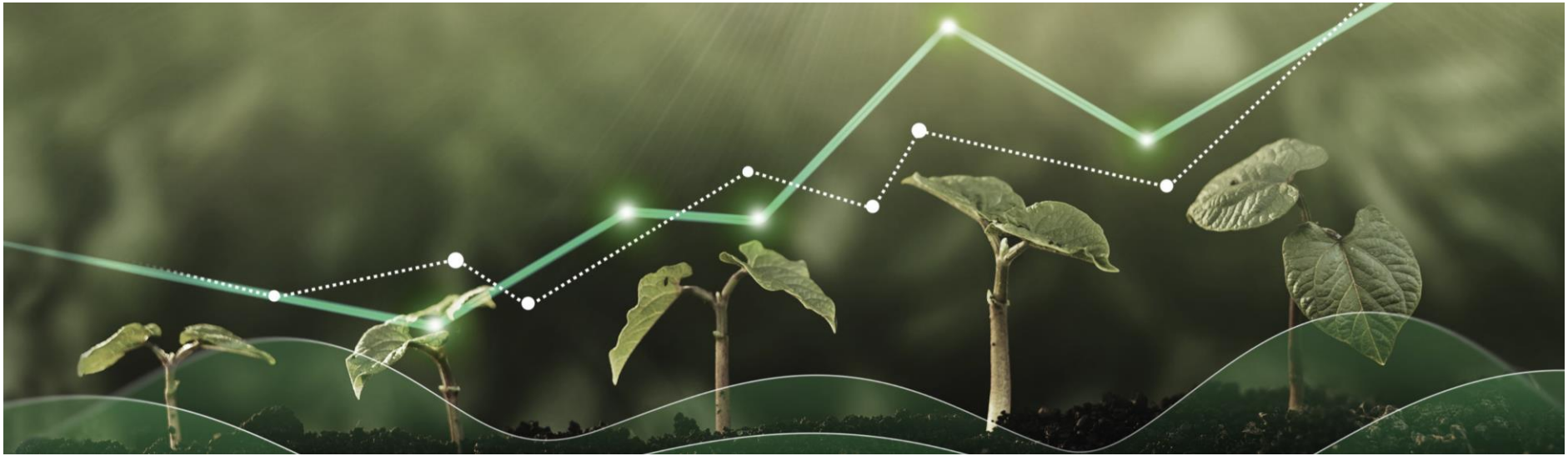
MENON ECONOMICS

Public support for the green transition in the US and Europe



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Foreword

Menon Economics, commissioned by Offshore Norway, has conducted an analysis of the state of public support programmes for green technologies in four geographic markets; US, EU, United Kingdom, and Norway. The study focuses on three industries; hydrogen, carbon capture and storage (CCS), and offshore wind. The analysis includes an assessment of the available support programmes and their preliminary impact on investments in the respective regions and markets.

The project has been led by Jonas Erraia. Lotte Rognsås and Einar Wahl have contributed as team members. Even Winje has been the project's quality assurer.

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 analyses of economic policy, and our employees have economic expertise at a high scientific level.

We thank Offshore Norway for an interesting project.

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February 2024

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Introduction

The combination of the green transition and geopolitical tensions has led several countries and economic blocs to implement measures that, more than ever, support the development of green industries and associated national value chains. In the US, the Biden administration has introduced the CHIPS and Science Act and the Inflation Reduction Act (IRA). The IRA represents the largest ever support package for the green transition in the US, with a total framework of USD 370 billion and came into effect in August 2022. The broad support schemes in the IRA and embedded requirements for national content and national value chains have been heavily criticised by several of the US's trading partners, including the EU.

The European Commission has, partly in response to the IRA, loosened the state aid rules for green technology through, among others, the Temporary Crisis and Transition Framework, the EU Hydrogen Bank and the reform of the electricity market. The Temporary Crisis and Transition Framework was updated in March 2023 and is also applicable in EEA countries such as Norway. Both Norway and the UK have established support schemes that are closely aligned with the EU, due to Norway's close affiliation through the EEA agreement and UK's former membership in the union.

In this report, we examine the various support programmes available for green industries in the four markets US, EU, UK and Norway. The report focuses on three industries: hydrogen, carbon capture and storage (CCS), and offshore wind. For each sector, we assess the support mechanisms available in each market and how these mechanisms have influenced investments and the development of the industries in their respective markets thus far.

Main findings

Overall, we find that the US' Inflation Reduction Act (IRA) has contributed to the development of green industries in the US. At the same time, the EU, UK and Norway have established their own national or regional support schemes to develop green industries, and we observe that the IRA has, thus far, had a limited effect on the flow of capital between the continents. In the longer term, it is possible that the development of green industries in the US will accelerate and could lead to greater effects on the flow of capital. However, the risk varies across the different industries.

Hydrogen production

Government support for hydrogen production is granted to both blue and green hydrogen or specifically to green hydrogen. New support mechanisms have been developed over the last two years. The levels of support are higher in the US than in the EU and Norway. So far, we have not observed any significant acceleration in plans to develop hydrogen production in the US compared to Europe as a result of higher support levels in the US; however, this may change over time. We consider it likely that the differences in support levels between regions could have an effect on the flow of capital,[1] but the effect across continents will be smaller than the effect between EU/EEA countries and the UK. For blue hydrogen, the difference in support level is so substantial that it has the potential to influence capital flows from Europe to the US. This is clearly demonstrated in our case study of Barents Blue, where we find that the company could receive at least 23 times more support if they were established in the US.

Carbon capture and storage (CCS)

The US is at the forefront of establishing CCS. The US provides universal support for CCS through the IRA, and the universal scheme makes support more predictable in the US than in Europe, the UK, and Norway. The relative growth in announced American carbon storage plans indicates that the IRA has led to increased investments in the US relative to the EU. At the same time, it is considered unlikely that the American support mechanisms for CCS will influence investment plans in Europe. The UK has indicated plans for substantial support for CCS in the future and if the announced support is implemented, this could have a significant effect on the investment flow within Europe. However, the flow of investments will also be temporarily affected by how the EU will regulate the storage of CO2 outside the Union's borders.

Offshore Wind

In recent years, new support regimes for offshore wind have been established in both the US and Europe, but with variations in the mechanisms and the configuration of the schemes. However, delays in supply chains and increased costs have led to larger investments and planned developments being put on hold in 2022 and parts of 2023. This means that we have yet to see significant effects of the support regimes established in Europe and the US. Notwithstanding the recent challenges, we consider the profitability of offshore wind projects to be relatively similar across different countries when taking support schemes into account. Therefore, we believe there is no reason to think that the support schemes will significantly contribute to the movement of capital between countries.

[1] *In this report, capital flow refers to how subsidies in one region affect investments in another region.*

Universal support for hydrogen production in the US, competition-driven support in Europe

Over the past two years, several support mechanisms for hydrogen production have been established. In the US, the support sceemes has been neutral regarding different types of hydrogen, while in Europe there has been a greater focus on green hydrogen. Technology neutrality towards low-carbon hydrogen in the US means that blue hydrogen is far more supported in the US than in Europe and could lead to blue hydrogen becoming competitive against grey hydrogen.

Investment support

- Investment support for hydrogen R&D and infrastructure.
- Investment support of up to 60% of the additional costs compared with grey hydrogen.
- Allocation of competitively-driven investment support to both R&D and commercial activity.
- Primarily R&D support, can provide commercial district funds. Is included in EU support.

Production support

- Universal support ranging from USD 0.6-3.0/kg hydrogen, which is adjusted for inflation.
- Auction-based support up to EUR 4.5/kg green hydrogen. Actual amount likely to be somewhat lower
- Contracts for Difference per kg of green hydrogen will later be auction-based.
- Is part of the EU's auction-based support mechanism.

Support to the value chain

- Up to 30% of investment cost for equipment manufacturers and support for renewable power production.
- Member states may allocate support to equipment manufacturers. Supports renewable power generation.
- Supports renewable power production. Has presented a plan for hydrogen transport infrastructure.
- Can allocate support to equipment manufacturers under current EU regulations.

Effects of support

- The universal scheme in the US makes the support more predictable in the US than in other regions.
- The US has a technology-neutral support scheme for hydrogen which could lead to a larger share of blue hydrogen than in Europe.
- The allocated production support in the UK is greater than the support within the EU. Over time, production support will likely converge, as both regions will utilise auction-based support schemes.

Despite higher support levels in the US, it is unlikely that green hydrogen will be exported in large volumes between continents in the near future. We find that there is a possibility that blue hydrogen or blue ammonia will be exported from the US. The different levels of support are likely to have some effect on the flow of capital between regions. Nevertheless, we consider the long-term effect on the flow of capital between the US and Europe to be somewhat smaller than the effect on the flow of capital between EU/EEA countries and the UK. So far, we have not observed a significant increase in plans for hydrogen production in the US compared to Europe due to the high support levels provided through the IRA.

Support for CCS is greater and universal in the US, whereas in Europe there are significant differences between projects

The US is currently ahead of Europe in establishing CCS. However, the EU has announced the largest plans for expansion and the UK has made the greatest commitments to future support. Norway has smaller plans, but the plans are significant given the size of the economy.

Objectives and plans[1]

- Has the largest established storage capacity and announced plans for storing 74 million tonnes of CO_2 per year.
- Aims for a storage capacity of 50 Mt CO_2 per year. Has announced plans for storage of 84 Mt CO_2/year.
- Has a national target of capturing and storing 20-30 million tonnes of CO_2 per year. Announced plans for storage of 46 million tonnes of CO_2 per year.
- No quantified goals for capture and storage but announced plans for storage of 60 Mt CO_2/year.

Support measures

- Universal support of USD 60-180/t CO_2 through the IRA. Investment support through the BIL.
- Can cover up to 60% of the costs of utilising CCS. Indirect support through the ETS.
- Allocates both investment and production support to both capture and storage. ETS provides indirect support.
- Investment support that varies significantly between projects. Included in EU support programmes. Indirect support through the ETS.

Support to the value chain

- Manufacturers of capture equipment can apply for support of up to 30% of the investment cost.
- Member states can allocate support to equipment production through the TCTF.
- Norway also has the opportunity to allocate support for equipment production through TCTF. Has not yet been utilized.

Effects of support

- The universal system in the US makes the support far more predictable than in other regions.
- The relative growth in advertised American carbon storage plans indicates that the IRA has led to increased investments in the US relative to the EU.
- If the United Kingdom realises its statements of support for CCS, this could lead to a flow of capital from other European countries, and a leading role for the UK in Europe for carbon storage.

It is unlikely that the American support mechanisms for CCS will significantly affect investment plans in Europe. However, there are indications that CCS development in the US is progressing faster than in the EU. In the EU and Norway, there are currently no specialized support mechanisms for large-scale commercial CCS. In the United Kingdom, the government has indicated that it will make a substantial commitment to CCS and support the industry with up to £20 billion by 2040 – this could have a significant impact on investment flows within Europe.

[1] *Announced plans to be started before 2035.*

Large support schemes for offshore wind have so far had limited effect

In recent years, substantial support regimes for offshore wind have been established. Support for investments, support for production, and support through price guarantee measures are the most used support mechanisms. Tenders and opening of new areas for offshore wind are fully underway in both the US and Europe.

Support through price guarantees

- Not at the federal level. State level: Guaranteed price for a given quantity (long-term purchase agreements).
- Guaranteed price for a period through a two-way difference contract.
- Guaranteed price for a period through a two-way difference contract.
- Guaranteed price for a period through a two-way difference contract.

