potential in Europe of about 2,450 TWh at €40 per MWh. When larger amounts of hydrogen use in transport and buildings are taken into account in the S5 AllSect scenario, the potential surplus is approximately cut in half. If slightly higher costs of renewable energy production are considered, the surplus values increase substantially (see figure 1).

Clearly, not all of this theoretical potential for renewable energy generation can be realized, even in the long run. A host of factors, including impacts on landscapes, regulatory constraints and other environmental and socio-political factors, represent constraints that have to be considered. For the production of renewable hydrogen via electrolysis, the availability of water presents a further constraint that has not been considered here. Nevertheless, in the aggregate, the assessment reveals a significant potential for the generation of renewable energy to meet electricity demand, not only for direct use but also for the production of hydrogen within the EU and its immediate neighbours.

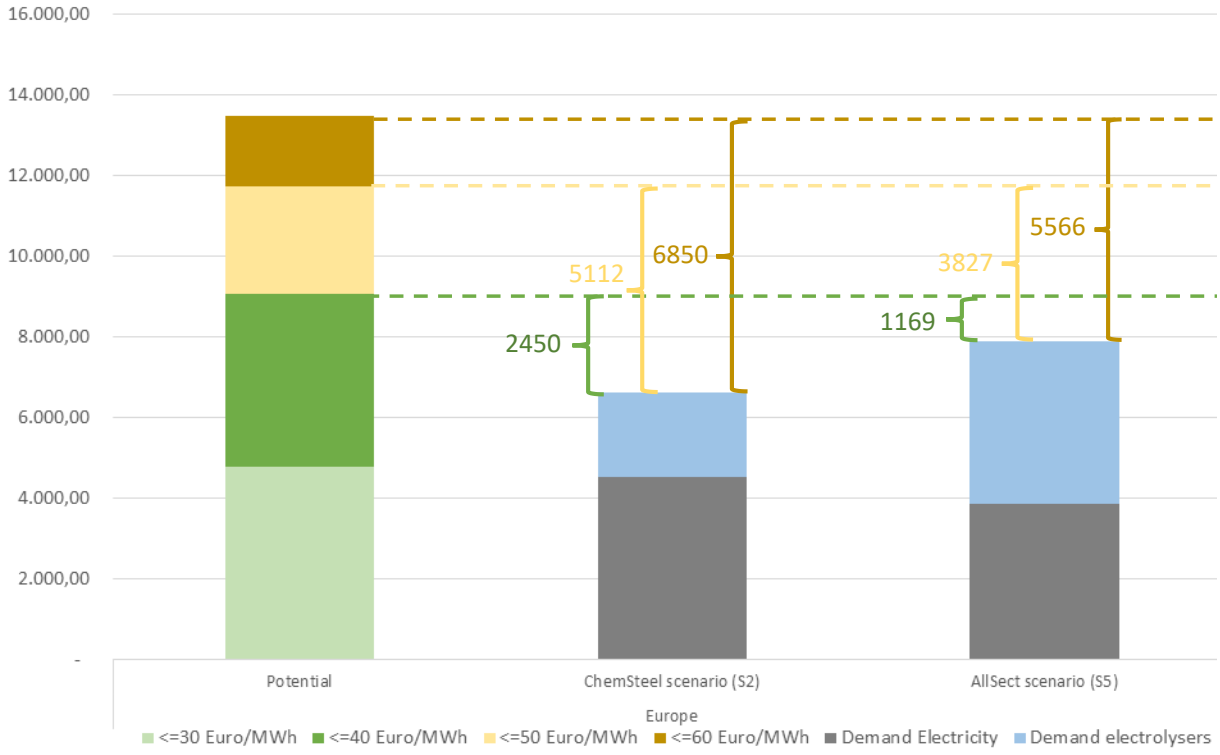

Figure 1: Technical renewable energy potential versus estimated demand in the EU, Norway, Switzerland and the UK in 2050, in TWh

Source: Renewable potential calculator 2.0 from the model Enertile; results of Transhyde project.

1.2 Diverging renewable potential across Europe: high surplus vs. deficit countries

The consideration of aggregate renewable energy potential at the European level hides another important fact. Although European countries collectively exhibit the renewable energy potential to meet the domestic electricity demand to decarbonize their economies, there are important differences across countries. Figure 2 provides estimates of renewable energy

potentials for individual European countries at costs up to 60 Euro/MWh. These are contrasted with the sum of electricity demand required for direct use and for hydrogen production via electrolysis in 2050, based on the S2 ChemSteel scenario. According to these estimates, Norway and Spain have the largest potential renewable energy surplus within Europe, followed by France and Sweden. Germany will most likely have the largest deficit followed by the Netherlands and Belgium. In addition, Czechia, Luxembourg and Slovenia do not have the potential to generate the amounts of renewable energy needed to meet their estimated demand.

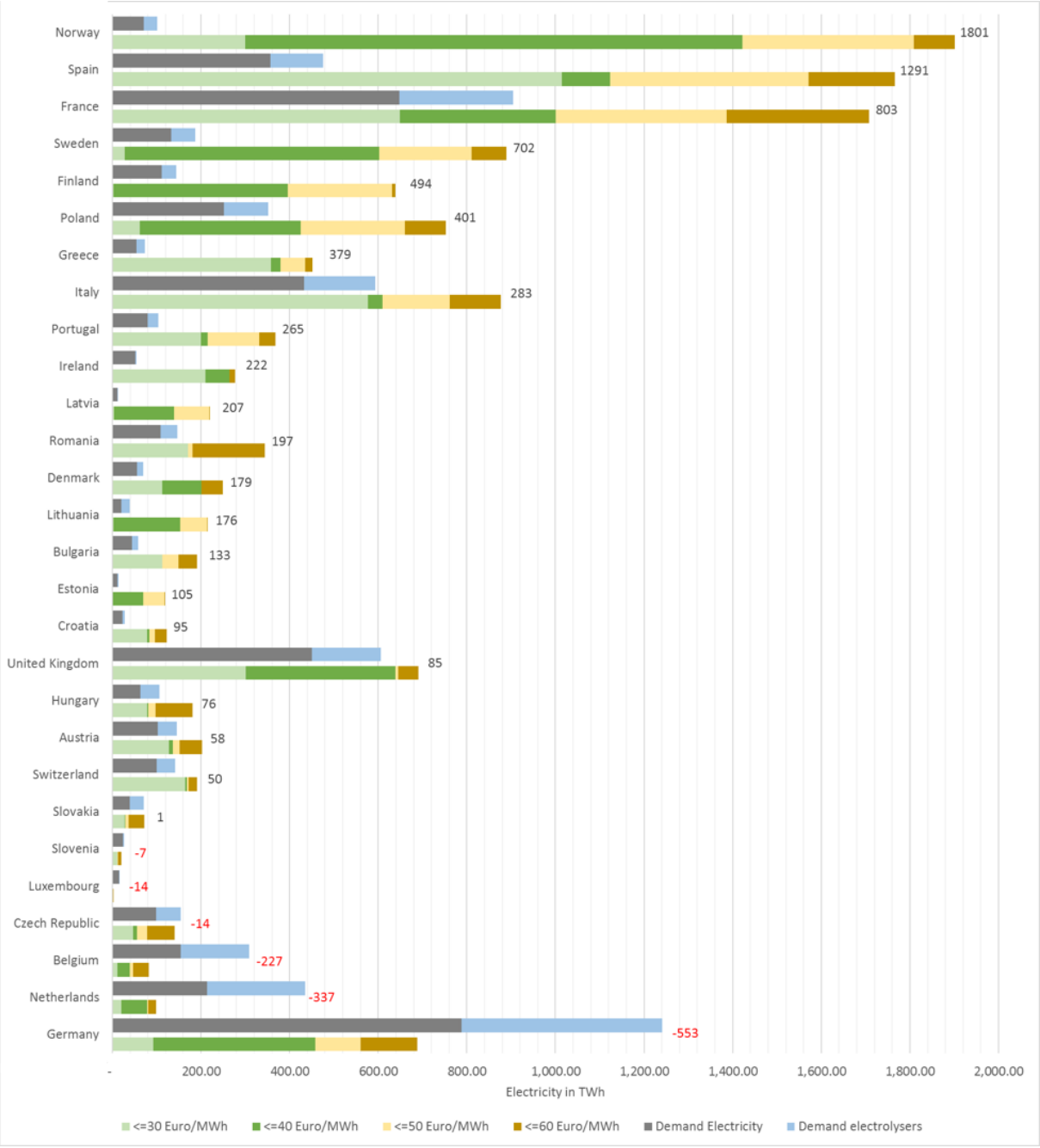

Figure 2: Technical renewable energy potential versus demand in individual EU Member States, Norway, Switzerland and the UK in 2050 (S2 ChemSteel scenario), in TWh

Source: Renewable potential calculator 2.0 from the model Enertile; results of Transhyde project.

