



Norwegian Ministry  
of Petroleum and Energy

Meld. St. 33 (2019–2020) Report to the Storting (white paper)

# Longship – Carbon capture and storage





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## Longship

The Norwegian Government has decided to call the Norwegian project on carbon capture, transport and storage *Longship*, in Norwegian *Langskip*. The characteristic shape, and flexible, supple construction of the Vikings' longships made them one of the greatest innovations and most ground-breaking ship-building technologies of their day. Longships were sleek, seaworthy and fast vessels, making them highly suitable for war and plundering voyages. However, trade was more important than plundering. The longships enabled the Vikings to become long-distance traders who exchanged valuable goods from the North with goods from faraway lands, such as silk and spices. Despite our ancestors often spreading fear along their path, longships have become a familiar symbol worldwide of the Viking Age and are associated with Norway.

Like those who built the longships, we also aim to take our technology out into the world, but only by peaceful means. The Government places major emphasis on Longship being a cost-effective solution for carbon capture and storage, and a technology that many can utilise.

In the same way as it was hard work to build a longship using the clinker method, a major effort from companies and a significant amount of public financing are required to realise a cost-effective solution for carbon capture and storage. Longship is the result of many years of hard work across several Norwegian governments. Authorities and industry representatives have worked together towards a shared goal, and the decision basis the Government is now presenting to the Storting is extensive, robust and quality-assured. The Vikings' longships could make use of the wind through their sails, but it was often necessary to use raw manpower to row the ships. In both instances, the crew had to work *together*. In much the same way, we must also continue to work together to implement the project in the best way possible.

Those boarding a longship and setting out to sea in the Middle Ages quite often sailed into the unknown. Now that our own Longship is ready for construction, we are also entering uncharted waters. We do not know for sure what price will be levied upon CO<sub>2</sub> emissions over the next decades. Uncertainty in terms of how the market for CO<sub>2</sub> storage will develop in Europe will remain. However, we can be relatively certain that Longship will be an important contribution to creating value chains for carbon capture and storage in Europe. We can also have great faith that the project will contribute to technological development and learning at such a scale that the costs of the next carbon capture facility to be built will be lower than the first.

Longship will bring Norway to the forefront of the development of a technology that could prove decisive in achieving our climate targets.



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*Recommendation from the Ministry of Petroleum and Energy of 21 September 2020,  
approved by the Council of State on the same date.  
(Solberg Government)*

## 1 Introduction

The Government will contribute to developing technology for carbon capture, transport and storage and facilitate a cost-effective solution for full-scale carbon capture and storage (CCS) in Norway, which will stimulate technological development in an international perspective.

The Government proposes to the Storting that funding be provided for the implementation of a Norwegian demonstration project for full-scale CCS that encompasses carbon capture, transport and storage. The project has been named ‘Longship’. The Government proposes implementing a carbon capture project at Norcem first, and then at Fortum Oslo Varme, conditional on sufficient own funding and funding from the EU or other sources. Fortum Oslo Varme must clarify whether it wants to implement the project on these conditions within three months of the funding decision from the second round of calls issued by the EU’s Innovation Fund, but no later than 31 December 2024. Northern Lights will realise a solution for transport and storage of CO<sub>2</sub>.

The Government proposes that Norcem and Northern Lights be awarded state aid in line with the negotiated agreements. The state aid allocated to Fortum Oslo Varme is also based on negotiated agreements, but the funding is limited to a maximum of NOK 2 billion in investments and NOK 1 billion in operating expenses. The total expected costs for the project are estimated at NOK 25.1 billion. The Government’s recommendation will have an overall expected cost for the state of NOK 16.8 billion. This means that the state expects to cover around two thirds of the project expenses.

Longship will demonstrate that CCS is safe and feasible, and will facilitate learning and cost reductions in subsequent projects. Infrastructure will be developed with additional capacity that other projects can utilise. Hence, the threshold for establishing new carbon capture projects will be lowered. Longship can also facilitate business development through harnessing, transforming and developing new industries in Norway.

Based on the knowledge currently available, CCS will be necessary to reduce global greenhouse gas emissions in line with climate targets at the lowest possible cost. Without using CCS to mitigate the source of CO<sub>2</sub> emissions or by contributing to negative emissions, it may prove challenging to reduce greenhouse gas emissions quickly enough. In some sectors, such as cement production, it is not possible given our current knowledge and technology to avoid emissions without using CCS. For some sectors and some sources of CO<sub>2</sub> emissions CCS may be the cheapest and best way to reduce emissions. CCS is one of many instruments that must be employed to reduce greenhouse gas emissions, and must work alongside other measures. The Government plans to return to this in a separate white paper on climate change to the Storting towards the end of 2020.

Norway is in pole position for contributing to the development of carbon capture and storage. The country has a strong technical community in the field of CCS, developed over 25 years of research and experience from planning and implementing projects in Norway, including from the

planning of a full-scale CCS project in Mongstad. Furthermore, there is great potential for CO<sub>2</sub> storage in geological formations beneath the seabed on the Norwegian continental shelf.

The current market situation does not provide sufficient incentives to implement and develop CCS. This is in part due to high investment costs, low income potential in the short term and high risk. In addition, the price of emitting greenhouse gases is lower than the cost of CCS, and the development of technology may have the characteristics of a public good. The current state of technology and the market make it necessary for countries to contribute to the development of CCS to achieve faster dissemination and deployment. The Norwegian project will further develop carbon capture and storage technology and thereby reduce the costs for subsequent facilities. This will be an important contribution to creating a market for CCS.

A solution for full-scale CCS has now matured that facilitates the further development of CCS in both Norway and Europe. The project has encompassed carbon capture from Norcem's cement factory in Brevik and carbon capture from Fortum Oslo Varme's waste incineration facility at Klemetsrud, Oslo. Northern Lights, which is a collaboration between Equinor, Shell and Total, has been responsible for the CO<sub>2</sub> transport and storage part of the project. This part of the project comprises ships for transport of liquid CO<sub>2</sub>, a reception terminal in Øygarden municipality, and pipeline to a well where CO<sub>2</sub> will be injected into a storage formation beneath the seabed.

The companies will own and develop the project. State aid agreements have been entered into, regulating cost and risk distribution between the state and the companies. These have been designed to provide good incentives for keeping costs low and keeping to the schedule.

Furthermore, the state aid agreement that applies to the transport and storage part of the project has been designed to give Northern Lights the incentive to incorporate new projects. All Northern Lights' revenues will come from CO<sub>2</sub> storage from new projects. Northern Lights therefore has a strong incentive to develop the market for CO<sub>2</sub> storage.

Gassnova and external quality assurers Atkins and Oslo Economics have evaluated the project. Their evaluations indicate that the project has matured to the level required for an investment decision, and the results of the front-end engineer-

ing design (FEED) show that all parts of the project are feasible. Based on the set criteria for the project, the Ministry of Petroleum and Energy ranks Norcem significantly higher than Fortum Oslo Varme.

Today, there are relatively few carbon capture and storage facilities in the world in operation and none that capture CO<sub>2</sub> from flue gas emitted by cement and waste-to-energy facilities. By developing more projects, the world as a whole will benefit from learning, technological development and economies of scale. This will provide the necessary cost reductions and efficiencies.

Longship is the first project of its kind. Risk is still associated with a number of factors, despite the fact that the technology in the individual parts of the project has been rigorously tested. The state bears a substantial share of this risk. There will be risk associated with the interfaces between the different parts of the project. There will also be risk related to cost development, project schedules and whether all parts of the project function as intended. It is a matter of striking a balance between reducing risk and keeping costs at a minimum. If the project is to have a good demonstration effect, the costs must be kept as low as possible. We must therefore expect, for example, to run into problems in connection with start-up of operations and to experience periods with low capture rates. The learning achieved from resolving such problems will form an important part of the project.

International cooperation on technological development and emissions reductions are a necessary part of Longship. If CCS is to become an efficient and competitive climate policy instrument, subsequent facilities must be established in Europe and globally.

By implementing Longship, Norway is taking the lead by demonstrating a complete value chain and investing in CO<sub>2</sub> storage infrastructure that can be utilised by industry companies in other countries. The Government expects that Europe will now follow suit and that the remaining capacity in the storage facility will be utilised by third parties that are not directly financed by the Norwegian state. Future Norwegian carbon capture facilities will need to compete for grants/state aid from general funding schemes, including Enova and the EU's Innovation Fund. The state will not engage in direct negotiations on state aid with individual stakeholders.



## 2 The background for prioritising CCS

### 2.1 The Paris Agreement as the basis for prioritising CCS

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The 2015 Paris Agreement was adopted in recognition of the irreversible loss and damage being caused by climate change and the serious threat it poses to nature and society. Together with growing pressure on natural resources and land area accompanied by the loss of species and ecosystems, climate change is a serious threat to the world's capacity to provide fundamental services, such as clean water, sufficient food and safe homes.

The goal of the Paris Agreement is holding the increase in the global average temperature to well below 2 degrees Celsius above pre-industrial level, and pursuing efforts to limit the temperature increase to 1.5 degrees Celsius above pre-industrial levels. To achieve the long-term temperature goals, the parties agreed that they would aim to reach peak global greenhouse gas emissions as quickly as possible, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century.

A number of countries, including the EU, have committed to a net-zero target, or to be climate-neutral, by 2050. These targets mean that emissions must be equivalent to the removal of greenhouse gases. This could be achieved by increasing the natural sequestration of CO<sub>2</sub> in e.g. agriculture, forestry and other land use, or by capturing and permanently storing CO<sub>2</sub> in geological reservoirs.

Norway's Nationally Determined Contribution under the Paris Agreement is to reduce greenhouse gas emissions by at least 50 per cent and up to 55 per cent in 2030, compared with the 1990 level [1]. The main goal of the Norwegian Climate Change Act is that Norway will be a low-emission society by 2050. The Norwegian Government proposed in the autumn of 2019 a low-emission strategy in accordance with the Govern-

ment's political platform, 'Granavolden'. The strategy proposes to increase the rate of reduction of greenhouse gas emissions for 2050 by 90–95 per cent compared with 1990 levels. The effect of Norway's participation in the EU Emissions Trading System must be taken into account when assessing whether this target has been reached.

As the world moves towards the long-term goal of the Paris Agreement, it will be important to shift production to goods and services that are competitive as the price of emissions rises, stricter regulation of emissions is introduced and consumer preferences change. Technology development, resource efficiency, better use of energy, more use of renewable raw materials and input factors, and circular solutions and waste management will all be important elements in the transition to a low-emission society. In many industries, a long-term focus on technology development and dissemination will be needed.

Norway has strong ties to Europe. The EU is our most important trade partner and closest climate partner. Through the cooperation with the EU and Iceland, Norway will also take part in EU climate legislation in the period 2021–2030. This will be an important part of the framework for Norway's climate policy and ensure a shift to a low-emission pathway in line with neighbouring countries. All sectors in Norway are included in the same system as applies in the EU under the agreement. Norway is seeking to fulfil its enhanced ambition through its cooperation on climate action with the EU. The Government is therefore encouraging the EU to step up its goal for 2030 to 55 per cent. The European Commission has proposed increasing the EU's target for 2030 to 55 per cent.

In the event that Norway's enhanced Nationally Determined Contribution goes beyond the target set in the updated Nationally Determined Contribution of the European Union, Norway intends to use voluntary cooperation under Article 6 of the Paris Agreement to fulfil the part that goes beyond that fulfilled through its climate cooperation with the European Union.

The Paris Agreement and the climate agreement with the EU and Iceland provide the framework and foundation for Norway's investment in carbon capture and storage (CCS). The Norwegian demonstration project for full-scale CCS underlines the need for and value of international cooperation on technological development and emission reductions. If CCS is to become an efficient and competitive climate policy instrument, new projects must follow suit in Europe and globally.

## 2.2 What is carbon capture and storage?

Different industrial processes, power, and heat production release large amounts of CO<sub>2</sub> into the atmosphere. CO<sub>2</sub> is a by-product of the processing of various raw materials and combustion of different fuels. These CO<sub>2</sub> emissions can be reduced by capturing CO<sub>2</sub> and then transporting and permanently storing it, thus preventing its release into the atmosphere. We can also capture CO<sub>2</sub> directly from the air. The characteristics of the various sources of emissions from which it is possible to

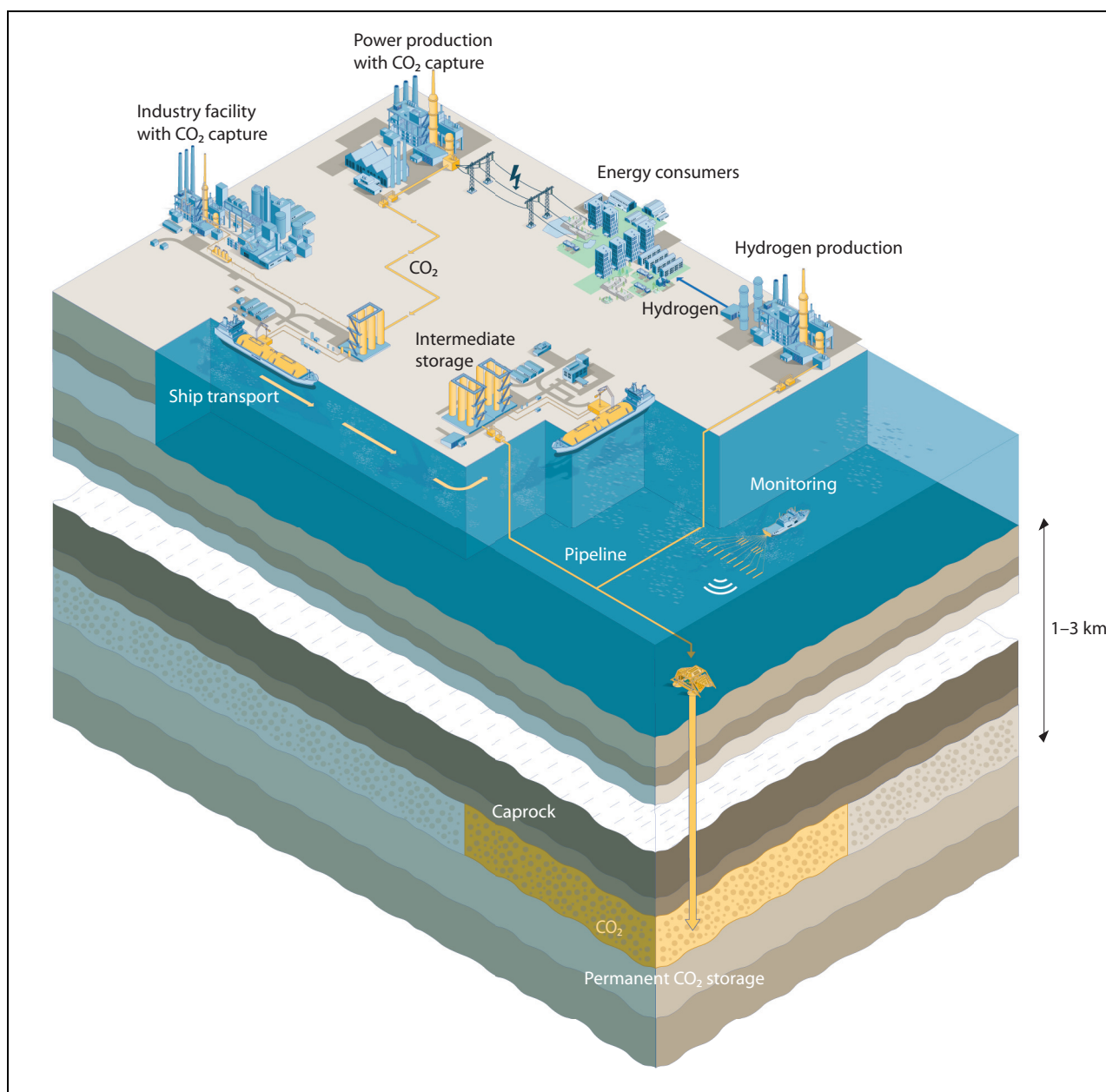


Figure 2.1 Illustration of carbon capture from different industrial facilities and power production, transport by pipeline and ship, geological CO<sub>2</sub> storage

Source: Gassnova

### Box 2.1 Same thing, different names – concepts

*Carbon capture and storage, CCS, carbon control and sequestration* – these are all overlapping terms that have been used to describe much the same thing. Carbon capture, utilisation and storage or CCUS can also refer to the use of CO<sub>2</sub> for example to enhance oil recovery. We can therefore distinguish between carbon capture and storage for climate purposes, where CO<sub>2</sub> is stored permanently, and carbon capture and storage where CO<sub>2</sub> is not permanently stored. Unless otherwise specified, the meaning of carbon capture and storage in this white paper is in the context of climate efforts.