Investment support and production support

- Up to 30-50% of the investment cost.
- No limit on support if given at competitive auction.

Support to the value chain

- 30% of the investment cost or support per unit produced equipment/materials.
- 15-55% of investment cost but can be increased if there is a real risk of losing investments.
- Similar as the EU, but with a cap of 20 percent due to local conditions

Effects of support

- Challenging market conditions have limited investments in recent years, even with substantial support schemes.
- The development in Europe has progressed faster than in the US, and the support scheme in the US is assumed to primarily level the playing field.
- The EU has recently loosened state aid rules in the Union, offsetting the benefits given to the American offshore wind industry through the IRA.

The development of offshore wind has progressed further in Europe than in the US, but given the high support levels in the US, the pace of development may increase over time. Both 2022 and partially 2023 were challenging for the global offshore wind industry, with several planned developments being put on hold. Due to the temporary decline in investments, we have so far seen limited effects of the support regimes established in both Europe and the US. Although the size of the support schemes varies, the profitability of offshore wind projects is relatively similar across countries. Therefore, there is no reason to believe that the support schemes will greatly contribute to the relocation of capital between the regions.

Hydrogen

Sidebar: blue and green hydrogen

Hydrogen, including hydrogen carriers such as ammonia, is often highlighted as a key energy carrier to achieve net-zero emissions by 2050. There are three main reasons for this:

- Hydrogen is suitable for transport and industry where direct electrification or batteries are challenging. For instance, hydrogen can be a sustainable alternative in sectors that have traditionally used oil or coal in production.
- For existing industries that currently use hydrogen with significant emissions, such as fertiliser production and petroleum refining, the transition to green or blue hydrogen can significantly reduce emissions.
- In the future, hydrogen could play an important role in energy storage, especially with increased energy production from variable sources such as wind and solar power. Hydrogen can then be produced during periods of overcapacity in the grid and stored for later use.

The report will focus on two main types of low-emission hydrogen:[1] blue and green. Blue hydrogen is produced through steam reforming of natural gas with carbon capture, while green hydrogen is produced through electrolysis of water with renewable energy, a CO_2-free, but energy-intensive process. We illustrate the production processes for these types of hydrogen in the figures to the right.

In the remainder of this chapter, we will first present the support options for hydrogen production in the US, EU, Norway, and the United Kingdom. Before comparing support in the US with the EU. We will then look at developments in announced plans, and changes in plans between the US and Europe following the introduction of the IRA. We will also explore a specific example, Horisont Energy's Barents Blue project.

Illustration of **blue** hydrogen production

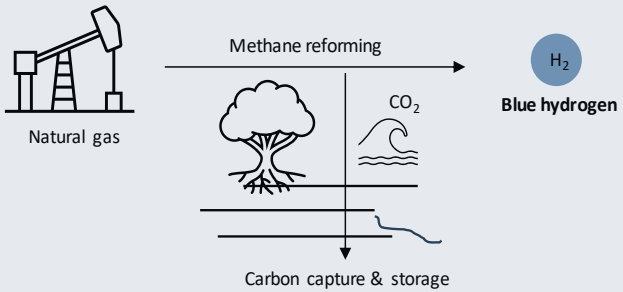
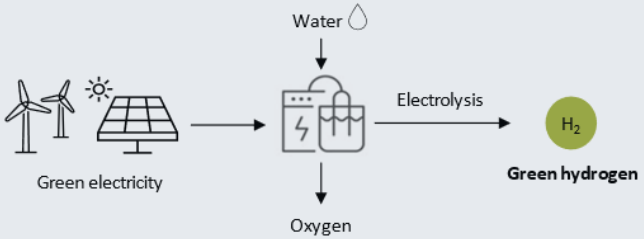


Illustration of **green** hydrogen production



[1]*Low-emission hydrogen is a collective term for various types of hydrogen produced with low greenhouse gas emissions. Blue and green hydrogen are two of several types of low-emission hydrogen.*

Hydrogen support in the US

One of the most generous support schemes under the Inflation Reduction Act (IRA) is the production support for low-emission hydrogen. It is by far the most important support for hydrogen producers, and the support has been estimated to potentially amount to over USD 100 billion over the next 10 years. [1,2] This is by far the largest support package for hydrogen in the world.

The support package differs from its European counterparts for at least three reasons:

- All producers receive support without the need for an application.
- The total amount of support is not limited in size.
- The scheme is technology-neutral and is only adjusted according to lifecycle emissions from production.

These differences from the European support mechanisms make the assistance in the US far more predictable and reduce bureaucratic processes for support.

However, there is uncertainty surrounding how support for green hydrogen production will be implemented, especially in relation to the declaration of green power from the grid. Producers will likely have to purchase renewable energy certificates (RECs) to prove that their energy consumption is matched by corresponding green energy production in the network. It is unclear what specific requirements there will be for the certificates, including when green energy is produced in relation to hydrogen production ('temporal matching'), the requirement that the energy producer is recently installed ('additionality'), and that the power producer delivers to the same grid as the hydrogen production ('deliverability'). There are rumours that there will be requirements for 'additionality', 'deliverability', and hourly-based 'temporal matching' from 2028.[3]

Low emission hydrogen (blue and green hydrogen)

IRA "Clean Hydrogen Credit" (§45V): Offers between **USD 0.6-3.0 per kilogram of hydrogen**[4] for the first 10 years of production. Support is determined based on lifecycle emissions and adjusted for inflation. Requirements for wage levels and the use of apprentices to achieve full support are set. Companies can choose to be granted investment support instead of production support, but this has a much lower net present value of the subsidies.

Bipartisan Infrastructure Law: Allocates **USD 9.5 billion to hydrogen infrastructure**, of which USD 8 billion goes to regional low-emission hydrogen hubs, USD 1 billion goes to research aimed at reducing the cost of green hydrogen, and USD 0.5 billion goes to equipment suppliers for clean hydrogen production.

Local support: States can freely allocate additional support that can be combined with support from the IRA.

Other support for green hydrogen

IRA offers support to the green hydrogen value chain. This support can be combined with other support programs.

Electrolyzer manufacturers can receive up to **30 percent investment support** through the "Qualifying Advanced Energy Project Credit" (§48C). This is an application-based support scheme of USD 10 billion.

Renewable power producers receive support through the technology-neutral energy support scheme, "Clean electricity investment/production credit" (§48E/§45Y).

Other support for blue hydrogen

IRA "Credit for carbon oxide sequestration" (§45Q): Offers blue hydrogen producers **USD 85 per ton of captured CO_2**. The support cannot be combined with §45V. Menon's calculations show that it will usually be advantageous for blue hydrogen producers to use §45Q for lifecycle emissions over 1.5 kg CO_2 per kilogram of hydrogen.

Equipment manufacturers can receive up to 30 percent investment support for the production of carbon capture equipment through the "Qualifying Advanced Energy Project Credit" (§48C).

[1]Bloomberg, 2023. [2]BNEF, 2023. [3]FT, 2023. [4]See the attachment for various support levels depending on the degree of lifecycle emissions.

Hydrogen support in the EU

Support for hydrogen producers in the EU was, prior to the implementation of the IRA in the US, for all practical purposes aimed at large flagship projects through the Innovation Fund and IPCEI initiatives or support for research projects.

As a direct response to the IRA, the Hydrogen Bank was established in 2023. This allowed all producers of green hydrogen to apply for production support. This has been among the most important measures for the green hydrogen industry in the EU/EEA. As the Hydrogen Bank appears to be the main instrument for supporting hydrogen production, there is a high likelihood that many auction rounds will be conducted to facilitate the conditions necessary to achieve the EU's goal of annual production of 10 million tonnes of green hydrogen by 2030.[1]

A distinction from other areas is that the EU still has a greater focus on supporting green rather than blue hydrogen.

In addition to the support mechanisms described to the right, the quota market (Emissions Trading System) indirectly supports low-emission hydrogen producers by increasing the cost of fossil alternatives. Based on our calculations, this equates to an indirect support of about NOK 10 per kilo of low-emission hydrogen produced relative to grey hydrogen. Direct support for hydrogen research is also provided through Horizon Europe/Clean Hydrogen Joint Undertaking. EUR 1 billion has been earmarked for such research support.

Under the temporary arrangement "Temporary Crisis and Transition Framework" (TCTF), member countries have an additional opportunity to support green energy and technology. Both hydrogen producers and manufacturers of electrolysers are covered by this scheme. Support levels, types of technology, and the duration of the TCTF are further described in the annex.

Low emission hydrogen (blue and green hydrogen)

Innovation Fund: Can support up to **60 percent of the additional costs** associated with producing green or blue hydrogen relative to gray hydrogen. However, there are few examples where the level of support has reached this level. The support is awarded through calls for proposals, where hydrogen producers compete with other emission-reducing projects to be granted support. The application process is long and requires significant effort from producers. The Innovation Fund is expected to allocate EUR 40 billion towards 2030, however, this is not earmarked for hydrogen.

IPCEI: Can support up to **100 percent of the financing gap** for hydrogen producers. IPCEI is not a direct European support scheme but part of the European support regulations. IPCEI rules allow member states to come together to start a support initiative for important European projects. These support initiatives then give member states the opportunity to grant support beyond what is accepted under the regular European state aid regulations. There are no ongoing IPCEI initiatives for hydrogen that new producers can apply for. There have previously been two hydrogen IPCEI collaborations that have allocated EUR 10.6 billion. Only a smaller part of this went to hydrogen producers, while the majority went to other parts of the hydrogen value chain.

Green hydrogen

The European Hydrogen Bank (EHB): Is the only direct production support for hydrogen in the EU/EEA. The level of support is determined through auctions, where those bidding the lowest support[2] need are awarded support for the entire offered quantity, until the budget limit is reached. The support is granted per kilogram of hydrogen produced over 10 years. The support to be allocated in the first auction through the EHB has a budget of EUR 800 million and will be awarded during 2024. The second round is expected to have a budget of EUR 2.2 billion and will be awarded in 2025. The EHB is expected to offer the highest support for hydrogen projects in the EU/EEA but is only open to green hydrogen producers. Producers applying for support through the EHB will not be able to receive support through other support mechanisms, and vice versa, those who have already received state aid will not be able to apply for support from the EHB. This is to ensure equal competition conditions among the applicants.

[1]European Commission, 2020. [2]Max amount is set to EUR 4.5 per kilo hydrogen.

Hydrogen support in the UK

The United Kingdom aims to have a production capacity of 10 GW of low-emission hydrogen by 2030. Of this, the target is 4 GW through blue hydrogen and 6 GW through green hydrogen. The UK have stated that in the work towards the 2030 target of 10 GW, 2 GW should be operational by 2025, with green and blue hydrogen each making up 1 GW.

To achieve this goal, the United Kingdom recently allocated the highest level of support for green hydrogen production of all the regions we have assessed, via the Hydrogen Allocation Round.[1] Here, 11 projects, with a total installed capacity of 125 MW, received production support to an estimated value of GBP 2 billion over the next 15 years. It is unlikely that the next round of support will be as substantial, but annual allocations will be conducted. Currently, these allocations are application-based, but from 2026 will be carried out as price-based auctions. This support can also be combined with investment support through the "Net Zero Hydrogen Fund".

Blue hydrogen producers have the opportunity to receive support through the support mechanism "CCUS allocation rounds"; this support is primarily aimed at CCS hubs, but blue hydrogen producers can be a part of these. This support mechanism is covered in more detail in the CCS chapter.

The British government has also made plans to develop and support infrastructure for the transport and storage of hydrogen. Additional support is also allocated to research projects through Hydrogen Production Innovation.