If additional hydrogen demand in the transport and buildings sectors is taken into account as in the S5 AllSect scenario, the deficits in these countries increase by varying degrees (see Figure 3). Germany sees the largest increase in absolute terms, with the deficit growing from 553 TWh to 883 TWh. Czechia faces the largest relative increase, with the deficit growing by 143 percent compared to the S2 ChemSteel scenario[8]. Moreover, this adds two additional countries to the list of deficit countries: Slovakia with a deficit of 10 TWh and the United Kingdom with a deficit of 99 TWh.[9]

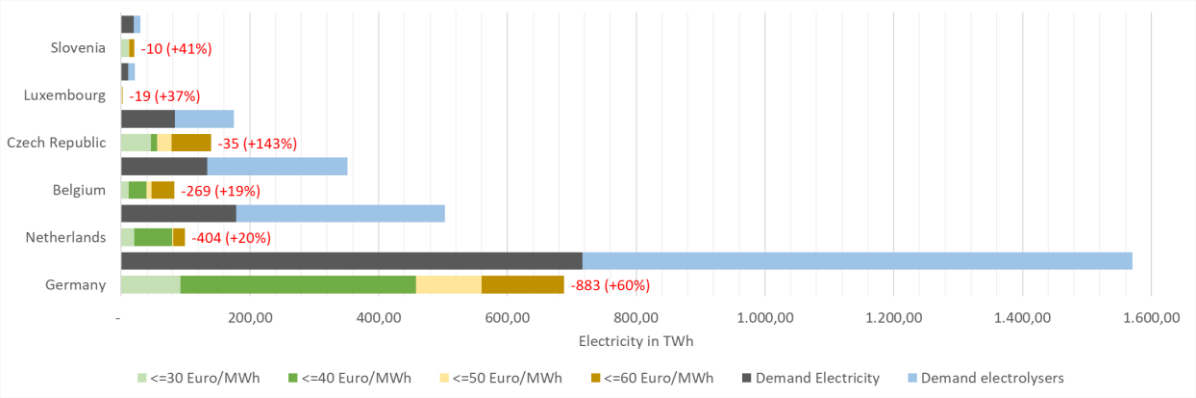

Figure 3: Technical renewable energy potential versus demand for the countries with a potential deficit in the scenario S5 AllSect scenario (increase of deficit compared to S2 ChemSteel scenario in parentheses), in TWh

Source: Renewable potential calculator 2.0 from the model Enertile; results of Transhyde project.

1.3 The mismatch between renewable hydrogen ambitions and potential: a problem for Europe's hydrogen ramp-up?

The estimates presented in the previous sub-section indicate that the EU has substantial renewable energy potential that could help meet an important share of hydrogen demand with domestic production in 2050. However, EU member states differ in their renewable production, transport infrastructure and demand structures, resulting in a mixed landscape of potential renewable surplus and deficit countries. Hence, the EU's ability to meet a substantial share of domestic hydrogen demand depends on the ambitious deployment of renewable energy in potential surplus countries combined with the development of intra-European hydrogen trade. Renewable energy expansion in potential surplus countries needs to substantially exceed the quantities required to meet their domestic decarbonization needs, and infrastructure for facilitating hydrogen transport from surplus to deficit countries will be essential to realize Europe's hydrogen potential.

8 The demand is taken from the project Transhyde S2_chemSteel scenario. This scenario considers the hydrogen demand for the chemical and steel industry together with the maritime sector. No hydrogen demand is considered for any other sector.

9 In the case of the UK, it should be noted that the cost constraint of 60 euros/MWh has a major impact on the availability of offshore wind potential.

And, indeed, several countries, like Spain, France, Sweden and Italy, with a high potential renewable energy surplus are already among the countries with the most ambitious electrolyser targets. However, many other Member States with a potential for a significant renewable energy surplus have yet to formulate quantitative electrolyser targets. Such countries include Norway, Finland, Latvia, Romania, Lithuania, Bulgaria and Estonia. Other potential surplus countries have defined rather modest targets for now, including Ireland, Poland, Portugal, Greece and Croatia. Moreover, a number of these countries have yet to launch a formal national hydrogen strategy process, including Latvia, Estonia, Greece and Bulgaria.

At the same time, Germany and the Netherlands, the countries with the highest projected deficit, feature among the countries with the most ambitious electrolyser targets for now (see Figure 4). Germany recently increased its 2030 target from 5GW to 10 GW in a revision of its national hydrogen strategy. Only Spain has a higher target after increasing its target from 6 to 11 GW, making it the EU Member State with the highest target. In other words, a substantial mismatch exists between the potential to generate surplus renewable energy to meet hydrogen demand, on the one hand, and current activities to actually develop hydrogen production.

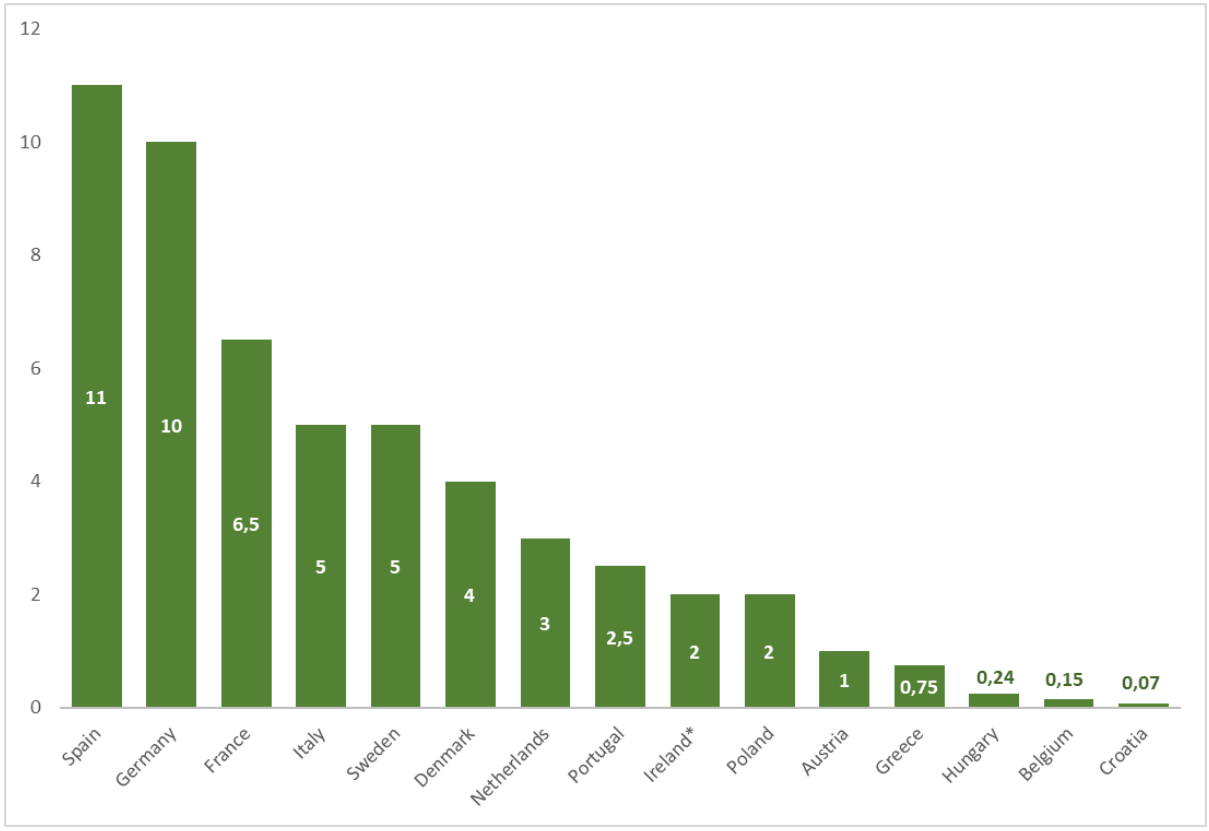

Figure 4: Electrolyzer capacity targets in EU Member States by 2030, in GW

* According to its national hydrogen strategy, Ireland targets "2GW of offshore wind, for the production of renewable hydrogen".
Source: Authors, based on official documents.

A corresponding mismatch can be observed when considering hydrogen-related funding among Member States as well as emerging investments in hydrogen production. Germany and France have the largest volumes of dedicated funding for hydrogen-related activities, with €10 and €9 billion committed in their hydrogen strategies, respectively. No other Member State comes close to these volumes of funding (see Figure 5). A similar gap is visible in the sphere of project-level investment. Germany has over 50 projects for the production of renewable hydrogen in operation and over 30 at advanced planning stages (i.e. final investment decision or construction). Otherwise, France and Spain represent the most prominent countries in terms of projects in operation or in advanced planning stages. In contrast, a number of high potential countries, including Portugal, Greece, Bulgaria, Romania, Latvia, Croatia, Lithuania, Estonia, do not have any projects at advanced planning stages and have less than 5 or no projects in operation (see Figure 6 and Figure 7).