If such use of CO<sub>2</sub> is to have a positive effect on the climate, CO<sub>2</sub> must be permanently removed from the atmosphere. The term *Bioenergy with Carbon Capture and Storage* or *BECCS/bio-CCS* has been used to describe the capture and storage of CO<sub>2</sub> from energy production that uses biogenic matter (matter formed by biological processes).

capture CO<sub>2</sub> can vary considerably. Major differences in temperature, pressure, CO<sub>2</sub> content and other content, mean that carbon capture can take many different forms. It also means that the costs of carbon capture vary a great deal. Different technologies on the market are suited to the different sources of emissions. Most of the available technologies on the market for capturing flue gas from today's industry and power production are different forms of amine technology.

CO<sub>2</sub> can be transported by pipeline or in tanks, for example on ships or tankers. CO<sub>2</sub> transport by pipeline has taken place in the US for close to 50 years, and in Norway since 1996. An example is CO<sub>2</sub> transported from the Melkøya LNG plant through a 145-kilometre pipeline to a reservoir on the Snøhvit natural gas field. CO<sub>2</sub> transport by ship and road is already part of the routine operations of the food industry for instance, although in lesser volumes.

CO<sub>2</sub> can be stored in suitable geological formations both underground on land and beneath the seabed. These include geological formations in salt water (saline aquifers), depleted oil fields or

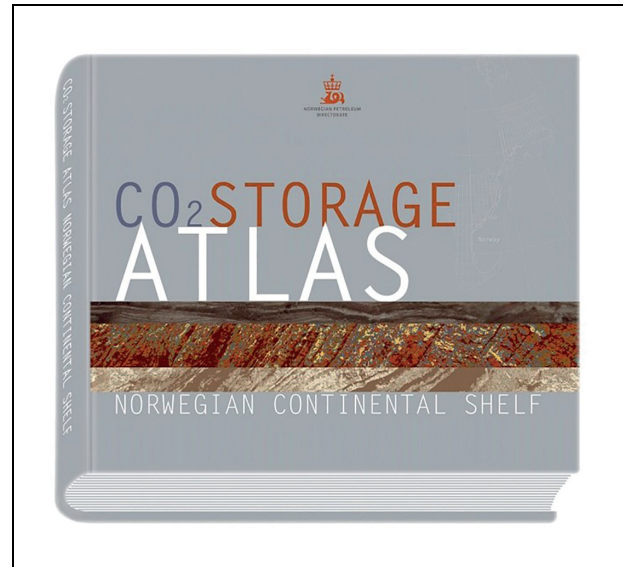


Figure 2.2 CO<sub>2</sub> Atlas for the Norwegian Continental Shelf

in connection with increased extraction in oil fields. Geological mapping conducted by the *Geological Survey of Norway* indicated that Norway does not have suitable underground geological formations on land. It is therefore only possible for Norway to store CO<sub>2</sub> under the seabed on the Norwegian continental shelf. Norway has stored CO<sub>2</sub> from the Sleipner field for nearly 25 years and from the Snøhvit field since 2008. The Petroleum Directorate has prepared a CO<sub>2</sub> Storage Atlas that covers the whole Norwegian continental shelf [2]. The atlas shows that more than 80 billion tonnes of CO<sub>2</sub> can theoretically be stored on the continental shelf. This corresponds to Norway's greenhouse gas emissions for more than a thousand years. Such theoretical potential is uncertain and does not take costs into account. The Petroleum Directorate has categorised a capacity of around 1.25 billion tonnes of CO<sub>2</sub> as the expected amount for effective and safe storage.<sup>1</sup> Identifying CO<sub>2</sub> storage locations is costly and time consuming. It is also important that the CO<sub>2</sub> storage locations are secure and can be properly monitored.

<sup>1</sup> For categorisation and methods, see <https://www.npd.no/en/facts/publications/co2-atlases/co2-atlas-for-the-norwegian-continental-shelf/3-methodology/>

## 2.3 CCS and the Sustainable Development Goals

### 2.3.1 Climate targets and the role of CCS

The reports from the UN Intergovernmental Panel on Climate Change and the International Energy Agency (IEA) show that CCS will be necessary to reduce global greenhouse gas emissions in line with the climate targets at the lowest possible cost. The findings in the UN Intergovernmental Panel on Climate Change’s Fifth Assessment Report states that if CCS is not used, the global costs of keeping the global increase in average temperature below 2 degrees Celsius may be more than doubled [3].

Subsequent reports from both the UN Intergovernmental Panel on Climate Change and the IEA have also shown that achieving the Paris Agreement’s global temperature goals will be very challenging, particularly pursuing efforts to limit the global increase in average temperature to 1.5 degrees Celsius, without CCS. The alternative is achieving even more rapid emission reductions,

which entails a more intensive restructuring of industry, energy systems and consumer patterns [4]. The climate panel’s models are mainly based on negative emissions. This can be achieved, for example, by capturing and storing CO<sub>2</sub> from bio-fuel production or combustion of biogenic matter (BECCS/bio-CCS).

Biogenic matter includes wood, biogases and biodegradable waste. The removal of biogenic CO<sub>2</sub> entails negative emissions since the biomass has absorbed CO<sub>2</sub> throughout its lifetime. The climate effect of capturing and storing biogenic CO<sub>2</sub> is therefore considered to be zero in air emissions accounts.

It is also possible to achieve negative emissions by capturing CO<sub>2</sub> directly from the air, or increasing sequestration of CO<sub>2</sub>, for example by planting forests. Most low-emission scenarios considered by the UN Intergovernmental Panel on Climate Change require negative emissions to compensate for emissions that are challenging or extremely costly to remove.

CICERO Center for International Climate Research has concluded that CCS is one of several

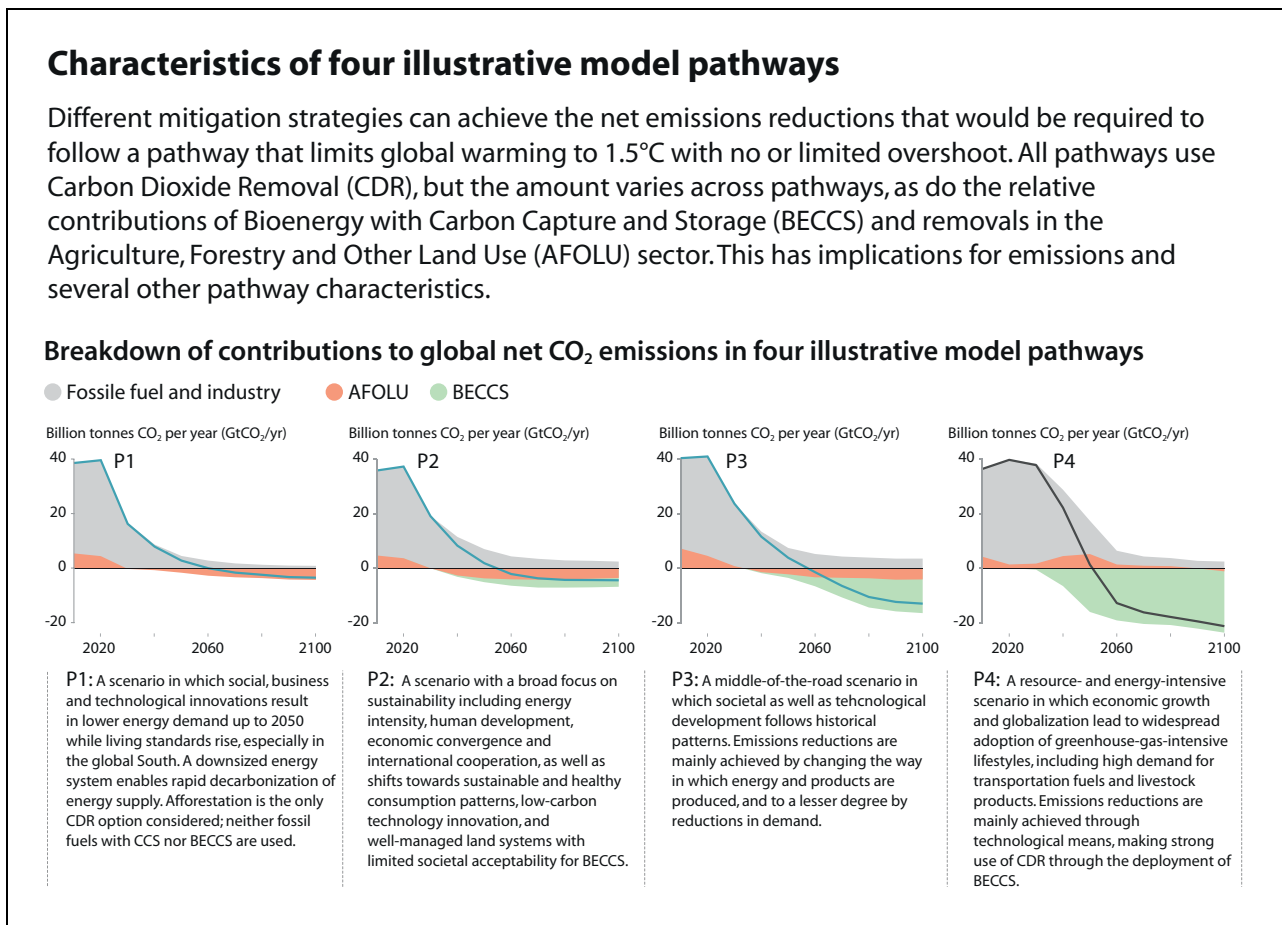


Figure 2.3 Distribution of global net emissions of CO<sub>2</sub> in four illustrations of modelled emission pathways

Source: UN Intergovernmental Panel on Climate Change [4]

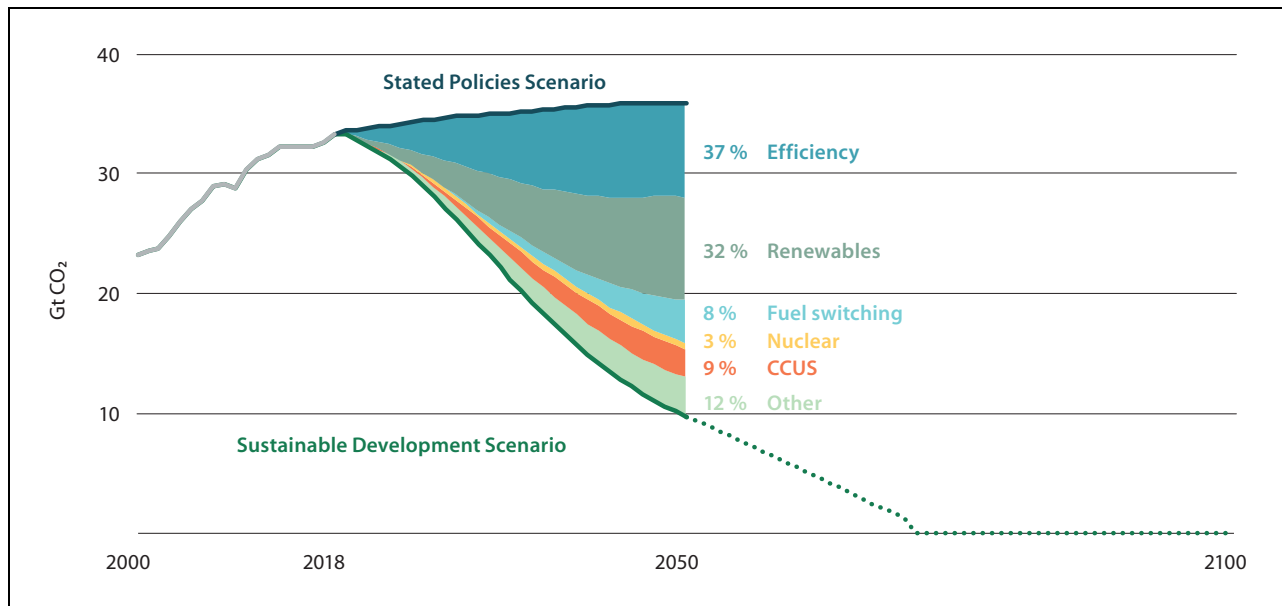


Figure 2.4 Energy-related emission reductions in the IEA's Sustainable Development Scenario 2019 [8]

Source: IEA World Energy Outlook 2019 [8]

critical technologies in most emission pathways to achieve the Paris Agreement's temperature goals, and that it will be extremely challenging to reduce emissions quickly enough without CCS [5]. There are three reasons why CCS may be necessary: Firstly, it may be challenging to reduce emissions to net zero quickly enough without using CCS on the sources of emission or by contributing to negative emissions. Secondly, there are currently no competitive alternatives to CCS for certain sectors, such as cement, steel, and long-distance sea and air transport, and nor is it certain that there will be in the future. Thirdly, CCS may be the cheapest and best way of reducing emissions for some sectors and sources of emissions. CICERO has stressed that it is likely that public funding of innovation will be necessary to ensure that CCS is sufficiently utilised.

In *Energy Technology Perspectives 2020* [6], the IEA highlights CCS as one of four technologies that are critical to achieving the climate targets. The IEA emphasises the importance of building infrastructure and demonstrating technology in order to stimulate innovation related to clean energy. The IEA's models of the years leading up to 2030 show that the scope of CCS in both industry and power production needs to increase significantly. The report also states the importance of developing clusters of capture facilities that connect to a joint storage facility in order to increase utilisation of CCS and to create business models [3].