Low-emission hydrogen in the UK also has indirect support through the UK's carbon emissions trading scheme. This is approximately 40 percent lower than the EU/EEA's quota price.

Green hydrogen

Hydrogen Production Business Model/Hydrogen Allocation Round: Is the UK's most generous support scheme for green hydrogen. The program awards production support to hydrogen projects over 15 years. Annual calls for proposals are to be conducted, which will gradually become larger. The first call was concluded in December 2023 and will support 11 projects with a total electrolyzer capacity of 125 MW. The selected hydrogen projects will receive a "strike price" for their hydrogen at GBP 9.49 per kilogram of hydrogen.[2] It is estimated that the total support for the 11 projects will be over GBP 2 billion.[3] The next call will be for 875 MW. From 2025, it is a goal that these allocations will occur through price-based auctions.

Low emission hydrogen (blue and green hydrogen)

Net Zero Hydrogen Fund: This is an instrument that awards investment support for low-emission hydrogen producers. The fund has a cap of GBP 240 million and has already allocated GBP 90 million across 15 projects.

[1]The support scheme is open to certain other technologies, such as pyrolysis of biomass and gas splitting that produces solid carbon [2]Hydrogen Insight, 2023a. [3]UK Department of Energy Security and Net Zero, 2023.

Hydrogen support in Norway

Norway is included in the aforementioned EU support mechanisms through the EEA Agreement. This enables Norwegian projects to receive support through both the Innovation Fund's project support and the Hydrogen Bank's production support. Norway also participated in the the integrrated IPCEI Hy2Use project. For Norwegian producers of green hydrogen, it is very likely that the Hydrogen Bank can provide the highest level of support.

Norway also allocates support through several different policy instruments. These are mentioned to the right. In its allocations, Norway has to a lesser extent than the EU made a distinction between green and blue hydrogen. Nevertheless, it is a distinction that is more prominent than in the US, where support opportunities are solely based on life cycle emissions and not the method of production.

A large proportion of the support distributed to Norwegian hydrogen projects today is linked to R&D, demonstration projects, or regional development. These fall under the exemption rules in the state aid regulations of the EU/EEA (GBER). Few of the Norwegian support schemes are open to commercial production. The support that is granted is also largely directed towards the use and systems for hydrogen, with only 30 percent of the support being allocated to hydrogen producers.

In addition to the support opportunities mentioned on the right, there are at least two indirect sources of support. These are through the EU's quota market which Norway is a part of, and through public tenders where requirements for hydrogen are made, for example in ferry transport.

Low emission hydrogen (blue and green)

Enova: Enova is the largest Norwegian public contributor to the hydrogen industry and has contributed approximately NOK 3.7 billion since 2020. Enova's hydrogen initiative is aimed at technology and cost development. Enova primarily supports hydrogen producers in the pilot phase or earlier, with a particular focus on applications of hydrogen within maritime transport and the process industry. Enova has also been responsible for the allocation of IPCEI support.

Innovation Norway (IN): The most relevant schemes for supporting hydrogen production in IN are the environmental technology scheme, green investment grants in the districts, and regional district funds. IN has since 2020 allocated NOK 875 million to blue and green hydrogen projects.

The Research Council: Support allocated through the research council has even greater requirements for R&D than the aforementioned two instrument actors. This makes it less suitable for support to commercial hydrogen actors. The Research Council has since 2020 allocated NOK 930 million in support to hydrogen-related projects.

Blue hydrogen

Gassnova (CLIMIT): The CLIMIT program is the national program for CCS technology. CLIMIT also supports the development of technology for the production of blue hydrogen. According to the HEILO database, Gassnova has only allocated NOK 15 million to hydrogen since 2020.

Enova (Preliminary study for carbon capture 2030): The support program "Preliminary study for carbon capture 2030" is aimed at industrial carbon capture. Existing grey hydrogen producers who want to switch to blue hydrogen production will be able to apply for support from this program. However, it is only open for carbon capture from existing emission points. The support amount is limited to a maximum of NOK 50 million.

Green hydrogen

Hydrogen Bank (auction as a service): Under the current and future hydrogen bank auctions, it is possible for member states to support their own hydrogen producers through a scheme called "auction as a service." Norway will under this scheme be able to commit an optional budget to the auction, which only Norwegian producers will be able to compete for after the hydrogen bank's budget is exhausted. In the current auction round, only Germany has chosen to use the scheme, with an additional budget of EUR 250 million.[1]

[1] *Hydrogen Insight, 2023b.*

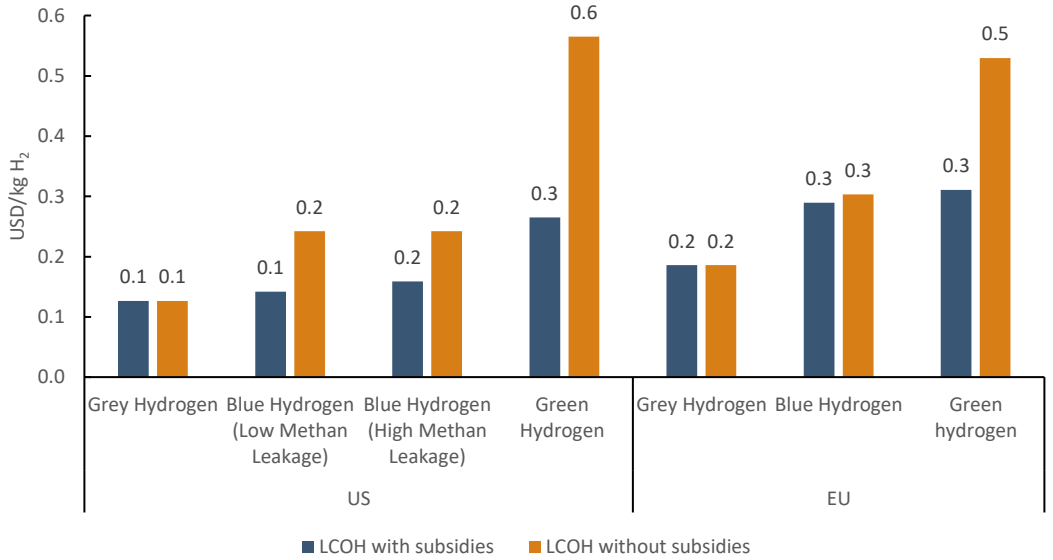
Estimated cost levels for hydrogen in the EU/EEA and the US

The differences in the levels of support for hydrogen in the regions naturally influence the relative cost levels. To the right, we present our estimates for the lifetime cost of hydrogen (LCOH) to produce one kilogram of grey, blue, and green hydrogen in the EU/EEA and the US, with and without subsidies.

As the graph shows, the cost to produce green hydrogen in the US and Europe will not be dramatically different for those projects receiving support through the Hydrogen Bank. However, it is important to note that not all hydrogen producers in the EU/EEA will receive this support, as opposed to the support allocated in the US. Moreover, it is likely that the support in the EU will decrease over time due to technological changes and the fact that the support is auction-based. This contrasts with the support in the US, which will remain fixed and adjusted for inflation over time.

The fact that support in the US is technology neutral means that the support level for blue hydrogen in the US is far higher than the support level in the EU/EEA. The US's support opportunities for blue hydrogen result in the cost difference between grey and blue hydrogen becoming relatively small. This can make blue hydrogen competitive in the US market.

Lifetime production cost (LCOH) for hydrogen with and without subsidies in the US and EU. Source: Menon Economics



Development in advertised plans

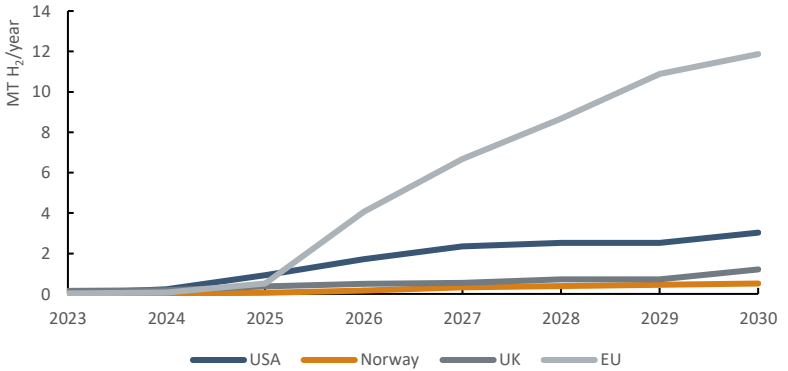
Among all the areas we have analysed, it is the EU that has the most ambitious plans for the development of green hydrogen production in the coming years. Among the already announced investment plans, the EU is on track to have an annual production capacity of nearly 12 million tonnes of hydrogen by 2030. In comparison, the US, Norway, and the UK have announced plans for a capacity of 3.0, 0.75, and 1.2 million tonnes per year, respectively. However, this does not capture all the latest projects launched in the UK following the first round of support through the "hydrogen allocation round".

Regarding blue hydrogen, it is the US that has announced the largest investment plans. American expansion of blue hydrogen facilities will, based on announced plans, have a total production capacity of 5.7 million tonnes of hydrogen per year. In comparison, the EU, UK, and Norway have announced investment plans for respectively 2.4, 3.2, and 0.9 million tonnes of blue hydrogen production per year.

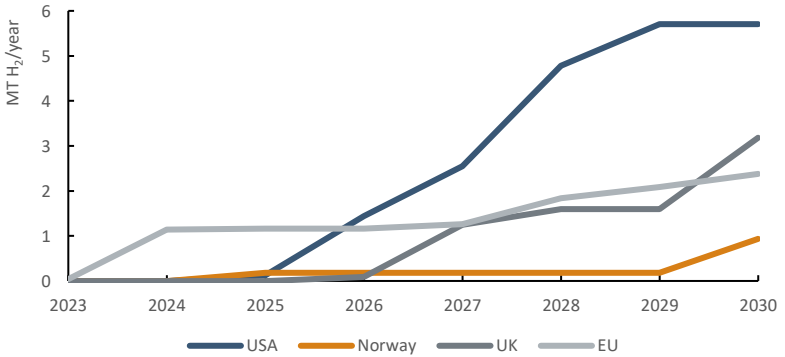
Among the announced plans for both blue and green hydrogen in the US, 15% of the projects have reached the 'First Investment Decision' (FID), which is a far greater proportion than in Europe, where only 4%of the projects have reached FID. [1] This suggests that the projects in the US are more mature than in Europe.

It is important to note that these estimates are based on companies' own plans for production capacity and start-up date, and do not necessarily correspond to projects that will be realised.

Companies' announced plans for production capacity of green hydrogen in various years.[2] Source: IEA database (updated Oct. 2023)



Companies' announced plans for production capacity of blue hydrogen in various years.[2] Source: IEA database (updated Oct. 2023)



[1]McKinsey & Company, 2023. [2]The estimates are based on companies' own stated plans for production capacity and start-up date and are not synonymous with projects that will be realised.