In summary, many EU countries with high potential for renewable hydrogen production lag behind in terms of their ambitions to realize this potential. France, Spain and Denmark are notable exceptions with ambitious hydrogen targets as well as a promising pipeline of renewable hydrogen projects. Sweden and Italy, both potential surplus countries, are also among the EU Member States with the most ambitious hydrogen targets for 2030. However, both exhibit only a relatively modest number of projects in operation or at advanced planning stages.

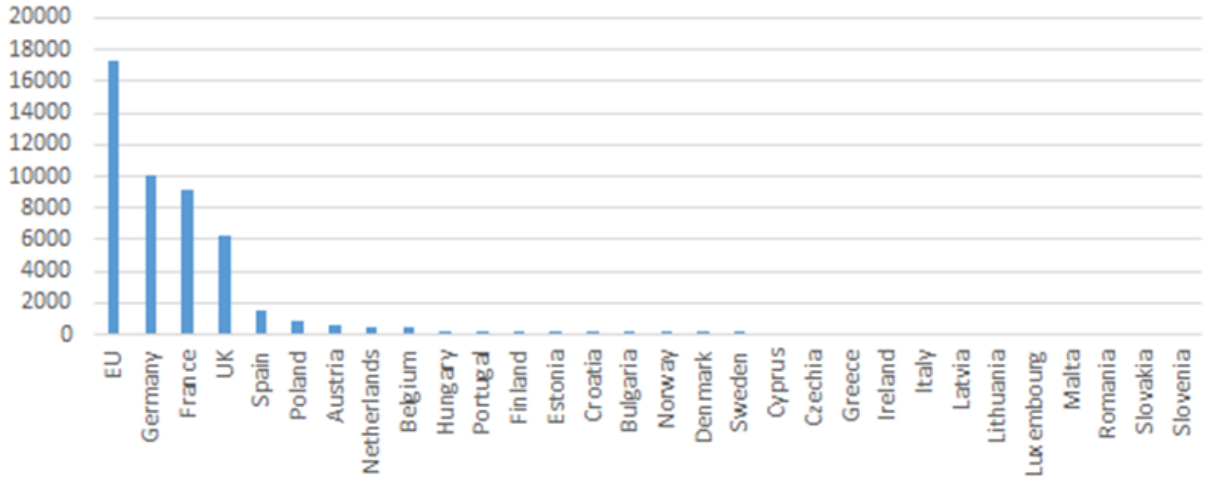

Figure 5: Volume of hydrogen-related funding programs in the EU and the UK, in million EUR

Source: dena/Global Alliance Powerfuels Public Funding for Powerfuels Database[10]

[10] The Global Alliance Powerfuels started mapping existing funding programmes worldwide in 2020. The database was updated and extended in 2022. It compiles data from literature research of publicly available policy datasets (e.g. the IEA "Policies database"), national and regional hydrogen strategies, other government publications/reports and press releases. Programmes were included if hydrogen or powerfuels were eligible for funding and if they had been announced by November 2022. The database includes 224 support schemes from 44 countries and the EU.

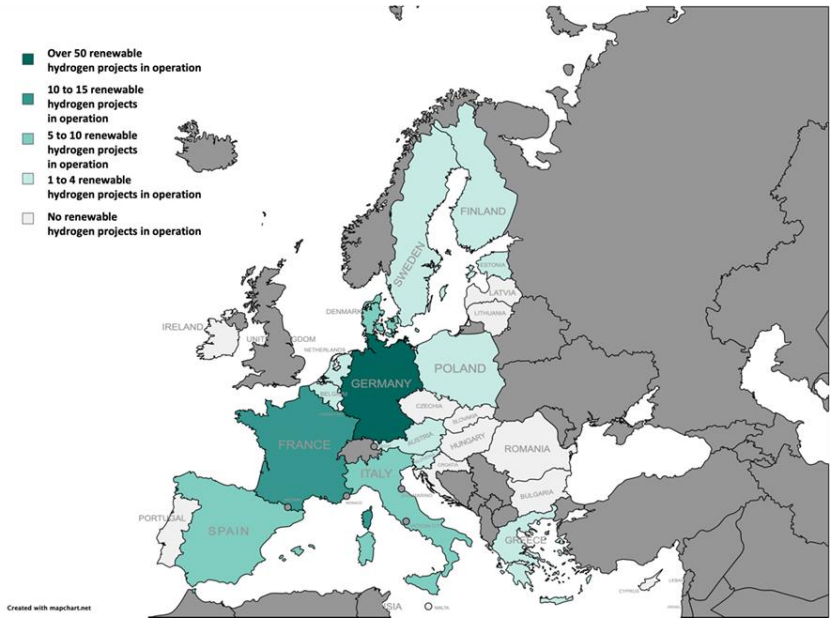

Figure 6: Number of renewable hydrogen projects in operation in EU Member States

Source: IEA Hydrogen Projects Database.

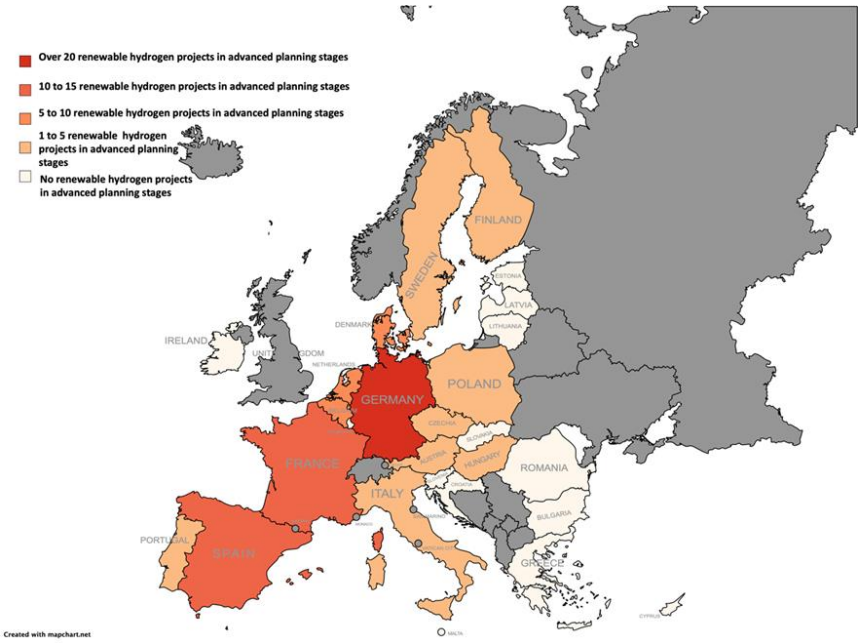

Figure 7: Number of renewable hydrogen projects in advanced planning stages (construction or post-final investment decision) in EU Member States

Source: IEA Hydrogen Projects Database.

Overall, the long-term potential for renewable hydrogen production does not represent a determinant of hydrogen development across the EU. Instead, it seems that pre-existing financial and institutional capacities are the most important drivers of hydrogen-related ambitions. If this mismatch between hydrogen potential, on the one hand, and actual investments in hydrogen supply, on the other, is not addressed, the EU will fail to mobilize large parts of its domestic potential for hydrogen production and increase its dependence on hydrogen imports.

Moreover, it will contribute to an uneven development of the European hydrogen economy and the related economic opportunities. Such an uneven distribution of economic development across EU Member States may in turn erode support for decarbonization in Member States that fail to capture the economic opportunities of a future climate-friendly economy. Notably, these may include not only value creation from hydrogen production. Rather, high potential Member States could mobilize their renewable energy resources to attract investments in hydrogen end-use sectors, including industrial production. Indeed, locational advantages related to renewable resource potential are likely to gain in importance. Therefore, mobilizing these potentials represents an important entry-point for securing European industrial production in the context of decarbonization.

Against this background, this policy paper argues that addressing the uneven development of Europe's hydrogen economy should represent an important priority of EU-level hydrogen policy going forward. In this vein, the remainder of the paper provides a review of existing EU-level policy with the aim of identifying key gaps in confronting the challenges outlined in this section. On this basis, it then formulates a number of policy recommendations to overcome these challenges. In other words, it will identify entry-points to support countries with important potential for renewable hydrogen production but only modest hydrogen-related policy and investment activity to realize this potential.

2 EU hydrogen policy and governance: the state-of-play and key challenges

This section provides a comprehensive review of EU-level hydrogen governance and policy. It begins with a review of the EU's hydrogen targets and governance in sub-section 2.1. This is followed by a review of the emerging regulatory framework for hydrogen in the EU in sub-section 2.2. Finally, sub-section 2.3 provides a review of EU-level funding schemes in support of hydrogen-related investments. Each sub-section closes with an identification of key challenges and remaining barriers to ramping-up the hydrogen economy in Europe.

2.1 The EU hydrogen strategy and governance: engaging stakeholders to realize European hydrogen ambition

This section briefly reviews EU-level hydrogen targets and governance mechanisms. It highlights the existing mechanisms and initiatives for the engagement of private sector stakeholders, Member States and sub-national actors.

