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2024 State of the European Hydrogen Market Report

OIES ENERGY COMMENT

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Key Takeaways

- Developing a hydrogen economy is one of the critical requirements for the achievement of the 2050 Net Zero target as well as in the consideration of the interim 2040 target.
- Like many of the EU climate policies, hydrogen policy is currently overly regulatory in nature, rather than a more market driven approach with technological neutrality.
- In 2023, important progress has been made in completing the regulatory framework on the low-carbon hydrogen market in the EU and UK. However, some important parts of the policies are still missing, particularly in the EU.
- The EU and UK regulatory approaches are different: (1) the UK is technology neutral, as long as it is sustainable, that is, as long as the hydrogen's carbon intensity is lower than 20 gCO2e/MJ, while the EU requires technology to be only renewable (in accordance with RED II definition); (2) the UK framework includes a set of implementing acts and a production support approach, while the EU relies on Member State decisions, in particular on implementation of targets and quotas.
- However, it is too early to say which is the winning approach, as the EU and the UK have not made significant progress on the low-carbon hydrogen market deployment in 2023 and it is most unlikely that the EU and UK targets for 2030, in terms of low-carbon hydrogen production, will be achieved.
- The lagging growth of the EU and UK low-carbon hydrogen market has a negative impact on the environmental delivery which remains mainly dependent on changes to current hydrogen production and increased efficiency. This is demonstrated by the very low level of committed supply compared to both announced projects and ambitious targets which have been set.
- European governments have made low to moderate progress on nine key performance indicators (KPIs) for low-carbon hydrogen. More ambitious policy implementation is needed to kickstart a European hydrogen market.
- Government funding and local content requirements in hydrogen projects have shown the most progress. Europe has announced one of the largest budgets for low-carbon hydrogen which is set to lead to more final investment decisions once funding is allocated. However, further work is required to translate that willingness into actual project commitments. Domestic electrolyser manufacturers currently dominate sales to European hydrogen projects, accounting for 80-90% of sales since 2022, far exceeding the Net Zero Industry Act target of 40%. However, the funding seems concentrated in limited number of countries in EU.
- More progress is needed on implementing quotas for hydrogen use and expanding domestic electrolyser manufacturing. EU quotas for hydrogen use could create 2-3.8 million metric tons (Mt) of demand by 2030, far below the REPowerEU target to use 20Mt. The slow implementation of quotas on a national level is creating further uncertainty for project developers, leading to delays in investments.
- Progress on raising domestic supply and demand is lacking as most projects are failing to make it out of planning stages. Just 3.6% of supply planned for commissioning by 2030 is past final investment decision or operational. Only 4.5% of supply needed to meet the REPowerEU demand target has signed a binding offtake agreement. There is not yet sufficient incentive for potential offtakers to commit to purchase quantities of low-carbon hydrogen to support the targets. The end use for much proposed hydrogen supply is unclear.
- Over the next 12 months, key things to look for which could indicate significant progress: (a) how many of the projects which won the first European Hydrogen Bank auction actually progress to FID and start construction, (b) whether significant FIDs are taken on UK low-carbon hydrogen projects (c) how many firm offtake agreements are signed between customers and suppliers.

1. Background

The State of the EU Hydrogen Report is an independent initiative that is not intended to duplicate or replace mandated work undertaken by the EU or other institutions.

The report is intended as a 'snapshot', providing policymakers and stakeholders with an overview of how the European hydrogen market is progressing each year, based on the previous year's data. Despite the limitations imposed by the availability of publicly accessible data, the Report analyses relevant key performance indicators (KPIs) to assess the status and the development of the EU hydrogen market.

This report has been the subject of stakeholder consultations organised by the authors and feedback has been provided by different stakeholders including NGOs, think tanks, academia, policymakers, market participants, and industry representatives.

The views expressed in this report are solely those of the authors in their personal capacity and do not reflect the opinions of any associated institutions.

2. Introduction to hydrogen

As context for the rest of the report, this section introduces the topic of hydrogen as part of a decarbonised energy system, highlighting (a) the demand drivers for low-carbon hydrogen, (b) the potential production routes and (c) the infrastructure requirements. It considers some of the key challenges and possible paths forward which will help to interpret the data presented in subsequent sections. Further details on many of the issues raised in this section can be found in a recent OIES publication "Clean Hydrogen Roadmap"[1].

Demand drivers for low-carbon hydrogen

In this report, we define low-carbon hydrogen as hydrogen, regardless of production process, with a significantly lower carbon footprint than traditional fossil fuel derived hydrogen.

The underlying and most important observation is that at this time, the driver for low-carbon hydrogen demand is government decarbonisation policy. The vast majority of hydrogen currently used is in oil refining, ammonia-based fertilisers and other petrochemicals. Nearly all of that hydrogen is "high-carbon" fossil-fuel derived hydrogen (when produced from natural gas, 1 tonne of hydrogen produces around 10 tonnes of CO_2), and on current projections, any form of lower carbon hydrogen will be at significantly higher cost.

Similarly, potential novel uses of hydrogen (e.g. reduction of iron ore, decarbonisation of aviation and international shipping) are also higher cost than current alternatives. Thus, in the absence of government policy, significant demand for low-carbon hydrogen would not exist as customers would tend to choose the lower cost alternatives. For this reason, this report contains sections on the regulatory and policy framework supporting hydrogen development in the EU and the UK.

Assuming that the underlying decarbonisation policy driver is in place, hydrogen is not a universal solution for all sectors and its suitability varies by end use. These priorities may evolve over time as technology develops which may impact hydrogen's competitiveness compared to other decarbonisation alternatives. An underlying principle which appears unlikely to change is that, wherever feasible, direct electrification is likely to be more efficient, lower cost and hence preferable to use of hydrogen.

Hydrogen will, however, be necessary in some applications. Firstly, there is a need to decarbonise the current high-carbon hydrogen use as a feedstock in refineries, ammonia and petrochemicals, as referred to above. Current global hydrogen demand is estimated at 95 million tonnes of which around 8 million tonnes is in Europe[2]. Less than 1 million tonnes of current global hydrogen demand is from low-carbon sources.

[1] https://www.oxfordenergy.org/publications/clean-hydrogen-roadmap-is-greater-realism-leading-to-more-credible-paths-forward/

[2] IEA Global Hydrogen Review 2023 https://www.iea.org/reports/global-hydrogen-review-2023

Hydrogen should also be used for the decarbonisation of some other industrial applications, particularly in the iron and steel industry. With a need to move away from use of coal in blast furnaces, one of the most promising low-carbon alternatives is use of hydrogen in the direct reduction of iron (DRI) process. Some significant demonstration projects are under construction, notably in Sweden[3]. Other European steel makers are also developing plans for introduction of DRI into their processes. One uncertainty which will be important to track over the coming years is the extent to which the transition to low-carbon hydrogen may result in some industrial relocation: there could be a logic for DRI processes to be carried out in regions of the world with the lowest cost renewable power and suitable iron ore (e.g. Australia, South America) rather than importing low-carbon hydrogen for a DRI process in Europe.

A third area for the use of hydrogen will be in production of hydrogen derivatives as ammonia and "e-fuels" – synthetic hydrocarbons derived from renewable hydrogen combined with a carbon source (preferably biogenic or otherwise non-fossil carbon). It is likely that over time some existing oil refineries will evolve into e-fuel production facilities, probably with integrated low-carbon hydrogen production.

In all of these first three uses, it is notable that hydrogen is being used as a feedstock to an industrial process rather than directly being used as an energy vector. The remaining potential uses of hydrogen are as an energy vector, but here there will be greater competition from other alternatives.

Hydrogen is likely to play some role in long-duration energy storage, in order to balance power grids at times when there is insufficient wind and solar generation and the storage capacity of batteries and other sources of flexibility has been exhausted. A recent report considering the future Great Britain electricity system concluded that there could be a need for between 60 and 100 TWh (2 to 3 million tonnes) of hydrogen storage in underground salt caverns – or about double the energy storage capacity of the current natural gas storage capacity in the UK – to provide security of supply for periods of low wind and low sun.[4]

Finally, hydrogen may play some role to support direct electrification in areas like road and rail transport, space heating and industrial heat. In recent years, however, as battery and heat pump technology has developed and reduced in cost, the role of hydrogen in such areas appears to be limited to smaller and smaller niche applications (for example glass manufacturing and very long-distance road transport where direct electrification is particularly challenging).

Low-carbon hydrogen production routes

The two leading contenders for low-carbon hydrogen production are (a) electrolytic hydrogen using zero-carbon electricity such as renewables or nuclear (called "green" hydrogen if renewables are used) and (b) hydrogen from natural gas with carbon capture and storage (CCS) (sometimes called "blue" hydrogen). Both routes have distinct advantages and challenges.

Electrolytic hydrogen has the advantage of being potentially zero-carbon but requires significant amounts of power generation in addition to that required for immediate electricity demand. For example, the REPowerEU target[5] of 10 million tonnes renewable hydrogen production within EU by 2030 would require 500 TWh of additional power generation – or 18per cent of EU's electricity production in 2021[6] – and over 125 GW of electrolyser capacity, so is very unlikely to be achievable.

In some parts of Europe, nuclear power is an alternative source of low-carbon electricity to power electrolysers: both will be considered in our analysis. In addition to the scale challenge, electrolytic hydrogen is also estimated to be considerably more expensive than existing high carbon hydrogen. While actual costs vary from case to case, indicative data suggests that current hydrogen costs are in the range 1 to 3 €/kg, electrolytic hydrogen is likely to be well in excess of 5 €/kg.

[3] Hybrit https://www.hybritdevelopment.se/en/ and H2 Green Steel https://www.h2greensteel.com/
[4] https://royalsociety.org/-/media/policy/projects/large-scale-electricity-storage/large-scale-electricity-storage-report.pdf
[5] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0230
[6] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_production,_consumption_and_market_overview

CCS-enabled hydrogen has had a mixed reception in different European countries. The UK has included it in its low-carbon hydrogen policies from the outset, and the Netherlands has developed plans for CCS (including the Porthos project which has taken the final investment decision[7]). Originally, European Union policy focused almost exclusively on electrolytic hydrogen, but during 2023, several policy announcements indicated a growing acceptance that CCS would play a significant role in decarbonisation.[8] While CCS-enabled hydrogen is likely to be lower cost than electrolytic hydrogen, development of the required infrastructure at sufficient scale will remain challenging.

This report will track the status of both electrolytic and CCS-enabled hydrogen.

Midstream infrastructure requirements

For hydrogen to reach its customers it is important to consider the whole supply chain, and midstream infrastructure is a vital part of that chain.

Most hydrogen today is used very close to its point of production, recognising that transport of hydrogen adds significant additional costs. To balance demand, however, some transport will be required, although the extent of this is difficult to predict at this early stage in the development of the industry. Pipelines are likely to be the most cost-effective way to transport hydrogen over distances up to around 2000km[9], sufficient for most intra-European requirements. A difficult dilemma is the linking of investment in pipeline infrastructure with the timing of production and demand to make use of the infrastructure. If large pipeline capacity is built well in advance of likely demand, there is a risk that the investment may become a regret and the pipeline a stranded asset. At this stage, it is likely that initial hydrogen transport will take place within industrial clusters, with subsequent links between such clusters.

Another key part of midstream infrastructure is the development of sufficient hydrogen storage capacity. With potentially intermittent production (linked to renewable power generation) and more steady-state customer demand (for example in an industrial process), storage will play a vital role. As noted earlier, use of hydrogen for balancing power grids at times of low renewable generation could also require significant storage. Large scale hydrogen storage has been demonstrated in underground salt caverns in UK and USA, and further projects are under development in the Netherlands and the USA.[10] Storage will be particularly challenging in locations without suitable geological storage structures – most crucially salt deposits suitable for the development of salt caverns.

A third part of mid-stream infrastructure, perhaps in the longer term, is likely to be development of import terminals for low-carbon hydrogen derivatives like methanol and ammonia. These derivatives could be used as final products (for example in the chemical industry), or the terminals could be combined with ammonia cracking or methanol reforming facilities to recover the hydrogen. Each additional process step increases cost and complexity and reduces efficiency of the overall supply chain, so the competitive landscape will be an important determinant of the speed of development of these facilities.

Key Challenges and path forward

As the above discussion shows, all aspects of the hydrogen supply chain have challenges, particularly around creating a business case to justify investments. Commercial structures, policy support and regulatory frameworks are all important to help create that business case. Subsidy auctions (like those of H2 Global and the European Hydrogen Bank) will be key enablers to provide the required support, so this report will track progress of these measures and, over time, it should become clearer which policy measures are most effective at achieving results.

