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The Climate Partnership for the Financial Sector

Analysis of barriers to increased financing and investment in the green transition

Background report

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Analysis of barriers to increased financing and investment in the green transition

Disclaimer

This document is an English translation of the original Danish report "*Analyse af barrierer for øget finansiering og investeringer i den grønne omstilling*", completed in March 2025. As the report was prepared between mid-2024 and early 2025, some references to events, data, or projections may treat 2024 and 2025 as future or ongoing. The content has been translated to reflect the original analysis and context as it stood at the time of writing.

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Executive summary

This report, prepared on behalf of the Climate Partnership for the Financial Sector, aims to identify and analyse the primary barriers that inhibit private investment and financing in the green transition. By drawing on experience from a number of relevant projects (case studies), the report contributes with a mapping of both the concrete challenges for private actors and the mechanisms that can be used to overcome these. The report covers a wide range of green technologies, including offshore wind, solar, onshore wind, Power-to-X (PtX), Carbon Capture and Storage (CCS), pyrolysis, etc. in order to provide a broad understanding of the specific barriers and opportunities.

The ambitions are high, but their fulfilment requires massive investments

Denmark has adopted an ambitious climate target of a greenhouse gas reduction of 70% in 2030 (The Danish Parliament, 2020). In addition, the current government has set targets for climate neutrality in 2045 and a 110% reduction in 2050 (The Government of Denmark, 2022). Achieving these targets, however, requires significant investments in renewable energy (RE) and green infrastructure. The report points out that investments will be needed up to 2050, with DKK 500 billion to be made by 2030 and a total of DKK 1,400 billion by 2050. Offshore wind, which plays a central role in the future energy supply, accounts for nearly 45% of the total investment need.

The report also examines some of the mechanisms that can potentially be used to promote the development, financing and implementation of various climate-friendly energy technologies. These include regulation, economic incentives and public investment. Each mechanism has its own strengths and limitations, and a combination of these will therefore often be required to achieve the desired results.

A number of examples show both challenges and opportunities in green projects

Concrete examples of how mechanisms are applied are further illustrated through a series of case studies, covering projects across different geographies and technologies within the green transition. These are divided into three categories: *established technologies*, *new technologies,* and *infrastructure*. Established technologies such as offshore wind, onshore wind and solar PV are commercially available and market-ready, while new technologies, such as PtX and CCS, constantly face challenges with scale and financing. Infrastructure, e.g. electricity cables and hydrogen networks, also supports the green transition, but requires extensive investments and cooperation - often across national borders. The cases are used to illustrate how investment barriers have either been overcome or continue to pose a challenge. Many projects combine public support and private funding, which emphasizes the importance of cooperation between public and private actors. Particularly successful projects show that partnerships can reduce risks, secure sufficient capital and create a framework for robust implementation.

Based on insights from the case studies, the final chapter of the report highlights a series of regulatory and market barriers, as well as areas for action that can help seize some of the opportunities and address some of the barriers outlined in the report.

Several barriers stand in the way of increased private investment

The barriers that inhibit or delay private investment in green technologies are complex and often closely interlinked. A central obstacle is the technological uncertainty associated with several of the new green technologies, such as PtX and CCUS. Lack of scaling and documented success makes it difficult for investors to predict stable, long-term cash flows. A significant part of this uncertainty is due to the classic "chicken-and-egg" dilemma: producers of e.g. green fuels hesitate to invest in production facilities, as they lack long-term offtake agreements that can ensure a stable income. At the same time, potential offtakers, such as industrial companies or the transport sector, are reluctant to commit to purchasing these fuels until reliable and sufficient production capacity is in place. The lack of stable offtake agreements discourages many investors from making firm commitments to projects. Investors seek secure, long-term contracts to protect themselves against price volatility, while offtakers remain cautious, anticipating that prices will decline as technologies mature.

The business case for many green technologies, such as offshore wind, PtX and CCS, is further affected by the development of the necessary transport infrastructure, such as the electricity, hydrogen and CO_2 networks. Without clear and concrete plans for the infrastructure, such as grid connection or the establishment of a hydrogen pipeline between Denmark and Germany, significant uncertainty arises for producers, offtakers and investors alike. This uncertainty not only delays decision-making but can also directly hamper the commercial operation of several green projects.

The market for green technologies is characterized by high volatility, which makes it difficult to predict future costs and financial results for the projects. Increased raw material prices, driven by factors such as inflation and supply chain disruptions, have led to higher production costs. At the same time, Danish producers are experiencing significant competition from foreign players on the market, which puts further pressure on prices. This creates a challenging investment climate, where large capital commitments are necessary to realize the projects, and investors face considerable financial risk.

Effective regulation plays a decisive role in creating the right framework conditions for investments in green technologies. When the regulation is complex, unpredictable, or not adapted to the needs of green projects, it can hinder the necessary progress. Lengthy permitting and administrative procedures often extend RE projects' timelines and create uncertainty regarding both costs and feasibility. At the same time, unpredictable regulation – particularly around CO_2 pricing and sustainability requirements – makes it difficult for investors to plan and assess the risks of their investments. This combination of regulatory challenges can ultimately inhibit both the development and scaling of green solutions.

Common to all these barriers is the central challenge of insufficient government risk-sharing. Without a more active role from the state to ensure competitive market conditions in Denmark, including sharing the financial risks associated with RE expansion, private actors will struggle to take on the significant challenges that come with the scaling of green technologies.

Overall, these barriers create great uncertainty for private actors and require significant political efforts to create a more stable and predictable investment environment.

Three cross-cutting themes should guide climate policy action

To ensure that the barriers are overcome and the necessary investments realised, three specific themes have been identified as central to future climate policy initiatives:

- **Danish export and competitiveness must be maintained**: Denmark's green competitive advantage is an important driving force for exports. Technological advances in offshore wind, PtX, CCS and other renewable energy technologies place Denmark in a favourable position to deliver solutions that not only address national needs but also meet the rising global demand for sustainable energy solutions. A particular opportunity lies in strengthening the export of green hydrogen to our neighbouring countries, such as Germany, which is undergoing a significant transition in its energy-intensive industries.

  In order to maintain Denmark's competitive edge, it is crucial that the Danish market conditions remain competitive. Danish companies face increasing competition from other nations investing massively in similar technologies. If investments in offshore wind and other green technologies are more attractive elsewhere, Denmark risks losing market share to both European players and global players such as the USA and China.

- **Infrastructure is the backbone of the green transition:** Without a coordinated expansion of critical infrastructure such as electricity, hydrogen and CO_2 transport networks, we risk that investments in renewable energy sources and technologies lose their value. The report emphasizes that without a hydrogen infrastructure, the incentives for investments in offshore wind and PtX will be weakened. For example, effective tender models for offshore wind require a clear plan for how both electricity and hydrogen produced from renewable energy can be integrated into the Danish and European energy system.

- **Security of energy supply must be ensured both in Denmark and Europe:** War in Europe and instability in the energy markets have made security of supply a crucial priority. Here, Denmark plays an important role as both a producer and exporter of green energy. Denmark's capacity to develop and export green energy can contribute to strengthening security of supply throughout Europe. However, this requires a targeted effort to establish robust value chains, strengthen cooperation across national borders and ensure that Danish companies can compete on the global market.

These themes form the basis for a number of action areas, drawing on experiences from relevant case studies, input from market players as well as the mapping of barriers and support mechanisms. The focus areas should be seen as an indication of how the necessary frameworks can be created to enable an effective expansion of green technologies, and how the individual themes can be operationalized in practice.

Experiences from case studies and potential areas of action

- **Various forms of support ensure competitiveness in offshore wind tender models:** In order to attract investment and avoid a zero-bid situation as seen in the most recent offshore wind tender, future tenders must offer flexible and competitive terms. Experiences from Hornsea 2 in the UK and IJmuiden Ver Alpha and Beta in the Netherlands show that different tender structures, where the state assumes a greater share of the risk (e.g. either through CfD or by supporting the establishment of electricity transmission infrastructure) can be successful.
- **System integration as an award criterion in offshore wind tenders can increase the profitability of PtX:** Inclusion of system integration as an award criterion can optimize the use of renewable energy and remove some of the uncertainty in PtX projects. Examples such as the IJmuiden Ver Beta offshore wind tender illustrate how combined development of offshore wind, solar, and PtX can be effectively promoted.
- **A more proactive government role in establishing transport infrastructure can reduce risks for private actors and encourage investment:** Especially in connection with the development of hydrogen infrastructure, inspiration could be drawn from the German financing model, where state guarantees reduce financing risks and support private investments by covering potential deficits.
- **State aid can contribute to accelerating PtX development:** Financial support is necessary to overcome the risks associated with PtX technologies, which currently face high market risk. Stable and predictable support for first movers can promote private investment and help scale PtX technologies. Examples such as European Energy’s Kassø project show how long-term support can reduce risks and strengthen project profitability by securing long-term offtake agreements.
- **EIFO already plays an important role in financing Danish solutions and its green efforts can be further strengthened:** Experience from projects such as Golden Plains Phase 2 shows how EIFO can reduce risks and support investments in Danish renewable energy solutions. EIFO could increase support for high-risk investments in renewables to attract private capital and promote the development of new technologies. Specifically, increased reinsurance capacity may be one way to achieve this.

Additional experiences and areas of action

- **Several developers are ready to take greater ownership in the development and establishment of renewable energy projects:** The government can let developers play a more leading role in RE expansion by giving them greater freedom to design and adapt projects based on market needs and technological possibilities.

- **Lengthy and complex permitting processes delay renewable energy projects and requires simplification:** There are long processing times and numerous permits required for green projects such as onshore wind turbines, hydrogen networks and PtX facilities. At the same time, CCS actors often find themselves and the authorities facing repeated processes as well as new challenges. Greater efficiency in administrative procedures is necessary to reduce delays and uncertainty. Examples include the implementation of NEKST's recommendations, such as the creation of a dedicated taskforce (in Danish “rejsehold”) to support permitting procedures for renewable energy projects.
- **Implementation of EU rules can strengthen demand for and financing of PtX fuels:** Denmark should implement the EU's Renewable Energy Directive as soon as possible in order to reduce regulatory uncertainty and promote investment in sustainable fuels.
- **Limited grid connection models can accelerate the development of green energy projects:** Developing models for limited grid connection can reduce delays and costs for renewable energy projects, thereby facilitating investments and promoting the green transition.
- **Simplifying land registration for the electricity grid can ease financing of grid expansion:** Simplifying the land registration process for small transformer stations can reduce complexity, including financing costs for electricity grid extensions, and ease access to capital.
- **A balanced tax structure can promote the use of green energy in Denmark:** Denmark could consider reducing consumption taxes on green energy to ensure local use and national CO_2 savings.
- **Revised tariffs for batteries can support energy storage and promote grid stability:** Batteries, which can enable power storage and reduce grid strain, could be exempted from tariffs.

The report shows that close cooperation between public and private actors is crucial to overcoming barriers and ensuring a successful green transition. By implementing the identified mechanisms and strengthening efforts in areas such as regulation, economic incentives and public investment, Denmark can move closer to achieving its ambitious climate targets. Central to this process, however, is a clear and balanced risk-sharing between the state and private actors, where both parties share responsibility for promoting green technologies in Denmark and globally.

Abbreviations

Abbreviations	
AF	Analysis assumptions (Danish: *Analyseforudsætninger*)
B-HJT	Bifacial heterojunction technology
CAPEX	Capital expenditure
CfD	Contract for Difference
CCfD	Carbon Contracts for Difference
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture, Utilization and Storage
CEF	Connecting Europe Facility
CO_2	Carbon dioxide
CO_2e	CO_2 equivalents
CPI	Consumer Price Index
DAC	Direct Air Capture
DGIF	Denmark's Green Investment Fund
DOE	US Department of Energy
EHB	European Hydrogen Backbone
EIB	The European Investment Bank
EIFO	Denmark's Export and Investment Fund
EUDP	Energy Technology Development and Demonstration Programme
EU ETS	EU Emissions Trading System
FiP	Feed-in premium
FiT	Feed-in tariff
GBP	Great Britain Pounds
GO	Guarantees of Origin
GW	Gigawatt
GWh	Gigawatt-hour
H_2	Hydrogen
HVDC	High-Voltage Direct Current
IPCEI	Important Projects of Common European Interest
IRA	Inflation Reduction Act
IRBC	International Responsible Business Conduct

kW	Kilowatt
kWh	Kilowatt-hour
LCCC	Low Carbon Contracts Company
MW	Megawatt
MWh	Megawatt-hour
NMVOC	Non-methane volatile organic compounds
NO_X	Nitrogen oxides
OPP	Public-private partnership (Danish: *Offentligt-privat partnerskab*)
PCI	Projects of Common Interest
PM2.5	Particles smaller than 2.5 µm
PNRR	Italy's national recovery plan
PPA	Power Purchase Agreement
PtX	Power-to-X
RE	Renewable energy
RED	Renewable energy directive
RFNBO	Renewable Fuels of Non-Biological Origin (typically PtX/e-fuels)
SAF	Sustainable aviation fuel
SO_2	Sulphur dioxide
SO_X	Sulphur oxides
SDE++	Dutch support scheme for energy projects (Dutch: *Stimulering Duurzame Energietransitie*)
SOEC	Solid Oxide Electrolyser Cells
TSO	Transmission system operator
TWh	Terawatt-hour
VOC	Volatile organic compounds
PV	Photovoltaic

1 Introduction

1.1 Purpose of the project

The Climate Partnership for the Financial Sector has asked COWI to carry out an analysis of the most significant barriers to private investment in the green transition. The project aims to identify and evaluate the challenges and propose solutions that can create a better framework for private actors to contribute to Denmark's climate objectives.

The analysis focuses on:

- Identification of barriers: A mapping of the factors that limit private investment in green projects, including technical, regulatory and market conditions.
- Investment opportunities: Identification of mechanisms and incentives that can promote private investment, including new financing models, public-private partnerships, and support schemes.
- Case studies and examples: Inclusion of concrete examples from Denmark and abroad that illustrate how similar barriers have been handled in practice.

The purpose of the project is to create an in-depth understanding of how the financial sector can play a central role in the green transition. The results are intended to inform the Climate Partnership’s work in developing proposals to advance the green transition, and thereby potentially support politically strategic decision-making.

1.2 Purpose of the document

This document presents the analyses and calculations carried out during the implementation of the project. It results in a series of action areas that can support the green transition by removing some of the barriers currently preventing investors and financing partners from engaging more actively. The report contains the underlying calculations for the estimated investment needs in green technologies, an in-depth description of the various mechanisms that can promote the production and uptake of green technologies, as well as a detailed analysis of selected case studies illustrating the effect of various mechanisms and barriers.

The purpose is to provide a solid and in-depth professional base, which supports the overall conclusions and areas of action, which this project leads to.

The report is structured as follows:

- Chapter 1 contains an overview of Denmark's political goals in relation to the green transition.
- Chapter 2 maps the overall investment needs to reach Denmark's climate targets. This includes both the expansion of renewable energy and investments in new and established green technologies.
- Chapter 3 focuses on the mechanisms that can promote the production and uptake of green technologies. Here, regulation, economic incentives as well as public investment and procurement are analysed as key drivers.
- Chapter 4 describes offshore wind tender models.
- Chapter 5 presents selected case studies, which showcase experiences and solutions related to both established and new technologies, as well as infrastructure projects. These cases offer practical examples of barriers and opportunities for private investment in green projects.
- Chapter 6 points to a number of regulatory and market barriers, as well as areas of action, which can contribute to exploiting some of the opportunities and countering some of the barriers outlined in the report.

1.3 Denmark's ambitions within the green transition

Denmark has several declared goals in connection with the expansion of renewable energy (RE). The Climate Act states that Denmark must achieve a 70% reduction in greenhouse gas emissions by 2030, while the current government’s platform states that Denmark must be climate neutral by 2045. In addition, Denmark has entered into a number of international agreements to expand wind production capacity by 35 GW in the North Sea (the Esbjerg Declaration) and 6 GW in the Baltic Sea (the Marienborg Declaration). An overview of Denmark's agreements and targets in relation to climate and expansion of renewable energy can be found in Table 1-1 below.

Table 1-1 Denmark's agreements and targets for climate and renewable energy

Objective	Year	Source	Date
70% greenhouse gas reduction compared to 1990	2030	Climate Act (The Danish Parliament, 2020)	June 26, 2020
Climate neutrality	2045	Government Platform (*Regeringsgrundlag*) 2022 (The Government of Denmark, 2022)	December 2022
110% greenhouse gas reduction compared to 1990	2050	Government Platform 2022	December 2022
PtX target of 4-6 GW electrolysis capacity	2030	Agreement on green hydrogen and green fuels (The Danish Government, 2022)	March 15, 2022
Make it possible to quadruple electricity production on land	2030	Climate agreement on green electricity and heating (The Danish Government, 2022)	June 25, 2022
Expansion with 9 GW offshore wind with the possibility of overplanting	2030	Supplementary agreement on tender frameworks for 6 GW offshore wind and Bornholm Energy Island (The Danish Government, 2023)	May 30, 2023
Utilization of 6.3 GW offshore wind in the Danish part of the Baltic Sea	2030	The Marienborg Declaration (The Danish Government, 2022)	August 30, 2022
Utilization of 35 GW offshore wind in the North Sea	2050	The Esbjerg Declaration (The Danish Government, 2022)	May 18, 2022
100% supply of green gas	2030	Climate agreement on green electricity and heating	June 25, 2022
Phasing out of gas for heating in households	2035	Climate agreement on green electricity and heating	June 25, 2022

In addition to the climate and decarbonisation goals, which drive Denmark's green transition, there are also several other factors playing a significant role in the European agenda and which are of great importance for shaping green transition policy. Two of the most prominent areas, which are fully central to energy policy, are European competitiveness and energy security.

European competitiveness

In light of the green transition and the rapid development of renewable energy, Europe is facing challenges in securing its economic competitiveness on a global level. The so-called Draghi report (Draghi, 2024), presented by the former president of the European Central Bank Mario Draghi, points to the importance of preserving Europe's leading position in green technology and innovation while ensuring continued economic growth.

An important factor in this context is how the EU's green policies affect European companies' costs, especially in relation to the strict climate and emissions requirements, which may lead to increased production costs. In order to maintain competitiveness on a global level, the EU has previously introduced initiatives such as the European Green Deal, which also supports innovation and new markets within sustainable technology. In this way, Europe is attempting to strike a balance between achieving its ambitious climate goals and ensuring that European companies remain competitive in the global marketplace.

For Denmark, this means that Danish companies must navigate a global market in which competition from other countries is intensifying. To ensure that Danish companies remain competitive, it is therefore crucial to maintain stable and predictable framework conditions that support investments in the green transition.

Energy security in light of the war in Ukraine

At the same time, energy security has become an increasingly urgent topic in European politics, especially after Russia's invasion of Ukraine in 2022. The war has highlighted the vulnerabilities that Europe's energy supply faces, especially in relation to the dependence on Russian gas and oil. As a result, the EU has adopted a number of strategies to reduce dependence on fossil fuels from Russia and increase security of supply. This includes the acceleration of energy transition towards renewable energy sources such as wind, solar, and biomass, as well as strengthening connections between EU countries and building energy storage capacity.

For Denmark, this means that the green transition is not only about reaching the climate goals but also about ensuring a robust and independent energy supply in an increasingly uncertain geopolitical context. Energy policy and security are therefore closely connected with the decarbonisation objectives, and Denmark plays an important role in the EU's efforts to promote both greener and more secure energy solutions.

2 Investment needs to achieve climate targets

In order for Denmark to meet its ambitious climate targets, a significant expansion of renewable energy sources is required. This chapter describes the necessary scope of expansion across technologies such as offshore wind, onshore wind, solar PV and Power-to-X (PtX), as projected by the Danish Energy Agency's 2024 Analysis Assumptions for Energinet (Analyseforudsætninger - AF24).

Based on the Danish Energy Agency's projections, the necessary investments towards 2050 are calculated. This includes the expansion of the electricity transmission and distribution network, the hydrogen network, and other critical components of the green transition. As the results show, the expansion of offshore wind constitutes a significant part of the expected costs, as this energy source in particular is expected to meet the increased energy demand in Energinet's latest projection.

2.1 Need for expansion of renewable energy

Every year, the Danish Energy Agency publishes a projection of RE capacities, based on the Danish agreements and targets currently in place. The present overview is presented in Table 1-1 in the previous chapter. These projections can be found in the 2024 Analysis assumptions for Energinet. The latest version was published in October 2024 and is therefore referred to as AF24 (The Danish Energy Agency, 2024). AF24 is based on energy system modelling and outlines the required expansion of various technologies and sectors, assuming that the political targets are met, even though the specific policy measures to achieve them may not yet be in place.

In this analysis, the need for expansion of renewable energy is primarily based on AF24, but is supplemented by other sources, as shown in Table 2-1.

Table 2-1 Sources of need for expansion of renewable energy

Development of technology	Source	Author	Year
Offshore wind	AF24	The Danish Energy Agency	2024
Onshore wind	AF24	The Danish Energy Agency	2024
Solar PV	AF24	The Danish Energy Agency	2024
PtX	AF24	The Danish Energy Agency	2024
Hydrogen network	Economic framework conditions for hydrogen infrastructure. Second sub-agreement on pipeline hydrogen infrastructure.	The Danish government	2024
Biogas	AF24	The Danish Energy Agency	2024
Batteries	AF24	The Danish Energy Agency	2024

CCUS	AF24	The Danish Energy Agency	2024
Electricity transmission	The Danish power system towards 2040 and 2050	Ramboll (Rambøll, 2023)	2023
Electricity distribution	Electricity grid for much more	Green Power Denmark (Green Power Denmark, 2023)	2023
Charging infrastructure	Employment effects of the investments in the green transition	Danish Energy (Dansk Energi, 2020)	2020
District heating network, heating and energy efficiency improvements	Employment effects of investments in the green transition of industry 2023-2035	COWI (COWI, 2023)	2023

The need for expansion of the electricity transmission grid towards 2040 is based on an analysis prepared by Rambøll (Rambøll, 2023). The annual investments in the transmission grid are distributed on the basis of the expansion of wind and solar energy from AF24. Potential additional investments in the grid after 2040 have not been taken into account.

The need for expansion of the electricity distribution grid is based on an analysis made by Green Power Denmark (Green Power Denmark, 2023), with the assumption that the investments are distributed evenly over the period.

The need for charging infrastructure is based on an analysis also prepared by Dansk Energi (now Green Power Denmark) from 2020. Corrections have been made for the investments that were assumed to take place in the years 2021-2024.

The need for investments in the hydrogen network, amounting to DKK 15 billion, is based on an agreement entered into by the Danish Government and a number of other parties in the Danish Parliament (The Danish Government, 2024). The annual investments in the hydrogen network are assumed to follow the development in PtX capacity.

There are also declared targets to establish energy islands in the North Sea and the Baltic Sea. Due to uncertainties surrounding their future, the costs for establishing the islands themselves are not included, while the renewable energy expansion in connection with the energy islands is included.

Figure 2-1shows the expected development in electricity consumption if Denmark's targets for renewable energy expansion are met.

At the time of writing, it appears unrealistic that the Danish targets will be achieved – among other reasons due to the failed Danish offshore wind tender, but also because of delays to the hydrogen network as well as the declining interest in PtX that can be observed in the market, where companies such as Ørsted are withdrawing from large-scale projects. At the same time, there is a very long lead time for building offshore wind farms, which can further delay the achievement of the Danish targets.

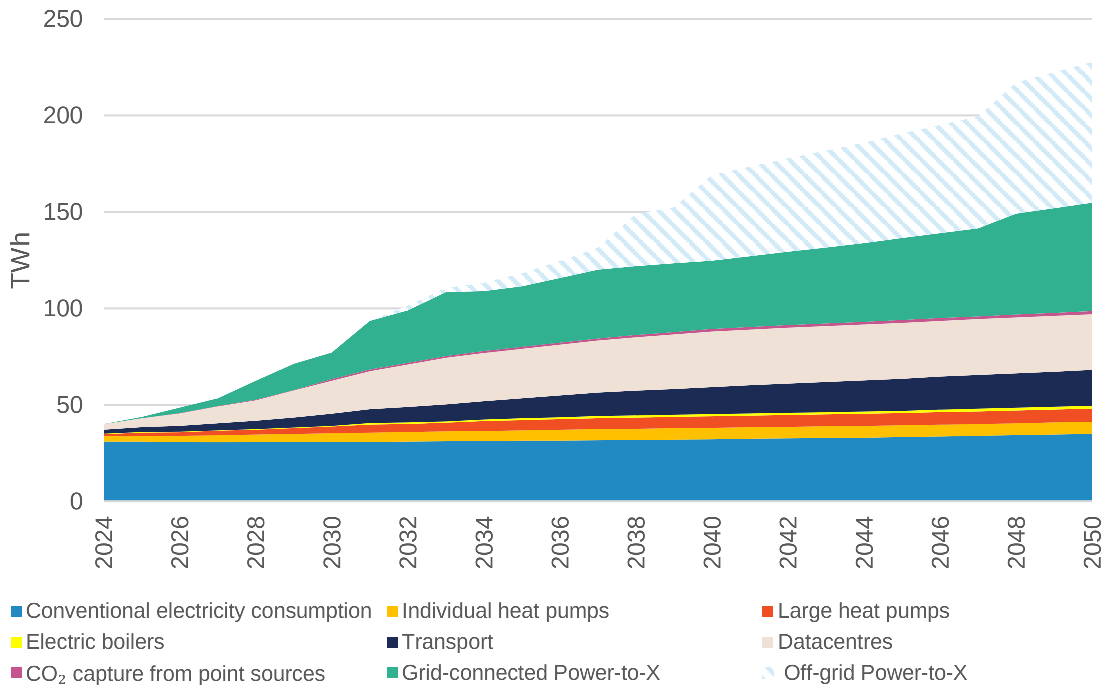

Figure 2-1 Projection of the expected development in electricity consumption in Denmark, in the event of the achievement of renewable energy targets.

Electricity consumption is expected to increase fivefold, from 40 TWh in 2024 to nearly 200 MWh in 2050, which is mainly due to the expected expansion of hydrogen production and PtX, which will rise from 0 TWh in 2024 to almost 100 TWh in 2050, while data centres, the transport sector and heat pumps also contribute significantly to the increase. Traditional electricity consumption[1] is expected to remain roughly unchanged.

In order to meet the increased electricity demand, the RE production capacities are expanded as shown in Figure 2-2.

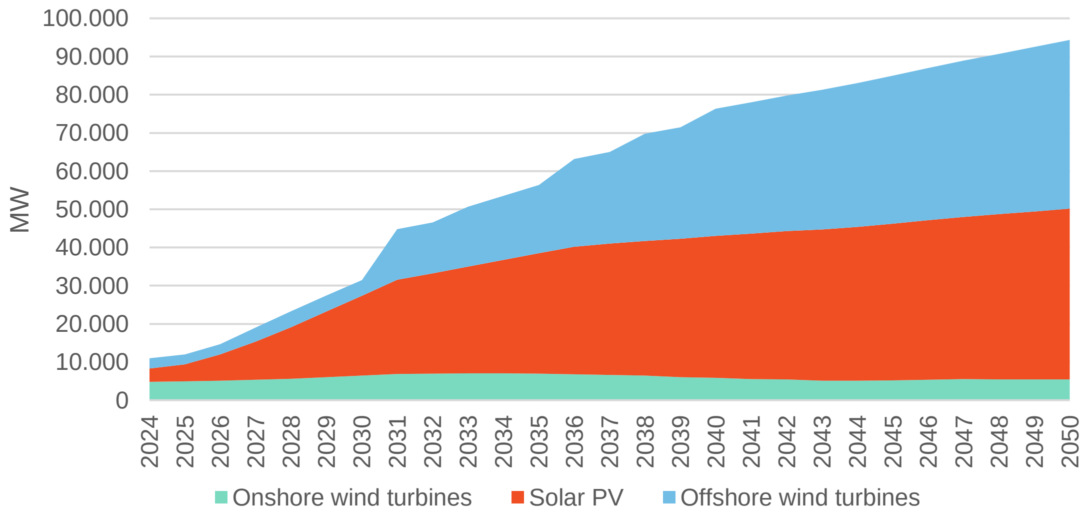

Figure 2-2 Expected expansion of energy production capacity from RE sources. Based on the AF24.

Figure 2-2 shows that the capacity for onshore wind turbines is expected to remain relatively stable, while a significant increase in production capacity is expected for solar PV and offshore

[1]The traditional electricity consumption covers the historical consumption pattern of electricity, typically for households and lighter industrial processes.

wind turbines, rising to 45 GW and 44 GW respectively by 2050. For solar energy, it should be noted that there is greater and greater local resistance to solar PV projects, growing regulatory requirements and higher grid connection costs. This has reduced investor appetite for large-scale solar PV projects, leading to delays and cancellations of several new Danish solar PV projects from developers' pipeline, which makes it unrealistic that the expansion for solar PV shown in Figure 2-2 can actually be realised.

Moreover, the figure above does not account for the actual amount of electricity expected to be produced from the various renewable sources but rather, shows the maximum production capacity. The expected actual production is shown in Figure 2-3. From this, it appears that production from onshore wind is expected to rise by 60%. This is because new onshore wind turbines are better at producing electricity at low wind speeds than current types. Figure 2-3 also illustrates that offshore wind turbines are expected to account for a significantly larger share of the overall energy production, even though the maximum production capacity is the same as for solar PV. This is because offshore wind turbines have a higher utilisation rate than solar panels - they can, for example, also produce at night.

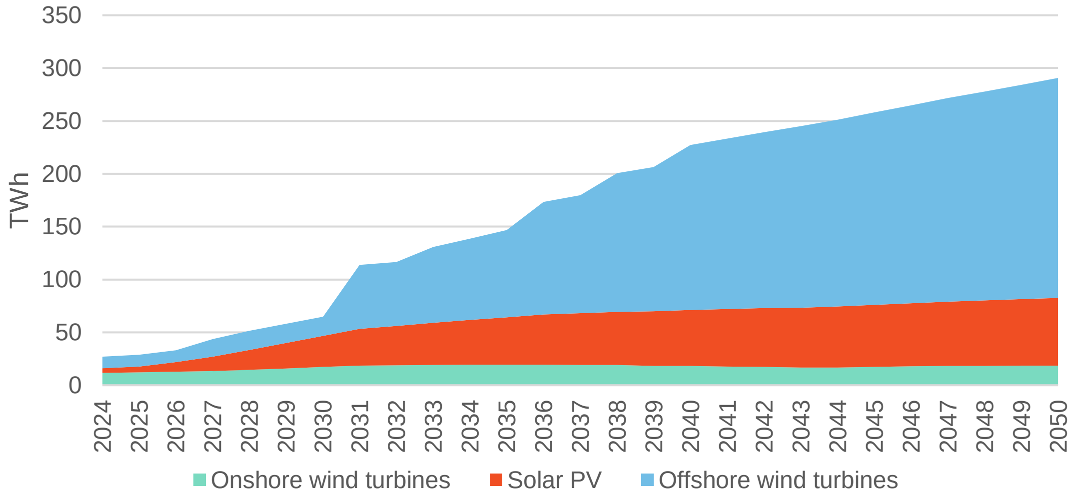

Figure 2-3 Energy production from solar PV and wind turbines.

Electricity production from offshore wind turbines is therefore expected to rise from 11 TWh in 2024 to 208 TWh in 2050, while electricity production from solar PV is expected to rise from 4 TWh to 64 TWh in the same period. The average Dane consumes approximately 1,600 kWh of electricity per year. Consequently, the production from offshore wind and solar PV could cover the electricity consumption of around 130 million and 40 million Danes, respectively.

Production from onshore wind turbines is expected to increase from 12 TWh to 19 TWh by 2050. However, it should be noted that with the ongoing electrification of society, electricity will increasingly be used for heating, transport, Power-to-X, industry, and data centres. In 2023, the total Danish energy consumption across all sectors (electricity, heating, transport, industry, households etc.) was 160 TWh. Thus, the Danish targets for a combined 298 TWh of renewable electricity production through offshore wind, onshore wind and solar PV correspond to almost double Denmark's total energy consumption. The surplus electricity that is not consumed domestically will therefore be exported abroad, e.g. in the form of pure electricity or as hydrogen, e-methanol, e-ammonia, e-jet fuel or other PtX products.

Figure 2-4 shows how grid-connected electricity production is expected to develop towards 2050. It is evident that the capacities for offshore wind, onshore wind and solar PV will be expanded, while electricity production from other energy sources will decrease. It is worth noting that there is some electricity production that is not shown in this figure, as a large share of the electricity production is not expected to be connected to the grid. This particularly applies to production capacity established for PtX purposes, as shown in Figure 2-1.

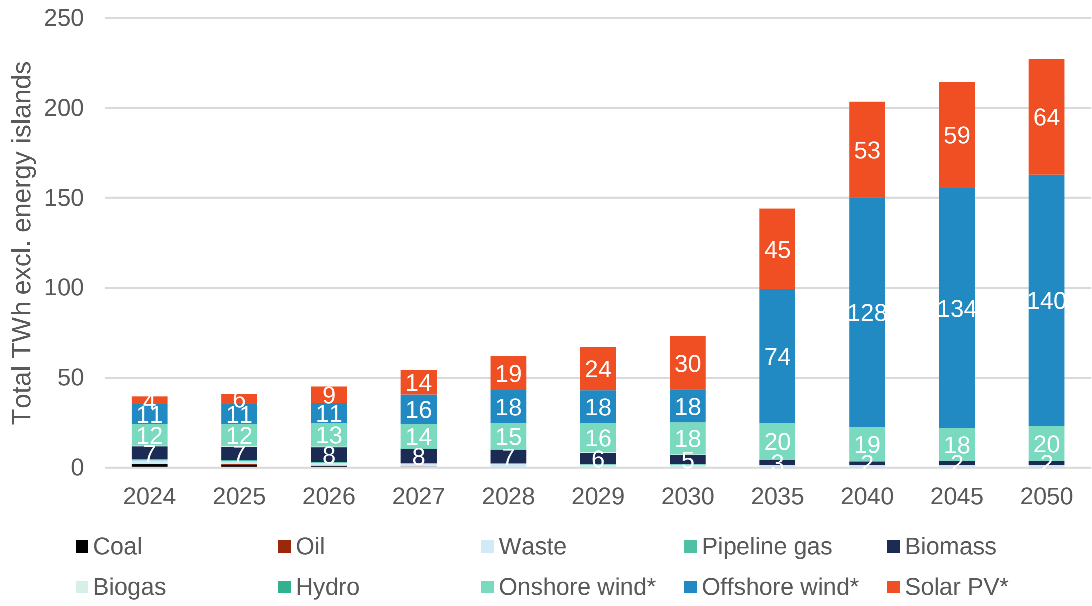

Figure 2-4 Total grid-connected electricity production from various sources, excl. energy islands. Offshore wind, onshore wind and solar PV are calculated according to potential production, i.e. excluding curtailment.

Figure 2-5 illustrates the expected transition in district heating production. Here, a significant electrification of district heating is anticipated, where heat pumps, supplemented by electric boilers, will largely replace fossil fuels such as natural gas, coal and oil, just as production from biomass is expected to decrease substantially.