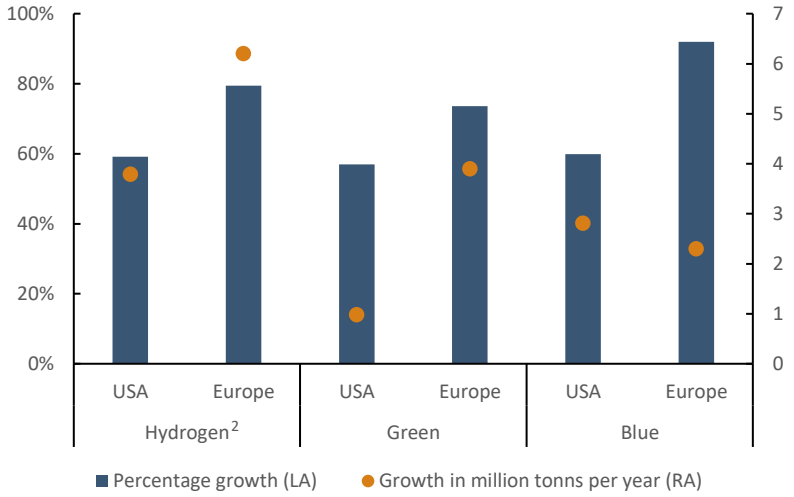
Growth since the introduction of the IRA

To assess how the IRA has influenced hydrogen project plans in Europe and the US, we have chosen to look at the growth in announced hydrogen plans up to 2030. The IRA was launched in August 2022. With the data available, we have estimated the growth in announced plans from May 2022 to October 2023. This is illustrated in the figure to the right.

As the figure shows, there has been significant growth in advertised plans in both the US and Europe for both green and blue hydrogen production. Looking at the development in advertised plans, before and after the IRA, there is still no indication that the IRA has influenced European hydrogen plans, and that projects have been marked out to the US. In fact, there has been greater growth in European plans during this period. However, this does not prove that the IRA has not influenced plans or led to the relocation of projects, as we do not know what the growth would have been in the two areas if the IRA had not been launched. Based on the lower production costs per kg of hydrogen in the US, we consider it likely that the support difference will lead to capital flow [1], but that this will be somewhat smaller between continents than between different regions within Europe.

Growth in Europe has also been greater when looking at the growth in announced hydrogen plans measured in tonnes of production capacity per year. However, there has been a greater growth in blue hydrogen plans in the US than in Europe in terms of tonnes, with respectively 2.8 and 2.3 million tonnes of annual production in 2030. For green hydrogen production, the opposite is the case, with growth in the US and Europe respectively at 1 and 3.9 million tonnes of annual production.

Growth in advertised plans for hydrogen production by 2030 from May 2022 to October 2023. Source: McKinsey & Company, 2023.



[1] *In this report, capital flow refers to how subsidies in one region affect investments in another region.* [2] *Total for blue and green hydrogen*

Case: Barents Blue

Barents Blue is a project led by Horisont Energi, in collaboration with Fertiberia. The project aims to produce 1 million tonnes per year of blue ammonia. This will lead to the capture and storage of 2 million tonnes of CO_2 per year, which will be stored in the Polaris reservoir. The capture rate of the project is estimated to be at 99.4 percent. If achieved, the project will be among the world's most carbon-efficient blue hydrogen producers.

The project was selected as one of two Norwegian projects in the hydrogen IPCEI programme Hy2Use. This resulted in their approval for an allocation of NOK 482 million in state aid through Enova.

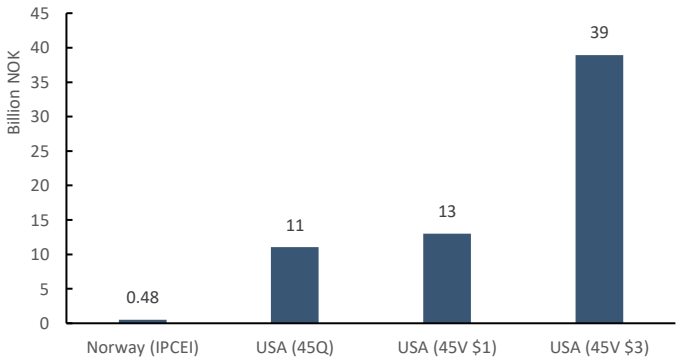
Following the launch of the IRA in August 2022, the relative operating conditions for such a project in Norway and the US have changed dramatically. In the US, the Barents Blue project could receive support through either the Clean Hydrogen Credit (§45V) or the Credit for Carbon Oxide Sequestration (§45Q). This would provide support of either 1 or 3 dollars per kilo of hydrogen production or 85 dollars per ton of CO_2 captured and stored.

It is uncertain what level of support the Barents Blue project would have received in the US for hydrogen production, as the level of lifecycle emissions per kilo of hydrogen in an American production modality has not been calculated. Presently, Horizon Energy has estimated that they will have emissions of about 0.3 kg CO_2 per kilo of hydrogen. This would place them in the highest support level of 3 dollars per kilo of hydrogen. However, this calculation has been made using the ISO model and not the GREET model which is used in IRA calculations. Another uncertainty is also related to the difference in methane leakage from Norwegian natural gas and American natural gas. Norwegian natural gas has far lower methane leakage, and it is not certain that the Barents Blue project would have been able to stay below 0.45 kg CO_2/kg H2 if they had used American natural gas. They would therefore probably have been placed in the support level that gives 1 dollar per kilo of hydrogen.

We have calculated the net present value of the various support options Barents Blue would have been eligible to receive under the IRA compared to the support awarded in Norway, as shown in the figure to the right. As we can see, the level of support the project could have received in the US is 28 times higher than what they have received in Norway. This is despite the conservative estimate of 1 dollar of support per kilo of hydrogen. The net present value of the support in the US under 45Q, 45V ($1) and 45V ($3), is NOK 11, 13, and 39 billion respectively, all far higher than the NOK 482 million the project has received in Norway.

Assumptions	
Production period evaluated	10 years (12 years for Q45)
Production quantity	200 000 tonne H_2 / year
Volume of captured CO_2	2 MT CO_2 / year
Hydrogen subsidy US	USD 1 or USD 3 / kg H_2
CCS subsidy US	USD 85 per tonne CO_2
Subsidy Norway (IPCEI)	NOK 482 mill.
Discounting rate	10 %
NOK/USD	10,56

Net Present Value of support for Barents Blue in Norway compared to the US




Carbon Capture and Storage (CCS)

CCS impact on green transition

Carbon capture and storage is an important technology in the green transition, which is likely to be necessary to meet the goals of the Paris Agreement from 2015. For many large emission sources, we currently do not have technology that can significantly reduce the emission intensity. Here, CCS will be a necessary measure to achieve emission reductions, unless new production technologies or substitute products are developed. This is the case, for example, with cement production, steel production, and a number of chemical processes.

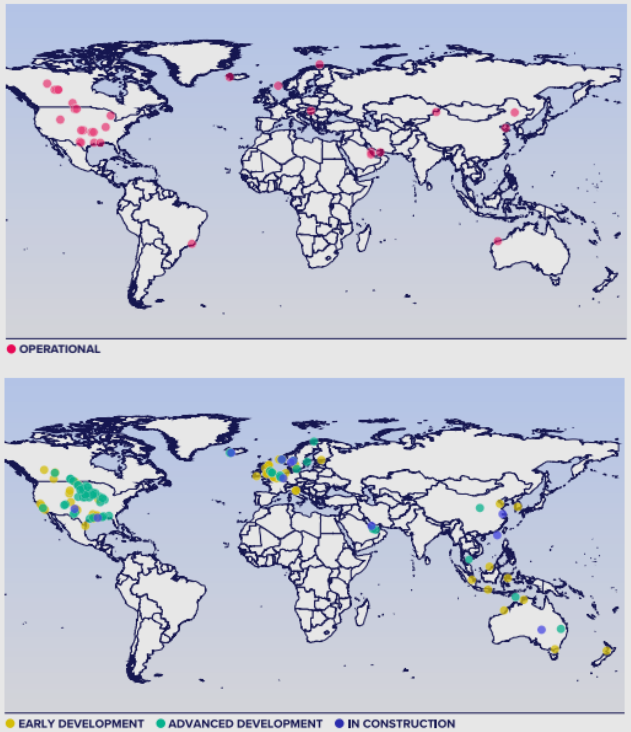
By removing CO_2 from industrial processes, CCS can directly contribute to the reduction of significant amounts of greenhouse gas emissions. In addition to industrial application, CCS plays a role in supporting the transition to clean energy by enabling the development of zero-emission carriers such as blue hydrogen.

Globally, CCS is a relatively mature technology, with over 40 operational projects. Global CCS capacity is also undergoing rapid growth: planned CCS capacity increased by 44 percent during 2022 alone.[1] The figure on the right illustrates the locations of operational and planned CCS projects worldwide. The strong growth is indicative of the increasing role that CCS will play in the global effort to combat climate change.

CCS distinguishes itself from other green technologies in that it primarily increases production costs, if one disregards the quota markets, without in itself leading to a revenue-generating product. This means that CCS is to a small degree economically viable for businesses. To incentivise companies to use CCS, measures such as raising the levies on emissions to a level that exceeds the cost of capture and storage, increasing the willingness to pay for products with lower emissions or offering direct public support schemes are therefore necessary. Currently, it costs between EUR 130 and EUR 230 to both capture and store one tonne of CO_2.[2] The cost of capture varies greatly depending on how concentrated the emissions are in the industrial process.

In the remainder of this chapter, we will first present the support options for CCS in the US, EU, Norway, and the United Kingdom. Before examining the developments in announced plans, and changes in plans following the introduction of the IRA.

Map of CCS facilities at various stages of the development cycle. Source: Global CCS Institute, 2022



[1]Global CCS institute, 2022. [2]IOGP, 2023.

CSS support in the US

The US was one of the first countries in the world to store CO_2 in underground geological formations. This began in the 1970s to increase the proportion of oil that could be pumped from reservoirs, through a practice known as "enhanced oil recovery". Although the main goal was not to reduce greenhouse gas emissions, a significant portion of the CO_2 remained underground. 50 years later, the US is the country with the most CCS projects that are operational or under construction.[1] This is largely driven by the fact that the US has supported carbon capture and storage through tax incentives since 2008.[2] This tax incentive was further expanded under the IRA in both increased support levels and reduced requirements for support allocation.

The primary support mechanism in the US for CCS is the assistance allocated under the "Credit for carbon oxide sequestration," which was expanded from USD 50 to USD 85 per tonne of captured CO_2 under the IRA. The Congressional Budget Office has estimated that the cost of this change will be USD 3.2 billion from 2022 to 2031. However, this is merely an estimate of the impact on the federal budget, with the scheme not limited to a certain size.

One of the major advantages of the American support system for CCS is that significant portions are open to all who utilise the technology. There is no application process as seen in the other areas we have evaluated. This makes the scheme predictable for the stakeholders.

In addition to the federal support indicated on the right, there are also relatively flexible opportunities for states to offer local support to CCS projects within their own state.

Support for CCS:

IRA "Credit for Carbon Oxide Sequestration" (§45Q): This support mechanism is the largest and most important for CCS in the US. It is a production support that is open to anyone who captures and stores their carbon emissions. The support will be granted for the first 12 years after startup and will be adjusted for inflation from 2027. Requirements for wage levels and the use of apprentices are in place to obtain full support. The support levels for various forms of carbon capture and storage are described in the list below.

- CCS: USD 85/t CO_2
- CCUS: USD 60/t CO_2
- Direct air capture (DAC): USD 180/t CO_2
- Direct air capture and USge (DACU): USD 130/t CO_2

"Qualifying Advanced Energy Project Credit" (Section 48C): This is a support mechanism that can be used by equipment manufacturers for CCS. The level of support is up to 30 percent of the investment requirement. The support package is limited to USD 10 billion and is application-based. The support is not exclusive to CCS but can be used by various green technology manufacturers.