The IEA's Sustainable Development Scenario illustrates a transformation of the global energy system showing how the world can change course to reach the three Sustainable Development Goals most relevant to energy at the same time [7]. The Sustainable Development Goals the IEA has based its scenario on are Affordable and clean energy (Goal 7), reduce the severe health impacts of air pollution (part of Goal 3) and Climate action (Goal 13). The scenario corresponds to a 66 per cent probability of keeping the global temperature increase to within 1.8 degrees Celsius without being dependent on negative global CO<sub>2</sub> emissions. As shown in Figure 2.4, carbon capture, use and storage represents 9 per cent of the cumulative emission reduction between 2018 and 2050 in the IEA's Sustainable Development Scenario [6, 8].

CCS may also be a relevant and necessary solution to achieve Norway's emission reduction targets. In addition to the overall emission targets for 2030 that Norway has endorsed under the Paris Agreement, and the goal to become a low-emission society by 2050, the Granavolden platform states that the Government wants to reduce Norway's emissions in sectors not included in the Emissions Trading System by at least 45 per cent by 2030 compared to the 2005 level. The Government aims to achieve this reduction by means of domestic measures, and is planning for this. If strictly necessary, the flexibility of the EU framework can be utilised. Over time, more ambitious climate targets will require a restructuring of existing industry [9-11].



### Box 2.2 Distinction between sectors included and not included in the European Emissions Trading System

Norway has participated in the European Emissions Trading System (EU ETS) since 2008 and cooperates with the EU and Iceland on reducing emissions from sectors included in the system. The goal is to reduce emissions from sectors included in the EU ETS by 43 per cent compared to the 2005 level. The system currently applies to emissions from installations in industry, energy supply and aviation within the EEA.

Around half of Norway's emissions are covered by the EU ETS. The primary sources of emissions within the ETS system (on a European scale, not Norway specifically) are natural gas and coal fired power plants, on-site energy installations in business and industry, petroleum production including offshore facilities, refineries, wood-processing industry, and production of steel, aluminium, mineral fertiliser, cement and lime. Sectors included in the EU ETS in Norway contribute on the same basis as with those of other European countries to reaching the emission target.

Norway's participation in the EU ETS is an important aspect of Norwegian climate policy

and the strategy for meeting our 2030 obligations. With unified efforts to meet the climate agreement with the EU and Iceland, emission reductions within the EU ETS will be assessed for the EU, Iceland and Norway together. The primary sources of emissions from sectors that are not included in the EU ETS are transport, agriculture, construction and waste, but also emissions from industry and petroleum activities that are not subject to the trading system.

As part of the agreement with the EU and Iceland, Norway will also cooperate with the EU on reducing emissions from sectors not included in the EU ETS (The Effort Sharing Regulation). The EU aims to cut overall emissions from these sectors by 30 per cent from 2005 to 2030. The efforts needed to achieve this are to be distributed between countries by means of binding emission targets. Norway's emissions target under its agreement with the EU is to cut emissions from sectors not included in the EU ETS by 40 per cent.

### 2.3.2 Carbon capture and storage in different sectors

Industry currently accounts for around a fifth of global greenhouse gas emissions [12], most of which come from the production of raw materials such as metal, cement and chemicals. In Norway, industry accounts for 23 per cent and oil and gas production for 28 per cent of emissions, calculated in CO<sub>2</sub> equivalents (CO<sub>2</sub>e).<sup>2</sup> Global growth in terms of both population and prosperity leads to increased use of raw materials. Emissions come primarily from production processes, and reducing emissions will require new technology to be developed and used [11].

CCS is particularly important in industries that cannot sufficiently reduce their CO<sub>2</sub> emissions by changing their source of energy, such as the steel

and cement industries [12, 13]. With the knowledge currently available, it will be extremely challenging to maintain current industry and achieve our climate targets by 2050 without using CCS [10]. CCS appears to be the most promising solution to drastically reduce emissions from the processing industry [14].

The energy sector is the sector that accounts for the largest share of global greenhouse gas emissions [15]. CCS can reduce emissions from energy production based on coal, natural gas and biomass [11]. The power sector can also cut emissions by switching to renewable energy sources. A solution in the long term could be to produce energy from hydrogen, either by electrolysis (using renewable energy sources) or from natural gas with CCS [6, 11].

In the long term, it will be necessary to increase the amount of negative emissions, for example by capturing and storing more biogenic CO<sub>2</sub> [8, 16]. Models developed by the UN Intergovernmental Panel on Climate Change and the IEA also show that in the longer term, technology

<sup>2</sup> In addition to carbon dioxide (CO<sub>2</sub>), CO<sub>2</sub> equivalents also include gases such as methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and fluoride gases (HFCs, PFCs and SF<sub>6</sub>) converted into CO<sub>2</sub> equivalents.



**Box 2.3 Climate Cure 2030**

Klimakur (Climate Cure) 2030 describes measures that can cut emissions in sectors not included in the EU ETS by 50 per cent by 2030 compared to 2005 levels. Climate Cure was put together by the Norwegian Environment Agency, the Norwegian Public Roads Administration, the Norwegian Coastal Administration, the Norwegian Agriculture Agency, the Norwegian Water Resources and Energy Directorate and Enova. The Government has not determined how the measures described in Climate Cure 2030 should be followed up, and, therefore, the report is not an expression of Government policy.

The Government aims to present a report in the course of this year to show how Norway can meet its international obligations on reducing

emissions by 50 per cent and up to 55 per cent. The report will describe the collaboration with the EU and how we can meet the ambition of a 45 per cent reduction in sectors not subject to the EU ETS.

Climate Cure 2030 forms an important part of the basis for this plan. Climate Cure has looked at the possibility of using CCS for emissions from sectors not subject to the EU ETS and assesses measures at three waste incineration facilities. The costs of the measures are estimated to be in the middle of three cost categories for measures, in the range of NOK 500–1,500 per tonne of CO<sub>2</sub>e.

Source: Climate Cure 2030 [21]

to capture CO<sub>2</sub> directly from the air is required. At present, such technologies use a lot of renewable energy and cost more than capturing emissions from industry and power production [6]. The development and use of technologies that lead to negative emissions and carbon capture directly from the air are dependent on the commercialisation of carbon capture technology in industry, thus making it more widely available and cheaper.

Waste incineration for energy production produces CO<sub>2</sub> emissions. Part of the waste comes from fossil raw materials and produces greenhouse gas emissions, but often, waste also contains some bio-based materials. Using CCS for waste incineration may therefore lead to negative CO<sub>2</sub> emissions. All countries have waste incineration facilities and this therefore has the potential to significantly reduce European emissions [17, 18]. The possibility of using BECCS in certain countries such as Sweden to achieve rapid emission reductions has also been identified [19].

In 2018, Norway's emissions from waste incineration represented just under 1 million tonnes of CO<sub>2</sub>e [20].

**2.3.3 The Sustainable Development Goals**

In 2015, UN member states adopted the 2030 Agenda for Sustainable Development. This comprises 17 Sustainable Development Goals and 169 targets related to the economic, social and environmental aspects of sustainability.

The Sustainable Development Goals apply to all countries and all segments of society. They emphasise cooperation, partnership and how the goals are interconnected. The goals are universal, which means that Norway has the same responsibility as all other countries to contribute to achieving the goals by 2030. The Government has decided that the Sustainable Development Goals will constitute the main course of policy for addressing the biggest challenges of our time, including in Norway.

Goal 13 on Climate Action is to take urgent action to combat climate change and its impacts. It will be particularly challenging to reduce global greenhouse gas emissions in line with the climate targets at the lowest possible cost without using CCS. Investment in CCS will therefore contribute to achieving Goal 13.

CCS can also contribute to achieving Goal 7 on Affordable and Clean Energy in that CO<sub>2</sub> can be captured and stored in conjunction with electricity production from coal and gas, and in hydrogen production from natural gas, known as blue hydrogen. Large-scale CCS will require new technical solutions, significant infrastructure development, and will create new jobs. This will contribute to achieving Goal 9 on Industry, Innovation and Infrastructure.

If the development of CCS is to contribute to economic growth in a long-term perspective, successful large-scale CCS must develop at the global level to become profitable, seen in relation to

existing and alternative energy solutions. This is an important prerequisite for CCS to contribute to achieving more Sustainable Development Goals, including Goal 8 on Decent Work and Economic Growth.

## 2.4 Status of the global development of CCS

According to the Global CCS Institute<sup>3</sup> (GCCSI), 58 projects for large-scale CCS have currently been given the go-ahead worldwide. The projects are in different phases of development. The estimated capture capacity of all the projects combined is around 127 million tonnes of CO<sub>2</sub> per year.

Twenty of the projects are already in operation, with an overall capture capacity of just under 40 million tonnes of CO<sub>2</sub> per year. Of these, 13 are in North America, while five are distributed between Asia, Australia and South America. With its two CO<sub>2</sub> storage projects on Sleipner and Snøhvit, Norway is the only country in Europe with projects in the operational phase. At the global level, CO<sub>2</sub> has been stored on land and under the seabed, and been used to enhance oil recovery and as an input factor in industrial processes. See Figure 2.5 for a global overview of CCS facilities.

Two new CCS projects have become operational in the past year: Gorgon in Australia in 2019 and Alberta Carbon Trunk Line in Canada in June 2020.

Gorgon uses CCS at a gas processing facility and will capture and store four million tonnes of CO<sub>2</sub> per year. This project is similar to Norway's Snøhvit project, and is solely for climate purposes.

The initial phase of the Alberta Carbon Trunk Line project will transport around 1.6 million tonnes of CO<sub>2</sub> from a mineral fertiliser plant and a refinery that produces hydrogen. The CO<sub>2</sub> has been used to enhance oil recovery. The pipeline has the capacity to transport 14.6 million tonnes of CO<sub>2</sub> per year, and Canada assumes that new carbon capture projects will utilise this infrastructure over time.

In July 2020, it was announced that Petra Nova in the USA, which has been operational since 2017, had halted operation of its carbon capture project installed on coal-fired power because it was no longer considered profitable. CO<sub>2</sub> captured from coal-fired power plants was sold for the purpose of

### Box 2.4 How does Longship contribute to innovation?

Longship stands apart from most other CCS projects currently in operation in Norway and internationally. The project will contribute to learning and greater efficiency, resulting in lower costs for subsequent projects. The following elements are innovative:

- Demonstration of a full, but flexible, value chain with carbon capture from cement production and potentially from waste management and shipping, and CO<sub>2</sub> storage beneath the seabed.
- The use of European and Norwegian regulations in projects involving a whole chain of different stakeholders. The project demonstrates, among other things, the use of the EU ETS and the EU Directive on CO<sub>2</sub> Storage.
- A flexible transport and storage solution that will have the capacity to receive CO<sub>2</sub> from many sources.
- A commercial framework that provides incentives for further development of CCS in Europe.

enhancing oil recovery, and the low oil price meant that the project was no longer profitable.

According to GCCSI, three new projects are currently under construction. Two are in China, both related to the chemical industry, and one related to power production is in the USA.

A further ten projects, including Norway's project, are in what is known as the advanced development phase. Three of these are in the power sector, while the remaining seven are in industry. The project in Norway is the only project to consider CCS from waste incineration and cement production.

There are also a number of demonstration facilities for CCS in operation, and carbon capture technology has been tested at different test centres. The Technology Centre at Mongstad is one of the biggest CO<sub>2</sub> test facilities in the world.

According to the World Bank, around 22.3 per cent of global emissions are currently covered by carbon emissions pricing [23]. The cost of emitting CO<sub>2</sub> is the most important economic driver for implementing CCS projects. Higher CO<sub>2</sub> emission prices and greater scope will facilitate the

<sup>3</sup> <https://www.globalccsinstitute.com/>

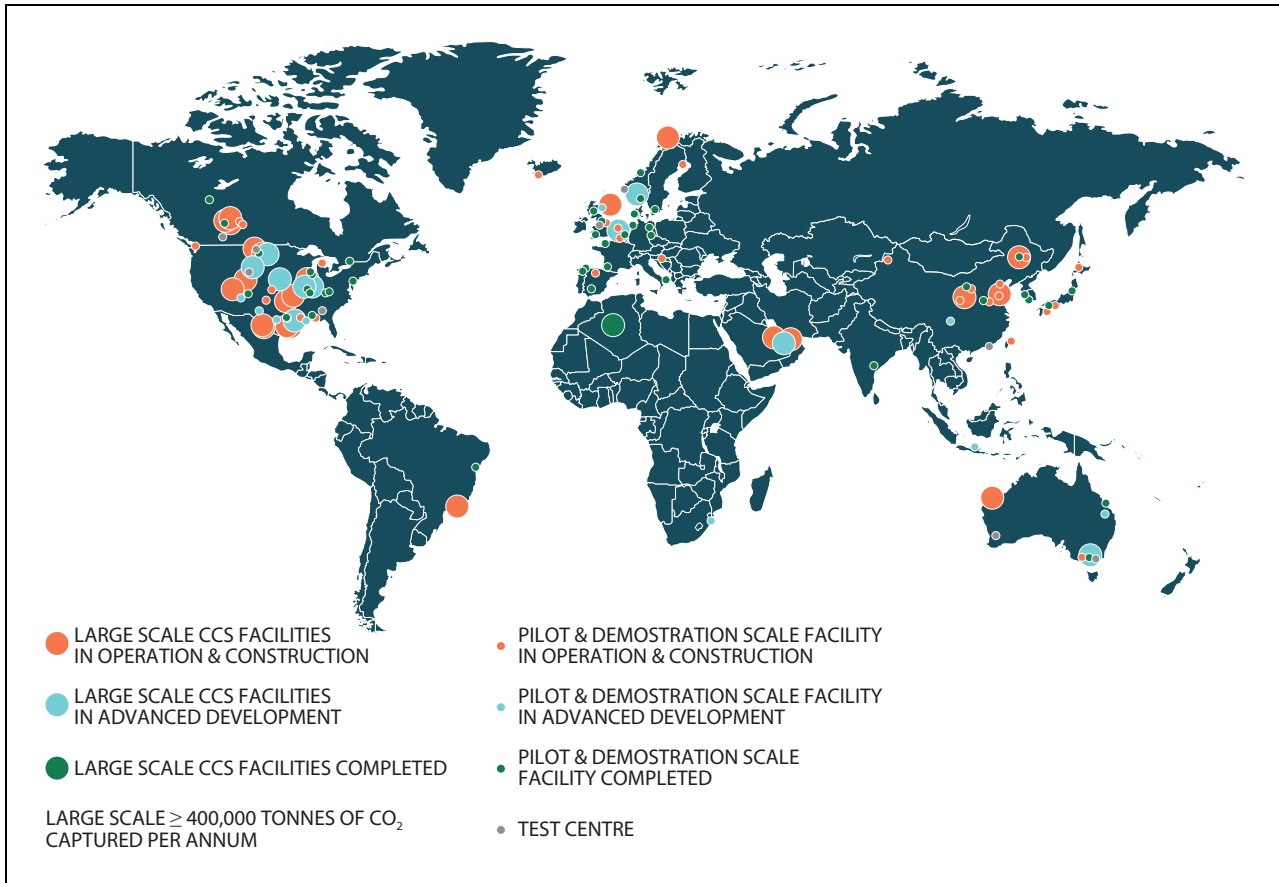


Figure 2.5 Global overview of CCS facilities in 2019 from the Global CCS Institute. The figure shows large-scale facilities, smaller pilots and test facilities. Large-scale facilities are defined as those that capture more than 400,000 tonnes of CO<sub>2</sub> per year. The figure shows projects under planning, construction and operation, as well as discontinued projects.