[7] https://www.porthosco2.nl/en/
[8] See for example, Commissioner Simson's speech to the EU CCUS forum in Denmark in November 2023: https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_23_6086
[9] IEA Global Hydrogen Review 2023 https://www.iea.org/reports/global-hydrogen-review-2023
[10] https://www.hystock.nl/en/about-hystock/the-project, https://aces-delta.com/hubs/

3. Regulatory developments

The goal of this chapter is to offer an overview of the hydrogen regulatory framework in the EU and in the UK. Since the report is a 'snapshot' of 2023, the developments which occurred in that year are specified. After discussing the EU and the UK respective frameworks, a comparison of the two has been made to highlight their similarities and differences. Finally, in order to provide a glance to the rest of the world, US and China hydrogen markets are mentioned.

3.1. EU Regulatory Developments

3.1.1 Overview of EU Policies Concerning Hydrogen & Financing

This sub chapter focuses on two topics. The first part (3.1.1) identifies and provides an overview of the policies containing provisions on hydrogen, specifying which aspects of hydrogen they address, and how they impact the components (supply, demand, infrastructure) of the EU hydrogen market. The second part (3.1.2) offers an insight in the financing of the EU hydrogen framework, categorizing the instruments available according to the type of support they provide, their deployment stage, the technologies they cover, and whether they are open to applications from all EU Member States.

Overview of EU Policies Concerning Hydrogen

The Table below classifies the policies which contain provisions on hydrogen according to whether they are impacting the supply, demand and/or infrastructure.

Table 1: Components of the EU H_2 regulations

Components of H_2 Market	**Policies (communications, directives, regulations, delegated acts)**
Supply	EU Hydrogen Strategy, RED II Delegated Acts, Hydrogen and Decarbonised Gas Market package, EU Taxonomy, Net Zero Industry Act, REPowerEU Plan, RefuelEU Aviation, Critical Raw Materials Act
Industrial and Transport Demand	EU Hydrogen Strategy, recast Renewable Energy Directive (RED III), REPowerEU Plan, Carbon Border Adjustment Mechanism (CBAM), FuelEU Maritime, RefuelEU Aviation, EU ETS
Infrastructure	EU Hydrogen Strategy, Hydrogen and Decarbonised Gas Market package, Net-Zero Industry Act, Alternative Fuels Infrastructure Regulation (AFIR), Trans-European Transport Network (TEN-T), Trans-European Networks for Energy (TEN-E), Critical Raw Materials Act

EU Hydrogen Strategy[11]

Objectives of the EU Hydrogen Strategy: the Hydrogen Strategy serves as an initial long-term policy declaration by proposing a strategic roadmap for hydrogen uptake in the EU economy. As such, it elaborates on the technological deployment phases, supporting policy framework, market and infrastructure development, research and innovation opportunities, and international dimension.

[11] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0301

It set an intermediate 2030 objective of up to 10 million tonnes of renewable hydrogen (see Chapter 4, KPI 3) produced in the EU to reach carbon neutrality in 2050[12]. Low-carbon hydrogen is considered as a transitional energy source.

On hydrogen demand, the Strategy envisages the need for dedicated demand-side policies for industrial demand to gradually include new applications, including steelmaking, refineries, chemical applications and transport applications. On the supply side, the importance of developing and scaling up hydrogen supply chain is mentioned. Finally, the Strategy recognized the need for an EU-wide logistical infrastructure which is key to transport hydrogen from the areas where it is produced to the areas where it is needed, linking producers and consumers.

EU Taxonomy[13]

- **Objectives of the EU Taxonomy**: establishing a classification system that identifies which economic activities can be considered environmentally sustainable, within the framework of the European Green Deal. In particular, the EU Taxonomy aims to help companies in making informed sustainable investment decisions, be eligible for green bonds, and limit the risk of "greenwashing". This is in contrast to a market-based approach that would be focused on emissions intensity only.
- **Hydrogen provisions**: the production of hydrogen and other hydrogen-based fuels can be considered sustainable under the EU Taxonomy even if the energy used is not renewable, as long as the product achieves a 70 per cent reduction in life cycle GHG emissions compared to the fossil fuel comparator of 94 g CO2e/MJ[14](28.2 g CO2e/MJ). By providing a list of environmentally sustainable economic activities, the EU taxonomy will have an impact on investments, redirecting them to those activities that are included in the scope of the regulation.

Fit for 55 package

The Fit for 55 package does not have a specific directive/regulation on hydrogen. The EU hydrogen regulatory framework is scattered across the building blocks of the Fit for 55. The regulations that directly concern hydrogen are:

a) **Hydrogen and Decarbonised Gas Market package** revision[15]

- **Objectives of the Hydrogen and Decarbonised Gas Market package**: enabling the market to decarbonise gas consumption, ensuring energy security, facilitating the establishment of optimal and specialized infrastructure for hydrogen to ensure a more integrated network planning between electricity, gas, and hydrogen networks[16].
- **Hydrogen provisions**: the Hydrogen and Decarbonised Gas Market package establishes a system of terminology and certification of low-carbon hydrogen and low-carbon fuels. To be deemed as such, low-carbon hydrogen shall meet a GHG emission reduction threshold of 70 per cent vs the fossil fuel comparator. However, this definition is incomplete until the Delegated Act (DA) that will specify the methodology to assess the GHG emissions savings from low-carbon fuels is published (see 3.3 Policy gaps paragraph). When it is published, producers will have to comply with the emissions thresholds stated in the Hydrogen and Decarbonised Gas Market package.

[12] ibidem
[13] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32021R2139
[14] as outlined in Section 3.10 of Annex I of the Climate Delegated Act under the Taxonomy Regulation https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32021R2139
[15] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A804%3AFIN&qid=1640001545187
[16] ibidem

b) **Renewable Energy Directive**

- **Objectives of the Renewable Energy Directive**: setting a legal framework for the development of clean energy across all sectors of the EU economy.
- **Hydrogen provisions:**

b.1) **RED II delegated Acts**[17] (these two Delegated Acts focus on the definition of what is renewable hydrogen in the EU):

- The **first Delegated Act**[18] (namely 'Delegated Act establishing a minimum threshold for greenhouse gas (GHG) emissions savings of recycled carbon fuels') defines under which conditions hydrogen, hydrogen-based fuels or other energy carriers can be considered as Renewable Liquid and Gaseous Fuels of Non-Biological Origin (RFNBOs). In particular, the rules aim to ensure that RNFBOs are only sourced from "additional" renewable electricity[19] and comply with temporal[20] and geographical correlation[21] criteria.
- The **second Delegated Act**[22] (namely 'Delegated Act on a methodology for renewable fuels on non-biological origin') provides a methodology for calculating lifecycle GHG emissions for RFNBOs. This methodology considers the whole lifecycle of the fuels to calculate the emissions and the associated savings. In particular, using recycled-carbon fuels should lead to a minimum 70 per cent decrease in GHG emissions compared to the fuels they replace.

These Delegated Acts will impact the supply of hydrogen. Producers will have to comply with the criteria stated in the RED II Delegated Acts to ensure that the hydrogen they produce can be classified as RNFBOs.

b.2) **Recast Renewable Energy Directive (RED III)**[23]:

- **Objectives of RED III**: the Directive mandates that the EU's energy mix be composed of at least 42.5 per cent renewable energy by 2030, with an indicative goal of 45 per cent renewable energy. The obligation is on Member States.
- **Sectoral targets**: RED III sets targets for RFNBOs in industry and transport as detailed below.

  RFNBOs in industry (Article 22a): RED III set an annual target of a 1.6 percentage points increase in the use of renewable energy by 2030. Additionally, at least 42 per cent of the hydrogen used in industry should come from RFNBOs by 2030 increasing to 60 per cent by 2035. However, the Member States have the possibility to 'discount' the share of RFNBO by 20 per cent in 2030 if they meet these two conditions (Article 22b):

  - First, the country must be on track to meet its national contribution to the EU's overall target for 42.5 per cent renewables in final energy consumption by 2030.

[17] https://energy.ec.europa.eu/news/renewable-hydrogen-production-new-rules-formally-adopted-2023-06-20_en
[18] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1184&qid=1704969010792
[19] Additionality means that the renewable electricity must come from assets that would not exist in the absence of the RFNBO production plant. Why? Because the production of RFNBOs requires large amounts of renewable electricity and entails higher losses compared to direct use of electricity. Consequently, if the production of RNFBOs would divert existing renewable electricity away the market, other electricity production alternatives, frequently non-renewable, will be needed to address the electricity shortfall, potentially resulting in an overall increase of GHG emissions.
[20] Temporal correlation means that the time frame in which renewable electricity is generated should coincide with the hydrogen production time frame.
[21] Geographical correlation means that renewable electricity and the electrolyser need to be located in the same bidding zone.
[22] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2023.157.01.0011.01.ENG&toc=OJ%3AL%3A2023%3A157%3ATOC
[23] https://eur-lex.europa.eu/eli/dir/2023/2413/oj

- Second, the share of hydrogen or derivatives made using fossil fuels must be 23 per cent or less in 2030 and no more than 20 per cent in 2035.

RFNBOs in transport (Article 25): By 2030, hydrogen and e-fuels need to account for at least 1 per cent of all fuels used in the transport sector. However, every 1 MJ of RFNBOs can be double-counted as 2 MJ towards the target. On top of that, a so-called 'multiplier' allows every 1 MJ of RFNBOs used in the aviation and shipping sectors to be counted as 1.5 MJ towards the target[22].

Due to these double counting and multipliers the actual required volumes of RFNBOs in the transport sector will be around one third lower than implied by the 1 per cent target.

RED III will therefore impact hydrogen demand in industry and transport. Targets are set both for industry and transport, but it is worth noting that the market maturity and the readiness to implement the switch to hydrogen within the two sectors is different, with transport being ahead of industry. Moreover, the RED target on transport creates an obligation on final demand (fuel). On the contrary, the target on industry concerns the energy inputs (fuel/feedstock) which will be used in manufacturing other "green" products, subject to international competition, without clear market targets and certification.

c) **EU Emissions Trading System (EU ETS) Revision**

- **Objectives of EU ETS**: reducing greenhouse gas emissions by establishing a cap-and-trade system that incentivizes emission reductions and the adoption of clean technologies.
- **Hydrogen provisions**: Under the revised EU ETS Directive, eligibility for free allocation of EU Allowances (EUAs) has expanded to encompass hydrogen production processes beyond fossil fuels, including through electrolysis.[24] This expansion aims at incentivizing the adoption of cleaner practices, such as clean hydrogen[25]. It is worth noticing that extending CBAM to hydrogen (Annex II – CBAM Regulation[26]) will reduce free allocations at a swifter pace, compared to non CBAM covered goods. A full phase out of free allocation for CBAM covered goods is set into the EU ETS Directive to take place by 2034, while no specific phase out deadline is set for other carbon leakage products not covered by CBAM. The phase out will significantly strengthen the economic case for using clean hydrogen in the production of ammonia and steel, sectors that today pay zero effective carbon price because of free allocation.

d) **Carbon Border Adjustment Mechanism (CBAM)**[27]

- **Objectives of CBAM**: CBAM is a tool that aims to put a price on the carbon emitted during the production of carbon intensive goods imported from abroad where they do not have to comply with EU environmental standards and are not covered by the EU ETS. CBAM also aims to limit the risk of industrial production relocating outside the EU as a consequence of the reduction of free allocations under the EU ETS. CBAM covers imports of cement, iron and steel, aluminium, fertilisers, electricity and hydrogen[28].
- **Hydrogen provisions**: CBAM covers hydrogen as a good but does not include the indirect emissions (electricity used for electrolysis) caused by hydrogen production. Therefore, CBAM will have an impact on non-renewable demand of hydrogen (which produces direct emissions), raising the costs of importing it from abroad. This will support the purchase of EU renewable hydrogen.