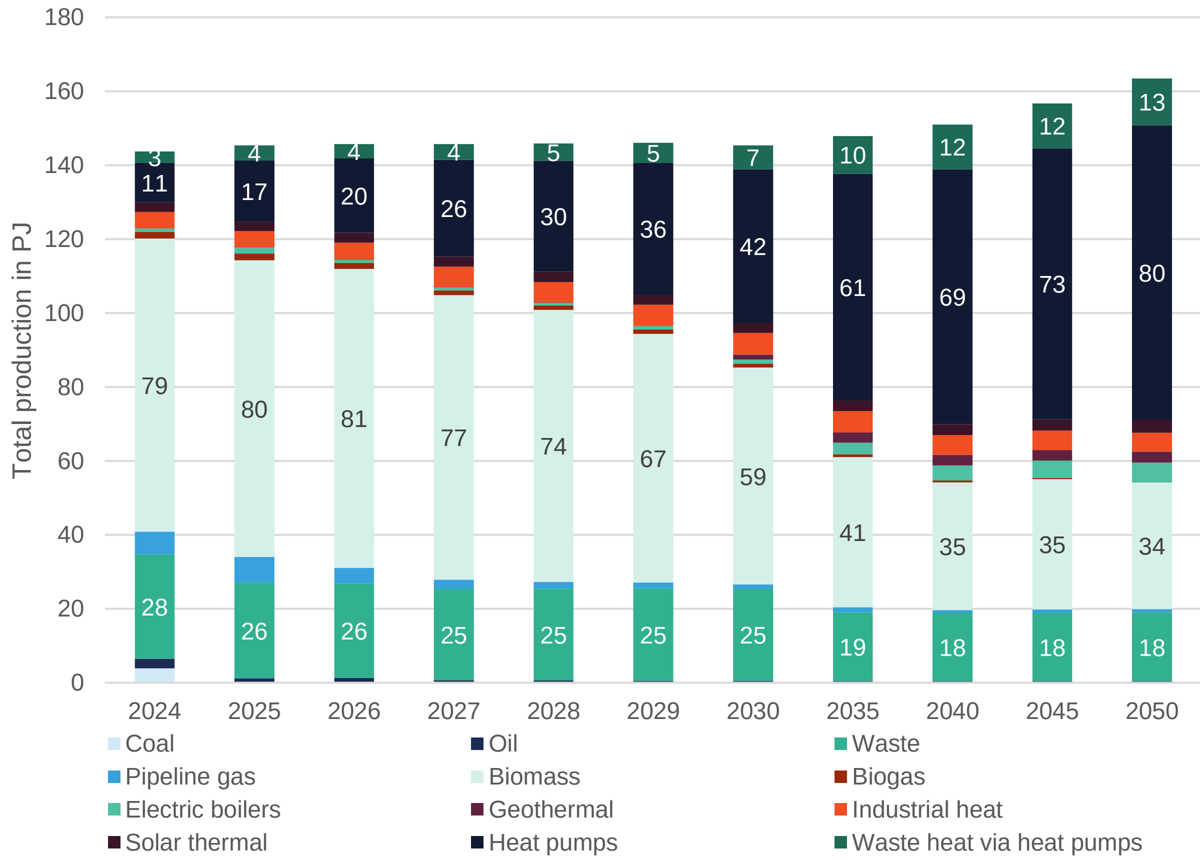

Figure 2-5 Expected transition of district heating production.

Figure 2-6 provides a more detailed view of the expected expansion of offshore wind capacity. It shows that a number of offshore wind turbine projects are already in the pipeline up to and including 2030, either as a result of political agreements or under the former "open door" scheme. The figure also indicates the amount of offshore wind capacity expected in connection with the establishment of the energy islands.

The element labelled 'Additional expansion' represents the expected further build-out based on the 2022 *Climate Agreement on green electricity and heating* (The Danish Government, 2022). Figure 2-6 also shows the proportion of offshore wind production that will be connected to the Danish electricity grid.

Offshore wind turbines can, for example, engage in "overplanting"[2], which means that they may not be able to allocate their full capacity at maximum production, or the grid connection may be to another country even though the offshore wind turbines are located in Danish waters. Various offshore wind turbine projects directly connected to PtX production may also opt not to have a grid connection, for example, to avoid tariffs and fees.

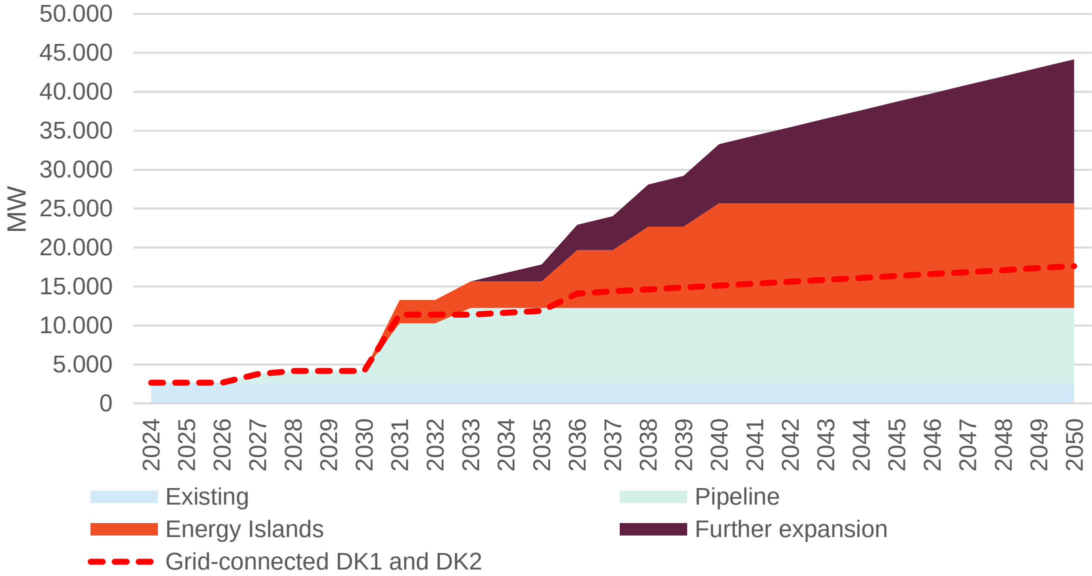

Figure 2-6 Offshore wind capacity divided between existing wind turbines, projects in the pipeline, capacity in connection with energy islands and further expansion to fulfil political agreements. The figure also shows what proportion of the capacity is connected to the two Danish bidding zones, DK1 and DK2.

Figure 2-7 shows the expected expansion of onshore wind capacity. By 2050, the majority of the existing onshore wind turbines will be replaced by new ones. In addition, the capacity of onshore wind at test centres is expected to rise. Overall, onshore wind capacity will rise until around 2035, after which it will decline again. The capacity in 2050 is thus expected to be the same as in 2024. Despite this, electricity production from onshore wind turbines will increase due to rising capacity factors for the wind turbines. This is because new turbine types can produce more electricity at lower wind speeds than the existing types.

[2]Overplanting in an offshore wind farm means that installing more turbines than the grid connection to land can handle. This ensures a higher utilization of the grid capacity, as in periods of lower wind production, production can be closer to maximum. When the wind is strong, not all the electricity can be sent to land, and some production is curtailed. The goal is to achieve more stable and efficient electricity production without necessarily expanding the grid capacity.

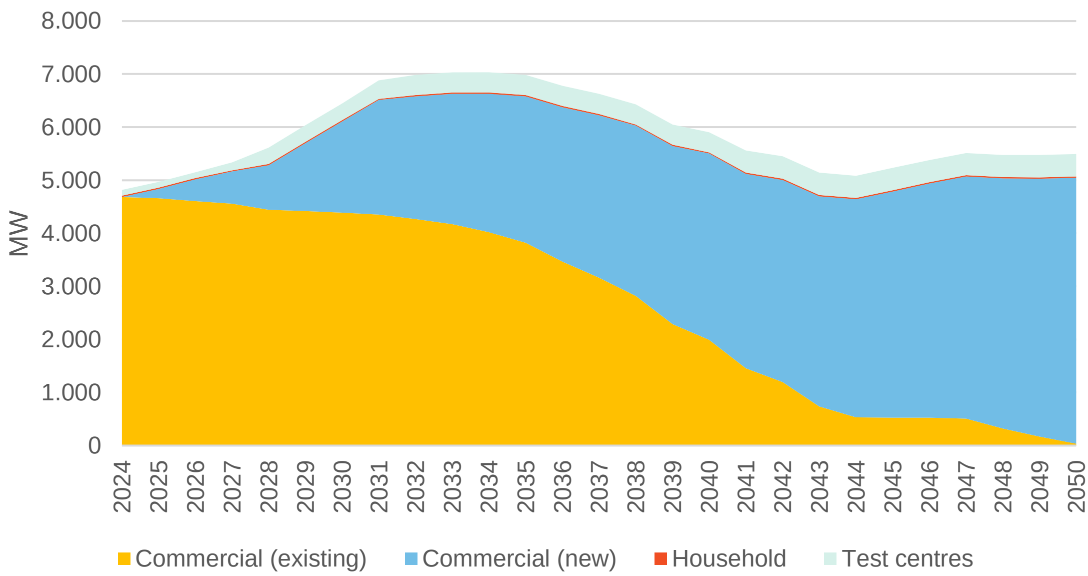

Figure 2-7 Expected expansion of onshore wind capacity.

Figure 2-8 shows the expected expansion of solar PV capacity towards 2050. The development is mainly driven by ground-mounted systems, with fixed solar panels making up the largest share. The expansion of ground-mounted systems with solar trackers and rooftop installations is also significant.

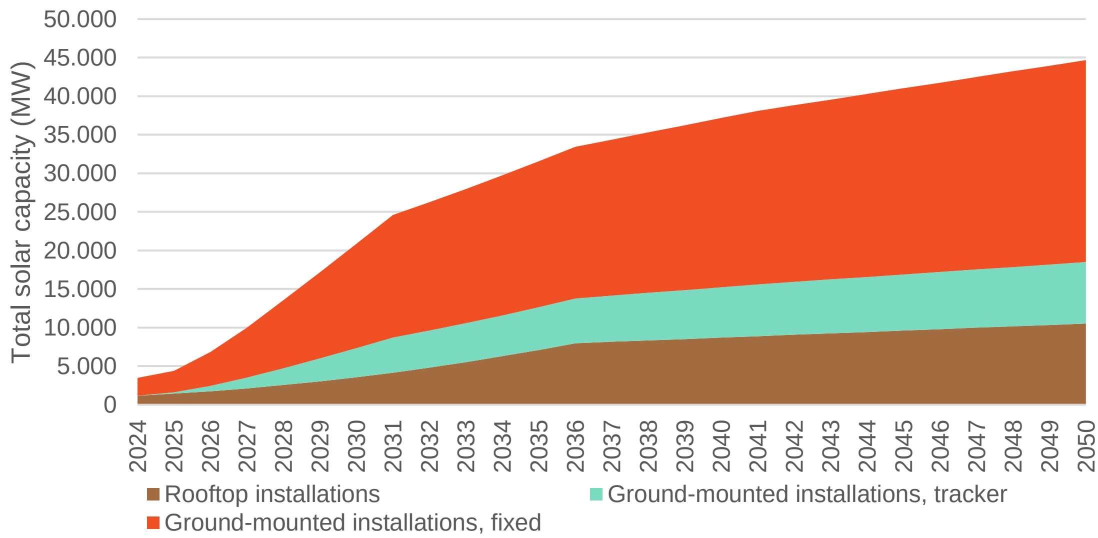

Figure 2-8 Expected expansion of solar PV capacity.

Figure 2-9 shows the expected increase in electrolysis capacity needed to meet Denmark's declared climate and renewable energy targets. The projection is divided into capacity already in the pipeline, capacity in connection with the energy islands, capacity related to the overplanting of radial offshore wind (the excess offshore wind capacity where the grid connection is not strong enough to deliver to the electricity grid, but which is instead allocated to PtX), as well as additional expansions needed to reach Denmark's targets. The figure also shows the capacity connected to the grid in Denmark. A number of PtX plants are expected not to have a grid connection, but instead to produce on the basis of direct connections to solar and wind installations, i.e. bypassing the collective electricity grid.

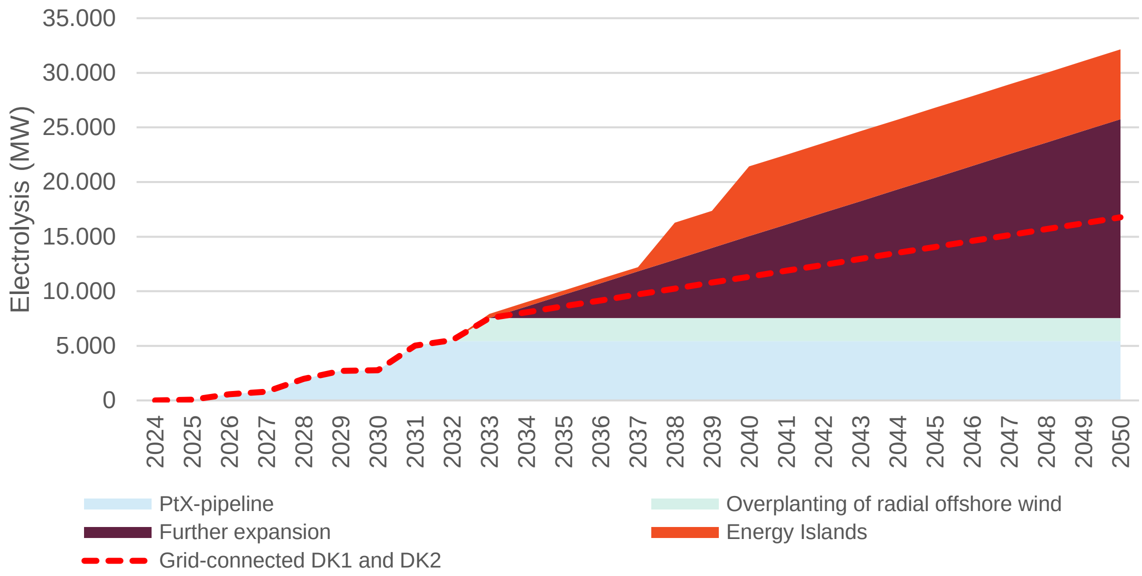

Figure 2-9 Expected expansion of input capacity for electrolysis.

Figure 2-10 shows the expected expansion of grid-connected batteries, which contribute to the storage of renewable energy and stabilization of the electricity grid. The capacity is expected to be expanded from 250 MWh in 2024 to 1,300 MWh in 2050.

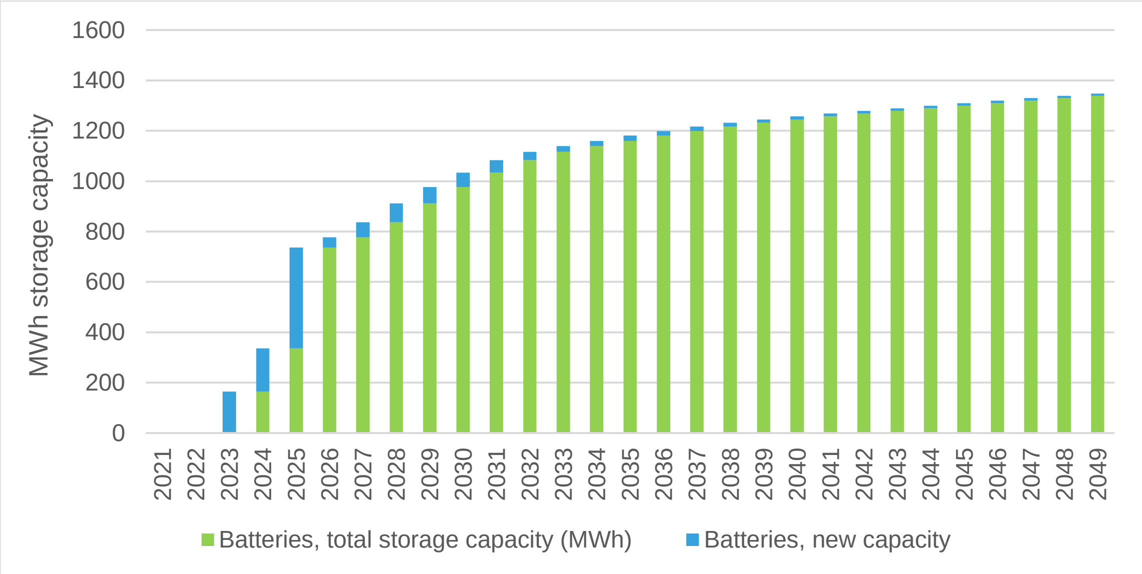

Figure 2-10 Expansion of storage capacity of grid-connected batteries.

Figure 2-11 shows the expected expansion of CO_2 capture capacity calculated in million tonnes of CO_2 captured annually. This includes both CO_2 capture for permanent storage (CCS) and CO_2 capture used in connection with PtX (CCU). It is assumed that the capacity for permanent storage and for transport of CO_2 via pipeline follows the capacity for CO_2 capture.

In particular, a major expansion is expected in 2026 and 2029. The expansion in 2026 is related to the CCUS tender, where Ørsted received support for CO_2 capture at the Avedøre and Kalundborg plants, which are large biomass combined heat and power plants, from which 430,000 tonnes of CO_2 per year are expected to be captured from 2026 and shipped from Kalundborg. The expansion in 2029 is due to the CCS tender, which opened for applications in October 2024. The projects that receive support in this tender are expected to capture CO_2 starting from 2029.

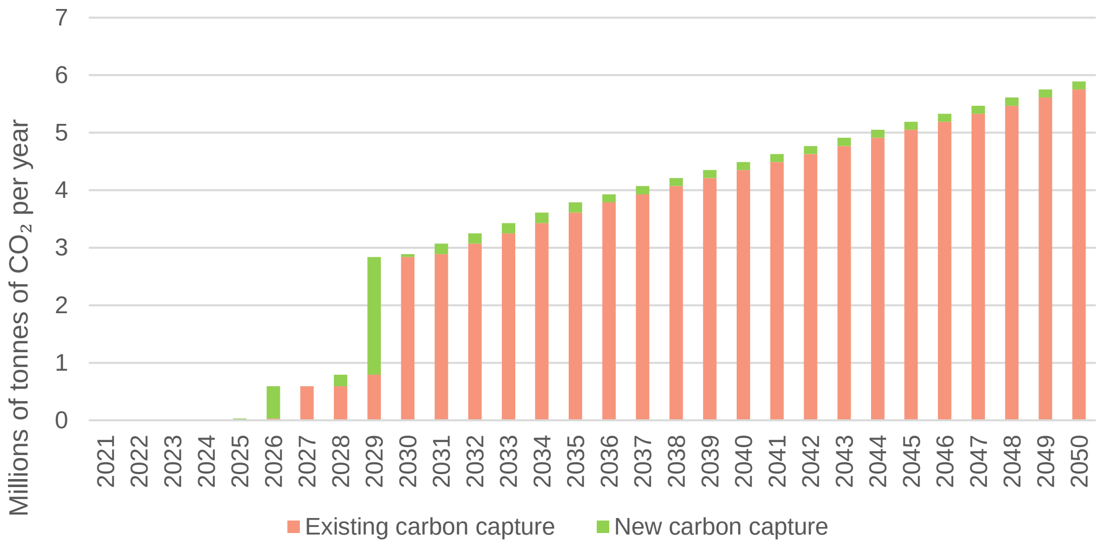

Figure 2-11 Expansion of carbon capture capacity.

2.2 Investment needs in green technologies

There is a significant need for expansion of renewable energy and CO_2 capture. Solely towards 2030, there is an investment need of DKK 500 billion if Denmark is to fulfil its climate ambitions, while the need towards 2035 and 2050 is respectively DKK 900 billion and DKK 1,400 billion.

It is especially within offshore wind that massive investments are necessary. Already within the next five years, nearly DKK 200 billion should be invested in this technology. In general, offshore wind accounts for just under half of the overall investment need. The required expansion of offshore wind arises from three specific agreements that Denmark has entered into:

- Utilization of 6.3 GW offshore wind in the Danish part of the Baltic Sea, in connection with the Marienborg Declaration (The Danish Government, 2022).
- Expansion of 9 GW offshore wind from 2030, in connection with supplementary agreement on tender frameworks for 6 GW offshore wind and Bornholm energy island[3] (The Danish Government, 2023)
- Utilization of 35 GW offshore wind in the North Sea, in connection with the Esbjerg Declaration (The Danish Government, 2022).

In addition to these specific agreements on offshore wind, there is a further need for expansion of onshore wind, solar PV, PtX and the electricity grid in particular in order to achieve the government's targets of climate neutrality by 2045 and 110% reduction of greenhouse gases by 2050. Climate neutrality will require a massive electrification of society, especially within industry, transport, and district heating. The energy for this electrification will largely come from offshore wind, but also from solar PV and onshore wind, while PtX will convert the electricity into chemicals and fuels such as e.g. hydrogen, ammonia, methanol and aviation fuels, which will contribute to indirectly electrifying sectors where the electricity cannot be used directly, such as agriculture, heavy industry as well as shipping and aviation.

In 2023, COWI conducted a similar analysis, which also estimated the investment need in relation to the green transition (COWI, 2023). The investment need was estimated at DKK 800 billion in the years 2023 to 2035. This figure has now risen to DKK 900 billion. The increase is primarily due to a higher general price level in society, but also because the need for investments has been revised upwards for solar PV and for the transport and storage of captured CO_2 . The costs, which are presented in this analysis, are in fixed 2024 kroner (DKK), whereas the 2023 analysis used fixed 2022 kroner. Since 2022, the net price index has risen by 6.2%. Thus, approximately half of the price increase, corresponding to around DKK 50 billion from the COWI 2023 analysis to now, can be attributed to price increases in society.

Both COWI analyses are based on the technology catalogues from the Danish Energy Agency, in which there have been no changes in the cost of constructing offshore wind turbines, measured in fixed 2022 kroner. In actual markets, however, it has been clear that offshore wind has become significantly more expensive to build in recent years. An analysis prepared by which PwC for the Partnership for Offshore Wind in 2024 shows that over two years, the cost of constructing one gigawatt offshore wind has increased by 5.2 billion DKK, so that it cost DKK 22.4 billion in 2023, compared to DKK 17.2 billion in 2021 (PwC, 2024). By comparison, the COWI analyses, based on the technology catalogues from the Danish Energy Agency, show that constructing one gigawatt offshore wind costs DKK 16.5 billion in 2024.

Offshore wind has become more expensive to build because the prices for materials and components have risen significantly, especially steel (which according to PwC rose by around 180% from 2020 to 2021) and magnets (which rose by around 25% in the same period). Although some prices have subsequently fallen slightly, they remain at a higher level than before. At the same time, general inflation in Denmark has been at a historically high level, peaking at 11.4% in October 2022 and then 5.6% in April 2023. This development affects both wage and production costs. The industry is also challenged by a strained supply chain, where high demand and

[3]This is an additional agreement to the 6.3 GW offshore wind mentioned before. With this agreement, additional 2.7 GW offshore wind is added to the previous agreement.

competition from e.g. China are combined with increased production costs. The result is that wind turbine manufacturers and subcontractors experience higher prices and longer delivery times throughout the value chain. Despite new initiatives such as the EU's "European Wind Power Action Plan" from September 2023 (European Commission, 2023), which aim to alleviate supply chain problems, several market participants do not expect that the previously more favourable cost levels will return in the near future.

The overall investment needs towards 2030, 2035 and 2050 are presented in Figure 2-12[4].

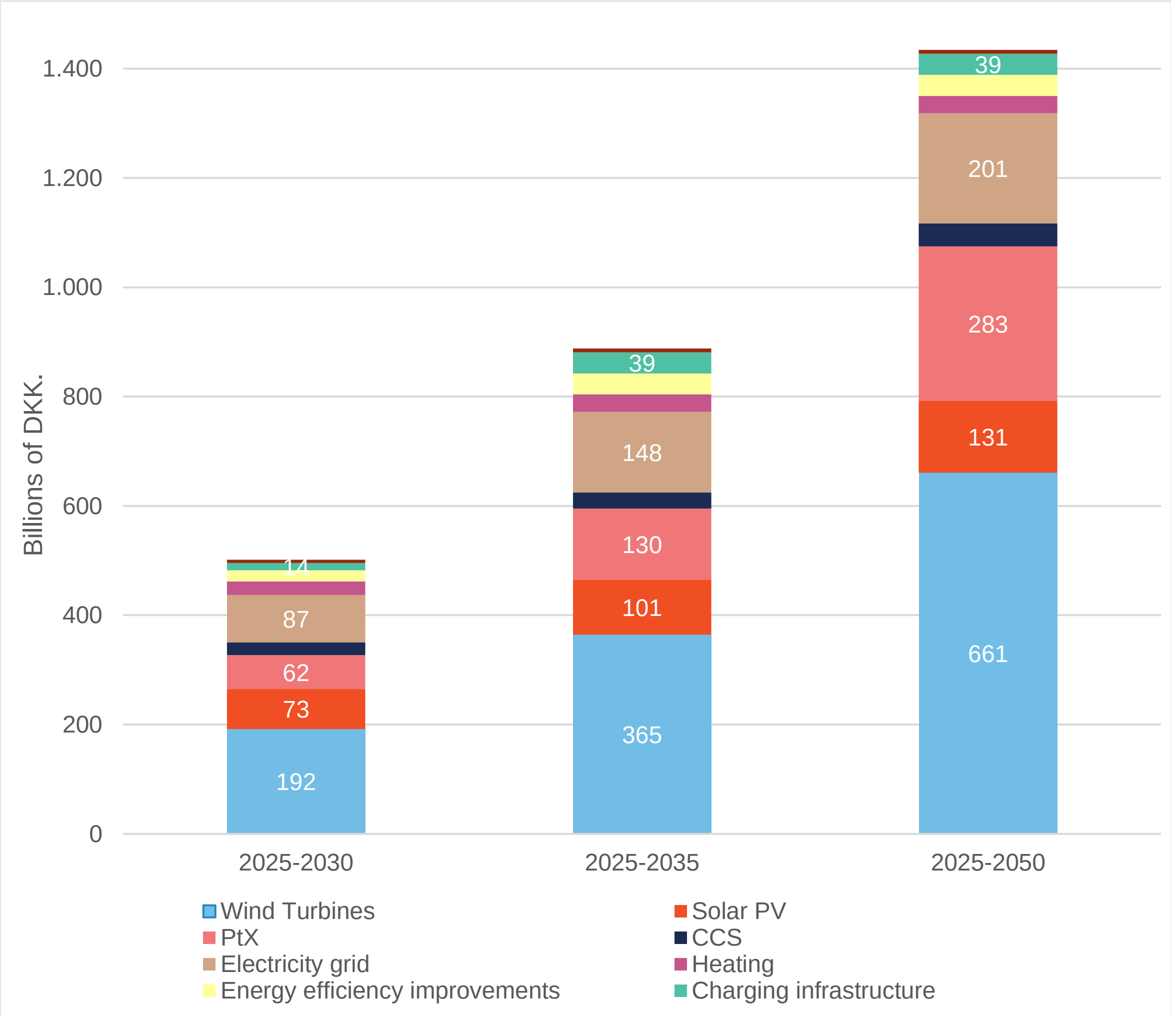

Figure 2-12 Investment needs for the green transition in Denmark.

The investment need is estimated on the basis of the expansion of RE described in the previous chapter, combined with construction costs from the Danish Energy Agency's technology catalogues, as presented in

[4]Note that these are based on the technology catalogue's costs for offshore wind, which have since become higher.

Table 2-2 below. All prices and costs are in 2024 Danish kroner.

Table 2-2 Investment costs for RE technologies from the Danish Energy Agency's Technology Catalogues.

Technology type	Technology[5]	Unit	2020	2025	2030	2040	2050	Source
Wind turbines	21 Offshore turbines	2020-MEURO / MW_e	2.12	1.88	1.80	1.68	1.64	*Technology catalogue for the production of electricity* (The Danish Energy Agency, 2024)
	21 Nearshore turbines	2020-MEURO / MW_e	1.70	1.49	1.38	1.24	1.19	
	20 Domestic turbines	2015-MEURO / MW_e	4.04	NOW	3.84	NOW	3.65	
	20 Onshore turbines	2020-MEURO / MW_e	1.11	1.18	1.15	1.11	1.09	
Solar PV	22 Utility-scale PV	2020-MEURO / MW_e	0.56	NOW	0.38	0.32	0.29	
Biogas	81 Biogas plant, Basic, Large	MEURO /MW output	1.10	1.17	1.02	0.98	0.93	*Technology catalogue for renewable fuels* (The Danish Energy Agency, 2024)
	82 Biogas upgrading	MEURO /MW output	0.13	0.14	0.12	0.10	0.09	
PtX	86 PEMEC 100 MW	MEURO / MW of total input_e	1.3	0.98	0.65	0.50	0.35	
	98 Methanol from hydrogen	MEURO /MW Methanol	1.4	1.4	1.1	1.0	0.9	
	103 Hydrogen to ammonia	MEURO /MW Ammonia output	1.7	1.4	1.1	0.9	0.8	
Carbon capture	401.b Post comb - large biomass	2020-MEURO/(t CO_2 output/hour)	4.1	2.9	2.3	2.0	1.9	*Technology catalogue for carbon capture, transport and storage* (The Danish Energy Agency, 2024)
	401.b Post comb - large biomass	2020-MEURO/ million t CO_2 output / year	911	644	511	444	422	
	401.c Post comb - Cement kiln	2020-MEURO/(t CO_2 output/hour)	4.3	3.0	2.5	2.1	2.0	
	401.c Post comb - Cement kiln	2020-MEURO/ million t CO_2 output / year	614	429	357	300	286	
CO_2 storage	451.1b 3 MTA Onshore	€/tonne CO_2, 2020	2.3	2.2	2.0	1.9	1.9	
	451.2b 3 MTA Near shore	€/tonne CO_2, 2020	4.4	4.2	4.0	3.6	3.6	
	451.3b 3 MTA Offshore	€/tonne CO_2, 2020	3.5	3.3	3.1	2.8	2.8	
Batteries	180 Lithium-ion batteries for grid-scale storage	2015-MEURO / MW_e	2.1	NOW	1.2	0.8	0.5	*Energy storage technology catalogue* (The Danish Energy Agency, 2024)

In addition to AF24 and the Technology Catalogue, the investment need is based on sources from, among others, Green Power Denmark, Rambøll and Dansk Energi, as mentioned in Table 2-1.

[5]The numbers before the technology refer to the chapter number from the Danish Energy Agency's technology catalogues, from which the data in the table is taken.

In relation to the timing of the construction costs, the payments are assumed to be due in connection with the actual construction of the facility. For example, if a facility takes three years to build, then the investments are assumed to take place during the three years leading up to its commissioning.

The annual investment needs for the various technologies are presented in Figure 2-13.

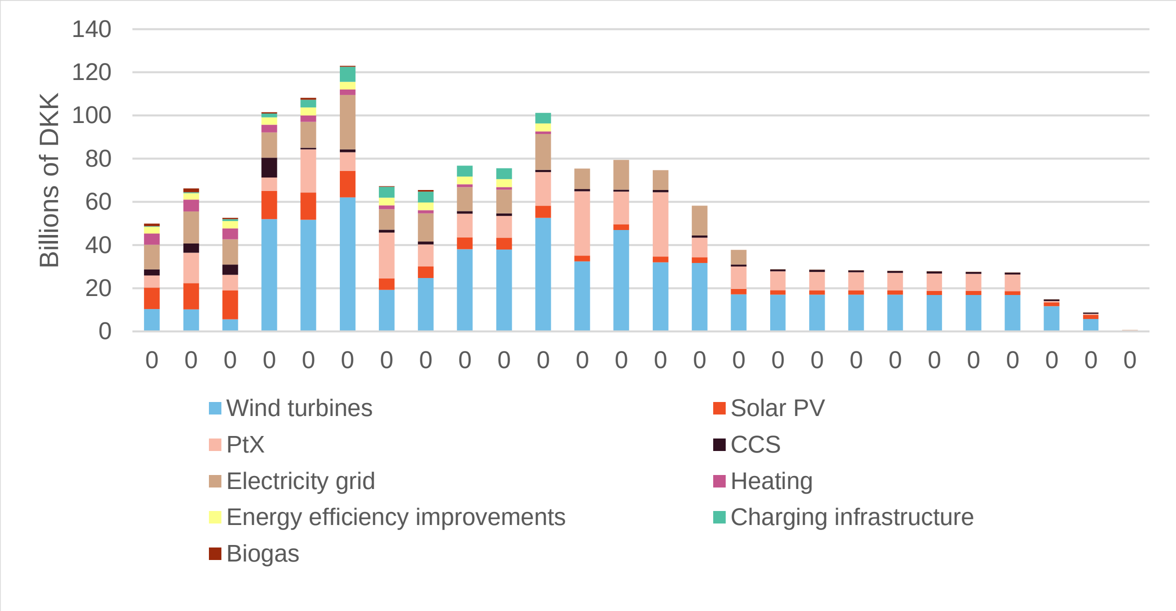

Figure 2-13 The annual investment needs to meet the Danish climate and expansion of renewable energy targets.

The figure shows that already from the year 2025 there is an annual investment need of DKK 50 billion until 2028, when investments in offshore wind in particular begin to accelerate, and the total annual investment need rises to over DKK 100 billion towards 2030. After this point, the annual investment need declines, primarily because the investments required to fulfil the agreement on 9 GW offshore wind in the Baltic Sea are covered by the investments made up to 2030. The investments required to fulfil the agreement on 35 GW offshore wind in the North Sea by 2050 are expected to be more or less evenly distributed up to 2050, although slightly increasing towards 2035, when the investment need for offshore wind is expected to peak at DKK 50 billion, before declining annually towards 2050.

It should also be noted that it is assumed that the investments in electricity transmission and distribution follow the investments in offshore wind, onshore wind and solar PV, which amplifies the impact of certain investment-intensive years in the overview.

2.3 Status of meeting climate targets

Denmark has very ambitious climate targets, including a 70% reduction in CO_2 emissions by 2030 compared to 1990 (The Danish Parliament, 2020), and the government has an ambition of CO_2 neutrality by 2045 and 110% CO_2 reduction by 2050 compared to 1990 (The Government of Denmark, 2022). It should be noted that, according to the Climate Act, it is actual domestic emissions that must be reduced. Reduction in international emissions through, for example, the export of green electricity and green fuels do not count towards the climate targets. Therefore, it is necessary that green electricity from, among other sources, offshore wind, and green fuels from, for instance, Power-to-X, are primarily directed towards the Danish market. Likewise, there is a need to supplement with technologies that can contribute with negative emissions, such as e.g. CCS, pyrolysis, and DAC.

The Danish Energy Agency's 2024 Climate Status and Projections (The Danish Energy Agency, 2024) gives an idea of how far we are from achieving the 2030 targets based on the measures and market conditions already in place. The projections show that by 2030, total CO_2e emissions are expected to be 25.4 million tonnes. This corresponds to a CO_2 reduction in 2030 of 68%, as emissions in 1990 amounted to 78.3 million tonnes of CO_2. There is thus a lack of measures to reduce 2 million tonnes of CO_2e in 2030.

By 2050, the Danish Climate Council on Climate Change (Klimarådet, 2024) expects that total CO_2e emissions will have been reduced to 8 million tonnes CO_2e, corresponding to a 90% reduction compared to 1990. However, by then, nearly all remaining greenhouse gas emissions are expected to come from agriculture, along with waste treatment, where it will not be possible to directly capture the released carbon. The Climate Council therefore points out that it will be necessary either to implement direct air capture of CO_2 (DAC) and/or to convert agricultural land into natural areas in order to reach the 110% target by 2050.