Bipartisan Infrastructure Law (BIL): BIL is a USD 62 billion national expenditure package to build up American infrastructure, especially in green energy. In this package, USD 12 billion is earmarked for carbon capture and storage. Of this, CCS and CCUS are to receive USD 6.4 billion, DAC and DACU are to receive USD 3.6 billion, and USD 2.1 billion is to go to CO_2 transport infrastructure.[3]

[1]Global CCS institute, 2023. [2]Global CCS institute, 2020. [3]DOE, 2021.

CSS support in the EU

There are no support programmes in the EU specifically targeted at CCS. The EU has set a quantitative goal under the Net Zero Industrial Act for an annual storage capacity of 50 million tonnes of CO_2 per year by 2030[1]. The European Commission has stated that CCS technology will be an important part of the EU's efforts to reduce greenhouse gas emissions. At the end of 2022, the European Commission adopted a proposal to establish a voluntary framework for certifying CCS[2]. The European Commission will also present a strategy for "Industrial Carbon Management" in February 2024.[3]

The greatest opportunities for direct support for commercial CCS projects come from the Innovation Fund. They support both projects for capturing CO_2 from industrial activity, the production of zero-emission energy carriers, and projects working with the storage of CO_2.

Carbon capture, however, receives indirect support through the emissions trading system. The Commission has stated that the trading system is one of their main mechanisms to incentivise the use of CCS.[4] This is because businesses that are part of the trading system must pay for their emissions, but if the emissions are captured and stored, they are not registered as emissions. Consequently, they avoid paying for emissions they would otherwise be liable for.

Under the temporary scheme, Temporary Crisis and Transition Framework (TCTF), member countries have expanded opportunities to support green energy and technology. Both equipment manufacturers for CCS and investments in capture equipment are covered by this arrangement. Support levels, technology types, and the duration of the TCTF are described in more detail in the annex.

Support for CCS:

Innovation Fund (IF): IF can support up to 60 percent of the additional costs associated with establishing capture or storage of CO_2. Support from the fund is allocated through calls for proposals, where CCS projects compete with other emission reduction projects. It is expected that IF will allocate EUR 40 billion by 2030. The largest grant that has been awarded through the Innovation Fund to date went to the carbon storage project Kairos-at-C, which received approximately EUR 360 million.

National support mechanisms: Although there are strict requirements for how state aid is managed within the EU/EEA, it is possible to provide support under various exceptions to the state aid rules through the GBER scheme. For larger projects with a low degree of distortion of competition, it is also possible to apply to the European Commission for the allocation of aid that goes beyond the exceptions from the state aid regulations. An example of one of the larger national schemes where CCS can be supported is the Netherlands' support program for sustainable transition at EUR 13 billion. Another example is Denmark's CCUS fund which is set to allocate DKK 16 billion to CCS projects between 2025 and 2048.5

Horizon Europe Cluster 5 – Climate, Energy and Mobility: Horizon Europe, the European support programme for research and development, also backs CCS research projects. These grants are distributed through calls that projects can apply for.

IPCEI: So far, no IPCEI for CCS has been established, but this was proposed for further investigation in 2021 by the implementation working group for the European Strategic Energy Technology Plan. It is therefore possible that this will be carried out in the future.

[1]IEA, 2023. [2]European Commision, 2022. [3]European Comission, 2023a. [4]European Comission. [5]Danish Energy Agency, 2022.

CCS support in the UK

The United Kingdom aims to capture and store 20 to 30 million tonnes of CO_2 per year by 2030. In this context, it has been decided to support the development of four CCS hubs by 2030, with two to be established by 2025 and two to be established before 2030.

To support the CCS initiative, the British Chancellor of the Exchequer stated in his speech regarding the Spring Budget 2023 that the current government wishes to allocate up to GBP 20 billion to carbon capture and storage.[1] It has not been specified which instrumental apparatuses or support programs this will be distributed through, and it has not been mentioned over what period. We have not been able to identify further confirmations of this amount in any official statements since the spring speech, but if the government follows through with its plans for GBP 20 billion in support, this will become one of the most generous environments for CCS investments, possibly only outcompeted by the US. The industry in the UK itself states that they are operating under the assumption that the support will be distributed over 20 years, and that the ICCBM will be one of the allocation mechanisms for the support.

In addition to the support mentioned on the right, CCS may also receive indirect support through the UK's emissions trading system for greenhouse gases. Participants in the ICCBM may also sell their free quotas to the state.

Support for CCS:

CCUS Infrastructure Fund (CIF): CIF is the support programme designed to allocate funds for the development of four CCS hubs by 2030. The programme currently has a budget of GBP 1 billion and offers investment support for CCS infrastructure of up to 50 percent of the investment cost. Should the British government follow through on its declared plans to allocate GBP 20 billion, it is likely that this will be done partly through the CIF, which would in that case increase the CIF budget. To date, 8 projects have received support through CIF's first allocation to two of the four CCS hubs.

Industrial Carbon Capture Business Model (ICCBM): ICCBM is a support scheme for revenue support for industrial use of CCS. Production support will be awarded per tonne of CO_2 captured and stored. The amount of production support will be the difference between a reference price based on carbon prices in the quota system and a strike price per tonne of captured CO_2. The fixed price will be negotiated bilaterally for each project, based on capital investment (plus return), operational costs, and T&S costs. The duration of the support is 15 years from project start. No budget has been disclosed for this support scheme, but it will likely be included in the government's plans to support CCS with GBP 20 billion.

Net Zero Innovation Portfolio (NZIP): NZIP is a support programme for research and development of low-carbon technology, where GBP 115 million has been earmarked for research and development of CCS technology.

DACCS & other GGR innovation programme: Support programme that in 2022 allocated GBP 60 million to the development of DACCS technology.

[1] *UK Treasury, 2023.*

CCS support in Norway

Norway is one of the countries that is at the forefront of CCS and began this work as early as the mid-1990s with the Sleipner project. This has given Norway a competitive edge when it comes to CCS, especially in the storage within subsea geological formations.

Additionally, Norway possesses large tracts of subsea geological formations that are well-suited for conversion to carbon storage. This makes Norway a particularly attractive country for investment in CCS. We can also play a significant role in the storage of European-captured CO_2.

Norwegian CCS projects can apply for the same support schemes that are available at EU level. On an overarching basis, the levels of support allocated through the Innovation Fund are significantly higher than those attainable through national policy instruments (with the exception of the direct support to the Longship project).

In the Green Industrial Initiative, the Government has identified CCS as a particular focus area. Here, the government states that they will facilitate commercial CO_2 storage on the Norwegian continental shelf by actively allocating storage areas. To date, the MPE has awarded seven licences for exploration and exploitation of subsea reservoirs on the Norwegian continental shelf for the storage of CO_2.[1]

Support for CCS:

Gassnova (CLIMIT-Demo): The CLIMIT programme is the national programme for demonstration of CCS technology. Gassnova is responsible for the demonstration part of this support programme. This entails support to pilot and demonstration scale projects for capture, storage, handling, and transport of CO_2. Over the last ten years, Gassnova has awarded NOK 975 million to CCS projects within late-phase technology development.

The Research Council (CLIMIT-R&D): The CLIMIT programme is the national scheme for research and development of CCS technology. The Research Council is responsible for the R&D component of this support programme. This encompasses research projects, innovation projects for the industry, and international project announcements targeted at CCS. Over the past ten years, the Research Council has allocated just over NOK 1 billion to CCS projects in the research and early development stages.

Innovation Norway: Although Innovation Norway has provided support for the experimental development of CCS technology, it is not among the primary instrument actors within CCS. Over the last ten years, Innovation Norway has awarded close to NOK 300 million to CCS projects.

Direct support from the departments: The OED has provided direct support to the Longship project. It is expected that the governmental support for the project will amount to NOK 20 billion out of a total budget framework of NOK 30 billion. This is the largest climate investment in Norwegian history. This project received direct support and had to be approved by the European Commission. Gassnova is responsible for the oversight of the project. Mongstad Technology Centre has also received direct support from the OED through Gassnova.

Enova: Over the past ten years, Enova has accounted for a very small part of the support awarded to CCS projects. However, in September 2023, they announced a new support scheme, "Feasibility Study Carbon Capture 2030", which is aimed at industrial carbon capture. However, it is only open to carbon capture from existing emission points. The support amount is limited to a maximum of NOK 50 million.

[1] *Sokkeldirektoratet, 2023.*

Comparison of support levels for carbon capture projects

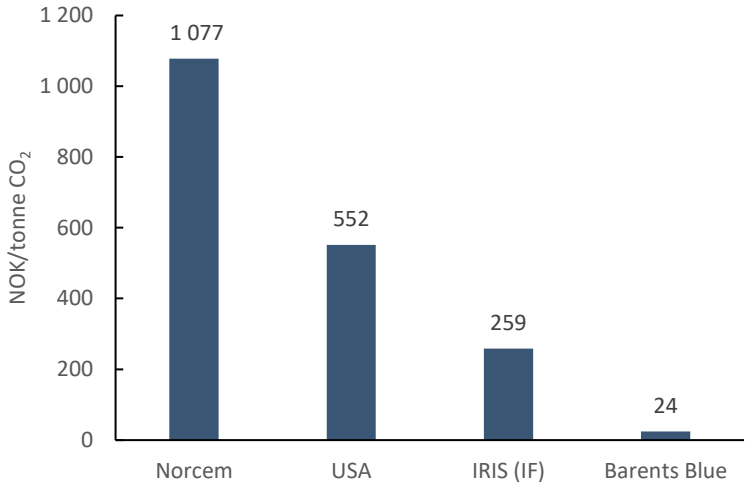
To provide a concrete comparison of the support level between regions, we have estimated the net present value of the universal support mechanism for carbon capture projects in the US and compared it with the net present value of the support to a project that has received support in the EU and two projects that have received support in Norway. These projects are Norcem and Barents Blue in Norway, and IRIS in the EU.

The support provided to Norcem in the Longship project is the carbon capture project that has received by far the most support per tonne of CO_2 captured. This is a project that will utilise CCS to capture 400,000 tonnes of CO_2 per year from cement production. The Norwegian state covers approximately 80 percent of both CAPEX and OPEX costs. According to our estimates, the net present value of this support over the first ten years will amount to nearly 1,100 kroner per tonne of captured CO_2.

For comparison, the net present value of the support in the US is approximately 552 Norwegian kroner per tonne of CO_2. The IRIS project, which is set to produce blue hydrogen and capture about 560,000 tonnes of CO_2 annually, has, according to our calculations, received 259 kroner in support per tonne of captured CO_2 through the Innovation Fund. Barents Blue, which aims to capture up to 2 million tonnes of CO_2 per year, has received a meagre 24 kroner per tonne of CO_2 through the IPCEI programme Hy2Use.

A significant difference between the support allocated in the US compared to Europe and Norway is that the support is available to all entities wishing to utilise CCS. This ensures that the support is not only substantial but also far more accessible and predictable than the support opportunities in Europe.