[24] Marcu, A., et al. (2023) "2023 State of the EU ETS Report." ERCST, BloombergNEF, Ecoact, and Wegener Center.
[25] For electrolytic hydrogen, the main source of emissions is related to the production of the electricity used to produce the hydrogen. In other words, the carbon footprint of electrolytic hydrogen will be as high as its indirect embedded emissions. Given its high energy intensity, hydrogen has been included as an eligible sector for indirect cost compensation as part of the revised EU ETS State aid Guidelines beyond 2021 (source)
[26] https://eur-lex.europa.eu/eli/reg/2023/956/oj
[27] https://eur-lex.europa.eu/eli/reg/2023/956/oj
[28] ibidem

Additionally, this can also marginally impact supply, as EU producers will be protected to some extent from international competition. In particular, in the ammonia sector, CBAM will help ensuring that ammonia producers who require large amounts of renewable hydrogen remain operational. CBAM will also have an impact on other sectors that are not directly included in the scope of CBAM but which make use of hydrogen and/or hydrogen derivatives.

e) **Alternative fuels infrastructure regulation (AFIR)**[29]

- **Objectives of AFIR**: promoting the development of the EU infrastructure for alternative fuels for road vehicles, trains, vessels and aircrafts, standardizing the development of the charging infrastructure across the EU.
- **Hydrogen provisions**: AFIR establishes mandatory deployment targets for hydrogen refuelling infrastructure for road vehicles. By 2030, publicly accessible hydrogen refuelling stations need to be deployed along the Trans-European Network - Transport (TEN-T)[30]. AFIR deployment targets will bolster the development of the hydrogen infrastructure as more refuelling stations will be built. This will bring direct benefits to the distribution network, facilitating the connection between producers and the final consumers. AFIR is also complementary to ReFuelEU aviation and FuelEU maritime which focus on aviation and maritime sectors respectively (more details below).

f) **FuelEU maritime**[31]

- **Objectives of FuelEU maritime**: boosting the demand for renewable and low-carbon fuels in the shipping sector to reduce its GHG emissions, while avoiding distortions in the internal market. The legislation applies to ships of above 5000 gross tonnages arriving at or departing from ports under the jurisdiction of EU Member States and European Economic Area (EEA) countries[32].
- **Hydrogen provisions**: FuelEU maritime supports the adoption of RFNBOs in the maritime sector (Article 5). Despite this provision, FuelEU Maritime will encourage LNG more than RFNBO in the first 10 years.

g) **RefuelEU aviation**[33]

Objectives of RefuelEU aviation: increasing both demand and supply of sustainable aviation fuels (SAF). The regulation sets SAF volumes, rules about the blending on fuels, and aims to ensure a level playing field across the EU air transport market[34].

Hydrogen provisions: RNFBO hydrogen is included in the definition of SAFs, whose consumption in the aviation sector should rise and match certain shares over the years. Specific shares for renewable hydrogen in aviation are set as well[35].

RefuelEU aviation establishes obligations for both supply and demand. This will potentially support the matching of the two. More specifically, on the supply side, all fuel suppliers will have to gradually increase the share of SAFs in the fuel supplied to operators at EU airports. On the demand side, the regulation sets SAFs shares to be met.

[29] https://eur-lex.europa.eu/eli/reg/2023/1804/oj
[30] ibidem
[31] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1805
[32] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1805
[33] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R2405&qid=1716547448481
[34] ibidem
[35] ANNEX I of the regulation specifies the Shares of SAF that should be reached. From 1 January 2025, each year a minimum share of 2 % of SAF should be met. These shares increase over the years and from 1 January 2050, each year a minimum share of 70 % of SAF, of which a minimum share of 35 % of synthetic aviation fuels should be met.

REPowerEU Plan[36]

- **Objectives of the REPowerEU Plan**: reducing Europe's dependence on Russian fossil fuels and accelerating the energy transition.
- **Hydrogen provisions**: REPowerEU recognizes hydrogen as an important fuel to reduce energy dependency. Ambitious targets for renewable hydrogen are set: 10 million tonnes (Mt) to be imported and another 10 Mt produced within the EU by 2030, totalling 20 Mt of overall consumption. This figure roughly doubles the renewable hydrogen aspirational target outlined in the EU Hydrogen Strategy. REPowerEU therefore impacts both the supply and the demand of renewable hydrogen, setting targets that will be implemented at Member State level.

Green Deal Industrial Plan

a) Net Zero Industry Act[37]

- **Objectives of the Net Zero Industry Act**: strengthening and scaling up EU manufacturing of 'net zero technologies', setting a 2030 benchmark of 40 per cent domestic production of these technologies. To achieve this, the proposal strives to create better conditions for net zero technology manufacturing projects streamlining bureaucratic procedures in the EU[38]. The Act also aims to reinforce EU international competitiveness with a view of reaching 15 per cent of world production of net zero technologies by 2040[39].
- **Hydrogen provisions**: regarding the hydrogen market, electrolysers and fuel cells have been identified as net-zero technologies[40]. This means that projects are eligible for administrative support and faster permitting procedures.

b) Critical Raw Materials Act[41]

- **Objectives of the Critical Raw Materials Act**: ensuring resilience, diversification, and sustainability of the EU critical raw materials supply chain. Benchmarks for domestic extraction, processing and recycling are established[42]. Moreover, to diversify the Union's strategic raw materials imports and reduce external dependencies, no more than 65 per cent of the Union's annual consumption of each strategic raw material can come from a single third country. [43]
- **Hydrogen provisions**: the scope of the regulation encompasses raw materials such as nickel and platinum that are used to produce electrolysers, fuel cells and hydrogen storage technologies. Ensuring the reliability of the supply chain of those materials and boosting their circularity should enhance critical raw material security of supply.

[36] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN
[37] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0161
[38] https://www.europarl.europa.eu/doceo/document/TA-9-2024-0378_EN.html
[39] except where the increased Union manufacturing capacity would be significantly higher than the Union's deployment needs for the corresponding technologies necessary to achieve the Union's 2040 climate and energy targets (Article 5).
[40] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0161
[41] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023PC0160
[42] The Critical Raw Materials Act sets the following 2030 benchmarks for domestic capacities along the strategic raw material supply chain: At least 10% of the EU's annual consumption for extraction; At least 40% of the EU's annual consumption for processing; At least 15% of the EU's annual consumption for recycling.
[43] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023PC0160

EU Financing Mechanisms

The table below briefly summarizes the EU funds supporting hydrogen for the period 2021-2027[44].

Each fund is analysed based on the following criteria:

- **Support specifics**: what kind of financing instrument does the fund use?
- **Deployment stage**: which phase of development is targeted? Early stage (ES – R&D and innovation), mid-stream (MS – technology and infrastructure manufacturing), and downstream (DS – large-scale consumption and production) (NA – not applicable).
- **Technological neutrality**: does the fund target diverse technologies and decarbonisation strategies?
- **EU wide**: are projects open to applications from every Member State?
- **MFF Financing:** are the funds financed by the Multiannual Financial Framework (MFF)?

The **Innovation Fund** emerges as a decarbonisation catalyst for hard-to-abate industries and a key enabler of the broader transition towards a low-carbon economy. It recycles a share of EU ETS carbon revenues into projects with high emission abatement potential. Successful projects gain support through grants or competitive bidding[45].

Working as an arm of the Innovation Fund, the **Hydrogen Bank**'s core aim is to attract private investments in the EU and oversee hydrogen value chains while addressing initial investment challenges. The first pilot auction took place on November 23rd, 2023, with a budget of €800 million and a disclosed ceiling price of €4.5/kg of hydrogen available for renewable hydrogen projects only[46]. Subsequent to proposal calls, projects which met qualification requirements entered competitive bidding and were then ranked by offered prices with up to 30 per cent weighting for non-price factors, such as emissions abatement. The first pilot auction targeted exclusively RFNBOs production with no sectoral preference. Germany will award an additional €350 million to projects on its territory under the Hydrogen Bank "Auctions-as-a-service" mechanism[47].

Hydrogen can be eligible for State aid. State aid in the EU is a form of public assistance that gives certain organizations a competitive advantage. State aid mechanisms are governed by strict regulations to maintain fair competition across the EU. The General Block Exemption Regulation (GBER) is a key component in this framework. It allows EU countries to implement certain categories of State aid, such as aid for small to mid-sized projects, without prior notification to the European Commission, thereby streamlining the process. Renewable hydrogen is covered by GBER[48]. Another crucial aspect of State aid is defined in the Guidelines on State aid for Climate, Environmental Protection and Energy (CEEAG). These guidelines set criteria for evaluating State aid measures that aim to achieve environmental protection and secure energy supply, with a strong focus on sustainability[49].

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[44] Hydrogen Public Funding Compass https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide_en#:~:text=The%20hydrogen%20public%20funding%20compass,funding%20sources%20for%20hydrogen%20projects.

[45] https://cinea.ec.europa.eu/programmes/innovation-fund_en

[46] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0156&qid=1682349760946

[47] The "Auctions-as-a-Service" mechanism allows Member States to finance additional projects on their territory which have not secured EU funding but do meet the eligibility criteria. Member States' participation to this mechanism is voluntary, and project developers that express interest in using the "Auctions-as-a-Service" in their bid are eligible for selection. The support provided by Member States through this service will be considered as State aid and can be granted after allocating the Innovation Fund's budget.

[48] https://competition-policy.ec.europa.eu/state-aid/legislation/regulations_en

[49] https://eur-lex.europa.eu/EN/legal-content/summary/2022-guidelines-on-state-aid-for-climate-environmental-protection-and-energy.html

Important Projects of Common European Interest (IPCEIs) are another relevant component of the hydrogen funding mosaic. They allow Member states to provide significant public funding (State aid) without breaching competition regulations, contributing to the integrity of the single market. IPCEIs supports large-scale transnational projects crucial for economic growth, job creation, and competitiveness in the EU. Such projects, involve collaboration among multiple Member States and entities[50]. Chapter 4 'Hydrogen Economy KPIs' will offer an overview of IPCEIs in the hydrogen sector.

Table 2: EU funds supporting hydrogen, 2021-2027, by category

Fund	Support specifics	Deployment stage	Tech neutral	EU wide	MFF Financing
Innovation Fund • Hydrogen Bank	Grants Fixed premium	MS-DS DS	YES[51] NO – renewable H_2	YES YES	NO
Development and Cohesion (ERDF, REACT-EU, CF)	Grants	ES – DS	YES	YES	YES
Connecting Europe Facility – Transport	Grants – guarantees – bonds	DS	YES	YES[52]	YES
Horizon Europe • Clean Hydrogen Partnership	Grants Grants	ES ES-DS	YES NO – renewable & Low Carbon H_2	YES YES	YES
Modernisation Fund	NA[53]	NA	YES	NO	YES
Just Transition Fund	Grants	NA	YES	YES[54]	YES
Connecting Europe Facility – Energy	Grants – guarantees – bonds	DS	YES	YES	YES
Invest-EU	Guarantees	ES – MS – DS	YES	YES	YES
LIFE	Grants	ES – DS	YES	YES	YES

Note: Chapter 4 'Hydrogen Economy KPIs' will provide data on the various amounts earmarked by the funds.

3.1.2 Progress in 2023

In 2023, some of the policies mentioned in the previous section were adopted. The table below summarizes them, providing information about their publication date in the Official Journal of the European Union and their entry into force date.

[50] https://competition-policy.ec.europa.eu/state-aid/ipcei_en

Table 3: Policies progress

POLICY	PUBLICATION IN THE OFFICIAL JOURNAL	DATE OF ENTRY INTO FORCE
Hydrogen Strategy	**8 July 2020**	**-**
EU Taxonomy	**22 June 2020**	**12 July 2020**
Hydrogen and Decarbonised Gas Market package revision • Delegated Acts H2	**(21 May 2023 regulation and directive signed)**[51] • Delegated Acts H2: expected in 2025	
RED II Delegated Acts	**20 June 2023**	**10 July 2023**[52]
RED III	**31 October 2023**	**20 November 2023**
CBAM	**16 May 2023**	**1 October 2023**[53]
EU ETS (Revision)	**16 May 2023**	**5 June 2023**
Alternative fuels infrastructure regulation (AFIR)	**22 September 2023**	**12 October 2023** BUT the new rules will enter into force six months after the date of entry into force of the regulation (12 April 2024)[54]
FuelEU maritime	**22 September 2023**	**12 October 2023.** BUT the regulation will apply from 1 January 2025, apart from articles 8 and 9 which will apply from 31 August 2024
RefuelEU aviation	**31 October 2023**	**20 November 2023.** BUT the new regulation will apply from 1 January 2024. However, Articles 4, 5, 6, 8 and 10 will apply from 1 January 2025
Green Deal Industrial Plan (Communication)	**1 February 2023**	**-**
REPowerEU Plan	**28 February 2023**	**29 February 2023**[55]
Net Zero Industry Act	**(adopted on 27 May 2024)**	
Critical Raw Materials Act	**3 May 2024**	**23 May 2024**
Hydrogen Bank (Communication)	**16 March 2023**	**-**

Legend: **policies entered into force in 2023**, **policies awaiting approval**, policies approved before or after 2023

Note: In order to implement directives, Member States have two years from the directive's publication in the Official Journal of the EU to transpose it into National legislation.