3 Mechanisms to promote the production and uptake of green technologies

This chapter investigates some of the mechanisms that can potentially be used to promote the development, financing, and implementation of various climate-friendly energy technologies, such as CCS, offshore wind, solar, onshore wind, biogas, and PtX. In this context, three general types of mechanisms are identified to promote green technologies:

1. Regulation
2. Economic incentives
3. Public investment and procurement

Within each of these mechanisms, there are a number of underlying categories, which target efforts and address specific challenges and needs. It is important to note that each mechanism has its own strengths and limitations, and that a combination of these is often required to achieve the desired results. The effectiveness of the mechanisms also depends on local conditions, the political environment as well as technological and economic prerequisites.

3.1 Mechanisms: Regulation

Regulation encompasses the laws and mandates that directly require or prohibit specific actions. This approach is known as "command-and-control mechanism", where the state obliges companies or consumers to comply with specific standards, targets, or behaviours.

For example, the EU has adopted usage requirements for hydrogen and hydrogen-based fuels within transport and industry, and technical standards have been developed for hydrogen quality. While direct regulation can ensure rapid change and effective enforcement, it can also be costly to industry and lead to inefficient allocation of resources.

Table 3-1 Overview of the advantages and disadvantages of regulation

Benefits	Disadvantages
Fast results and high compliance	Lack of flexibility
Uniform rules for actors	High compliance costs can hamper growth
Can stimulate innovation	Administrative burdens can lead to delays

Overall, direct regulation plays an important role in promoting green technologies across the RE value chain by establishing clear and binding frameworks. A balanced policy approach, which combines direct regulation with other mechanisms, such as financial incentives and market-based instruments, may therefore be necessary to achieve optimal results in the green transition.

Examples of direct regulation are described in the following.

3.1.1 Environmental standards and emission requirements

Emission and energy efficiency requirements, along with environmental standards, are key elements of direct regulation aimed at limiting the environmental impact of both energy production and energy consumption. By setting binding limits on emissions and establishing standards for environmental performance, companies are forced to implement cleaner technologies and processes. Within the renewable energy value chain, these requirements promote the transition to sustainable energy solutions by reducing greenhouse gas emissions and improving environmental quality.

Mandatory targets for the reduction of greenhouse gas emissions are binding targets for reducing greenhouse gas emissions within the production and consumption of energy. By establishing specific CO_2 reduction targets, it is ensured that CO_2 emissions are reduced in the sectors subject to the requirements, thereby creating an incentive to produce renewable energy products that can contribute to lowering CO_2 emissions. However, this mechanism can also increase price formation complexity, as it implicitly creates new markets where prices are initially unknown and where information asymmetry exists between producers and offtakers regarding what the market price should be.

This can make it difficult to reach agreements on offtake at an early enough stage - typically necessary to secure financing for renewable energy projects.

Examples of mandatory greenhouse gas reduction targets can be found in the following:

- ***FuelEU Maritime*** (EU 2023/1805): Sets limits on the CO_2 intensity of fuels used in maritime transport. The CO_2 savings from PtX fuels that are certified as RFNBOs[6] also count double until the end of 2033. Under this regulation, operators who exceed the CO_2 reduction targets will also be able to sell excess surplus reductions to other players through bilateral agreements.
- ***EU regulation on CO_2 Emission Performance Standards for Passenger Cars and Light Commercial Vehicles*** (EU 2019/631): Sets a CO_2 emission limit per kilometre for vehicle fleets produced by car manufacturers. A certain share of zero-emission vehicles, including hydrogen-powered vehicles, must be produced to meet the requirements. From 2035, the emission limit will be reduced to zero, meaning that only zero-emission vehicles will be allowed to be manufactured.
- ***EU regulation on CO_2 Emission Performance Standards for New Heavy-Duty Vehicles*** (EU 2019/1242): Sets requirements for a 15% CO_2 emission reduction by 2025 and 30% by 2030 for manufacturers' fleets of heavy-duty vehicles over 16 tonnes.

Legally binding emission limits are requirements for the maximum allowable emission of pollutants. Renewable energy products are typically cleaner than fossil alternatives and result in fewer emissions - not just of CO_2. Stricter emissions limits often lead to higher costs for fossil-based alternatives, while clean renewable energy products are less affected. Thus, emissions limits help make renewable energy alternatives more attractive and increase the risk-adjusted returns on investments in renewable energy projects.

Some examples of emission limits include:

- ***The NEC Directive*** (EU 2016/2284): Sets national emission ceilings for certain pollutants, including SO_2, NOx, ammonia (NH_3), non-methane volatile organic compounds (NMVOCs) and fine particles (PM2.5).
- ***IMO's MARPOL Annex VI:*** Sets limits on emissions from ships, including sulphur, NOx, and Volatile Organic Compounds (VOCs).
- ***USA's Clean Air Act:*** Sets limits on emissions of pollutants such as ozone, particulate matter, carbon monoxide, sulphur, NOx, lead, mercury, asbestos, and benzene.

[6] RFNBO: RFNBO stands for "Renewable Fuels of Non-Biological Origin". According to EU legislation (Renewable Energy Directive - RED), the term “RFNBOs” refers to fuels, which are produced from renewable energy sources, but do not originate from biological materials. This includes fuels such as hydrogen and synthetic fuels (or PtX fuels), which can be produced using renewable electricity, for example from RE sources such as the sun or wind. According to the RED, RFNBOs must meet certain sustainability criteria to be recognized as sustainable.

3.1.2 Product and technology standards

This category includes energy efficiency standards and eco-labels of products to inform consumers and promote sustainable choices. Product and technology standards help ensure that only genuinely sustainable products are eligible for support, while also increasing transparency around how sustainable a product is. However, a high level of complexity in complying with product and technology standards can result in significant costs for RE projects, costs that are often not imposed to the same extent on fossil-based alternatives. These costs affect project developers, investors, and public authorities alike.

Examples of product and technology standards include:

- ***Guarantees of Origin (GOs)*****:** Certify the renewable origin of, for example, electricity and gas. In Denmark, these guarantees are issued by Energinet.

- ***Energy labelling:*** The EU Ecodesign Directive (Directive 2009/125/EC) and the Energy Labelling Regulation (Regulation 2017/1369) set the general framework for ecodesign and energy labelling schemes.

- ***Certification of sustainable fuels*****:** The EU's renewable energy directive (RED) requires producers to document the sustainability of fuels (e.g. RFNBOs) through approved certification schemes such as ISCC-EU.

- ***EU Taxonomy:*** A classification system that defines sustainable activities and requires documentation from companies and investors to live up to specific environmental standards. For the RE value chain, this means increased requirements for documentation and certification, but it also opens up opportunities to attract green investments and financing from funds focused on sustainable projects. By fulfilling the taxonomy's requirements, solar, wind, and PtX projects can more easily qualify for green capital and be supported in their development.

- ***Energy efficiency requirements:*** Regulations and standards aimed at reducing energy consumption by improving the efficiency of products, buildings, and industrial processes. These requirements force producers and consumers to adopt more energy-efficient technologies and processes, which contributes to lower energy costs, reduced greenhouse gas emissions and sustainable development. An example of this is the Danish building regulations, which contain requirements for energy efficiency in new buildings and major renovations. These include the level of insulation, energy performance of windows, and the efficiency of heating, cooling, and ventilation systems, with the aim of reducing energy consumption in buildings.

3.1.3 Demand-side mandates

By establishing demand-side mandates, it is ensured that there is a market for renewable energy products such as hydrogen, thereby reducing investment and financing risk for renewable energy projects. However, the mechanism can also increase the complexity of price formation, as it creates new markets with initially unknown prices and asymmetrical information between producers and offtakers regarding the expected market price. This can make it difficult to reach agreements on the offtake of renewable energy products at an early stage – an aspect that is often necessary for securing financing of renewable energy projects.

Some examples of consumption requirements include:

Demand-side mandates for green fuels in the transport sector: Mandates to use a specific type of fuel (e.g. synthetic or biofuels) in the transport sector. These requirements are included in, among others:

- **The Renewable Energy Directive** (EU 2018/2001), which establishes that 14% of the energy consumed in the transport sector must come from renewable energy sources by 2030.

Correspondingly, there is a sub-target that 2.6% of the energy used in the transport sector must be RFNBO-based by 2030.

- **ReFuelEU Aviation**, establishes a minimum share obligation for sustainable aviation fuels (SAF), requiring that at least 2% of aviation fuel supplied in the EU must be sustainable by 2025, increasing to 20% by 2035 and 63% by 2050. Within these shares, there are specific sub-targets for RFNBOs, corresponding to minimum shares of 0.7% in 2025, 5% in 2035, and 28% in 2050.
- **FuelEU Maritime,** which contains the option to introduce a minimum use obligation, requiring at least 2% of the energy used in the maritime sector to be from RFNBOs from 2034.

Application requirements for green fuels in industry: Requirements to use a specific type of fuel (e.g. renewable hydrogen) in industry.

The Renewable Energy Directive stipulates that 42% of hydrogen consumption in energy-intensive industries must be covered by RFNBO hydrogen by 2030, increasing to 60% by 2035. It is up to the individual EU member states to establish legislation to implement this requirement, with flexibility to define how it is achieved - for example, through consumption mandates, CO_2 reduction targets, taxes, subsidies, etc. To date, no country has directly implemented this requirement. Instead, the focus has been on supporting PtX technologies via economic incentives. However, it is expected that dedicated consumption mandates will also be necessary to comply with the RED requirement.

3.1.4 Mandates, bans, and restrictions

Bans on the production and installation of technology that uses fossil energy force the adoption of sustainable technologies. However, this is often not the most cost-effective solution from a societal perspective, as it might be cheaper to decarbonise other sectors first. From an investor perspective, this could lead to lower CO_2 reductions per invested euro than would otherwise be possible without the bans. Furthermore, bans on fossil fuel technologies can sometimes unintentionally restrict sustainable alternatives - for example, the use of biogas in Danish gas boilers or sustainable fuels in combustion engine vehicles - thereby creating additional barriers to investing in renewable energy technologies.

Bans on installing new fossil heating systems in buildings and on selling new vehicles with combustion engines fall into this category.

- In **Denmark,** the 2010 Building Regulations introduced a ban on installing oil heaters and gas heaters in new buildings from 2013. In practice, this means that e-methane from PtX is also prohibited as a heating source for gas heaters, although it can still be used for the production of district heating.

- **Germany** has introduced a law (*Gebäudeenergiegesetz*), which prohibits the installation of new fossil heating systems in new construction from 2024. This law requires all new heating systems to be based on RE, including electric heat pumps, solar thermal systems, biogas, or hydrogen-based solutions such as PtX technologies. Gas boilers will therefore only be permitted if the gas used is renewable rather than fossil natural gas.

- **The UK** has announced a ban on the installation of new gas boilers in new construction from 2025 as part of their Future Homes Standard. All new buildings must be heated using zero-emission technologies such as electric heat pumps, solar thermal, or district heating.

- **The EU** prohibits the sale of new cars with internal combustion engines from 2035 under the regulation on CO_2 emission performance standards for passenger cars and vans (EU 2019/631). There is, however, an exception in the regulation, allowing to sell cars with internal combustion engines provided that they run exclusively on PtX fuels. Further regulation to ensure these vehicles actually use PtX fuels instead of fossil fuels is still pending.

- In **the UK,** a similar ban is being introduced on the sale of new cars and vans with internal combustion engines from 2035.

- **California** is introducing a similar ban from 2035. This also mandates that all new heavy-duty trucks must be zero-emission vehicles from 2045.

3.1.5 Infrastructure regulation

There are several rules and quality requirements for products destined to energy networks (e.g. the electricity grid, gas grid, hydrogen network and CO_2 network), which should contribute to promoting the integration of PtX technologies. Uniform product quality requirements reduce investment risks, by ensuring that renewable energy products can be used in all relevant appliances and transported across different infrastructures, thereby increasing the potential offtake market. However, these requirements may also entail additional production costs.

3.1.5.1 Requirements for infrastructure development

- Certain regulations set requirements for the development of infrastructure. One relating to RE is the **AFI directive**, which is an EU directive that requires EU member states to build the necessary refuelling infrastructure for alternative fuels in road and maritime transport. This includes electric vehicle charging stations, hydrogen refuelling stations, gas refuelling stations, and LNG terminals. However, the AFI directive does not mandate the establishment of refuelling infrastructure for e.g. methanol and ammonia for ships.

3.1.5.2 Hydrogen blending in the gas network

- **Germany** aims to integrate green hydrogen into its existing gas network in order to reduce CO_2 emissions. In certain areas, Germany allows up to 10% hydrogen blending in the natural gas network in connection with pilot projects.
- **France** currently allows blending up to 6% hydrogen in the natural gas network. There are pilot projects underway to investigate how higher levels of hydrogen can be integrated. The aim is to be able to integrate up to 20% in certain parts of the gas network in the future.
- **Denmark** does not yet allow the blending of hydrogen into the gas network, but analyses from Energinet show that a 2% hydrogen blend is technically feasible.
- **The Netherlands** has also experimented with blending green hydrogen in the natural gas network via pilot projects. As part of their Hydrogen Valley project, which receives funding from the EU, the Netherlands is testing the integration of hydrogen into the gas network. However, it is not yet widely permitted to blend hydrogen into the Dutch gas network.

3.1.5.3 Hydrogen quality standards

The EU has implemented the international **ISO 14687 standard**, which sets requirements for hydrogen quality for various applications. Hydrogen for fuel cells must e.g. have a minimum purity of 99.97%. Denmark, Germany, France and the UK have all implemented this standard. In the US, the SAE J2719 standard is used, which also prescribes hydrogen purity of 99.97%. Hydrogen quality requirements for the upcoming European hydrogen backbone have not yet been implemented but are expected to follow the 99.97% purity requirement of ISO 14687.

3.1.5.4 Rules for the transport of hydrogen and green gases

- **The EU Hydrogen and Gas Decarbonisation Package** was presented in December 2021 and involved revisions of the Gas Directive and the Gas Regulation. The proposals were put forward as a supplement to the “Fit-for-55” package, which aims to realize the EU's climate target for 2030 of at least 55% greenhouse gas reductions compared to the 1990 levels. Both regulations entered into force on August 4th, 2024.
- **The Gas Directive** (EU 2024/1788) and **Gas Regulation** (EU 2024/1789) lay down common rules for the internal markets and transport of renewable gas, natural gas and hydrogen.

  These rules are to be supported through gas infrastructure, as well as through a new and independent regulation of the hydrogen network, aiming to ensure timely, efficient access to hydrogen systems and to a future European hydrogen market.

EU member states must ensure that companies producing sustainable and low-carbon gases gain access to the gas infrastructure, regardless of whether the gases are to be transported through the distribution or transmission system. Transmission system operators are required to cooperate across borders on gas quality.

In addition, the regulation covers consumer protection, e.g. when changing energy suppliers, as well as increased security of supply and cooperation through integrated planning of the electricity, gas, and hydrogen networks. In addition, solidarity arrangements are introduced between EU countries to deal with crisis situations.

3.1.6 Regulation on energy security and industrial transition

This section outlines relevant regulatory packages in the energy sector aimed at promoting the green transition and addressing the barriers that energy projects often encounter. The regulations establish framework conditions, which support faster implementation of renewable energy sources and net-zero emission technologies, while at the same time ensuring security of supply and promoting innovation.

- **The Net Zero Industry Act** (2024/1735) is a regulation with the general aim of strengthening the EU's supply of net-zero technologies and ensuring resilient supply chains to support the climate goals. The regulation contains measures to:
  - Reduce supply risks and support scaling of manufacturing capacity
  - Establish an EU market for CO_2 storage
  - Promote demand through public tenders and interventions
  - Support innovation and job creation through education and research activities
  - Improve monitoring of supply risks

  The regulation also contains deadlines for the approval procedure, environmental impact assessment and approval of strategic net-zero projects.

- **The EU's emergency regulations**: In light of Russia's invasion of Ukraine, three emergency regulations were adopted in the EU, which were designed to address security of supply and rising gas and electricity prices in the EU. The regulations have been introduced as temporary measures.

  One of the three regulations, the EU Emergency Regulation (2022/2577), aims to accelerate renewable energy projects. In order to speed up permitting processes for renewable energy production, it sets rules and deadlines for permits relating to solar PV and heat pumps (maximum three months) as well as for the renewal of older electricity-producing renewable energy plants (maximum six months). Furthermore, the regulation introduces a presumption that renewable energy projects are of significant public interest, which simplifies environmental approvals under the EU's Habitat and Birds Directives. The regulation was originally adopted as a temporary measure with a validity period of 18 months from December 30th, 2022. This meant that the regulation would expire on June 30th, 2024. However, the EU decided on December 19th, 2023, to extend the application period for certain provisions until June 30th, 2025.

How can regulation contribute to solving the barriers to private investment?

Regulation plays a central role in addressing the barriers that private investors encounter in connection with green investments.

One of the identified barriers is *uncertainty about the offtake* of green products. Offtake agreements and long-term consumption mandates, such as those introduced in ReFuelEU Aviation and FuelEU Maritime, reduce the risk for investors by ensuring a stable demand for green fuels in the future. These requirements make it easier to predict demand and reduce the risks associated with investing in new technologies.

Similarly, *uncertainty about future infrastructure and markets can* be effectively addressed through regulation of hydrogen and CO_2 transport network as well as storage facilities. Such regulation ensures that the necessary infrastructure is developed in parallel with technological advancements. Long-term political goals, such as those laid down in the EU's hydrogen strategy and the national climate laws, as well as concrete mandates, such as those set out in the RED, create greater certainty that technologies such as PtX and CCS will play a central role in the green transition. This increases investor confidence in these technologies' future relevance and political support.

Although regulation can be an effective tool to address many of the identified barriers, it can also pose a challenge if it is complex, constantly changing or leads to long approval times for RE projects. For investors, stability and predictability in the regulation are essential to make decisions on long-term investments in green technologies. In addition, simplified and more efficient permit processes, such as those proposed by the National Energy Crisis Staff's (NEKST) recommendations, and which are part of EU policy such as the Net-Zero Industry Act, are necessary to reduce waiting times and uncertainty.

Overall, regulation can create the necessary framework to reduce risks and uncertainties, making it easier for private investors to commit to long-term investments in the green transition.

3.2 Mechanisms: Economic incentives

Economic incentives play a central role in promoting green technologies. They can stimulate investment, innovation, and the uptake of sustainable energy solutions, making green technologies more attractive to both businesses and consumers.

Economic instruments are powerful tools that motivate actors to make sustainable choices without directly mandating or prohibiting specific actions. For example, the EU Emissions Trading System (EU ETS) is an economic instrument that both sets an upper limit for on actors' greenhouse gas emissions and at the same time allows companies to trade CO_2 allowances if they are either above or below the quota they must comply with. The aim is to create financial incentives to reduce emissions by pricing CO_2. Likewise, subsidies for technologies such as green hydrogen and PtX can give companies an incentive to invest in sustainable solutions.

Generally, these incentives include policies such as subsidies, taxes, tax breaks and trading of emission allowances. Subsidies can reduce the initial investment costs of PtX projects, thereby lowering financial risk and promoting market access. Taxes on CO_2 emissions or fossil fuels increase the cost of non-renewable energy sources and encourage consumers to choose zero- or low-emission technologies such as PtX.

Tradable certificates and allowance systems allow companies to trade emission rights, giving them the flexibility to meet climate targets cost-effectively. When companies invest in green technology, they reduce their emissions and can obtain surplus allowances for sale. Tax incentives, such as deductions or credits, can also improve the economics of green projects.

Table 3-2 Overview of the advantages and disadvantages of economic incentives

Benefits	Disadvantages
Exploit market forces to promote the green transition without necessarily making specific technological choices	Require precise implementation to avoid disproportionately high costs for the state
Enable actors to make decisions based on costs and benefits, which stimulates competition, innovation and efficiency	Require precise implementation to avoid market distortions
Promote innovation and efficiency	

This section presents different types of economic incentives, their mechanisms, and applications in renewable energy and PtX.

3.2.1 Taxes

Taxes are one of the most effective methods to promote RE products, as they close the cost gap between fossil and renewable energy. Likewise, they are a relatively simple form of regulation, which means that renewable energy competes on the same markets as fossil energy. However, due to existing EU regulations, particularly *the* Energy Taxation Directive, it is difficult to promote renewable energy via taxes, as it is not permitted to tax fuel used for international shipping and aviation.

The following are some examples of taxes that support the use of renewable energy.

- **CO_2 tax:** A CO_2 tax is a tax levied on companies based on their CO_2 emissions. The purpose of the tax is to create financial incentives to reduce greenhouse gas emissions and promote sustainable energy sources.
    - In ***Denmark***, with the 2022 green tax reform, a uniform CO_2 tax of DKK 750/tonne CO_2 was introduced for companies outside the EU ETS. For companies covered by the EU ETS, the tax is DKK 375/tonne CO_2, although there may be differences between the sectors. This CO_2 tax supports a technology-neutral transition to sustainable energy, including PtX, by encouraging the use of low-emission technologies. However, the tax does not apply to air

and sea transport, where domestic flights are instead subject to a passenger tax, the proceeds of which are invested in green technologies for aviation.

- In ***Norway,*** a CO_2 tax has also been introduced on aviation fuel for domestic flights as part of a strategy to reduce greenhouse gas emissions.

- **Energy taxes:** Energy taxes are taxes imposed on the consumption of energy products, such as gas, petrol, diesel, and electricity. The aim of these taxes is to regulate energy consumption and promote the use of more sustainable and environmentally friendly energy sources.

  These taxes are regulated by the EU *Energy Taxation Directive,* which was revised as part of the "Fit for 55" process. This directive sets minimum levels for energy taxation across the EU and aims to promote an internal energy market. However, the directive requires that energy taxes for diesel and petrol-like products are uniform across the EU, which creates challenges for promoting greener alternatives. The challenge when revising the EU Energy Taxation Directive is that EU tax legislation requires unanimity to be adopted. The directive has thus not been revised since it entered into force on January 1st, 2004.

- In ***Denmark,*** consumption of green hydrogen and several PtX products is exempt from energy taxes, which is an advantage with regard to using hydrogen and PtX for road transport, where fossil fuels are subject to high energy taxes. Within air and sea transport, however, there is no advantage, as the competing fossil fuels are also exempt from energy taxes.

  In connection with the green transition of road transport, there is the possibility that part of the current energy tax in road transport can be replaced by a higher CO_2 tax. However, the Danish energy tax for diesel is already close to the minimum tax set by the EU. There are therefore limited opportunities to change the energy tax to a CO_2 tax without raising the overall tax burden on Danish fuels. Since prices and taxes on fuel are already high, it will be difficult to gain political support for further increasing the tax burden.

- **Environmental taxes:** Environmental taxes are taxes levied on companies and individuals for the emission of harmful substances, such as sulphur oxides (SOx) and nitrogen oxides (NOx).

  - In ***Denmark and several other countries,*** emissions of environmental pollutants such as sulphur oxides (SOx) and nitrogen oxides (NOx) are subject to environmental charges. This taxation benefits RE sources, as fossil fuels typically have higher emissions of these harmful substances. The purpose of the environmental taxes is to encourage the use of cleaner energy sources and reduce the environmental impact from energy production and consumption.

3.2.2 Tax benefits

The American *Inflation Reduction Act* (IRA), adopted in 2022, is a comprehensive piece of legislation that aims to reduce the US's greenhouse gas emissions and promote the green transition.

Under the IRA, a number of tax credits (tax breaks) have been introduced for the production of certain RE technologies, such as hydrogen, carbon capture, wind turbines, solar PV, batteries, etc. The tax credits reduce the corporate tax that companies owe to the state, and it is possible to carry forward the tax credits to future annual statements if the corporate tax payment in a year is zero due to a negative accounting result. Likewise, companies can resell their tax credits to other companies.

Table 3-3Overview of examples of IRA tax credits

Examples of IRA tax credits	
Production of zero-emission electricity	$27.5/MWh
Carbon Capture and Storage (CCS)	$85/ton CO_2
Carbon Capture and Utilization (CCU)	$60/ton CO_2
DAC CCS	$180/ton of CO_2
DAC CCU	$130/ton of CO_2
Clean hydrogen production credits	Up to $3/kg of green H_2 until 2032 – depending on production emissions
Clean fuel production credits	$1/gallon for non-aviation fuel $1.75/gallon Sustainable Aviation Fuel (SAF)

Canada has also introduced a similar system, where tax credits can be obtained by making investments in green hydrogen.

By granting renewable energy projects tax benefits, a higher return can be achieved. However, there are major uncertainties associated with how much higher the return can be, as it largely depends on the tax base and, thus, the overall profit that the RE project will generate. The American model also introduces a number of new markets for trading tax credits, which are opaque and have a high degree of asymmetric information between buyer and seller.

3.2.3 Production support

Sustainable energy production can be supported through various subsidies, e.g. via a price premium on top of the market price that would otherwise be achievable, or through a guaranteed fixed price for a certain period. There are various subsidies that are relevant for RE. Production support is very similar to taxes, only with the opposite sign, and is an effective method of closing the cost gap between fossil and renewable energy by increasing returns. The problem with production support can be that it distorts the balance between production and offtake, providing incentives to produce renewable energy without there being an actual demand. Likewise, production support in one country and offtake support (e.g. via reduced taxes) in another country can result in the country providing production support not itself benefiting from the renewable energy produced, as market forces may drive it towards countries with offtake support.

Production support is typically awarded through tender models, which can be designed in several ways, depending on the selection of evaluation criteria that are assigned weight in the assessment of bids submitted by developers. Evaluation criteria could include project costs, level of support, economic analysis of e.g. electricity production and electricity prices, as well as how project risk is distributed between the state and the developers.

During the bid collection phase, the tender model can generally be structured in two different ways: a *non-auction-based tender* and an *auction-based tender.* The two systems are described below.

Non-auction-based tender

Before auction-based bidding systems became predominant for offshore wind, the bidding systems were non-auction-based. In a non-auction-based tender, the focus is on choosing the tenderer who best meets the provider's specific needs and criteria, including technical expertise, local presence, quality standards, etc. In a non-auction-based tender, the provider uses a more qualitative approach to choosing the recipient of the contract. Here, the provider evaluates the offers based on factors other than price, such as experience and technical qualifications.

Table 3-4 Advantages for respectively non-auction-based and auction-based tenders

Advantages of non-auction-based tender	Advantages of an auction-based tender
Can be cheaper for the developer, if designed and structured not to imply a long and uncertain permitting process.	More market-driven system, which usually results in lower support costs per amount of energy produced.
Lower transaction costs.	Balances risk more equally between wind developers and the state, in contrast to the administrative allocation system, where the state often bears most of the risk.
Appeals better to small developers.	Correlation between the greatest growth and markets, which have used auctions.

Auction-based tender

Auctions are today the leading tender design for support for RE. Auctions are considered an effective tool for achieving the EU's and national climate objectives, as they allow a flexible tender design and provide certainty for both investors and political decision-makers.

Auctions can, however, be structured and carried out in several ways, which gives different advantages and risks for both developers and the state. The auction model and structure can thus be chosen depending on how large a share of the project and the market risk the state is willing to take in order to ensure that national targets are met.

The auction-based tenders can be divided into three different models:

1. **Sealed-bid auctions** refer to an auction *where all bidders submit bids to the provider at the same time*, without having knowledge of the other participants' bids. The bids are not known until the auction deadline. Bidders normally have only one bid.
2. **Dynamic “descending clock” auctions** involve *all participants simultaneously*. If the amount of energy that has been bid exceeds the set target, the price is lowered by the provider. Bidders will then again present a bid in relation to the amount of energy they are willing to deliver at this new price. This process continues until the supplied and requested quantities match. The price set in this situation is the "clearing price".
3. **Hybrid auctions** are normally structured as a *combination of sealed-bid auctions* and *dynamic "descending clock" auctions*, where the advantages of both auction structures can be drawn on. A combination of the two is normally structured in such a way that the auction starts with a dynamic "descending clock" structure, while a sealed bid structure is introduced in the second phase.

Like all other auction models, these are **single-criterion auctions**, which are often referred to as auctions where the winner is determined solely based on price. The main principle is that whoever can offer the lowest price wins the auction. **Multi-criterion auctions** include e.g. societal parameters, such as sustainability requirements or socio-economic parameters, in addition to price criteria. This may mean that it is not necessarily the lowest bidder that is selected as the winner. A concrete example of this is the Dutch 4 GW offshore wind tender for *the IJmuiden Ver Alpha and Beta areas*. 85% of the overall point score was awarded on the basis of criteria with a social or environmental purpose. The remaining 15% of the points could be obtained based on the company's financial bid for the license to build and operate the offshore wind farms. This case study is elaborated in Chapter 5.1.3.

3.2.3.1 Feed-in tariffs (FiT)

Feed-in tariffs (FiT) are a support mechanism that ensures energy producers receive a fixed amount per unit of energy produced, regardless of the market price of the product they sell. Another option is to calculate a fixed maximum number of full load hours for which the FiT will be paid. The FiT is guaranteed for a certain period, which is often related to the financial lifetime of the respective renewable energy project. FiTs are typically fixed and not negotiable, unlike Contract-for-Difference (CfD) agreements, which are typically awarded via auctions. However, China has used auctions within the FiT system as a way of securing both investment and low costs for offshore wind projects, while maintaining control over the financial framework for the projects.

The advantages of a FiT system are that it is a relatively simple policy instrument, which is both easy to implement and manage. FiT, combined with long-term contracts, gives the renewable energy producer predictability and security, significantly lowering investment risks and financing costs. Historically, FiTs have helped drive the development of technologies at early stages.

The disadvantage of FiTs is that the level of support can be either disproportionately high or low, and that it can be difficult to hit the right level encouraging the production of sustainable products without overcompensating the producers. Likewise, it can be difficult for the state to predict the future costs in connection with the support scheme, as the support that the state pays out varies depending on the market price. FiT can also have unintended consequences, such as wind turbines having an economic incentive to produce electricity even when the market price for electricity is negative, which can lead to technical imbalances in the electricity system. Another disadvantage of the FiT model is that in markets driven by bilateral purchase agreements, it can be difficult to define the market price against which the level of support is benchmarked.

In Denmark and several other countries, this support model has been phased out and replaced with either feed-in premium or CfD auctions.

Some examples of support models where FiTs have been applied include:

- The support, which is granted to Danish biogas plants that came into operation before 2019, functions as a FiT linked to the natural gas price. At a higher natural gas price, the support is reduced, while the support is increased at lower natural gas prices.
- The support granted to Danish wind turbines commissioned before 2004 guarantees a fixed price for the electricity the wind turbines produce.

3.2.3.2 Feed-in premium (FiP)

A FiP is a fixed price premium to which the market price is added. The premium can either be determined in advance or awarded through an auction, where the actors who bid with the lowest premium are granted the contract. The FiP can either be **fixed** (i.e. at a constant level independent of market prices) or **sliding** (i.e. with variable levels depending on market price movements).

The advantage of a FiP with a **fixed premium** is that the state reduces its risks in relation to a FiT, as the premium is predetermined and predictable, and does not depend on the market price. Since the premium in this model is independent of the market price, it is also easier to implement in markets where bilateral trading dominates. A FiP model is relatively easy to implement and manage, but when market prices rise, the state runs the risk of overcompensating the asset owner, whereas the asset owner is exposed to under compensation when prices fall. To avoid such a situation, so-called *floor-and-cap* levels can be introduced.

A disadvantage of the model includes that it shifts part of the risk associated with variable prices onto the producers. As with FiTs, it can be difficult to determine the right level of support that encourages sustainable production without overcompensating. However, this problem is partly addressed by allocating the support via auctions. FiPs may also lead to a financial incentive to produce electricity, when there is a need to stop the production of electricity, such as during periods of negative electricity prices.

An alternative FiP model is one where the premium is calculated dynamically as the difference between (technology-specific) market prices and a predefined reference tariff level. This is called a **sliding premium**. If market prices are higher than the reference tariff level, there is no compensation. The advantages of a sliding FiP are that it follows market movements and limits the potential risk for both the state and the asset owner of overcompensating or being exposed to under compensation. However, this is a more complicated design, which requires market knowledge so that the tariff level is set correctly, and it can be difficult to implement in markets dominated by bilateral trade, such as e.g. within PtX. When a sliding FiP is used in an auction-based design, prices are set at regular intervals to close the gap between the average market price and the "strike price" in the auction. In Germany, a sliding FiP model is used for offshore wind projects, and it has been used in auction-based support schemes to promote renewable energy.

Examples of support models based on FiP include:

- The support given to Danish onshore wind turbines commissioned after 2004.
- PtX tender of DKK 1.25 billion awarded in 2023. The support was granted as a fixed price premium (DKK/GJ hydrogen).
- The DKK 28 billion CCS fund announced in October 2024. The fund has been criticized by e.g. Green Power Denmark and Hydrogen Denmark. Critics argue that CCS funding may reduce the potential for PtX production, as the storage of biogenic CO_2 will reduce the volume of CO_2 available for producing carbon-based PtX products, thereby increasing the costs of PtX.

3.2.3.3 Contracts for Difference (CfD)

Under the CfD model, the state guarantees a minimum price for energy producers. If the market price is lower than the agreed strike price in the CfD contract, the difference is compensated by the government.

In contrast to the FiT, which is fixed regardless of the market price, CfDs allow for additional earnings if market prices rise above the strike price. Likewise, support in this model is only provided if the market price falls below a certain threshold. There are generally two types of CfD models:

Double-sided CfD : Under a double-sided CfD, the project developer is required to compensate the state for the negative difference between the strike price and the market price of the produced electricity. This means the developer always receives the agreed strike price, as the state assumes the downside risk (if market prices fall below the strike price) and the developer assumes the upside risk (if market prices exceed the strike price).

One-sided CfD : This CfD, on the other hand, gives the project developer the right to retain the negative difference between the strike price and the market price. The strike price therefore acts solely as a minimum price that the producer is guaranteed for their energy production. The developer is protected from downward price risk without sacrificing the potential for higher returns.

CfD contracts are typically awarded through auctions, with contracts granted to bidders offering the lowest price.

Examples of CfDs are:

- The support provided to Danish wind turbines, especially offshore wind, since the early 2000s. Among the offshore wind turbine projects that have received support through CfD are Horns Rev 2 and 3, and Anholt.
- Carbon Contracts for Difference (CCfD): Germany has introduced climate contracts to support emission-intensive companies with the additional costs incurred by switching to hydrogen-based technologies. This includes both capital expenditure (CAPEX) and operating costs (OPEX) for companies converting to climate-friendly technologies. This is crucial to ensure that hydrogen technologies are competitive and economically viable for the industry. The basis for this model is that support is given in relation to reduction of greenhouse gas emissions rather than to the amount of energy produced.
- SDE++ (*Stimulering Duurzame Energietransitie*) is The Netherlands' national support scheme that promotes sustainable energy transition by supporting technologies that reduce CO_2 emissions. SDE++ builds on previous support schemes and has been expanded from focusing on renewable energy production to also include CO_2-reducing technologies, such as industrial electrification, heat production, carbon capture and storage (CCS), and PtX. The scheme covers the difference between the costs of green technologies and market prices, and the support varies according to energy prices. Projects are assessed based on their CO_2 reduction per euro invested, which ensures efficient use of the funds.
- *The UK* has used the CfD scheme in its offshore wind tenders since 2014. Offshore wind farms such as Hornsea and Dogger Bank have been tendered under a CfD, where a "strike price"

(target price) ensures a fixed settlement price for the owner of the farm. The 5th auction for CfD in the UK in 2023, which was supposed to award support for up to 5 GW offshore wind, resulted in no bid (Energy Institute, 2023). Instead, support was awarded to 3.7 GW onshore wind and solar energy. The auction's biggest issue was the very low strike price for offshore wind, which was set at £44/MWh (approximately DKK 400/MWh), including grid connection costs. This price was considered insufficient to cover the rising development costs for offshore wind projects, which have been affected by high inflation and higher capital costs. Many developers found it financially unsustainable to bid under these conditions. Following the disappointing result of the 5th auction, the British government has adjusted the strike price to £73/MWh (approximately DKK 650/MWh), i.e. 66% higher than in the previous auction. The adjustment has resulted in 5 GW offshore wind and a total renewable energy capacity of 9.6 GW being allocated, including onshore wind and solar (Energy UK, 2024).

