

REPORT

HYDROGEN SUBSIDIES IN THE EU, NORWAY, AND THE US



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Foreword

Menon Economics, commissioned by NHO, has carried out an analysis of the state of public support programmes for green technologies in Europe and the USA, in view of recent changes to the respective subsidy regimes. The study, which is the second in a series of three reports, focuses on the hydrogen industry. The series also covers the battery and offshore wind industries.

The Inflation Reduction Act has been hailed as one of the world's largest subsidy programs for green technologies, having significantly improved investment profitability across industries in the USA. This public support programme prompted the EU to respond quickly, relaxing existing state aid rules and allowing Member States more flexibility to provide state aid. The analysis delves into the public support programmes in both regions and examines their implications on investment profitability.

The analysis was led by Jonas Erraia. The analytical team consisted of Piotr Śpiewanowski, Einar S. Wahl, Henrik Foseid. Erik W. Jakobsen provided quality assurance.

Menon Economics is a research-based analysis and advisory company at the intersection of business economics, economics, and industrial policy. We offer analysis and advisory services to companies, organisations, municipalities, counties, and ministries. Our main focus is on empirical analysis of economic policy, and our employees have economic expertise at a high scientific level.

We thank NHO for an interesting project. We also thank all interviewees for their valuable input during the process. The authors are responsible for all content in the report.

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Executive summary

Low-carbon hydrogen is expected to play an important role in decarbonising critical sectors like transportation, industry, power generation, and heating, serving as a reliable dispatchable and backup power supply. However, its widespread adoption faces significant investment challenges. Currently, production costs of low-carbon hydrogen are two to three times higher than fossil fuels, making it crucial to scale up production and reduce costs to enable widespread adoption of low-carbon hydrogen. This requires developing dedicated hydrogen infrastructure and opening new demand sectors for renewable and low-carbon hydrogen.

To overcome these challenges, authorities in the US and EU have proposed various strategies and initiatives. In the next decade, hydrogen producers in the USA are set to receive a significant subsidy of roughly USD 100 billion under the IRA. This subsidy will be primarily provided through a production subsidy, with a subsidy level depending on life cycle emission intensity. Producers of renewable hydrogen can receive up to USD 3 for every kilogram of renewable hydrogen for 10 years after production start. Blue hydrogen, due to its higher emission levels, qualifies for lower subsidy levels of up to USD 1 per kilogram hydrogen. The production subsidy is disbursed to all producers and is best regarded as a simple cash transfer through the tax system, as it is not depending on having sufficient tax liabilities to be offset with. A key feature of the subsidy structure under the IRA is that it does not involve lengthy, burdensome, and uncertain application processes.

In Europe, the European Commission has proposed the European Hydrogen Bank which will offer subsidies to renewable hydrogen producers in the form of a fixed premium per unit of hydrogen produced. Norway is also eligible to participate in the scheme. The value of the premium will be determined through a competitive auction process. This process will help to identify and cover the funding gap necessary to scale up hydrogen production, while also minimising the costs needed to achieve the EU's hydrogen production targets. It is expected that the subsidy at the initial auctions will result in a fixed premium of between EUR 1.7 and EUR 2.5 per kg H₂ produced for 10 years after production start. The proposed budget of the programme, however, is not yet sufficient to support large scale green hydrogen production. However, the value of subsidies awarded in subsequent auction is expected to be lower as the hydrogen production technology matures potentially allowing to support larger volumes in the future. Finally, as per proposal, the European Hydrogen Bank will support only green hydrogen projects.

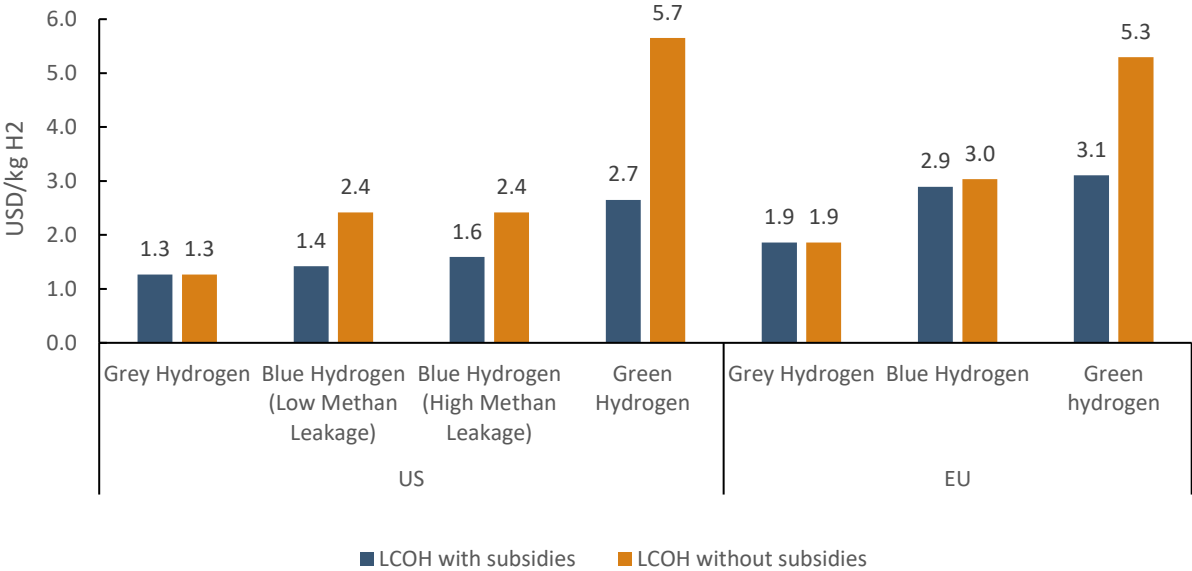
Our analysis of the various public support schemes reveals that the US currently provides more generous subsidies than those proposed in Europe. The difference in proposed public support for green hydrogen is expected to be relatively small in the first rounds of the auction, it is, however, expected to increase as technology matures. There are, however, several factors which make the support for green hydrogen in the EU considerably more uncertain than in the US. Firstly, the support levels will remain unknown until after the auctions. Secondly, the limited budget of the programme in Europe creates uncertainty regarding the actual availability of the support mechanism for projects seeking public support. In addition, and as already mentioned, the support for hydrogen through the Hydrogen Bank still has not been confirmed by the EU.¹

Furthermore, the US programme offers much more certainty about the actual level of subsidies to be received. Moreover, the levels of support in the US are significantly higher for blue hydrogen, which is eligible for production subsidies only in the US. In addition, it is important to note that US LCOH of blue hydrogen after

¹Similar uncertainties exist for the support for electrolysers through IPCEI and TCTF. See below.

subsidies is competitive with grey hydrogen in our calculations. The LCOH for various production technologies in the EU and US respectively is shown in the figure below.

Figure: Levelised cost of hydrogen production with and without subsidies in the US and EU². Source: Menon Economics



If the anticipated European Hydrogen Bank provides the expected level of support, it is unlikely that there will be a significant shift in investment from the EU to the US for green hydrogen. However, for blue hydrogen, the significant gap in production costs may attract more investment in the US, despite potential transportation costs that could hinder export potential. This presents an investment opportunity for Norwegian industry players who focus on blue hydrogen to expand production in the US. It is important to note that primary cost drivers, such as energy prices, demand growth, and technological advancements, are uncertain and could potentially lower market prices in the future.

Within electrolyser manufacturing, it is also unlikely that the difference in support regimes between the United States, Europe, and Norway will result in significant capital outflow to the US. Additionally, high transportation costs play a role in mitigating the potential impact of these differences. This view is confirmed by the European Commission which in its staff working paper from March 2023³ indicates that shipping complete electrolyser systems is not expected to be economically viable due to their weight. Typically, electrolyser manufacturing is located in close proximity to deployment sites as large electrolyser installations need to be customised for specific projects. European Commission have also not found any evidence of a shift in manufacturing investments from Europe to the US.

Differences in support level between the two regions are also likely to have implications on the hydrogen downstream industries such as ammonia production. Nonetheless, examining these markets falls outside the scope of this report.

²The subsidies for green hydrogen in the EU are based on expected levels of subsidies in the first auctions in the Hydrogen Bank. As technology matures, it is expected that subsidies for green hydrogen in the EU will fall. Subsidy levels in the US will stay constant adjusted for inflation through 2032.
³https://single-market-economy.ec.europa.eu/system/files/2023-03/SWD_2023_68_F1_STAFF_WORKING_PAPER_EN_V4_P1_2629849.PDF

Introduction

In 2021, global demand for hydrogen surged to 94 million tonnes, equivalent to 2.5 percent of the world's final energy consumption.⁴ The primary application of hydrogen is in the manufacturing of various chemical products, including fertilisers and plastics. Globally 96 percent of this hydrogen is produced with fossil fuels resulting in significant amounts of CO₂ emissions.⁵

To achieve the goal of net-zero emissions by 2050, low-carbon hydrogen has a crucial role to play. Hydrogen is indispensable in decarbonising critical sectors such as transportation, industry, power, and heat generation as dispatchable and backup power supply. It is estimated that more than 660 million tonnes of low-carbon hydrogen are required to reach this goal⁶, which indicates a significant growth potential for the industry over the next three decades.

The adoption of low-carbon hydrogen faces significant investment challenges, which must be addressed to facilitate the transition to a cleaner, more sustainable energy system. Firstly, the production costs of low-carbon hydrogen are three times higher than those of fossil fuels. As such, it is critical to scale up production levels and reduce production costs to enable widespread adoption of low-carbon hydrogen. This requires developing dedicated hydrogen infrastructure and opening new demand sectors for renewable and low-carbon hydrogen.

To overcome these challenges, authorities in the US and EU have proposed various strategies and initiatives. The European Commission's REPowerEU plan, for instance, aims to produce 10 million tonnes of renewable hydrogen and import another 10 million tonnes of hydrogen by 2030.⁷ Similarly, the DOE National Clean Hydrogen Strategy and Roadmap in the US envisage a demand for 10 million tonnes of low-carbon hydrogen. Additionally, the DOE has launched the Hydrogen Shot program, which aims to reduce the cost of clean hydrogen by 80 percent to USD 1 per kilogram within a decade.⁸ However, this goal seems rather ambitious, and many experts doubt its feasibility.⁹

The differences in wording used in the European and American aspirations highlight variations in the desired production technologies. The European Union's strategy emphasises production and import of renewable hydrogen, which is commonly known as green hydrogen, and can be produced via electrolysis using renewable electricity to split water into hydrogen and oxygen.

In contrast, the United States' strategy references low-carbon hydrogen, which includes both green hydrogen and blue hydrogen. Blue hydrogen is produced from natural gas. The production process combines steam methane reforming, a traditional method to produce the so-called grey hydrogen, with carbon capture and storage (CCS) of the CO₂ emissions generated during the process. While green hydrogen production involves a completely renewable process, blue hydrogen production relies on non-renewable energy sources. The two production pathways are illustrated in Figure 1.

⁴<https://www.iea.org/reports/global-hydrogen-review-2022/executive-summary>

⁵<https://www.irena.org/Energy-Transition/Technology/Hydrogen>

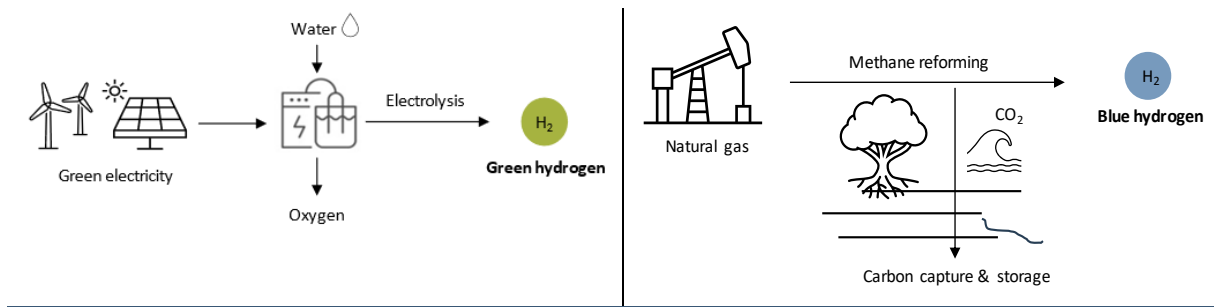
⁶<https://hydrogencouncil.com/wp-content/uploads/2022/10/Global-Hydrogen-Flows.pdf>

⁷https://ec.europa.eu/commission/presscorner/detail/e%20n/ip_22_3131

⁸<https://www.energy.gov/eere/fuelcells/hydrogen-shot>

⁹<https://sustainability.crugroup.com/article/energy-from-green-hydrogen-will-be-expensive-even-in-2050>

Figure 1: Production pathways of green (left) and blue (right) hydrogen.