Comparison of net present value[1] of support per tonne of captured CO_2 between the US and individual projects in the EU and Norway. Source: Menon



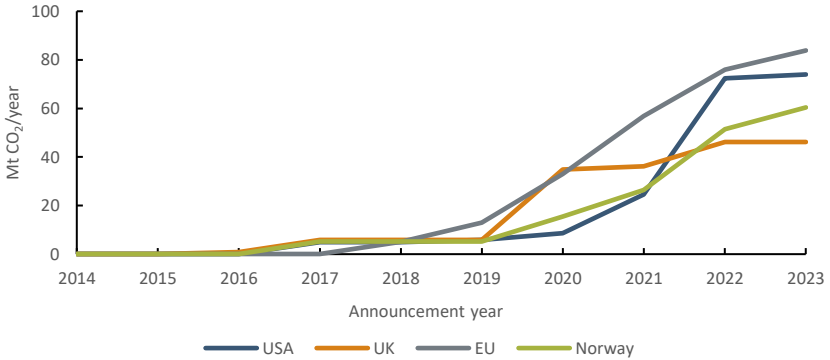
[1] *10 percent discount rate.*

Advertised plans for carbon storage

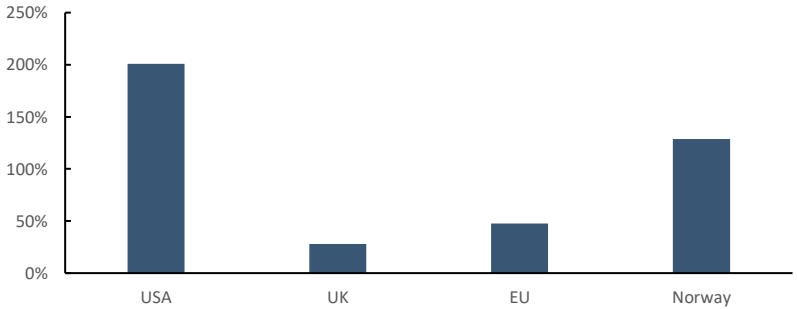
Among all the areas we have analysed, it is the EU which has announced the largest investment plans for the establishment of carbon storage facilities to be operational by 2035. As of March 2023, the total planned annual storage capacity stood at 84 million tonnes of CO_2.[1] This is marginally higher than the US, which has a planned annual storage capacity of 74 million tonnes of CO_2. By comparison, the plans in Norway and the UK were for 60[2] and 46 million tonnes of annual storage capacity, respectively. How the announced plans in the different areas have changed over time is shown in the figure at the top right. These figures are based on the announcements made by the actors themselves and are not necessarily synonymous with the amount of storage capacity that will be realised. The database we have used was last updated in March 2023 and does not capture carbon storage that has been announced after this.

To assess how the IRA has influenced plans for CCS, we have presented the growth in announced plans for carbon storage between January 2022 and March 2023 in the figure below to the right. As we can see, growth has been significantly higher in the US than in the UK and EU, and about 40 percent higher than in Norway. This may indicate that the IRA has created a more favourable investment climate for the establishment of carbon storage than is the case in Europe, and the IRA allows for greater use of capture technology in American companies. However, it is less likely that this is driven by capital moving from Europe to the US, as carbon storage is a relatively regional market, with stores located near the emission point having a competitive advantage.

Companies' advertised plans for carbon storage with start-up before 2035.[3] Cumulative sum of announced storage capacity by year of announcement. Source: IEA database (updated March 2023)



Growth in advertised plans for carbon storage with a start-up before 2035, from January 2022 to March 2023. Source: IEA database (updated March 2023)



[1]IOGP (2023) estimates 50 Mt CO_2/year. [2]Konkraft (2023) estimates 60 to 90 Mt CO_2/year. [3]The estimates are based on companies' own stated plans for storage capacity and are not synonymous with projects that will be realised.

Offshore Wind

Support for offshore wind in the US - IRA

The US has support mechanisms for offshore wind at both federal level and state level. At the federal level, the **Inflation Reduction Act (IRA)** is the primary mechanism for support. At state level the support schemes varies between the states. Overall, states with major commitments to offshore wind deployment have long-term, risk-reducing schemes. We will first present the IRA, followed by other available support schemes for offshore wind.

The IRA is the largest support package for green transition in the history of the US. The IRA offers support for the entire value chain of offshore wind, both operators and equipment suppliers. The parties can choose between support given as a percentage of the investment costs, or support per unit produced. The IRA allows for the support to be taken as a cash grant by transferring the expected tax deduction to a third party willing to trade the tax deduction for cash.

Investment support to offshore wind developers: The investment support is initially 30 percent of the investment cost for an offshore wind facility.[1] The support is universal and can be increased to 50 percent upon meeting certain requirements, including the use of local suppliers. However, actors have described this as challenging, so the support is often limited to 40 percent.[2] Menon's calculations show that with the current cost level and presently limited capacity, investment support will be the most lucrative option for offshore wind operators.[4] However, this may change over time and the table to the right shows both investment support and production support.

Support to the value chain: Equipment manufacturers for offshore wind farms may receive support amounting to 30 percent of the investment cost for production facilities. The scheme is application-based. Production support is granted based on fixed amounts for different equipment. Refer to the table on the right.

Support to producers

Type of support	Support	Requirements
Investment support	6% of investment cost	
	30% of investment cost	Requirement for wages and use of apprentices
	Up to an additional 10 % is given if respectively requirement 1) and 2) are met. Can be combined	Requirement for 1) local content, 2) energy community
Production support	0.52 cents per kWh[1] produced over 10 years. Adjusted for inflation	
	2.6 cents per kWh[1] produced over 10 years. Adjusted for inflation	Requirement for wages and use of apprentices
	Up to an additional 10 percent is given if respectively requirement 1) and 2) are met. Can be combined to 20 percent	Requirement for 1) local content, 2) energy community

Support to the value chain

Type of support	Support	Requirements
Investment support	6% of investment cost	Based on applications
	30% of investment cost	Based on applications Requirement for wages and use of apprentices
Production support	Tax deduction on the sales price for produced units/materials, the amount varies from 2-5 cents per produced unit multiplied by the turbine's capacity. The scheme applies to produced equipment such as turbine blades, turbines, turbine towers, and foundations. For offshore wind vessels: tax deduction of 10% of the sales price.	Production must happen in the US

[1]Reduces to 6% percent if the firm does not fulffill requirements to wages and apprentices. [2]Power Magazine, 2023. [3]2022 USD. Adjusted for inflation. [4]Menon, 2023

Support for offshore wind in the US – other support mechanisms

State-level support

In addition to federal-level support, the states with commitments in offshore wind provide varying degrees of support for offshore wind. The available programmes with support schemes and the sizes of the schemes vary between the states. Generally, states with major offshore wind undertakings back the development of offshore wind farms through long-term power purchase agreements for electricity from the offshore wind farms and/or renewable energy certificates from offshore wind. Both of these arrangements involve a fixed price for offshore wind operators, thus reducing risk. This is factored into the prices that offshore wind developers are willing to pay for the right to develop, resulting in higher land and development rights prices in states with such schemes. These arrangements are prevalent in states with significant commitments to offshore wind, such as New York, New Jersey, Massachusetts, and California. States also support the development of the value chain and infrastructure with their own funds. For instance, New York has invested USD 700 million in port infrastructure.

The Infrastructure Investment and Jobs Act, IIJA: Through the IIJA, nearly USD 30 billion has been allocated for the construction of infrastructure which will also benefit offshore wind farm development, including USD 2.25 billion for the development of ports and USD 27 billion for the development of the power grid.

Support for research and development

At the federal level, the Department of Energy allocates support for research and development within offshore wind, through a variety of different schemes and programmes. Among other things, USD 300 million has been appropriated, which is awarded on a competitive basis to research, development, and demonstration projects for offshore wind.

A specialised programme for floating offshore wind, Floating Offshore Wind Shot, aims to contribute to making American entities leaders in the design, development, and production of floating offshore wind. The programme's objective is to reduce the costs of floating offshore wind by 70 percent, to $45/MWh, by 2035.

Allocation of Areas for Offshore Wind

Allocation of areas for offshore wind in the US takes place through auctions where developers compete to pay the highest price to lease land areas. This differs from allocation processes in Norway, where developers compete to offer the lowest bid price per kilowatt-hour.

Support for offshore wind in the EU

State aid for offshore wind is awarded by member states in accordance with EU state aid regulations. The actual auctions and allocations are handled by the individual member states but must be approved by the European Commission. The member states' ability to provide state aid for renewable energy production was expanded in March 2023 through the EU's Temporary crisis and transition framework. The increased possibilities for state aid must be viewed in light of the EU's target that 40 percent of energy should come from renewable sources by 2030 and the respective countries' emission reduction targets.

In December 2023, the EU reached a consensus on a reform of the EU's internal power market which sets out guidelines for support to offshore wind and other renewable energy to be provided through bilateral Contracts for Difference awarded via competitive auctions or similar schemes.[1] Several Member States have already been using Contracts for Difference for some time, and within three years, the support mechanism is to be adopted by all EU countries. Contracts for Difference guarantee a fixed electricity price per unit produced - known as the "strike price". If the market price is lower than the strike price, the power producer receives a subsidy from the state equivalent to the difference. If the market price is higher than the contract price, the producer repays the difference. This scheme ensures that the producer receives a steady income for the electricity while also capping revenue when market prices are high. In the EU's new arrangement, any surplus income will be used for the benefit of end consumers of electricity, including electricity support for private consumers and industry or investments to reduce electricity expenses for end users.

Examples of support schemes and allocations in EU countries

Germany: Support scheme for offshore wind at EUR 1.5 billion was approved in 2021, replacing the previous scheme from 2017. The support is provided as a one-way contract for difference, where the producer does not have to pay a surcharge to the state if the market price exceeds the set reference price. Menon's mapping of allocations finds that between 2018 and 2021, six out of ten large-scale offshore wind projects were awarded exclusive development rights with so-called zero-subsidy bids, i.e. a reference price of 0 EUR per kWh. [2] The support schemes, although significant in size, have thus not been decisive for the pace of offshore wind development in Germany.

Denmark: Denmark previously had an "open door policy," where developers in certain areas could apply for licenses to operate in areas on their own initiative and in this way decide the location and capacity themselves. The support under the scheme was DKK 25 øre/kWh on top of the market price, but the last allocations under the scheme were stopped due to Danish authorities being uncertain about whether the arrangements were in compliance with EU state aid regulations. Now, primarily bilateral difference contracts are used for the allocation of support. The largest offshore wind farm in Denmark – Thor – has been awarded support through the scheme. The contract price was set at EUR 0.01/MWh, essentially a zero-subsidy bid. The total framework for support is EUR 372 million, and the developer will thus likely pay the amount to the Danish state.

[1] Europakommisjonen, 2023b. [2] Menon, 2023.

Support for offshore wind in the EU

Support through the Temporary Crisis and Transition Framework (TCTF): The EU's TCTF allows for state aid to be granted to production facilities for green technology firms and producers of green energy, and for the aid amounts to be increased compared with before. The framework thus extends the member states' opportunities for supporting the development of renewable energy sources, including offshore wind. The support through the framework can, in principle, be granted until 2025, but allocations for offshore wind development can be awarded beyond 2025. Under the framework, the EU Commission recently approved the first state aid for the development of floating offshore wind farms totalling EUR 4.3 billion, which is granted by the French state.

Manufacturers of wind turbines, associated key components, and critical raw materials qualify for support provided to green technology firms. The maximum support level is calculated based on the size of the company and the location of the project. For direct support to investment costs, support levels vary from 15 to 55 percent of the investment costs. Should support be provided in the form of tax reliefs, loans, or guarantees, the maximum support amount increases to 60 percent. If there is a real risk that investments will be diverted away from Europe, the support can be increased to match the amount available in the alternative location or a sum that incentivises the company to remain within the EEA region. In this way, the support scheme is a response to the American IRA.