3.2.4 Innovation support and research and development support

This category includes grants for research and development (R&D) of new green technologies. Financial support is provided by national (and European) institutions as non-refundable payments for the project's development and construction phase. The support is typically allocated for capacity building, which means that the financial support is aimed at establishing the physical facilities and technological systems necessary to enable production. This type of support helps cover the costs of construction and establishment but does not necessarily affect the operation or efficiency in the subsequent production phase. The amount of product generated by the project is not directly targeted by the grant, which means that the support does not depend on specific production targets or quantitative output requirements for hydrogen production. The support is thus primarily intended as an investment in infrastructure and technical capacity, rather than a guarantee of the actual amount of hydrogen that will be generated in the long term.

As this type of support directly finances the costs of setting up the facility, it significantly reduces the risk associated with securing the remaining financing. However, it does not address challenges that may exist in relation to market uptake. Also, the renewable energy plant receiving the support must still compete with fossil alternatives, which will have a lower market price unless other financial incentives can contribute to minimizing the price difference between fossil and renewable energy, or create new markets for renewable energy, as seen in e.g. demand-side mandates.

Examples of this kind of support are:

- **The EU Innovation Fund** is one of the world's largest funding programs for the development and demonstration of CO_2-reducing technologies. The EU Innovation Fund supports the deployment and commercialization of new technologies aimed at decarbonising European industry and energy supply. The fund focuses on the market maturation of technologies that can deliver CO_2 emission reductions in line with the EU's climate targets for 2050, while also ensuring European competitiveness. The fund annually provides approximately EUR 5 billion, financed through the EU ETS via the sale of 530 million CO_2 allowances.

- **IPCEI (Important Projects of Common European Interest)**: IPCEI is an EU initiative that supports large strategic projects capable of contributing to Europe's green transition and economic competitiveness. IPCEI funds the capital investments and reduces establishment costs for commercial actors. It does not, however, support operational expenditures. The IPCEI on hydrogen focused on developing a coherent hydrogen network in Europe and promoting technological innovation within green hydrogen and PtX. The program allows for flexibility in granting state aid, even where EU competition rules would normally limit this, on the grounds that these projects are considered to create significant societal value and have the potential to drive green change on a large scale.

- **Projects of Common Interest (PCI)**: PCI is an EU-initiated framework designed to develop and promote cross-border energy infrastructure projects that are crucial for strengthening the energy market and meeting Europe's climate and security of supply targets. The projects are identified by the EU Commission in collaboration with member states and stakeholders. The selected projects become part of the EU's so-called "PCI list", which is updated every two years, and gain access to administrative and financial benefits. To qualify, a project must benefit at least two EU countries and contribute to one of the EU's energy policy objectives: competitiveness, security of supply, sustainability, or integration of the European energy market. PCI projects receive special benefits, including accelerated permitting procedures and financial support from the Connecting Europe Facility (CEF).

- **Energy Technology Development and Demonstration Program (EUDP)**: The EUDP is a Danish support scheme that funds the development and demonstration of energy technologies capable of reducing CO_2 emissions and strengthening Denmark's position in green technology. The program is administered by the Danish Energy Agency and aims to promote technologies that support Denmark's goal of climate neutrality by 2050. The support is primarily given to projects that are in the advanced development and demonstration phases, where the technologies are tested under realistic conditions to validate their commercial viability and effectiveness. Support is typically provided as a grant that cover part of the project costs, helping to reduce the financial risks associated with advanced technology development.

3.2.5 Tariffs

Tariffs for the transport of electricity, CO_2, hydrogen, gas and other energy carriers are crucial to ensure fair and efficient access to infrastructure. These tariffs cover the costs of operation, maintenance and expansion of the networks transporting energy carriers, and they vary depending on the type of energy and the nature of the infrastructure.

Tariffs, which cater for renewable energy products, increase the potential return on investment compared to corresponding investments in fossil-based products.

3.2.5.1 Electricity tariffs

For electricity, tariffs are typically divided into transmission and distribution costs, where transmission systems transport electricity over long distances and distribution systems deliver it locally. Electricity tariffs are often regulated to ensure stability and reliability in the system.

- In Denmark, Energinet has introduced a new model **for system tariffs for electricity transmission,** which entered into force on January 1st, 2024. It entails a significant reduction of 90% in the tariff for consumers who use more than 100 GWh annually. This measure is designed to support large electricity consumers, such as companies involved in PtX and other energy-intensive processes, by significantly lowering the costs of using electricity. Similar tariff models have been introduced in the Netherlands and the UK.

- Many countries have special **grid-connection fees**, which are either reduced or waived for companies investing in renewable energy systems such as PtX. This can support the development of PtX projects by reducing the costs of connecting to the electricity grid, which is crucial for large plants producing hydrogen and synthetic fuels.

- **Hourly electricity tariffs**: In several countries, PtX plants can also benefit from variable electricity tariffs, where electricity is cheaper at times of high production of renewable energy (e.g. from wind or sun). This gives PtX plants the opportunity to plan their energy consumption so to take advantage of low electricity prices, thus making electrolysis cheaper and more profitable.

- **Tariff models for storage and balancing**: PtX facilities may also indirectly benefit from storage and balancing schemes that reduce tariffs on electricity used for energy storage. Since PtX works as a form of energy storage by converting electricity into hydrogen or other energy carriers, existing support schemes and tariffs for storage can function as a form of support.

3.2.5.2 CO_2 tariffs

CO_2 tariffs apply to transport through pipelines in projects involving CCS. These tariffs are set based on the costs of storage and ensure that CO_2 can be transported to storage facilities.

3.2.5.3 Hydrogen and natural gas tariffs

For hydrogen and natural gas, tariffs typically cover both transport and distribution costs and vary depending on the pressure of the pipelines and the nature of the energy carrier. The tariffs can be adjusted in line with the transition to greener energy sources, such as green hydrogen, which requires new pipelines and distribution networks. Overall, these tariffs are essential for ensuring economic balance in energy transport and for guaranteeing equal access for all market participants.

- In Germany, efforts are being made to reduce **gas grid tariffs** for green hydrogen to make the transport of green hydrogen through existing gas pipelines economically attractive. However, no specific tariff models have yet been formally adopted.

3.2.6 Tradable certificates and quota systems

Tradable certificates and allowance systems are market-based mechanisms designed to reduce environmental impacts, such as CO_2 emissions, by putting a price on pollution. In a quota system, such as the EU ETS, the principle is that companies must purchase allowances (permits to emit CO_2) to cover their emissions. In some sectors, companies are allocated a limited number of free allowances. If a company reduces its emissions, it can sell excess allowances to other companies, which creates an economic incentive to invest in green technologies.

Tradable certificates work in a similar way and cover areas such as renewable energy. Certificates can be issued for the production of green energy, where energy producers can sell the certificates to other companies using them to meet their sustainability targets. These mechanisms promote cost-effective environmental solutions by rewarding those who reduce their environmental footprint and creating a market-based approach to sustainable development.

Tradable certificates and allowances increase revenues for RE projects and thus the return. However, the mechanism can also increase the complexity of price formation, as new markets can emerge where current or future prices are unknown. Moreover, asymmetric information may arise between producers and buyers regarding what the market price should be. This can make it difficult to reach agreement on the offtake of certificates and allowances at a sufficiently early stage, which is typically necessary to secure financing for RE projects.

Examples of relevant regulation in this category are:

- ***EU ETS:*** The system is the world's largest allowance trading system and aims to reduce greenhouse gas emissions in a cost-effective way. The system was established in 2005 as a central tool for achieving the EU's climate targets and is designed to reduce emissions by setting a price on CO_2. The EU ETS covers sectors such as energy, heavy industry and commercial aviation within Europe and regulates over 11,000 plants, which together account for around 40% of the EU's total greenhouse gas emissions. Under the EU ETS, companies must cover their emissions with a corresponding number of allowances, i.e. one allowance corresponds to one tonne of CO_2 emitted. If a company emits less than expected, it can sell its surplus allowances to others, while companies that emit more must purchase additional allowances on the market. This market-based approach creates an economic incentive to reduce emissions, as companies can achieve savings by minimizing their need for allowances.

  The allowance volume is reduced annually through a linear reduction factor, decreasing the total number of allowances over time and creating a tighter market. The EU ETS has also implemented a "Market Stability Reserve" to stabilize the allowance price by adjusting the supply of allowances during periods of price volatility. In recent years, the CO_2 price has risen significantly, increasing the incentive for companies to invest in green technologies .

As part of the EU's ambitious "Fit for 55" package, the goal is to achieve a reduction of at least 55% in greenhouse gas emissions by 2030. Under this package, the EU ETS is being gradually expanded to include several sectors, including maritime transport. As of January 1st, 2025, EU ETS2 has come into force. EU ETS2 is a quota system for fuel suppliers in the construction sector, road transport and additional sectors currently not covered by the existing EU ETS. EU-ETS2 will be fully implemented with allowance prices by 2027.

- ***Danish CO_2 displacement requirement in the transport sector:*** The Danish CO_2 displacement requirement limits the CO_2 intensity of fuels sold for road transport. It also allows for trading of compliance, providing a financial incentive for actors who use 100% renewable energy in their fuels.

- ***Guarantees of Origin (GOs):*** Trading of GOs creates a market-based mechanism for the certification of renewable energy, giving consumers the opportunity to choose and pay for green energy. GOs are certificates which confirm that a given amount of energy – typically one megawatt-hour (MWh) – has been produced from renewable sources, such as wind, sun or biomass. Each certificate can be sold and traded separately from the energy itself, which makes it possible for end-users, companies and public entities to purchase GOs to document that their energy consumption originates from renewable sources, even if they technically use e.g. electricity from the general grid or gas from the gas network.

  When a company or customer purchases GOs, they can "redeem" them to document their green consumption. For example, a company that uses gas for heating can show that their gas consumption is CO_2 -neutral through the biogas GOs it has purchased.

  Regulatory mechanisms, such as the RED, gives GOs value by generating demand through legislative requirements and sustainability targets. National energy authorities regulate the issuing and trading of GOs and ensure that the certificates can only be used once, so that double counting is avoided. Furthermore, many countries have implemented minimum requirements for the use of renewable energy, further increasing the demand for GOs.

  This creates value for energy producers, who can earn additional revenues through the sale of GOs, while also supporting the green transition by attracting investment into renewable energy projects.

- ***FuelEU Maritime:*** The regulatory framework behind FuelEU Maritime gives value to certificates by setting binding targets for emission intensity. As ships must gradually achieve lower emissions, the regulation creates a market demand for certificates among those who may find it difficult to transition to green fuels at the same pace. These certificates can be sold and bought, and the value is adjusted based on supply and demand, just like in traditional quota systems such as the EU ETS. This mechanism motivates ship operators to invest in green technologies and fuels, as compliance can result in financial benefits from the sale of surplus certificates, while the whole sector simultaneously moves towards the EU's climate targets.

3.2.7 Loans and guarantees

Public loans and guarantees play a central role in promoting investments in RE and PtX technologies by reducing financial barriers. By offering favourable loan terms and risk hedging, state institutions and international financial organizations can support companies in realizing green energy projects.

- **Denmark's Export and Investment Fund (*Danmarks Eksport- og Investeringsfond*, EIFO)** is a state-owned financial institution established in 2023 through the merger of the Danish Growth Fund (Vækstfonden), EKF Denmark's Export Credit Agency (EKF) and the Danish Green Investment Fund (Grønne Investeringsfond). EIFO's purpose is to strengthen the growth of Danish companies and promote the green transition through financial solutions. The fund offers loans, guarantees and equity investments to companies within green technologies, including PtX. By reducing risk through guarantees, EIFO makes it easier for companies to obtain loans on favourable terms.

- **The European Investment Bank (EIB)** is the EU's financing institution supporting projects that contribute to the EU policies on climate targets and sustainable development. The EIB provides loans, guarantees and technical assistance for both public and private projects within renewable energy and innovation. The bank can finance large-scale energy projects in Denmark and other EU countries, thus promoting the development of green fuels and technologies. The EIB has committed to increasing its investments in climate-related projects to at least 50% of its portfolio by 2025.

By reducing financial risks and offering favourable financing terms, loans and guarantees from e.g. EIFO and EIB make it more attractive for private actors to invest in renewable energy. This contributes to realizing national and European climate targets and supports the development of sustainable energy systems.

3.2.8 Public offtake guarantees and risk reduction

Another mechanism through which the state can promote the production and purchase of green technologies is by offering public offtake guarantees, which reduce financial risk for producers. By securing long-term agreements on the purchase of green fuels, the state can help producers obtain the necessary financing and investment.

- **Germany's H2Global initiative:** Germany has introduced the H2Global initiative, a mechanism designed to promote the market for green hydrogen and PtX products. In brief, the H2Global initiative includes the following elements:
  - *Long-term purchase contracts:* The state, through an intermediary entity, enters into long-term purchase contracts with producers of green hydrogen and PtX fuels. These contracts provide producers with security through a guaranteed buyer over an extended period of time, typically 10 years.
  - *Short-term sales contracts:* The purchased green hydrogen and PtX products are then sold on the European market through short-term contracts at prevailing market prices. Buyers may include industrial consumers, the transport sector, or the energy sector.
  - *Price difference covered by the state:* The difference between the higher purchase price and the potentially lower selling price is covered by the state through subsidies. This is financed by the German government with an initial budget of approximately EUR 900 million.

  The H2Global scheme can reduce risk for producers by securing them long-term agreements, making it easier for them to obtain financing and investment, as they have a guaranteed offtaker for their products. By absorbing the price difference, the state supports the development of the market for green hydrogen and PtX products until these technologies mature and become competitive without support.

  The H2Global initiative is an example of how the state can reduce market risks and price uncertainty for producers of green fuels. By taking on the role of intermediate buyer and seller, the state stabilizes the market and promotes investment in the production of green hydrogen and PtX products, as well as shifting part of the risk from producers to the public sector.

  This model can serve as inspiration for other countries, including Denmark, that wish to promote the development of new technologies within renewable energy, where the market is still immature. By offering similar offtake guarantees or contractual mechanisms, governments can reduce financial barriers and accelerate the deployment of green technologies.

How can economic incentives contribute to solving the barriers to private investment?

Economic incentives can play a decisive role in addressing some of the most pressing barriers to increased investment in the green transition.

Public support schemes, both in the form of production support and R&D support, are an important tool for addressing barriers such as:

- ***Lack of maturity and scaling of new green technologies:*** where R&D support in particular helps to mature technologies, create documented results and increase technical credibility towards investors.
- ***Market volatility:*** where production support – especially through CfD models – ensures stable framework conditions and makes investments more commercially viable.
- ***High capital requirements in the early stages:*** where various support schemes as well as loans and guarantees can help reduce the initial financial burden and create attractive conditions for private investment.

In the ***latest Danish offshore wind tender based on zero support***, where the state both required fixed concession payments and to be a co-owner of 20% of the projects, lack of support reduced the interest of the developers, who had to bear a greater part of the financial risk without receiving financial compensation. By introducing more flexible conditions, such as the possibility of bidding for either support or concession payments, the state can reduce investors' perceived risk and make the projects more attractive.

It should also be noted that long-term support schemes contribute to increasing investor confidence, just as seen in the biogas industry, by reducing ***unpredictability in regulation*** and thereby giving investors certainty in their planning.

Moreover, market-based mechanisms, such as guarantees of origin and CO_2 allowances, create additional incentives by rewarding investments in green solutions. Revenues from trading can increase projects' financial robustness, thereby making them more attractive to private financial actors.

3.3 Mechanisms: Public investment and procurement

Public investment and procurement are effective mechanisms to promote the production and uptake of green technologies. By leveraging the state's financial resources and purchasing power, public institutions can stimulate the development and implementation of renewable energy solutions. Through investments in critical infrastructure and targeted procurement of sustainable products and services, the state can reduce its own environmental impact and create favourable market conditions, making it economically attractive for private actors to invest in and use green technologies. Public investment can play a role in risk-sharing with private investors and ensure that projects are developed in accordance with national energy policy goals and societal interests.

By focusing on investments in infrastructure, which function as natural monopolies, governments can create the necessary framework for private actors to invest in production facilities such as offshore wind and PtX. Conversely, announcements of public investments in energy infrastructure, such as energy islands and hydrogen networks, can also create uncertainty in the market until final investment decisions for the public infrastructure are made.

3.3.1 Public investment in infrastructure

Public investments in infrastructure are crucial for establishing the physical framework that enables the production, distribution and uptake of renewable energy and PtX technologies. The state typically focuses on infrastructure classified as natural monopolies, where private investment may be insufficient or unviable.

By making public transport infrastructure available, it is ensured that the producers of renewable energy are connected to offtakers. This creates a larger market, enabling higher prices to be obtained. At the same time, transport costs for the individual operator are also reduced. Taken together, public transport infrastructure can contribute to significantly increasing the risk-adjusted return on investment.

3.3.1.1 Development of hydrogen networks and the European Hydrogen Backbone

Public investments in hydrogen networks, such as the hydrogen transmission and distribution network, are essential to facilitate the transport of hydrogen from production sites to offtakers in the industry and the energy sectors. By establishing an extensive network of hydrogen pipelines, the state can support the development of an efficient and integrated hydrogen economy.

A central initiative in this context is **the European Hydrogen Backbone** (EHB), a project launched by a group of European gas transmission system operators (TSOs). The EHB plan aims to develop a pan-European hydrogen network by repurposing existing natural gas pipelines to hydrogen transport and building new pipelines where necessary. The goal is to create a coherent network across Europe, which can connect areas with great potential for hydrogen production with offtakers throughout the region.

In **Denmark,** Energinet is working on developing national hydrogen grid plans, which are compatible with the EHB. By repurposing the existing natural gas infrastructure for hydrogen transport, Denmark can become an important part of the European hydrogen network. This will not only support the national transition to green energy but also enable the export of green hydrogen to other European countries. The Danish H2 backbone is elaborated further in section 5.3.5.

Germany is also actively involved in the development of the hydrogen network and cooperates with neighbouring countries to integrate their infrastructure into the EHB. By investing in hydrogen transmission networks, Germany ensures access to both nationally produced and imported green hydrogen, which is essential for decarbonising its industry and energy sectors. The German H2 hydrogen infrastructure is discussed further in section 5.3.4.

Public investments in hydrogen networks are often necessary, as the establishment of the transmission and distribution network is considered a natural monopoly. Therefore, the state or state-owned enterprises play a central role in the planning, financing and development of these networks to ensure efficiency, standardisation, and fair access for all market participants.

By participating in projects such as the EHB, Denmark and other countries can benefit from a coordinated effort that accelerates the development of hydrogen networks, reduces costs through economies of scale, and promotes the integration of the European energy market. This supports the common goal of reducing greenhouse gas emissions and creating a sustainable energy future for Europe.

In Denmark, approximately DKK 15 billion has been allocated to allow the state-owned company Energinet to invest in hydrogen networks. This corresponds approximately to the cost of establishing a 280 km of hydrogen network, including pipelines, metering and regulation (M/R) stations, connection points, etc.

3.3.1.2 Establishment of CO_2 networks

Public investment in CO_2 infrastructure is essential to enable the transport and storage of carbon dioxide, supporting both Carbon Capture and Storage (CCS) and Carbon Capture and Utilization (CCU) technologies. By establishing a network for the transport of CO_2 from point sources to storage sites or utilisation facilities, the state can facilitate significant reductions in greenhouse gas emissions and promote the development of a circular economy.

In Denmark, it is primarily Evida, the state-owned gas distribution company, which is responsible for the development of the CO_2 infrastructure. Evida plans and establishes the necessary CO_2 pipelines and associated infrastructure to transport captured CO_2 from industrial emitters to underground storage sites or to be used in industrial processes. This involves both the reuse of existing gas pipelines and the construction of new pipelines where required.

CO_2 transmission infrastructure, such as pipelines, is considered a natural monopoly due to the high fixed costs and inefficiencies associated with having parallel, competing networks. Public investment and ownership are therefore often necessary to ensure the development of this critical infrastructure in an efficient and coordinated manner. The state can ensure that the infrastructure is accessible to all relevant actors on fair and non-discriminatory terms, thereby promoting competition in the CO_2 capture and utilisation market.

3.3.1.3 Energy islands

Denmark plans to build energy islands in the North Sea and the Baltic Sea, which will collect and distribute electricity from large offshore wind farms. These energy islands are designed to enable large-scale integration of renewable energy into the energy system and act as central hubs handling significant amounts of electricity. By centralizing the infrastructure, the need for individual cables to land can be reduced, potentially reducing costs and minimising the environmental impact on the seabed. The energy islands also provide the opportunity for the integration of PtX technologies, where excess electricity can be converted into green fuels such as hydrogen, which can support energy storage and be used in sectors that are difficult to electrify directly. State investment in the energy islands is under consideration due to the scale and complexity of the projects, as well as the need to manage natural monopolies within transmission infrastructure. In addition, state involvement can facilitate coordination with international partners, promote economic growth and job creation as well as ensure environmental responsibility in the development of the energy islands.

Considerations around the energy islands include both the potential to advance the green transition through increased renewable energy production and the economic and technological challenges associated with such extensive projects. Public investments in the energy islands can therefore be considered a way to support the development of renewable energy on a large scale and contribute to Denmark's and Europe's climate goals, while at the same time taking economic and environmental aspects into account.

The financing of the energy islands is planned to be based on a combination of public and private investment, which reflects the project's large scale and complexity. The Danish state plans to own at least 50.1% of the energy island in the North Sea, which ensures state control and influence on the project's development. The rest of the financing is expected to come from private investors through public-private partnerships (PPP).

3.3.1.4 Import terminals and port facilities

In order to meet the need for imports of green hydrogen and PtX products, the state can invest in import terminals and upgrading port facilities.

Germany expects to import up to 70% of its hydrogen needs by 2030 and has launched initiatives to establish import channels from countries such as Norway and North Africa.

3.3.2 Public procurement

Public procurement is an important tool for creating demand for green technologies and sustainable solutions. By prioritizing the purchase of products and services with a low environmental impact, the state can influence the market and promote innovation. If public procurement contracts are structured as long-term agreements, it can reduce risks for the producers and for those financing the facilities.

- **Procurement of hydrogen-powered vehicles for public fleets:** Public authorities can purchase hydrogen buses, trucks, or service vehicles for use in municipal services and public transport. This reduces emissions and supports the development of the hydrogen networks by creating a stable and long-term demand.
- **Purchase of green electricity and use of PtX fuels in public services:** Governments can commit to purchasing electricity produced from renewable energy sources for use in public buildings and facilities. In addition, the use of PtX fuels can be promoted in public vehicles and equipment, such as service vehicles, emergency generators and other machines. This stimulates the market for renewable energy and supports producers of green fuels.
- **Public tenders with green criteria:** By including environmental requirements and criteria in public tenders, governments can promote the use of PtX-based products and services. For example, requirements for the use of synthetic fuels or green hydrogen in industrial processes or heating can be included in the tender material.
  Collective purchasing arrangements: Public institutions can cooperate to buy renewable energy or PtX products in larger quantities and on long-term contracts, which can reduce the risks for producers of renewable energy and PtX fuels.

How can public investment and procurement contribute to solving the barriers to private investment?

Public investment and procurement are crucial to overcoming several of the barriers that inhibit private investment in green technologies.

Investments in renewable energy infrastructure projects such as energy islands, electricity, hydrogen, and CO_2 transmission networks can have a major positive effect on the Danish economy.

State investments in these projects can play a significant role in removing *uncertainty about future infrastructure*. By investing in infrastructure projects, *the state can share the risk with private actors and cover* some of the *high capital requirements.* This creates a more favourable investment climate, where the private sector and the public sector jointly manage the investment risks inherent to these projects.

Although it is crucial that the state actively engages in the co-financing of infrastructure, private actors also demand sufficient flexibility to be able to run and develop the projects, e.g. in connection with energy islands. Excessive state influence can raise doubts among private lenders or investors regarding the decision-makers and the decision-making ability within the project. Such a risk to project progression can reduce the willingness to get involved in these projects.

Public procurement is also an effective method to stabilize the market and create demand for green technologies, thereby addressing *the uncertainty about offtake* of these. Long-term public contracts for green products, such as hydrogen-powered vehicles to public fleets, reduce risk for producers and make it easier for investors to predict future revenues. At the same time, collective purchasing arrangements, where public institutions buy renewable energy or PtX products in larger quantities, can create volume and stability in the market, making such investments more attractive.

4 Offshore wind tender models

This section provides a thorough review of the tender models used in connection with offshore wind projects, with a particular focus on Denmark. Tender models are crucial for how offshore wind projects are financed and implemented, and different approaches can be applied.

The section will describe the various auction forms that can be implemented in Danish offshore wind tenders, as well as the support schemes associated with the projects. In addition, it will be discussed how these models can affect both the investors' incentives and the long-term development of the offshore wind sector in Denmark.

4.1 Establishment of offshore wind farms

In Danish waters, offshore wind turbines can only be established after a tender by the owner of the seabed - the Danish state. This is also common international practice.

Prior to a tender, the Danish government identifies the areas that are suitable for the establishment of offshore wind farms. Suitability is assessed, among other things, based on conditions on the seabed, sea depth, the area's wind resources and environmental studies. The identified areas are then put out to tender in an open process, where companies interested in developing offshore wind farms can bid with a project that they believe is profitable.

The tender material, which is issued by the Danish government, sets out a number of requirements that must be for a bid to be considered. Some of the central requirements set out in the tender documents may include:

- **Capacity and production requirements:** Specifications for how much production capacity must be installed in the tendered area.
- **COD requirement:** COD stands for Commercial Operation Date, referring to the deadline by which the park must be fully constructed and delivering its first power and/or full capacity.
- **Connection requirements:** Requirements regarding when and how the connection to the grid must be completed, as well as who will bear the costs of that connection.

The above is not an exhaustive list, and requirements may also be included in a different way than described above. In addition to this, there may also be qualification criteria that must be met in order for the bid to be considered at all. For example, in the most recent Danish offshore wind tender, developers were required to submit ESG reports and verified environmental product declarations for central technical components (see the green box under 4.5).

4.2 Auctions and evaluation criteria

The government's tender material is made public through an official auction. It is thus open for anyone to bid with projects that can meet the requirements set by the state in the tender documents. In the past, it was not common to bid through auctions; instead, agreements were concluded directly with developers.

The transition from non-auction-based tender systems to auction-based tender systems has been largely driven by the proven success of auctions as the most efficient method for the delivery of new offshore wind installations. Government-controlled auctions are today the leading tender design for the deployment of offshore wind. Auction-based tenders have gained momentum since governments across Europe realized that the deployment of wind energy will be central to meeting both the EU's and national climate targets. In Europe, offshore wind has seen its strongest growth in markets where auction-based tendering systems have been chosen.

The bids that come in through the auction round are assessed based on the criteria set out in the tender documents. In Danish tenders, it has typically been the price at which electricity can be produced to be the decisive factor. Examples of criteria that may be used to determine the winner of the auction round include:

- **Price (CfD and/or selling price):** The price at which the electricity can be produced, or the amount of support required from the state to make the project economically viable.
- **Profit sharing model:** A potential profit for the state is introduced if the developer achieves a certain level of profit from their activities.
- **Non-monetary aspects:** This includes various factors such as the plan for integrating the production from the new plant into the existing energy system, as well as specific social or sustainable initiatives unique to the project.

The government outlines a number of conditions in the tender documents that must be met in the project a developer bids on. These conditions can range from requirements for established capacity and commissioning time to whether the developer must pay a concession fee to the state or receives subsidies from the state.

As illustrated by the IJmuiden Ver-case from the Netherlands (described in 5.1.3), this tender also included evaluation criteria such as planned system integration and sustainability.

Previously, there was also an option for developers to establish offshore wind farms without prior government tenders. It happened under the so-called "open door" scheme. Under this scheme, a developer could apply for permission to build a renewable energy plant with specifications in terms of capacity and location, defined by the developer himself and based on a profitable business case. The developer was to bear all costs, and profits from the project also accrued to the developer. In February 2023, however, the "open door" scheme was put on indefinite hold, reportedly due to concerns from the Danish authorities that the scheme may violate EU state aid rules. In December 2023, the scheme was officially closed. Two projects that had been approved while the "open door" scheme was still in operation were however exempted and, as of late 2024, given the green light to proceed. These include a project in Jammerland Bay owned by European Energy and a project in the southern Little Belt owned by TotalEnergies and European Energy.

4.3 Subsidy models in offshore wind tenders

A central element of the tender process is designing the form and scope of a potential subsidy for energy production. Key models are described below. In practice, these models can be applied either in pure form or in combination to achieve the desired results. For example, the agreements may be designed to generate the most possible revenue for the state while still providing subsidies to companies, while other models may focus solely on generating state revenue.

Concession models can generally be structured according to two overarching principles:

1. **Production-dependent payments**. These can be further divided into:

   - **Models with fixed production-dependent payments:** In this concession model, payments between the parties are based on the volume of electricity produced (kWh). Whether the state or the company makes the payment depends on whether the company bids a negative or positive price in the tender process, which is then incorporated into the concession agreement. With zero bids, no payments are made. If the state makes a payment, it is considered a production subsidy; if the company pays the state, it is referred to as a concession fee. In the case of state subsidies, these take the form of FiTs or FiPs as described in sections 3.2.3.1 and 3.2.3.2.
   - **Models with variable production-dependent payments:** This concession model is characterized by the fact that the company and the state enter into a contract for difference (CfD), where payments between the parties depend on the market price for electricity. This model is described in more detail in section 3.2.3.3.

2. **Production-independent payments**. These can be further divided into:

- **Models with one-off payment**: Under this concession model, the company makes a one-off payment to the state prior to using the designated offshore area.
- **Models with periodic payments**: Under this model, payments between the parties are made over a period specified in the concession agreement. The periodic payments may be either fixed or variable. In the most recent Danish offshore wind tender, described below, companies were required to submit a bid for a fixed annual concession payment, indicating what they would pay the state over a 30-year period in return for the right to use the offshore area.

For each offshore wind farm, any production subsidy is determined through the tender process, meaning that the settlement price varies between different offshore wind farms. The difference between the fixed settlement price and the prevailing market price at any given time constitutes a price premium, which the state uses to support the offshore wind farm. This premium is granted during the support period defined in the tender. Once this period expires, the electricity must be sold at the market price without any price premium.

Denmark has held several offshore wind tenders with an auction and containing a production-dependent support mechanism. The respective support amounts are shown in Figure 4-1 below.

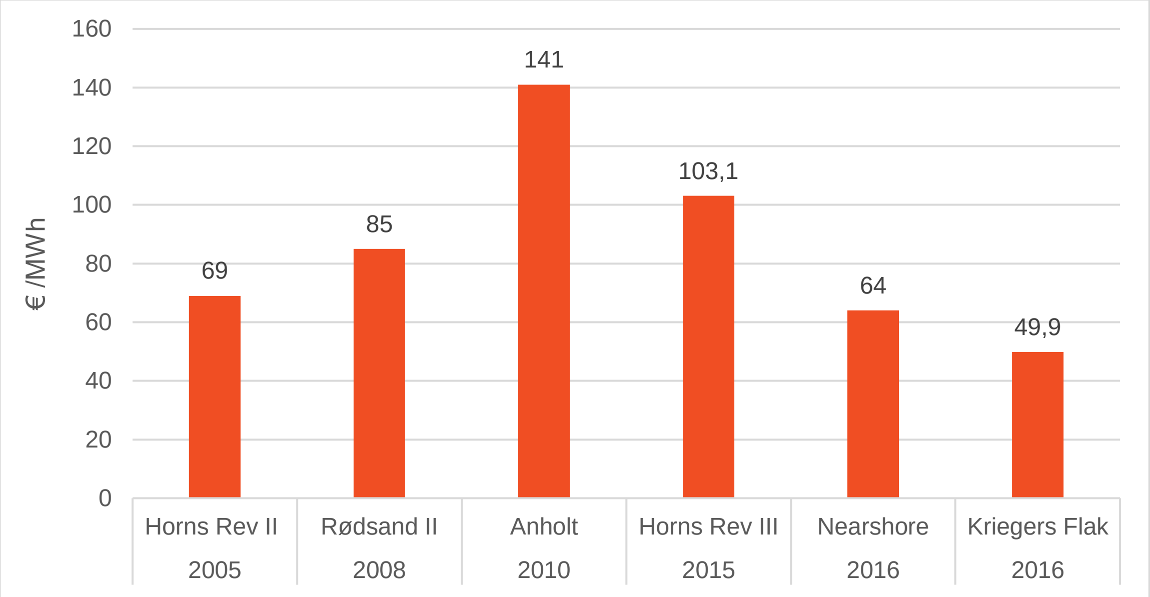

Figure 4-1 Strike price in the Danish offshore wind tenders 2005-2016. Source: (Danish Energy Agency, 2022)

There have also been cases of concession models without state support - so-called zero-subsidy models - in which companies do not receive financial support for the electricity they produce but instead, pay the state for the right to build and operate the offshore wind farm (concession). An example of this is IJmuiden Ver Alpha and Beta in the Netherlands, where the developers won the right to develop the projects without being granted any production support for the electricity.

Another relevant case is the Thor offshore wind farm in Denmark, which was originally planned as a two-sided CfD model. However, following the tender round, it became clear that the project could be realised as a zero-subsidy project, as several zero bids were submitted in the round. The winning bidder (RWE) has therefore entered into a concession agreement in which they pay the state for the right to construct the wind farm, without receiving any production support from the state for the electricity generated by RWE.

4.4 The concession agreement

When a tender round has been completed and a winner has been found, the winning company and the state enter into a concession agreement. This agreement grants the company the right to carry out a specific activity, for example, to use a designated offshore area for the production of offshore wind energy. The agreement is entered into once the tender process has ended and the winning bid has been selected. In the agreement, the developers commit to fulfilling the requirements set out in the tender documents, as well as the commitments they themselves made in their bid.

The agreement also includes any sanctions that may be imposed on the developer if the state's conditions are not met. These may include penalties or termination of the agreement.

4.5 Concrete examples of national offshore wind farm tenders

Over recent years, several tender rounds have been held for the development of offshore wind farms across Europe. The most recently completed one was in Denmark, with an application deadline of December 5th, 2024.

At the deadline, no developers had submitted project proposals for one of the three tendered offshore areas. Developers cited the inability to achieve a commercially viable investment under the current tender conditions as the primary reason for not submitting bids. The Danish Ministry of Climate, Energy and Utilities is currently examining the barriers identified by the developers to gain a deeper understanding of the challenges associated with this specific tender round.