The production of renewable and low-carbon hydrogen requires significant investments, not only in the capacity for hydrogen production but also in renewable electricity generation, as well as in transportation and distribution infrastructure. According to the proposed EU definitions, electrolyzers that produce renewable hydrogen must be connected to new renewable electricity production to ensure that the generation of renewable hydrogen leads to an increase in the volume of renewable energy available to the grid. This means that approximately 500 TWh of renewable electricity is needed to meet the 2030 ambition in REPowerEU of producing 10 million tonnes of renewable hydrogen. To put this into perspective, this is equivalent to 14 percent of total EU electricity consumption or more than triple the electricity generation in Norway.¹⁰

According to EU estimates, the total investment required to produce, transport and consume 10 million tonnes of renewable hydrogen is expected to range between EUR 335 and 471 billion.¹¹ An additional investment of EUR 500 billion will be needed in international value chains to enable the import of 10 million tonnes of renewable hydrogen, including in the form of derivatives. The investment needs to reach the US goals are likely to be lower as blue hydrogen is expected to constitute a significant share of production. Although production of blue hydrogen requires a lower level of investment than green hydrogen, the gap between them is expected to shrink in the coming decades.¹²

The ambitious objectives to rapidly deploy large-scale renewable and low-carbon hydrogen production as envisioned by EU and US authorities cannot be achieved without public support that bridges the cost gap between fossil-based and renewable/low-carbon hydrogen. This report aims to present the various public support regimes for hydrogen production in the EU, Norway, and the US. The report is structured as follows: In the next section, we briefly outline the key differences in the design of public support regimes in the EU and US. Subsequently, we provide an in-depth analysis of the public support regime in the US, with a primary focus on the provisions of the Inflation Reduction Act. This is followed by a similar examination of the European programs, where we present the support programs both at a general level and with details of individual investment cases in Norway, Sweden, Denmark, France, and Germany. Finally, we compare the European and American regimes and assess their implications for the Norwegian hydrogen industry.

¹⁰ Approximately 146 TWh in 2022 according to SSB.

¹¹ Of this, EUR 200-300 billion is needed for additional renewable electricity production. Key hydrogen infrastructure categories are estimated to require EUR 50-75 billion for electrolyzers, EUR 28-38 billion for EU-internal pipelines, and EUR 6-11 billion for storage by 2030. Upscaling of electrolyser manufacturing capacities will require investments of up to EUR 1.2 billion.

¹² https://energy.ec.europa.eu/system/files/2023-03/COM_2023_156_1_EN_ACT_part1_v6.pdf

A brief introduction to public support for green technologies

Public support programs play a crucial role in promoting emerging technologies or industries that offer public benefits but are faced with market barriers. The production and implementation of renewable and low-carbon hydrogen, for instance, require public subsidies to offset the cost differential between these alternatives and fossil fuels, as well as to encourage the necessary infrastructure and technology development for the hydrogen supply chain. As technology matures, the amount of subsidies needed to bridge the gap decreases. As we show in this report the approach taken by the EU and US in determining the value of subsidies for the hydrogen industry differs between the two regions. Those differences may affect project profitability and investment decisions.

In the **United States**, federal support programs such as the Inflation Reduction Act (IRA) often offer fixed levels of subsidy for net-zero technologies. This subsidy can take the form of a direct payment per unit produced for production subsidies or a fixed percentage of investment costs for investment subsidies. The level of subsidies may differ among technologies and change over time, however only at a predefined rate without considering potential changes or other factors that could affect regional differences in project profitability. While this approach has the advantage of being low in administrative burden, it carries a high risk of either over- or under-compensation.

Public support programs for green technology in **Europe** are generally more complex and fragmented than in the US. While the IRA subsidies primarily focus on mass deployment of green technologies, the main objective of EU programs has traditionally been research and innovation. This distinction is in part due to the European Union's strict state aid rules, which aim to prevent unfair competition between Member States. These regulations require that state aid must not unduly distort competition in the single market and must be necessary and proportionate.

In the past, state aid rules in the EU allowed Member States to allocate funds proportionally to the funding gap, or the difference between the total costs of a project or investment and the amount of private funding available to finance it. To determine the existence of a funding gap, the European Commission requires a thorough analysis of the investment or project, including a detailed assessment of the costs, potential revenues, and the availability of other sources of funding. The analysis should demonstrate that the investment or project would not be viable without the aid, and that the aid is necessary to fill a genuine funding gap. The approach focused on closing the funding gap guarantees the required profitability for the supported projects. However, it often results in lengthy administrative processes and relatively limited funding for mass production of mature technologies thus not enabling speeding up mass deployment of strategic technologies.

To address this issue, the EU has recently presented details of its proposal to extend the possibility to subsidise renewable energy production through competitive auctions for renewable and low-carbon hydrogen via the newly established European Hydrogen Bank. This mechanism will minimise public funding required to achieve the European hydrogen production goals.

When comparing subsidy schemes across different regions, it is important to understand that the objective of industrial policy is not solely to maximise the value of public support, and subsidies are not the primary determinant of investment decisions. There are various reasons for this. Firstly, subsidies can differ significantly in their design, making some easier to obtain or more extended than others. Secondly, investment decisions are influenced by multiple factors beyond just subsidies, such as local production costs, resource and labour availability, and expected demand. Thirdly, if subsidies surpass the necessary level to incentivise the desired production, they become inefficient, and taxpayers bear the additional cost.

However, the relative size of subsidies still plays a role since, all else being equal, companies aim to maximise their profits and may select regions with higher subsidies to locate their production facilities. Therefore, while subsidies should not be the sole factor considered, they can significantly impact a company's decision-making process.

IRA and the hydrogen industry

In the next decade, hydrogen producers in the USA are set to receive a significant subsidy of roughly USD 100 billion under the IRA. This subsidy will be primarily provided through a production subsidy, with a subsidy level depending on life cycle emissions intensity. Hydrogen producers can instead opt for investment subsidy, or in the case of blue hydrogen carbon capture subsidy. Producers of renewable hydrogen can receive up to USD 3 for every kilogram of renewable hydrogen. Blue hydrogen, due to higher emission levels qualifies only for lower subsidy levels up to USD 1 per kilogram hydrogen. The production subsidy is disbursed to all producers and is best regarded as a simple cash transfer through the tax system, though it is not depending on having sufficient tax liabilities to be offset with. A key feature of the subsidy structure under the IRA is that it does not involve lengthy and uncertain application processes.

Brief introduction to the IRA

IRA is the largest investment in green energy in US history. The legislation was signed into law by President Biden on 16 August 2022. It provides incentives to accelerate the green transition in the US, with USD 369 billion allocated for investments in energy security, renewable energy, and zero-emission technologies. This includes tax credits and subsidies for production in areas such as renewable energy, carbon storage, hydrogen, zero-emission fuels, batteries, and electric vehicles.

The IRA reflects the US administration's commitment to achieving a green transition and positioning the United States as a major producer of renewable energy and green technology. Additionally, the Act supports the US's ambition to reduce dependence on China and Asia for critical minerals and components, with some subsidies requiring US content or production within the country.

Within hydrogen industry, the IRA includes public support for developers of hydrogen production facilities (hereafter referred to as “hydrogen producers”) and manufacturers of equipment for hydrogen production facilities (hereafter referred to as “equipment manufacturers”) as well as producers of renewable electricity. The following chapter presents the main elements affecting these two groups of actors.

Hydrogen producers

The tax credits available to hydrogen producers, vary according to whether they produce green or blue hydrogen. Green hydrogen is produced from electricity using electrolyzers, while blue hydrogen is produced using natural gas and carbon capture and storage (CCS). Producers of green hydrogen can receive a production subsidy (PTC), while producers of blue hydrogen have the choice between either this production subsidy (PTC) or a subsidy to capture CO₂.

The production subsidy (§45V) provides a support for hydrogen producers based on the volume of hydrogen produced. The hydrogen producer receives this subsidy over ten years from the start of production. The subsidy will be adjusted for inflation. The production subsidy provided varies between USD 0.6 and USD 3 per kilogram of hydrogen produced, depending on the life cycle emissions of the production. Life cycle emissions include emissions in the production of hydrogen itself and emissions generated upstream, which are mainly related to the production of electricity or gas used to produce hydrogen. Due to the higher life-cycle emissions from blue hydrogen, only producers of green hydrogen will be able to receive the maximum subsidy of USD 3 per kilogram of hydrogen. The requirements to how grid connected electrolyzers shall be treated with respect to upstream GHG-emissions when buying renewable energy credits are still uncertain and is discussed in the next section. In

addition, to be eligible for the production subsidy mentioned above, hydrogen producers must comply with certain criteria regarding the payment of wages and the utilisation of apprenticeships.¹³

As previously mentioned, producers of blue hydrogen have the option to receive a subsidy for the capture of CO₂ (§45Q). While a CCS subsidy existed before the implementation of the IRA, the Act has increased the subsidy from USD 50 to USD 85 per tonne of captured CO₂.

The Inflation Reduction Act enables the incorporation of clean hydrogen production plants within the purview of the clean energy investment tax credit (ITC) program. Clean hydrogen projects can obtain ITCs that equals 30 percent of their investment expenses, contingent on the emissions intensity of their production process and that certain wage and apprenticeship requirements are satisfied. Such energy projects are also eligible for a 10 percent domestic content bonus credit amount and a 10 percent increase in credit rate for investment in the so-called energy communities – impoverished areas around closed coal mines or coal-fired power plants. To be eligible for ITCs under Energy Credits §48 the producer must irrevocably elect to abstain from the PTCs granted under §45V and §45Q. In other words, a hydrogen producer must choose between production and investments tax credits.

¹³ *The specific requirements related to wages and the use of apprentices are elaborated in Annex A.*

Table 1: Overview of relevant paragraphs for hydrogen producers

Type of support	Support	Requirements
Clean Hydrogen Credit (§45V)	<p>Between USD 0.60/kg to USD 3.00/kg of hydrogen produced over ten years. Adjusted for inflation.</p> <p>The following production aid is granted per tonne of hydrogen for different emissions (measured in kilograms of CO₂ per kilogram of hydrogen produced)</p> <ul style="list-style-type: none"> • 2.5-4 kg CO₂ = USD 0.60 • 1.5-2.5 kg CO₂ = USD 0.75 • 0.45-1.5 kg CO₂ = USD 1.00 • <0.45 kg CO₂ = USD 3.00 	<p>Depending on life cycle emissions, as well as requirements for wages and the use of apprentices.</p> <p>Cannot be combined with §45Q.</p> <p>Construction of facilities must start before 2032.</p>
Credit for carbon oxide sequestration (§45Q)	<p>Tax credit of USD 85/tonne of captured CO₂</p>	<p>Cannot be combined with §45V.</p>
Energy Credit §48 (a) (15)	<p>Tax deductions on investments in production facilities</p> <p>The following investment tax credits is granted for different emissions (measured in kilograms of life cycle CO₂ emissions per kilogram of hydrogen produced)</p> <ul style="list-style-type: none"> • 2.5-4 kg CO₂ = 6 percent • 1.5-2.5 kg CO₂ = 7.5 percent • 0.45-1.5 kg CO₂ = 10 percent • <0.45 kg CO₂ = 30 percent <p>Additional 10 percentage points if local content requirements are met¹⁴</p> <p>Additional 10 percentage points in energy communities¹⁵</p>	<p>Cannot be combined with §45V and §45Q</p> <p>Wage requirements and use of apprentices.</p>

¹⁴ All iron and steel products must be produced in the United States, and manufactured products must satisfy a domestic content threshold of 40 percent.