2.1.1 Key targets

The EU hydrogen strategy was launched in 2020, aiming to install at least 6 GW of renewable electrolyzers and to produce up to 1 million tonnes of renewable hydrogen by 2024 and 40 GW of electrolyzer capacity and up to 10 million tonnes of renewable hydrogen production by 2030 (EC, 2020). In May 2022, with the REPowerEU Plan, an additional import target of 10 million tonnes of hydrogen by 2030 was introduced, thereby also doubling the EU's renewable hydrogen target (EC, 2022c). Finally, in March 2023, the European Commission formulated the goal in its proposed Net-Zero Industry Act to ensure that 40 percent of strategic net-zero manufacturing needs are met domestically, which includes electrolysers and fuel cells. As a benchmark it specifies that at least 100 GW of domestic electrolyser capacity should be installed domestically by 2030 (EC, 2023f). In other words, since the first introduction of EU hydrogen targets in 2020, the EU ambitions with regards to domestic hydrogen production have increased substantially. However, this increased ambition is not yet reflected in most national hydrogen strategies and targets.

2.1.2 Engaging industry

To achieve its goals, the EU hydrogen strategy proposed the creation of an investment pipeline in cooperation with industry via the **European Clean Hydrogen Alliance (ECH2A)**. Besides identifying bankable hydrogen projects, the ECH2A functions as a forum for exchange among industry stakeholders, other interested parties and the European Commission, identifying barriers to scaling-up Europe's hydrogen economy and devising strategies to overcome them. The Alliance has a range of roundtables and working groups and hosts policy and stakeholder events that work on different aspects of the hydrogen economy. At its European Electrolyser Summit, for instance, the European Commission and major European electrolyser manufacturers signed a joined declaration, where manufacturers commit to the ramp-up of

manufacturing capacity to 17.5 GW by 2025 while the Commission confirms a series of policy commitments[11].

In addition to the ECH2A, the **Clean Hydrogen Partnership** functions as a public-private partnership in support of hydrogen-related research and innovation activities. It is co-funded with equal amounts of EU-funding from its Horizon Europe programme and funding from industry members. Among other things, the partnerships support the CertifHy consortium, which is developing schemes for the certification and labelling of green and low-carbon hydrogen.

2.1.3 Engaging Member States

The European Commission currently engages Member States in hydrogen governance via a number of different vehicles. First, the **revision of the Renewable Energy Directive (RED III),** as adopted by the European Parliament in September 2023, includes requirements for Member States to report on their measures to promote increasing shares of renewable energy in industry (for energy and non-energy purposes) as well as providing information on planned production and imports of so-called Renewable Fuels of Non-Biological Origin (RFNBOs) (i.e. renewable hydrogen and derivatives; see also section 2.2.2 below) in their National Energy and Climate Plans (required under the Regulation on the governance of the energy union and climate action) (EP & Council, 2018). The latter will represent the basis for developing a new EU strategy for domestic production and imports of hydrogen, to which Member States will be required to convey their contributions via their National Energy and Climate Plans (NECPs).

In addition, the European Commission channels EU-level debt to Member States via the **Recovery and Resilience Facility (RRF)**, which can be invested in hydrogen-related projects. To access funding, Member States are required to develop National Recovery and Resilience Plans. Initially, these did not include any hydrogen-related requirements. However, in December 2022, the Commission, the Council and the Parliament reached an agreement to utilize the RRF as a vehicle to meet the goals of the REPower EU Plan (Council, 2022). Going forward, Member States will be required to add REPowerEU chapters to their National Recovery and Resilience Plans, adding a soft form of steering by the Commission to EU hydrogen governance.

Finally, the newest **Trans-European Networks for Energy (TEN-E) regulation** (see also section 2.3.3 below) passed in 2022, which promotes investment in priority energy infrastructure corridors, now also targets three dedicated hydrogen corridors (EP & Council, 2022b). For these corridors, so-called regional groups are responsible for selecting so-called Projects of Common Interest (PCIs). These regional groups include stakeholders, regulators and Member State representatives from the affected regions. However, only the Commission and the represented Member States are conferred decision-making power, which is based on consensus.

These requirements and processes are further complemented by the **EU Hydrogen Energy Network** where energy ministry representatives from the Member States meet regularly to exchange on hydrogen-related issues.

[11] For more details see https://ec.europa.eu/docsroom/documents/43526

2.1.4 Engaging sub-national jurisdictions: the EU's hydrogen valleys

To promote sub-national governments in the emerging hydrogen economy, the European Commission has launched a **European Hydrogen Valley Partnership** under its Smart Specialisation Platform. The Platform facilitates learning and exchange to support regions in the development of so-called smart specialization strategies. These strategies form the basis for developing Operational Programmes to access EU structural funds under its Cohesion Policy. In this vein, the European Hydrogen Valley Partnership supports regional actors to develop hydrogen-related strategies. As the map indicates, participating regions are concentrated in France (14), Spain (8), Netherlands (8), Germany (6), Norway (5), and Italy (5). Additionally, a number of countries have one or two participating regions each, i.e. Belgium (2), Sweden (2), Portugal (2), Greece (2), Poland (2), Slovakia (2), Denmark (1), Bulgaria (1) and Czechia (1). Overall, Eastern and Southeastern European countries are strongly underrepresented, even though they are among the primary recipients of EU structural funding (see Figure 8).

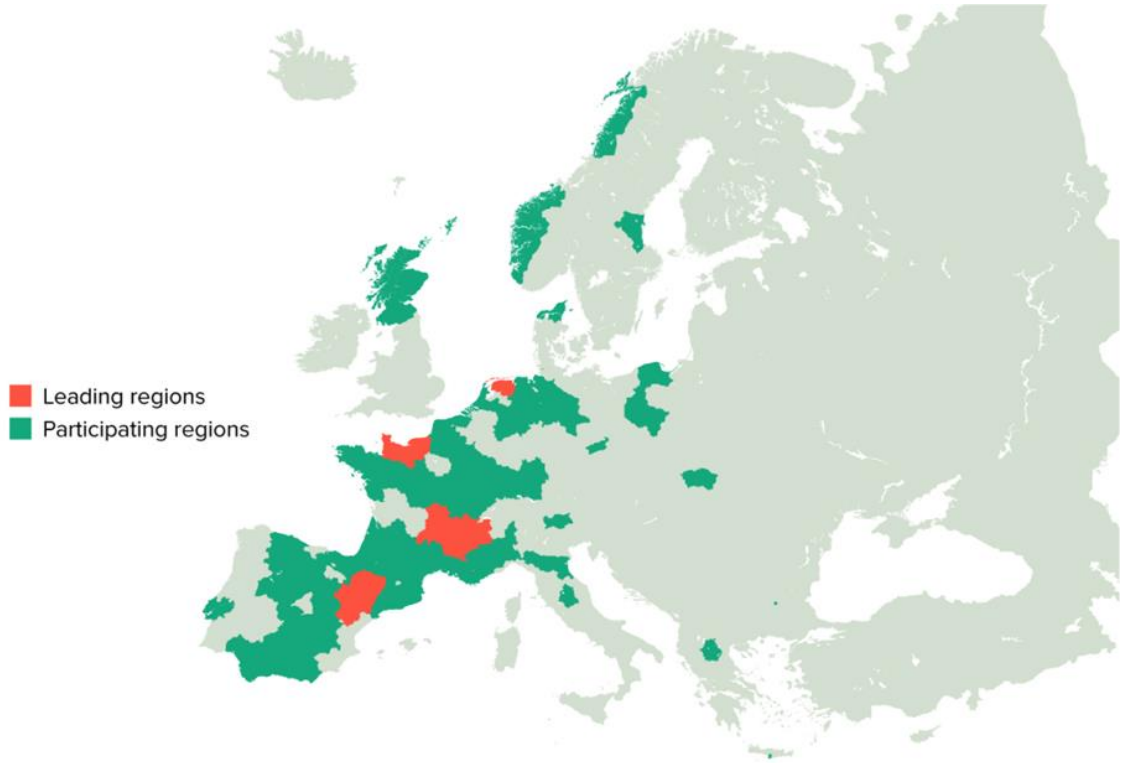

Figure 8: Regions engaged in the European Hydrogen Valley Partnership

Source: https://s3platform.jrc.ec.europa.eu/hydrogen-valleys

Data on the most advanced hydrogen valleys provided by the Hydrogen Valley Platform, co-sponsored by the EU's Clean Hydrogen Partnership and Mission Innovation, reveals a similar trend, albeit with an even stronger showing in Germany. Seven of twelve hydrogen valley projects that are operational or in advanced planning stages are located in Germany. The Netherlands, Denmark, Romania, Sweden and Austria each have one such hydrogen valley project (see Figure 9 below).