Developers' primary reasons for not bidding include:

- **Capacity requirements:** The framework was deemed too restrictive in requiring a minimum capacity of 1 GW to be met.
- **High costs of grid connection:** Developers were expected to finance costly CAPEX components such as transformer stations and export cables to the transmission grid. This is in contrast to practices in, for example, Germany and the Netherlands, where these costs are not imposed on developers (see Table 4-1). Depending on the park design and location, these costs can account for up to 15% of the total CAPEX of constructing an offshore wind farm.
- **State co-ownership:** The requirement for 20% state ownership caused concern among developers about political influence and slow decision-making processes.
- **Zero-subsidy regime:** It was not possible to develop a commercially viable electricity production project under the zero-subsidy regime set out in the tender.
- **Strict penalty mechanisms**: The risk of heavy penalties for non-compliance with guarantee requirements made the investments too uncertain relative to the expected return.
- **Lack of clarity about hydrogen infrastructure**: Delays and continued lack of clarity regarding the establishment of Danish hydrogen infrastructure - considered by many to be essential for supporting the business case for offshore wind - were also highlighted as a key concern.

In addition, several stakeholders pointed out that macroeconomic factors, such as high interest rates and rising prices for raw materials and components, have had a negative impact.

The box below contains a detailed description of the tender.

Latest Danish offshore wind tender - Denmark's largest offshore wind tender in history

As a follow-up to *the Supplementary Agreement on Tender Frameworks for 6 GW offshore wind and Bornholm Energy Island* from May 2023 (The Danish Government, 2023), the Danish Energy Agency launched a tender in April 2024 aimed at enabling the development of at least 6 GW offshore wind capacity, to be completed by 2030. The tender covered six sites in the following areas:

- North Sea I: Minimum 3 GW. This is distributed over three areas of at least 1 GW each.
- Kattegat: Minimum 1 GW
- Kriegers Flak II: Minimum 1 GW
- Hesselø: 0.8-1.2 GW

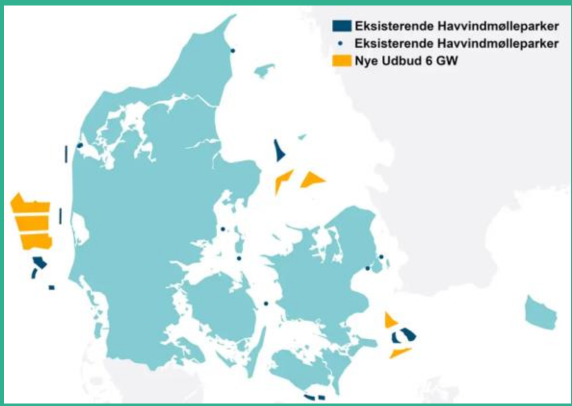

Image from the Danish Energy Agency and Ministry of Climate, Energy and Utilities.
Blue: Existing OWF. Orange: New tender 6GW.

In addition to the 6 GW, bidders were allowed to overplant within the tendered areas - except for the Hesselø area. Overplanting refers to the right of the winning bidder to install more turbines than the minimum required on the allocated site. If bidders made use of this flexibility to optimise spatial use, the total potential capacity could reach up to 10 GW.

The 6 GW offshore wind capacity was tendered without subsidies. Bidders were required to submit a fixed annual concession payment, stating what they would pay the Danish state over a 30-year period for the right to use the offshore area. The winning bidder would gain the right to develop offshore wind on the site. Additionally, the Danish state would hold a 20% ownership share in each of the six upcoming offshore wind farms.

The *Supplementary Agreement on Tender Framework for 6 GW Offshore Wind and the Bornholm Energy Island* also introduced a set of new eligibility requirements for participating in the tenders, aimed at raising the bar for sustainability and social responsibility compared to previous rounds. These included the obligation to obtain third-party verified environmental product declarations for main components - such as blades and towers - based on a life cycle analysis, as well as compliance with social clauses designed to prevent social dumping, ensure respect for human rights and international conventions, and require the use of a certain number of apprentices. The purpose of these new eligibility criteria was to ensure that all bidders met the same high standards for sustainability.

The application deadline for the three sites in North Sea I was December 5th, 2024, while the deadlines for the sites in Kattegat, Kriegers Flak II, and Hesselø were set for April 1st, 2025. However, since no bids were received for the three North Sea I areas by the December 5th deadline, it was subsequently decided to cancel the tender for the remaining three sites.

Danish offshore wind tenders are designed by the national authorities. Similarly, tenders in other countries are developed by the respective national authorities, which creates international competition between countries to attract strong bids. When comparing European offshore wind tenders conducted in recent years, both similarities and significant differences in tender conditions can be observed (Table 4-1). The outcome of a tender round is the result of developers' assessment of whether a commercially viable project can be realised under the given tender conditions and surrounding circumstances, such as the global economic situation and the availability of necessary materials through international supply chains.

Table 4-1 Comparison of central tender conditions in European tenders for offshore wind in 2024. Source: Frontier Economics.

	Netherlands (Mar 2024)	Norway (Mar 2024)	Germany (Jun 2024)	Germany (Aug 2024)	Denmark (Dec 2024)	United Kingdom (2023-2024)
Tendered capacity	4 GW (in two areas)	1.5 GW	2.5 GW (in two areas)	5.5 GW (in three areas)	3 GW (in three areas)	4.9 GW
Tendered product	The right to use the seabed, which has been investigated in advance	Production subsidy for already investigated seabed	The right to use the seabed, which has **not** been investigated in advance	The right to use the seabed, which has been investigated in advance	The right to use the seabed, which has been investigated in advance	The right to use the seabed, which has been investigated in advance
Network connection*	Paid by provider	Winner's cost	Paid by provider	Paid by provider	Winner's cost	Winner's cost
Subsidy form	No subsidy	Two-sided CfD	Premium	No subsidy	No subsidy	CfD
Award criteria	Highest payment to the state wins (15%) Other Qualitative criteria (85%)	CfD price. The bidder with the lowest CfD subsidy requirement wins (100%)	Subsidy need. Lowest subsidy need through premium wins (100%)	Highest payment to the state wins (60%) Other Qualitative criteria (40%)	Highest payment to the state wins (100%)	CfD price. The bidder with the lowest CfD subsidy requirement wins (100%)
Warranty and sanctions	100 million euro/GW. The developer has 6 years to commission the facility. Exceeding this limit costs EUR 10-40 million/month.	Will be determined individually per tender agreement	200 million euro/GW. Scale of fines for delays unknown. Cap corresponds to warranty.	200 million euro/GW. Scale of fines for delays unknown. Cap corresponds to warranty.	200 million euro/GW. Activated for delays with gradual increase over 3-4 years, which may result in termination and an overall fine over the guarantee.	No guarantee or fine, but any significant delay disqualifies for participation in future tenders within the same area.
Result	Agreements concluded with Zeevonk and Nordzeeker.	Agreement concluded with Ventyr.	Agreement concluded with TotalEnergies.	Agreements concluded with RWE and Waterekke Energy.	No agreements.	6 agreements concluded.

*Network connection includes costs for export cables and bringing electricity to land, and in most cases also offshore substations.

As can be seen from Table 4-1, the Danish tender was the only one in 2024 that failed to attract any bids, which—according to public statements—was due to the reasons mentioned above. This outcome highlights the importance for Danish authorities to take into account the varying market conditions between Denmark and other countries in the region and to design tender rounds accordingly. For example, in terms of grid connection and flexibility in design criteria, developers should be allowed to configure renewable energy installations in the most economically viable way.

In addition to the parameters in Table 4-1, there are also differences in the cost of delays in delivering the desired output from projects. This was specifically one of the key uncertainties raised by developers in the recently concluded Danish tender. In an international comparison, these potential penalties are relatively high in Denmark. A similar level is found in the Netherlands, whereas developers in Germany and the UK face less severe consequences in the event of delays or, in the worst case, cancelled projects. In the UK, there is no financial penalty for cancelling a project; however, the developer is disqualified from participating in the next tender round.

There have been previous instances of tenders not attracting any bids. This was the case in the UK's tender round concluded in September 2023. At the submission deadline, no bids had been received from developers. The reason given was that the embedded CfD price was too low. The authorities had set a CfD cap of £44/MWh, and based on previous rounds, it was expected that developers would compete to offer even lower prices. Thus, the final CfD price per project was expected to be below the £44/MWh cap. However, this turned out not to be the case. According to the developers, cost developments had made offshore wind more expensive to establish, making it impossible to deliver profitable projects at the offered CfD level. Consequently, no bids were submitted. The UK authorities then relaunched the areas with a new CfD cap of £73/MWh. This resulted in a successful round which, in early September 2024, led to the announcement of contracts totalling 4.9 GW bottom-fixed offshore wind, across six contracts at CfD prices between £54/MWh and £59/MWh. Additionally, one contract was awarded for floating offshore wind, at a CfD price of £140/MWh.

The UK tender did not include the cost of grid connection, which is otherwise a requirement in the Dutch and German tenders.

Looking further back, there have also been successful Danish tenders under zero-subsidy conditions. In the Thor tender (see also 5.1.2), concluded in December 2021, it was possible to conclude a concession agreement with the German developer RWE. Similar to the most recent tender, the Thor model required the private developer to take on a relatively large share of the risk associated with developing the renewable energy installation. The model also included a concession payment from RWE to the Danish state.

This was a model that worked for RWE under the macroeconomic conditions prevailing at the time. However, since then, many changes have occurred in the geopolitical and macroeconomic landscape, affecting the conditions for developing offshore wind. As a result, both the costs of establishing offshore wind farms, supplier security, and the electricity markets in which the power is to be sold have been affected. The uncertainties associated with offshore wind projects have grown significantly in the time between the Thor tender and the most recent round. Part of the explanation for the different outcomes lies in the fact that developers can no longer bear all the increased risks associated with development projects on their own. There is thus a need for the state to take on a greater role in risk-sharing under these new realities.

When the Danish state launches offshore wind tenders, it is therefore crucial that it considers the project-specific and macroeconomic conditions and risks developers must assume during the course of the tender process.

5 Selected case studies

This chapter presents a number of selected case studies covering projects across geographies and technologies within the green transition. The case studies are divided into three main categories: *established technologies*, *new technologies,* and *infrastructure*. Established technologies include those that are already commercially available and widely deployed - such as offshore wind, onshore wind, solar energy, biogas, and batteries. These technologies tend to be well developed and have reached a degree of market maturity. New technologies cover more innovative and forward-looking solutions such as Power-to-X (PtX), direct air capture (DAC), and carbon capture and storage (CCS). These are at various development or deployment stages, facing ongoing challenges related to scale, integration, and financing. Infrastructure includes the critical systems that support the green transition - such as electricity interconnectors and hydrogen networks - which are essential for connecting and distributing green energy across borders, and which often require significant coordination and investment shared among countries.

The cases illustrate whether the identified barriers to increased investment in green technologies have either been overcome or have proven challenging to address. Through this diversity of projects, the purpose of this chapter is to gain a broad insight into the factors that can promote or hinder the implementation of sustainable solutions.

In addition, the case studies focus on the financing models used in each project. Many of these are closely linked to the financing mechanisms, which were reviewed in Chapter 3 and provide concrete examples of how these models can be used in practice.

In many instances, private financing is combined with public support, underscoring the importance of robust public–private partnerships. As shown particularly in the successful projects, such partnerships are often crucial for securing sufficient capital, reducing investment risk, and establishing the necessary framework conditions for project success.

5.1 Established technologies

5.1.1 Offshore wind: Hornsea 2 (UK)

Project description

Hornsea 2 (Ørsted, 2024) is an offshore wind project, located 89 km off the Yorkshire coast in the North Sea. The project was officially commissioned on August 31st, 2022, and has a total capacity of 1.32 GW. It consists of 165 turbines from Siemens Gamesa, each with a capacity of 8 MW, and covers an area of 462 square kilometres.

Hornsea 2 is connected to the UK grid via three export cables, which together stretch over 430 km, and land at Horseshoe Point in Lincolnshire. In addition, inter-array cables with a total length of 373 km have been installed connecting the turbines in the wind farm.

Figure 5-1 One of the turbines in the Hornsea 2 offshore wind farm. Source: Ørsted

Development status

Hornsea 2 is in operation and was officially opened in 2022. It has since then been an important source of renewable energy in the UK and is part of the country's overall strategy to reduce CO_2 emissions and meet its climate targets.

Financing

The project was awarded a "Contract for Difference" (CfD) in September 2017 (Ørsted, 2024) at a price of £57.50/MWh. At the time, it was the lowest CfD price ever granted for an offshore wind project in the UK.

In addition to public support, the project has seen a large involvement of commercial banks in its financing:

- In May 2020, Siemens Gamesa secured a bank guarantee line of up to EUR 600 million to cover the production of components for Hornsea 2. This financing was led by BNP Paribas with participation from BBVA, Mizuho and Santander.
- In March 2022, Ørsted sold half of Hornsea 2 to AXA IM Alts and Crédit Agricol Assurances for three billion pounds. This transaction was financed through a combination of investors' equity capital and a senior multi-tranche financing package provided by thirty banks, including a tranche guaranteed by Denmark’s Export Credit Agency (EKF).

Ørsted also secured financing for the Hornsea 2 project by issuing green bonds in 2019 (Ørsted, 2019) to a total value of GBP 900 million. This financing is part of Ørsted's strategy to achieve climate neutrality and support the expansion of their portfolio of renewable energy projects. The bonds were divided into three tranches:

- GPB 350 million fixed-rate tranche maturing in 2027: This tranche had a coupon rate of 2.125% and was issued at a rate of 99.551% of the nominal amount. It was heavily oversubscribed with more than 3.3 times demand and is listed on the Luxembourg Stock Exchange.
- GBP 300 million fixed-rate tranche maturing in 2033: This tranche had a coupon rate of 2.5% and an issue price of 98.563% of the nominal amount. Demand was also high here, with the order book oversubscribed 1.6 times. This bond is also listed on the Luxembourg Stock Exchange.
- GBP 250 million CPI-indexed tranche maturing in 2034: This bond was indexed to the British consumer price index (CPI), with a coupon rate of 0.375% and an issue price of 99.927% of the nominal amount. Here, too, there was high interest, with an oversubscription of 1.2 times.

The varied maturities and coupon structures were designed to appeal to different investor profiles and market conditions. Barclays, Goldman Sachs, Morgan Stanley, and NatWest were among the financial institutions that managed the issuance.

Ørsted's green bonds

Ørsted has developed a framework for green financing (Ørsted, 2019), which supports the company's work in promoting sustainable energy through green bonds and other green financing instruments.

The net proceeds from Ørsted's green bonds are deposited into a separate "Green Account" and allocated to eligible offshore wind projects, including for acquisition, development and construction of wind farms. The focus is primarily on new projects; however, existing projects may be refinanced retrospectively up to two years. Ørsted's Sustainability Committee annually approves the allocation of the funds, which ensures a rigorous and transparent process. Projects financed through green bonds must not be "double-funded" through other green finance sources, and the overall investment will match Ørsted's share in the specific projects.

Ørsted annually publishes an investor report, which describes the allocation of funds and the environmental results of the projects. The reporting includes information on the annual capacity for renewable energy, the annual production of renewable energy and the annual greenhouse gas reductions, to which the projects contribute. In addition to this report, an external auditor must annually review and confirm the allocation and tracking of the green funds.

5.1.2 Offshore wind: Thor Offshore wind farm (DK)

Project description

Thor Offshore wind farm will be located in the North Sea approximately 20 km from the west coast of Jutland. With a capacity of 1,000 MW, the project is designed to deliver green electricity to one million Danish households. Thor is Denmark's first project that was awarded without direct state subsidy (zero-subsidy), which means that the developers do not receive a fixed support premium for the electricity produced. RWE, one of the world's leading energy companies, won the project after a bidding round where several developers submitted zero bids.

Figure 5-2 Visualization of offshore wind farm. Source: RWE.

Development status

The park is expected to be operational in 2027.

Financing

Thor was awarded on the basis of a zero bid, which means that the developer does not receive financial support from the state. The Danish tender concluded with a draw between participants that had submitted identical zero bids.

The Thor tender can be described as a *concession tender*, although it was officially presented as a *CfD tender*. This was due to the ceiling, which was set on the state payments. The tender was structured as a "double-sided CfD contract", where the winner could either receive up to DKK 6.5 billion in support or pay up to DKK 2.8 billion in revenue to the state, depending on the difference between the offered electricity price and the actual market price, adjusted annually.

The wind farm was required to have a capacity of between 0.8 and 1.0 GW and would be granted a 30-year production licence. The winner of the tender was to finance all costs related to transmitting the electricity to shore, including necessary grid connections and upgrades to the transmission network.

For the first time in Denmark, an offshore wind farm generated revenue for the state instead of receiving support, as RWE is required to pay DKK 2.8 billion for the concession.

On the zero-subsidy offshore wind model
The success of the zero-subsidy model in the Thor tender demonstrated how far the offshore wind market has progressed, showing that projects can in fact be financed without direct state subsidies under favourable market conditions. The absence of subsidies in such a large project indicates that private actors had confidence in future markets for offshore wind and renewable energy, supported by expected revenues from electricity sales.

The fact that bidders were willing to offer such low prices also reflects how competitive and efficient the sector has become. Technological advances have contributed to cost reductions, which are crucial for scaling up investment in the green transition.

For investors, this model demonstrates that viable returns can be achieved in such projects even without direct financial support from the state, provided that market conditions are favourable - e.g. stable long-term power purchase agreements, strong demand for renewable energy, and robust regulatory frameworks.

However, the recent outcome of the Danish tender round in the North Sea, which attracted no bids, also shows that market dynamics can change, making it impossible for private investors to take favourable conditions for granted. Global geopolitical uncertainty, bottlenecks in international supply chains, and rising interest rates to curb inflation are among the developments that have affected the market situation since the Thor tender, rendering conditions less favourable.

It is therefore not possible to approach each new tender as a continuation of the last. Each must be seen in the context of the broader societal and market circumstances at the time. Despite the positive development of greater efficiency and innovation in the offshore wind sector, this does not necessarily mean that support schemes can be entirely phased out in favour of zero-subsidy models alone.

Criticism of zero-subsidy models

However, there has also been criticism of zero-subsidy models in wind auctions (Balticwind.eu, 2022) (GWEC, 2024), especially with regard to the financial consequences for both developers and society. One of the main issues with zero-subsidy models, as seen in the Thor offshore wind farm case, is that developers offer to pay for the right to build projects, which may result in additional costs that are ultimately passed on to society. Critics argue that such costs could lead to higher energy bills for consumers, which runs counter to the aim of making renewable energy more affordable.

There are also concerns that developers may be forced to squeeze their suppliers due to having tighter budgets for essential components such as turbines. This could worsen the financial situation Furthermore, experts warn that zero-subsidy projects can be risky, as they depend on, among other things, future electricity and CO_2 prices. Investors are exposed to what is known as merchant price risk, which generally increases the cost of capital for offshore wind projects (PwC, 2020). This can affect the availability of capital, if the higher risk no longer matches the risk appetite of financial actors, e.g. lenders.

In summary, while a zero-subsidy model may reduce the financial risk for the state, it can simultaneously increase the risk for private actors, particularly when budgets are tight or when market conditions change.

5.1.3 Offshore wind: IJmuiden Ver Alpha and Beta (NL)

Project description

IJmuiden Ver is a large offshore wind project encompassing the Alpha and Beta areas in the Dutch North Sea. The project is expected to have a combined capacity of around 4 GW, supplying energy to millions of Dutch households. IJmuiden Ver forms part of the Netherlands' offshore wind strategy, which aims to reduce CO_2 emissions and strengthen the country's energy security.

SSE and APG (representing the Dutch pension fund ABP) are expected to make a final investment decision (FID) on the 2 GW IJmuiden Ver Alpha project by the end of 2025 (Offshorewind.biz, 2024). The project is owned by the consortium "Noordzeker", jointly owned 50:50 by SSE and APG, with SSE Renewables responsible for construction.

CIP and Vattenfall (together in the joint venture "Zeevonk") were selected as the developers of the Beta area. The project is expected to attract private investment and international partners. It comprises 2 GW offshore wind capacity, a 50 MWp floating solar power installation, and a large electrolysis plant to be built in the Port of Rotterdam, which will convert electricity from the wind farm into green hydrogen.

The scale and innovative approach of IJmuiden Ver strengthen the Netherlands' position as a leader in renewable energy in Europe.

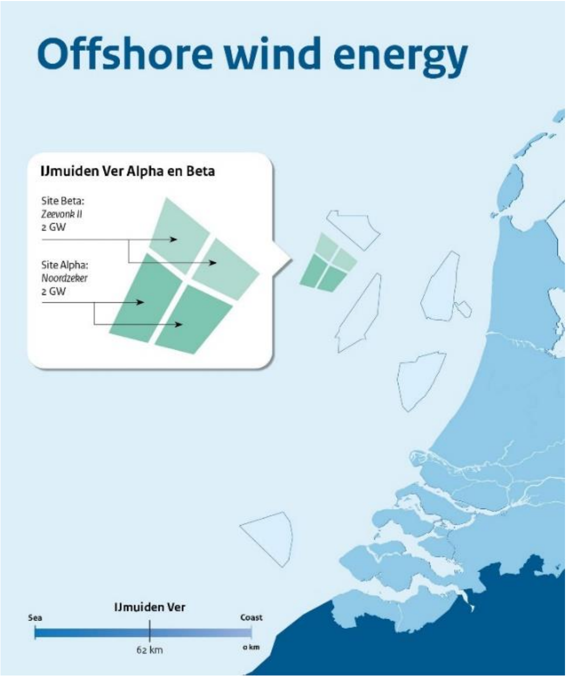

Figure 5-3 Location of IJMuiden Ver Alpha and Beta. Source: RVO (Netherlands Enterprise Agency).

Development status

In 2024, the Dutch government granted permits for the construction of the two offshore wind farms, which are expected to be commissioned in 2029 (Offshorewind.biz, 2024).

Financing

The tender was conducted under the "Permit Plus" model, where qualitative criteria were given greater weight than financial bids. Specifically, 85% of the overall score was based on qualitative criteria focusing on social and environmental considerations, while only 15% was based on the financial bid submitted by the participants. The financial score was mainly assessed based on what the developers offered to pay for the rights to build the wind farm (concession model).

In accordance with the requirements of this tender round - in addition to a financial bid and guarantees that the project would be implemented and contribute to the Dutch energy supply - the Dutch government assessed the extent to which each developer adhered to the principles of the International Responsible Business Conduct (IRBC) Agreement for the Renewable Energy Sector.

The Netherlands Enterprise Agency (RVO) also considered the extent to which proposals included circularity, environmental impact, and value retention across the design, construction, operational, and decommissioning phases of the projects.

An additional criterion for IJmuiden Ver Alpha was the wind farm's contribution to the ecosystem of the Dutch North Sea. For IJmuiden Ver Beta, emphasis was placed on improved integration of the wind farm into the energy system. Moreover, the government required measures to reduce disturbance days for harbour porpoises during the construction phase.

Both IJmuiden Ver Alpha and Beta will be built without subsidies (see "Zero subsidy" box). Zeevonk (CIP/Vattenfall consortium that will develop the Beta area) made a financial offer of EUR 20 million annually, to be paid each year over a 40-year license period. The developer will also build an electrolysis plant with a capacity of 1 GW for the production of hydrogen at the Maasvlakte in the Port of Rotterdam, where the grid connection comes ashore. In addition, Zeevonk will establish a 50 MW floating solar PV plant in the North Sea.

Noordzeker (the other consortium that will develop the Alpha area) offered over EUR 1 million annually, which is also to be paid annually for the entire license period of 40 years. Their plans include turbine and wind farm designs that protect birds, as well as measures to reduce disturbance to marine mammals during both construction and operation. Noordzeker will also install artificial reefs at three quarters of the turbines.

Both winners must also pay EUR 20 million each for the costs of environmental impact assessments and area studies.

Eneco, together with its partner Equinor, withdrew from the tender in March 2024, criticizing the tender conditions as "not future-proof". Eneco cited rising interest costs, high material prices, and uncertainty in the electricity market as reasons why it was difficult to establish a sustainable business model for the wind farm. Eneco also recommended that future tenders adopt the CfD model, which would provide a more stable revenue stream. The company further suggested that individual wind projects be scaled down to 1 GW to reduce risks associated with large-scale tenders.

Why these case studies are relevant

Hornsea 2 demonstrates how the CfD model can ensure stable and predictable income streams for developers and investors. CfD gives developers a guaranteed minimum price for the electricity produced, which reduces exposure to market volatility (Barrier 3). At the same time, offtake security is strengthened through Power Purchase Agreements (PPAs), e.g. those entered into with E.ON, which further contribute to the project's financial robustness (Barrier 4 and Barrier 5). The project also illustrates the crucial role that commercial banks can play in financing offshore wind. 50% of shares in Hornsea 2 were sold to a consortium consisting of AXA IM Alts and Crédit Agricole Assurances for GBP 3 billion. This transaction was financed through a combination of equity and a financing package provided by 30 banks. Hornsea 2 therefore shows how a balanced risk-sharing between the state and private actors can enable capital-intensive green projects, an approach that can be transferred to other areas to reduce risks for private investors (Barrier 8).

IJmuiden Ver Alpha and Beta and Thor Offshore wind farm are relevant examples of the development towards zero-subsidy offshore wind tenders. IJmuiden Ver Alpha and Beta are successful zero-subsidy projects, which have obtained contracts without the need for financial support from the state. A significant factor in the awarding of the contracts was the use of non-price criteria in the tender, such as technological innovation, sustainability, security of supply and environmental considerations. These factors contribute to the long-term viability of the projects and enable them to deliver added value beyond simply offering a competitive price. Grid connection is also handled by the state, which reduces the developer's risks, especially in light of rising offshore wind costs (Barrier 3 and Barrier 10). It is worth emphasizing that the IJmuiden Ver tender also promotes technological innovation such as PtX, which can contribute to reducing the risks associated with new technologies (Barrier 1and Barrier 5).

In the 2021 Thor tender, it was still possible to attract several bidders, who could choose either to receive state support or pay a concession fee to the state. Since then, however, the regulatory framework has changed significantly. The most recent offshore wind tender, where a zero-subsidy model combined with a concession payment to the state was the chosen approach, resulted in no bids being submitted (Barrier 9).

5.1.4 Biogas: Tønder Biogas (DK)

Project description

The Tønder Biogas project (Copenhagen Infrastructure Partners, 2024), located in Southern Jutland, will become one of the largest biogas plants in Europe when it reaches full capacity in

2025. The plant will annually convert approximately 900,000 tonnes of organic waste from agriculture and industry into approximately 40 million normal cubic meters (Nm³) of biogas. This gas will make a significant contribution to the green transition and energy security in Europe, particularly by reducing reliance on Russian natural gas.

Figure 5-4 Tønder Biogas. Source: Lundby Renewables.

The project was originally developed by the Canadian company Anaergia and was acquired in February 2023 by Copenhagen Infrastructure Partners (CIP) through the fund CI Advanced Bioenergy Fund I. This was the fund's first investment and marks CIP's entry into the biogas market. Shortly after the acquisition, CIP entered into an EPC (Engineering, Procurement, and Construction) contract with Lundsby Renewable Solutions A/S to complete the facility's construction.

Anaergia had also entered into an agreement with European Energy to supply up to 60,000 tonnes of CO_2 annually from the plant to European Energy's PtX production. The CO_2 will be used in the production of green methanol.

Development status

The project is in operation since November 2022, full capacity expected in 2025.

Financing

The project's financial structure is designed to reduce risks, including via a 20-year state-supported subsidy scheme for gas deliveries, which ensures stable financial support. According to the *Energy Agreement* of June 29th, 2018, (The Danish Government, 2018), support for the use of biogas production from existing plants will continue until 2032 and for at least 20 years for individual installations. The Danish Energy Agency pays out the support on the basis of measurement data, and recipients must meet certain requirements, e.g. on sustainability and documentation. The recipients of aid must therefore disclose each year which biomass has been used for biogas production. This long-term support helps make biogas production economically attractive.

Regarding new biogas plants, six tenders are planned in the period 2024-2030 targeting biogas and other green gases to be injected into the gas system. Funding for these tenders has been set aside through *the Climate Agreement for Energy and Industry* of June 22nd, 2020, (The Danish Government, 2020). The support will be granted for 20 years, with financing phased in gradually until 2030. An important condition in the tender is that recipients will not be eligible to receive guarantees of origin for the subsidised biogas they produce.

CIP Advanced Bioenergy Fund

Copenhagen Infrastructure Partners (CIP) has established the Advanced Bioenergy Fund I (ABF I), which is an important part of their strategy for investing in renewable energy. The fund has a capitalization of approximately EUR 750 million and focuses on investments in advanced bioenergy infrastructure in Europe, including Denmark, Spain (Catalonia), Belgium and the Netherlands.

Investments will focus on sustainable raw materials such as waste wood, agricultural biomass and household and industrial waste. The outputs include green gas and green fuels, such as renewable natural gas (RNG), liquefied natural gas (bio-LNG) and 2nd generation bioethanol.

In 2022, PensionDanmark announced an investment of one hundred million euros in the fund.

In addition to PensionDanmark, the fund has also received capital commitments from Industriens Pension, Andra AP-fund and Fjärde AP-fund.

Why this case study is relevant

The Tønder Biogas project demonstrates how the combination of long-term public support mechanisms and the market's demand for green solutions can make biogas production an economically attractive business.

With a 20-year state-supported subsidy scheme for gas deliveries, economic and regulatory uncertainty (Barrier 7) is reduced by ensuring stable income streams for project developers and investors. At the same time, the project emphasizes the value of combining public support schemes with market-based sources of revenue, such as the sale of guarantees of origin (described in 3.2.6). This approach makes biogas production an economically sustainable business, even in a time of increasing demands for sustainability and documentation.

In addition, the project illustrates synergies with other green technologies, including European Energy's PtX production, where excess CO_2 from the biogas plant is used to produce green methanol. This highlights how biogas projects can be integrated into the broader green value chain and contribute to the development of future green fuels (Barrier 1).

5.1.5 Sun: Tango Gigafactory (IT)

Project description

3Sun Srl, an Italian company owned by Enel SpA, will develop TANGO (iTaliAN PV Giga Factory), an industrial production facility for the manufacture of innovative and sustainable solar modules in EGP's 3Sun solar factory in Catania, Sicily. The solar modules use bifacial heterojunction technologies (B-HJT), which absorb sunlight on both sides for increased efficiency. In addition, 3Sun is developing tandem solar PV technology, which will increase efficiency to over 30% by combining two-layer solar PVs. The project involves the construction of a "Gigafactory", which increases the production of cells and modules from the current 200 MW/year to up to 3 GW/year. The factory will utilize existing buildings and facilities, invest in new buildings as well as upgrade existing facilities for the production of cell and module assembly lines. The factory will also follow circular economy principles by reusing materials, reducing resource consumption, and using artificial intelligence to minimise waste.

Figure 5-5 TangoSolarFactory. Source: SolarAlliance.

Development status

The project is expected to be fully commissioned in 2024.

Financing

The project's total costs are expected to be approximately EUR 667 million.

The project has received support from several sources:

- *EU Innovation Fund* : In 2022, Enel Green Power and CINEA (Enel, 2022) (European Commission, 2022) signed a grant agreement of approximately EUR 118 million.

- *EIB:* In 2024, the project has secured a financing package of EUR 560 million (SolarQuarter, 2024). This financing was made possible through a collaboration between the European Investment Bank (EIB) and InvestEU as well as a consortium of Italian banks led by UniCredit, which also includes BPER Banca and Banco BPM, with support from SACE, Italy's export credit agency.

The specific funding structure is as follows:

- 47.5-million-euro EIB loan, supported by InvestEU.
- 147.5-million-euro UniCredit loan, of which 80% is guaranteed by a SACE green guarantee, plus 85-million-euro VAT loan. Of the EUR 147.5 million, the EIB has committed to EUR 118 million of intermediate financing to UniCredit, which enables the Italian bank to improve the financing conditions for 3Sun.
- 140-million-euro Banco BPM loan, 80% of which is guaranteed by a SACE green guarantee.
- 140-million-euro BPER Banca loan, 80% of which is guaranteed by a SACE green guarantee.

- In February 2024, the project also received EUR 89.5 million from Italy's National Recovery Plan (PNRR) to promote the green energy transition in Italy. The purpose of this investment is to increase the annual production capacity to 3 GW innovative solar panels by the end of 2024.

  The PNRR is a comprehensive plan, which was launched to support the recovery of the Italian economy after the COVID-19 pandemic. It includes investments in green energy, sustainable infrastructure, digitisation, and social cohesion.

5.1.6 Onshore wind, offshore wind and solar + PtX: Megaton (DK)

Project description

GreenGo Energy is actively collaborating with Ringkøbing-Skjern Municipality to develop a green energy park based on 4 GW renewable energy from solar panels and wind power. The energy will primarily be transferred to an energy park with an associated 2 GW electrolysis plant in Stovstrup. The project will encompass 4,000 hectares of onshore solar and wind projects in Ringkøbing-Skjern municipality, together with an additional 2 GW offshore wind drawn from GreenGo Energy's development portfolio, primarily applied for under the now closed open-door scheme.

Figure 5-6 Megaton visualization. Source: Greengo

The aim is to produce over 1 million tonnes of green fuels annually, making Megaton one of the largest fully integrated energy parks in the world. The target is approximately 11.5 TWh of green electricity per year, of which 85 % will go directly to the energy park.

Development status

Phase 1 (2024-2028): Focuses on onshore wind and solar, as these are independent of the hydrogen pipeline. This entails approximately 600 GWh Solar (1000 Hectares) and 650 GWh onshore wind (30-40 turbines).

Phase 2 (2025-2031): Additional development of onshore solar energy. Almost 3,000 hectares. 1,800 GWh and 7,500 GWh of offshore wind. Phase 2 is potentially dependent on the hydrogen pipeline, which is why a final decision on development has not yet been made.

The whole project is generally still in the development phase, but on October 8th, 2024, the municipality decided to go ahead with four of the presented energy projects.

Like other VE projects, long permit-processing times are also a barrier for Megaton, where a number of factors come into play. For example, the high concentration of energy projects in the region creates a large volume of applications to process. Additionally, planning uncertainties - such as whether areas are designated as energy parks or as natural and biodiversity zones - intensify the complexity of the process. Further issues stem from the need to coordinate with concurrent energy-sector activities, such as Energinet’s expansion of transformer stations. These heavy permitting processes often delay and complicate the realisation of renewable energy projects like Megaton.

Financing

GreenGo Energy is primarily responsible for securing financing for the Megaton project.

The total investment in the Megaton project is expected to be around DKK 60 billion. Although specific investors have not yet been announced, GreenGo Energy uses its experience from previous projects to attract capital from prominent players on the market.

GreenGo Energy has also expressed concern about the Danish Energy Agency's decision to put the open-door scheme for offshore wind projects on hold, which has great significance for the Megaton project. In this regard, the company has warned that unclear framework conditions and changes to the rules with retroactive effect could undermine Denmark's competitiveness, especially in relation to other countries such as the US (GreenGo Energy, 2023).

5.1.7 Onshore Wind: Golden Plains Windfarm, Phase 2 (AU)

Project description

Golden Plains Wind Farm Phase 2 in Australia is an expansion of the existing project, aimed at strengthening the renewable energy supply in the state of Victoria. This project has a total capacity of 1.33 GW, of which the second phase involves the installation of 93 wind turbines with a combined capacity of 577 MW. The project is expected to be completed around mid-2027, and will, at that point, be able to supply approximately 9 % of Victoria's electricity demand.