Support through EU programmes: The EU Commission utilises twelve different support mechanisms to allocate funding to offshore wind development, ranging from support for R&D to innovation, infrastructure, and the construction of offshore wind farms. The EU's Innovation Fund, which supports the upscaling of innovative production projects, has provided funding for three offshore wind projects since 2021[1]. Horizon Europe, which is the EU's programme for research and innovation, has in its current work programme several calls related to offshore wind and related fields. Other relevant support programmes include the Cohesion Fund, the European Regional Development Fund, and the Just Transition Fund.

Indirect support through the EU's Emissions Trading System (EU ETS):

The EU ETS sets a cap on total greenhouse gas emissions in the quota-obliged sector in the EU. The system leads to increased costs associated with CO_2 emissions as power stations falling under the EU ETS must purchase one emission allowance for each tonne of CO_2 they emit. Higher production costs for fossil-based electricity raise the price of electricity in the power market, which contributes to increased profitability for renewable technologies. With the prevailing prices of emission allowances, electricity prices in the EEA area are estimated to be 30 to 75 EUR per MWh higher than they would have been without the system.

[1]*Including allocations that was made public july 20223.*

Support for offshore wind in Norway

Previously, support for renewable power production in Norway was provided through the green certificate scheme. The approach has now shifted to Contracts for Difference, and it is Contracts for Difference that will be used for offshore wind farm developments. As in the EU, the scheme ensures that the producer receives a stable income for the electricity while also limiting income when market prices are high.

Currently, two areas have been opened for offshore wind, Utsira North and Sørlige Nordsjø. In March 2023, a competition for project areas for Utsira North and phase 1 of the Sørlige Nordsjø II was announced. The two project areas are each tendered for up to 1500 MW.

To support offshore wind from the first phase of **Sørlige Nordsjø II**, a bilateral contract for difference will be entered into, whereby the state's support will be capped by an upper limit. The government has set a cap of NOK 23 billion in state subsidies. The contract will have a duration of 15 years from the start of production.

Support for the development of **Utsira Nord** is planned to be allocated in two rounds, in which areas for three project zones will initially be awarded with a time-limited exclusive right to conduct impact assessments and submit concession applications. Subsequently, auctions will be carried out for the actual allocation of support, and the government has indicated that two of the three entities that have been allocated areas will be granted state support for 500 MW for each project. No cap has been set for the state aid. The development is expected to be significantly more expensive than Southern North Sea II as Utsira Nord is being opened for floating offshore wind.

Temporary Crisis and Transistion Framework

Following amendments to the EU's Temporary Crisis and Transition Framework (TCTF) in March 2023, the TCTF regulations also apply to EEA countries, thus enabling Norwegian authorities to provide support to offshore wind actors and equipment suppliers in line with the TCTF. The first Norwegian support scheme for offshore wind based on the TCTF was approved by the ESA in August 2023. The programme 'Floating Offshore Wind – Competition for Demos of Cost-Effective Concepts' is managed by Enova with a total framework of up to NOK 4 billion. Under the scheme, support may be granted for up to 100 percent of the total investment cost.

Support for R&D: There is also governmental support available for research and development, through the Research Council of Norway, Innovation Norway, and Enova. Most of the support for offshore wind has been provided by Enova as direct investment support (CAPEX). Additionally, comparatively smaller amounts (against the investment support) have been provided by the Research Council as support for R&D, and from Innovation Norway and Enova as support for experimental development. The Support Programme for Small-Scale Floating Offshore Wind allows for funding of commercial, floating offshore wind projects requiring support of more than EUR 15 million. The first application deadline was in December 2023 with a total budget of NOK 2 billion, with the possibility of a new round with an equivalent budget in 2024. Currently, Enova has opened for applications for support through the Offshore Wind 2035 programme, where a maximum of NOK 10 million can be granted for pilot projects and feasibility studies and investment support of up to EUR 15 million.

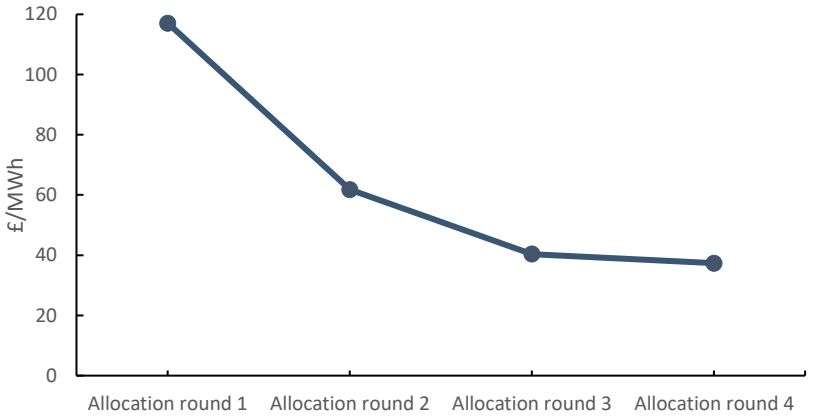
Support for offshore wind in the UK

The United Kingdom is one of the leading countries in offshore wind, with an installed capacity of 14 GW. Moreover, the country has ambitions to deploy a combined capacity of 50 GW of offshore wind by 2030, of which 5 GW is from floating offshore wind. The primary support mechanism for offshore wind is long-term bilateral Contracts for Difference. Contracts for Difference have been used in the United Kingdom for nearly a decade and are now the norm.

Since 2015, five auction rounds have been conducted. From 2023, plans are in place to conduct annual auction rounds for the allocation of contracts for difference in the United Kingdom, as part of achieving the ambitious production goals by 2030. The average strike price for offshore wind projects fell from £120/MWh in the first auction round to less than £40/MWh in the fourth auction round in 2022 due to cost reductions in the development of offshore wind. However, in 2023, cost increases and rising inflation impacted offshore wind producers significantly, and the auction round in 2023 had no participants. Offshore wind producers criticised the government for the low strike prices not allowing the profitable operation of offshore wind farms.

To stimulate interest in the next auction round, the British government has increased the maximum prices for the Contracts for Difference ahead of the 2024 auction round. For fixed-bottom offshore wind projects, the price has been raised by 66 percent to £73/MWh, while the price for floating offshore wind has increased from £116/MWh to £176/MWh. This corresponds to respectively £100/MWh and £240/MWh in today's value.[1]

Average strike-price achieved in the auction rounds, £/MWh in 2012 prices and capacity-weighted average. Source: Watson and Bolton, 2023



[1]*Adjusted for inflation as the contract prices are set in 2012 prices*

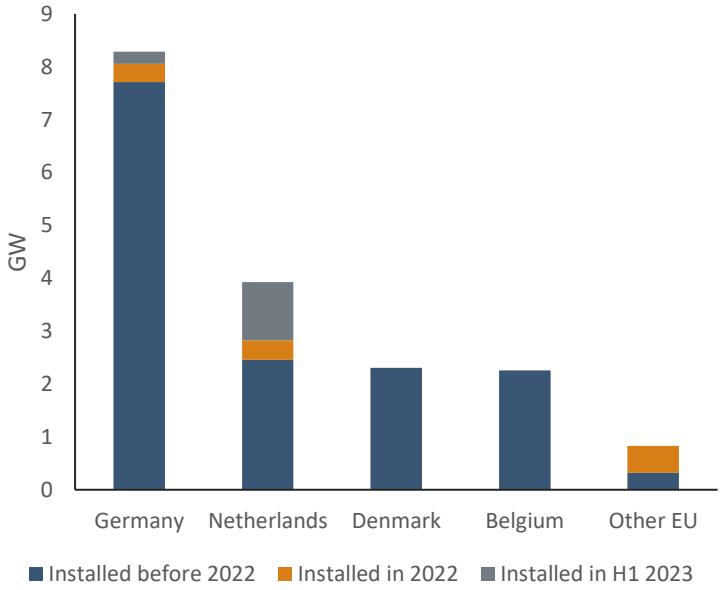
Developments in offshore wind and the effect of state aid in Europe I

EU: In the first half of 2023, a total of 1.3 GW of new offshore wind capacity was installed in the EU.[1] This followed total installations in 2022 amounting to 1.2 GW. Although the pace of installation increased significantly from 2022 to H1 2023, it is still below what is required for the EU to meet the ambitious target of 110 GW by 2030, equivalent to an average of 11 GW annually. The capacity in H1 2023 was installed in Germany and the Netherlands. Along with France, these were the countries that accounted for the most installed capacity in 2022.[2] The capacity in H1 2023 was installed in the following offshore wind farms.

- **Germany:** Arcadis Ost 1 (257 MW) [2]
- **Netherlands:** Hollandse Kust South 1&2, Hollandse Kust South 3&4 and Hollandse Kust North 5 (respectively 760, 749 and 759 MW) [3]

Under the EU's Temporary Crisis and Transition Framework, the European Commission approved French support for two offshore wind farms amounting to EUR 4.12 billion at the end of 2023. The wind farms are expected to have a capacity of around 250 MW each, which makes the planned level of support per MW capacity very high compared to previous allocations. Auction rounds and the selection of operators are expected to take place in 2024.

Total capacity of offshore wind by country and time of installment. Source: WindEurope, 2024a and WindEurope 2023.



[1] WindEurope, 2024a [2] WindEurope, 2023 [3] Europakommisjonen, 2023c

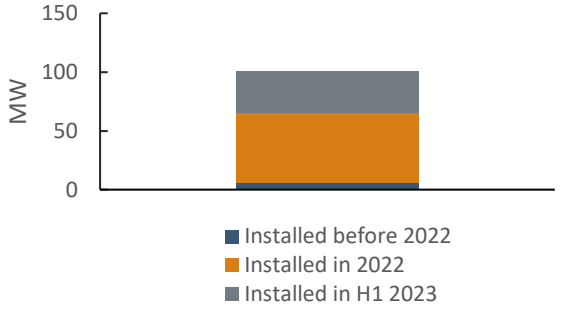
Expansion of offshore wind and the effect of government support in Europe II

Norway: The development of large-scale offshore wind in Norway has not commenced, and the total installed capacity is limited to just over 100 MW, of which 95 MW were installed in the Hywind Tampen project in 2022-2023.[1] To date, the project is the world's largest floating offshore wind farm and has received support of nearly NOK 2.3 billion from Enova through Enova's programme for full-scale innovative energy and climate initiatives. Additionally, the project has received support due to the wind farm being connected to platforms, amounting to NOK 566 million from the NOx Fund, and the project qualifies for support via the petroleum tax system. The high levels of support relative to the production capacity are due to the use of floating turbine technology at Hywind Tampen. Actors in Norway are also experiencing challenges in the value chain and cost increases. As a result of these challenges, Equinor has indefinitely postponed the planned offshore wind project, Trollvind.

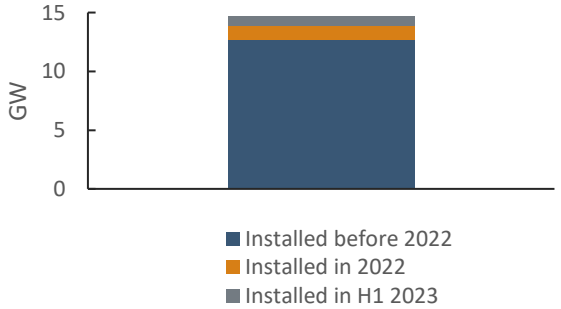
United Kingdom: Through auction rounds and previous support schemes, allocations have been made to offshore wind with a combined capacity of approximately 20 GW. The total installed capacity in the United Kingdom is currently 14.7 GW, positioning the UK as one of the leading nations in offshore wind. In the first half of 2023, a total of 783 MW was installed at the Seagreen offshore wind farm.[2] Significant capacity was also installed in British offshore wind in 2022, with a total of 1,179 MW installed across the two offshore wind farms, Hornsea Two and Seagreen.[3]

Throughout 2023, activity in the European offshore wind market surged significantly following a sluggish 2022. While no final investment decisions were made on any large-scale offshore wind projects in 2022, 2023 saw final investment decisions on a total of eight European offshore wind projects with a combined capacity of 9.3 GW. In 2023, offshore wind farms with a record-high combined capacity of 4.2 GW were commissioned, representing a 40 percent increase from 2022. The supply chain also experienced high activity, with new factories announced in Poland, Denmark, Germany, the Netherlands, and Spain.[4]

Total capacity of offshore wind in Norway by time of installment. Source: WindEurope, 2024 og WindEurope 2023.