¹⁵ Impoverished areas around closed coal mines or coal-fired power plants and other fossil fuel production and processing facilities.

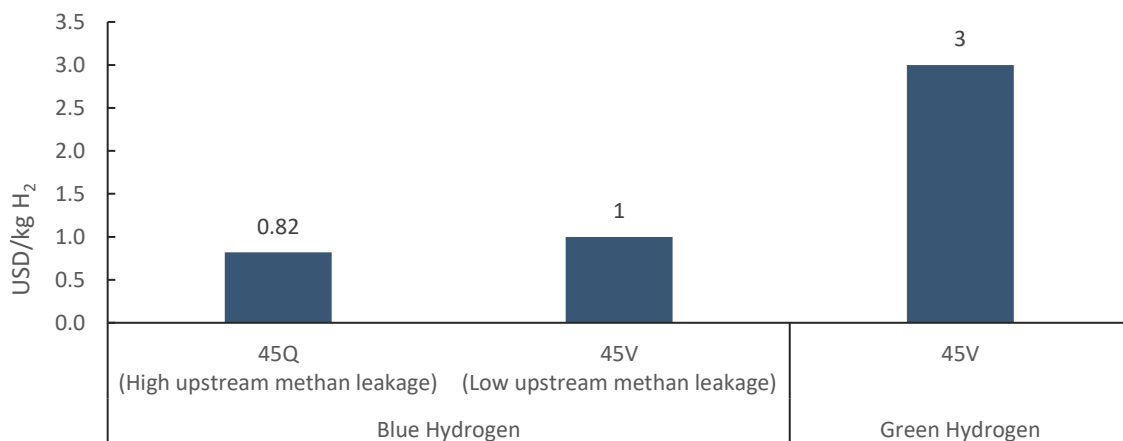
Estimates of hydrogen production subsidies for various technologies

The amount of subsidies available to hydrogen producers depends on their choice to produce blue or green hydrogen, as well as lifecycle emissions intensity. In the case of **green hydrogen**, the subsidies depend on the source of electricity. For a grid-connected electrolyser with no renewable energy contracts, the producer would not receive any subsidies because the upstream GHG emissions would be higher than the allowed 4 kg CO₂/kg H₂. However, this could potentially be resolved by purchasing Renewable Energy Credits (RECs) equivalent to the power consumed or by connecting to an external green power source. In such cases, green hydrogen producers would be eligible to receive USD 3/kg H₂ under 45V clean hydrogen credits. However, the specific methodology for calculating emissions for grid-connected green hydrogen facilities has yet to be determined.¹⁶

The amount of subsidies available to **blue hydrogen** producers is a bit more complex, as it depends on factors such as upstream methane leakage and the percentage of CO₂ captured during production. For example, for relatively high methane leakage rate at 2.2 percent and typical carbon capture rate is 96 percent, the producer would receive more subsidies by opting for the credit for carbon oxide sequestration rather than the clean hydrogen credits, as the CO₂ emissions per kg of H₂ produced would be too high to qualify for the higher clean hydrogen credit levels. Under the credit for carbon oxide sequestration, the subsidies would amount to USD 0.82/kg H₂.¹⁷ However, if methane leakage is assumed to be low (0.3 percent) then for the same carbon capture rate would be more advantageous for the blue hydrogen project to opt for the clean hydrogen credits, as the life cycle emissions per kg of hydrogen would be less than 1.5 CO₂e, resulting in a subsidy of USD 1/kg H₂. The level of subsidy per kg hydrogen for various technologies and subsidy regulations is summarised in Figure 2.

Both blue and green hydrogen producers may instead opt for investment tax credit. In such a case low-carbon hydrogen producers receive up to 50 percent subsidy for the incurred investment costs. However, given the high level of production subsidies, this option is favourable for the investor only for plants with either very low expected capacity utilisation or without access to renewable electricity.

Figure 2: Subsidies for hydrogen production under IRA according to production method.



¹⁶ The forthcoming regulations, which will be specified within a year of the IRA's enactment, will have a significant impact on the subsidies available to a large part of planned green hydrogen projects. These regulations will determine, among other things, whether a hydrogen producer that purchases Renewable Energy Credits must match the production profile of the renewable energy producer on an hourly basis (temporal matching) or averaged over longer periods. Another crucial issue that needs to be decided is whether subsidies will be based on average emissions on an hourly basis or over longer periods.

¹⁷ <https://www.rff.org/publications/reports/incentives-for-clean-hydrogen-production-in-the-inflation-reduction-act/>

Indirect subsidies

In the United States, hydrogen production is also subsidised indirectly through support programs aimed at promoting the development of upstream industries, renewable energy generation, and hydrogen transportation infrastructure. In addition to direct production and investment public support, these programs play a crucial role in promoting the widespread use of hydrogen as a clean energy source. This report outlines some of the key programs supporting hydrogen production and use in the United States.

Electrolyser manufacturers

Electrolyser manufacturers are eligible for investment aid through the IRA. The Qualifying Advanced Energy Project Credit (§48C)¹⁸, is an investment subsidy available to equipment manufacturers who construct new, or upgrade existing, factories. This subsidy can be granted at either a 6 percent or 30 percent level, depending on whether wage and apprenticeship requirements are met. It's worth noting that the ITC under section 48C is granted through a competitive application process and awarded to the projects that demonstrate the highest level of commercial viability, domestic job creation, and net impact in avoiding or reducing air pollutants or greenhouse gas emissions. The subsidies will be available until its budget of USD 10 billion is depleted. However, these USD 10 billion are not exclusively designated to electrolyser manufacturers but also include other low-carbon technology producers, such as fuel cells, CCS, and other advanced energy property designed to mitigate greenhouse gas emissions.

Table 2: Overview of relevant clauses for equipment manufacturers of hydrogen production plants

Type of support	Support	Requirements
Qualifying Advanced Energy Project Credit (§48C)	6 percent of investment cost in new or upgraded factories.	
	30 percent of investment cost in new or upgraded factories	Wage requirements and use of apprentices

Renewable energy production

Access to renewable electricity is crucial when producing green hydrogen. Through the IRA renewable and low-carbon electricity producers are eligible for public support. Players who choose to produce renewable electricity can choose from either an investment tax credit (ITC) or a production tax credit (PTC) which extends the existing production tax credit for applicable renewable energy sources.

The support in the IRA is essentially a continuation of the renewable electricity tax credit, which was first introduced by the IRS in 1992 as part of the Energy Policy Act to promote the development of renewable energy.¹⁹ This tax credit has played an important role in driving the growth of renewable energy in the US and is an important tool for a more sustainable and clean energy future. However, since the range of changes to the public

¹⁸ <https://www.taxnotes.com/research/federal/usc26/48C>

¹⁹ https://afdc.energy.gov/laws/key_legislation

support scheme is at best moderate, we do not expect substantial impact of the new regulations on the electricity prices, at least in the short to medium run.

The first option for a renewable (solar or wind) producer is an investment subsidy (\$48/48E) on a given share of the investment costs. The share of the investment cost is either 6, 30 or 50 percent, depending on whether the requirements related to salaries, use of apprentices, local content and location are met. In addition to this, there are also requirements for emissions at the facility to qualify for investment support. The second option is a production tax credit (\$45/\$45Y), where the developer receives an amount per kWh of electricity produced at the facility over a period of 10 years. The amount is either 0.53 cents/kWh or 2.6 cents/kWh in 2022 USD^{20,21}, depending on whether requirements relating to wages and the use of apprentices are met.²²

The new ITC (\$48E) and PTC (\$45Y) replaces the old ITC (\$48) and PTC (\$45) schemes. The current sections are technology specific, while the new schemes are intended to be technology neutral and will replace the ITC and PTC for facilities placed in service on or after January 1st, 2025.

Table 3: Illustrates the investment subsidy (ITC) and production subsidy (PTC) of equivalent but technology-neutral (\$45Y) paragraph in 2025.

Support type	Support	Requirements
Energy Credit (\$48) / Clean Electricity Investment Credit (\$48E)	6 percent of total investment costs	
	30 percent of total investment costs	Requirements regarding salaries, use of apprentices
	Additional 10 percentage points if local content requirements are met ²³ Additional 10 percentage points in energy communities ²⁴	
Electricity produced from certain renewable resources (\$45) / Clean Electricity Production Credit (\$45Y)	0.53 cents/kWh produced over 10 years. Adjusted for inflation.	
	2.6 cents/kWh produced over 10 years. Adjusted for inflation.	Requirements regarding salaries and the use of apprentices.
	Additional 10 percent if local content requirements are met ²⁵ Additional 10 percent in energy communities ²⁶	

Infrastructure Investment and Jobs Act

Infrastructure Investment and Jobs Act, commonly known as the Bipartisan Infrastructure Law, is an infrastructure investment plan in the United States. The plan includes investment in various priorities such as road and bridges, rail, transit, ports, airports, the electric grid, water systems, and broadband. The plan aims to improve permitting processes, reduce emissions, improve air and water quality, and does also include development of infrastructure in rural areas. The goal is to improve economic efficiency, productivity, GDP, and

²⁰ Equivalent to USD 0.3 cents/kWh and USD 1.5 cents/kWh in 1992 USD.
²¹ <https://taxnews.ey.com/news/2022-0741-irs-corrects-2022-inflation-adjustments-for-renewable-energy-production-tax-credits>
²² https://www.energy.gov/sites/default/files/2022-10/IRA-Energy-Summary_web.pdf
²³ All iron and steel products must be produced in the United States, and manufactured products must satisfy a domestic content threshold of 40 percent.
²⁴ Impoverished areas around closed coal mines or coal-fired power plants and other fossil fuel production and processing facilities.
²⁵ All iron and steel products must be produced in the United States, and manufactured products must satisfy a domestic content threshold of 40 percent.
²⁶ Impoverished areas around closed coal mines or coal-fired power plants and other fossil fuel production and processing facilities.

revenue without increasing inflation in the longer term.²⁷ In November of 2021, USD 9.5 billion was allocated to support the hydrogen value chain through the Bipartisan Infrastructure Law (BIL). Of these USD 9.5 billion BIL allocates USD 8 billion for Regional Clean Hydrogen Hubs to expand the use of clean hydrogen in the industrial sector and beyond. It also includes USD 1 billion for a Clean Hydrogen Electrolysis Program to reduce the cost of hydrogen produced from clean electricity and USD 500 million for Clean Hydrogen Manufacturing and Recycling Initiatives to support equipment manufacturing and strong domestic supply chains.²⁸

²⁷ <https://www.cardin.senate.gov/wp-content/uploads/2022/09/Infrastructure-Investment-and-Jobs-Act-Section-by-Section-Summary.pdf>

²⁸ <https://www.hydrogen.energy.gov/pdfs/clean-hydrogen-strategy-roadmap.pdf>

Public support for hydrogen production in the EU

In the past, public support for renewable and low-carbon emission hydrogen producers in Europe was primarily provided through scattered programs aimed at research, development, and innovation, as well as for pilot projects. However, there has been a shift in this approach with the introduction of IPCEI, a programme that provided investment subsidies specific hydrogen producers at a higher level than previously allowed. Furthermore, the European Commission has recently unveiled plans for a European Hydrogen Bank, which will offer subsidies to green hydrogen producers in the form of a fixed premium per unit of hydrogen produced. Blue hydrogen producers are not eligible to participate in the auction. The value of the premium will be determined through a competitive auction process. This process will help to identify and cover the funding gap necessary to scale up hydrogen production, while also minimising the costs needed to achieve the EU's hydrogen production targets. However, the first auction will take place only in autumn 2023 and there remains a significant degree of uncertainty about the programme's budget.