Vestas plays a central role in the project as the supplier of the wind turbines. In 2024, Vestas signed a new contract with the developer TagEnergy, which includes the design, manufacturing, and installation of the turbines for Phase 2. Vestas' experience from the first phase - which has a capacity of 756 MW - has been crucial to securing successful financing for this project.

Figure 5-7 Vestas' turbines - Golden Plains Wind Farm. Source: Vestas.

Development status

Golden Plains Wind Farm Phase 1 is expected to produce green energy already from the first quarter of 2025, Phase 2 will follow in the summer of 2027.

Financing

The financing of Golden Plains Phase 2 has been secured through a consortium of international lenders, including the Australian Government, which supports the project through its *Capacity Investment Scheme*. Among the financing partners are the Clean Energy Finance Corporation, Commonwealth Bank of Australia, Westpac, Denmark's Export and Investment Fund, Natixis Bank, Bank of China, Deutsche Bank, and Mizuho Bank of Japan. The total financing for the entire project amounts to approximately AUD 4 billion (around DKK 17.2 billion).

Denmark's Export and Investment Fund (EIFO) has committed to providing up to DKK 1.3 billion in export loans, ensuring that Vestas is awarded the turbine supply contract as well as a 30-year service agreement for the project.

Ingka Investments, part of the Ingka Group (the majority owner of IKEA stores), has also acquired a 15 % equity stake in the project.

Denmark's Export and Investment Fund

Denmark's Export and Investment Fund (EIFO) was established in the summer of 2022 through an amendment to the law and is the result of a merger of the former funds Growth Fund (Vækstfonden), Denmark’s Export Credit Agency (EKF), and the Danish Green Investment Fund (Danmarks Grønne Investeringsfond). EIFO functions as a financing and investment fund, which is independent but owned by the Danish state.

EIFO offers a wide range of financing products, including:

1) Loan financing: EIFO provides loans to Danish companies, which can be critical for supporting growth and development.
2) Equity: The fund can also invest directly in Danish companies by offering equity capital, which is particularly important for entrepreneurs and smaller companies that need risk capital.
3) Financing for foreign offtakers: EIFO also offers the possibility of financing foreign offtakers of Danish products and services, which helps promote Danish exports.
4) Insurance of international business: The fund also offers insurance solutions for companies entering international markets, thereby reducing the risks associated with foreign trade.

Why these case studies are relevant

Case studies within onshore wind and solar show how these technologies have reached a significant scale and global relevance. A combination of public subsidies and political support has helped to reduce risks for private investors.

The Tango Gigafactory project demonstrates how massive political and financial support can contribute to promoting the production of sustainable energy technologies. Diversification of support from several sources, i.e. the Italian government, the EU and European banks, has enabled the project to scale from the current 200 MW to the expected 3 GW. This highlights the importance of access to EU support schemes as a key factor in reducing risks and attracting private investment.

The Megaton project highlights how regulatory uncertainty (Barrier 7) and long case processing time of the RE projects (Barrier 6) can be significant barriers to the green transition. The closure of the open-door scheme has delayed the project by over two years, which creates uncertainty about Denmark's competitiveness in relation to other countries. Moreover, the burdensome and complex permitting process - entailing coordination among many different authorities - represents a further challenge that could risk additional delays in project implementation. This case therefore underlines the importance of stable and efficient regulatory frameworks to ensure investment and progress in large-scale renewable energy projects.

Finally, **the Golden Plains Windfarm Phase II** is an example of how Danish technology can play a key role in the global green transition. The project benefits from Vestas' expertise and paves the way for Danish technology to contribute to an increased supply of renewable energy in Australia. At the same time, EIFO's export loans (described in 3.2.7) demonstrates how support mechanisms such as loans and guarantees can help Danish companies gain a central role in international projects.

5.1.8 Batteries: Northvolt One (SE)

Project description

The Northvolt Ett Expansion project is aimed to expand the Northvolt Ett gigafactory to produce batteries for electric cars in the Swedish city of Skellefteå. The purpose of the factory is to design and produce vertically integrated lithium-ion battery cells for the automotive industry and other applications. The original production capacity was 16 GWh per year, but in 2023, Northvolt announced an expansion of the factory to increase the capacity to 42 GWh annually. The total price for the construction project was EUR 7.3 billion (European Investment Bank, 2023).

However, the planned expansion of the factory was stopped in September 2024, and the responsible entity, Northvolt Ett Expansion AB, was declared bankrupt in Sweden in October 2024. Northvolt subsidiary had taken on a debt of between SEK 2 and 3 billion, which made it impossible to continue the expansion. The bankruptcy was therefore seen as a necessary step to protect the Northvolt Group as a whole. The group filed for bankruptcy protection in the US in November 2024 (so-called Chapter 11 case), which was approved by a court in Texas in December 2024 (Finanswatch, 2024).

Europe’s battery market is currently characterised by high production costs, declining demand, and fierce competition - especially from Chinese manufacturers, who are able to produce batteries at lower cost. These conditions have made it difficult for Northvolt to scale up production economically (Børsen, 2024).

Figure 5-8 Northvolt One. Source: Northvolt.

Development status

The project has been fully designed and has been under construction from 2021 until September 2024, when Northvolt stopped the expansion due to financial challenges. At the same time, the company announced it will have to cut around a quarter of its workforce in Sweden, almost 1,600 employees (Northvolt, 2024). This decision was made in the wake of the termination of a major contract with BMW, resulting in a loss of about EUR 2 billion (SiftedEU, 2024).

Later, it was also announced that Volvo Cars wanted to buy Northvolt out of another jointly managed Swedish factory (The Guardian, 2024).

Financing

Northvolt has received financial support in several rounds from both private investors and public entities. The private financing originates, among other things, from pension funds, banks, and several Swedish and Danish investors, while public institutions such as the Swedish state, the EIB and the German state have also provided support. (SiftedEU, 2024).

Among private investors:

- ATP has invested approximately DKK 2.3 billion in Northvolt through the purchase of shares. ATP is the fifth largest shareholder in Northvolt with a stake of about 5%.
- PFA Pension has granted a loan of a three-figure million amount.
- Danica Pension has also contributed with a loan of DKK 827 million.
- Swedish pension funds such as AMF and Folksam Group have also invested in Northvolt. AMF has invested EUR 168 million (approximately DKK 1.25 billion) in shares and owns 2.8% of the company. Folksam Group has invested EUR 88 million (approximately DKK 656 million) through loans.
- At the beginning of 2024, Northvolt secured a project financing of five billion dollars for the expansion of the Northvolt One gigafactory. This loan was arranged by a consortium consisting of 23 banks, including prominent institutions such as French BNP Paribas, Dutch ING, American JP Morgan and Korea Eximbank.

Among public sources of support:

- **The EIB** granted a loan of EUR 52.5 million (approximately DKK 391 million) in 2018 and EUR 319 million (2.3 billion DKK) in 2021 to finance the first phase of the Northvolt Ett factory in Sweden. Additional one billion euros has been promised, but the payment depends on the fulfilment of specific milestones in the construction process. The EIB's financing is guaranteed by the Swedish National Debt Office and the European Commission's InvestEU program and is partly channelled through commercial banks involved in the project financing.
- **German state:** In 2022, Northvolt was promised EUR 902 million (approximately DKK 6.7 billion) in loans, of which EUR 700 million (approximately DKK 5.2 billion) is direct support, and the remaining EUR 202 million (approximately DKK 1.5 billion) as loan guarantees. Of this support, EUR 202 million has been paid out, while the EUR 700 million has not yet been received.
- **Canadian government:** EUR 473 million (approximately DKK 3.5 billion) pledged, of which EUR 160 million (approximately DKK 410 million) has been disbursed as loans. The remaining amount is made up of two investments in Northvolt's Swedish subsidiary, both as convertible debt investments - i.e. loans that can be converted into shares in the company, which receives the loan. One is an investment of EUR 134 million (approximately DKK 1 billion) from the state pension provider Caisse de Dépôt et Placement du Québec (CDPQ); the second is an investment of EUR 181 million (approximately DKK 1.3 billion) from Invest Québec, the Quebec government's investment arm.

Why this case study is relevant

The Northvolt Ett Expansion case study highlights the challenges currently facing Europe’s battery market. While batteries play a crucial role in the green transition and the electrification of transport, the project also shows how high production costs and intense competition - especially from Chinese producers - put pressure on European manufacturers.

The company's bankruptcy in 2024 shows that even strategically important projects can be at risk if the financial framework conditions are not robust enough to handle fluctuating demand and sudden market changes (Barrier 3 and Barrier 10), including the loss of major offtake agreements. The case also highlights that massive public support (described in Chapter 3.2) alone does not ensure the success of projects, if it is not supplemented by stable market conditions and a strong commercial foundation.

This makes the case a key learning point for future investments in battery production and green technology, underscoring the need for coordinated efforts that combine financial support with stronger regulatory frameworks. Such frameworks must focus on enhancing Europe’s competitiveness in a global market, for example by addressing supply chain challenges, including securing sustainable and stable access to critical raw materials. The case also shows how dependence on a few customers and market uncertainties remain significant barriers to scaling up green technologies.

5.2 New technologies

5.2.1 PtX: European Energy Kassø (DK)

Project description

The Kassø PtX project is a major investment in green fuel production, operated by European Energy together with Mitsui in a joint venture, Solar Park Kassø ApS (SPK). The project includes a 304 MW solar park and a 52 MW plant for e-methanol production, with an annual capacity of 42,000 tonnes of e-methanol. The methanol will be used for industrial purposes such as more sustainable plastic production and as fuel for shipping. The project is also expected to supply heat to the local district heating network in Aabenraa, create new jobs as well as stimulate activity in Engsted Harbor for the distribution of e-methanol. European Energy estimates that the solar park will supply approximately 90% of the electricity requirement for methanol production, with the remaining 10% coming directly from the grid

Figure 5-9 European Energy's Kassø project. Source: European Energy.

Development status

The project is under development and is expected to be operational by the end of 2024.

Financing

The project is co-financed by a significant investment from the Japanese company Mitsui & Co., which has acquired a 49% stake.

The financing of the project includes, among other things, support from the Danish Green Investment Fund (DGIF - now Export and Investment Fund), which has invested DKK 400 million (Ritzau, 2022), with Jyske Bank also participating as co-founder. EIFO's commitment supports the plant's goal of promoting the green transition, with the fund's capital being used for the construction costs of the PtX facility, which aims at large-scale production of e-methanol. The Kassø project, expected to become the world's largest commercial PtX facility, also benefits from a power optimisation agreement with Danske Commodities. This agreement balances the solar park's output with the PtX plant's energy consumption to maximise efficiency.

Furthermore, European Energy was one of the winners of Denmark's PtX tender in 2023 (The Danish Energy Agency, 2023), securing approximately DKK 82 million for the project. The total budget for the tender was DKK 1.25 billion. The support model is based on a fixed premium per produced unit, granted over a 10-year period.

In October 2024, European Energy was selected to receive EUR 50 million in support from the EU's Innovation Fund (European Energy, 2024) for a new plant. This facility, which is expected to triple the production capacity compared to Kassø to over 100,000 tonnes annually, is planned to start construction in 2026 and become operational in 2028–2029.

In discussions with European Energy, it was highlighted that the support received was crucial in securing long-term offtake agreements, as it contributed to lowering the price of methanol. This has enabled European Energy to negotiate more favourable deals with buyers, ultimately supporting the project's financial viability.

The co-location of the solar park and methanol production serves as a form of risk mitigation for European Energy's operations. It allows flexibility in response to variations in electricity prices: when electricity prices are high, they opt to sell power to the grid to maximise revenue; when prices are low, they use the generated electricity for PtX, where electricity is the key input. This ensures optimal utilisation of the production setup in relation to fluctuations in electricity market prices.

5.2.2 PtX: Arcadia E-fuels (DK)

Project description

Arcadia eFuels' project in Vordingborg is planned to be the world's first large-scale facility for producing e-kerosene, a type of sustainable aviation fuel (SAF) made from green hydrogen and CO_2, using Power-to-X (PtX) technology. The project has an estimated budget of around DKK 7.5 billion and is expected to produce approximately 68,000 tonnes of e-SAF annually (Arcadia eFuels, 2023).

The plant will use green electricity from nearby solar farms and offshore wind farms in the Baltic Sea. The choice of Vordingborg Port is due to both its strategic location in relation to available green energy and support from Vordingborg Municipality.

Figure 5-10 Visualization of Arcadia eFuels' facility at Vordingborg Harbour. Source: Arcadia eFuels

In 2023, Arcadia eFuels, Sasol, and Topsoe signed a licensing agreement for the Vordingborg facility. Sasol and Topsoe will provide their G2L technology, designed to convert CO_2 and hydrogen into fuels.

Development status

The project is under development. Due to delays caused by the lack of offtake contracts for the product, the facility has been postponed and is now expected to open in 2028 (Energywatch, 2024).

Financing

Investment in the project has been secured from, among others:

- The French green investment fund Swift 2: a triple-digit million DKK amount (Business Vordingborg, 2023). The fund is managed by SWEN Capital Partners, a billion-euro private investment fund specialising in green projects in renewable energy production.
- The German KGAL's ESPF 6 fund (Business Vordingborg, 2023): EUR 250 million (approximately 1.8 billion DKK). KGAL is a German investment and asset management firm with an investment volume exceeding EUR 16 billion. Their investments focus on real estate, sustainable infrastructure, and aviation. The firm was founded 55 years ago and is headquartered in Grünwald, near Munich.

Arcadia eFuels has also appointed BNP Paribas as capital advisor to help raise financing for the project. BNP Paribas will support Arcadia eFuels with their experience in advising and financing low-emission projects.

Arcadia eFuels is now seeking contracts worth between EUR 1.5 and 2 billion (approximately DKK 11-15 billion) to complete the construction of the plant. Arcadia needs long-term purchase agreements to secure the necessary bank loans, as half of the project's financing will come from loans.

5.2.3 PtX: Green Fuels for Denmark (DK)

Project description

The Green Fuels for Denmark project involves a consortium of reputable Danish companies from across the renewable energy and fuel sectors, collectively aiming to build a 1.3 GW electrolysis plant powered by 2–3 GW offshore wind energy. In the first two phases, Green Fuels for Denmark is to produce renewable hydrogen for trucks and enough e-methanol to supply an ocean-going vessel or several ferries. The longer-term ambition is to develop e-kerosene, i.e. aviation fuel for Copenhagen Airport, sufficient to meet all of Denmark’s domestic aviation needs (Ørsted, 2022).

The consortium includes Copenhagen Airport, A.P. Møller-Maersk, DSV Panalpina, DFDS, SAS, Everfuel, NEL, Molslinjen, Haldor Topsøe, COWI, the City of Copenhagen, the Capital Region, and Ørsted (The Danish Business Authority, 2022). However, Ørsted has withdrawn from the project in October 2024 (Børsen, 2024).

Figure 5-11 Avedøre power station. Source: Ørsted.

Development status

The project was originally planned in the following phases:

- Phase 1 (10 MW) - to be completed in 2025.
- Phase 2A (100 MW) – to be completed in 2027.
- Phase 2B (300 MW upscaling) – to be completed in 2028/2029.

- Phase 3 (1300 MW) – to be completed in 2030 (Ørsted, 2022).

Financing

The Danish Business Authority has allocated DKK 600 million to the project through the IPCEI programme to realize the first three phases: Phase 1, Phase 2A & Phase 2B (State of Green, 2022). After the project was paused, there has been interest from other parties, including European Energy, to redirect the allocated financial support into a common fund (Energywatch, 2024).

Important Projects of Common European Interest (IPCEI)

IPCEI stands for Important Projects of Common European Interest and is the EU Commission's tool to enable national state aid for projects that can address societal challenges or market failures which the private sector alone cannot resolve. These projects support cross-border and cross-sectoral collaboration, promoting innovation and scaling of new technologies.

IPCEI projects have been launched in three key technology areas: microchips, batteries, and hydrogen.

The Danish government has earmarked DKK 850 million for IPCEI. Ørsted's Green Fuels for Denmark project, along with HySynergy in Fredericia, has received support under this scheme.

State aid is disbursed as pre-defined project milestones are achieved and documented.

5.2.4 PtX: Topsoe US-SOEC factory (US)

Project description

Topsoe will invest nearly USD 400 million (approximately DKK 2.7 billion) in a new factory in Chesterfield, Virginia to produce advanced and energy-efficient Solid Oxide Electrolyzer Cells (SOEC), which are essential for producing green hydrogen and related products such as e-ammonia and e-methanol. With a planned capacity of over 1 GW, the factory's production of electrolysis stacks will make it possible to avoid up to 2 million tonnes of CO_2 emissions annually - equivalent to the emissions from more than 400,000 petrol cars in a year. (State of Green, 2024).

Figure 5-12 Topsoe's planned factory in Virginia. Source: Topsoe

The factory will be Topsoe's largest investment in the US to date. If the final investment decision (FID) is made, the facility, together with the company's SOEC factory in Herning, Denmark, will make Topsoe the world's largest producer of SOEC electrolysis technology.

Development status

Construction has not yet started, as Topsoe is awaiting final details on the IRA scheme and whether additional tax benefits will take effect (Energiwatch, 2024). The tentative date for commissioning is 2028.

Financing

Topsøe has received USD 136 million (approximately DKK 966 million) in support from the US Inflation Reduction Act, in the form of tax credits under the 48C programme (Topsoe, 2024).

48C Advanced Energy Project Credit

The 48C credit is a tax incentive introduced under the Inflation Reduction Act (IRA) to support advanced energy projects in the US that reduce CO_2 emissions and strengthen domestic clean energy technology production. It targets companies investing in green energy projects in manufacturing, recycling, and emissions reduction.

Total Allocation: USD 10 billion, of which USD 4 billion is earmarked for projects in so-called "energy communities" (areas with closed coal mines or retired coal power plants).

Credit amount: 30% of eligible capital investment for projects that meet wage and apprenticeship requirements. 6% for projects that do not.

Eligible projects: Establishment, expansion, or refurbishment of facilities for producing or recycling advanced energy technologies; installation of technology at industrial sites to reduce CO_2 emissions by at least 20%; projects involving the processing, refining, or recycling of critical materials.

In addition, the company received USD 6 million (approximately DKK 43 million) from The Commonwealth Opportunity Fund and stands to receive more funds from The Port of Virginia

Economic and Infrastructure Development Zone Grant Program (Governor of Virginia, 2024). The rest of the project's value is earmarked for Topsøe, but they will likely need to find investors.

The remainder of the project's value is covered by Topsoe, although external investors will likely be needed. It is also worth noting that Topsoe received EUR 94 million (approximately DKK 705 million) in support from the EU Innovation Fund for its planned SOEC electrolysis plant in Herning, Denmark.

5.2.5 PtX and other green technologies: Greenlab Skive (DK)

Project description

Greenlab Skive is an innovative industrial energy park in Denmark, developed as a green symbiosis facility where companies can engage in circular energy exchange and collaborate on PtX and renewable energy solutions. The park integrates various renewable energy sources such as wind, solar, and biogas to support the sustainable production of green energy and e-fuels. One of the key developments at Greenlab is the GreenHyScale project, which aims to construct a 100 MW electrolysis facility to produce green hydrogen for industrial use, including PtX applications, and to support Denmark's and the EU's goals for green transition and CO_2 emission reductions (GreenLab, 2023).

Figure 5-13 Greenlab Skive. Source: Greenlab.

Development status

The first 6 MW electrolysis module was installed in 2023 and has since been tested. The plan is to install the full 100 MW by late 2024/early 2025, but no current status updates are available (GreenLab, 2023).

Financing

In 2022, Norlys invested DKK 200 million in GreenLab (Greenlab, 2022), thereby becoming the majority shareholder. GreenLab continues as a public-private partnership with the three other shareholders (Skive Municipality, Spar Vest Foundation, and Climate Foundation Skive) and operates as a regulatory test zone.

In 2021, GreenLab received EUR 30 million in funding from the EU Horizon 2020 programme to build a 100 MW PtX facility (Energywatch, 2021).

A prerequisite for the EU funding is that Greenlab's proprietary energy grid, SymbiosisNet, must be ready to both supply and receive energy.

With Norlys' investment, GreenLab can expand the SymbiosisNet and undertake the necessary construction works to bring PtX and other green technologies into operation.

Why these case studies are relevant

The Kassø case study from European Energy demonstrates how long-term public support can promote the development of new technologies and reduce investor risk. The support received through the Danish PtX tender played a crucial role in securing long-term offtake agreements by reducing the price of methanol. This strengthened European Energy's negotiating position and the project's overall financial viability.

The tender's support model is based on a fixed premium per unit produced, granted over a 10-year period. This type of mechanism creates predictability and financial stability for both producers and investors (Barrier 7).

Topsoe's US-SOEC electrolysis plant in Chesterfield Virginia will be made possible by the IRA's tax credit allocation of nearly USD 136 million. The IRA (described in Chapter 3.2.2) introduces significant tax incentives for companies that invest in environmentally friendly technologies. These incentives reduce the costs of implementing green solutions (Barrier 1 and Barrier 5) and make them more attractive to private investors. Policy uncertainty has often been a barrier to investment in green technologies (Barrier 7). By establishing long-term tax incentives and financing arrangements, the IRA reduces this uncertainty, making it easier for private investors to plan and implement investments in sustainable projects.

The importance of public support is also emphasized by the **Greenlab Skive project,** where EU funding in 2021 helped attract a large private investment from Norlys, now the majority shareholder.

The cases also illustrate that even with support, many PtX projects continue to face barriers, which limit their ability to attract private capital and secure financial sustainability.

Arcadia eFuels has received investments from e.g. German and French investment funds but is still missing offtake contracts worth EUR 1.5-2 billion (Barrier 4) to complete their e-SAF facility in Vordingborg and thereby secure the necessary bank loans.

The IPCEI project **Green Fuels for Denmark** was put on hold in autumn 2024, after Ørsted's withdrawal. The lack of offtakers (Barrier 4) as well as delays and significant price increases in the value chain (Barrier 3and Barrier 10) are cited as key reasons.

A central barrier for many PtX projects, including those analysed in the case studies, is the lack of offtakers (Barrier 4), which is directly connected to regulatory uncertainty (Barrier 7).
This stems from the fact that the requirements of the Renewable Energy Directive regarding the use of PtX fuels (RFNBOs) in sectors such as transport and industry have not yet been implemented nationally. Nor have enforcement mechanisms (e.g. in aviation via FuelEU Aviation) been established.

As a result, sectors expected to use PtX fuels lack clarity on the consequences of non-compliance, reducing their incentive to invest in alternative solutions. At the same time, producers are experiencing a lack of demand, as future regulatory requirements and market conditions remain uncertain. This creates a challenge for both investors and companies, who lack clarity on future regulatory frameworks and market conditions.

A potential way forward is the rapid implementation of EU regulations, as described in Chapter 6, which can contribute to creating a more stable and predictable framework for the PtX market.

5.2.6 CCS: Ørsted Kalundborg CO_2 Hub (DK)

Project description

The project Ørsted Kalundborg CO_2 Hub will capture and store CO_2 emissions from the woodchip-fired Asnæs Power Station in Kalundborg as well as the Avedøre straw-fired power plant in Hvidovre. The project has been awarded a 20-year contract by the Danish Energy Agency and is already expected to begin capturing 430,000 tonnes of biogenic CO_2 annually from 2026 (Ørsted, 2023). Of this,150,000 tonnes are anticipated to be captured from the Avedøre power station and 280,000 tonnes to be captured from the Asnæs power station. Once captured, the CO_2 will be stored at the Ørsted Kalundborg Hub and transported by ship to Øygarden in Norway, where it will be injected into a CO_2 storage site beneath the North Sea seabed. This storage facility is the first of its kind. By capturing CO_2 from biomass-fired combined heat and power plants and storing it underground, it is possible to remove CO_2 from the atmosphere, as CO_2 from sustainable biomass is part of a natural biogenic carbon cycle. This results in negative emissions (Ørsted, 2024).

Figure 5-14 Ørsted's Asnæsværket. Source: Ørsted.

Development status

The project was initiated in June 2023 by NCC and is expected to be completed and operational in early 2026 (NCC, 2024).

Financing

The project has received funding from the Danish state via the CCUS fund. The fund was launched and allocated for the first time in 2023 with a budget of DKK 8.17 billion for the tender round (The Danish Energy Agency, 2023). The Danish Energy Agency has not wished to disclose the exact amount awarded to Ørsted.

In addition to public funding, the project has secured a deal with Microsoft to sell 3.67 million tonnes of carbon certificates over a ten-year period. This represents one of the world's largest CO_2 removal offtake agreements to date (Ørsted, 2024). Ørsted has also entered into a ten-year agreement to sell 330,000 carbon credits to the Norwegian company Equinor (Equinor, 2024). According to Ørsted, the main source of project financing comes from the sale of carbon credits. These credits are estimated to have been traded at a price of between DKK 750 and 1,000 per tonne of CO_2 (Klimamonitor, 2023).

5.2.7 CCS: Porthos (NE)

Project description

Porthos is a CCS project in Rotterdam that involves the transport and storage of CO_2 from industrial plants in the Rotterdam harbour area to a depleted gas field beneath the North Sea. The CO_2 will be captured by various actors, and then collectively fed into a pipeline that transports it to the newly built compressor station at Azlëweg. From there, it is transported via a subsea pipeline to an offshore platform, which injects it into depleted gas fields. Once fully operational, the project will be able to store 2.5 million tonnes of CO_2 annually for 15 years, amounting to a total of 37 million tonnes of CO_2 over the lifetime of the project (Porthos, 2023).

The three main partners behind the project are the Port of Rotterdam, Gasunie, which is responsible for the transport infrastructure, and EBN (Energie Beheer Nederland), which plays a key role in storing the CO_2 underground.

Development status

The project received a final investment decision in October 2023, and construction started in 2024 with expected operation in early 2026 (Porthos, 2024).

Figure 5-15 Port of Rotterdam. Source: Porthos.

Financing

The project received financial support of EUR 1.2 million (approximately DKK 9 million) for the preparation phase in the form of subsidies from RVO (the Dutch Enterprise Agency) and EUR 6.5 million (approximately DKK 50 million) from the EU Commission for initial studies (Porthos, 2024).

The total project has an expected construction budget of EUR 1.3 billion. For implementation, Porthos received €102 million (approximately DKK 760 million) from the EU's Connecting Europe Facility (CEF) and is classified as a Project of Common Interest (PCI) (Agro & Chemistry, 2023).

Furthermore, Porthos' four customers (Air Liquide, Air Products, ExxonMobil & Shell) are compensated through SDE++ subsidies (International Energy Agency, 2022). This is a Dutch scheme lasting 15 years, which covers the cost difference between production with and without CCS (Netherlands Enterprise Agency, 2023).

5.2.8 CCS: Greensand (DK)

Project description

Project Greensand in Denmark aims to store CO_2 in depleted oil and gas fields in the North Sea . It is developed by INEOS and Wintershall Dea in collaboration with 21 other partners, including Danish authorities and Energinet. The project is designed to provide permanent CO_2 storage and potentially function as a CO_2 import hub, with CO_2 expected to be shipped from other parts of Europe to the Nini platform in the North Sea. Here, it will be injected from the offshore platform into a sandstone reservoir underground, where it will be stored permanently (Project Greensand, 2023). The project's initial capacity is expected to be 400,000 tonnes of CO_2 annually from 2025, with further development up to 8 million tonnes per year by 2030 (INEOS, 2024).

Figure 5-16 Visualization of Ineos' facilities in the North Sea. Source: INEOS.

Development status

In September 2024, Greensand completed its pilot phase and confirmed that it is feasible to store CO_2 under the expected conditions. Final approval from authorities is pending, but the project expects to begin receiving CO_2 from 2025 (INEOS, 2024).

Financing

The project receives support from:

- EUDP: DKK 197 million for the concept development and demonstration (Phase 2) (Semco Maritime, 2021)
- Own financing: DKK 241.45 million for Phase 2.
- EU Innovation Fund: The project is one of 85 projects selected in 2024 and invited for negotiations as of late October 2024. Three of these are in the 'large-scale' CCS category and are expected to receive up to €225 million per project. The exact amount is not yet disclosed (Bellona, 2024).

Several industrial players have also invested, and it is considered a flagship project for CO_2 storage in Europe.

5.2.9 DAC: Orca (IS)

Project description

The Orca project in Iceland, operated by Climeworks and Carbfix, is the world's first large-scale direct air capture (DAC) combined with CO_2 storage (CCS). The plant captures CO_2 from the air, mineralizes it and stores it permanently in basalt formations underground. Orca consists of eight capture modules, each capable of capturing 500 tonnes, meaning a total annual capacity of 4,000 tonnes of CO_2. The facility's energy and heat demands are met by the Hellisheidi geothermal power plant, ensuring the entire process is powered by renewable energy sources (Climeworks, 2021).

Figure 5-17 ORCA DAC system. Source: Climeworks.

Development status

The facility was commissioned in September 2021 and serves as a pioneering pilot for future large-scale DAC and CCS technologies. The companies behind the project are using it as a stepping stone for their next project, Mammoth, which is expected to become operational in early 2025 with a capacity of 36,000 tonnes per year (Climeworks, 2024).

Financing

The project is financed through private investments and funding from major corporations seeking CO_2 removal as part of their climate commitments. Notably, Microsoft was one of the first buyers, acquiring 10,000 tonnes of carbon credits over a ten-year period (DataCenterDynamics, 2022).

Climeworks is also planning to expand its DAC facilities in the United States. It has applied to participate in three of the U.S. Department of Energy's (DOE) regional Direct Air Capture hubs, which have received a total of USD 3.5 billion in funding. Each hub aims to reach a capacity of one megatonne of CO_2 capture by 2030.

Why these case studies are relevant
Carbon capture and storage (CCS) and Direct Air Capture (DAC) are technologies that play a central role in the global effort to reduce CO_2 emissions. These technologies are still at the pilot and demonstration stage and are associated with high costs (Barriers 1 and 5), which in turn entail greater risks for private investors. The permitting processes for CCS also require close coordination between many different authorities, which can delay project timelines and create the need for a consolidated schedule and joint guidelines. Stakeholders point out that several issues are handled repeatedly, as both applicants and authorities are often faced with new procedures and challenges (Barrier 6 and Barrier 7). However, national climate goals, robust public support schemes, and agreements on the sale of carbon credits are helping to advance the development of CCS and DAC. The Danish and Dutch projects **Greensand** and **Porthos** both focus on CO_2 storage in the North Sea and have received substantial funding from both national governments and the EU. The Greensand project also highlights the importance of close collaboration between industrial actors and authorities, as it is developed by INEOS and Wintershall Dea in cooperation with 21 other partners, including Danish authorities and Energinet. In addition, for both the Danish **Ørsted's Kalundborg Hub** and **the Orca DAC project** in Iceland, the sale of carbon credits (described in Chapter 3.2.6) has played a decisive role in the

financing of the projects, demonstrating the growing importance of carbon markets in driving sustainable solutions.

Political attention to CCS plays a significant role in reducing risks and uncertainties surrounding the technology (Barrier 1). CCS can directly contribute to reducing CO_2 emissions in Denmark, which is essential to achieving national climate goals. This role has increased the Danish state's willingness to support - both financially and through regulation - the development and implementation of CCS as a key component of the green transition.

5.2.10 Nuclear power: Seaborg Technologies (DK)

Project description

Seaborg Technologies is a Danish company focused on the next generation of nuclear power, specifically Small Modular Reactors (SMRs). The company is developing a Compact Molten Salt Reactor (CMSR), a technology it has been working on since 2014. The CMSR offers several advantages, including a lower risk of nuclear accidents, as the salt used in the reactor cools and solidifies upon contact with air, thereby encapsulating radioactive material.

In addition, CMSRs are more flexible than traditional nuclear power, cost-effective, and easily integrated into many types of power grids. The reactor is built modularly, allowing for scalable capacity (100 MWe each), and is designed for transportation on a barge.

Seaborg has already signed Memoranda of Understanding (MoUs) with several Asian countries, including Thailand, South Korea, and Indonesia, as well as Norway.

Figure 5-18 Visualization of the Seaborg floating nuclear power plant concept. Source: Seaborg.

Development status

Founded in 2014, Seaborg has been developing its technology ever since. In 2023, the company made a key design change by switching from High-Assay Low-Enriched Uranium (HALEU) to Low-Enriched Uranium (LEU), due to potential delays in HALEU supply (Seaborg Technologies, 2023). While there is no specific date yet, the commercial prototype is expected to be ready in 2026, with potential commercial production by 2028 (WNN, 2023).

Financing

Seaborg Technologies' financing has evolved over time, including both private investment and shareholdings, initially involving the Danish state, which invested in 2018. These shares have since been sold to HEARTLAND and Team Europe (Seaborg Technologies, 2021).

In November 2020, Seaborg held a Series A financing round worth USD 21.7 million (TRACXN, 2021). In the same year, it received two loans from the Danish Growth Fund (Vækstfonden).

In 2021, Seaborg and its sister company Hyme received DKK 24.6 million from EUDP to develop a prototype of their energy storage system (Seaborg Technologies, 2021).

In 2022, Seaborg was awarded an undisclosed amount from the EIC Accelerator, potentially up to EUR 17.5 million in the form of grants or equity investments (ING, 2022).

Why this case study is relevant

Nuclear power, especially small modular reactors (SMRs) such as that developed by **Seaborg Technologies,** is a technology with significant potential to support the green transition both in Denmark and globally.

Despite these promising features, SMRs face several challenges. First, as a technology still under development, they entail uncertainty related to technological maturity and scalability (Barrier 1). The lack of commercial operation and proven reliability can affect investor confidence.

Moreover, nuclear energy is currently not part of Denmark's energy mix (apart from electricity imports from countries like Sweden), which would require a major shift in public perception and political acceptance.

Extensive investments in infrastructure (Barrier 2) as well as regulatory frameworks (Barrier 7) are also needed to integrate SMRs into the Danish energy system.

To overcome these challenges, further funding from both public and private actors is crucial to support the development and commercialisation of SMR technology. Clear political frameworks and regulations are also essential to create a stable and predictable environment for nuclear energy investment. This includes the development of safety standards, waste management policies, and incentives that promote sustainable energy production.

In the Danish context, there are signs of growing political interest in nuclear energy. In March 2024, the Minister for Climate, Energy and Utilities, Lars Aagaard, announced that test reactors could be built in Denmark, provided they do not produce electricity. This suggests an openness to exploring the role of nuclear energy in the future energy mix.

In summary, integrating SMR technology in Denmark requires a combination of technological innovation, political will, and financial support. By addressing the identified challenges and implementing appropriate measures, SMRs could play a role in Denmark's efforts to achieve a sustainable and carbon-neutral energy supply.

5.2.11 Pyrolysis: SkyClean (DK)

Project description

SkyClean is a technology developed by Stiesdal Fuel Technologies, aimed at addressing three major climate challenges: reducing greenhouse gas emissions from agriculture, capturing and storing atmospheric carbon, and producing carbon-neutral fuels for the transport sector.

The SkyClean process involves pyrolysis, where organic waste from agriculture and forestry is heated at high temperatures without oxygen. This produces biochar, oil, and gas. Half of the carbon is stored in the biochar, effectively removing CO_2 from the atmosphere. The remaining carbon is released as oil and gas, which can be used as fuel in industry or refined into transport fuels, including aviation fuel.