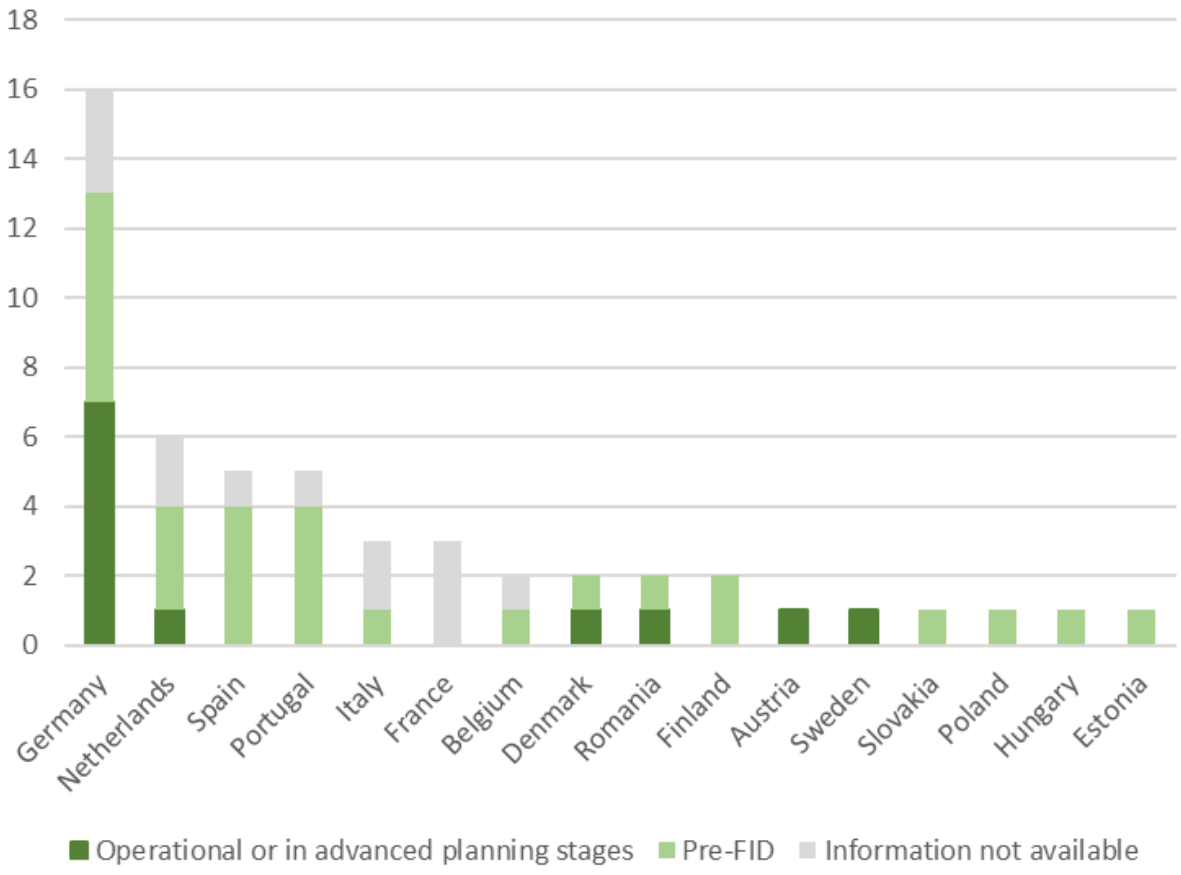

Figure 9: The most advanced hydrogen valley projects in Europe

Source: Hydrogen Valley Platform, https://h2v.eu, Data from 26.05.2023

2.1.5 Key challenges

Any EU-level strategy process faces the challenge of ensuring that diverging Member State interests do not undermine the coherence of EU-level policy and that Member States adequately contribute towards implementing EU-level strategies. Traditionally, the European Commission has relatively limited capacities to ensure this. Its primary lever is the development of EU-level regulations and directives (discussed in more detail in section 2.2).

A second entry-point rests in its power to convene Member States and stakeholders and engage them in benchmarking and reporting exercises. The latter has been further strengthened in the context of REDIII and the Recovery and Resilience Facility. The EU now requires Member States to publish information on renewable hydrogen production and imports under the NECPs as well as REPowerEU chapters within their broader National Recovery and Resilience Plans. However, since these reporting obligations are still rather new, monitoring of the coherence between EU and Member States hydrogen targets and plans is still limited. Moreover, the EU has fallen short in creating further space for Member States to exchange and share knowledge on their approaches for building up hydrogen economies and related challenges and lessons learned.

Moreover, there is a clear gap between Western and Northern European countries, on the one hand, and Eastern and Southeastern Member States on the other. This is visible not only in the

context of national target-setting and project-level activity, as outlined in section 2. It is also visible in the discrepancy in participation in the European Hydrogen Valley Partnership. Going forward, a key question therefore is how to engage high-potential Eastern and Southeastern Member States more actively in the hydrogen economy.

2.2 The EU's evolving regulatory framework for hydrogen: the struggle to provide certainty

The following section reviews what is traditionally the strongest EU-level entry-point for policy action – its power as a regulator. In the climate and energy sector, the most prominent regulatory framework is the EU Emissions Trading Scheme (EU ETS). In the near future, this will include an added trade-policy dimension with the Carbon Border Adjustment Mechanism (CBAM). In addition, this is complemented by regulations defining renewable hydrogen as a basis for GHG accounting rules and different types of support policies, such as EU-level quotas, and rules governing hydrogen transport and storage.

2.2.1 The EU ETS and CBAM: what's in it for hydrogen?

Given its central role in the EU climate and energy policy framework, the **EU Emissions Trading Scheme (EU ETS)**, which places a price on CO_2 emissions from energy-intensive industries, also represents a key starting point for creating an enabling environment for the production and market uptake of renewable hydrogen. The EU ETS is intended to provide an incentive for firms to invest in lower-emitting production methods, including hydrogen-based processes. In practice, however, many of the industries are considered vulnerable to carbon leakage and, therefore, receive free CO_2 allowances. This also applies to conventional fossil-based hydrogen production, thus failing to incentivize a shift towards renewable hydrogen. In the short-term, there is no intention to change this. However, the ETS revision will level the playing field for renewable hydrogen by providing producers with free CO2 allowances from 2026 onwards. These can be turned into revenues by selling them on the allowances market. Until 2035, it is planned to gradually phase-out free allocations for a number of sectors in tandem with the introduction of the **Carbon Border Adjustment Mechanism (CBAM)** (EP & Council, 2023d). As a result, fossil-based hydrogen as well as fossil-based steel and fertilizer production will be required to purchase CO_2 certificates. At the same time, producers of renewable hydrogen will no longer be able to sell free allowances. Instead, the cost-competitiveness of renewable hydrogen is intended to further improve in tandem with increasing CO_2 prices within the ETS and the corresponding tariffs on hydrogen imports under the CBAM. [12]

2.2.2 Defining renewable hydrogen

A particular challenge in the creation of an enabling environment for renewable hydrogen in the EU has been the process of finding agreement on an appropriate definition for renewable hydrogen. Establishing such a definition is crucial, as it provides Member States with the

[12] While accounting for hydrogen imports, the CBAM does not address the import of hydrogen derivatives, which could potentially represent a challenge for European producers.

information to what extent and under which condition renewable hydrogen and its derivatives will count towards the fulfilment of renewable energy and greenhouse gas reduction targets, outlined in the RED. Moreover, it provides the basis for designing funding schemes or other types of support schemes for renewable hydrogen production and use. Among other measures, this includes the introduction of quotas for renewable hydrogen and derivatives – so called **renewable fuels of non-biological origin (RFNBOs)** – as part of the RED III and other initiatives to promote their use in the transport and industry sectors (see more details on the specific quotas in section 2.2.3).

A set of eligibility criteria for being considered as an RFNBO has been defined in two so-called delegated acts (DAs), which specify elements of the RED. One DA specifies the methodology for assessing GHG emissions savings of 70 percent required for RFNBOs over their life cycle in order to be accounted towards the renewable goals (EC, 2023b). The other DA defines electricity sourcing criteria, i.e. the additionality of renewable energy feeding the production of hydrogen as well as geographical and temporal correlation of renewable electricity and hydrogen production (EC, 2023c). According to the current version, producers have several options for proving the renewability of hydrogen production, with different phase-in periods for related requirements starting in 2028 or 2030 respectively. Table 1 below provides an overview of the various options that have resulted from various interventions by Members of the European Parliament, national governments and private stakeholders to the Commission's initial proposal.

Table 1: Criteria for proving renewability of hydrogen production in the DA to the RED, based on method of renewable energy provision

Method of renewable energy provision	Additionality	Temporal Correlation
Direct use of renewable power without grid connection or at same grid node with smart metering system	Unsubsidised renewable plant not older than 3 years	No additional requirement
Grid-connected in a bidding zone with 90% renewable power	No additional requirement	No additional requirement
PPA with renewable power installation in same or adjacent bidding zone* with an average emission intensity over 64,8 CO_2eq/kWh	From 1.1.2028: PPAs with unsubsidised renewable plant not older than 3 years	Until 31.12.2029: same month From 1.1.2030: same hour**
PPA with renewable power installation in same or adjacent bidding zone with an average emission intensity under 64,8 CO_2eq/kWh	No additional requirement	Until 31.12.2029: same month From 1.1.2030: same hour**

Source. Authors based on EC (2023c)
* In case of adjacent biddings zones, the day-ahead spot market price for electricity in the adjacent bidding zone needs to be higher or equal to the price in the electrolyser's bidding zone for the relevant period.
** Temporal correlation is not required when day-ahead electricity prices are below €20/MWh or 0,36 times the EUA price per tonne of CO_2.