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[51] https://www.consilium.europa.eu/en/press/press-releases/2024/05/21/fit-for-55-council-signs-off-on-gas-and-hydrogen-market-package/?utm_source=brevo&utm_campaign=AUTOMATED%20-%20Alert%20-%20Newsletter&utm_medium=email&utm_id=320

[52] 20 days after publication in the OJ

[53] On 1 October 2023, the CBAM entered into application in its transitional phase, with the first reporting period for importers ending 31 January 2024. During the transition period from October 2023 until the end of 2025, importers of goods in the scope of the regulation (cement, iron and steel, aluminium, fertilisers, electricity and hydrogen) will only have to report greenhouse gas emissions (GHG) embedded in their imports (direct and indirect emissions), without the need to buy and surrender certificates (source).

[54] BUT the new rules will enter into force six months after the date of entry into force of the regulation (source)

[55] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R0435 Article 6 'This Regulation shall enter into force on the day following that of its publication in the Official Journal of the European Union'.

3.1.3 Policy Gaps

After having provided an overview of the EU hydrogen regulatory framework in paragraph 3.1 and mentioning the 2023 regulatory developments in paragraph 3.2, this section makes an assessment of what is currently missing from the policy framework to create a thriving EU hydrogen market.

- **Implementation gap**: the EU has created a complex framework of regulations and directives. However, the implementation of the directives and the development of subsidy mechanisms is up to the Member States.
- **High entry barriers and lack of investment security:** renewable hydrogen projects require high upfront investments, and the viability of projects is currently uncertain. Higher production costs, lack of project offtakers, high technical and commercial risks not mitigated by the regulatory framework dampen investment appetite and make the market inaccessible to smaller players.
- **Competitiveness:** currently renewable hydrogen prices are higher than those for hydrogen produced from traditional fossil fuels. Support is needed to narrow the gap between the two and to make the renewable option more attractive and competitive. However, we should be careful with the business models that require indefinite subsidies.
- **Technological neutrality**: the EU hydrogen regulatory framework is not technologically neutral,[56]. For instance, imposing a strict uptake requirement for RFNBOs by 2030 in sectors reliant on a consistent hydrogen supply, such as refining and steel, may prove ineffective due to the limited capacity to produce renewable hydrogen round the clock[57]. The EU should also consider the advantages of low-carbon electrolytic hydrogen (based on nuclear electricity and electricity network) to have a large-scale hydrogen production. Indeed, this type of hydrogen could complement renewable hydrogen production as it is dispatchable and has a higher load factor. Examining the UK model is something that could be worth considering.
- **Technology readiness:** the EU framework does not sufficiently consider the development stage of EU hydrogen technologies. The technology readiness varies across EU sectors. For instance, while the transport sector has more mature technologies such as fuel cells, the industrial sector lacks in business model, therefore resulting in a less mature development stage of the technologies characterized by higher prices and increased risks associated with investing in these technologies.
- **Financing**: hydrogen investors face a large and intricate pool of generic funds, contrasted by a small pot of targeted funds. The financial support currently available needs to be strengthened and reinforced, as larger funds are needed to meet the 2030 REPowerEU target of 20 Mt renewable hydrogen.
- **Low-carbon hydrogen definition**: a complete definition of low-carbon hydrogen is missing. The hydrogen and gas decarbonised market package Delegated Act on the methodology needed for the certification of renewable and low-carbon hydrogen will be published in 2025. The absence of a finalized low-carbon hydrogen definition poses an additional challenge for businesses aiming to develop comprehensive strategies that encompass various hydrogen technologies.

3.2 UK Regulatory developments

3.2.1 UK Hydrogen Regulation

The UK announced its Hydrogen Strategy in 2021[58] and since then it has been developing a number of initiatives to support the production, demand and infrastructure for low-carbon hydrogen. The UK gave a

[56] https://ercst.org/hydrogen-the-imports-dimension-of-repowereu/
[57] https://ercst.org/taking-stock-of-the-eu-hydrogen-regulatory-framework/
[58] UK Hydrogen Strategy, Department for Energy Security and Net Zero, August 2021.

major update on delivery of its Hydrogen Strategy in December 2023,[59] and work has been progressing since then.

Legal framework

The Energy Act 2023 was passed in October 2023. This creates the legal framework for a number of measures relating to hydrogen.

- Government support mechanisms for hydrogen production and Carbon Capture Use and Storage (CCUS).
- A levy on natural gas network users to finance the subsidy of hydrogen production.
- Regulatory framework for hydrogen and CO_2 transport and storage.
- Strategic planning for energy infrastructure, including hydrogen, by the Future System Operator.
- Trial of hydrogen in home heating.

Hydrogen production

The main support mechanism for low-carbon hydrogen is the Hydrogen Production Business Model (HPBM) which uses a Contract for Difference (CfD) model to bridge the gap between the cost of hydrogen production and the sales price producers achieve. Producers must have an offtake agreement in place to qualify for subsidy, but this cannot include sales for export, blending into the natural gas network, or sales to middlemen (utilities, traders etc.)

Hydrogen can be produced by a variety of production pathways but must have a carbon intensity of 20gCO_2e/MJ or less (See Low Carbon Hydrogen Standard below). Current allowed pathways include:

- Electrolysis
- Fossil gas reforming with CCS
- Biogenic gas reforming
- Biomass gasification
- Waste gasification
- Gas splitting producing solid carbon (e.g. pyrolysis or plasma splitting).

Support is allocated via competition. Hydrogen production which requires CCS is chosen as part of the CCUS Cluster Sequencing process. The UK government has identified a number of industrial clusters which are suitable for developing CCUS infrastructure. HyNet near Merseyside and the East Coast Cluster based around Humberside and Teesside have been chosen as the first clusters, and within these, three hydrogen projects have been shortlisted for negotiation: HyNet HPP1, H2 Teesside and Teesside Hydrogen CO_2 Capture. The first two will receive support under the HPBM. Teesside Hydrogen CO_2 Capture is the retrofitting of existing hydrogen production based on Steam Methane Reforming, and therefore receives support under a different mechanism, the Industrial Carbon Capture model. This uses a CfD model based on a carbon price, and therefore does not have the same carbon intensity requirement as the HPBM.

Other hydrogen projects compete for support via the Hydrogen Allocation Rounds (HAR). Currently the approach is more qualitative but as the market matures the government wishes to move towards a price-based auction approach. The first round (HAR1) concluded in 2023 and awarded support to 125MW of electrolytic production spread over 11 projects. HAR2 is currently underway aiming to support up to 875MW, in order to reach the government's target of 1GW of hydrogen production in place in the mid 2020s. By

[59] Hydrogen Strategy Delivery Update. Hydrogen Strategy Update to the Market. Department for Energy Security and Net Zero. December 2023.

2030 it aims to have 10GW of production in place, split by 6GW electrolytic and 4GW CCS based, but the final split will depend on which projects are successful. Future HAR will be held each year up to and including 2029.

Hydrogen projects can also apply for development and capital expenditure support under the Net Zero Hydrogen Fund. To date the government has awarded £59 million in support, and the total available is £240 million.

Hydrogen Infrastructure

Hydrogen pipelines and storage will be regulated and also receive government support. The detailed framework is being developed but Ofgem will regulate onshore infrastructure, whilst the North Sea Transition Authority will regulate offshore. The Future System Operator will assume responsibility for strategic planning of electricity, gas and hydrogen infrastructure from 2026 to ensure alignment between different networks.

The government issued its Hydrogen Transport and Storage Networks Pathway[60] in December 2023 which lays out its expectations for the development of infrastructure. In the early stages this will be small scale connecting adjacent production and demand, before regional networks are developed around industrial clusters. Regional networks may connect with each other in the longer term, leading ultimately to a core hydrogen network similar to the current gas transmission network. However, the government only sees a core hydrogen network as a possibility at this stage, whose existence is dependent on the overall development of the hydrogen market.

Small scale infrastructure may receive support under the HBPM. For larger scale projects the Hydrogen Transport Business Model will use a Regulated Asset Base model with government providing additional revenue support during the early stages when there are insufficient users to pay for the network. The details of the HTBM are still being developed but the government hopes to award first contracts by the end of 2025 with operational start up between 2028 and 2032. Storage will also receive support but based on a revenue support basis with government guaranteeing a minimum revenue to enable a low return on capital investment in the event that demand for storage does not materialise as expected. Subsidy will decrease as revenues from storage users increase, in a way designed to incentivise storage owners to increase revenues and hence reduce the amount of subsidy required.

Demand

Industrial demand for hydrogen is encouraged by the requirement that recipients of HPBM subsidy must have an offtake agreement in place. Government also supports industry switching to lower carbon energy sources via the Industrial Energy Transformation Fund which provides grants for feasibility and engineering studies, and the deployment of decarbonisation technologies including hydrogen.

The government also sees a role for hydrogen-based power generation (H2P) based on its analysis that deployment of H2P will result in lower overall system costs in a fully decarbonised electricity system. The government is currently consulting on Reform of Electricity Market Arrangements (REMA) to incentivise low-carbon electricity generation, and specific measures to support H2P.

In December 2023 the government took a 'strategic policy decision' to allow blending of up to 20 per cent hydrogen by volume in distribution networks. Subject to further studies, blending could start in the late 2020s. However, the government is clear that blending is seen only as a transitional measure, which can support the development of hydrogen market in its early stages, and not as a means to decarbonise gas networks. No decision on the use of hydrogen in space heating is due until 2026. A trial of 100 per cent hydrogen heating in houses is due to run from later this year until 2027.

Hydrogen or its derivatives will also play a role in transport, mainly aviation and maritime. The UK has announced a Sustainable Aviation Fuel mandate which includes an obligation that 3.5 per cent of UK jet

[60] https://www.gov.uk/government/publications/hydrogen-transport-and-storage-networks-pathway

fuel demand be supplied by power-to-liquid fuels from 2028. In 2024 the government will update its Clean Maritime Plan setting out how it plans to decarbonise shipping. Government provides funding for development of low-carbon solutions for shipping via the Clean Maritime Demonstration Competition and the Zero Emission Vessels and Infrastructure Competition. Hydrogen based fuels can also qualify as renewable fuels under the UK's Renewable Transport Fuel Obligation which requires fuel suppliers to sell an increasing percentage of renewable fuels.

Hydrogen Standards and Certification

All recipients of support under the HPBM must meet the Low Carbon Hydrogen Standard (LCHS) which requires a carbon intensity of 20gCO_2e/MJ or below measured on a "well to production gate" basis i.e. including Scope 3 upstream emissions associate with inputs, Scope 1 emissions from production, and Scope 2 emissions for electricity used, but excluding Scope 3 downstream emissions associated with transport and storage, or emissions associated with the manufacture of the equipment used. Emissions are measured on a 30-minute batch basis, including for electricity emissions, but averaging of batches is allowed so long as they use the same production method, and the overall carbon intensity meets the 20gCO_2e/MJ requirement. Any type of electricity can be used so long as the resultant hydrogen is compliant with the LCHS.

The government is also consulting on a Low Carbon Hydrogen Certification Scheme to enable trade in hydrogen.

3.2.2 Similarities and differences between the UK and EU approach

Whilst both the EU and the UK view low-carbon hydrogen as a key element of their strategies to reach net zero by 2050, there are several key differences between the two:

- The UK is a sovereign state and therefore has control over all aspects of its hydrogen policy including support mechanisms, targets, and regulation. By contrast the EU is a political and economic union of 27 Member States. Whilst certain aspects are determined at the EU level – for example targets for hydrogen use in RED III or regulation of hydrogen infrastructure – others are determined at the Member State level. For example, there is some EU level funding for hydrogen, but it will be up to the Member States to implement most of the support funding to enable the hydrogen market to develop. Whilst the EU sets guidelines, with varying degrees of detail, for aspects such as state aid or regulation of infrastructure, the implementation and detailed frameworks are the responsibility of the Member States.
- The EU has taken a 'preferred technology' approach to low-carbon hydrogen compared to a 'technology neutral' approach in the UK. Whilst the EU sets similar GHG savings requirements for RFNBO hydrogen and for low-carbon hydrogen based on non-renewable energy, its preference is for the former. This is demonstrated by the different definitions for hydrogen types based on production pathway, and by the targets for RFNBO use whereas there are no targets for non-renewable based low-carbon hydrogen. By contrast the UK does not distinguish between hydrogen based on production pathway so long as the hydrogen is below the required carbon footprint threshold.
- The UK and EU include different elements of the hydrogen supply chain in their measurement of the hydrogen's carbon footprint. The UK uses a 'well to production gate' system boundary so that it includes upstream emissions associated with the supply of inputs to the hydrogen production process (e.g. the production and supply of natural gas) and emissions associated with the production of hydrogen. The EU takes a 'well to wheel' approach whereby it includes the upstream and production emissions, as well as emissions associated with the transport and storage of hydrogen, and any conversion and reconversion of hydrogen into hydrogen derivatives such as ammonia, or e-fuels or e-methane, which are also included in the RFNBO definition.