Source: Global CCS Institute, The Global Status of CCS. 2019 [22].

development of more CCS projects worldwide. Although CO<sub>2</sub> emissions pricing is important to ensure investments in CCS facilities, political support will also be imperative. Targeted measures will be necessary to increase early investments and reduce costs [24].

## 2.5 CCS in Europe

### 2.5.1 Status

A number of countries, including the EU, have committed to a net-zero target or to be emission-neutral by 2050. The EU's green growth strategy 'the European Green Deal', provides a more ambitious European climate policy both leading up to 2030 and 2050. The European Commission has defined CCS as one of seven strategic building blocks to achieve its target. CCS is therefore included in the Commission's climate policy instruments.

Although it is preferable to avoid emitting greenhouse gases at the source, the EU recognises that it will be necessary to remove greenhouse gases in order to compensate, among other things, for emissions from sectors in which it is difficult to cut emissions all together. Emissions can be compensated for by increasing the natural absorption of CO<sub>2</sub> in agriculture, forestry and other land use, and by capturing and storing CO<sub>2</sub> in geological reservoirs.

Along with the Netherlands and the UK, Norway is at the forefront of European CCS efforts. GCCSI's overview shows that there are eleven full-scale CCS projects of various degrees of maturity under development in Europe, all of which are located in Norway, the Netherlands or the UK. Of these, Norway's Longship and the Dutch project Porthos in Rotterdam are the most advanced projects under development.

Taking a slightly longer perspective, an analysis by Thema and Carbon Limits [25] identified 41

potential projects in Europe. Of these, 35 are additions to the projects included in GCCSI’s overview and some of them have started to develop new projects based on the possibility of utilising Northern Lights’ storage facility. In recent years, CCS has also received more attention in a number of EU countries that are now looking to CCS as a potential measure for meeting the climate targets in their national climate and energy plans [26].

Northern Lights is one of very few projects that can develop more extensive infrastructure for CO<sub>2</sub> storage in Europe. Figure 2.6 gives an overview of CCS projects that are EU Projects of Common Interest. Two similar projects are the Dutch

Porthos and the British CO<sub>2</sub> Sapling, both of which are located in the North Sea. CO<sub>2</sub> sources from all over Europe will be able to connect to the storage infrastructure these projects develop. Many of the European projects only cover carbon capture and see the Northern Lights storage facility as a potential storage solution for their CO<sub>2</sub>.

**2.5.2 EU support schemes**

The EU has several funding schemes that are applicable to CCS. The Innovation Fund’s first round of calls for proposals was issued in July 2020. The Innovation Fund is the EU’s most exten-

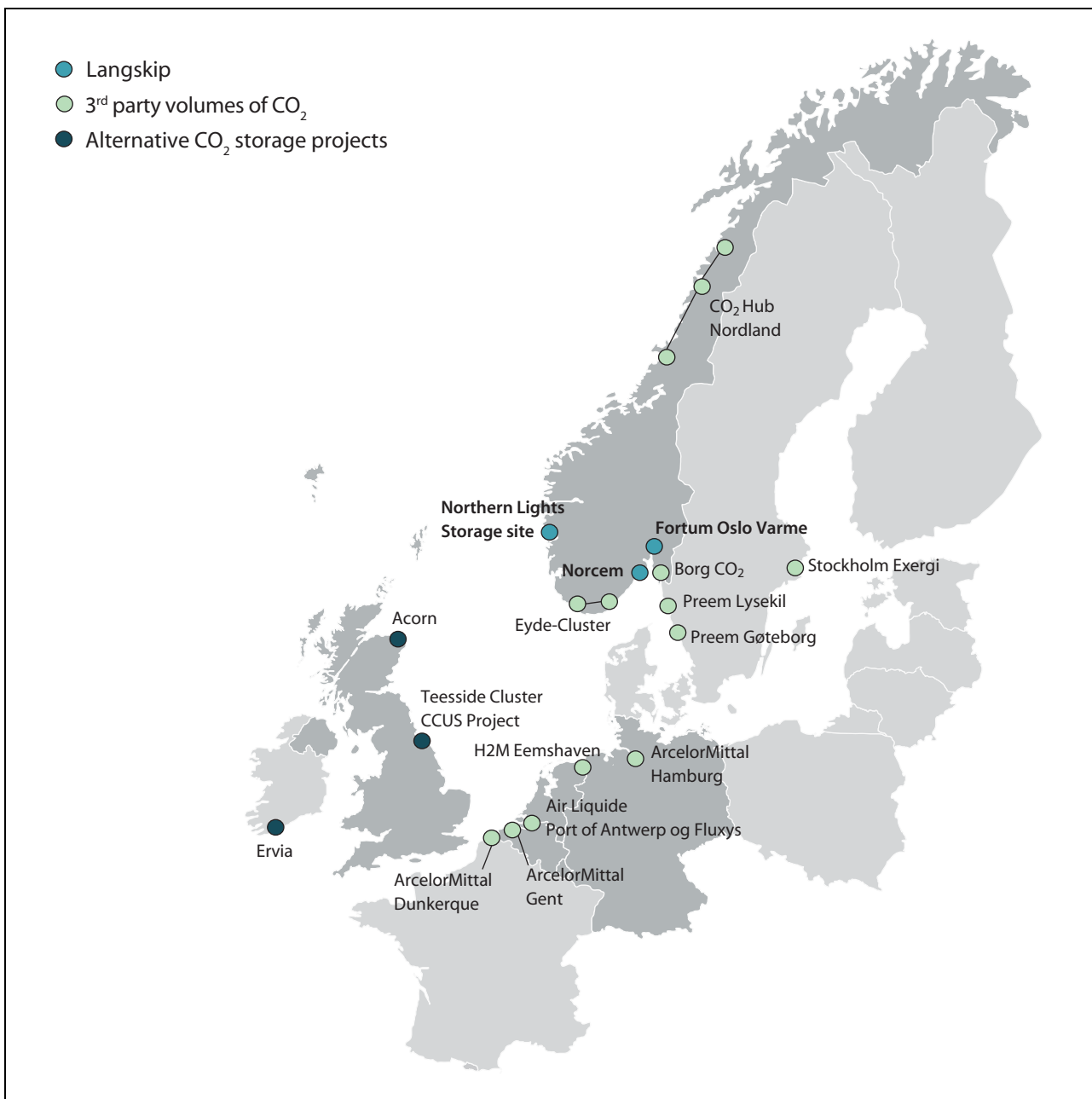


Figure 2.6 Stakeholders affiliated to Northern Lights’ Project of Common Interest (PCI) for CCS

Source: Northern Lights

### Box 2.5 The Porthos project

Porthos (Port of Rotterdam CO<sub>2</sub> Transport Hub and Offshore Storage) is a project based in the Netherlands developed by the Rotterdam Port Authorities, EBN (Energie Beheer Nederland) and Gasunie, and will transport and store CO<sub>2</sub> from industry in Rotterdam. CO<sub>2</sub> will be captured from various activities and then transported to a joint pipeline that runs through Rotterdam's port area. It will then be transported to a platform in the North Sea about 20 km from the coast. The CO<sub>2</sub> will then be pumped from this platform into empty gas fields more than 3 km beneath the seabed. If an investment decision has been made for the project by the end of

2021, the system can be operational by 2024. The project's capacity the first few years is expected to be around 2.5 million tonnes of CO<sub>2</sub> per year. The Porthos project received EUR 1.2 million in funding from the Dutch authorities in 2018 and a grant of EUR 6.5 million from the European Commission in 2019.

Porthos and the Norwegian project are considered to be the most mature projects currently under development in Europe and are included on the EU list of Energy Projects of Common Interest.

Source: porthosco2.nl

sive funding scheme for innovative climate technology. The EU also has the Connecting Europe Facility (CEF) funding scheme for trans-European infrastructure projects.

Infrastructure projects of Common European Interest<sup>4</sup> can apply for funding from CEF. Three CCS projects have been awarded funding under this scheme: Two in the UK (two sub-projects under Net Zero Teeside and The Acorn Project) and one in the Netherlands (Porthos). The EU Energy Projects of Common Interest list has five projects involving trans-European CO<sub>2</sub> transport that are eligible to apply for funding under CEF.

The projects are located in the area in and around the North Sea and include Belgium, the Netherlands, Norway and the UK. One of these is Northern Lights, which can receive CO<sub>2</sub> from industry players in a number of European countries. Equinor, together with several other potential European CO<sub>2</sub> sources, has applied for funding from CEF for studies in connection with phase 2 of Northern Lights. The EU also provides funding for research projects through the EU Framework Programme for Research and Innovation Horizon 2020, and from 2021, its successor Horizon Europe.

In June 2020,<sup>5</sup> the European Commission started the process of assessing potential incentives for nature-based solutions to CO<sub>2</sub> removal. Nature-based solutions entail absorption by agriculture, forestry and other land use, and CCS on

emissions from biogenic matter, also known as negative emissions.

## 2.6 Norway's conditions for investment in CCS

Norway has a strong technical CCS community. We have developed extensive expertise in the area over the past 25 years due in no small part to the experience gained from planning CCS projects in Norway. Furthermore, the Norwegian continental shelf is large with abundant possibilities for CO<sub>2</sub> storage in geological formations beneath the seabed. For many years, various governments have supported technology development, testing and pilot projects, and emphasised CCS as an important climate mitigation tool in international climate negotiations.

The technical CCS community in Norway covers all aspects of activities. We have a strong research environment. Our research groups are active in international research communities and networks. The Norwegian CCS Research Centre (NCCS), a centre for environmentally-friendly energy in Trondheim<sup>6</sup> is dedicated to the field of CCS. The research programme CLIMIT is an important source of funding for research and demonstration. Development and operation of Technology Centre Mongstad (TCM) has also provided substantial learning, and TCM has established itself as a leading international competence

<sup>4</sup> Projects of Common Interest (PCI).

<sup>5</sup> <https://etendering.ted.europa.eu/cft/cft-display.html?cftId=6709>

<sup>6</sup> <https://www.sintef.no/projectweb/nccs/>



### Box 2.6 The EU Innovation Fund

The EU Innovation Fund is a European funding programme for demonstration of innovative low-emission technologies in the period 2021–2030. The fund aims to contribute to achieving Europe's specified contribution under the Paris Agreement and the target of net-zero emissions in Europe by 2050. It will award funding to technology projects in renewable energy, energy-intensive industry, energy storage and CCS.

The fund is financed by the sale of 450 million allowances from the EU ETS. The size of the fund is dependent on the price of allowances. According to the European Commission's estimates, the fund will amount to around EUR 10 billion in the period 2021–2030 if the price of carbon allowances is EUR 20 per tonne of CO<sub>2</sub>, while EUR 15 billion will be available with an allowance price of EUR 30 per tonne of CO<sub>2</sub>.

Support from the fund can cover up to 60 per cent of the additional costs associated with the

use of innovative technology to prevent greenhouse gas emissions. The fund can support additional costs related to both investments and additional operating costs over a period of ten years. The funding is paid out when the project reaches the agreed milestones. Up to 40 per cent of the funding can be paid when the total funding for the project has been secured.

Funding from the Innovation Fund does not count as state aid. This means that projects that receive funding from the Innovation Fund can still be awarded state aid for other costs in accordance with the applicable state aid rules.

Norwegian projects can receive funding on the same terms as European projects. The fund's first call for proposals was issued on 3 July 2020 with a deadline for applications of 29 October 2020. Enova is responsible for the administration of Norway's participation in the Innovation Fund.

centre for demonstration of capture technology. The planning of full-scale projects at Kårstø and Mongstad has provided valuable learning both in the industry and administration, which has been useful to the project the Government is now presenting.

Through several research and development projects, and not least TCM, we have developed world-leading expertise in proper measurement, management and regulation of the use of different amines in carbon capture facilities. Norway now has a competent regulator and extensive expertise in setting emission limits for such facilities. This ensures that capture facilities that receive an emissions license will not pose an undesirable risk to health or the environment.

For decades, the development and operation of CCS projects on Sleipner and Snøhvit have demonstrated safe CO<sub>2</sub> storage in geological formations beneath the seabed on the Norwegian continental shelf. Monitoring programmes and reservoir simulations have been developed that have proven that CO<sub>2</sub> storage is safe, which will benefit new projects. Knowledge and experience from petroleum activities have been essential to the development of CCS in Norway. The strong technical environments in oil companies have been a prerequisite for developing these projects

and the companies have further developed their expertise through them.

Our natural advantage in the form of having a large and well-explored continental shelf with good possibilities for CO<sub>2</sub> storage is also a decisive factor. The Petroleum Directorate has documented a vast potential for storing CO<sub>2</sub> beneath the seabed on the Norwegian continental shelf [2], which entails a possibility of storing large volumes of CO<sub>2</sub> from the rest of Europe.

The EU Directive on CO<sub>2</sub> storage has been implemented in relevant Norwegian legislation to establish the necessary framework. Based on the legal authority of this framework, Exploitation Licence 001 has been awarded to Equinor for the Northern Lights project.

The amount of CO<sub>2</sub> emissions in Norway that is suitable for CCS is limited. International cooperation on CCS will be essential if Norway's investment in CCS is to result in an emissions reduction that makes a difference.

The petroleum industry's experience and expertise has been important to realise dedicated business models for CCS. A model has been developed on the basis of the Norwegian project, which provides a good premise for increasing the number of projects that want to connect to a storage facility in Norway.



In line with the Paris Agreement, the parties will strengthen cooperation on the development and transfer of climate technology. CCS is an example of a technology where Norway is in a good position to contribute to technology transfer.

The value of this transfer will increase significantly if we can also share experience from our planning and implementation of the project underlying this white paper with other countries.

## 3 Need for state aid for CCS

### 3.1 Market failure in relation to CCS

Two sets of market failure work together to prevent actors in the market from developing and using necessary climate technology of their own initiative [27, 28].

The first and most important market failure is that the price of emitting greenhouse gases is lower than the socioeconomic costs associated with such emissions. For this reason, actors who produce emissions do not bear the socioeconomic costs of emissions. This makes it more profitable from a business economics perspective to emit more greenhouse gases than is sensible from a socioeconomic perspective. In economics, this is called negative externalities.

By putting a price tag on emissions equal to the socioeconomic costs, the cost of emissions will be encompassed by micro-economic adaptations. This pricing of emissions, either by way of taxes or a market for emission allowances, is the single most important measure in Norwegian climate policy.