2.2.3 Creating demand for renewable hydrogen: quotas for RFNBOs and other renewable-based synthetic fuels

The introduction of quotas for RFNBOs and other synthetic fuels in the transport and industry sectors represents a central EU-level regulatory intervention to support the demand for hydrogen and its derivatives. The RED III introduces a combined advanced biofuels and RFNBO quota of 5.5 percent (with a minimum of 1 percent stemming from RFNBOs) in the transport sector by 2030 as well as a 42 percent RFNBO share in hydrogen use in industry (both for energy and non-energy purposes) by 2030 and 60 percent by 2035. As part of **the REFuel EU Aviation initiative**, the Council and the Parliament also reached a provisional political agreement to ensure EU airports provide a minimum share of sustainable aviation fuels (SAF), currently consisting mainly of biofuels, from 2025. This includes a minimum share of synthetic fuels, based on renewable hydrogen. SAF quotas should progressively increase from 2 percent in 2025, to 6 percent in 2030 and 70 percent in 2050. Synthetic fuel shares in the blend should reach 1.2 percent in 2030, progressively increasing to 35 percent in 2050 (EP & Council, 2023c). Finally, a provisional political agreement on the **FuelEU Maritime Regulation** sets increasing carbon intensity reduction targets from 2025 to 2050 for vessels above 5000 tonnes calling at European ports. The agreement includes a commitment to introduce a 2 percent renewable fuels usage target by 2034 if the RFNBO share in shipping fuels remains below 1 percent in 2031 (EP & Council, 2023a).

2.2.4 A supportive regulatory environment for hydrogen transport and storage

With its **Hydrogen and Decarbonised Gas Market Package**, the European Commission has launched a revision of the EU's existing Gas Directive and its Gas Regulation aimed at creating an enabling environment for the development of hydrogen-related transport and storage infrastructure. It is supposed to set out rules for the development of dedicated hydrogen networks. This legislative process is still ongoing and the starting trialogue will have to solve a range of questions, such as vertical and horizontal unbundling rules[13], caps for blending and cross-financing regulations. It also seeks to set the basis for another DA defining so-called low-carbon fuels. According to the legislative proposal by the European Commission as well as the positions of the European Parliament and Council, low-carbon hydrogen would need to meet a greenhouse gas emission reduction threshold of 70 percent (EC, 2021b). However, the methodology for proving this, including the specific scope of emissions, has yet to be defined and is not expected before 2024. Among other things, this definition will be the basis for potential exemptions from network tariffs.

2.2.5 Key challenges

The EU ETS as well as the target and sub-target architecture under the RED, the RefuelEU Aviation and FuelEU Maritime are the main EU-level regulatory elements to induce Member

[13] Unbundling rules refer to regulations aimed at separating generation, transmission and distribution (vertical unbundling) or ownership and management of the transmission or distribution infrastructure (horizontal unbundling) in order to support fair competition and transparency.

States and their market actors to develop renewable hydrogen projects and plans. However, it remains uncertain whether the introduced price and regulatory incentives provide a sufficient basis for driving the needed investments to scale-up hydrogen production and use to meet the EU's ambitions targets. While the EU represented a frontrunner in promoting an enabling regulatory framework for hydrogen, this original advantage has been eroded, due to lengthy decision-making processes. This is exemplified in the repeated delay in finalizing the DAs for the definition of RFNBOs as well as the Hydrogen and Decarbonised Gas Market Package, which is still under negotiation. The EU hydrogen framework remains incomplete with open questions on core issues, like the role of low-carbon hydrogen, financing of hydrogen infrastructure or the transposition of RFNBO quotas into national law.

Moreover, the EU regulatory approach is characterized by a high degree of complexity. This is exemplified by the multi-dimensional definition of RFNBOs and the various criteria with their own phase-in periods and exemptions. Similarly, the various quotas have differing timelines, exemptions and underlying definitions (i.e. combined biofuels and RFNBOs vs. sustainable aviation fuels). This not only makes it difficult for market participants to understand and comply with the respective requirements but also for Member States to implement the directives in a harmonized and market-friendly way.

2.3 Funding schemes in support of hydrogen-related investments in the European Union

Based on the evolving regulatory framework outlined in the previous section, the EU is increasingly developing mechanisms to channel funding to the hydrogen sector and to enable the financing of hydrogen projects by private actors and Member States. The most important schemes are outlined below. There are also a range of more general schemes that can be utilized for hydrogen-related investments but are not primarily aimed at these. These are not highlighted below.

2.3.1 Dedicated EU-level support for hydrogen-related investments

To date, the most significant amount of EU-level investment in hydrogen-related projects has been channelled through its research and innovation-oriented programs. Firstly, this includes funding disbursed via the Clean Hydrogen Partnership (previously known as the Hydrogen and Fuel Cells Joint Undertaking), including €1 billion in EU-funding from its **Horizon Europe** program over the period 2021 to 2027 with corresponding co-funding from industry. Since 2021, two calls for proposals have been launched, amounting to a total of €495 million in funding. This has included €105,4 million for projects in support of Hydrogen Valleys (Clean Hydrogen Partnership, 2023). In addition to the Clean Hydrogen Partnership, a range of other Horizon Europe programs, which target the decarbonization of end-use sectors, such as the European Partnership for Clean Aviation, have supported hydrogen-related end-use technologies.

On top of dedicated calls for hydrogen-related technologies in Horizon Europe, the **Innovation Fund,** has awarded €835 million to hydrogen-related projects. Of this, 95 percent went to beneficiaries in Sweden (€320 million), the Netherlands (€296 million), Germany (€96 million) and Finland (€88 million). An ongoing call dedicates an additional €1 billion to hydrogen-

related projects. The *Innovation Fund* was launched in 2020 and is funded with revenues from auctioning CO_2 certificates within the ETS, currently estimated at approximately €38 billion until 2030, depending on the development of the ETS allowances price. It is one of the world's largest funding programmes for the demonstration of innovative low-carbon technologies. The fund focuses on commercializing innovative clean technologies that are past the research stage but are not yet bankable. The EU's contribution is capped at 60 percent of the so-called relevant costs, that is the funding gap over a period of 10 years (based on both CAPEX and OPEX).

On the supply-side, the EU has announced **Pilot Renewable Hydrogen Auctions** as part of the Communication on the EU Hydrogen Bank (EC, 2023d), partially financed by the Innovation Fund. They will provide a production subsidy for renewable hydrogen produced in the European Economic Area (EEA), in the form of a fixed premium paid per 1 kg of renewable hydrogen over a period of up to 10 years. The first pilot auction is planned for November 2023 and will have a dedicated budget of €800 million. The EU Hydrogen Bank is also meant to comprise a second funding stream for hydrogen imports from non-EU countries, which will be administered by the H2 Global Foundation launched by the German government.

In addition to quotas for RFNBOs and other hydrogen-based fuels, EU-level demand-side support in the form of **Carbon Contracts for Difference (CCfDs)** have been pledged to promote the use of hydrogen to decarbonize energy-intensive industry, also to be funded via the Innovation Fund. CCfDs compensate the difference between the CO_2 abatement cost (or CO_2 "strike price") and the current carbon price in the EU ETS that producers would have to pay when relying on conventional, high-emission technologies. CCfDs will be awarded based on price-competitive bidding and for a period of ten or more years.

Within the European Green Deal Industrial Plan, the EU had announced the so-called **Sovereignty Fund** to support investments in manufacturing of strategic net-zero technologies, including electrolysers, fuel cells and other RFNBO technologies, within the EU (EC, 2022a). However, the aim of generating additional resources for this purpose has given way to the creation of the **Strategic Technologies for Europe Platform (STEP)**, which aims to "reinforce and leverage existing EU instruments" (EC, 2023e) to mobilize funding. While an additional €10 billion are envisaged by the European Commission to be provided by the Member States, this is dependent on the development of the Multiannual Financial Framework (MFF) discussion. Up until now, the Member States have not agreed to contribute these new means.

Finally, as already mentioned in section 2.1.4, sub-national authorities already have the possibility of funding hydrogen-related activities via the **EU's cohesion policy funds**, including the European Regional Development Fund (ERDF) and the recently created Just Transition Fund. The European Hydrogen Valley Partnerships within the EU's Smart Specialization Platform supports strategy development for this purpose. STEP aims to provide some additional incentives to invest in strategic net-zero technologies within cohesion policy funds by offering higher levels of pre-financing and co-financing for this purpose (EC, 2023e).

2.3.2 Enabling funding of hydrogen-related investments by the Member States

Another important channel for EU-level hydrogen-related funding has been the **Recovery and Resilience Facility (RRF).** The RRF is financed via EU-level debt, which is turned over to Member States for disbursement based on their National Recovery and Resilience Plans.