- The UK approach only applies to hydrogen produced and used in the UK and not to hydrogen produced outside the UK or for export, or hydrogen derivatives. The EU RFNBO standard applies to both hydrogen and its derivatives, and to hydrogen produced outside the EU and then imported for use in the EU.
- The UK takes a stricter approach when measuring the carbon intensity of any electricity used in electrolysis to produce hydrogen. The UK uses a temporal correlation of 30 minutes in its Low Carbon Hydrogen Standard, whilst the EU uses a temporal correlation of one month until 2030, and then hourly thereafter.
- The UK is still developing its regulatory framework for hydrogen infrastructure so a full comparison with the EU Hydrogen and Gas Decarbonisation Package is not yet possible.

3.2.3 Insights on the international dimension/rest of the world

The focus of this Report is the European hydrogen market (EU and UK). However, given the interactions between the domestic and the international dimensions, it is worth mentioning a few global developments.

In the hydrogen sector, two markets emerged as main actors in the international arena.

Firstly, the **US**. The Inflation Reduction Act (IRA) introduces an attractive framework for hydrogen and fuel cells investments, with four 'tiers' of hydrogen production tax credit (referred to as 45V) spanning from 3.0 $/kg for carbon intensities less than 0.45kg CO_2/kg H_2 to 0.6 $/kg for carbon intensities between 2.5 and 4.0 kg CO_2/kg H_2[61]. In particular, electrolytic hydrogen is eligible for the highest-level tax credit if electricity produced from renewable sources or by nuclear power is used. The average cost to produce renewable-based electrolytic hydrogen, before the tax credit is around $5-6/kg[62]. After applying the highest-level tax credit which accounts for up to $3 per kg of hydrogen the production cost of green hydrogen will decrease significantly[63]. Some EU electrolyser manufacturing companies are looking with interest at the US framework and are considering investing in the US. However, no Final Investment Decision (FID) has been reached so far.

Secondly, **China** has emerged as the main electrolyser manufacturer (it accounts for around 70 per cent of planned electrolyser manufacturing capacity globally). The cost of Chinese electrolysers is around $600/kW, while estimated costs in Europe are roughly $2,500/kW[64]. Export of Chinese electrolysers could represent a challenge for the EU's electrolyser manufacturing sector.

4. Hydrogen Economy KPIs

To make a quantitative assessment of the state of the European hydrogen industry, this publication tracks progress against nine key performance indicators across four categories: Targets and incentives, supply, demand, and electrolyser manufacturing.

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[61] https://www.federalregister.gov/documents/2023/12/26/2023-28359/section-45v-credit-for-production-of-clean-hydrogen-section-48a15-election-to-treat-clean-hydrogen
[62] ibidem
[63] ibidem
[64] https://www.bnef.com/insights/33495

Table 4: Key performance indicators tracked in this report

Category	KPI	Progress
Targets and incentives	KPI 1: Electrolyser targets	Moderate. National targets exceed the EU's hydrogen strategy target but make up less than half of the estimated deployment to meet REPowerEU.
	KPI 2: Funding	Good. Europe has committed one of the largest budgets for low-carbon hydrogen projects.
Supply	KPI 3: Committed supply versus pipeline and targets	Low. Just 3.6 per cent of the announced pipeline for 2030 are operational or have taken final investment decision.
	KPI 4: Committed supply versus the US and China	Moderate. The US leads Europe on committed low-carbon hydrogen supply but Europe leads China on this metric.
Offtake and demand	KPI 5: Supply in offtake discussions	Low. 29.5 per cent of the 20 million metric ton REPowerEU 2030 target is in offtake discussions.
	KPI 6: Binding offtake	Low. 4.5 per cent of supply needed to meet REPowerEU has signed a binding offtake.
	KPI 7: Quotas for hydrogen use	Moderate. The world's first binding quotas have been set on an EU level, but not enough to reach EU targets. Some still need to be transposed into national law.
Electrolyser sales and manufacturing	KPI 8: Share of local content in electrolyser sales	Good. Domestic manufacturers currently dominate sales to European projects.
	KPI 9: European makers' share of global manufacturing capacity	Moderate. European electrolyser manufacturers could account for 23 per cent of global manufacturing capacity by the end of 2024.

Source: BloombergNEF. Legend: Good progress, moderate progress, low progress.

4.1 Category 1: Targets and incentives

KPI 1: Electrolyser targets

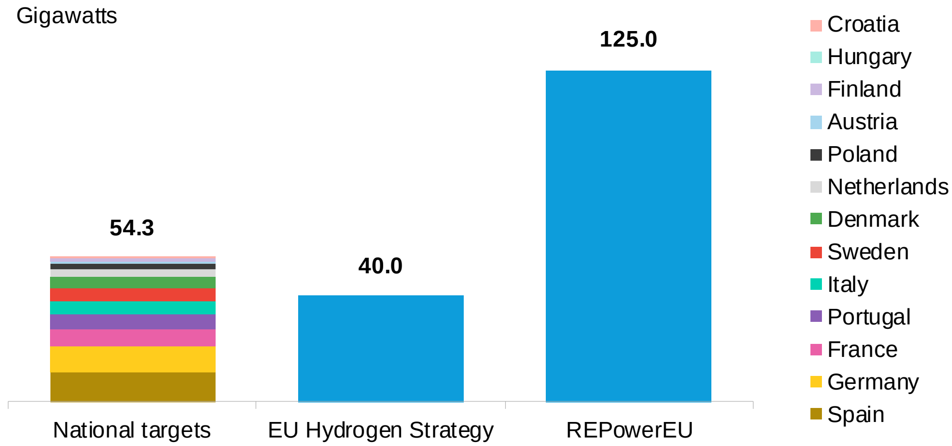
Progress: Moderate. EU set to meet one of its two electrolyser deployment targets.

Ambitious targets and government incentives that tend to follow them are key to the growth of the nascent low-carbon hydrogen market. Europe has been at the forefront of setting such targets with the adoption of the EU hydrogen strategy in 2020, which set a target to deploy 6 gigawatts (GW) of electrolysers by 2024 and 40GW by 2030.

The EU's REPowerEU plan to phase out Russian natural gas raised this ambition even further in 2022. It targets 20 million tons of renewable hydrogen use by 2030, half from domestic production. BloombergNEF estimates that meeting the domestic portion of the REPowerEU target would require electrolyser deployment of 125GW – three times higher than the 40GW under the EU's hydrogen strategy.

EU Member States have set their own electrolyser targets in their national hydrogen strategies. These currently total 54.3GW by 2030 (Figure 1). National ambitions would therefore, if achieved, meet the EU hydrogen strategy target of 40GW but not the REPowerEU goal of 125GW. However, BNEF currently forecasts EU Member States to deploy at most 23GW by 2030 based on the maturity of current projects and announced policies, meaning most countries will not meet their national electrolyser goals.

Figure 1: National versus EU electrolyser targets for 2030



Source: BloombergNEF, National government strategies, European Commission.

Note: Data as of March 15, 2024, from BloombergNEF’s Hydrogen Strategy Tracker.

KPI 2: Funding

Progress: Good. Europe ranks second in global funding for low-carbon hydrogen.

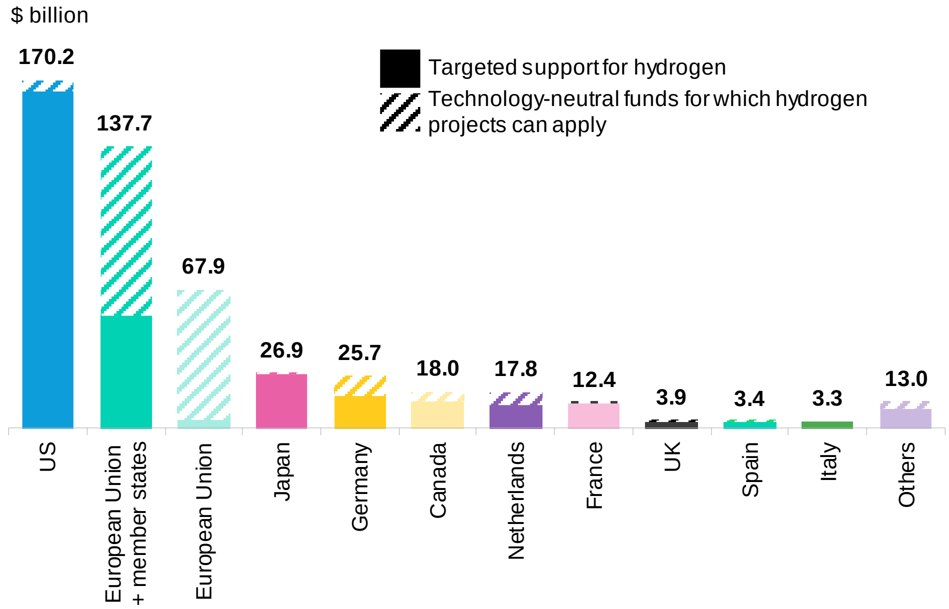
Many European hydrogen strategies also promise funding to support low-carbon hydrogen projects. Availability of funding encourages project development in Europe and means more announced projects are likely to materialize in the EU than elsewhere.

Across the EU and its Member States, commitments towards the sector are estimated to total almost $138 billion (Figure 2), with EU funds making up almost half of available funding. Funding commitments in the UK add another $3.9 billion to this total.

European funding including the UK and Norway accounts for 39 per cent of estimated global funding for the hydrogen sector, making Europe one of the largest supporters of the industry. European funding commitments are some 17 per cent lower than in the US, if one were to assume that all currently announced US hydrogen projects materialize and receive the highest available tax credit.

The perceived simplicity of accessing US tax credits has made the market lucrative for project development. However, final guidance on accessing hydrogen tax credits is still outstanding, creating uncertainty for US projects.

Figure 2: Estimated hydrogen funding by market and funding type, as of April 30, 2024



Source: BloombergNEF.

Note: Data from BloombergNEF's Hydrogen Subsidies Tracker.

4.2 Category 2: Supply

<u>KPI 3: Committed supply versus announced pipeline and targets</u>

Progress: Low. Just 3.6 per cent of announced supply until 2030 is operational or past final investment decision.

Despite targets and large funding commitments, only 3.6 per cent of the announced low-carbon hydrogen supply in Europe with plans to come online by 2030 was operational or had taken a final investment decision (FID) as of May 7, 2024 (Figure 3).

Over 60 per cent of this committed supply currently comes from fossil fuels with carbon capture and storage ('blue' hydrogen), largely consisting of retrofitted gray hydrogen plants. Just 0.2 million metric tons (Mt) per year could be produced from committed electrolysis projects. Virtually all committed supply in Europe is in EU Member States (Figure 4).

Figure 3: Committed low-carbon hydrogen production in Europe versus the announced pipeline until 2030

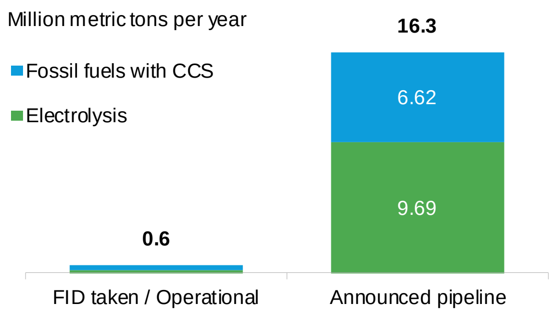
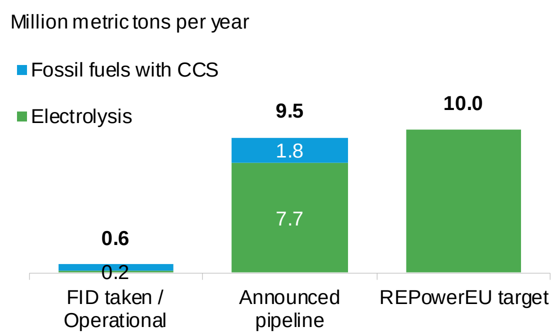


Figure 4: Committed low-carbon hydrogen production in the EU versus announced pipeline until 2030 and REPowerEU target



Source: BloombergNEF.

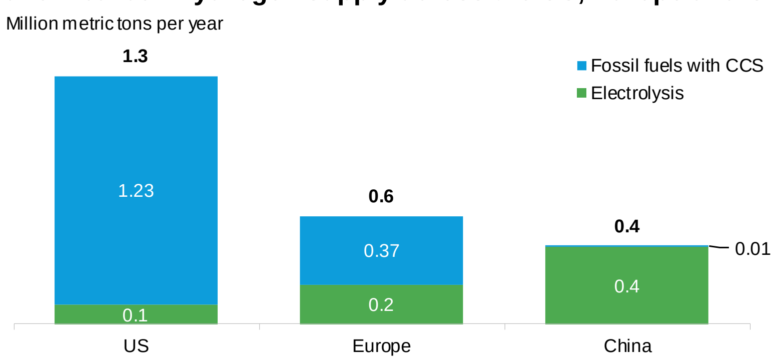
Note: Data from BloombergNEF's hydrogen project database as of May 7, 2024. 'CCS' refers to carbon capture and storage.