Figure 5-19 Skyclean's 20 MW pyrolysis plant in Vrå. Source: Energiwatch

The project is supported by several key partners, including Stiesdal A/S, KK Wind Solutions, Topsoe, and research institutions such as DTU and RUC. Stiesdal A/S leads the development and commercialisation of the SkyClean technology, focusing on industrial-scale pyrolysis plants.

Development status

The SkyClean process has been tested at a 200 kW plant at Risø Campus and at a 2 MW pilot plant at GreenLab Skive in 2022. A 20 MW demonstration plant was inaugurated in Vrå on 7 October 2024.

Financing

The 2 MW plant was self-financed by Stiesdal A/S.

The SkyClean Scale-up project, which involves building the 20 MW plant in Vrå, received DKK 124 million in 2022 from the Pyrolysis Fund and NextGenerationEU. The funds are administered by the Danish Energy Agency under the Pyrolysis Fund, established in the 2021 Finance Act to support technologies that reduce agricultural emissions.

In addition, EUDP granted the project DKK 23 million in 2022.

In 2024, Stiesdal A/S received a further double-digit million DKK investment from EIFO and DKK 202 million from the tobacco company Chr. Augustinus Fabrikker. These investments support Stiesdal’s growth and internationalisation. Both investors have now become shareholders in Stiesdal A/S, alongside PensionDanmark and Nordvest A/S.

5.2.12 Pyrolysis: CIBI – Circular Biorefinery, BioCirc (DK)

Project description

The project is a research and development collaboration between BioCirc, Circlia, and Aarhus University. The aim is to integrate HTL and wet oxidation technologies to treat digestate (a residual material) from biogas plants. The existing biogas facility at Vesthimmerland Biogas (owned by BioCirc Group) is the focal point of the project. The process is known as brown biorefining, which mimics nature's way of producing oil. The end product can be used by the agricultural sector as fertiliser (The Danish Business Authority, 2023).

Figure 5-20 Vesthimmerland Biogas. Source: BioCirc.

Development status

The project was never implemented due to lack of co-financing.

Funding

The project received DKK 33,272,824 from the Just Transition Fund, an EU fund designed to support regions in Europe most in need of transitioning to a climate-neutral economy. In 2022, the fund focused on projects that "supported the development of brown biorefining such as pyrolysis" but is generally available for all green technologies. BioCirc lost the grant as it was unable to secure the required co-financing of approximately DKK 18–19 million (Klimamonitor, 2024).

Why these case studies are relevant

Interest in pyrolysis is growing due to its potential to reduce agricultural emissions and produce green fuels. However, scaling from small pilot projects to industrial-scale deployment requires large investments, as illustrated by the two cases.

In **the SkyClean project,** the 2 MW plant was self-financed, while the scale-up to 20 MW received support from the Pyrolysis Fund, EUDP, and private investors, who have also become shareholders in Stiesdal A/S. This highlights the importance of a combination of public support and private capital to unlock the full potential of pyrolysis as a green technology.

Conversely, projects such as **CIBI - Circular Biorefinery** have struggled to obtain the necessary co-financing. Although the BioCirc project received a grant from the EU Just Transition Fund, it lost the funding due to lack of matching capital. This demonstrates that technologies like pyrolysis still face financial barriers (Barrier 1 and Barrier 5), and still require political prioritization, clear support mechanisms (such as those described in Chapter 3) and significant investments from both private and public actors in order to succeed and become market-ready.

5.3 Infrastructure

5.3.1 Electricity: Celtic Interconnector (FR + IR)

Project description

The Celtic Interconnector project is an undersea cable that will connect Ireland and France and allow for the exchange of up to 700 MW of electricity between the two countries. Electricity will be transported over 575 km, of which 500 km will be subsea, with the capacity to supply up to 450,000 households. The project aims to safeguard Ireland's electricity security by establishing a direct connection to continental Europe. It is being developed by EirGrid in cooperation with Réseau de Transport d'Électricité (RTE). The project uses several established technologies including: High Voltage Alternating Current (HVAC) and High Voltage Direct Current (HVDC) electricity cables for both land and subsea circuits (EirGrid, 2024).

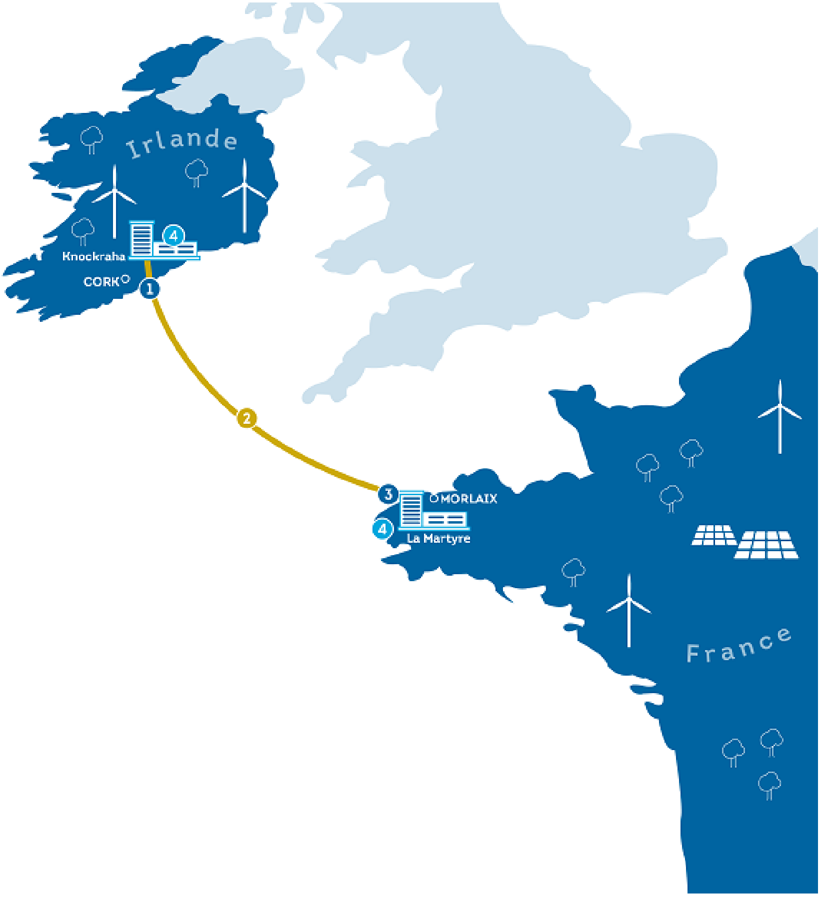

Figure 5-21 Celtic interconnector. Source: Energies de la mer

Development status

The project has been under construction since November 2023 and is expected to be operational from 2026 (EirGrid, 2024).

Financing

The total project cost is estimated at EUR 1.6 billion. The project is owned and co-financed by RTE and EirGrid (European Investment Bank, 2022).

The project is classified as a PCI and received a total of EUR 530.7 million from the European Commission's Connecting Europe Facility in 2019 (EirGrid, 2024).

In addition, funding from the EIB has been secured amounting to EUR 300 million, as well as EUR 500 million in loans distributed between Danske Bank, Barclays and BNP (European Investment Bank, 2022).

5.3.2 Electricity: Viking Link (DK + UK)

Project description

The Viking Link project is a 1,400 MW HVDC electricity cable linking the Danish and British electricity transmission systems. The cable runs between Bicker Fen in England and Revsing in southern Jutland. Viking Link stretches 765 km, using both overhead and subsea cables, enabling electricity to flow between the two countries. The project facilitates optimisation and utilisation of renewable energy production while improving energy security in both countries (Viking Link, 2024). The project cost around USD 2.25 billion to develop (Global, 2024).

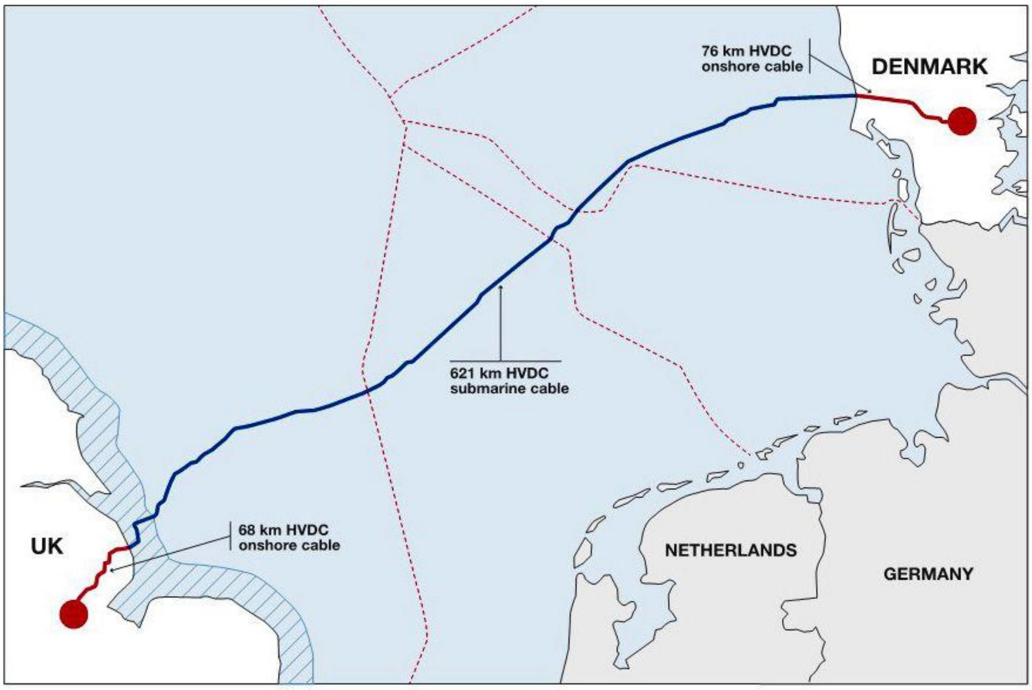

Figure 5-22 Viking Link. Source: Nordic Investment Bank

Development status

The establishment of Viking Link began in 2019 and was completed and put into operation in December 2023 (National Grid, 2023). The project is currently only running with a capacity of 800 MW due to the delay of another project in southern Jutland, the Endrup-Idomlund high-voltage connection, which is under construction and expected to be operational from the end of 2026 (National Grid, 2023).

Financing

The USD 2.25 billion project cost is equally divided between the British transmission operator National Grid plc and the Danish operator Energinet, with both companies financing their respective shares.

In order to finance its share, Energinet has entered into two 10-year loan agreements with the Nordic Investment Bank (NIB) for DKK 1 billion in 2021 and DKK 1.5 billion in 2022 (Nordic Investment Bank, 2022).

National Grid plc secured a green loan worth USD 743 million in 2020. This included USD 255 million from Euler Hermes Export Credit and USD 488 million from Servizi Assicurativi del Commercio Estero (SACE) Export Credit. The loan process was facilitated by BNP Paribas with support from HSBC and NatWest (Technology, Power, 2024).

In addition to this, the project has been designated as a PCI project, and in 2016 received funding through CEF of EUR 3 million, which is why the last part of the development phase is partially financed by the European Union (Viking Link, 2024). Since Brexit, European financing for projects between the UK and EU countries has become highly uncertain (4C OffShore, 2019).

5.3.3 Hydrogen Network: Enagás H2Med (ES)

Project description

H2Med is a transnational initiative that will establish a hydrogen network from the Iberian Peninsula through France and Germany, connecting to wider Northern European hydrogen networks. The Spanish company Enagás has been given the task of developing the project. The goal is to connect all of Europe to green hydrogen from 2030. The actual construction for the H2Med project involves a 248 km pipeline that will connect Spain with Portugal from Celorico de Beira to Zamora (CelZa) and a 450 km subsea pipeline between Spain and France from Barcelona to Marseilles (BarMar). The expected output is 0.75 Mt hydrogen/year for CelZa and 2 Mt hydrogen/year for Barmar (H2MedProject, 2024).

The estimated cost of the project is around €2.5 billion - approximately €350 million for CelZa and €2.1 billion for BarMar. The project has been granted PCI status by the EU and is thus well positioned to seek EU funding (HydrogenToday, 2023). H2Med is part of a larger hydrogen initiative for the whole of Europe and an important component in the EU's ambition for climate neutrality by 2050. The project's success is therefore also dependent on other similar national and transnational hydrogen projects being carried out in the rest of Europe (H2MedProject, 2024). This includes, for example, HyFen in Northern France, Teréga in Southern France, and H_2ercules in Germany (H2MedProject, 2024).

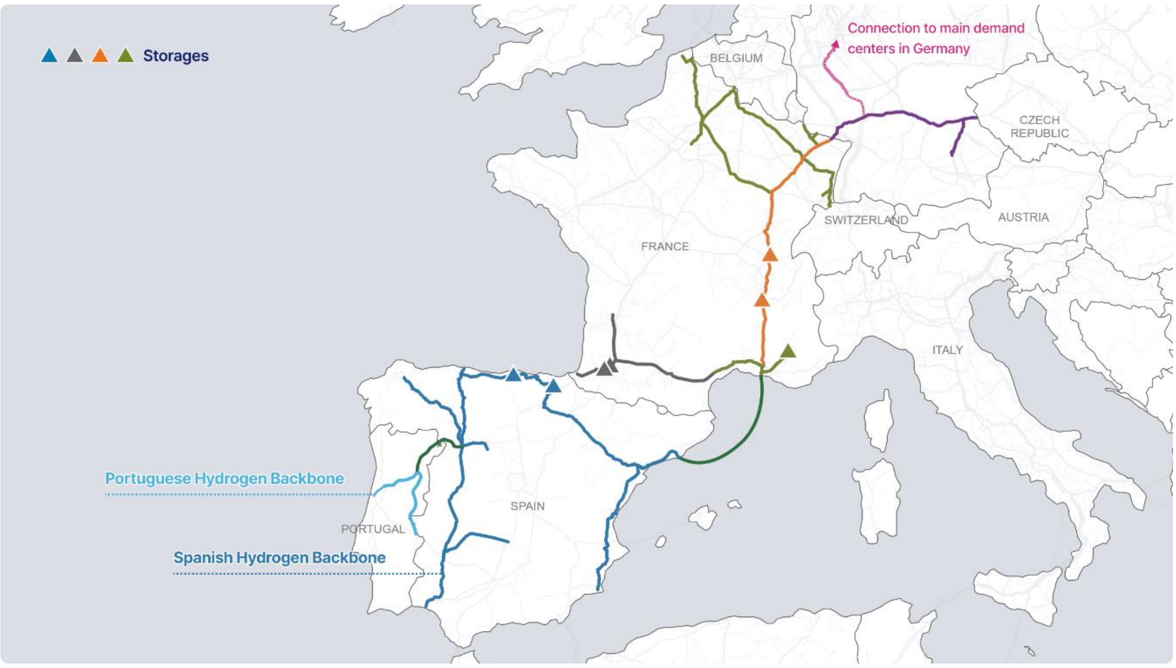

Figure 5-23 H2Med project. Source: H2Med.

Development status

Initial phases commenced in October 2022. Permits for the early engineering studies and environmental impact assessments were granted in October 2023.

The period 2024-2025/26 will and has been used for various studies as well as seeking funding from the EIM (European Interconnection Facility) also known as CEF-E. A response is expected in 2026 (H2MedProject, 2024).

The project is scheduled for construction between 2026 and 2029, with operations to begin in 2030 (H2MedProject, 2024).

Financing

The primary financing is expected to come from the EU via the CEF-E programme and other European funding mechanisms. This underlines the project's application for PCI status (H2MedProject, 2024).

As the transmission system operator, Enagás has issued “calls for interest” to assess demand from future industrial customers. If binding commitments are secured from relevant industrial actors, private loans and investment financing may also become viable (H2Tech, 2024).

5.3.4 Hydrogen Network: Hyperlink – Hydrogen Network (DE)

Project description

Hyperlink is a hydrogen pipeline network under construction in Germany by Gasunie, intended to ensure a stable energy supply. The project is divided into several sub-projects, to be established in phases from 2023 to 2032.

Hyperlink will make use of both new and repurposed infrastructure to create a 1,000 km hydrogen network connecting major industrial regions in northern and western Germany with hydrogen storage facilities and import points in Denmark and the Netherlands. Up to 70% of the network will be converted from former natural gas pipelines to minimise cost and environmental impact.

The project’s first two phases, Hyperlink 1 and Hyperlink 2, have been designated as IPCEI under the EU's Hy2Infra initiative, granting the project priority status, although no EU funding has yet been allocated (Hyperlink-Gasunie, 2024).

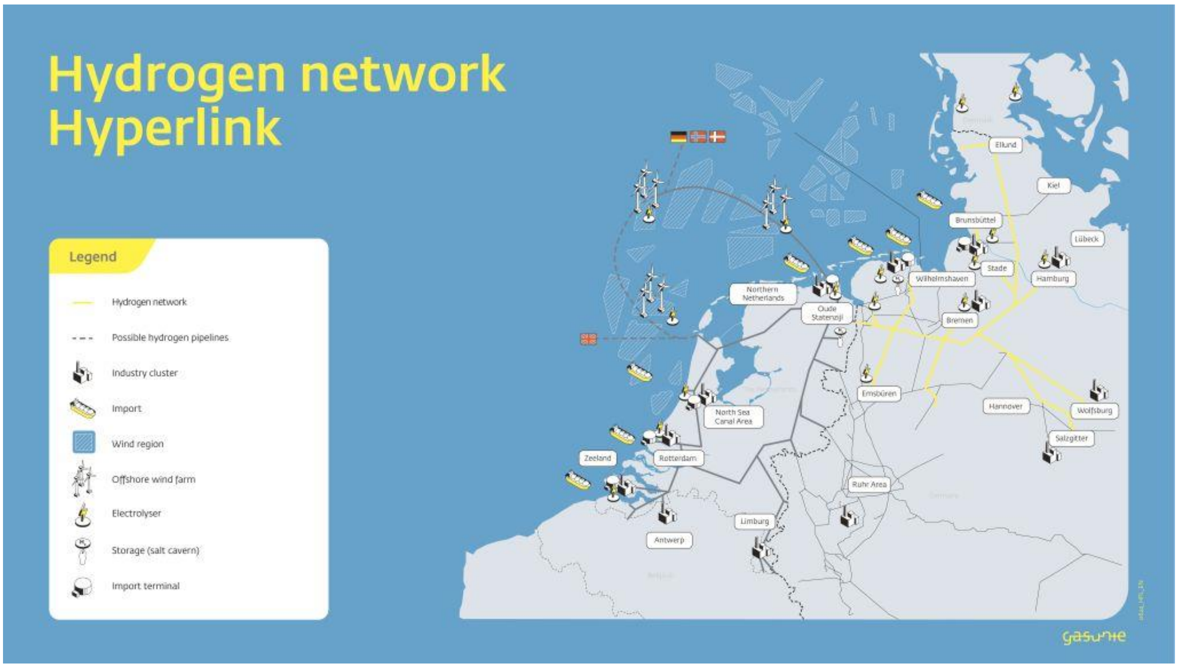

Figure 5-24 Visualization of Hyperlink. Source: Gasunie

Development status

Work began in 2023 and in 2024 almost 150 km of pipelines had already been completed.

Hyperlink 1 & 2 - Capacity 4.1 GW – Operational by 2027 & 2029.

Hyperlink 3 (Connection to Denmark) – Capacity 2.5-8.6 GW – Operational by 2028

Hyperlink 4 – Capacity 3.8-10.8 GW – Operational by 2027

Hyperlink 5 – Capacity 3.8-10.8 GW – Operational by 2028

Hyperlink 6 – Capacity up to 15 GW – Operational by 2030

Financing

The total cost of the project or its subcomponents has not been disclosed. However, Hyperlink 1 and 2 are financed by German federal and regional authorities, including: the Federal Ministry for Economic Affairs and Climate Protection, the Lower Saxony Ministry for the Environment, Energy and Climate Protection, the Lower Saxony Ministry for Economic Affairs, Transport, Building and Digitization and the Senate for Economy, Ports and Transformation of the Free Hanseatic City of Bremen (Hyperlink-Gasunie, 2024).

It should also be emphasised that Germany plans to establish an extensive hydrogen network (German backbone), which will be Europe's largest. The proposed network will extend over 9,700 km and require an investment of EUR 18.9 billion (DKK 141 billion) until 2032. Approximately 60% of the network will consist of repurposed natural gas pipelines, while the rest will be new construction. This project will connect industrial areas, ports and energy production sites as well as create close integration with Germany's neighbouring countries.

In 2024, the EU Commission approved Germany's plan to introduce a support scheme of EUR 3 billion to finance the construction of the hydrogen network. The support will be given as state guarantees, which will enable the hydrogen transmission system operators (TSOs) — private companies, which will build and operate the network — to take out loans at a lower interest rate from the KfW development bank, thereby reducing the costs of repurposing existing gas pipelines and building new hydrogen pipelines and compressor stations.

The government has also set up an "amortization account" to cover construction costs. The account, which guarantees the same amount as the cost of the infrastructure, is funded by a tariff paid by users, calculated based on projected usage until 2055. To ensure financial stability, there will be a tariff cap with the state covering any additional expense, if the infrastructure costs along the way become higher than expected. If the infrastructure is not fully repaid by 2055, the state will cover the shortfall, with a 24% deductible.

5.3.5 Hydrogen network: Hydrogen Backbone (DK)

Project description

The H2 Backbone project entails the establishment of an extensive hydrogen transmission network in Denmark, connecting central production sites with consumers and export points. The infrastructure will combine the repurpose of existing natural gas pipelines with the establishment of new hydrogen pipelines. The pipelines will stretch from a potentially future underground hydrogen storage facility in Lille Torup to the German border.

With the agreement on ownership and operation of infrastructure from May 2023, it was decided that Energinet will act as the system operator responsible for establishing and operating the hydrogen backbone. On June 19th, 2023, the Minister for Climate, Energy and Utilities approved Energinet’s application to initiate preparations for developing the hydrogen infrastructure.

Figure 5-25 Visualization of the Danish H2 Backbone. Source: Energinet.

In the spring of 2024, Energinet conducted an extensive market dialogue (Energinet, 2024) to assess the demand for hydrogen transport in Denmark. Thirty responses were received from 15 market actors, primarily with projects located along the backbone - especially near Fredericia, Esbjerg, and Holstebro. Most projects focused on producing hydrogen for export to Germany.

The results indicated a potential transport demand of 4.9 GW by 2032, rising to 6.9 GW by 2050. However, the project maturity varied considerably. Energinet has identified an immediate transport demand of approximately 0.8 GW in 2031 with high maturity for the southernmost pipeline section from Esbjerg to the German border. In addition, approximately 1.3 GW demand was reported for 2031 from projects linked to tendered offshore wind areas in the North Sea, which depend on concession awards.

Development status

The network is planned in several phases, of which the most important sections include:

- "The Seven", or "*Syvtallet*": Connects Esbjerg to the border with Germany.
- "Lower T, or "*Nedre T*": Stretches from Esbjerg over Fredericia to the border with Germany.
- "Full hydrogen backbone": Covers the entire network including storage facilities.

These routes are designed to enable both national distribution and hydrogen export, which is essential to meet growing European demand.

The government announced in January 2025 that the project will initially focus on the establishment of The Sevel (*Syvtallet*), i.e. stretch from Esbjerg to the German border. The pipeline is expected to be ready for commissioning by the end of 2030, but even in the best scenarios there is a risk that the project will only be completed in 2031. In the longer term, the ambition remains to develop a full hydrogen backbone, including northern and eastern connections to Fredericia.

Energinet is working on a FEED study in collaboration with COWI, which, together with the market dialogue results, will form the basis for a conditional business case and a §4 application under the Act on Energinet. These documents are expected to be submitted to the Ministry of Climate, Energy and Utilities by the end of Q1 2025. Approval will depend on the results of capacity sales in the second half of 2025. A final business case is expected to be completed in early 2026.

Financing

Energinet has estimated that a backbone can cost around DKK 15 billion in capital expenditure. According to *the Agreement on financial framework conditions for hydrogen infrastructure* from April 2024 (The Danish Government, 2024), Energinet's access to government funding (including equity injections, loans, guarantees, etc.) is subject to a range of conditions:

- Booking requirements: Pipeline users must legally and financially commit to purchasing at least 1.4 GW hydrogen capacity (out of a total of 3 GW) for a period of 10–15 years.
- Contract with Gasunie: Energinet must secure a contract with Gasunie on a hydrogen pipeline to Germany with mutual obligations.
- Creation of a subsidiary: Energinet must establish a subsidiary without state liability to handle the hydrogen system's development, financing, and operation.
- Responsible public co-financing: It must be demonstrated via the business case that public co-financing is economically responsible and does not result in state expenditure.
- Flexible tariffs: If flexible tariffs are desired, the Danish Utility Regulator must approve a revenue model allowing the deferral of deficits.

It should be noted that Energinet has adjusted the booking requirement geographically in October 2024:

- "The Seven": 0.8 GW. This was adjusted down to 500 MW in February 2025.
- "Lower-T": 0.9 GW.
- "Hydrogen backbone without storage": 1.2 GW.
- "Full hydrogen backbone": 1.4 GW.

These requirements may be further adjusted based on FEED results and changes to financial frameworks.

The booking requirement has faced criticism from industry actors, who generally advocate for lower thresholds to ensure the pipeline is actually built.

In February 2025, the government concluded a new political agreement (The Danish Government, 2025), establishing a public loan facility (so-called "on-lending") of DKK 7.4 billion to Energinet and operational support of up to DKK 8.3 billion for establishing "The Seven." Financing is contingent on Energinet's capacity sales. According to the agreement, the state will also cover Energinet's stranded costs of up to DKK 0.4 billion if the project is cancelled based on insufficient capacity sales.

Why these case studies are relevant
Infrastructure for the transport of green energy and CO_2 requires significant investments and public risk-sharing. Transnational electricity connections enhance energy security and enable better integration of renewable energy across Europe. Projects such as **Celtic Interconnector** and **Viking Link** are financed through a combination of EU grants, loans from the EIB, commercial banks, and large-scale investments by TSOs. They illustrate the need for robust risk-sharing between the state and private actors when developing energy infrastructure, along with close international cooperation. For hydrogen infrastructure, initiatives such as Spain's **H2Med**, Germany's **Hyperlink** network and Denmark's **H2 Backbone** highlight the need for deeper integration and international partnerships. As with electricity grids, these examples show the state's crucial role in expanding essential infrastructure. As previously mentioned, Germany - like Denmark - is developing an extensive hydrogen infrastructure spanning 9,700 km. Compared to the Danish case, the German approach, which includes state guarantees and an amortisation account, illustrates how the government can take a proactive role in developing the future hydrogen market. This model enables long-term infrastructure financing and reduces risks for private operators, which is essential to ensure investment certainty and unlock export potential. Germany aims to have the first phase of its hydrogen network ready by 2028 - two years before the first section of Denmark's hydrogen backbone. Recent developments indicate that the Danish government now seeks to accelerate infrastructure development, which is a step forward. However, the final financing decision for "The Seven" depends on the outcome of Energinet's

capacity sales, which are only expected to conclude by the end of 2026. Meanwhile, overall development of the hydrogen infrastructure remains subject to considerable uncertainty.

Lack of certainty regarding future infrastructure (Barrier 2) was also cited as one of the reasons behind the disappointing outcome of the most recent Danish offshore wind tender, highlighting the need for a more holistic approach to planning and financing renewable energy. If the risk of establishing hydrogen infrastructure is placed solely on developers - such as through capacity booking requirements, as seen in the Danish financing model **(The Danish Government, 2024)**, this may ultimately inhibit the development of PtX projects and thus delay the green transition.

There is also a need to strengthen Danish-German cooperation on cross-border hydrogen infrastructure to ensure an integrated approach to hydrogen market development in both countries. This would help create a market for Danish hydrogen (Barrier 4) and thereby reduce the risks for private investments in PtX projects.

Germany is therefore a good example of how to create clarity for investors about future hydrogen infrastructure (Barrier 2) as well as future regulation (Barrier 7). It also demonstrates how early state aid and risk-sharing between actors (Barrier 8) can help mitigate the risks associated with new green technologies, including PtX.

5.4 Linking barriers and measures in the case studies

This section describes the connection between the identified barriers (Chapter 6) and the applied or potential instruments (Chapter 3 and Chapter 6) in the green technology projects mapped in the chapter. Through a systematic review of the cases, it is illustrated how different actors - both public and private - work to meet the challenges through specific measures and strategies. The section provides insight into which policy instruments have proven effective in different contexts, and which instruments could potentially be used to tackle the remaining barriers.

Table 5-1 Overview of cases and associated barriers, measures, actors responsible for their implementation and possible relevance in the Danish context.

Cases	Technology	Connection with barrier	Measures *(both current and potential)*	Responsible actors	Relevance in the Danish context
Hornsea 2	Offshore wind	High capital requirements	Public subsidy (CfD), Green bonds, Loans/guarantees	The state Private actors (Ørsted, banks)	Yes – CfD has been used for many years in DK
Thor	Offshore wind	High capital requirements	Double-sided CfD with cap (in reality concession model - zero subsidy)	Private actors due to zero subsidy	Yes – Danish project
IJmuiden Ver Alpha and Beta	Offshore wind	Market volatility, High interest rates and inflation Lack of maturity and scaling of new green technologies, Uncertainty about supply (of electricity)	Zero subsidy with non-price criteria + grid connection costs are borne by the state Criteria for system integration (including PtX) for IJmuiden Ver Beta	The state and private players Private players (CIP + Vattenfall establish electrolysis plant and floating solar PV plant)	Yes
Tønder Biogas	Biogas	High capital requirements, Lack of offtakers	30-year subsidy scheme, clear political ambitions on the use of biogas in the gas network Private investments (CIP AB Fund), sale of guarantees of origin, 10-year agreement on the sale of biogenic CO_2 to European Energy	The state Private actors	Yes – Danish project
Tango Gigafactory	Sun	High capital requirements, Lack of scaling	Financial support, Loans and guarantees	The state EU National banks	Possibly

				and other financial institutions	
Megaton	Solar, wind and PtX	High capital requirements, Lack of buyers , Complexity and unpredictability in regulation, Long case processing time	Open-door scheme (applied - now closed) *Potential measures* include*:* Providing more flexible frameworks for RE supply, for example offshore wind; Implementation of the RE directive: can contribute to promoting the uptake of PtX products in key sectors; faster permitting processes for VE projects	Private actors The state + private actors The state	Yes – Danish project
Golden Plains Windfarm II	Onshore wind	High capital requirements	Loan Clear framework for investments in green technologies	EIFO (export loan to Vestas) + a number of international banks The state (Australian government's Capacity Investment Scheme)	Yes, support from EIFO can be used to reduce risks, especially in new technologies
Northvolt Ett	Batteries	High capital requirements, Volatility in the market, rising interest rates and inflation	Loan Direct investment (shares) *Possible instruments:* robust regulatory framework at EU level for the battery market with a focus on strengthening European production and securing access to key raw materials.	EIB, national governments, banks, pension funds Pension funds EU in cooperation with national states	Possibly
Kassø PtX	PtX	Lack of maturity and scaling of new, green technologies, High capital requirements, Uncertainty about offtake, Volatility in the market, Complexity and unpredictability in regulation	Public subsidy (through the Danish PtX tender): Has helped remove several barriers, including the lack of offtakers Risk hedging through co-location - co-locating the solar park and methanol production provides a form of risk hedging Innovation support Possible measures: Rapid implementation of the Renewable Energy Directive (see Megaton) Greater willingness to pay from private actors (offtakers) – e.g. due to regulatory or voluntary sustainability requirements	The state Private actors (developers) EU The state Private actors	Yes, Danish project
Arcadia E-fuels	PtX	Lack of maturity and scaling of new green technologies,	Investment from international funds Possible instruments:	Investment funds	Yes, Danish project

		High capital requirements, Uncertainty about offtake, Volatility in the market, Complexity and unpredictability in regulation	Public support for PtX projects, Implementation of the Renewable Energy Directive (see Megaton). Greater willingness to pay from private actors (offtakers) – e.g. due to regulatory or voluntary sustainability requirements	The state Private actors	
US-SOEC	PtX	Lack of maturity and scaling of new green technologies, High capital requirements, Complexity and unpredictability in regulation	Tax deductions (IRA)	The state (US government)	Partially – Topsoe is building the same plant in Herning (with support from the EU Innovation Fund)
Greenlab Skive	PtX	Lack of maturity and scaling of new green technologies, High capital requirements, Complexity and unpredictability in regulation	R&D support Public-private partnership	EU EU, Norlys, Skive Municipality, Spar Vest Fund and Climate Fund Skive	Yes, Danish project
Green Fuels for Denmark	PtX	Lack of maturity and scaling of new green technologies, High capital requirements, Uncertainty about offtake, High interest rates and inflation, Market volatility, Complexity and unpredictability in regulation	Public support (IPCEI) *Possible solutions:* Implementation of the Renewable Energy Directive (see Megaton), clear framework for hydrogen infrastructure Greater willingness to pay from private actors (consumers) – e.g. due to regulatory or voluntary sustainability requirements	The State The State Private actors	Yes – Danish project
Kalundborg Hub	CCS	Lack of maturity and scaling of new green technologies, High capital requirements , Complexity and unpredictability in regulation	Public subsidy Sale of CO_2 credits; Shorter and more uniform processing times for RE projects, including CCS	State Private actors	Yes, Danish project
Porthos	CCS	Lack of maturity and scaling of new green technologies, High capital requirements	Public support EU support (CEF-E)	State EU	Yes
Greensand	CCS	Lack of maturity and scaling of new green technologies, High capital requirements , Complexity and unpredictability in regulation	R&D support (EUDP) EU innovation support	State EU	Yes – Danish project
Orca	DAC	Lack of maturity and scaling of new green technologies, High capital requirements	Sale of CO_2 credits	Private actors	Yes
Seaborg Technologies	Nuclear power	Lack of maturity and scaling of new green technologies, High capital requirements Complexity and	Loan Private financing R&D support (EIC	Growth Fund (now EIFO) Various investors EU	Yes – Danish company

		unpredictability in regulation	Accelerator) *Possible instruments:* Public and private financing, clear political and regulatory framework for nuclear power		
SkyClean	Pyrolysis	Lack of maturity and scaling of new green technologies, High capital requirements	Public support (Pyrolysis pool) R&D support (EUDP) Direct subsidy and co-ownership of Stiesdal A/S *Possible instruments:* additional public subsidy; loans and guarantees; clear political and regulatory frameworks	State State EIFO + Chr. Augustinus Factories	Yes, Danish project
CIBI	Pyrolysis	Lack of maturity and scaling of new green technologies, High capital requirements	Public support (FRO) - discontinued due to lack of co-financing *Possible instruments:* additional public subsidy; loans and guarantees; clear political and regulatory frameworks	State State + private actors	Yes, Danish project
Celtic Interconnector	Electricity	High capital requirements	EU support (CEF-E) Loan Consumers' tariff payment	EU EIB , Danske Bank, Barclays and BNP TSOs (RTE + EirGrid)	Yes
Viking Link	Electricity	High capital requirements	Loan EU support (CEF) Consumers' tariff payment	Banks (Nordic Investment Bank) and credit institutions (SACE export credit). EU TSOs (Energinet and National Grid)	Yes, half-Danish project
H2Med	Hydrogen	Uncertainty about future infrastructure, Insufficient risk sharing between the state and private actors	Consumers' tariff payment *Possible instruments:* EU support (CEF-E)	TSOs (Enagas, GRTgaz, Teréga, REN, OGE) EU	Yes
Hyperlink and German hydrogen grid	Hydrogen	Uncertainty about future infrastructure, Insufficient risk sharing between the state and private actors	Support in the form of state guarantees for loans. Amortisation account that is financed through tariff payments with a guarantee that the state will cover possible deficits (deductible of 24%)	The state + development banks TSOs + the state	Yes
Danish H2 Backbone	Hydrogen	Uncertainty about future infrastructure, Insufficient risk sharing between the	Booking requirements (capacity requirements) with pipeline users for 10-15 years.	Private actors TSO	Yes – Danish project

		state and private actors	Possibility of state co-financing (conditional on the results of the capacity sale). Consumer tariff payment *Possible measures:* Inspiration from the German model with greater risk assumption by the state.	Possibly the state (conditional)

6 Barriers and areas of action to promote investments in the green transition

This chapter identifies various barriers that may hinder increased private investment and financing in the green transition, as well as different areas of action that can address these barriers. To achieve global and national climate targets, the transition to renewable energy requires comprehensive support and adaptation of framework conditions. The necessary technologies must not only be economically sustainable but also ensure social and industrial transformation from a broad societal perspective. The barriers identified in this chapter highlight challenges faced by private investors and lenders and provide a basis for understanding how these can be overcome.