Norway participates in the EU Emissions Trading System (EU ETS) and has introduced its own taxes on greenhouse gas emissions. According to the World Bank, only about 22.3 per cent of global emissions are currently covered by emission pricing [23], but the scope of sectors and sources of emissions covered by pricing is being continuously extended. Although national and regional emission pricing measures were stepped up and extended in 2019 [29], fossil fuel consumption still receives significant subsidies in a number of countries [29, 30].

Furthermore, the prices of global emissions remain significantly lower than many believe necessary to reduce emissions in line with the Paris Agreement's temperature goals in a cost-effective way [31]. The International Monetary Fund (IMF) estimated the global average price of emissions to be around NOK 18 per tonne of CO<sub>2</sub>e in 2019 [32]. The allowance price in the EU ETS stabilised at around NOK 250 per tonne of CO<sub>2</sub>e in 2019 [29]. For the sake of comparison, the general carbon tax in Norway increased to NOK 544 per

tonne of CO<sub>2</sub>e in 2020. Emission pricing may play an important role in achieving the goals of the Paris Agreement going forward.

Article 6 of the Paris Agreement enables countries to cooperate to achieve their national contributions to reducing greenhouse gas emissions, including by way of a mechanism for market-based cooperation. As yet, no detailed regulation has been prepared nor a final decision made on how this market-based mechanism can be used. The detailed regulation under Article 6 will facilitate more extensive global emission pricing and help to realise the potential for cost-effective emission reductions.

The other market failure is related to the development and scope of new technology. The development of technology may have the characteristics of a public good. This means that the technology is useful to others and not just the actor that developed it. The actors that develop the technology will therefore bear the costs, while the benefits are shared by many [33]. In economics, this is called positive externalities, and a market left to its own devices will create too little of this kind of public good [27, 34].

The initial actors, both producers and consumers, develop experience and knowledge that will entail lower costs for subsequent actors. Again, this means that the costs are borne by few, while the benefits are shared by many. From a business economics perspective, it can therefore be profitable to wait until others have borne the costs of development and early application. This is a particular problem for technologies that lead to large positive externalities that are difficult to patent or that are necessary, but do not in themselves provide a significant competitive advantage in the market. CCS is an example of this.

A potential willingness to pay for 'green products' may mitigate the problem to some degree. The challenges of underinvesting in the market are amplified by the fact that many of the necessary investments in the development of technology are complementary to other investments in new technology [27, 28]. One actor's investments can thereby make other actors' investments more

valuable [35]. As an example, the development of better carbon capture technology will make new CCS technology more valuable because it increases the effectiveness of the whole value chain.

These two sets of market failure have a cumulative effect. This means that setting the price of emissions equal to the socioeconomic cost of emissions is not on its own sufficient to stimulate new technology.

It also means that if emissions are priced high enough for the market to generate the necessary new technology, it would need to be priced higher than the socioeconomic costs of emissions and thus entail an economic efficiency loss. This is problematic in a situation where we need to develop new technologies and use them on an industrial scale. The most effective solution is therefore emissions pricing combined with funding of new technology development.

Further investment barriers also apply to CCS. There are clear economies of scale, particularly for storage activities: Establishing the storage facility entails high costs, while the costs are lower, relatively speaking, for new users to utilise the facility. It is also the case that CCS requires a whole chain of activities and actors – capture, transport and storage. A CO<sub>2</sub> storage facility is of little value if no CO<sub>2</sub> is captured. The same is true of CO<sub>2</sub> capture without storage. Before the markets have developed, risk will therefore be associated with how other actors develop solutions for the other parts of the CCS chain. This is a risk that is difficult for any one industry actor in the chain to take.

### **3.2 Development of new CCS projects will lead to lower costs**

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High investment and operating costs combined with low income potential and technical risk make it challenging for commercial actors to invest in CCS. CCS is necessary to achieve the global temperature targets, but its development will take time and require technological, industrial and regulatory innovation. If the measure is to be effective after 2030, more facilities must be developed now, even if the price signals do not indicate profitability in a short-term business economics perspective. The low price of emissions together with the risk of companies moving production to areas with less stringent climate regulations (carbon leakage) mean that it is not a realistic scenario for industry exposed to competition

in Europe to bear all the costs of establishing CCS in the short term.

A large number of empirical studies show that the costs of new technologies will be lowered in step with increased use. [36–40]. Experience also shows that it takes a long time for many technologies to generate experience that moves us up the learning curve. On the basis of Norway's demonstration project for full-scale CCS, DNV GL has assessed the potential cost development of CCS when more facilities are built [41]. The analysis shows how the cost of CCS measures is expected to fall when capacity utilisation increases, solutions in the chain are optimised and technology improves, as a result of higher utilisation of CCS.

The results are shown in Figure 3.1. They are based on the assumption that economies of scale are utilised by a Norwegian CO<sub>2</sub> storage facility.

By utilising the capacity of a Norwegian CO<sub>2</sub> storage facility, the costs will be reduced for subsequent projects. Technological optimisation, development and learning will bring further reductions. DNV GL believes that, on average, a doubling of capacity will give a ten per cent reduction in costs over time. The cost curves in the graph are based on Norway's project and are average values.

The costs of CCS will vary immensely depending on what kind of process, industry and sector carbon is captured from. The actual costs for subsequent projects may therefore be both higher and lower than that shown in Figure 3.1. This is illustrated in an analysis by Thema and Carbon Limits [25]. The analysis includes an assessment of the varying costs of carbon capture, transport and storage measures from different industry sources. With the technology currently available, the cost per tonne of CO<sub>2</sub> captured, transported and stored from ammonia/hydrogen production can be as low as EUR 39 per tonne of CO<sub>2</sub>, while the equivalent cost of waste incineration with today's technology is estimated to be EUR 150–200 per tonne of CO<sub>2</sub>.

The results of DNV GL's study combined with rising CO<sub>2</sub> prices, as illustrated in Figure 3.1, show that CCS can be profitable in a business economics perspective if a facility with flue gas capture was built today that could capture and store around 40 million tonnes of CO<sub>2</sub> per year. The cost curve would then intersect the estimated CO<sub>2</sub> price in 2030 in the IEA's sustainability scenario. Given that CCS is necessary to achieve our climate targets, although there are measures that cost less in the short term, postponing the devel-

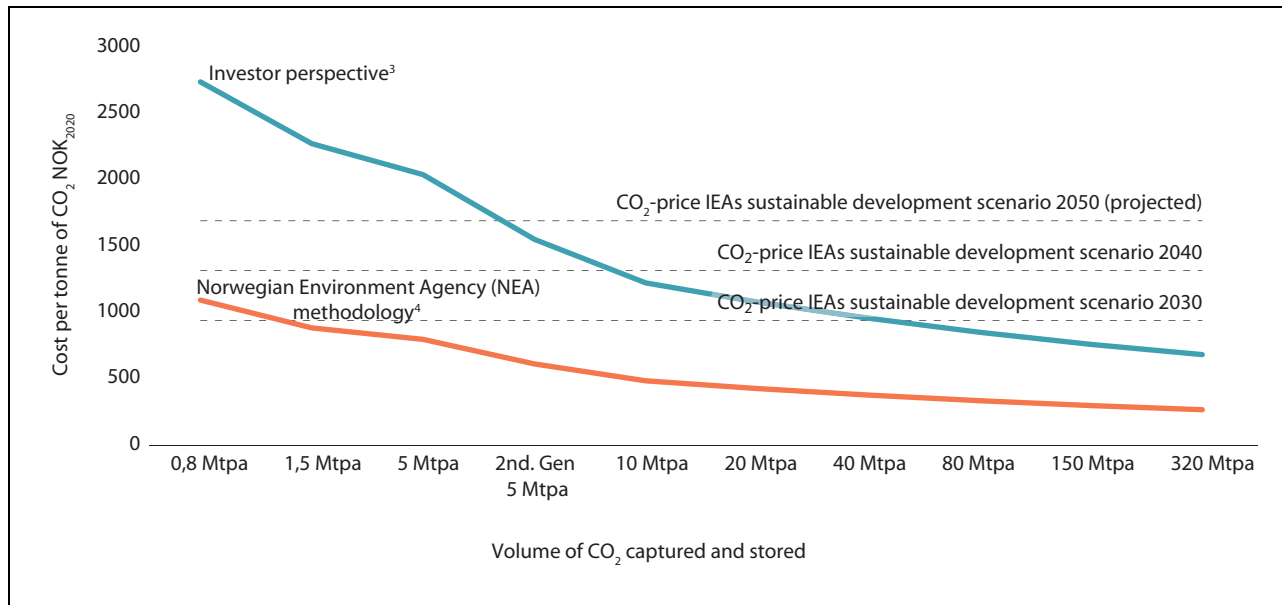


Figure 3.1 Expected development of average cost per tonne CO<sub>2</sub> for CCS projects<sup>1</sup> and expected CO<sub>2</sub>-prices<sup>2</sup>

<sup>1</sup> Cost curves (NOK per tonne CO<sub>2</sub>) are based on “Potential for reduced costs for carbon capture, transport and storage value chains (CCS)”, DNV GL, 2019. Costs have escalated from 2018-NOK to 2020-NOK. The curve’s starting point (to the left) is adjusted with updated costs from the FEED studies as presented in “Oppdatert samfunnsøkonomisk analyse av demonstrasjonsprosjekt for fullskala CO<sub>2</sub>-håndtering”, Gassnova/DNV GL, 2020. The cost curves are average cost curves, and there will potentially be projects with both higher and lower costs per tonne CO<sub>2</sub>.

<sup>2</sup> Expected CO<sub>2</sub>-price is based on IEA’s Sustainable Development scenario from World Energy Outlook 2019. The price reflects expected CO<sub>2</sub>-prices in advanced economies for sectors such as power and industries, and the price is escalated to 2020 prices. The exchange rate is assumed to be 9 NOK/USD. IEA WEO gives expected prices for 2030 and 2040. DNV GL has projected linear price growth up to 2050. IEA’s price expectancies are based on policy expectations beyond CO<sub>2</sub> prices. E.g. the price is based on increased support for CCUS projects. IEA’s CO<sub>2</sub>-price expectation is therefore not a marginal cost curve. This explains why IEA’s price expectation is lower than the marginal cost curves in line with the Paris accord from other agencies.

<sup>3</sup> Investor-perspective is based on a 8 per cent rate of return (real, before tax) both on CO<sub>2</sub> reductions and costs over 25 years.

<sup>4</sup> NEA’s methodology is based on a 4 per cent rate of return on project costs over the lifetime of the project (25 years), but the CO<sub>2</sub> reduction is not discounted

Source: Gassnova based on DNV GL

opment of CCS is likely to increase the costs for the world as a whole. Postponing development may mean that CCS would have to be developed faster, which would reduce the possibility of

exploiting learning effects from one project to the next.

The project’s contribution to cost reductions is described in Section 6.

## 4 The result of the targeted work on carbon capture and storage

### 4.1 Follow-up of the Government's strategy for CCS work

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The Government will contribute to developing technology for carbon capture, transport and storage. The Government presented its strategy for carbon capture and storage (CCS) work in 2014.<sup>1</sup> The strategy comprises a broad range of measures in research and development, demonstration, work on realising a full-scale demonstration facility and international work.

Technology Centre Mongstad has been operational since 2012. A large number of technology suppliers have tested and are planning to test their technology at the centre. The CLIMIT research and development programme has supported the development of several different technologies and solutions that can make CCS safer and more efficient, and a new research centre for environment-friendly energy (FME) dedicated to CCS has been established. Through its international work, Norway has contributed to the development of CCS at a global level.

The set of available policy instruments has been well-suited to support the development of full-scale CCS demonstration in Norway.

#### 4.1.1 Gassnova SF

Gassnova SF contributes to technology development and competence building by supporting specific CCS projects. The entity is responsible for key policy instruments for the development of CCS technology and is the advisor to the Ministry of Petroleum and Energy on issues related to CCS. Gassnova administers the state's interests in Technology Centre Mongstad (TCM) and shares administrative responsibilities with the Research Council of Norway for the national research programme for CCS technologies CLIMIT. In recent years, a number of activities undertaken by both TCM and CLIMIT have been specifically aimed at solving challenges related to the project now

known as Longship. Gassnova has coordinated the different sub-projects and worked on benefit realisation in the main project. Gassnova has also been responsible for following up and evaluating the actors' projects, including the potential for benefit realisation.

#### 4.1.2 National policy instruments for promoting research, development and demonstration

##### *Technology Centre Mongstad*

Technology Centre Mongstad (TCM) is the biggest and most flexible facility in the world for the development, testing and qualification of carbon capture technology. TCM contributes to international dissemination of accumulated experience in order to reduce the costs and risks associated with full-scale carbon capture. TCM has been operational since 2012. Alstom, Shell Cansolv, Aker Solutions, CCS Limited, ION Engineering and Fluor Corporation have all conducted extensive testing at TCM.

TCM has also tested different measuring devices and process components and carried out test campaigns with open results in cooperation with Norwegian and international universities and research institutes. A key part of the open campaigns is publication of results. Projects with funding from the US authorities have tested technology at TCM, and in 2018, the US Department of Energy allocated USD 33.7 million for four new advanced capture technology projects planning to test at TCM.

The Norwegian Government and the current industry owners of TCM have entered into a new operating agreement for the period from the end of August 2020 until the end of 2023. The state on its part wishes to increase industry participation and industry funding of TCM.

##### *CLIMIT*

CLIMIT is a national programme for research, development and demonstration of technologies

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<sup>1</sup> The Ministry of Petroleum and Energy's Proposition No. 1 to the Storting (2014–2015)

for carbon capture, transport and storage. Support from the programme is intended to develop knowledge, expertise, technology and solutions that can reduce costs and lead to widespread international dissemination. CLIMIT has made an important contribution to full-scale CCS by funding the development and demonstration of technology that will now be employed in the project, e.g. by funding pilot testing of carbon capture technology. CLIMIT also supports projects that look at capture solutions from other emission sources in Norway.

#### ACT

CLIMIT has also funded international projects and knowledge sharing through Accelerating CCS Technology (ACT).<sup>2</sup> ACT is an international collaboration for joint calls for proposals for research projects related to CCS, the goal of which is to coordinate efforts between countries and facilitate international cooperation on research projects. ACT's activities are supported by the EU Commission through the Horizon 2020 programme. It was established in 2016 and comprises 16 participating parties. ACT has developed projects of relevance to Norway's CCS project. The collaboration can contribute to integrating emission sources from Europe into the Norwegian CO<sub>2</sub> transport and storage infrastructure. The initiative has also contributed to enhancing international research efforts in the field of CCS.

#### Research centres for environment-friendly energy (FME)

Norway has one research centre for environment-friendly energy (FME) dedicated to carbon capture and storage. The Norwegian CCS Research Centre (NCCS) started up in 2016.<sup>3</sup> The centre will have a duration of eight years. NCCS has around 30 research and industry partners and a budget of NOK 570 million over eight years.<sup>4</sup> SINTEF Energy Research manages the centre in close cooperation with, among others, the Norwegian University of Science and Technology (NTNU) and the University of Oslo (UiO). The centre works specifically on industry-driven innovation for accelerated demonstration of CCS.