KPI 4: Committed supply versus the US and China

Progress: Moderate. The US leads Europe on total low-carbon hydrogen supply but Europe leads China on this metric.

In a global comparison, Europe's committed low-carbon hydrogen production supply is less than half that in the US, where some large blue hydrogen projects, such as Louisiana Clean Energy Complex by Air Products[65], are under construction (Figure 5). Total low-carbon supply in Europe past FID is larger than in China. However, China currently leads Europe and the US on electrolysis projects under construction.

Figure 5: Committed low-carbon hydrogen supply across the US, Europe and China



Source: BloombergNEF.

Note: Data from BloombergNEF's hydrogen project database as of May 7, 2024. 'Committed' refers to projects that are operational or have taken final investment decision. 'CCS' refers to carbon capture and storage.

FIDs in Europe are lagging as most projects are yet to receive or lack sufficient government funding. For example, allocation of major funds such as the Important Projects of Common European Interest (IPCEI) program, which has selected some 6.8GW of electrolyser projects, has been severely delayed in most EU Member States.

[65] https://www.airproducts.com/energy-transition/louisiana-clean-energy-complex

National electrolyser auctions to be launched across Europe in 2024, as well as the EU Hydrogen Bank[66] auctions, could support additional capacity to come online in the near term.

4.3 Category 3: Offtake and demand

KPI 5: Supply in offtake discussions

Progress: Low. 29.5 per cent of the 20 million metric ton REPowerEU 2030 target is in offtake discussions.

Low demand is a key bottleneck for low-carbon hydrogen. Some 5.9Mt of annual low-carbon hydrogen supply were in offtake discussions with European buyers as of April 1, 2024 (Figure 6). Some 56 per cent of this supply comes from projects looking to export hydrogen or derivative products to Europe with the rest from domestic producers. Just 16 per cent of announced European supply with plans for commissioning by 2030 is in offtake discussions, suggesting that most projects are yet to identify an offtaker (Figure 7).

Figure 6: Annual low-carbon hydrogen supply in offtake discussions with European buyers by production origin

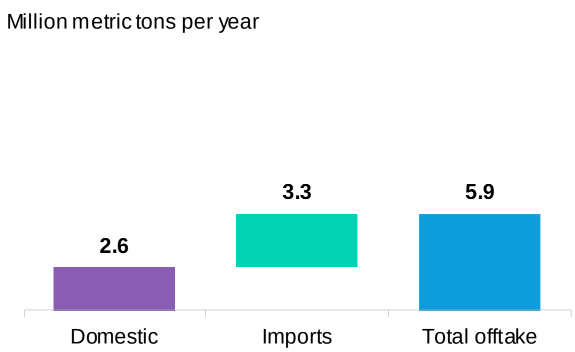
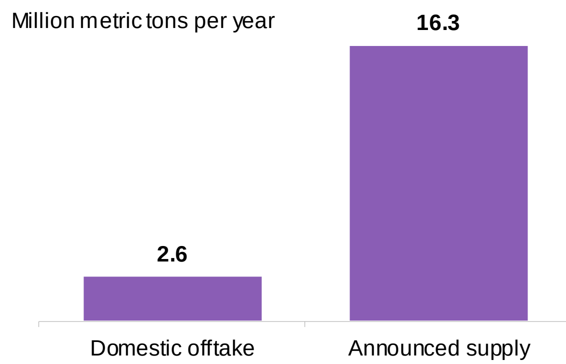


Figure 7: Domestic low-carbon hydrogen supply in offtake discussions versus announced supply until 2030



Source: BloombergNEF.

Note: Offtake data from BloombergNEF's Hydrogen Offtake Agreement Database as of April 1, 2024. Announced supply from BloombergNEF's hydrogen project database as of May 7, 2024.

KPI 6: Binding offtake

Progress: Low. Just 4.5 per cent of the supply needed to meet REPowerEU has signed a binding offtake agreement.

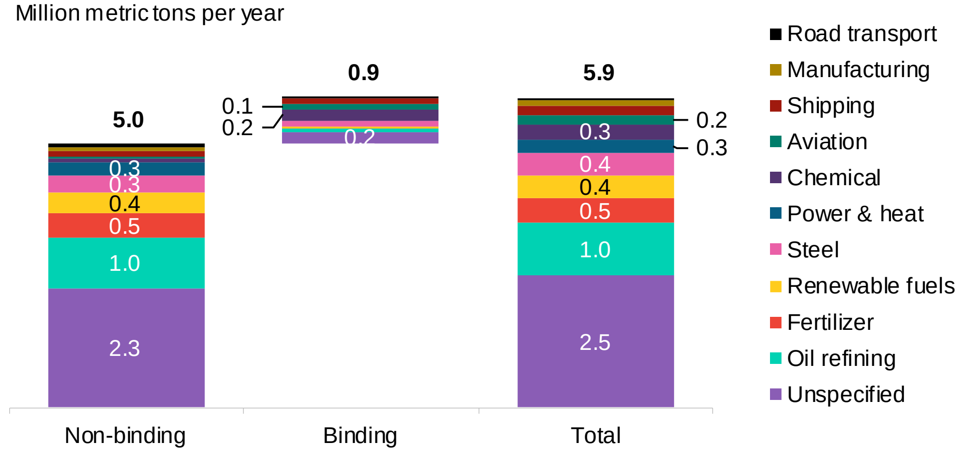
While few buyers in Europe have signed any kind of offtake agreement, fewer buyers still have signed *binding* offtake agreements. Just 15 per cent or 0.9Mt of supply from projects in offtake discussions with European buyers has signed a binding agreement so far (Figure 8). Steelmakers and renewable fuels producers make up the largest share of binding agreements, likely due to a willingness to pay a green premium by some end users as well as government regulation.

Another 0.2Mt of supply has agreed on offtake terms. Most offtake negotiations, representing some 1.3Mt of supply, have a signed a memorandum of understanding or letter of intent but have not disclosed an end use for the hydrogen. Some agreements do not specify their type. Steel producers, oil refineries and

[66] https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/european-hydrogen-bank_en

fertilizer makers dominate this category. More early-stage discussions will need to be turned into binding offtake agreements to enable final investment decisions on production projects.

Figure 8: Annual low-carbon hydrogen supply in offtake discussions with European buyers by contract type

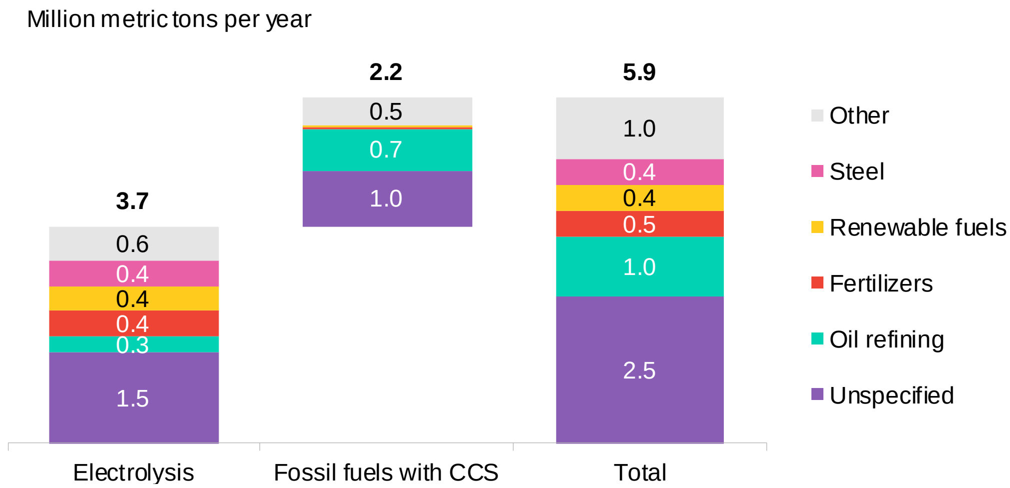


Source: BloombergNEF.

Note: Data from BloombergNEF's Hydrogen Offtake Agreement Database as of April 1, 2024.

Electrolysis dominates over blue hydrogen in offtake discussions, likely driven by European regulation, which has set specific targets and quotas for the use of green hydrogen (Figure 9). Over 40 per cent of hydrogen supply in offtake discussions still needs to specify its end use and of this 60 per cent are for electrolysis-based hydrogen. Oil refiners are currently one of the only end users in Europe that are considering buying blue hydrogen in significant quantities. Other users have yet to make or disclose similarly sized commitments.

Figure 9: Annual low-carbon hydrogen supply in offtake discussions with European buyers by end use and production method



Source: BloombergNEF.

Note: Data from BloombergNEF's Hydrogen Offtake Agreement Database as of April 1, 2024.

KPI 7: Quotas for hydrogen use

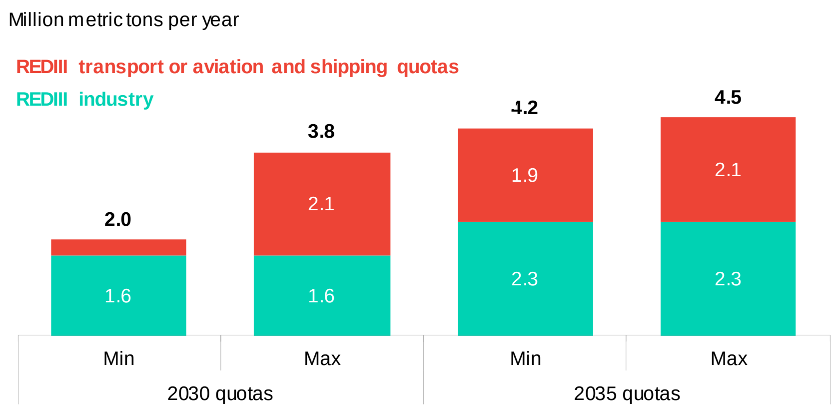
Progress: Moderate. Quotas have been set on an EU level but may not be enough to reach EU targets. Some still need to be transposed into national law.

Besides direct subsidies that lower production costs, quotas and mandates on end-users could further raise willingness to pay a premium for low-carbon hydrogen. Europe leads on enacting such quotas as part of the revision of the Renewable Energy Directive, REFuelEU Aviation and FuelEU Maritime.

Quotas across these policies currently could drive some 2-3.8Mt of demand for electrolysis-based hydrogen that fits the EU's criteria for renewable fuel of non-biological origin (RFNBO) by 2030, rising to 4.2 to 4.5Mt by 2035 (Figure 10).

However, for buyers to be willing to pay a premium based on these quotas, the penalties for non-compliance need to be clear. A large part of the quota-supported demand comes from the revision of the Renewable Energy Directive, which still needs to be transposed into national law by EU Member States. The effectiveness of these quotas in stimulating demand for clean hydrogen will therefore depend on how Member States enforce them.

Figure 10: EU quotas for renewable fuels of non-biological origin in industry and transport



Source: BloombergNEF.

Note: Transport quotas consider quotas in the revision of the Renewable Energy Directive, REFuelEU Aviation and FuelEU Maritime.

4.4 Category 4: Electrolyser sales and manufacturing

KPI 8: Share of local content in electrolyser sales

Progress: Good. Domestic manufacturers currently dominate sales to European projects.

The European Union's Green Deal intends to promote domestic manufacturing of clean technologies such as electrolysers. The EU's Net Zero Industry Act therefore set a target for at least 40 per cent of annual electrolyser deployment in the bloc to come from domestic manufacturing by 2030.

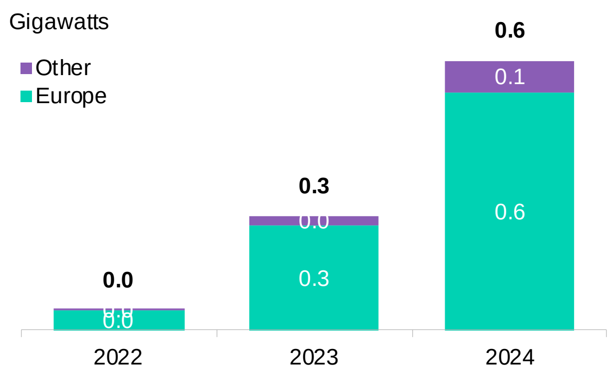
BNEF data reveal that foreign manufacturers are yet to get a foothold in the European market, with 80-90 per cent of electrolyser deliveries to European projects since 2022 coming from European manufacturers (Figure 11).