Renewable and low-carbon hydrogen are crucial components of the EU's decarbonisation strategy, and the role of hydrogen has recently been emphasised by Ursula van der Leyen, the President of the European Commission, in her State of the Union speech in September 2022.²⁹ One of the key initiatives announced during that speech is the European Hydrogen Bank. Although the Bank is still being developed, the available information suggests that it has the potential to make a substantial impact on the European renewable hydrogen industry. The Bank is expected to provide a fixed premium to support the industry, allocated through a competitive auction process. This approach is likely to encourage increased investment in the sector and help to accelerate the growth of the renewable hydrogen market in Europe.

The European Hydrogen Bank fits other recent changes to the EU state aid regulations in response to the IRA's advocacy for green technology and the growing renewable energy sector. These amendments pave the way for increased public support in the mass production of green technologies, emphasising the EU's commitment to strategically advancing net-zero industries. This noteworthy shift in focus is expected to have a significant impact on the renewable energy sector. Thanks to these recent changes, it is expected that nearly 75 percent of the public aid allocated to all net-zero technologies³⁰ between 2021 and 2027 will be dedicated to downstream deployment.

Until recently, the EU has focused more on supporting innovation in the hydrogen industry, providing application-based support on a project-by-project basis, which differs from the production support provided by the US.

The EU support programme has also been fragmented thus in this section we describe in detail the broad range of programmes available to hydrogen producers in EU and Norway.

European Hydrogen Bank: Planned production subsidies

The European Hydrogen Bank is a financing mechanism proposed by the European Commission to support the production of renewable hydrogen both within and outside the EU. The European Hydrogen Bank aims to reduce the cost differential between renewable hydrogen and the fossil fuels it seeks to replace by bridging the funding gap required to scale up hydrogen production.³¹ In addition, the EU hopes it will enhance transparency in

²⁹ https://ec.europa.eu/commission/presscorner/detail/en/speech_22_5493

³⁰ Distribution of support may differ between individual technologies.

³¹ https://energy.ec.europa.eu/system/files/2023-03/COM_2023_156_1_EN_ACT_part1_v6.pdf

hydrogen-related transactions, flows, and prices. The proposal for the European Hydrogen Bank, which was recently unveiled, indicates that it will facilitate the production of renewable hydrogen domestically and the importation of hydrogen from foreign producers to European consumers.

To facilitate the implementation of the domestic component of the European Hydrogen Bank, the European Commission is developing the first pilot auctions for renewable hydrogen production, which are slated to be launched under the Innovation Fund in autumn 2023. These auctions will provide a subsidy to renewable hydrogen producers in the form of a fixed premium per kilogram of hydrogen produced for a maximum of ten years of operation. As per the proposed design, the mechanism will be financed through the Innovation Fund and will only provide support for the production of renewable hydrogen within the EU, Norway, and Iceland. The European Commission has stated that only renewable hydrogen production will be eligible for this support mechanism. Thus, as proposed no support is available for producers of blue hydrogen through this regime.

By closing the cost gap and increasing revenue stability, this will enhance the bankability of projects and reduce overall capital costs. The indicative budget for the first auction is set at EUR 800 million funded through the Innovation Fund. European Commission estimates that a budget of EUR 1 billion will enable 40-60 thousand tonnes of renewable hydrogen production capacity per year, suggesting that the subsidy in the initial stage would amount to between EUR 1.7 and EUR 2.5 per kg H₂ produced. However, it is expected that the market premium will decrease after 2025 due to the expected technologically driven decrease in production costs and the increased demand for green products produced with renewable hydrogen.

According to the newly published draft of economic Terms and Conditions of the 2023 pilot auction,³² the scheme is likely to be structured as “pay-as-bid” static auctions, with applicants submitting a single bid during the qualification phase for a ten-year fixed premium (in €/kg), which is then ranked compared to other bids on price. Successful applicants will be awarded the fixed premium they specified in their bid, up to €4/kg. Bidders must have a project of at least 5MW of installed electrolyser capacity of any technology, and not bid for support of more than 33% the total €800m budget.

Individual Member States have the option to extend the total budget for hydrogen auctions by utilizing the European Hydrogen Bank auction platform to support projects within their territory using their own resources once the Innovation Fund budget is depleted. This approach extends the total budget available for supporting green hydrogen production and ensures unified auction rules, thereby preventing fragmentation during the early stage of hydrogen market formation in Europe.

Based on the expected decline in production costs and the increasing demand for renewable hydrogen, estimates suggest a total green premium of around EUR 90-115 billion for both the domestic production and import of a total of 20 million tonnes of renewable hydrogen.

Existing Investment Subsidies

Temporary Crisis and Transition Framework

On March 9, the European Commission introduced new measures, to further accelerate investments in key sectors for the transition towards a net-zero economy, enabling investment support for the manufacturing of strategic equipment including batteries. This was done by extending and re-diverting the “*Temporary Crisis and*

³² https://climate.ec.europa.eu/system/files/2023-03/policy_funding_innovation_draft_term_conditions_pilot_auction_en.pdf

Transition Framework” (TCTF). The new rules apply also to EEA countries including Norway³³ and are applicable until 31 December 2025.

The first possibility of increased state support in the TCTF is increased freedom for Member States to design schemes where companies can receive aid to green tech production facilities. This aid is to be capped at a certain percentage of investment costs, which is a function of the company size, as well as the location of the project as shown in Table 4. According to the latest regional state aid map, the areas that qualify for regional aid as “c-regions” cover 25 percent of Norway’s total population.³⁴ The Norwegian state aid map does not specify any “a-regions”.

Table 4: Maximum state aid amount and state aid intensity under the Temporary Crisis and Transition Framework.

	Maximum amount			Maximum intensity ³⁵		
	Non-assisted areas	c-regions ³⁶	a-regions	Non-assisted areas	c-regions	a-regions
Large enterprises	EUR 150 million	EUR 250 million	EUR 350 million	15 %	20 %	35 %
Medium sized enterprises	EUR 150 million	EUR 250 million	EUR 350 million	25 %	30 %	45 %
Small enterprises	EUR 150 million	EUR 250 million	EUR 350 million	35 %	40 %	55 %

In addition, Member States can grant even higher aid intensities if the aid is provided via tax breaks, loans or guarantees.

Moreover, in exceptional cases, where there is a real risk of investments being diverted away from Europe, Member States are now allowed to offer public support exceeding aid intensity thresholds shown above. In such situations, Member States may provide either the amount of support the beneficiary could receive for an equivalent investment in that alternative location (the so-called ‘matching aid’) or the amount needed to incentivise the company to locate the investment in the EEA (the so-called ‘funding gap’) whichever is the lowest.³⁷ The new regime allowing matching subsidies, which can be either cash or tax breaks, will be open until 2025. Subsidies for approved projects can run for longer time periods. This rule applies only to investments taking place in assisted areas. Large parts of Norway classify as assisted areas due to low population density.

However, the single market concerns mentioned earlier remain in place. Before granting state aid, national authorities must verify the concrete risks of the productive investment not taking place within the European Economic Area (‘EEA’) and that there is no risk of provoking relocation from other EEA countries. Thus, the procedure likely remains lengthy and administratively challenging.

³³ <https://www.eftasurv.int/state-aid/state-aid-rules-ukraine-crisis>

³⁴ <https://www.eftasurv.int/newsroom/updates/esa-approves-norways-regional-aid-map-2022-2027>

³⁵ Calculated as nominal aid amount / eligible costs

³⁶ A regional aid map can be found here: https://competition-policy.ec.europa.eu/state-aid/legislation/modernisation/regional-aid/maps-2022-2027_en

³⁷ https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1563

In our view, it is unlikely that the 'matching aid' clause could be utilised to support hydrogen production, given the EU's proposal of the European Hydrogen Bank as a market-based tool to address the funding gap. Nonetheless, the 'matching aid' clause could potentially be directed towards other facets of the hydrogen value chain, such as electrolysers.

Net Zero Industry Act

On March 16th, the European Commission put forward the Net Zero Industry Act (NZIA), which aims to ensure that the EU has the necessary production capacity to meet 40 percent of its deployment requirements for strategic net-zero technologies by 2030. The proposed definition of strategic net-zero technologies covers several technologies within the hydrogen value chain, including electrolysers, fuel cells, and carbon capture and storage.

The Act also proposes improvement in conditions for investment in net-zero technologies by reducing the administrative burden and simplifying permit-granting processes to increase planning and investment certainty. The Act also proposes to improve the use of already existing public support schemes, without providing new funds.³⁸ The Act incorporates a novel concept of "net-zero strategic projects," which will be accorded priority status to facilitate expeditious permitting processes. These projects may be regarded as being of overriding public interest for permitting purposes, subject to fulfilling the conditions enshrined in EU law. One of the main objectives of this provision is to accelerate the deployment of renewable electricity projects, which is a crucial step in overcoming one of the primary barriers to scaling up green hydrogen production.

The Act encompasses provisions targeted at the development and implementation of education and training programs to reskill and upskill the workforce required for net-zero technology industries. These provisions are designed to ensure that the industry has access to the necessary skills and expertise for a sustainable future. Additionally, the European Commission has introduced the Critical Raw Materials Act, which aims to enhance access to vital minerals necessary for the mass production of green technologies, including batteries.

IPCEI

Important Projects of Common European Interest (IPCEI) is a European public support arrangement that enables Member States to create initiatives for financing of large and strategically important co-operation projects within the EEA. The IPCEI scheme offers the possibility of providing state aid to certain projects that would not otherwise be allowed under the normal EU state aid rules. The arrangement can be used for infrastructure projects and projects within strategically important value chains, and all EU and EEA Member States can participate. The Member States are responsible for setting up, financing, and selecting the projects that become part of an IPCEI initiative, but the initiative and the projects within it must be approved by the Commission. The Member States and the selected companies must demonstrate that the projects contribute to achieving key strategic objectives.

Since 2014, seven IPCEI initiatives have been established, two for infrastructure and five for strategically important value chains. Of the IPCEI initiatives under strategically important value chains, two have focused on batteries, two on hydrogen and one on microelectronics. Norway currently participates in one of the hydrogen initiatives.

To qualify as an IPCEI initiative the Commission requires that the initiative; (1) contribute to strategic EU objectives, (2) help overcome market or system failures, (3) fund breakthrough innovation, (4) involve several

³⁸ https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1665

Member States, (5) generate positive impacts across the EU, (6) involve private funding from beneficiaries, (7) limit state aid to the necessary minimum and (8) include highly innovative projects. To qualify as "highly innovative", projects must have a strong innovative character and add significant value to RDI. Projects involving a "first industrial application" are eligible for state aid under IPCEI.³⁹ Commercial production is not part of the "first industrial application" and are not eligible for state aid. Upgrades of existing products and production processes are not eligible for state aid under the IPCEI scheme.⁴⁰

The EU Commission approved the first hydrogen IPCEI, named Hy2Tech, on July 15th, 2022. The initiative has a total budget of EUR 5.4 billion in public funding and is expected to attract EUR 8.8 billion in private investments. Hy2Tech involves 15 member states and 41 hydrogen projects, with the aim of supporting innovation, research, and initial industrial deployment of hydrogen technology. The initiative targets several technology areas within the hydrogen value chain, including hydrogen generation, fuel cells, storage, transportation, and distribution, as well as end-user technology, particularly in the mobility sector.⁴¹

On September 21st, 2022, the EU Commission approved the Hy2Use hydrogen IPCEI, the second of its kind. The initiative aims to complete 35 projects by 2036 and has received a total of EUR 5.2 billion from 13 member states, expected to attract an additional EUR 7 billion in private investments. The Hy2Use initiative targets several aspects of the hydrogen value chain, including the construction of hydrogen infrastructure, particularly large-scale electrolysis, and transport infrastructure, to produce, store and transport renewable or low-carbon hydrogen. The initiative also focuses on developing technologies to integrate hydrogen into industrial processes, particularly in sectors that are difficult to decarbonise, such as steel, cement, and glass.⁴²

Norway is a part of Hy2Use and participates with two individual projects. These are the Barents Blue project (blue hydrogen production), and the Tizir project which aims to utilise hydrogen in metallurgy.