<sup>2</sup> See <http://www.act-ccs.eu/> for more information.

<sup>3</sup> <https://www.sintef.no/nccs/>

<sup>4</sup> The Research Council of Norway finances NOK 240 million, industry NOK 210 million and R&D partners NOK 120 million. This includes other projects associated with the centre.

#### European CCS Research Infrastructure ECCSEL

Norway also leads the ECCSEL ERIC consortium (the European Research Infrastructure Consortium organised under the European Carbon Dioxide and Storage Laboratory Infrastructure) the main objective of which is to strengthen European research on carbon capture, transport and storage [42]. The consortium comprises 21 operators from 77 research facilities in Norway, the Netherlands, France, Italy and the UK. Overall, the Research Council of Norway has awarded close to NOK 250 million in funding since 2013 for the Norwegian part of the consortium. The consortium is important for research cooperation between countries and for implementation of CCS research projects in CLIMIT and NCCS, as well as international projects.

#### 4.1.3 International work

The Norwegian project underlines the need for and the value of international cooperation on technology development and emission reductions. International cooperation and successive projects in Europe and globally are prerequisites for CCS to become an efficient and competitive climate policy instrument. This is also essential in order to succeed in commercialising the solutions in Norway's project. Norway has implemented a number of measures aimed at sharing CCS knowledge. Learning effects will contribute to reducing the costs of CCS. At the same time, international cooperation is important to create better understanding of how important CCS is in achieving our climate targets.

The Ministry of Petroleum and Energy cooperates with other ministries, the foreign service system, the Research Council of Norway and Gassnova to promote CCS internationally.

Norway also works closely with the EU and participates in a number of forums and bodies working, among other things, to develop CCS frameworks and regulation. The Ministry of Petroleum and Energy has a close dialogue with the European Commission on CCS. The Ministry is head of the Government Group for the Zero Emissions Platform<sup>5</sup>, which is the technical adviser to the EU on the deployment of carbon capture and storage, and carbon capture and utilisation. The Ministry is also represented in an expert group for the Innovation Fund, and has

<sup>5</sup> <https://zeroemissionsplatform.eu/>



contributed to drawing up the rules for funding innovative technology, including CCS.

The Ministry also participates in the European Strategic Energy Technology Plan (SET Plan).<sup>6</sup> The SET Plan forms an important element of the Energy Union in the EU. The plan provides guidelines for work on energy research in the EU. Norway and the Netherlands are leading the work on carbon capture, utilisation and storage under the SET Plan.

The Ministry also works through regional forums, such as the North Sea Basin Task Force and Nordic Baltic Networking Group on Carbon Capture, Utilisation and Storage. The North Sea Basin Task Force works to establish common principles for safe CO<sub>2</sub> transport and storage in the North Sea basin, and comprises representatives from the authorities and industry in Norway, the UK, the Netherlands, Germany and the Belgian region Flanders. The Nordic Baltic Networking Group on Carbon Capture, Utilisation and Storage was established for the purpose of sharing experience and knowledge about carbon capture, utilisation and storage between the Nordic and Baltic countries.

Together with the USA, the UK and Saudi Arabia, the Ministry is head of the Carbon Capture, Utilization, and Storage (CCUS) Initiative under the Clean Energy Ministerial (CEM). A key objective of the initiative is to strengthen cooperation between public and private sector actors on CCS.

It cooperates with the Oil and Gas Climate Initiative (OGCI)<sup>7</sup> and with the major development banks and other international financial institutions on establishing common principles for funding of CCS. Norway has been one of the most important donors to the World Bank's capacity building fund for CCS, and we support the World Bank's inclusion of CCS funding principles in its strategy.

The Research Council of Norway is responsible for following up the memorandum of understanding between the Ministry of Petroleum and Energy and the Department of Energy in the USA [43]. Active efforts have been made for several years under this agreement to increase cooperation. This has led, among other things, to faster upscaling of capture technologies through cooperation at TCM, sharing of data on CO<sub>2</sub> storage between a number of countries, and US participation in ACT.

#### 4.1.4 Planning of the project

On the basis of the CCS strategy set out in the Ministry of Petroleum and Energy's Proposition No. 1 to the Storting (2014–2015), Gassnova carried out a pre-feasibility study in 2015 that identified several emission sources and storage locations that were technically suitable for carbon capture and storage, as well as industry actors that were interested in participating in future studies. The pre-feasibility study focused on existing land-based emission sources that emitted more than 400,000 tonnes of CO<sub>2</sub> per year.

A broad assessment of CO<sub>2</sub> storage possibilities on the Norwegian continental shelf and coordination of storage with other countries was also conducted. Transport by pipeline and ship were also assessed. The CO<sub>2</sub> transport study was conducted by Gassco.

The pre-feasibility study made a clear recommendation to establish a transport and storage actor that could provide services to industry actors with CO<sub>2</sub> emissions that lacked expertise in CO<sub>2</sub> transport and storage. Subsequently, the study recommended to divide the value chain into segments, where actors would only have to be concerned with the activities they carry out in their undertaking and in which they have expertise, whilst the state should alleviate the actors from the risk in the interface between segments. The interface risk involves ensuring the integrity of the value chain throughout the project design phase and into the realisation and operational phases, both with regards to interfaces, schedules, and operational risk.

In the Ministry of Petroleum and Energy's Proposition to the Storting (2016–2017), the Government proposed continuing this work and conducting feasibility studies. As part of the feasibility studies, Norcem assessed carbon capture at its cement factory in Brevik. Yara assessed carbon capture at an ammonia factory in Herøya, while Fortum Oslo Varme (then part of the Energy Recovery Agency (Energigjenvinningsetaten) in the City of Oslo) assessed carbon capture from its waste-to-energy plant at Klemetsrud. The feasibility studies were completed in the summer of 2016 and showed that carbon capture was technically feasible to implement at all three emission locations.

In addition, a study was conducted of transport by ship and three potential storage locations: the Sæter structure in Utsira Sør, the Heimdal structure and Smeaheia east of Troll. A development concept was identified with an onshore receiving

<sup>6</sup> [https://ec.europa.eu/energy/topics/technology-and-innovation/strategic-energy-technology-plan\\_en](https://ec.europa.eu/energy/topics/technology-and-innovation/strategic-energy-technology-plan_en)

<sup>7</sup> <https://oilandgasclimateinitiative.com/>

facility and pipeline to an injection well in the Smeaheia area. This concept had the lowest risk, greatest operational flexibility and greatest potential for future capacity expansion. Although the Heimdal structure appeared to be suitable for CO<sub>2</sub> storage, it would among other things be necessary to develop an offshore loading and unloading system for CO<sub>2</sub>, as well as solutions for direct injection of CO<sub>2</sub> from ships. The technical and operational risk associated with the direct injection concept was considered to be higher. The feasibility study also concluded that the structure investigated in Utsira Sør was not suitable as a storage location for the project due to an insufficient storage capacity in the structure for the envisaged volume of CO<sub>2</sub>.

In 2016, the Ministry of Petroleum and Energy conducted a concept selection study for the project [44]. The concept selection study was quality assured by Atkins and Oslo Economics in quality assurance phase 1 (QA1) of the project [45]. A socioeconomic analysis was also conducted under QA1. The analysis indicated in particular that the project benefits were uncertain, especially in terms of whether there would be subsequent CCS projects that could benefit from the learning effects of Norway's project. The QA1 report recommended not to continue the project until the resulting benefits could be better substantiated.

The Ministry of Petroleum and Energy proposed continuing the project nonetheless, and extensive efforts were initiated to identify the project benefits in addition to implementing measures to increase the probability of achieving the project goals. This work is hereinafter referred to as benefit realisation.

In autumn 2016, Gassnova announced two competitions for state aid to carry out concept selection and front-end engineering design (FEED) studies, one competition for studies on carbon capture from industrial facilities and one competition for studies on geological storage of CO<sub>2</sub>. Notification of the concept selection and FEED studies was submitted to the EFTA Surveillance Authority, which approved the notification [46].

On the basis of the competition, Gassnova signed carbon capture study agreements with Fortum Oslo Varme, Norcem and Yara in spring 2017. Gassnova also signed a CO<sub>2</sub> storage study agreement with Equinor.

After the concept selection and FEED studies had been awarded, Equinor ASA, A/S Norske Shell and Total E&P Norge AS formed a collaboration for the study phase. This collaboration was named Northern Lights. Gassco was given

responsibility for conducting the concept selection studies of CO<sub>2</sub> transport by ship.

The carbon capture concept selection studies were completed in autumn 2017. The Government decided at this time to present the project to the Storting. Proposition No. 85 to the Storting (2017–2018) provided a comprehensive presentation of the work on full-scale CCS. The Storting pledged funding to initiate the FEED studies at Norcem and Fortum Oslo Varme.

The Ministry recommended not proceeding with the project at Yara's ammonia factory in Porsgrunn due to low learning potential compared to the two other actors and uncertainty related to other aspects of the facility. Yara was also of the opinion that it would not be industrially sensible to continue their project.

The concept selection studies on CO<sub>2</sub> transport were completed in autumn 2017. Responsibility for further studies of transport was transferred to Equinor, among other things to reduce the number of interfaces and actors in the project. The concept selection study on CO<sub>2</sub> storage was completed in autumn 2018.

In the course of the concept selection study phase, Northern Lights concluded that the storage capacity of the selected storage location Smeaheia was too uncertain. An alternative storage location in the nearby Johansen formation, which had also been studied in connection with planning for the Mongstad full-scale project, had a greater storage capacity potential. This area was therefore selected as the storage formation. The change from Smeaheia to the Aurora complex in the Johansen formation reduced the risk associated with the project while also increasing the potential for storing CO<sub>2</sub> from other sources.

The FEED studies of carbon capture and the bulk of the transport and storage work was concluded in autumn 2019.

Late in 2018, the need to drill a verification well in the Johansen formation in the storage complex given the name 'Aurora' was identified. This drilling took place from November 2019 to February 2020. Certain parts of the FEED studies comprising the actual storage location were therefore not completed until the spring of 2020.

The Ministry has placed particular emphasis on substantiating the project's benefits. Gassnova has delivered benefit realisation plans in connection with a number of milestones throughout the project phases. The most recent benefit realisation plan also builds on an updated socioeconomic analysis conducted by Gassnova in cooperation with DNV GL in autumn 2019.

## 4.2 Longship – a cost-effective solution for full-scale CCS

Societal and impact goals for the project were defined in connection with the concept selection studies and the quality assurance phase 1 (QA1). These goals govern prioritisation in the project in general, and for work on benefit realisation in particular.

### Societal goals

*‘The demonstration of CCS shall provide the necessary development of CCS to ensure that Norway and the EU’s long-term climate targets can be achieved at the lowest possible cost.’*

Four impact goals have been defined to achieve this societal goal:

1. *The project shall generate knowledge to show that full-scale CCS is feasible and safe.*
2. *The project shall provide productivity gains for forthcoming projects through learning and economies of scale effects*
3. *The project shall provide learning related to regulation and incentivisation of CCS activities*
4. *The project shall facilitate business development*

A solution for industrial-scale CCS has been matured to facilitate further development of CCS in both Norway and Europe. The project has encompassed carbon capture from Norcem’s cement factory in Brevik in Porsgrunn municipality, and carbon capture from Fortum Oslo Varme’s waste-to-energy plant at Klemetsrud, in the City of Oslo. Northern Lights has been responsible for the transport and storage part of the project, which has comprised ships for transport of liquid CO<sub>2</sub>, a reception terminal in Øygarden municipality, and a pipeline to a well where CO<sub>2</sub> will be injected into a storage formation beneath the seabed under the exploitation licence 001, also known as Aurora; see Figure 4.1.

Norcem, Fortum Oslo Varme and Northern Lights’ work throughout the FEED phase has been regulated by study agreements with Gassnova. All of the companies have submitted comprehensive FEED reports that have been assessed by Gassnova and by Atkins and Oslo Economics as external quality assurers in accordance with the state’s project model.<sup>8</sup>

<sup>8</sup> Public versions of the FEED reports are available at <https://ccsnorway.com/reports/>

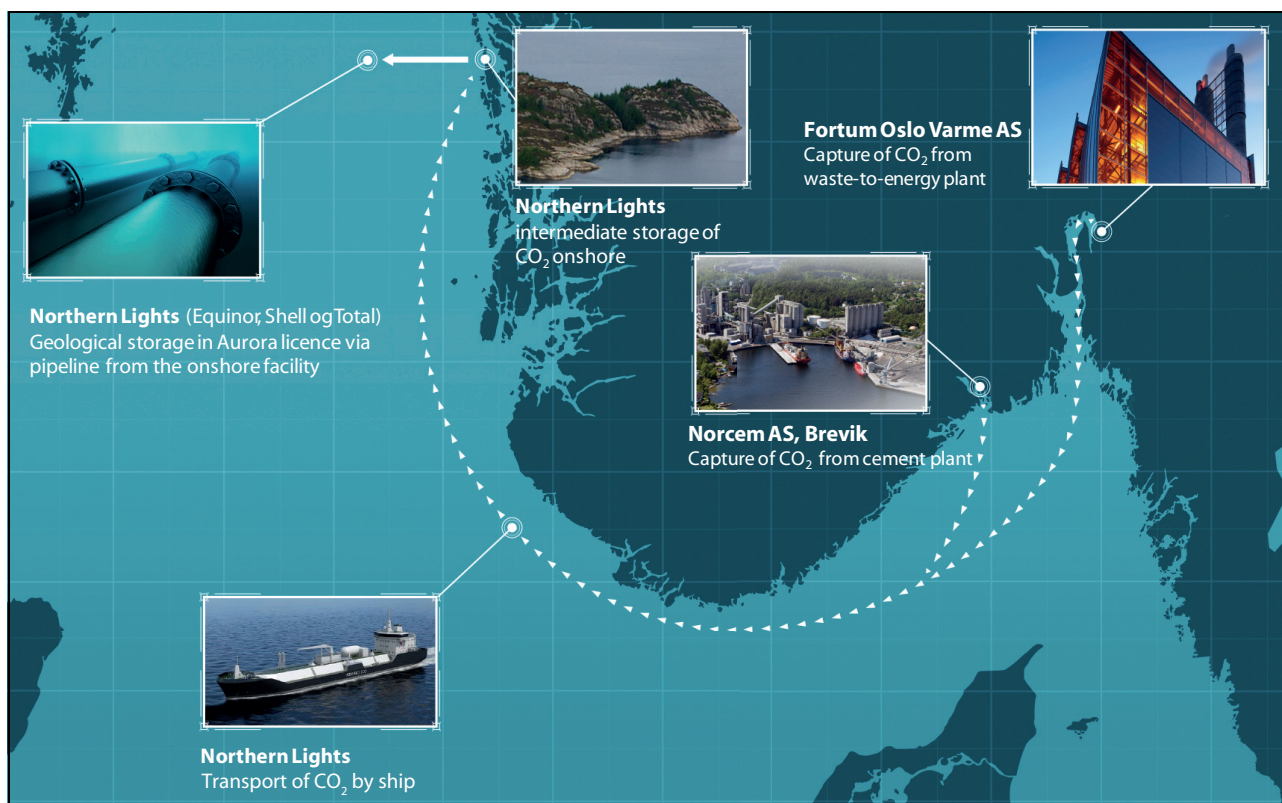


Figure 4.1 Longship

Source: Gassnova

The actors have matured their respective projects from the concept phase through the FEED phase. This maturation has mainly entailed continuing work on the selected solutions to reduce uncertainty in the implementation phase.