KPI 9: European makers' share of global manufacturing capacity

Progress: Moderate. European electrolyser manufacturers could account for 23 per cent of global manufacturing capacity by the end of 2024.

As foreign manufacturers have larger manufacturing capacity for electrolysers, the share of non-European electrolysers in domestic projects could increase over time (Figure 12). This is corroborated by the results of the first European Hydrogen Bank auction, in which 15 per cent of projects that submitted bids planned to use Chinese electrolysers. Beyond targets, concrete measures to encourage the use of domestic content are still lacking.

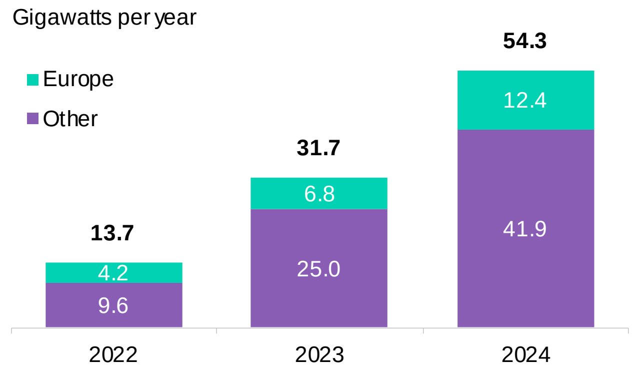
Figure 11: European electrolyser shipments by manufacturer origin



Source: BloombergNEF.

Note: Data from BloombergNEF's Hydrogen Supply Outlook as of May 7, 2024.

Figure 12: Global announced electrolyser manufacturing capacity by manufacturer origin



Source: BloombergNEF.

Note: Data from BloombergNEF's Electrolyser Manufacturing 2024 report as of March 26, 2024.

5. Environmental Delivery

Ensuring that the hydrogen economy delivers on environmental objectives, i.e decarbonisation efforts in line with the Climate Law and the Paris Agreement is key for the creation and long-term success of the hydrogen market. This chapter assesses the impact of low-carbon hydrogen market deployment on European decarbonisation using the most recent and comprehensive data from 2022.[67]

As discussed in Chapter 2, low-carbon hydrogen has the potential to contribute meaningfully to decarbonisation objectives, particularly for those activities where direct electrification is not a feasible alternative. From a broad environmental perspective, the pace of overall decarbonisation can alleviate the scarcity of low-carbon hydrogen. For instance, as the transition towards electric mobility accelerates, the demand for hydrogen in refining - which currently represents 43 per cent of total hydrogen production in the EU and UK - is likely to decrease.[68]

Technological and supply chain improvements are crucial for hydrogen's decarbonisation potential. Autothermal reforming (ATR) and proton-exchange membrane (PEM) electrolysers can reduce emissions and increase hydrogen production, respectively.[69,70] Reducing leaks in fossil fuel operations and sourcing low-emission materials for renewable technologies also enhance hydrogen's environmental impact.

[67] EU H2 Obervatory, available at: https://observatory.clean-hydrogen.europa.eu/
[68] *Ibid.*
[69] ATR is a process that combines steam and partial oxidation of hydrocarbons to produce hydrogen, achieving higher efficiencies and lower emissions than traditional methods.
[70] PEM electrolysers use a solid polymer electrolyte to facilitate water electrolysis, offering quick response times and the ability to operate at higher currents, making them suitable for large-scale hydrogen production.

This chapter develops four key performance indicators (KPIs) to monitor environmental impact. The chapter prioritises data integrity and comparability, focusing less on precise estimations or forecasts of hydrogen-related emissions. Data from the European Hydrogen Observatory (EHO) database provide the source for hydrogen production and consumption metrics by technology, sector, and country.

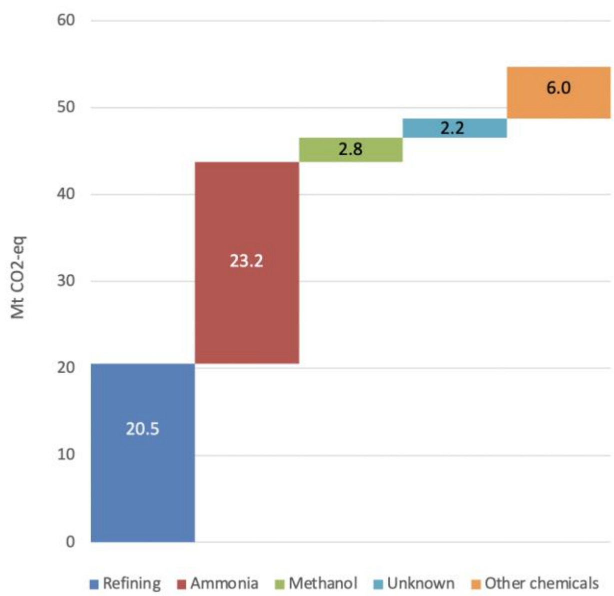
The assumptions underpinning the KPIs include using real Steam Methane Reforming (SMR) production values at 40 per cent of the reported EHO figures, excluding by-product hydrogen, and confining the emissions calculations to the pre-Haber-Bosch process in the case of ammonia.[71] A uniform carbon capture rate of 60 per cent is applied to SMR projects with carbon capture and storage (CCS).[72] While emissions from fossil-based hydrogen consider direct, upstream, and midstream contributions, those from electrolytic hydrogen are considered zero, following the EU RFNBO standards.[73] While acknowledging the limitations of this assumption, hydrogen and direct electrification are regarded as perfect substitutes in the mobility and residential heating sectors for the sake of KPI 3.[74] The environmental analysis is confined to CO_2 or CO_2-equivalent emissions where specified.

5.1 Total emissions from hydrogen production in Europe

This KPI estimates the aggregate emissions from hydrogen production at 54.6 Mt CO_2-equivalent in 2022.[75]

As shown in Figure 13, the ammonia (23.2 Mt CO_2-e) and refining (20.5 Mt CO_2-e) sectors account together for 80 per cent of total emissions, reflecting their higher overall production volumes. Virtually all these emissions can be traced back to unabated SMR production (99.7 per cent), with Partial Oxidation (POX) and SMR CCS-related emissions being only in the kilotonne range.

Figure 13: 2022 H2 emissions end use



Source: ERCST based on European Hydrogen Observatory

[71] This assumption follows the exclusion of catalytic reforming (by-product) from the EHO data. The assumed split of the reported refining SMR values (40% SMR, 50% catalytic reforming, 10% POX) are derived from Cefic.
[72] Based on publicly available information on the Port-Jérôme project.
[73] Emission intensity data for fossil-based hydrogen are derived from the IEA.
[74] This assumption is informed by the observation that 56% of H2 produced via electrolysis for mobility projects in the H2 Observatory database refer to generic "road transport refuelling stations" – where direct electrification is a feasible alternative. In other words, in the database used, mobility applications that cannot be electrified represent a minority of total H2 output for electrolytic mobility application.
[75] Formula: t H2 by production route * emissions intesities of different production routes.

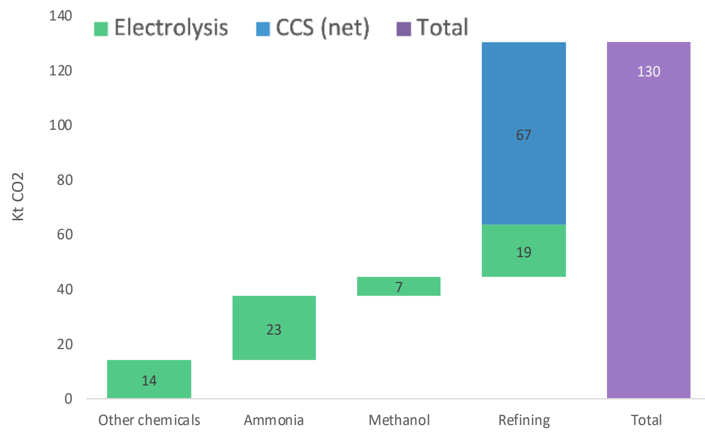
Weighting this KPI value for overall production leads to an implied average emission intensity of 9.1 t CO_2-e/t H_2 in Europe for 2022. For comparison, this value is aligned with the direct emission intensity reported by the IEA for natural gas-based SMR, as well as the median GHG emissions intensity of all hydrogen-producing installations under the EU ETS in 2016/2017.[76,77]

5.2 Emissions savings in traditional hydrogen consuming sectors

Emissions savings are defined as the amount of CO_2 that has not been emitted thanks to the deployment of electrolytic hydrogen and SMR with CCS against hypothetical, alternative uses. For the calculation of this KPI in traditional H_2 consuming sectors (refining, ammonia, methanol, and "other chemicals"), emissions savings are computed based on the avoided emissions from deploying electrolytic and SMR with CCS-based hydrogen instead of natural gas-based SMR.[78]

Figure 14 shows an aggregate value of 130 kt of CO_2 emissions saved. 66 kt of CO_2 are saved through SMR with CCS in refining processes, and 64 kt of CO_2 are saved through electrolysis.

Figure 14: 2022 emissions savings in traditional sectors



Source: ERCST based on Bellona and CCC methodologies

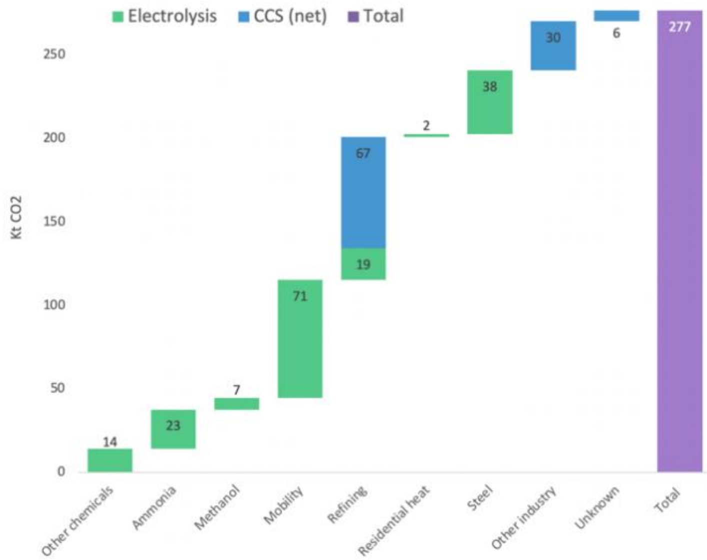
As illustrated in Figure 14, electrolysis-based emissions savings occurred along the full spectrum of the examined industrial processes, with ammonia leading the way.

These very small aggregate emissions savings results can be attributed to the low penetration of low-carbon hydrogen in these sectors, which currently equals only 0.3 per cent of total production (0.02 Mt). Hence, decarbonising existing hydrogen production demands a significantly higher availability of cost-effective, low-carbon hydrogen.

[76] https://climate.ec.europa.eu/system/files/2021-10/policy_ets_allowances_bm_curve_factsheets_en.pdf
[77] https://iea/Towardshydrogendefinitionsbasedontheiremissionsintensity.pdf
[78] Formula: (Electrolytic H2 production in traditional H2 consuming sectors (t) * emission savings from using 55 MWh of renewable electricity to produce renewable H2 that displaces grey H2 (tCO2)) + theoretical emissions accrued if all SMR-CCS production had been produced with SMR - emissions from SMR-CCS.

5.3 Emissions savings in overall hydrogen consuming sectors

Figure 15: 2022 emissions savings in overall H2 sectors



Source: ERCST based on Bellona and CCC methodologies

This KPI extends the previous one by including the amount of CO_2 that has not been emitted thanks to the deployment of electrolytic hydrogen and SMR with CCS in steelmaking, mobility, residential heat, and "other industry".

Considering these additional applications, the total emissions savings from low-carbon hydrogen amount to 277 kt of CO_2, with the refining, mobility, and steel sectors contributing over 85 per cent of these savings.

The avoided emissions from deploying low-carbon hydrogen technologies in these sectors is calculated based on these cleaner alternatives: a) electrolytic hydrogen for direct-reduced iron steel production, which displaces blast furnace methods in the steel industry; b) fuel cell electric vehicles replacing internal combustion engine vehicles (ICEVs) in the mobility sector; c) electrolytic hydrogen-fuelled boilers taking displacing natural gas boilers in residential heating.[79]

However, to assess fully the environmental impacts of these sectoral dynamics, it is crucial to recognise that certain applications of low-carbon hydrogen are in competition with direct electrification. This competition is particularly notable in the road passenger mobility and residential heating sectors, where hydrogen applications contend with battery electric vehicles (as alternatives to ICEVs) and with heat pumps or direct electric heating (as alternatives to natural gas boilers).