According to the Recovery and Resilience Scoreboard, as of 2021 15 Member States[14] had included hydrogen-related investments in the National Recovery and Resilience Plans, amounting to planned investments of €9,3 billion.

The European Commission has also taken measures to enable the mobilisation of public investments by Member States. One avenue has been the relaxation of restrictions on state-aid for certain projects in the sphere of environment, climate and energy (**Guidelines on State aid for climate, environmental protection and energy**) (EC, 2022b). This was expanded within the **Temporary Crisis Framework**, introduced in March 2022 in the wake of the invasion of Ukraine and then prolonged (until 31st of December 2025) and further expanded a year later in the context of the **Temporary Crisis and Transition Framework (TCTF)** (EC, 2022d). Furthermore, the so-called **General Block Exemption Regulation (GBER)** relaxes restrictions on state-aid on investments related to renewable hydrogen. The TCTF provides further amendments to simplify procedures and increase aid ceilings under certain circumstances (EC, 2023a). State aid for renewable hydrogen projects as well as manufacturing of electrolysers fall under the scope of the TCTF.

Another avenue for disbursing hydrogen-related state subsidies falls under the framework for **Important Projects of Common European Interest (IPCEI).** IPCEIs are multi-country projects that are considered important, due to their contribution to EU objectives, and fulfil a number of criteria justifying public support, such as their level of innovation or expected positive spill-over effects (EC, 2021a). Two hydrogen IPCEIs, totaling 76 sub-projects, have been launched with €10,6 billion in investment support in 16 countries.[15] A significant share of this will be supported with funding from the RRF. While IPCEIs may be supplemented with direct EU-level funding, this has not been the case for the two hydrogen-related IPCEIs.

In addition to IPCEIs, the main vehicle for supporting the long-term goal of developing an interconnected European hydrogen grid is the EU policy in support of **Trans-European Networks for Energy (TEN-E)**. The revised TEN-E regulation issued on June 23, 2022 defines three priority hydrogen corridors in Western Europe (HI West), in Central and Eastern Europe (HI East) and around the Baltic Sea (BEMIP Hydrogen). On this basis, a new list of so-called Projects of Common Interest (PCIs) will be defined in support of these and other priority infrastructure in the field of electricity by the end of 2023 (EP & Council, 2022a). Selected projects will be considered high-priority and can benefit from expedited permitting procedures and can apply for financial assistance from the **Connecting Europe Facility (CEF)**, which has allocated €5,8 billion in funding for energy-related projects in the period from 2021 to 2027 (EP & Council, 2021).

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[14] As of 2021, the following Member States had added specific hydrogen investment programs to their clean power programs: Austria EUR 176 million, Belgium EUR 111 million, France EUR 500 million, Germany EUR 2,047 billion, Italy EUR 1,690 billion, Portugal EUR 3.29 million, Romania EUR 15 million, Spain EUR 1,555 million additional for hydrogen. Source: https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/assets/thematic_analysis/5_Modernisation.pdf

[15] Among these countries, France (15 Hy2Tech and 2 Hy2Use), Italy (10 Hy2Tech and 4 Hy2Use) and Spain (4 Hy2Tech and 7 Hy2Use) have the most approved IPCEI sub-projects, followed by the Netherlands (1 Hy2Tech and 8 Hy2Use), Austria (5 Hy2Tech and 2 Hy2Use), Belgium (2 Hy2Tech and 4 Hy2Use) and Germany (6 Hy2Tech) (see graphs).

As part of the Communication on the EU Hydrogen Bank (EC, 2023d), the Commission is also proposing the concept of **Auctions as a Service** to support Member States in auctioning electrolyser capacities. The intention is to allow Member States to top-up EU-wide auctions for electrolyser capacities with national funds for national applications not cleared within the EU-wide budget. This would remove the need for both setting up national auction schemes and having them approved with regard to the State Aid Guidelines by the Commission. The exact conditions are not yet clear, and it remains to be seen whether this can be set up in a way favourable to Member States.

These channels for disbursing national funds are to be complemented by public procurement provisions recently announced in the **Net-Zero Industry Act** (EC, 2023f). The Act aims at boosting domestic manufacturing of so-called net-zero technologies, including fuel cells and electrolysers. It mandates the use of innovation, sustainability and resilience-related criteria for this purpose. The criteria should complement existing price and functionality-related criteria and should receive a weight of 15 to 30 percent. Specifically, when implementing the resilience criteria, this means that procurement should support diversification of suppliers wherever the EU relies on 65 percent or more of imports from a single source. It is expected that these new criteria will provide a more favourable environment for investment in the production of equipment produced in the EU or countries with similarly stringent environmental standards. However, a proposed 10 percent cap on additional cost potentially limits the implementation of these new award criteria.

2.3.3 Key challenges

Similar to the hydrogen-related regulatory landscape outlined in section 2.2, investment support for hydrogen projects in the EU suffers from a high degree of fragmentation and complexity. Accessing EU-level funds involves a host of regulatory hurdles and funding scheme-specific eligibility criteria and support mechanisms. Vehicles for enabling state-aid from Member States, such as IPCEI, TEN-E or exceptions granted under the TCTF, all require lengthy and complicated approval processes, constituting bureaucratic burdens for hydrogen projects.

While the European Green Deal Industrial plan intends to speed-up state aid approval processes, the increased use of national-level state-aid poses the risk that hydrogen-related investments are concentrated in those Member States with the greatest fiscal capacity. This is likely to leave behind a series of countries with high renewable energy potential. EU-level funding schemes, like the existing Innovation Fund or the planned Pilot Renewable Hydrogen Auctions and Carbon Contracts for Difference, could offer a counterweight to this trend. However, as the funding commitments of the Innovation Fund indicate, initial project funding also tends to reward beneficiaries in countries with higher fiscal capacity.[16] Moreover, to date, the volume of these hydrogen-specific funding schemes is relatively small compared to the funds allocated in important Member States like Germany and France. As outlined in section 2, these countries have allocated €10 billion and €9 billion to their hydrogen strategy

[16] Indeed, the lack of geographical balance within the context of the Innovation Fund has already been identified as a more general challenge by the European Commission. See https://ec.europa.eu/commission/presscorner/detail/en/QANDA_23_3788

implementation. This compares to less than €20 billion EU-level funding for hydrogen-related investments in projects across the entire EU (see Figure 5). The Recovery and Resilience Facility currently offers the most substantive EU-level scheme in terms of funding volume. However, given its nature as a vehicle primarily for channelling debt to Member States, it does not substantively enhance the fiscal space for pursuing hydrogen-related investments.

Cohesion policy funds do offer a well-established vehicle that could channel support specifically to regions with high renewable energy potential but relatively low fiscal capacity. However, for now, regional hydrogen valley initiatives are also concentrated in high-capacity Member States, indicating that the overall enabling environment in Eastern and Southeastern Europe is not yet in place to stimulate more ambitious hydrogen-related activities. Moreover, it is questionable whether regional schemes are sufficient to promote large-scale investments in hydrogen production or industrial end-uses.

3 Policy Recommendations

This review of hydrogen developments and key policies in the EU has shown that **there is significant renewable energy potential within Europe** that could be mobilized to meet a large share of domestic hydrogen demand. However, this potential is not only spread unevenly across countries. There is also a significant **mismatch between those countries with significant renewable energy potential and those investing most actively in the development of the sector**. Rather, a key factor in driving policy ambition and related project pipelines is the fiscal capacity to support hydrogen investments. As a result, some of the most ambitious Member States in terms of hydrogen policy and in terms of emerging project pipelines - most notably Germany - are also countries that are likely to suffer from a substantial renewable energy deficit in the context of their decarbonization scenarios.

In this vein, current trends indicate that the **EU is failing to leverage its full potential** for meeting its ambitious renewable hydrogen targets. Moreover, investments in both hydrogen production and use are **leaving behind some of the most promising regions** in terms of long-term potential to generate surplus renewable energy. A notable exception is the Iberian Peninsula, where Spain and Portugal are both actively engaging in the development of the sector.

Clearly, existing industrial clusters in Northern Europe represent an important source of potential demand for renewable hydrogen and, therefore, justify investments in local hydrogen supply. However, likewise, long-term potential for generating excess renewable energy may serve as an important advantage for investment in downstream industries, such as decarbonized steel and chemicals, including synthetic fuels. Indeed, where fiscal capacity and renewable energy potential coincide, such as in Sweden, ambition to develop such industries is apparent. For the long-term development of carbon-neutral industries within the EU, **it is important that intrinsic advantages related to the availability of renewable energy can be effectively mobilized for a competitive hydrogen economy. To ensure that investments can be allocated in the most promising locations across the Union, providing unbiased access to public fiscal support for hydrogen development across EU countries is essential.**

A second major issue relates to the **high level of complexity of EU regulations and support schemes**. The simplicity of the new tax-based incentive schemes under the US Inflation Reduction Act represents a stark contrast to the complex regulatory and administrative landscape in the EU. This complexity reduces the overall attractiveness of the EU for large-scale investments in the hydrogen sector. It may also reinforce the bias towards investments in those Member States that can offer national funding schemes that are independent from EU-level funding schemes, such as subsidies granted under the Guidelines on State aid for climate, environmental protection and energy.