Norcem and Fortum Oslo Varme have among other things verified their selected carbon capture technologies, optimised integration, prepared contracts with main suppliers and drawn up benefit realisation plans. Northern Lights has drilled a verification well, the results of which show that the reservoir is suitable for CO<sub>2</sub> storage. Solutions for transport by ship have also been developed as well as a Plan for Development and Operation (PDO) and a Plan for Installation and Operation (PIO), with the pertaining Impact Assessment (IA).

Some changes have also been made to the technical solutions through this phase. Fortum Oslo Varme, for example, has changed the transport solution from the facility to Oslo Port, and Northern Lights has simplified the design of the onshore reception facility.

The overall progress schedule for the project indicates that if the implementation phase is initiated in January 2021, Norcem and Northern Lights could be in operation in the course of 2024. When Fortum Oslo Varme can become operational is dependent on external funding; see section 2.6. The funding period is set to last until 2034.

All actors followed up the work on benefit realisation in the FEED phase.

All industry enterprises in the project have made investment decisions in their respective sub-projects based on the FEED reports and the draft contracts negotiated between the state and industry, conditional on the state also deciding to support the project.

#### 4.2.1 Norcem

Cement production represents around seven per cent of global CO<sub>2</sub> emissions [47]. Two thirds of the emissions from cement production result from the process of turning limestone into cement. As long as limestone is used, emissions from this process can only be reduced by CCS. The cement industry is therefore dependent on carbon capture to achieve a carbon neutral industry and products.

Norcem AS is a wholly owned subsidiary of HeidelbergCement Group AG. Norcem has produced cement in Brevik since 1916. Following upgrades, the facility is in many respects now one of the most modern cement production facilities in Europe. In 2019, Norcem emitted around 900,000 tonnes of CO<sub>2</sub> from its factory in Brevik. Of this, around 100,000 tonnes of CO<sub>2</sub> were from biogenic sources and around 800,000 tonnes of CO<sub>2</sub> were from fossil sources [48].

Norcem is planning to develop and operate a carbon capture facility that can capture around 400,000 tonnes of CO<sub>2</sub> per year of its existing emissions from the cement factory in Brevik. Norcem is planning to use the residual heat from the cement factory as an input factor in the carbon capture facility, and access to residual heat will thereby determine the proportion of emissions it is possible to capture. To capture all of its emissions, Norcem would need more energy and the costs would have been higher.

Two thirds of Norcem's emissions result from the process of turning limestone into cement. The remaining third of Norcem's emissions from Brevik are a result of combustion, around 35 per cent of which comes from biogenic sources. Extensive efforts have therefore already been made to

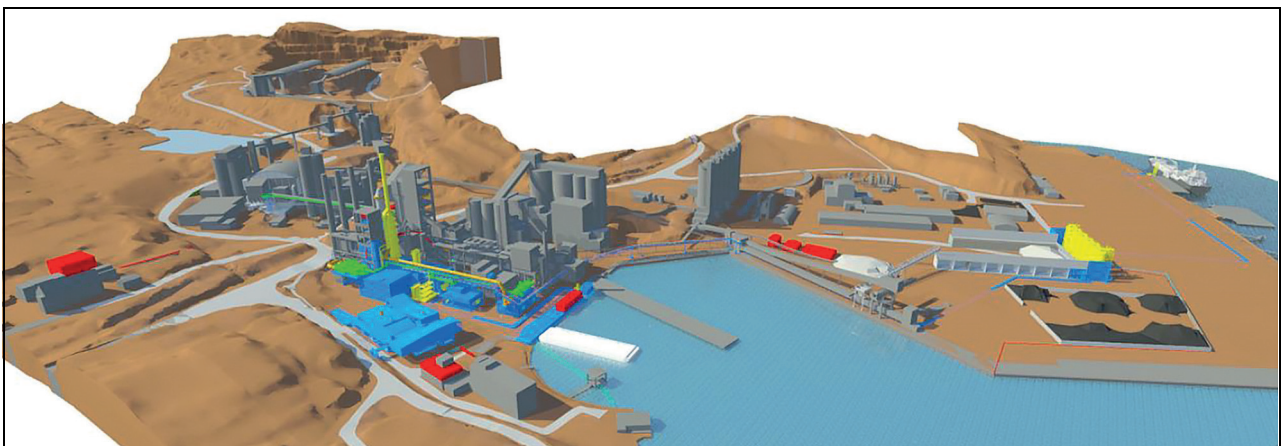


Figure 4.2 Illustration of Norcem's carbon capture facility

Source: Norcem



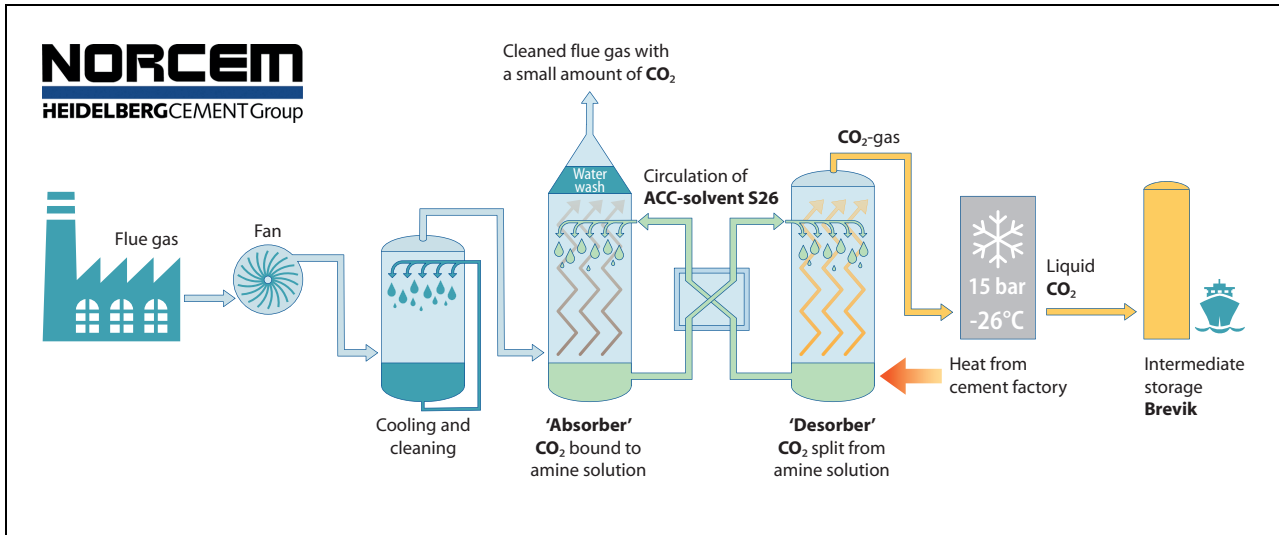


Figure 4.3 Illustration of Norcem's carbon capture process

Source: Gassnova, based on the FEED reports

reduce emissions from cement production, among other things by introducing alternative fuels.

Norcem has chosen Aker Carbon Capture as its main contractor and supplier of carbon capture technology. CO<sub>2</sub> is separated from the flue gas and liquefied before it is temporarily stored in storage tanks at Grenland Port, which has the capacity to store CO<sub>2</sub> from approximately four days of production.

On assignment from Norcem, Multiconsult has conducted an impact assessment of Norcem's carbon capture project [49]. The impact assessment has not revealed any factors indicating that the measure should not or cannot be implemented. Multiconsult considers the negative impacts of the measure to be minimal. The project will mean that some of the pollution currently emitted to air, will be discharged to sea as a result of implementing the capture process. Amines will become new components in the emissions to air, but the amounts are minimal and Multiconsult has deemed them harmless. Storing CO<sub>2</sub> in pressurised tanks entails a risk, but according to Multiconsult, this risk is very low.

In relation to the employment effects of the measure, Gassnova, based on Norcem's FEED reports and additional documentation, estimates that the project will trigger a direct employment effect during the construction phase equivalent to around 900 full-time equivalents [49]. This is primarily employment with the project suppliers. If indirect effects and consumption effects are taken into account, Gassnova estimates that Norcem's

project will have an employment effect of around 1,800 full-time equivalents during the construction phase. The bulk of the work will take place during the second half of 2023, but there will also be major activity related to groundwork and foundation construction from autumn 2022.

Norcem has contributed to the benefit realisation work during the FEED phase. The project has been presented in various forums and contexts, and learning from the project has been shared. Norcem is in dialogue with national and international actors that are closely following the development of its carbon capture project. Norcem has also received many visitors to its facility.

#### 4.2.2 Fortum Oslo Varme

Waste management is a growing industry globally. Greenhouse gas emissions from waste management make up around five per cent of total global emissions [50]. The transition from landfills to sorting, recycling and energy recovery from waste reduces greenhouse gas emissions and the general environmental impact considerably. CCS will be an important tool to achieve carbon neutrality for this industry. The industry is also in a position to contribute to carbon-negative emissions, which the UN Intergovernmental Panel on Climate Change among others considers important to achieve the goals of the Paris Agreement [4].

The waste-to-energy plant at Klemetsrud started up in 1985. Fifty per cent of Fortum Oslo



Figure 4.4 Fortum Oslo Varme's carbon capture facility

Source: Fortum Oslo Varme

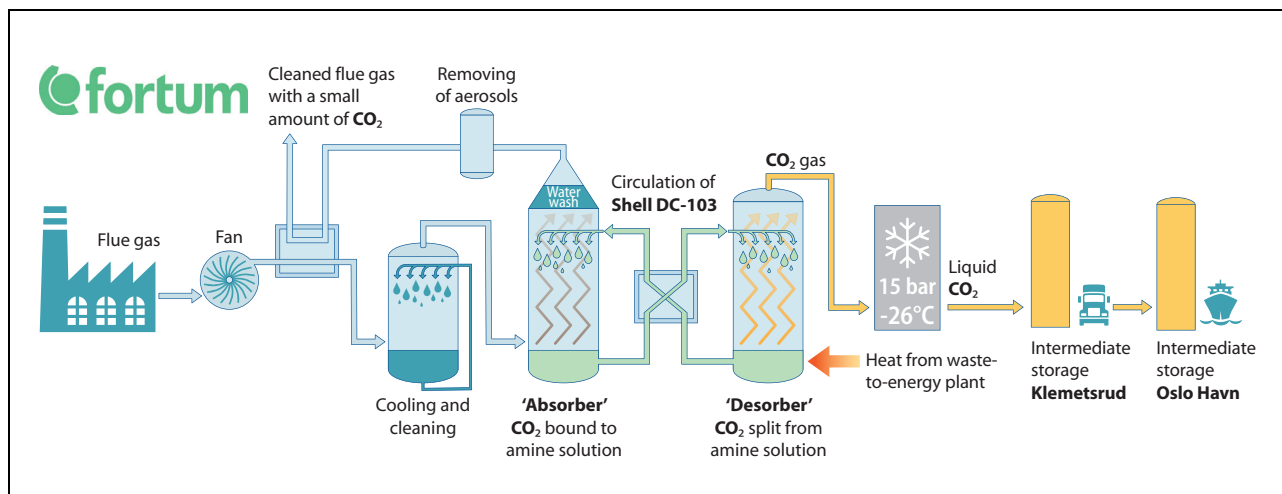


Figure 4.5 Illustration of Fortum Oslo Varme's carbon capture process

Source: Gassnova, based on the FEED reports

Varme is owned by the Finnish energy company Fortum Oy and 50 per cent by the City of Oslo. The waste incineration facility produces steam for electricity production and district heating. Around half of the waste that is incinerated in the facility comes from biogenic sources. This means that using carbon capture and storage at Fortum Oslo Varme will remove CO<sub>2</sub> from the atmosphere. Since it comes from biogenic sources, the CO<sub>2</sub> cannot be included in Norway's emission obliga-

tions. Waste incineration with district heating forms part of the City of Oslo's main infrastructure.

Fortum Oslo Varme is planning to build and operate a carbon capture facility that can capture around 400,000 tonnes of CO<sub>2</sub> per year of its existing emissions from the waste incineration facility. Emissions from Fortum Oslo Varme are not encompassed by the European Emissions Trading System (EU ETS); see Box 2.2. CO<sub>2</sub> is separated



from the incineration facility flue gas, liquefied and temporarily stored in tanks at Klemetsrud. From these tanks, trucks will transport the liquid CO<sub>2</sub> to Oslo Port, which has the capacity to store CO<sub>2</sub> from approximately four days of production. Fortum Oslo Varme has chosen TechnipFMC as its main contractor and Shell as the supplier of CO<sub>2</sub> capture technology.

According to Fortum Oslo Varme, more than 2 billion tonnes of waste is produced in the world each year, and management of this waste leads to huge greenhouse gas emissions [51].

Based on Fortum Oslo Varme's FEED report [51] and additional documentation, Gassnova estimates the direct employment effect during the construction phase to be around 1,400 full-time equivalents. If indirect employment effects and consumption effects are taken into account, the employment effect is estimated to be around 2,800 full-time equivalents during the construction phase. Since the engineering work will be managed from TechnipFMC's Lyon office, employment is initially expected to be highest outside Norway. Much of the local employment will be seen in 2022 and 2023.

Fortum Oslo Varme has contributed to the benefit realisation work during the FEED phase. The project has been presented in various forums and contexts, and learning from the project has been shared. Fortum Oslo Varme is in dialogue

with waste incineration facilities in Norway and abroad that are following the development of the carbon capture project at Klemetsrud. Fortum Oslo Varme has also received a large amount of visitors to its facility.

#### 4.2.3 Northern Lights

Northern Lights is a collaboration between Equinor ASA, A/S Norske Shell and Total E&P Norge AS. Northern Lights will transport CO<sub>2</sub> by ship to a new receiving terminal in Øygarden municipality. From here, CO<sub>2</sub> will be pumped through a pipeline to a template on the seabed and injected into a geological formation around 2,600 metres beneath the seabed for permanent storage.