Considering these alternatives, the potential emissions savings could more than double, from 72 kt of CO_2 with the current hydrogen decarbonisation approach in mobility and residential heating to 172 kt of CO_2 if the electricity used for producing electrolytic hydrogen for these uses was redirected to power battery electric vehicles and heat pumps instead.[80]

Given the scarcity of low-carbon hydrogen, as detailed in section 5.2, it is important to acknowledge that using this resource in less efficient applications, such as in mobility and domestic heating, diminishes the potential for environmental savings in these areas. Additionally, this practice restricts the availability of low-carbon hydrogen for other sectors where it could have a more significant environmental impact.

[79] https://network.bellona.org/content/uploads/sites/3/2022/07/EFFECTIVE-USE-OF-RENEWABLES-TO-REDUCE-EMISSIONS.pdf

[80] Assuming full substitutability between FCEVs and BEVs in mobility.

5.4 Share of RFNBO hydrogen in industry

As detailed in Chapter 3, article 22a of RED III mandates at least 42 per cent of the hydrogen used industry to come from RFNBOs by 2030, and 60 per cent by 2035. To assess the extent to which industry is approaching this target, this KPI tracks the 2022 share of RFNBOs in total hydrogen used in the EU industry. The industrial sectors considered for the scope of this KPI are ammonia, methanol, steel, and other chemicals. Among them, steel is the only non-traditional hydrogen-using sector.

Table 5: 2022 EU RFNBO consumption in industry

		Ammonia	Other chemicals	Steel	*Total*
t H2/Y	SMR	2037199	523268	0	*2560467*
	SMR CCS	0	0	0	*0*
	POX	0	0	0	*0*
	Electrolysis	2248	1343	1542	*5133*
	Total	*2039447*	*524611*	*1542*	*2565600*
	% electrolysis	*0.110%*	*0.256%*	*100.000%*	***0.200%***

Source: ERCST based on European Hydrogen Observatory

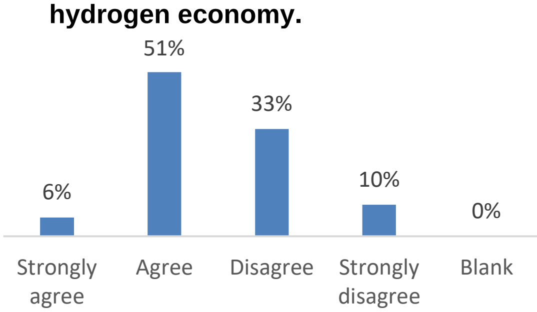
Table 5 shows that, as of 2022, 0.2 per cent of hydrogen used in industry is RFNBO, against the 42 per cent targeted by 2030. This implies that, assuming 2030 hydrogen consumption remains at 2022 levels, RFNBO consumption in industry should more than double every year, increasing by approximately 95 per cent annually until 2030. This suggests that meeting the target will likely require not only a significant increase in RFNBO production but also a reduction in the total hydrogen consumption. While a decline in hydrogen consumption within the refining sector appears foreseeable, other sectors, such as steelmaking, could potentially experience increased demand, further complicating this dynamic.

6. Market Sentiment Survey

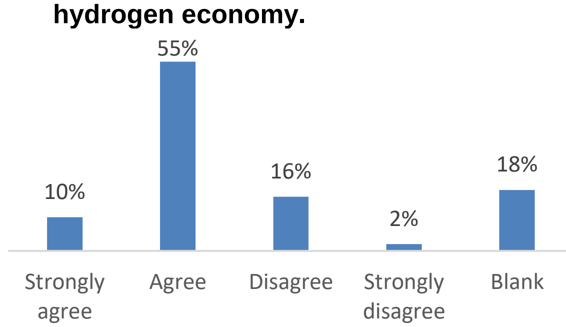
ERCST carried out a Market Sentiment Survey among stakeholders whom the authors believe to be ‘market players and opinion makers’ in the hydrogen market. The sample includes policymakers, industry associations, companies from different sectors dealing with hydrogen, NGOs, think tanks, academia, and civil society. The respondents who participated in the survey are anonymous, and the sample is not intended to be statistically representative.

Market Sentiment Survey results

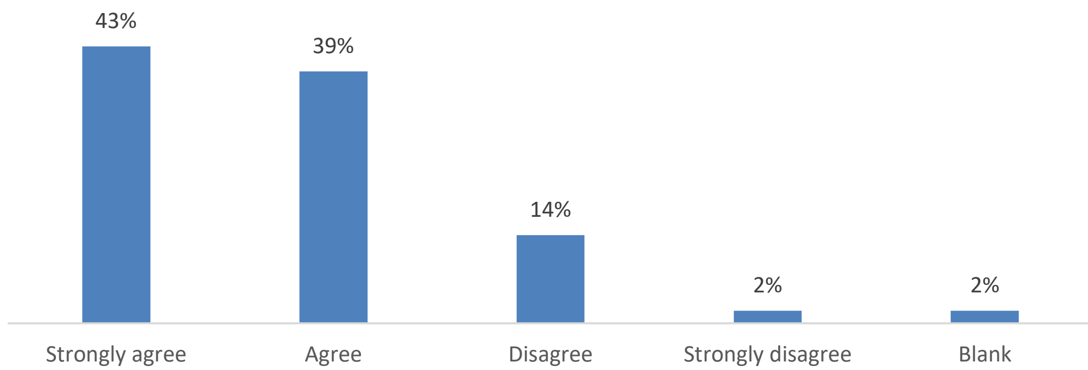
1. **The EU Regulations in their current set up are supporting the creation of the EU hydrogen economy.**



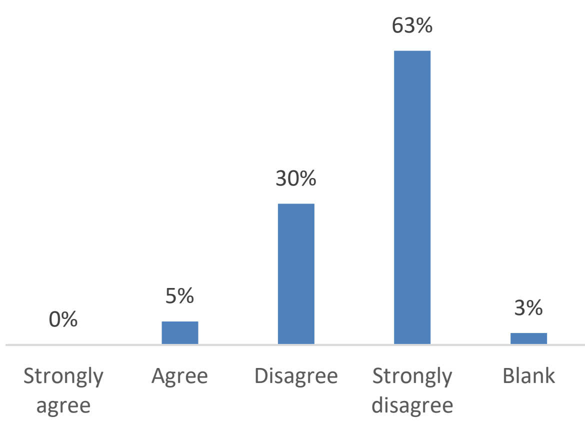
2. **The UK Regulations in their current set up are supporting the creation of the UK hydrogen economy.**



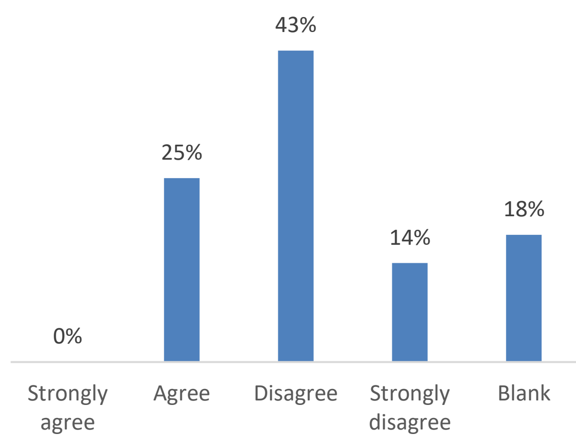
3. **The EU Hydrogen Regulatory Framework should be technology neutral as opposed to specific.**



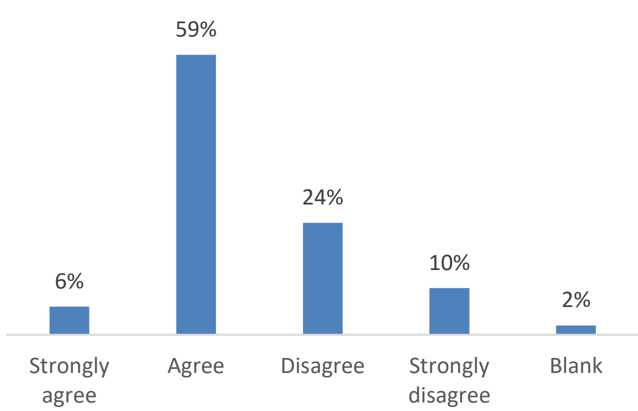
4. **The EU will be able to reach the REPowerEU green hydrogen target of 20 Mt by 2030 (10 Mt domestically produced in addition to 10 Mt imported).**



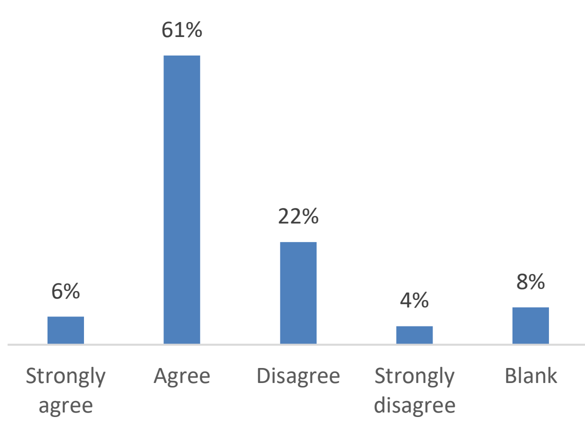
5. **The UK will be able to reach the hydrogen ambitions set in the UK Hydrogen Strategy.**



6. **The Renewable Energy Directive III (RED III) is supporting the uptake of hydrogen in industry.**



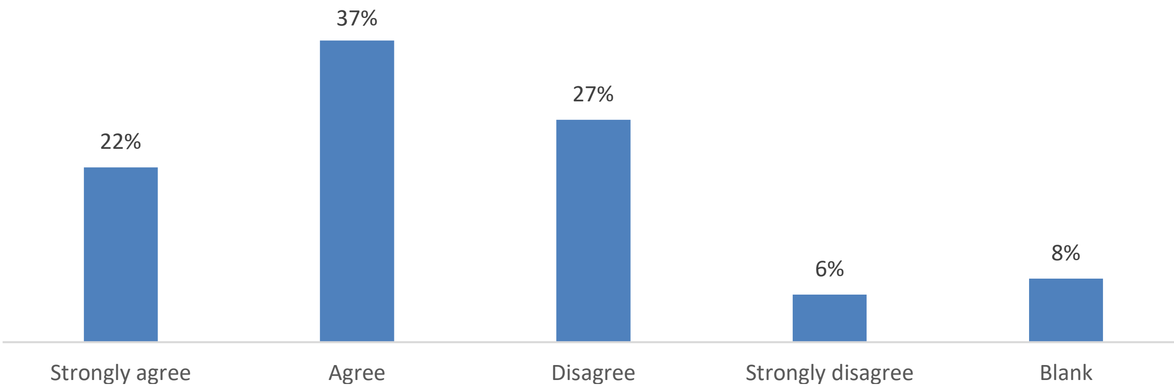
7. **The Renewable Energy Directive III (RED III) is supporting the uptake of hydrogen in the transport sector.**



8. **Which are the EU Member States (including UK) that have the more conducive public funding framework for the hydrogen sector?**

   Germany (41%); (UK 18%).

9. **The EU should consider a more flexible approach when defining Hydrogen emissions, like the UK (the UK approach is 'well to gate' while the EU's one is 'well to wheel').**



The results present a diverse range of perspectives, with certain measures and outcomes being perceived positively, whereas others viewed with more scepticism.

While respondents are divided on whether the EU Regulations in their current setup are supporting the creation of the EU hydrogen economy (Q1), most of them think that the UK's regulations are succeeding in this regard (Q2).

The majority of the sample agrees that the EU should consider a more technology-neutral approach, and be more flexible when defining hydrogen emissions, like the UK and its 'well to gate' approach (Q3 and Q9).

When it comes to meeting the hydrogen targets set by the EU and the UK in their leading strategy/plan, respondents are sceptical. Regarding the REPowerEU's green hydrogen target of 20 Mt by 2030 (10 Mt of hydrogen domestically produced in addition to 10 Mt imported), almost all respondents are convinced that the target won't be met (Q4). The figure for the UK Hydrogen Strategy is similar to the EU's one but slightly more positive, with a moderate percentage of respondents thinking that the UK hydrogen ambitions can be met.

Regarding the Renewable Energy Directive III (RED III), the majority of the sample agrees that it is supporting the uptake of hydrogen both in the industry and transport sectors (Q6 and Q7).

Finally, Germany, is the Member State with the most conducive public funding framework, followed by the UK, according to respondents' opinions.

Disclaimer and Acknowledgements

The views expressed in this Report are attributable only to the authors in a personal capacity, and not to any institution they may be associated with, nor to the funders of the Report.

This Report has been the subject of stakeholder consultations, including a workshop convened by the authors with stakeholders including NGOs, think tanks, academia, policymakers, market participants, and industry representatives.

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