Clean Hydrogen Joint Undertaking

The Clean Hydrogen Joint Undertaking, also referred to as the Clean Hydrogen Partnership, is a collaboration between public and private entities aimed at advancing hydrogen technology research and innovation in Europe. Its main objective is to enhance and integrate the scientific capabilities of the European Union, thereby accelerating the development and refinement of advanced clean hydrogen applications. The partnership comprises European Commission as well as representatives of fuel cell and hydrogen industries and the research community).

Established in November 2021, the Joint Undertaking is the successor of the Fuel Cells and Hydrogen Joint Undertaking. To support its endeavours, the EU has committed EUR 1 billion from the Horizon Europe program for the 2021-2027 period. This funding will be augmented by an equivalent or greater amount of investments from private partners, resulting in a total budget exceeding EUR 2 billion.⁴³

Between 2015 and 2021 the Fuel Cells and Hydrogen Joint Undertaking granted subsidies to a total of EUR 633 million from horizon 2020 program. The grants were given to 133 projects, and the total cost of these projects

³⁹ A "first industrial application" is defined as an extension of pilot plant, demonstration plant or "first in kind" equipment and facilities of its kind and includes scaling up to series production.

⁴⁰ <https://www.stortinget.no/globalassets/pdf/utredningsseksjonen/utredningsnotater/2022/notat-om-internasjonale-prosjekter-av-felleseuropeisk-interesse---ipcei-2022317.pdf>

⁴¹ https://ec.europa.eu/commission/presscorner/detail/en/ip_22_4544

⁴² https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5676

⁴³ https://www.clean-hydrogen.europa.eu/about-us/who-we-are_en

where projected at the time of receiving the grants to EUR 1 294 million. This means that the average funding intensity amounted to 49 percent of project costs.⁴⁴

The ongoing Clean Hydrogen Undertaking has in 2022 and so far in 2023 granted subsidies to a total of EUR 155 million from the Horizon Europe program. The grants were given to 27 projects, with a total cost of EUR 245 million. This means that the average funding intensity amounts to 63 percent of project costs.⁴⁵

Horizon Europe

Horizon Europe is the European Union's flagship research and innovation funding program for the years 2021-2027. With a budget of over EUR 95 billion, it aims to support breakthroughs, discoveries, and world-class innovation across a broad range of scientific and technological areas, from health to climate change, energy, and digitalisation. As much as 35 percent of the budget will contribute to climate action to achieve green change and sustainable value creation.⁴⁶

The program builds on the success of its predecessor, Horizon 2020, and offers a variety of funding opportunities for research and innovation projects, including collaborative research projects, innovation actions, and research infrastructures. It also aims to boost the impact of research and innovation by promoting its uptake and commercialisation.

The Clean Hydrogen Joint Undertaking, which is financed by the Horizon Europe budget, is the main funding opportunity for fuel cells and hydrogen technology RDI projects from Horizon Europe. However other parts of the Horizon Europe program may also fund projects related to hydrogen in areas such as transport, industry, and other hydrogen application projects.

The Innovation Fund

The Innovation Fund is an EU fund that supports the development of commercial demonstration of low-carbon technologies that can help the EU meet its climate goals. The fund is financed through the auctioning of emission allowances in the European Emissions Trading System (ETS) for greenhouse gas emissions. It is estimated that if the carbon price is EUR 75/tCO₂, the financial budget of the fund will be EUR 38 billion for the period 2020 to 2030.⁴⁷ The fund supports up to 60 percent of “relevant costs”. In case of large-scale projects, the relevant costs are the additional capital and additional operational costs linked to the innovation during the 10 years after project’s entry into operation. In case of small-scale projects, the relevant costs are defined as the project’s capital expenditure.⁴⁸ 40 percent of the subsidies can be disbursed based on pre-defined emission reduction targets, before the project is up and running, with the remaining 60 percent allocated on the basis of verified emission reductions.⁴⁹ Projects are chosen based on five main criteria: efficiency in terms of CO₂ emission reductions, level of innovation, maturity of the project, scalability of the project and cost-effectiveness. Additional criteria may also be imposed to strike a balance in terms of geographical location and industry type. The support awarded from the Innovation Fund is for pilot projects and commercial demonstration projects, not

⁴⁴ https://www.clean-hydrogen.europa.eu/projects-repository_en

⁴⁵ https://www.clean-hydrogen.europa.eu/projects-repository_en

⁴⁶ <https://www.forskningsradet.no/en/horizon-europe/facts/>

⁴⁷ https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund/what-innovation-fund_en

⁴⁸ https://climate.ec.europa.eu/system/files/2020-09/innovation_fund_cumulation_public_en.pdf

⁴⁹ https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund/what-innovation-fund_en

for pure R&D projects, as the support awarded is directly related to the amount of greenhouse gases that the project is estimated to cut.

So far, eight projects focused on hydrogen production has attained subsidies from the Innovation Fund. These eight projects have been granted a total of EUR 402 million. Of these eight projects four of them where large-scale projects (above EUR 7.5 million) with a combined funding of EUR 384 million, and four of them where small-scale projects (below EUR 7.5 million) with a combined funding of EUR 18 million. For the large-scale projects the subsidies accounted for 23.5 percent of the total investment cost.⁵⁰

Furthermore, as already mentioned, the Innovation Fund is funding the European Hydrogen Bank.

InvestEU Fund

InvestEU Fund is an EU initiative aimed at supporting investment in innovation and job creation across the EU and was created to bring together several independent financing instruments under the EU. The program is designed to provide long-term financing for projects that contribute to achieving EU policy objectives. This financing is in the form of debt financing, loan guarantees and equity financing. InvestEU is expected to mobilise up to EUR 372 billion of public and private funds, through an EU budget guarantee of EUR 26.2 billion over seven years (2021-2027). The European Investment Bank (EIB), the lending arm of the European Union, will be granted access to 75 percent of this guarantee and will act as the main partner for the implementation of the fund. InvestEU invests in sustainable infrastructure, RDI, digitalisation, small and medium-sized enterprises, and social investment. Over 30 percent of the financing will target the objectives of the European Green Deal and can finance such projects up to 60 percent.⁵¹

Regional Aid

There is currently the possibility under EU and EEA regional aid guidelines⁵² to provide state aid to certain regional areas. Regional aid aims to support economic development in disadvantaged areas of Europe, while setting limits to ensure fair competition between Member States. Under these rules, which are exemptions from the regular prohibition of state aid within the single market, regional areas that have either low GDP per capita, high unemployment or low population density (relative to the EU average) can be approved as areas where state aid is allowed. Under these exemptions from the regular state aid rules the aid intensity can be up to 20 percent of the investment cost for large enterprises.^{53,54} The availability of regional aid is country specific. So is the phase of production they support, but usually it is commercial production, as the goal of regional aid is to spur economic development in the above-mentioned regional areas.

Europe's hydrogen landscape: National strategies and subsidised projects

In this sub-chapter we describe the national hydrogen strategies for Norway, Sweden, Denmark, Germany, and France. The stated goal of the overall EU strategy is to produce and import 10 million tonnes of clean hydrogen

⁵⁰ Based on the average aid intensity of the Finnish SHARC project and the Dutch FUREC project.

⁵¹ https://investeu.europa.eu/what-investeu-programme/investeu-fund_en

⁵² [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021XC0429\(01\)](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021XC0429(01))

⁵³ <https://ec.europa.eu/docsroom/documents/42921/attachments/1/translations/en/renditions/native>

⁵⁴ For medium-sized enterprises the aid can be 30 % and for small enterprises the aid can be up to 40 %. The definition of medium-sized enterprises is less than 250 employees and less than EUR 50 million in turnover. Small enterprises are defined as less than 50 employees and less than EUR 10 million in turnover

per year in 2030. This equals an electrolyser capacity of between 80 GW and 100 GW across Europe⁵⁵, of which the European Commission has targeted 40 percent as “Made in Europe”.⁵⁶ On the national level the German government plans is to install electrolyser capacity of 5 GW, the French government aims at 6.5 GW, the Danish government 4 to 6 GW and the Swedish government aims at 5 GW. Norwegian government has also developed a hydrogen strategy, highlighting the importance of hydrogen in meeting the carbon neutrality goal by 2050. The strategy, however, does not set any quantitative goals on hydrogen production.⁵⁷

In addition to the national strategies, we describe some of the large-scale projects that have been announced and received subsidies in these countries. Most low-carbon hydrogen projects of substantial production capacity in Europe are still in its infancy and many of these large-scale projects have just been granted subsidies from their national governments through one of the two IPCEI initiatives in 2022. This means that the official numbers on these grants are yet to be disclosed and not available through the EU state aid register but are sometimes disclosed by the company or the national government. For each of the project we have analysed EU state-aid registers, CORDIS database, Innovation Fund project portfolio and news reports to identify the level of received aid. However, as most projects are relatively small and still in the planning stages, the overview may not give the full picture of the possibilities available to hydrogen producers today.

Norway

Norway has under the Paris Agreement committed to a collective ambition of limiting the overall impact on climate to the 1.5-degree goal. As part of the Norwegian government’s efforts to contribute to sustainable development and further reduce emissions, the Ministry of Climate and Environment and the Ministry of Petroleum and Energy launched the government’s hydrogen strategy in 2020. The Norwegian hydrogen strategy aims to develop new low-emission technologies and solutions which includes both the green and blue hydrogen production paths⁵⁸

Norwegian government funds hydrogen-related projects through Enova, The Research Council of Norway, Innovation Norway, and Gassnova to hasten the development of green fuel production.⁵⁹ Norwegian authorities have allocated over NOK 1,3 billion to projects targeting the production of blue or green hydrogen. These projects are diverse in nature, with planned production capacity and support varying significantly across different initiatives, ranging from small-scale pilot projects to full-scale production facilities. Production capacity of the projects spans from 1 to 600 tonnes per day. Below we describe some of the most important projects with production capacity above 20 MW electrolyser capacity (or 5 tonnes hydrogen per day) and received subsidies.

The four green hydrogen projects received nearly NOK 840 million from Enova against the total investment commitments of NOK 2.2 billion and combined electrolyser capacity of 84 MW. The average state aid intensity for those projects was 38 percent, ranging between 18 and 54 percent for individual projects. The only analysed blue hydrogen project – Barents Blue – received nominally by far the largest subsidy of nearly NOK 500 million. However, due to the scale of the project the investment needs are much larger reaching NOK 10 billion. For some of the projects the allocated state aid still needs to be approved by ESA.

⁵⁵ https://energy.ec.europa.eu/system/files/2023-03/COM_2023_156_1_EN_ACT_part1_v6.pdf

⁵⁶ <https://www.hydrogeninsight.com/production/eu-calls-for-100gw-of-green-hydrogen-by-2030-with-about-40-made-using-european-electrolysers/2-1-1421014>

⁵⁷ <https://www.regjeringen.no/contentassets/40026db2148e41eda8e3792d259efb6b/y-0127b.pdf>

⁵⁸ <https://www.forskningsradet.no/utlysninger/hydrogensatsing-2021/regjeringens-hydrogenstrategi-og-oremerking-av-midler-til-hydrogen/>

⁵⁹ <https://www.enova.no/heilo/hydrogen/stotte-til-hydrogenprosjekter/>

Table 5: Large hydrogen projects in Norway which have received support through Enova.