Total capacity of offshore wind in the UK by time of installment. Source: WindEurope, 2024 og WindEurope 2023.



[1] WindEurope, 2024a. [2] 4C Offshore/TGS, 2024. [3] WindEurope, 2023. [4] WindEurope, 2024b.

Expansion of offshore wind and the effect of government support in the US

The year 2022 and parts of 2023 have been challenging for offshore wind actors in the US. Increased financing costs, high inflation, rising commodity prices, and supply chain bottlenecks have contributed to delays and reduced profitability in planned projects. This has served to limit investments during this period, despite the IRA coming into effect in August 2022. Recent months have seen a brighter outlook, with high activity in the opening and tendering of new areas. In 2023, a final investment decision was made for the Revolution Wind offshore wind farm in the state of Rhode Island with an expected capacity of 704 MW and, as of the start of 2024, there are five ongoing auctions for new offshore wind projects.[1]

In 2023, at least five offshore wind projects that were under planning or development in the US were halted due to increased costs and/or delays in supply chains. The five projects had a combined planned capacity of 5.6 GW. In other projects, developers have requested that the contract prices in power purchase agreements be raised by up to approximately 50 percent to ensure profitability in planned developments. The state of New York, where several of the developments were planned, rejected the request and the developers have written down the value of the projects.

Challenges are also being experienced in the US's **supply chain**, but investments in the supply chain are not being put on hold to the same extent as investments in offshore wind projects. According to US authorities, 18 projects for the construction of vessels for offshore wind commenced from 2021 to July 2023, with almost USD 3.5 billion invested in 12 manufacturing facilities and 13 ports. Products being manufactured in the US include blades, nacelles, towers, foundations, cables, and steel plates. The capital being invested in the supply chain is expected to eventually help alleviate bottlenecks and is seen as crucial for the US to achieve the target of 30 GW of installed capacity by 2030. However, the future prospects for several of the investments in the production of wind turbines and components are more uncertain as several large offshore wind projects are being postponed or cancelled due to the challenging cost landscape for offshore wind developers.

[1] *4C Offshore/TGS, 2024.*

Cases: Investments in the US offshore wind supply chain

The company EEW American Offshore Structures (EEW-AOS) announced in December 2022 that they will construct the first facility for the production of monopiles for offshore wind turbines in the US.

Monopiles are a type of foundation for offshore wind turbines. The facility will have an annual production capacity of 100 monopiles and is expected to be completed by 2024. The facility is located in New Jersey and will provide foundations for the Atlantic Shores Project 1. The project is anticipated to have a capacity of 1.5 GW and will become the third-largest offshore wind project in the US. EEW-AOS also had an agreement to supply monopiles to Ørsted's offshore wind project Ocean Wind 1 with a capacity of 1.1 GW, but Ørsted announced in November 2023 that they are halting the expansion due to delays and increased interest rates.

EEW-AOS and partners announced in December 2022 a total investment of USD 250 million in the facility. Production of monopiles qualifies for support through the IRA, with the option to choose between an investment subsidy of 30 percent or production support of 2 cents per produced unit multiplied by the wind turbine's capacity for ten years. Should the producer opt for investment support, the subsidy amount from the IRA alone could equal USD 75 million.

Ørsted announced in April 2023 that they will establish the first advanced production centre for offshore wind foundation components in the state of Maryland.

The investment is made in the logistics centre TradePort Atlantic which is being developed into a hub for offshore wind in the region. The announced investment amounts to USD 14m, and Ørsted's total investments in TradePort Atlantic amount to USD 30m. The production facility will manufacture components such as boat landing systems, ladders, internal and external platforms, railings, gratings, and other elements for Ørsted's developments. Ørsted has previously entered into an agreement with a local steel manufacturer which will pre-fabricate steel components that will be sent to the production facility in TradePort Atlantic for completion.

Tradepoint Atlantic was meant to supply foundation components to Ørsted's offshore wind development Skipjack Wind, but Ørsted is now considering restructuring the project due to the challenging cost situation. How this will affect TradePort Atlantic is not yet known.

Preliminary effects of government support in the US and Europe

The IRA provides historically high support levels for the green transition, yet it is challenging to compare investments in offshore wind before and after the IRA's introduction, as major investments in the US have been delayed since its implementation. Globally, offshore wind operators have seen significant cost increases in 2022 and parts of 2023, leading to fewer investments and halts in planned developments. Global conditions have led to increased financing costs, high inflation, rising raw material prices, and delays in the supply chain, which in turn have caused delays and reduced profitability in planned offshore wind projects. The analysis agency Energy Monitor estimates that the costs for wind turbines have increased by nearly 40 percent and that the average price for critical minerals has risen by over 90 percent in the last two years.[1] The cost increase contrasts with the previous years' trends in the offshore wind industry, with significant cost reductions due to technological development and efficiency improvements. In Europe too, there have been challenges, notably demonstrated by the lack of uptake in auction rounds in the United Kingdom. On average, support levels in Europe have increased over the past year. The outlook now appears brighter, and in 2023, final investment decisions were made on a total of eight European offshore wind projects with a total capacity of 9.3 GW.

The figure to the right summarizes how challenging cost conditions and bottlenecks in supply chains have affected developments in recent years.

Despite generous support schemes in both the US and Europe, we expect the effects of support when it comes to shifting capital to offshore wind farm development to be limited. This is because the profitability of offshore wind projects in the US and the EU is relatively similar when subsidies are taken into account. In the US, there is a fixed limit for nominal support while the EU does not have a limitation on the level of support if it is granted through a competitive auction, but the subsidies that have been given in Europe have been well below the level permitted in the US. The EU's support regime with two-way Contracts for Difference provides operators with income stability and is risk-reducing, but offshore wind projects in the US have risk-reducing support measures at state level.

Summary of developments in offshore wind in 2023

US

- At least five offshore wind projects with a combined capacity of 5.6 GW have been halted.
- In other projects, developers have requested that support levels be increased beyond contractual levels. In some of the projects, the request has been declined and future development is uncertain.

Norway

- The offshore wind project Trollvind has been postponed indefinitely.
- The maximum support amount for Southern North Sea II was increased from NOK 15 billion to NOK 23 billion in 2023.
- The Enova programme for support to offshore wind has been approved under the EU's TFEU, which allows for support to cover up to 100% of the total investment cost.

UK

- No participants took part in the auction round in 2023, due to overly low strike prices.
- Ahead of the auction round in 2024, the strike prices were increased by up to 66 percent to ensure further development.

EU

- TCTF provides member countries with the opportunity to increase state aid for the development of, among other things, offshore wind. Support can cover up to 100% of investment costs.
- A governmental programme has been approved in France where very high levels of support are made available.

[1] *Average cost for wind turbines calculated from 2020 to 2022. Average cost for critical minerals calculated from Jan. 2020 to Mar. 2023. Source: Ferris/Energy Monitor, 2023*

Appendix

US – Inflation Reduction Act

- Different requirements are set for the various support levels.
  - *Requirements for local content stipulate that a proportion of materials, such as steel, aluminium or other products, must be manufactured in the US. The required share increases over time.*
  - *Requirements for "energy community" are requirements for the location of onshore facilities in specified areas with a high dependence on fossil energy production.*
  - *Requirements for wages and the use of apprentices involve demands for salary levels and benefits, as well as requirements for the use of registered apprentices. The requirement is tightened each year.*
- Investment support for the value chain is allocated based on the application process and is given to projects according to specified application criteria. The total framework is USD 10 billion, but the scheme also covers equipment manufacturers for other low-carbon technologies.
- Production support for the value chain is available to all equipment manufacturers (i.e., not application-based). The support is provided up to and including 2032, but with a gradual reduction in subsidies by 25 percentage points annually starting from 2030.

Support to producers

Type of support	Support	Requirements
Investment support	6% of investment cost	
	30% of investment cost	Requirement for wages and use of apprentices
	Up to an additional 10 percent is given if respectively Requirement 1) and 2) are met. Can be combined	Requirement for 1) local content, 2) energy community
Production support	0.52 cents per kWh[1] produced over 10 years. Adjusted for inflation	
	2.6 cents per kWh[1] produced over 10 years. Adjusted for inflation	Requirement for wages and use of apprentices
	Up to an additional 10 percent is given if respectively requirement 1) and 2) are met. Can be combined to 20 percent	Requirement for 1) local content, 2) energy community

Support to the value chain

Type of support	Support	Requirements
Investment support	6% of investment cost	Application based.
	30% of investment cost	Application-based. Requirement for wages and use of apprentices
Production support	Tax deduction on the sales price for produced units/materials - varies between equipment. • Turbine blade - 2 cents x mill capacity • Turbine - 5 cents x mill capacity • Turbine tower - 3 cents x mill capacity • Foundation, fixed-bottom - 2 cents x mill capacity • Foundation, floating - 4 cents x mill capacity • Offshore wind vessel – 10% of sales price • Production must occur in the US	Production must happen in the US

[1] 2022 USD.

IRA «Clean hydrogen credits» support levels

Life cycle emissions(kg CO_2e/kg H_2)	Investment support (percentage of sum)	Production support (2022$/kg H_2)
4 – 2.5	6 percent	0.60
2.5 – 1.5	7.5 percent	0.75
1.5 – 0.45	10 percent	1.00
0.45 – 0	30 percent	3.00

TCTF

The Temporary Crisis and Transition Framework is not a subsidy scheme, but a temporary exemption that eases the state aid regulations applicable within the EU/EEA for green technologies. A list of the various technologies covered by the scheme is shown at the bottom right. The changes will apply until 31 December 2025. This framework gives rise to two changes:

Increased support intensity: The TCTF is increasing the support intensity that can be granted as state aid for green technology, beyond what would have been possible under the normal state aid regulations. The various levels of support intensity made possible under the TCTF are shown in the table at the top right.

Matching Aid: TCTF additionally offers the option to allocate what they term "matching aid" in special circumstances. This means that EU/EEA member countries can match the support offered by another country if there is a risk that industries will leave the EU/EEA. However, the level of support must not exceed the amount needed to encourage the company to locate the investment within the EU/EEA, or the so-called financing gap.

	Maximum amount (euro)			Maximum support		
	Non-support areas	c-regions	a-regions	Non-support areas	c-regions	a-regions
Large companies	150 million	250 million	350 million	15 %	20 %	35 %
Medium size companies	150 million	250 million	350 million	25 %	30 %	45 %
Small companies	150 million	250 million	350 million	35 %	40 %	55 %

Technology supported by TCTF

Renewable energy and energy carriers

- Renewable energy production
- Hydrogen
- Biogas and biomethane
- Energy storage
- Renewable heat

Production of green technology or equipment

- Electrolysers
- CCS
- Wind turbines
- Batteries
- Solar panels
- Heat pumps
- Components for production and recycling of critical raw materials.

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