There is a need for a range of initiatives to promote financing and investments in renewable energy so that Denmark's climate targets and international agreements can be met. Based on the work for this report and experiences from relevant case studies, COWI has identified several areas of action that can help exploit opportunities and counteract barriers. These areas are based on what has already succeeded in international contexts and can be used as inspiration for Danish solutions.

In addition, further areas of action have been identified based on input from market actors and mapping of barriers and support mechanisms. These areas are grounded in the specific challenges and needs emphasised by market participants and aim to improve the regulatory framework and strengthen collaboration between public and private actors.

The focus areas in this chapter are built around three overarching themes:

- **Danish export and competitiveness must be maintained:** Competitive market conditions must be ensured for Danish green technologies, leveraging Denmark's strong position in exporting solutions such as offshore wind and PtX.
- **Infrastructure is the backbone of the green transition**: Transparent and strategic expansion of the electricity grid, hydrogen network, and CO_2 transport infrastructure is crucial for enabling investments in renewable energy and technologies like offshore wind and PtX to be realised and generate value.
- **Security of energy supply must be ensured both in Denmark and Europe**: Denmark must strengthen Europe's supply security through export of green energy by establishing robust value chains and cooperating internationally.

These three themes provide the framework for the areas of action outlined and serve as guidelines for solutions to promote investment and financing in renewable energy. Some of the solutions draw on COWI's own analyses and comparisons with what has been done and achieved abroad, while others have been collected through interviews with relevant actors. Additional solutions are inspired by literature in the field and have been substantiated through the work on this report.

The report covers many different technologies that will contribute to the expansion of renewable energy and the fulfilment of climate targets, each operating under different market conditions and regulatory frameworks. However, the primary focus is on offshore wind and PtX, as the investment needs for these technologies are among the largest and they face the most significant barriers.

Offshore wind is the technology that will provide the majority of the energy that Danish society will be based on in the future. There is also enormous potential in exporting energy from Danish offshore wind. Denmark currently has 2.6 GW installed offshore wind capacity but aims to have 9 GW by 2030 and 44 GW by 2050. Significant and rapid investments are needed to meet these ambitious targets. At the same time, offshore wind faces considerably more uncertainty today than it did just a few years ago, partly due to rising construction costs and higher interest rates.

PtX is a key technology to convert the large amounts of energy produced from offshore wind into fuels for sectors that are difficult to electrify directly, such as shipping, aviation, chemical industry, and agriculture.

Many of the barriers highlighted affect projects' business case and thus the possibility of delivering a risk-adjusted return that appeals to investors or provides sufficient security to lenders that their loans will be repaid. Therefore, some of the areas of action also aim either to strengthen the business case around projects or to split investment risk between actors, for example, with public entities.

6.1 Barriers to increased private investments

Despite the growing recognition of the need for a green transition and the many opportunities offered by the shift to sustainable energy sources, private investments still face several significant challenges. Investors, financial institutions, and other actors in the financial sector experience that complex barriers hinder their ability and willingness to fully engage in green projects, particularly when it comes to new and less mature technologies. The following barriers represent some of the most recurring obstacles identified during the project, through case studies and interviews with actors in the energy markets, and must be addressed to ensure stronger, more coherent, and long-term financing of the green transition.

1. **Lack of maturity and scaling of new green technologies**
   Many new green technologies, such as PtX and CCUS, are still at an early development stage and/or have not yet been fully scaled. This means there is often significant technological uncertainty and higher risks associated with these investments. Investors face challenges such as lack of historical data and the need for large capital injections to bring these technologies from pilot projects to commercial scale. Immature technologies are also more exposed to technological failures or market barriers, making it harder for private investors to predict stable returns and reduce risk in their investments.

2. **Uncertainty about future transport infrastructure**
   A major barrier to investments in green technologies is the lack of established transport infrastructure. For example, there is considerable uncertainty regarding the development of hydrogen networks, storage facilities, and connection to the existing electricity grid. This lack of clarity about where and how the necessary infrastructure will be developed creates significant uncertainty for investors. Infrastructure costs and availability are often decisive for these technologies to be scaled and become commercially viable.

3. **Market volatility**
   The market for new green technologies is characterised by significant volatility, posing a major barrier to investment and growth. Prices for necessary production components, such as electrolysis plants, have already risen considerably in a few years, creating uncertainty about actual production costs. Furthermore, changes in global energy prices, including natural gas and electricity prices, affect the economics of green projects. This uncertainty about price developments may deter investors from committing to projects.

4. **Uncertainty about offtake**
   Many financiers and investors refrain from funding and investing in hydrogen and CCUS projects due to uncertainties about offtake agreements and concerns over future price developments. They therefore prefer long offtake agreements of 10 years or more. Conversely, offtakers prefer shorter agreements as they expect prices to fall as new technologies mature.

5. **High capital requirements, especially in the start-up phase**
   Many green technologies require significant investments in early development stages, making it challenging for private investors to commit, especially without clear financing

frameworks or support schemes. Without subsidies or other public support instruments, the risks of investing in new technologies may be disproportionately large compared to expected returns. This creates a major barrier, particularly for small and medium-sized investors who do not have the capacity to commit large capital amounts to projects that have yet to prove their sustainability or commercial success.

6. **Long processing times**
   Lengthy and complex processing and permitting procedures, e.g., for offshore wind and/or PtX projects, can delay implementation. Slow permitting processes create additional uncertainty about project timelines and costs. This may cause investors to withdraw or wait to commit until all approvals are in place. For example, onshore wind projects face an average processing and grid connection time of six years. For the Danish hydrogen pipeline infrastructure, processing times are budgeted at four years. The EU's maximum approval deadline for renewable energy plants, as stipulated in the Renewable Energy Directive, is two years. Thus, Denmark exceeds the processing time limits set by the EU.

7. **Complexity and unpredictability in regulation**
   Complexity and unpredictability in regulation pose a significant barrier to investment in green technologies. Frequent changes in legislation, such as CO_2 pricing and sustainability requirements, create uncertainty for investors who fear that new regulations may reduce project profitability. Moreover, lack of implementation of EU regulations, such as the Renewable Energy Directive, and enforcement of the ReFuelEU Aviation Regulation delay growth in the renewable energy sector, as unclear and incomplete rules create doubt about future framework conditions.

8. **Insufficient risk-taking by the state**
   A lack of sufficient risk-taking by public authorities constitutes a major barrier to investment in green projects, particularly concerning infrastructure development and financing of new technologies. If the state is unwilling to share risk through subsidies, public investments, or guarantees, private investors will be more reluctant to invest, as the risk otherwise falls entirely on them.

9. **Unfavourable and rigid conditions in the latest Danish offshore tender**
   The first part of the latest Danish offshore wind tender of 6 GW (Chapter 4) resulted in no bids from developers, reflecting the challenges of the prevailing conditions. The tender was based on a concession model without subsidies, where developers were required to pay fixed annual concession fees to the state over 30 years and accept the state's demand for 20% co-ownership. The state's 20% ownership in offshore wind farms may lead to lower concession payments, as the 'rent' for the seabed is linked to the state's ownership. Without support to developers and with fixed annual payments, this reduced investors' interest.

   Similarly, the Danish tender, compared to other European countries, was characterised by a rigid design regarding capacities, grid connection, and seabed utilisation, further undermining Danish offshore wind competitiveness.

10. **Rising interest rates and inflation**
    Recent years' price developments have made capital-intensive renewable energy investments, such as offshore wind, significantly more expensive. Coupled with rising interest rates, this has caused the risk-adjusted returns to deteriorate substantially for capital-intensive energy plants.

11. **Lack of capacity in the electricity grid**
    There is significant interest in establishing solar power plants, with many projects and large capacity in the pipeline. However, in many places the electricity grid lacks the necessary capacity to transport the electricity from solar plants to consumers, such as PtX plants,

charging stations, heat pumps, etc. Without expansion of the electricity grid, the electricity price that solar plants can achieve will be lower, especially as more plants are established. The many solar plants may therefore risk cannibalising each other unless the necessary investments in grid expansion are made. Likewise, the electricity price for consumers will increase if grid capacity is insufficient.

12. **Double tariffs for electricity storage**
    There is a growing need to store electricity from wind turbines and solar plants, so production can be shifted to times of demand and to reduce stress on the electricity grid. However, storage facilities face significant barriers as they are subject to paying both production and consumption tariffs on grid connection, charging, and discharging. Storage technologies are already relatively expensive, and these tariffs further challenge the business case.

13. **High taxes on green energy**
    Danish taxes on green energy, such as electricity produced from wind turbines and solar panels, and biogas produced from manure, are often as high or higher than those on comparable fossil energy. Although production is subsidised, the sale of renewable energy is challenged, especially within Denmark's borders, as it often makes more sense economically to export the energy - and thus the CO_2 reductions - abroad.

14. **Land registration and registration fees**
    To finance the expansion of the electricity grid, security (collateral) can be placed in the transformer stations, which are regarded as real estate. However, there is a challenge with the small transformer stations in the distribution grid, as each must be individually assessed and registered (in Danish this is called "tinglysning"), which is an administratively heavy and time-consuming process. This practice leads to higher costs for both borrowers and lenders and limits the collateral value for lenders.

6.2 Three cross-cutting themes should guide climate policy action

To ensure that barriers are overcome and necessary investments realised, three concrete themes have been identified as focal points for future climate policy initiatives:

- **Danish export and competitiveness must be maintained**: Denmark's green strengths are an important export driver. Technological advances in offshore wind, PtX, CCS and other renewable energy technologies place Denmark in a favourable position to deliver solutions that not only address national needs but also meet growing global demand for sustainable energy solutions. A particular opportunity lies in strengthening exports of green hydrogen to neighbouring countries such as Germany, which faces a major transition of its energy-intensive industries.

  To maintain Denmark's strong position, it is crucial that Danish market conditions remain competitive. Danish companies face increasing competition from other countries investing heavily in similar technologies. If investments in offshore wind and other green technologies are more attractive elsewhere, Denmark risks losing market shares to both European actors and global players like the US and China.

- **Infrastructure is the backbone of the green transition:** Without coordinated expansion of critical infrastructure such as the electricity grid, hydrogen networks, and CO_2 transport networks, investments in renewable energy sources and technologies risk losing their value. The report highlights that without a hydrogen infrastructure, incentives for investments in offshore wind and PtX will be weakened. For example, effective tender models for offshore wind require a clear plan for how both electricity and hydrogen produced from renewable energy can be integrated into the Danish and European energy systems.

- **Security of energy supply must be ensured both in Denmark and Europe:** War in Europe and instability in energy markets have made supply security a critical priority. Denmark plays an important role both as a producer and exporter of green energy. Denmark's capacity to develop and export green energy can contribute to strengthening supply security across Europe. However, this requires a targeted effort to establish robust value chains, enhance cross-border cooperation, and ensure that Danish companies can compete in the global market.

These themes form the basis for a series of focus areas outlined in the following two sections. The focus areas are divided into two groups: the first group is based on experiences from relevant cases, while the second group arises from dialogue with market actors and the identified barriers.

The below should be regarded as a preliminary catalogue of possible actions, some targeting specific barriers, while others aim to broadly improve the framework conditions.

6.3 Experiences from case studies and potential areas of action

This section presents areas of action based on experiences from the mapped case studies in Chapter 5. These cases provide valuable insights into what has worked in practice and may serve as inspiration for future initiatives in Denmark. The identified focus areas concentrate on solutions - such as state aid or clear regulatory conditions - that have proven capable of promoting, or are expected to promote, increased financing and investment in green technologies.

6.3.1 Various forms of support ensure competitiveness in offshore wind tender models

The auction-based Danish offshore wind tenders have been based on bids ranging from a support level down to zero kroner or concession payments down to zero kroner. However, there has been no option for bids spanning from support to concession payments, except in the Thor tender. In a model ranging from zero subsidy to subsidy, there is a genuine risk that the state misses out on potential concession payments which market participants might be willing to pay. Conversely, in a model ranging from zero concession to concession, there is also a real risk that no bids are received, which could halt Denmark's green energy transition. Both models are therefore problematic as they do not necessarily capture the real price offshore wind is worth in the current tender.

Compared to other countries such as Germany, the Netherlands, and the US, where competition for offshore wind projects often relies on more flexible and attractive models, the Danish tenders are less competitive. Hornsea 2 demonstrates how it is possible to create stable and predictable economic frameworks through CfD (Contract for Difference), enabling the robustness of project economics and attracting investments.

The competitiveness of offshore wind tenders is also influenced by other factors that Denmark should consider. In several countries, for example, the state offers support for electricity transmission infrastructure, guarantees for establishing hydrogen infrastructure, or increased support for hydrogen production. IJmuiden Ver Alpha and Beta in the Netherlands have shown how zero-subsidy projects can succeed without government financial support. In these projects, non-price criteria such as technological innovation and sustainability were weighted highly, enabling developers to deliver competitive solutions that did not necessarily require subsidies. At the same time, grid connection was handled by the state, reducing developers' risks, particularly in light of rising offshore wind costs. These measures lower developers' risks and help make the business case for offshore wind more attractive. It is therefore necessary to ensure that Danish tender conditions are on par with the most competitive models found in comparator countries.

Based on experiences in other countries, future Danish offshore wind tenders could consider introducing a model spanning from subsidy to concession payments, allowing market participants to bid either with a need for subsidy or an offer to pay a concession. This approach ensures that the green transition is not hindered while allowing the state to capture potential concession revenues.

Moreover, payments from developers to the state (concession payments) can be structured as success-dependent payments, for example through profit-sharing models known from the oil and gas sector. Such a model typically involves offshore wind park developers bidding on the percentage share of the difference between a predefined benchmark price and the actual electricity price they will deliver to the state. The benchmark price is usually set relatively low, so the state only provides a limited minimum guarantee. If the electricity price exceeds this benchmark, the “surplus”, i.e., the difference, is shared according to an agreed percentage split. This mechanism is attractive to developers because they retain part of the income at high electricity prices. At the same time, the state benefits from the market’s upside potential without bearing the full risk of low prices. For offshore wind projects, this model is relevant as technology and operating costs have fallen in recent years but can still vary significantly. The developer gains a safety net in the event of low market prices and retains a financial gain when prices rise, creating an incentive to optimise production - for example, by scheduling maintenance to sell as much electricity as possible during peak price periods. The state receives revenue when the price exceeds the benchmark but avoids large, fixed payments at low price levels, as seen in CfD models.

6.3.2 System integration as an award criterion in offshore wind tenders can increase the profitability of PtX

A significant barrier to increased private investment in the green transition is the limited opportunities for system integration between offshore wind and PtX. A closer link between offshore wind production and PtX technologies can ensure better utilisation of renewable energy, particularly during periods of surplus electricity. This integration can both increase the socio-economic value of offshore wind and strengthen business models for PtX plants. Without a holistic approach to the interplay between electricity and hydrogen production, investor risk increases, potentially hindering the expansion of both renewable energy sources and PtX capacity.

Experience from IJmuiden Ver Beta in the Netherlands shows how system integration can support the development of both offshore wind and PtX. Here, system integration was used as a key award criterion in the tender, ensuring an integrated energy utilisation solution. CIP and Vattenfall (jointly in the joint venture “Zeevonk”) were selected as developers for the Beta area, where the project includes 2 GW offshore wind, a 50 MWp floating solar park, and a large electrolyser facility in Rotterdam Harbour for green hydrogen production. This setup enables balancing the energy system by converting electricity into hydrogen when prices are low, thereby increasing the project’s overall economic robustness.

By including system integration with PtX as an award criterion in future offshore wind tenders, projects can be made more resilient to electricity price fluctuations. At the same time, it will improve the risk-adjusted returns for PtX investments if the technology becomes an integrated part of offshore wind tender models.

Furthermore, it is important that the next offshore wind tender is better coordinated with the upcoming Danish hydrogen infrastructure, which was identified as a key reason why the most recent tender round with a deadline in December 2024 did not succeed.

6.3.3 A more proactive government role in establishing transport infrastructure can reduce risks for private actors and encourage investment

Investments in transport infrastructure can have a significant positive effect on the Danish economy but involve risks so substantial that market actors find them difficult to assume alone.

The state plays a key role in expanding shared infrastructure in Denmark, including for export. Clarity on the schedule, capacity, and pricing for expanding electricity grids and hydrogen pipelines creates the necessary certainty for offtake of renewable energy products, enabling private developers to make final investment decisions. If the risk of establishing infrastructure for new technologies falls solely on developers—for example, through capacity booking requirements—there is an increased risk that projects will not be realised. Delays in developing electricity and hydrogen networks significantly increase the risk that Danish renewable energy and hydrogen projects will not be realised, preventing Denmark from reaching its climate goals and international commitments on renewable energy.

To drive the expansion of renewable energy plants, it is essential that the state is willing to bear a larger share of the risk related to establishing the mentioned transport infrastructure. This could include hybrid financing models that combine public funds with private investment, reducing risk and encouraging private participation. The most recent political agreement on hydrogen infrastructure from February 2025 (The Danish Government, 2025), which accelerates the first phase of the Danish hydrogen infrastructure (*Syvtallet*) and provides for operating subsidies, is a step in the right direction. However, there remains a need for certainty regarding schedules, financing, and necessary framework conditions so that investors and developers can make informed decisions.

A possible inspiration from cases could be the German financing model for hydrogen infrastructure, where state guarantees reduce borrowing costs for transmission system operators, and an amortisation account ensures that users pay infrastructure costs over time through average tariffs. This model simultaneously ensures that the state assumes part of the risk and covers potential deficits. It can attract private investment and ensure financial stability for projects.

Increased cooperation between public and private actors, including for establishing hydrogen and CO_2 networks as well as expanding the electricity grid, is therefore essential to facilitate investment in new, riskier technologies such as PtX, CCS, pyrolysis, and more.

6.3.4 State aid can contribute to accelerating PtX development

A range of new RE technologies face a greater market risk than established technologies and therefore, require additional support to develop and become competitive. PtX is one of these promising technologies with enormous global potential. Denmark has advantageous competitive strengths in this regard, particularly due to offshore wind resources in the North Sea, but also thanks to opportunities for sector coupling, such as the use of surplus heat in district heating systems, and significant biogenic CO_2 resources from Danish biogas plants and biomass power stations, which can be used to produce, for example, methanol and aviation fuel. Although these advantages give PtX in Denmark a strong foundation, they are not sufficient to ensure the necessary development attract the multi-billion investments required to meet Denmark's climate targets.

Financial support is therefore needed to overcome the risks associated with being a first mover on PtX in Denmark. Support schemes do not necessarily need to be long-term, as the technology's potential, along with global development, is expected to ensure commercial viability over time. However, it is essential that support for first movers is stable and predictable, so that a project which has received funding can be guaranteed this for at least 10 years. It is critical that the technology is significantly supported in its early phase, so that the risk-adjusted return on PtX investments rises to a level where it can compete with investments in other sectors, since investors and lenders do not necessarily favour the energy sector in a way that would allow them to accept lower returns compared to other sectors.

Experience from European Energy's Kassø project shows how a long-term support scheme can reduce risks and promote private investment. In this case, the support obtained through the Danish PtX tender was crucial for securing long-term offtake agreements, including by lowering the price of methanol. The support model, based on a fixed price premium per unit produced over a 10-year period, creates financial stability and predictability for both producers and investors.

Similarly, the establishment of Topsoe's electrolysis plant in Virginia was made possible by the IRA's tax incentives, which reduce initial investment costs and offer long-term certainty to private investors. With its tax credits, the IRA provides a more stable framework for investment in green technologies, thereby reducing uncertainty and making it easier to attract capital.

These experiences underline the importance of a stable and predictable support scheme for PtX first movers in Denmark. A relevant area of focus in this context is at EU level, where Denmark could participate in an upcoming round of the European Hydrogen Bank's *Auction-as-a-Service* mechanism, which targets PtX projects. With *Auction-as-a-Service*, EU Member States can contribute national funding to support the production of RFNBO hydrogen. This mechanism mobilises such additional national funding through a shared European auction platform. In practice, participating companies in the respective countries submit a single bid for two funding sources: one from the EU as the primary source and one national source that supports projects located within the Member State.

The scheme allows Member States to finance additional projects in their country, even after the European Hydrogen Bank's budget is fully allocated. This reduces administrative burdens and supports an efficient rollout of green hydrogen projects. Germany participated in the mechanism as part of the first round of the European Hydrogen Bank Auction in 2023, and Spain, Austria, and Lithuania have all allocated funding for the second round, opening on 3 December 2024.

By joining the mechanism, Danish PtX projects will gain access to an auction-based feed-in premium. This can help increase the risk-adjusted return and thus cover the gap between the cost of producing RFNBO hydrogen and the price the market is willing to pay. At the same time, the mechanism ensures that the Danish state will face minimal administrative burden in managing the support.

6.3.5 EIFO already plays an important role in financing Danish solutions and its green efforts can be further strengthened

Market players bear significant risk when constructing renewable energy facilities, which is passed on to those providing investment and financing for the projects. This high risk limits the ability to attract the necessary private capital. To address this, it could be explored how the risk can be shifted from market actors to the state, for example, via Denmark's Export and Investment Fund (EIFO). This is particularly relevant for new technologies such as PtX, DAC, and pyrolysis, which are not yet well-established in Denmark.

Experience from the Golden Plains Phase 2 project in Australia shows how targeted public financing can support private investment and ensure the realisation of large renewable energy projects. EIFO committed up to DKK 1.3 billion in export loans, which ensured that Vestas supplied the project's wind turbines and was awarded a 30-year service contract. This case highlights the important role EIFO can play in reducing risk for private investors while supporting Danish companies in the green transition.

A relevant area of action could therefore be to explore options to prioritise EIFO's green transition focus by reserving a greater share of its budget to support renewable energy investments within Denmark. At the same time, EIFO could be more strongly committed to providing loans and other financial instruments for high-risk investments in renewables to promote the necessary development.

Additionally, the impact on Denmark's economy could become a central assessment criterion for EIFO when evaluating projects, so the fund contributes more actively to sustainable economic and green growth in Denmark.

EIFO has been able to play an important role in international wind energy transactions, partly due to a well-functioning reinsurance programme involving private reinsurers and the Danish Green Future Fund (DGFF). Strengthening EIFO's reinsurance capacity will ensure that this positive development can continue - not just in wind, but also for PtX, in line with rising investment levels.

It could therefore be worth considering whether to create opportunities for EIFO to increase its reinsurance capacity. This could take place under the auspices of the DGFF and/or at EU level (e.g. via the European Investment Bank or similar institutions).

6.4 Additional experiences and areas of action

This section highlights the areas of action developed based on dialogue with relevant market actors, industry proposals, and the identified barriers and mechanisms. Input from stakeholders such as private developers, industry organisations, financial institutions, and asset managers has provided insights into the specific barriers faced by private actors. The proposed actions are therefore based on a broad foundation of experience and aim to improve investment and financing conditions and increase private sector engagement in renewable energy.

6.4.1 Several developers are ready to take greater ownership in the development and establishment of renewable energy projects

There may be potential in giving developers a greater role in driving the development of new offshore wind areas, rather than having the state define and design this development. This could reduce developers' risk and give them more freedom to design the use and exploitation of specific areas for renewable energy, including offshore wind and offshore hydrogen production. The state could instead focus on tendering areas, where developers themselves adapt projects to market conditions and technological possibilities, making individual projects viable for the specific developer on the site.

This applies, for example, to capacity and design of renewable energy facilities, as well as the form and destination of the energy produced.

Flexibility in project size is an important parameter so that developers can propose solutions that are both commercially and socially optimal. One possible approach is to return to the state those areas where the developer cannot realise a profitable project. This ensures optimal resource utilisation while leveraging market knowledge and dynamics.

6.4.2 Lengthy and complex permitting processes delay renewable energy projects and requires simplification

Given the speed that the green transition must necessarily have in the coming years, there is a need for the authorities to reduce permitting times. Many renewable energy projects encounter lengthy and complicated approval processes, which delay implementation and create additional uncertainty regarding timelines and project costs.

For example, the budgeted permitting process for establishing the Danish hydrogen pipeline to Germany is 40 months, while the average permitting period for onshore wind projects is 6 years. PtX developers must obtain 29 different permits for setting up a facility on land (see table below). Meanwhile, CCS stakeholders note that multiple issues are revisited repeatedly, as both applicants and authorities often face new processes and challenges.

The revised Renewable Energy Directive stipulates that permitting procedures must not exceed 2 years. Prolonged approval processes can lead investors to withdraw or postpone their commitments until all permits are secured, which may further hamper project progress.

Table 6-1 Overview of permits for the establishment of PtX facilities on land. Source: DEA.

No.	Permission	Authority
1	Municipal plan (amendment)	Municipality
2	Local plan	Municipality
3	Coastal proximity zone plan	Municipality

4	Mineral extraction zone plan	Municipality
5	Rural zone permit	Municipality
6	Building permit	Municipality
7	Dispensation from the Agricultural Act	National Board of Agriculture
8	Any permits according to the Road Act	Municipality
9	Dispensation from Nature Conservation § 3 Areas	Municipality
10	Dispensation from dune protection line	Coastal Directorate
11	Dispensation from shoreline protection line	Coastal Directorate
12	Dispensation from watercourse and lake protection line	Municipality
13	Dispensation from ancient monument protection line	Municipality
14	Dispensation from church proximity line	Municipality
15	Dispensation from historic preservation	The Conservation Board
16	Dispensation from protection obligation	The Environmental Protection Agency
17	Dispensation from ancient monument protection	Municipality
18	Dispensation from the Species Protection Act	The Environmental Protection Agency
19	Soil Contamination Act (Jordforureningsloven - JFL)	The municipality grants permission pursuant to § 8 of the Soil Contamination Act (JFL), which must align with an opinion obtained from the regional authority, per JFL § 8a. According to § 50 (3), the minister's authority is implemented through the Executive Order on Soil Relocation.
20	Environmental approval for the reuse of excavated soil	Municipality
21	Screening and environmental report (plans and programs)	Municipality
22	Screening and EIA permit for the project	The municipality or the Environmental Protection Agency
23	Environmental permit	The municipality or the Danish Environmental Protection Agency depending on the PtX activity.
24	Risk assessment procedure	The municipality or the Danish Environmental Protection Agency depending on the PtX activity. Other risk authorities are the Danish Working Environment Authority, the municipal fire and rescue service, the

		Emergency Management Agency and the police.
25	Fire safety approval	The municipal rescue service, possibly with conditions from the Emergency Management Agency
26	Utility connection permit	Municipality
27	Extraction permit	Municipality
28	Notification to the Danish Safety Technology Authority (SIK)	Danish Safety Technology Authority
29	Grid connection permit	Energinet

The government has established the National Energy Crisis Staff (in Danish: *Nationale energikrisestab*, NEKST) with the aim of identifying and proposing measures to reduce permitting times for renewable energy projects. In February 2024, the working group published 27 recommendations to accelerate the deployment of solar and onshore wind energy (NEKST-working group, 2024).

It is important that the measures, which the government's NEKST working group has proposed to reduce processing times, are implemented as soon as possible. Among the recommendations is the implementation of acceleration areas for renewables and electricity infrastructure. The revised Renewable Energy Directive (REDIII) requires member States to designate such areas, where planning and environmental clearance processes can be made more efficient. Parallel implementation of provisions for both RE installations and electricity infrastructure in Danish legislation will ensure faster environmental clearances and, according to NEKST, reduce processing time by 1–2 years.

In addition, NEKST recommends strengthening the *national task force* (in Danish “rejseholdet”), which could be mandated to assist national and municipal authorities in reducing processing times for RE projects. The task force could prioritize those projects that contribute most to achieving Denmark’s climate targets.

In complement to NEKST’s recommendations, the task force could also function as a *one-stop shop*, where RE projects can directly address all their legal and permitting needs. By reducing fragmentation in communication between project developers and authorities, internal coordination within agencies is strengthened, while projects experience reduced complexity in obtaining the necessary permits.

6.4.3 Implementation of EU rules can strengthen demand for and financing of PtX fuels

Another barrier to financing and investment in renewable energy is significant regulatory uncertainty. This particularly affects potential offtakers of PtX products, who are hesitant to commit to long-term contracts. As a result, it is often difficult to secure the necessary investments, as well as bank loans and guarantees.

A concrete example is the 2023 revision of the EU Renewable Energy Directive (RED) and the adoption of the ReFuelEU Aviation and FuelEU Maritime regulations that same year. These mandate that a certain share of fuels used in road, maritime, and air transport must come from renewable and sustainable sources. Although these rules have been adopted at EU level, they have yet to be implemented into Danish legislation. This creates considerable uncertainty and reluctance among end-sector users of sustainable fuels, as they do not yet know what they will be required to commit to or what the consequences of non-compliance will be. For fuel producers, this uncertainty presents significant challenges to the business case, as future demand for their product cannot be predicted. Without committed offtakers, it is also difficult to attract financing and investment, which hampers the development and realisation of projects.

Denmark could benefit from fully implementing the usage requirements of the Renewable Energy Directive for PtX fuels (RFNBOs) as soon as possible, by introducing a general use requirement covering the entire domestic transport sector (road, maritime, and aviation). Furthermore, a PtX ticketing system could be introduced, allowing companies that exceed the blending requirement to sell excess volumes to those falling short - a system already in place for biofuels used in Danish road transport. This would ease the burden for companies subject to the most stringent usage and CO_2 reduction requirements, such as those in aviation and maritime transport. Additionally, there is a need to promptly implement the administrative processes for enforcing the ReFuelEU Aviation and FuelEU Maritime regulations, including penalties for non-compliance.

It is crucial that EU legislation is implemented quickly and thoughtfully, providing stable, long-term political frameworks and predictability for investors.

6.4.4 Limited grid connection models can accelerate the development of green energy projects

Green energy projects face major barriers due to long waiting times for grid connection—often up to 7–8 years—causing uncertainty and hampering investments. One potential area of action could be to develop a model that allows renewable energy projects to be established with limited grid connection, covering only part of their total production capacity.

This approach enables faster and cheaper grid connection by reducing connection costs and avoiding extensive electricity grid expansions. By limiting power feed-in, projects can be realised more quickly within existing financial and infrastructure frameworks. This increases flexibility for energy producers and makes it easier to plan and finance new projects.

Green Power Denmark has already established a method for limited grid access at the distribution level, setting a precedent for broader implementation. A similar model could be developed for the transmission level, which would promote investment and support the green transition with flexible and realistic solutions.

6.4.5 Simplifying land registration for the electricity grid can ease financing of grid expansion

To secure long-term financing for power grid expansion, including funding through mortgage lending (in Danish “realkreditfinansiering”), borrowers can offer the grid as collateral, such as by providing security (in Danish “pant”) over transformer stations, which may qualify as real estate, thereby allowing them to access more favourable loan terms. Under Danish law, there isn’t a strict legal definition of “real estate”; rather, whether a station constitutes real estate depends on whether it has the characteristics of a building and is intended to remain permanently in place.

In the distribution network, there are roughly 70,000 small 10 kV/0.4 kV transformer stations, each of which must be individually assessed. Those qualifying as standalone buildings must then be formally registered (in Danish this is called “tinglysning”) to support mortgage financing. This process is time-consuming, complex, and administratively costly, yet typically adds minimal collateral value for lenders. As the grid continues to expand, new transformer stations (such as 50–60/10 kV stations) that become integrated parts of the grid must be registered under current rules. For such registrations, a variable land registration fee (in Danish “variabel tinglysningsafgift”) must be paid, along with a smaller fixed fee. Under the current rules, expansions of already mortgaged infrastructure mean that electricity companies are, in practice, required to pay the full fee each time they expand the grid with a transformer station -that is, they must pay a fee on both the existing collateral and the new addition. The variable fee currently amounts to 1.45% of the mortgaged amount.

For long-term infrastructure financing of grid expansions, collateral must be land registered in transformer stations. One possible improvement would be to investigate whether all small 10/0.4 kV transformer stations could be included under the same registration requirement that currently applies to large 50–60/10 kV stations on the transmission grid. Such an approach would create an automatic, bundled solution, where lenders would automatically have a lien over the smaller stations once they hold liens over the larger ones. This could significantly reduce the complexity and administrative burden associated with financing grid expansion.

Additionally, it would be worth considering reform of the land registration fee rules, so that expansions to the transmission and distribution grid do not trigger a full new fee each time—instead only charging for net increases.

6.4.6 A balanced tax structure can promote the use of green energy in Denmark

Denmark is facing a major electrification of society. At the same time, the tax on green electricity is higher than on many fossil alternatives such as coal, natural gas, heating oil, diesel, and petrol. Electricity tax in Denmark is also the highest in Europe. This fundamentally contradicts the national objective of basing Danish energy consumption on electricity from wind and solar.

Similarly, Danish biogas is taxed at the same level as natural gas, whereas other countries have either removed or significantly reduced their biogas taxes. As a result, most of the biogas produced in Denmark is exported, along with the associated CO_2 savings.

Denmark lacks a balanced approach to support and taxation of renewable energy. Renewable energy typically receives production subsidies, but consumption is not supported to the same extent. This leads to a large share of Danish renewable energy production being exported instead of consumed domestically, meaning that Denmark forfeits substantial CO_2 savings despite providing significant production subsidies.

It may be worth investigating the potential for reducing consumption taxes on green energy that can be documented - via guarantees of origin - as originating from renewable sources. In this way, Denmark can ensure that renewable energy supported by national subsidies is also used within the country.

6.4.7 Revised tariffs for batteries can support energy storage and promote grid stability

With growing volumes of variable electricity production from solar and wind, the need to store electricity for later use is increasing. However, electricity storage technologies currently face double the grid connection costs compared to technologies that only produce or only consume electricity. This is because batteries and similar storage technologies are classified as both consumers and producers of electricity. Once commissioned, a battery is subject to tariffs as a consumer when charging, and as a producer when discharging. This is despite the fact that batteries reduce the load on the electricity grid, thereby benefiting grid stability and reducing the need for other types of expansion.

A relevant area of action is therefore to investigate the possibility of exempting batteries from tariffs, as they do not increase the load on the grid but rather help reduce it.

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