Owner(s)	Name of project	Purpose	Production capacity	Support (MNOK)	Total CAPEX (MNOK)
Horisont Energi ^{60, 61}	Barents Blue	Blue hydrogen production to produce ammonia	600 tonnes per day	482*	10 000
Yara ^{62, 63}	SKREI	Green hydrogen production to produce ammonia	24 MW	283	720
Nel, Greenstat, Troms Kraft, Meløy Energi ⁶⁴	Glomfjord Hydrogen	Green hydrogen for maritime fuel purposes	20 MW	150	350
NTE, H2 Marine ⁶⁵	Hydrogen Hub Rørvik	Green hydrogen for maritime fuel purposes	20 MW	125,7	300
HyFuel ⁶⁶	HyFuel Florø	Green hydrogen for maritime fuel purposes	20 MW	132	700
Everfuel, Greenstat ^{67, 68}	Hydrogen Hub Agder	Green hydrogen for maritime fuel purposes	20 MW (phase 1). 60 MW (phase 2)	148	344

* IPCEI-project

Sweden

The Swedish hydrogen strategy is aimed at promoting hydrogen development to achieve the climate goals, create innovations, jobs, and export products. The focus is on renewable hydrogen and low-carbon hydrogen produced from a low emission Swedish electricity mix.⁶⁹ Sweden aims to expand the electrolyser capacity to 5 GW in 2030 and to 15 GW in 2045 respectively. The Swedish Energy Agency estimates that this will reduce annual emissions by 1.5-3 million tonnes of CO₂e by 2030 and 7-15 million tonnes by 2045.

HYBRIT (Hydrogen Breakthrough Ironmaking Technology) is one of the hydrogen projects under the Hy2Use IPCEI initiative. HYBRIT plans to develop a fossil-free value chain for iron and steel production using renewable electricity and green hydrogen. The project plans to replace the coal-based blast furnace technology with direct reduction based on green hydrogen. The project aims to produce approximately 1.2 Mt of crude steel annually, representing 25 percent of Sweden's overall production. To enable this technology there is need for a substantial supply of green hydrogen. This will be made possible by HYBRIT's own first of a kind hydrogen production facility in Gällivare, that is planned to use a 500 MW electrolyser powered by fossil free electricity.⁷⁰ The plant will commence its operations in 2026 and enter full production 2029.⁷¹

⁶⁰ <https://horisontenergi.no/projects/barents-blue/>

⁶¹ <https://www.nordnorskrappport.no/2022/04/%EF%BF%BCvil-investere-10-milliarder-i-produksjon-av-bla-ammoniakk/>

⁶² <https://www.yara.com/corporate-releases/yara-and-linde-engineering-agree-to-build-a-24-mw-green-hydrogen-demonstration-plant-in-norway.-both-companies-aim-to-achieve-a-significant-carbon-dioxide-reduction-in-the-production-of-fertilizers-in-norway/>

⁶³ <https://www.yara.com/siteassets/investors/057-reports-and-presentations/other/2022/yca-capital-markets-day-full-length.pdf>

⁶⁴ <https://glomfjordhydrogen.no/ac/om-glomfjord-hydrogen/historie>

⁶⁵ <https://www.sintef.no/siste-nytt/2022/forste-hydrogendrevne-havbruksbat-klar-i-2023/>

⁶⁶ <https://grontskipsfartsprogram.no/wp-content/uploads/2022/03/Maritimt-utslippsfritt-drivstoff.-Infrastruktur-for-LOHC.pdf>

⁶⁷ https://api.greenstat.no/uploads/Greenstat_Investor_Presentation_Okt_2_62fdbd2344.pdf?updated_at=2022-10-11T14:24:17.339Z

⁶⁸ <https://greenstat.no/en/news/greenstat-og-everfuel-vil-etablere-hydrogen-knutepunkt-agder>

⁶⁹ <https://www.energimyndigheten.se/nyhetsarkiv/2021/forslag-till-nationell-strategi-for-fossilfri-vatgas/>

⁷⁰ <https://www.hybriddevelopment.se/en/hybrid-demonstration/>

⁷¹ <https://grafik.svd.se/filer/ledare/2021-200660-ansokan.pdf>

The HYBRIT project has received funding from Sweden through the IPCEI initiative. The granted amount is yet to be disclosed, but the amount of funding that HYBRIT and Sweden asked for authorisation for by the EU commission amounts to SEK 4.9 billion. This subsidy, if authorised by the Commission, would amount to an aid intensity of 30 percent, based on the planned project cost of SEK 16.2 billion. In HYBRIT's budget in the application process disclosed that SEK 5 billion were designated to the construction of the 500 MW electrolyser, amounting to a SEK 10 million per MW electrolyser capacity.⁷²

In addition to the SEK 4.9 billion provided through the IPCEI initiative, the project has also received subsidies of SEK 1 billion from the Innovation Fund. This brings the overall aid intensity, with respect to public funding programs, to 36 percent.

Denmark

The Danish government has signed a comprehensive agreement on a hydrogen strategy with several political parties. Within it the government sets a goal of building an electrolyser capacity of 4 to 6 GW by 2030, and a push for the production and use of green hydrogen in hard-to-abate sectors like shipping, aviation, heavy road transport and industry.⁷³

Currently, the government plans a government tender of DKK 1.25 billion, to support the upscaling of the production of renewable hydrogen and derivatives, such as renewables-based ammonia, methanol, and e-Kerosene. The tender will be awarded through a competitive bidding which is to be concluded in 2023. The aid will take the form of direct grants for a ten-year period.⁷⁴ Including the mentioned tender the Danish government has allocated DKK 3 billion in subsidies for hydrogen production and use since 2019.⁷⁵ The implementation of 4-6 GW electrolysis plants could reduce 2.5-4.0 million tonnes of annual CO₂ emissions by 2030.⁷⁶

The largest hydrogen project in Denmark is the "Green Fuels for Denmark" project, which received DKK 600 million in subsidies from the Danish government through, Hy2Tech, the first hydrogen IPCEI initiative.⁷⁷ Green Fuels for Denmark is led by the Danish energy company Ørsted. The project aims to establish an electrolyser capacity of 1.3 GW by 2030 using 2-3 GW offshore wind power from the Bornholm energy island. The funding will support the first phases of the project, which include the installation of 10 MW (2023), 100 MW (2025), and 300 MW (2027) electrolysis capacity, with estimated total costs ranging from DKK 1 billion to DKK 5 billion.⁷⁸ The subsidy represents between 12 percent and 60 percent of the project's estimated total cost.

Germany

The German National Hydrogen Strategy were announced in June 2020. It put forth goals relating to the use, production and import of green hydrogen. The access to hydrogen is especially important for Germany, if it wants to reach its climate goals, as hydrogen is an important base material for the German industrial sector that is hard to abate. Around 55 TWh of hydrogen, most of it grey hydrogen, is used for industrial applications in Germany each year. As part of the plan, the government will invest EUR 7 billion to develop use of hydrogen in the

⁷² <https://grafik.svd.se/filer/ledare/2021-200660-ansokan.pdf>

⁷³ <https://stateofgreen.com/en/news/new-strategy-kick-starts-denmark-production-of-green-hydrogen-and-e-fuels/>

⁷⁴ https://ec.europa.eu/commission/presscorner/detail/es/ip_23_323

⁷⁵ <https://kefm.dk/aktuelt/nyheder/2022/mar/bred-milliardafale-saetter-turbo-paa-nye-groenne-braendstoffer>

⁷⁶ <https://kefm.dk/aktuelt/nyheder/2022/mar/bred-milliardafale-saetter-turbo-paa-nye-groenne-braendstoffer>

⁷⁷ <https://orsted.com/en/media/newsroom/news/2022/12/13666863>

⁷⁸ <https://www.reuters.com/business/sustainable-business/orsted-plans-large-scale-green-hydrogen-project-denmark-2022-12-06/>

industrial sector and expand local production of hydrogen as well as establishing international hydrogen trade partnerships.

In its national strategy the German government has set forth several measures. First, a goal of an electrolyser capacity of 5GW by 2030, with an additional capacity of 5 GW by 2035. This will be done through tenders for electrolysis manufacturers and subsidies for building new hydrogen production facilities. Second, the industrial sector will be encouraged to use hydrogen to reduce fossil fuel usage in industrial processes. Third, the direct use of green hydrogen in aircraft engines will be promoted. Fourth, the Hydrogen Strategy includes EUR 2 billion to establish international trade partnerships with countries that have more favourable conditions for green hydrogen production and to build large production facilities using German technologies. The government has identified 31 potential exporting countries mainly located in West and South Africa.⁷⁹

An important hydrogen project in Germany is called Trail Blazer. This was the first project that received subsidies within the German National Hydrogen Strategy, granted by Federal Ministry for Economic Affairs and Climate Action of Germany. Trail Blazer is a joint green hydrogen projects between Air Liquide and Siemens Energy located in Oberhausen, Germany, and received a subsidy of EUR 11 million.⁸⁰ This represents about 50 percent of the investment cost of the project.⁸¹ The project aims at connecting a green hydrogen production plant with 20 MW electrolyser capacity to local pipeline infrastructure, to be able to supply key industries within one of the most industrialised parts of Germany. The hydrogen plant is expected to start delivering hydrogen to the pipeline infrastructure by the fall of 2023.⁸²

France

The French "*National strategy for the development of decarbonised and renewable hydrogen in France*" is a plan to accelerate France's transition to a low-carbon economy. The strategy was launched in September 2020 and is part of the country's wider efforts to achieve carbon neutrality by 2050. The strategy has a budget of EUR 7 billion between 2021 and 2030, which are going to be spent on three overarching priorities. The first is decarbonising industry by developing a French electrolysis sector, which aims at installing 6.5 GW capacity of electrolysers by 2030. The second priority is developing the use of decarbonised hydrogen for heavy-duty mobility. The third priority is supporting research, innovation, and skills development.⁸³

Air Liquide Normand'Hy aims to build an electrolyser of at least 200 MW in the industrial zone of Port-Jérôme in Normandy for the production of renewable hydrogen in France. Normand'Hy would supply renewable hydrogen for industrial and heavy mobility applications. The hydrogen plant is planned to be commissioned in 2025.

The green hydrogen project in France has been designated as an IPCEI project under the Hy2Use initiative. While the exact amount of subsidies for the project is yet to be confirmed, Air Liquide has requested EUR 190 million

⁷⁹ <https://www.iea.org/policies/11561-package-for-the-future-hydrogen-strategy>

⁸⁰ <https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2021/07/20210729-%20first-approval-notice-for-green-hydrogen-project.html>

⁸¹ Based on an assumption that investment cost of the electrolyser in this project is comparable to the electrolyser cost in the Swedish project HYBRIT.

⁸² <https://www.thyssenkrupp-steel.com/en/newsroom/press-releases/air-liquide-completes-hydrogen-pipeline-to-thyssenkrupp-steel-in-duisburg.html>

⁸³ <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

in subsidies from the French government. However, the approval of this amount is still pending the EU Commission's confirmation.⁸⁴

Public support for electrolyser manufacturing and other upstream industries

As already mentioned, electrolysers and carbon capture technologies are considered strategic net-zero technologies and thus have better access to public support schemes than other industries. Furthermore, the EU has over the last years offered significant support for renewable energy.

Public support for electrolyser manufacturing

European electrolyser manufacturing has access to all public support schemes mentioned in this chapter, except for the European Hydrogen Bank. Thus, under the TCTF, electrolyser manufacturing facilities can receive state aid to the tune of between 15 and 35 percent of investment costs, depending on project's location. RDI-intensive projects might have access to higher levels of subsidy through IPCEIs or the Innovation Fund.