The following recommendations address both of these challenges, identifying possibilities to tackle them either separately or jointly.

3.1 Recommendations for EU-level action

Recommendation 1: Scale-up and consolidate dedicated EU-level funding for renewable hydrogen production and use

An obvious entry-point for counterbalancing the current bias in favour of renewable hydrogen investments in countries with high fiscal capacity rather than high renewable energy potential would be to enhance EU-level funding for renewable hydrogen production and use. **To be effective, the funding volume of EU-level schemes would have to approach the level of state-aid being provided at the national level**. This would require additional financing, which could be organized via the introduced Strategic Technologies for Europe Platform, as proposed by the European Commission. Regardless of the financing modality, this should translate **into larger scale and consolidated support via planned renewable hydrogen auctions (on the supply-side) and CCfDs (on the demand-side).** As outlined in this paper, it should be in the very own interest of hydrogen deficit countries, such as Germany and the Netherlands, to make sure that there is sufficient EU-level funding available to finance the hydrogen ramp-up in Member States with high renewable potential but lower fiscal capacities.

Furthermore, future windows of the European Hydrogen Bank could also include dedicated auctions for structurally disadvantaged regions and should be complemented with technical assistance for project preparation in such regions, as is the case for the Innovation Fund. **It should be underlined that demand-side schemes should receive equal importance in this context, as demand centres for renewable hydrogen are likely to constitute an important factor in determining the location of hydrogen production.** This way investments along the entire hydrogen value chain – from supply to end-use - could be incentivized in countries with abundant renewable resources.

Finally, to avoid amplifying the bias in favour of richer Member States, **EU-level schemes should pose strong restrictions on cumulation with state aid for the same hydrogen projects**. This is particularly crucial when it comes to auction-based schemes. Hence, it is good news that the planned pilot auctions under the umbrella of the EU Hydrogen Bank set a positive example in that regard. Conversely, exempting the cumulation with cohesion policy funds rule could offer an additional incentive for investments in less-developed regions.

Recommendation 2: Introduce cross-border renewable hydrogen auctions

Another option for channelling investment to Member States and regions with high renewable energy potential but a relatively constrained fiscal capacity could be the use of cross-border renewable hydrogen auctions. In the upcoming revision of the Governance Regulation, which already includes the Renewable Energy Financing Mechanism for cross-border renewable electricity financing, a corresponding scheme could be established for renewable hydrogen. Among other things, **Member States could operate cross-border auctions with other EU Member States in order to fulfil their national RFNBO quotas**. The RED allows Member States to agree on a split between importing and exporting countries, when accounting for the use of RFNBOs. By developing such agreements with Member States with a potential hydrogen deficit, Member States with high renewable energy potential can contribute to the EU-wide ramp-up of hydrogen, while contributing to fulfilling their national quota. Moreover, the **proposed Auction-as-a-Service scheme under the domestic arm of the European hydrogen bank (see section 2.3.2) could be extended to such cross-border**

renewable hydrogen auctions, based on bi- or multilateral agreements between groups of Member States willing to do so.

Recommendation 3: Introduce national renewable electricity targets to identify priority areas for hydrogen investment

Not only is it crucial that investments are channelled to countries with high potential for renewable energy. But **it is equally important that investments in renewable hydrogen accelerate in tandem with investments in renewable energy more broadly.** The EU's additionality requirements seek to address this problem by ensuring that renewable hydrogen projects are exclusively powered by newly created - or "additional" - renewable energy installations. However, additionality requirements alone cannot ensure that renewable hydrogen projects do not - at least partially - replace investments in renewables in the power sector. As a result, there is a risk that the expansion of renewable hydrogen could slow down decarbonization of the power sector. This is of particular concern in countries with a future renewable energy deficit.

To avoid such a risk, the EU could introduce a system of national renewable electricity targets that are compatible with the EU's pathway to climate-neutrality by 2050. Targets for 2030 and beyond, including yearly interim targets, could be introduced in the context of the review of the Regulation on the Governance of the Energy Union and Climate Action in 2024. The definition of such targets could build on the existing formula for determining the national contributions for the share of energy from renewable sources in gross final energy consumption in 2030 in the existing governance regulation (EP & Council, 2018). **Indeed, if sufficiently ambitious, such targets would offer a more effective safeguard than additionality requirements alone against the risk of renewable hydrogen investments slowing down decarbonization of the power sector.**

In a first step, such a harmonized target system could remain voluntary and could be utilized as the basis for granting exemptions from additionality requirements for those countries that meet or exceed their interim renewable energy targets. Such an approach would allow countries that have ensured that the decarbonization of the electricity sector remains on track to reduce regulatory complexity and boost their attractiveness for investments in renewable hydrogen as well as the related downstream industries. Building on the conditions of the Renewable Energy Financing Mechanism established in Art. 33 of the Governance Regulation, such exemptions might be granted on the basis of progress reports on the NECPs, which are submitted every two years by Member States. In addition, such a target system could serve as a framework for granting additional financial incentives within hydrogen-related funding schemes at EU-level to high-performing countries. **At a later stage, such targets could be made mandatory in the context of a further revision of the RED**.

3.2 Recommendations for action by Member States

Recommendation 4: Develop bilateral or regional hydrogen partnerships between potential surplus and deficit countries in the EU

As outlined in section 2.1, EU-level coordination and exchange on national hydrogen policy remains limited. The EU Hydrogen Energy Network, the only platform for inter-governmental exchange, facilitates only basic information exchange. **Establishing bilateral or regional hydrogen partnerships could help deepen intra-European cooperation, in particular between potential surplus and deficit countries.** Firstly, such partnerships could facilitate knowledge exchange and mutual learning. This could help align national hydrogen strategies with EU targets and facilitate early agreement on EU-level hydrogen dossiers as well as their harmonized transposition into national law. The latter could accelerate the completion of the European regulatory framework for the hydrogen sector, which is needed to provide basic regulatory certainty for investors. Secondly, **such partnerships could provide the basis for agreeing on a split between importing and exporting countries when accounting the use RFNBOs towards the fulfilment of renewable targets.** As mentioned in recommendation 2, such agreements would allow Member States with high renewable energy potential to contribute to the EU-wide ramp-up of hydrogen, while also supporting the fulfilment of their national quota. This could be further enhanced by introducing cross-border auctions.

Recommendation 5: Focus support for hydrogen use in hard-to-electrify sectors, in particular in countries with a future deficit in renewable energy generation

The comparison of renewable energy potentials with the potential electricity demand for supplying energy-intensive industries, aviation and the maritime sector has shown that some Member States will not be able meet the demand of these hard-to-electrify sectors domestically at reasonable hydrogen production costs. Their deficit will increase substantially if hydrogen is allocated to sectors with cheaper mitigation options, such as residential heating and road transport. In these countries there is a clear benefit in focusing hydrogen use on hard-to-electrify sectors. It will limit their future need for hydrogen imports and strengthen the resilience of their energy sector.

Therefore, countries with a future renewable energy deficit should restrict national support schemes to hard-to-electrify sectors. To ensure that hydrogen is allocated to these sectors, demand-side schemes focusing on energy-intensive industries and the maritime and aviation sectors should be prioritized over supply-side support schemes. Alternatively, supply-side schemes can be designed for use in the hard-to-electrify sectors by requiring offtake agreements from the hard-to-electrify sectors for at least a substantial share of the production. The German H2 Global scheme, for instance, where the government conducts auctions for the supply with renewable hydrogen derivatives as well as its subsequent offtake, offers a suitable framework for this. In this case, the auctions for hydrogen use could be restricted to selected end-uses.

It is also sensible to reduce overall demand for hydrogen within the EU as a whole. This lower overall demand for renewable energy and alleviate the need to navigate trade-offs between large-scale domestic deployment and dependency on imports from non-EU countries. **Hence, EU-funding should also clearly prioritize hydrogen use in hard-to-electrify sectors to**

ensure that domestic resources will be able to meet a significant share of internal demand.

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List of acronyms

CBAM	Carbon Border Adjustment Scheme
CCfDs	Carbon Contracts for Difference
CEF	Connecting Europe Facility
ECH2A	European Clean Hydrogen Alliance
ERDF	European Regional Development Fund
EU	European Union
EU ETS	EU Emissions Trading Scheme
GBER	General Block Exemption Regulation
GW	Gigawatt
IPCEI	Important Projects of Common European Interest
NECP	National Energy and Climate Plan
RED	Renewable Energy Directive
RFNBO	Renewable Fuel of Non-Biological Origin
RRF	Recovery and Resilience Facility
MWh	Megawatt-hour
SAF	Sustainable Aviation Fuel
TCTF	Temporary Crisis and Transition Framework
TEN-E	Trans-European Network of Energy
TWh	Terawatt-hour

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