Twenty hydrogen generation technology projects in Europe have received support through the IPCEI Hy2Tech, as discussed earlier. However, Norwegian electrolyser manufacturers were not among the supported projects. Although the non-confidential version of the state-aid decision is not yet available, information released by some of the state recipients suggests that large-scale electrolyser manufacturing projects could receive state aid of exceeding EUR 100 million. For instance, French electrolyser manufacturer McPhy has been granted EUR 114 million to build an electrolyser gigafactory with a planned annual capacity of 1 GW.⁸⁵ Another French manufacturer, Elogen, will also receive support from the French State via IPCEI with an amount of EUR 86 million for its gigafactory project.⁸⁶

Public support for carbon capture and storage (CCS)

Carbon capture and storage is defined as one of the strategic net-zero technologies and as such can receive support through a majority of support programmes available for hydrogen. EU has set a goal of reaching 50 million tonnes of annual CO₂ storage capacity by 2030. The investment needed for CCS varies and depends on the site, techniques used, and onshore vs offshore storage, with estimates ranging up to EUR 10.5 billion in higher scenarios. Investment in renewable energy technologies can decrease the investment needs for CCS.

The use of CCS technologies will be important in the transition to zero emission activities and several projects are being financially supported to establish CCS-facilities in the European Union. The Innovation Fund has supported five CCS projects with almost EUR 1 billion, covering, on average 45 percent of the relevant project costs.⁸⁷

CCS also receives substantial support in Norway. In addition to the aforementioned Barents Blue project, the Norwegian state is expected to cover around two thirds of the project cost, or NOK 16.8 billion⁸⁸, of a large CCS

⁸⁴ <https://www.airliquide.com/group/press-releases-news/2022-03-08/air-liquide-receives-support-french-state-its-200-mw-electrolyzer-project-normandy-and-accelerates>

⁸⁵ <https://mcphy.com/en/press-releases/french-government-boosts-support-for-the-hydrogen-industry-e114-million-in-public-funding-for-the-mcphy-gigafactory-project/>

⁸⁶ <https://elogenh2.com/en/2022/09/29/press-release-as-part-of-the-hydrogen-ipcei-the-elogen-project-will-benefit-from-the-support-of-the-french-state-to-the-amount-of-86-million-euros/>

⁸⁷ https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund/innovation-fund-projects_en

⁸⁸ https://network.bellona.org/content/uploads/sites/3/2020/10/Longship-Briefing_Bellona-1.pdf

project named Longship. The project aims at storing about 800 thousand tonnes of CO₂ per year from cement and energy production from waste. The project, however, is not directly related to hydrogen.

Public support for renewable energy production

EU Member States offer significant subsidies for renewable energy generation. Though these are the subject of a more thorough analysis in another report in this series, we briefly discuss them here as renewable is central to the production of green hydrogen. The total level of subsidies for renewable energy across the Member States amounted to EUR 81 billion in 2020. However, subsidy regimes vary significantly between the Member States.

Expected effects of the IRA on the Norwegian hydrogen industry

The level of support for green hydrogen projects financed through the European Hydrogen Bank is likely to be comparable to the level of support offered in the US, at least in the first auctions. However, the auction mechanism that selects only some of the proposed projects and the limited budget of the programme in Europe create uncertainty regarding the actual availability of the support mechanism for projects seeking public aid. The level of support for blue hydrogen is likely to differ significantly between Europe and the US. As per the proposed design of the European Hydrogen Bank, only green hydrogen will be eligible for support in Europe, while in the US, the IRA supports blue hydrogen as well.

The impact of IRA on the Norwegian industry hinges on the resolution of uncertainty surrounding the European Hydrogen Bank. Should the Bank offer the expected level of support, it is unlikely that there will be a significant investment shift from Europe to the US for green hydrogen. However, the gap is large enough that we can expect more investment in the US for blue hydrogen, despite the significant transportation costs that hinder export potential. Additionally, the primary cost drivers, including energy prices, demand growth, and technological advancements, are still uncertain and could potentially lower market prices in the future.

Thus far, our analysis has revealed disparities in public support programs available in the United States and Europe. However, in order to evaluate the influence of these regulations on Norway's hydrogen industry, we must first quantify the subsidies offered in each region. We will then estimate how these subsidies affect the levelised costs of hydrogen production, accounting for regional variations in energy prices.

Significant differences in production costs could potentially prompt investors to shift their focus from one region to another. However, there are several factors that limit this risk within the hydrogen industry. These include uncertainty surrounding the market's future, the specifics of existing subsidy programs, and substantial transportation costs. The goal of this section is to provide a comprehensive analysis of these and other factors that impact investment profitability in the hydrogen sector.

Comparison of EU and US public support regimes

To effectively compare the various subsidy regimes in the US and Europe, a common yardstick must be established. When examining hydrogen, the most fitting measure is the impact of subsidies on the levelised cost of hydrogen (LCOH). This cost is determined by calculating the total cost of producing a single unit of hydrogen over its entire lifespan, taking into account all capital, operating, and fuel expenses, and then dividing this sum by the total amount of hydrogen produced.

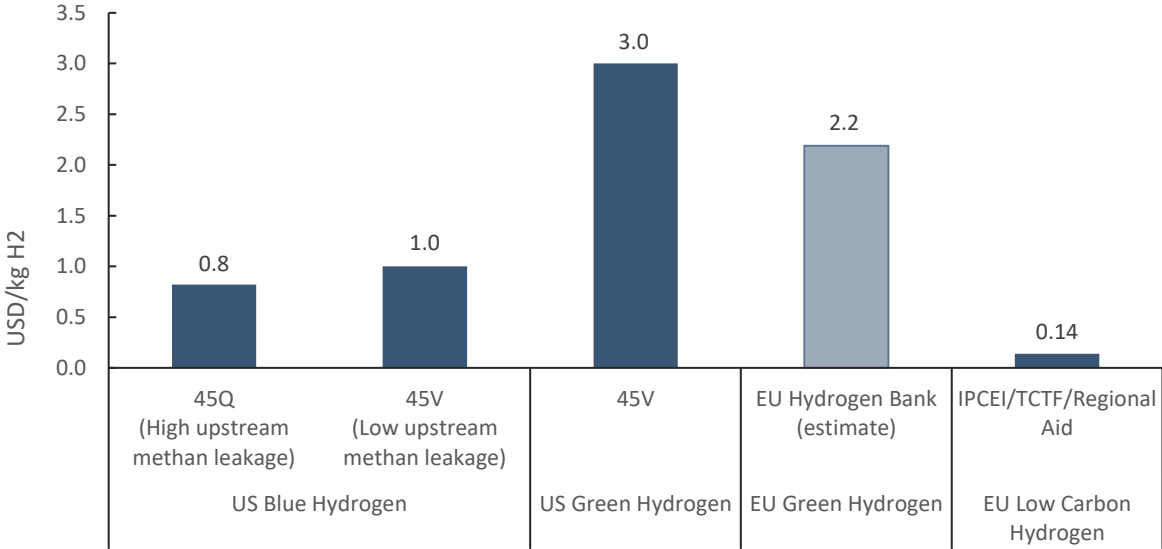
Figure 3 illustrates the expected subsidies per kilo of hydrogen produced in the EU and the US. The analysis relies on an assumption that the level of aid offered in the EU will be in line with the European Commissions' expectations outline in its Communication on the European Hydrogen Bank.⁸⁹ The analysis reveals that the most substantial subsidies are provided by the US green hydrogen production subsidy, totalling USD 3/kg H₂. Meanwhile, European subsidies for green hydrogen are expected to be slightly lower, amounting to approximately USD 2.2/kg H₂ for production commencing as early as 2023.⁹⁰ In Europe, the actual subsidy level

⁸⁹ https://energy.ec.europa.eu/communication-european-hydrogen-bank_en

⁹⁰ Calculated as average of the range presented by the European Commission in its Communication on the European Hydrogen Bank.

will be determined through an auction-based mechanism, whereby renewable suppliers compete to offer the lowest subsidy required to initiate production. It is anticipated that the subsidy level established through this competitive process will decrease over time reflecting the technological progress and reduction in uncertainty about the future hydrogen market. Furthermore, the limited budget of the programme in Europe creates uncertainty regarding the actual availability of the support mechanism for projects seeking public support. The announced budget is not sufficient to support large scale hydrogen projects. This differs from the US, where the level of support will remain constant⁹¹ and will be offered for 10 years to all participating projects that start production before the programme concludes in 2032.⁹²

Figure 3: Subsidies for hydrogen production in the US and EU according to production method.⁹³ Source: Menon Economics



Producers of blue hydrogen in the US can expect a subsidy of between USD 0.82 and USD 1 depending on the technology used and the level of upstream emissions. Although this level of support is significantly lower than for green hydrogen, it significantly exceeds the level of support offered in Europe. European blue hydrogen producers may expect only investment subsidy that reduces the capital costs of the project. However, since the variable energy cost are by far the largest cost component of hydrogen production, investment subsidies do not have large impact on the LCOH. Our analysis suggests that a blue hydrogen project that can expect subsidies in the EU up to 30 percent of the investment costs. Translated into the LCOH, such a subsidy implies a reduction by roughly USD 0.14 per kg hydrogen.

Impact of IRA and European public support regimes on levelised cost of hydrogen production in USA and Europe

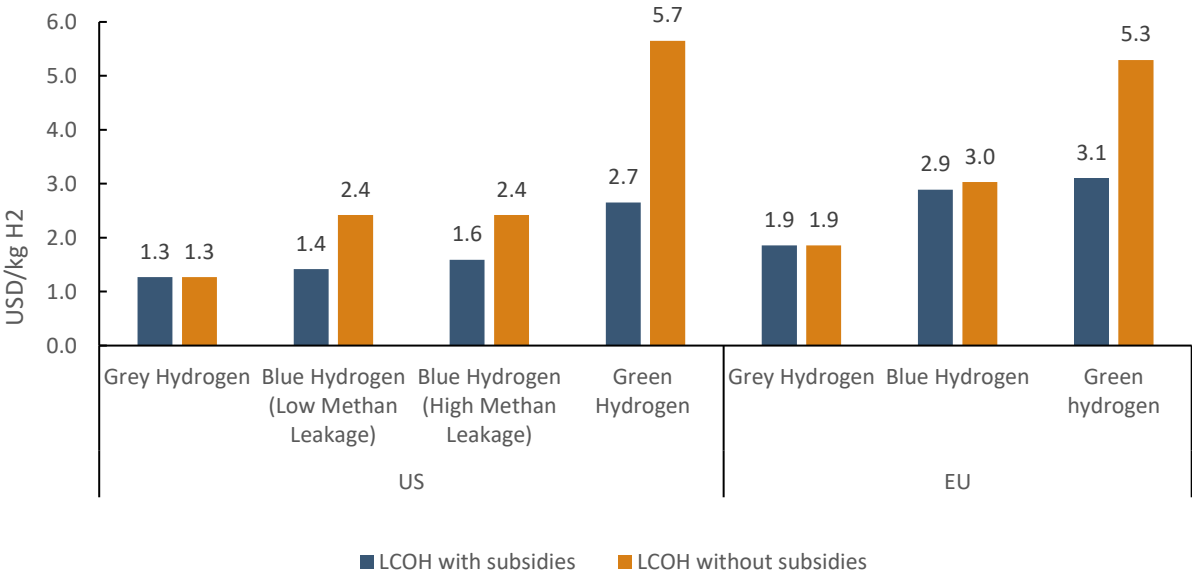
The levels of subsidy shown in the previous section need to be set in the light of regional differences in production cost. The cost of producing hydrogen is mainly influenced by energy expenses, with green hydrogen relying on

⁹¹ In real terms. The nominal level of subsidy will be adjusted for inflation every year.
⁹² There is some likelihood of differences in the definitions of green hydrogen eligible for the mentioned subsidy levels between the US and EU. However, there is still a significant level of uncertainty in both regions regarding the final provisions.
⁹³ The subsidies for green hydrogen in the EU are based on expected levels of subsidies in the first auctions in the Hydrogen Bank. As technology matures, it is expected that subsidies for green hydrogen in the EU will fall. Subsidy levels in the US will stay constant adjusted for inflation through 2032.

electricity and blue hydrogen on natural gas. LCOH is shaped by long-term predictions of energy prices, beginning a few years after the project's completion. However, future energy prices are highly uncertain. Although energy prices have been abnormally high in Norway and Europe as of late, this may not greatly impact investment decisions since prices are anticipated to decrease over time. Similarly, the low electricity prices in Northern Norway are expected to be temporary. Over longer time frames, energy costs are likely to converge to similar levels established by the levelised cost of electricity of the marginal producer.

The IRA provisions outlined earlier is expected to have significant impacts on the LCOH. Figure 4 illustrates LCOH cost with and without subsidies for various production technologies under the existing subsidy regime. Our analysis indicates that grey hydrogen in the US will be the cheapest among the analysed types of hydrogen, albeit only marginally higher than the cost of blue hydrogen in the US, taking into account the subsidy. The production costs of green hydrogen are over four times higher than the costs of grey hydrogen. The gap is more than halved with subsidies, both in the US and Europe. However, even after taking into account the subsidies, green hydrogen remains the most expensive type of hydrogen.

Figure 4: Levelised cost of hydrogen production with and without existing subsidies in the US and expected subsidies in the EU.^{94 95} Source: Menon Economics



To accurately compare production cost between regions, we have considered differences in subsidy levels and the levelised costs. Europe is expected to remain a net importer of natural gas, which will likely result in higher natural gas prices compared to the US. This will drive up the prices of grey and blue hydrogen in Europe compared to the US. Our analysis indicates that LCOH for blue hydrogen in the US (after subsidies) may even be lower than that of grey hydrogen in Europe. Equally importantly, is the fact that blue hydrogen in our calculations are

⁹⁴ US estimates are based on levelized cost of hydrogen from “Resources for the Future” report, based on capital cost, fixed cost, electricity cost, natural gas steam cost, natural gas feed stock cost and other variable costs. Estimates have been rescaled to 2022 US dollars. Assumptions for the levelized cost of hydrogen in Europe is based on historic ratios of electricity costs for industrial purposes and gas prices between US and EU. Similar levelized costs are found in reports by IEA 2019; International Renewable Energy Agency 2019; Hydrogen Council 2020. The EU subsidy level is based on estimates on production subsidy through European Hydrogen Bank and a subsidy of 30 percent of capital expenditures that can be attained either from IPCEI, TCTF or Regional Aid if granted by Member States.

⁹⁵ The subsidies for green hydrogen in the EU are based on expected levels of subsidies in the first auctions in the Hydrogen Bank. As technology matures, it is expected that subsidies for green hydrogen in the EU will fall. Subsidy levels in the US will stay constant adjusted for inflation through 2032.

competitive with grey hydrogen, given a potentially large boost to investment in the US. When it comes to green hydrogen, even if we assume higher energy costs in the US based on historical prices, taking into account the difference in subsidy levels, we anticipate that US LCOH for green hydrogen will be slightly lower than those in Europe.

Our analysis does not include indirect subsidies as we expect the impact to be low, at least in the short run. This is for the following reasons. The level of subsidies for electrolyzers production is comparable between the regions. There are larger differences in subsidies for renewable energies. However, those have not changed considerably in the US with IRA, although the inclusion of solar energy in the subsidies is likely to increase the availability of renewable energy. The impact of IRA on renewable energy costs in the US is thus expected to be limited. This is for two reasons. Firstly, for many years to come, it is expected that the marginal US price-setting producer will have a higher marginal cost than solar and wind. Secondly, there are significant restrictions on permits and zoning, which is expected to restrict the investment in new wind and solar farms somewhat.⁹⁶ In a case of restricted production (inelastic supply), the majority of the subsidy will go to the producers and not the consumer (e.g. a hydrogen producer). Both these arguments are explained in significantly more detail in the forthcoming report on IRA and offshore wind. Other analyses agree and estimate relatively small effects of the IRA on retail electricity prices.⁹⁷

Lessons from the shale gas revolution

The current difference in subsidy levels is not the first time the hydrogen production costs diverge between USA and Europe. Similar gap occurred in the case of grey hydrogen in the aftermath of the shale gas revolution. Grey hydrogen prices are almost entirely determined by natural gas prices which constitutes about 90 percent of production costs. At that time, grey hydrogen (ammonia) market was well developed and prices nearly identical in all regions of the world, despite significant differences in production costs. USA and Europe were jointly responsible for about a third of global production, but as marginal (highest cost) producers were setting global prices.

Until the shale gas revolution, natural gas prices were on very similar level in both US and Europe. However, once the US domestic supply drastically increased after the shale discovery, due to lack of LNG export facilities, the cost of natural gas in the US decreased. Consequently, the industry that was in decline in the early 2000s, with eleven hydrogen plants permanently closed between 1999 and 2006, and production capacity decreasing by about 650 thousand tonnes or nearly 25 percent, in that region. Once the US natural gas prices declines and the market understood that the cost advantage is there to stay, new investments started to flow. Nearly 1 million tonnes of annual hydrogen production capacity were commissioned between 2009 and 2018, and not a single plant was closed. There were no capacity additions in Europe during that period except for a relatively small ammonia plant in land-locked Slovakia.

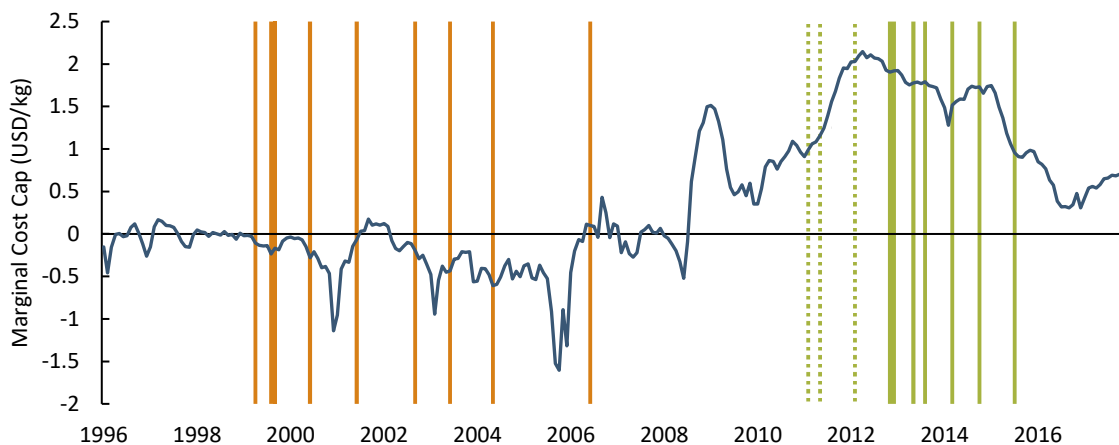
However, once the gap fell below USD 1/kg hydrogen, with the prospects of further fall due to new LNG terminals, investments in hydrogen production capacity stopped. Despite the significant increase in production capacity, USA remained a net ammonia importer. This has, however, changed recently, and newly announced

⁹⁶ <https://www.pnnl.gov/sites/default/files/media/file/Restrictions%20in%20Local%20Zoning%20-%20Memo%20-%20Jul22.pdf>

⁹⁷ <https://www.rff.org/publications/issue-briefs/retail-electricity-rates-under-the-inflation-reduction-act-of-2022/>

projects include CCS facilities.^{98,99} Project announcements mention CCS support as one of the reasons for locating investment in the US.¹⁰⁰

Figure 5: Marginal cost advantage of US hydrogen producers and investment decisions (source: Ellewanger et al. 2023)¹⁰¹



Notes: Orange lines: Disinvestments (plant closures). Green lines: Investment (announcement dates for completed/advanced projects; dotted for plant restarts/expansions, solid greenfield/brownfield projects) in the US ammonia industry. Each line represents a single event. A detailed list of all expansion and closure decisions are provided in the online appendix.

Implication for the Norwegian hydrogen industry

The experience from the past suggests that a significant hydrogen production cost gap can divert the investment flow from a high cost to a low-cost region if the cost gap between the regions is sufficiently large. At the same time, in our judgement, some factors will contribute to limiting this effect. In the case of the green hydrogen these mitigating factors are likely to suffice to prevent the investment flow out of Norway and Europe. However, in the case of blue hydrogen, the difference in LCOH is large due to the combination of higher levels of subsidies and lower natural gas prices. Therefore, there is a significant probability that IRA, even with the responses from the EU, almost will divert some investments to the US. This is likely to result in a slower industry ramp-up in Norway and the EU.

The main factor insulating the Norwegian hydrogen producers is the high transportation cost. Norwegian large-scale hydrogen producers have a significant cost advantage due to possibility of relatively cheap pipeline transport to demand centres in Europe. Norway has already announced a plan to build a pipeline capable of carrying 0.5 million tonnes of hydrogen per year to Germany by 2030.¹⁰² Costs of pipeline transport are estimated at about USD 0.5/kg H₂, while transportation costs across the Atlantic amount to USD 1-1.5/ kg H₂. Our analysis suggests that the difference in costs of transportation between hydrogen demand centres and production sites in Europe and USA exceeds the difference in production costs of green hydrogen between the two regions.

⁹⁸<https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/020623-linde-to-build-blue-hydrogen-facility-on-texas-coast-for-ammonia-production>

⁹⁹ <https://www.reuters.com/business/energy/yara-enbridge-eye-29-blm-texas-ammonia-plan-2023-03-31/>

¹⁰⁰ Ibid.

¹⁰¹ Ellewanger, R., Gnutzmann, H., & Śpiewanowski, P. (2023). *Cost Pass-Through with Capacity Constraints and International Linkages* (No. 2023-16). Bank of Canada.

¹⁰² <https://www.regjeringen.no/en/whatsnew/dep/smk/press-releases/2023/closer-cooperation-between-norway-and-germany-to-develop-green-industry/joint-statement-germany-norway-hydrogen/id2958105/>

However, the production cost gap may increase in the future as the level of subsidy determined through auctions organised by the European Hydrogen Bank decreases. Furthermore, the gap is larger in the case of blue hydrogen, making it more likely that the new investments will be located in the US.

Secondly, there is uncertainty about the availability of hydrogen transportation infrastructure both for export and import purposes. This is especially the case for smaller markets. With relatively high last-mile transportation costs, hydrogen is thus likely to be produced locally, as it is cheaper to transport electricity than hydrogen. This is particularly important for the hydrogen, which is to be used in industrial or maritime settings in more remote areas. It is hard to say how much hydrogen is going to be used locally versus traded on global markets, but particularly for Norway, the former is suspected to be sizable.

The magnitude of the effects for Norwegian hydrogen producers varies between different types of operators. Larger players looking abroad will probably be incentivised to establish facilities in the USA. On the other hand, smaller players, especially technology developers/suppliers, will not have the necessary resources to invest internationally and will thus lose out if the development in Europe is delayed. If this is the case, US suppliers could gain a competitive advantage when European development picks up speed. This is confirmed by the hydrogen actors we have interviewed in connection with this study.

Finally, it is important to emphasise that the support provided through the IRA for hydrogen will contribute positively to technology development and cost reduction, from which Europe and Norway could also benefit. Furthermore, there could be knowledge transfer from the US to Norway and Europe by establishing large Norwegian and European companies in the US. This applies to producers, technology suppliers and potential consumers of hydrogen.

The difference in support regimes for electrolyser manufacturing between the United States, Europe, and Norway is unlikely to result in significant capital outflow to the US. Additionally, high transportation costs play a role in mitigating the potential impact of these differences. This view is confirmed by the European Commission which in its staff working paper from March 2023¹⁰³ indicates that shipping complete electrolyser systems is not expected to be economically viable due to their weight. Typically, electrolyser manufacturing is located in close proximity to deployment sites as large electrolyser installations need to be customised for specific projects. European Commission have also not found any evidence of a shift in manufacturing investments from Europe to the US.

¹⁰³ https://single-market-economy.ec.europa.eu/system/files/2023-03/SWD_2023_68_F1_STAFF_WORKING_PAPER_EN_V4_P1_2629849.PDF



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