Northern Lights is planning a two-phase development: The first phase is planned to have an estimated capacity of 1.5 million tonnes of CO<sub>2</sub> per year, over an operational period of 25 years. A potential second phase is planned to have an estimated capacity of 5 million tonnes of CO<sub>2</sub> per year.<sup>9</sup> A further increase in capacity above 5 million tonnes of CO<sub>2</sub> per year going through the

<sup>9</sup> The pipeline will have the capacity to transport around five million tonnes of CO<sub>2</sub> per year. This will lead to somewhat higher costs compared to a pipeline with a capacity of 1.5 million tonnes of CO<sub>2</sub> per year, but significantly lower costs than if a new pipeline had to be laid later on.



Figure 4.6 Illustration of Northern Lights' receiving terminal in Øygarden municipality

Source: Northern Lights

infrastructure will require more investment than a phase 2 expansion (development phase 3).

The work to verify a safe and suitable CO<sub>2</sub> storage solution is costly and time consuming. To verify the storage potential of the Aurora complex, Northern Lights drilled a verification well with state funding. The well showed the presence of sandstone and an acceptable storage potential in the relevant formation. The well will later also be used as an injection well. Steps have been taken to enable a second well to be drilled in the course of phase 1 on certain conditions.

Arrangements have also been made for Northern Lights to invest in up to three ships in phase 1 to transport CO<sub>2</sub> from different capture facilities

to the onshore facility in Øygarden. See section 8 for more details about the Northern Lights project.

Northern Lights has also contributed to the benefit realisation work during the FEED phase. An important part of this work is activities that contribute to business development, which is described in more detail in section 4.2.5. The companies participating in Northern Lights will also use their experience from the project in their own research and development work. Experience from this project can also be utilised in any possible future projects or in the further development of Northern Lights.



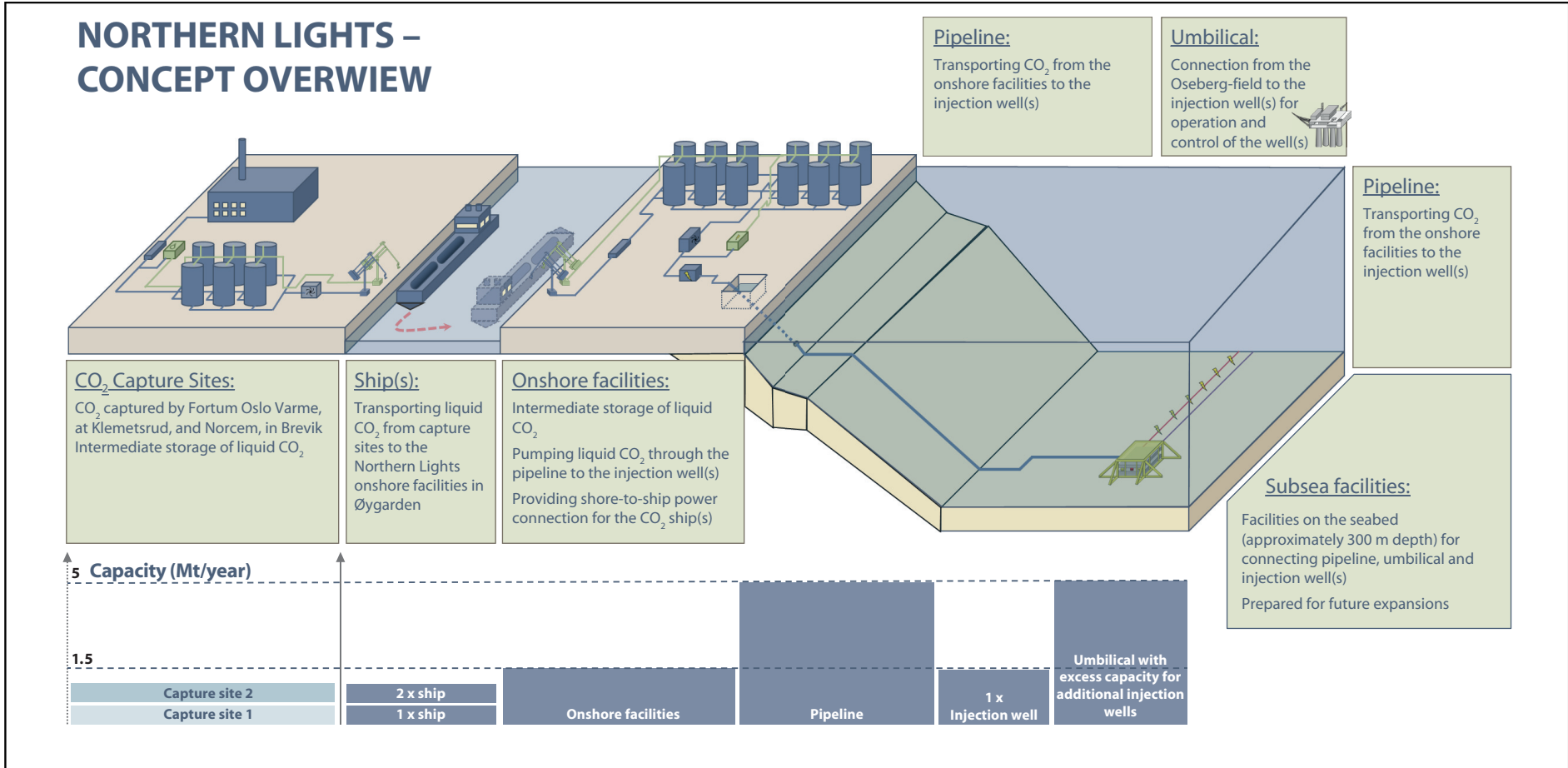


Figure 4.7 Northern Lights – concept overview

Source: Northern Lights

Table 4.1 Cost estimate (P50<sup>1</sup>) for overall investments and operating costs for the period 2021–2034. Atkins and Oslo Economics (QA2).

NOK Mill. 2021 (P50), with exchange rates at 2 June 2020	Transport and storage and Norcem	Transport and storage and Fortum Oslo Varme	Transport and storage and two capture facili- ties
Investment costs	12,900	13,900	17,100
Operating costs 10 years	5,700	6,800	8,000
Total P50 10 years	18,700	20,700	25,100

<sup>1</sup> P50 is the estimated project cost level for which there is an estimated 50 per cent probability of not exceeding.

#### 4.2.4 Cost estimate

In the quality assurance phase 2 report (QA2), a cost estimate for Longship based on the actors' FEED reports has been prepared. A project comprising carbon capture from Norcem's facility and transport and storage is expected (P50) to cost a total of NOK 18.7 billion, of which NOK 12.9 billion is investments between 2021 and 2024 and NOK 5.7 billion is operating costs for a subsequent ten-year operational period. A project comprising carbon capture from Fortum Oslo Varme's facility and transport and storage is estimated to cost a total of NOK 20.7 billion, of which NOK 13.9 billion is investments between 2021 and 2024 and NOK 6.8 billion is operating costs for a subsequent ten-year operational period. The overall cost for both capture projects, and transport and storage, is estimated to be NOK 25.1 billion, of which NOK 17.1 billion is investments and NOK 8 billion is operating costs. The state's costs and risks associated with the project are described in section 6.2.

It is challenging to make a direct comparison of the cost development from QA1 to QA2. Significant changes have been made to the project since QA1, which at the same time has matured during the FEED phase. Since QA1, there has been an overall cost increase in basic capital expenditures for the carbon capture facilities of 34 per cent and 75 per cent for Norcem and Fortum Oslo Varme, respectively. Seen in isolation, there has been a slight cost increase of 3 per cent to 7 per cent from the implementation of QA2 Part 1 to QA2 Part 2. If additional investments in a third transport ship and an additional injection well are included, the cost increase for the transport and storage part of the project is around 30 per cent. The estimates for the annual operating costs of the project were reduced somewhat after the concept selection phase.

#### 4.2.5 Benefit realisation

Gassnova has developed a framework for the work on benefit realisation based on the Norwegian Agency for Public and Financial Management's guidelines [52].

The work on benefit realisation is based on the societal goals and impact goals, as well as the economic assessments made during the project. It involves identifying benefits and increasing the probability of achieving the impact goals and thereby also the societal goals. The benefits to which the project should contribute to achieving have been defined and a plan has been developed for different measures and responsibilities. This is documented in a benefit realisation plan [53]. The benefit realisation plan has been updated a number of times during the project lifetime.

The industry actors in the project have described their contributions to benefit realisation as part of their FEED phase. The benefit realisation plan is a tool that can be used to coordinate and collate the plans of the industry actors and the state. Figure 4.8 shows the relationship between the project goals and benefits.

The benefit realisation work has a broad scope and the industry actors, Gassnova and the Ministry of Petroleum and Energy have invested great resources in this work throughout the FEED phase. Northern Lights' business development work is a key part of the benefit realisation efforts. Experience has also been shared with a number of succeeding projects, academia and the authorities in other European countries. International seminars, a European CCS conference with the European Commission, and study visits from the authorities of other countries and industry actors have been organised. In addition, a website has been developed to efficiently share reports and experience with stakeholders. Input has also been

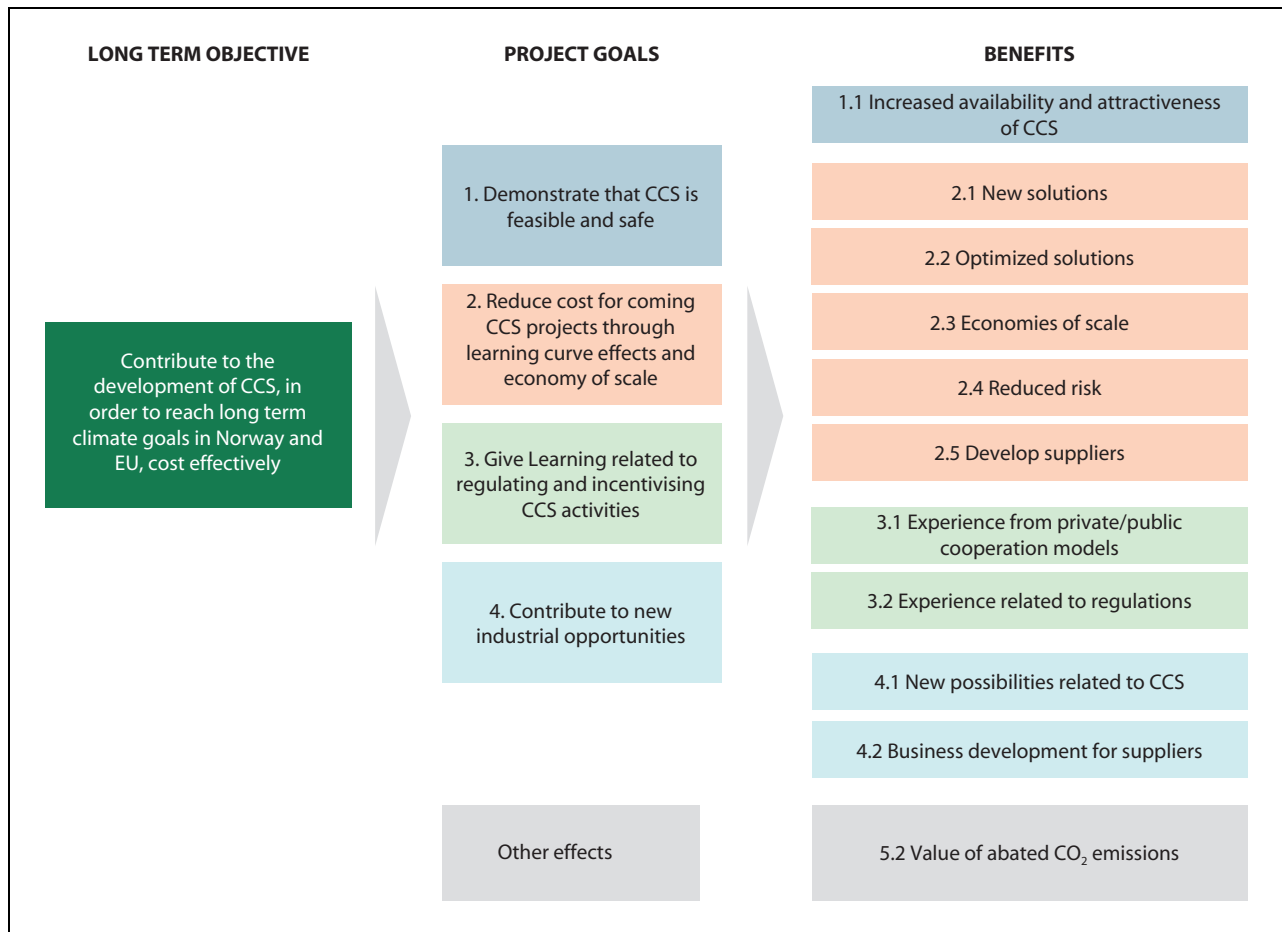


Figure 4.8 The relationship between the project goals and benefits

Source: Gassnova's benefit realisation plan

provided on the development of the EU Innovation Fund. Work on regulatory clarifications, such as the London Protocol, is also a benefit realisation from the project.

Northern Lights is working with emission owners in Europe that are considering using a Norwegian storage facility, on the condition that a full value chain for CO<sub>2</sub> capture, transport and storage is established. Carbon Limits and Thema Consulting, on assignment for the Ministry of Petroleum and Energy, have assessed relevant projects under development in Europe [25].

The consultants found 41 projects under development in Europe at different levels of maturity. Eight of these projects are planning to develop their own CO<sub>2</sub> storage facilities, but are considering using Northern Lights as a back-up solution. These are shown in the top lines of Figure 4.9 'Projects planning for other/own storage'. Eleven projects are planning to store CO<sub>2</sub> in a Norwegian storage facility, and are referred to as 'potential candidates capture Northern Lights'. A further 22 potential projects have been identified that are in

the early planning phase and are 'future possible prospects Northern Lights'. These projects are mainly based in countries without their own CO<sub>2</sub> storage facilities and, if implemented, may entail increased demand for CO<sub>2</sub> storage in Norway. Carbon Limits and Thema Consulting therefore consider Northern Lights' overall market potential to be between 20 and 60 million tonnes of CO<sub>2</sub> per year; see Figure 4.9.

If all potential and possible future carbon capture candidates for Northern Lights were implemented according to schedule, a storage capacity of 1.5 million tonnes of CO<sub>2</sub> per year would be utilised from start-up in 2024, while the capacity of 5 million tonnes of CO<sub>2</sub> in phase two would be filled from 2026. It remains uncertain how many of the identified projects will actually be implemented, and the emission sources are also dependent on third-party funding.

Northern Lights' efforts to create a market for CCS in Europe show a similar result. In September 2019, Northern Lights signed a Memorandum of Understanding (MoU) with a number of indus-

try actors in Europe on CCS cooperation; see Box 4.1. Figure 4.10 shows the current market potential according to Northern Lights. This is a very dynamic image. Each colour in the figure represents an emission source in Europe that Northern Lights is in contact with. The increase in volume illustrates that the various industrial companies

have signalled that they initially want to capture a lesser volume of carbon and then increase the volume when they have more experience. Uncertainty is attached to the projects and volumes in the figure, and third-party funding will be necessary for a number of the projects.

#### Box 4.1 Northern Lights' memoranda of understanding

In September 2019, Equinor signed MoUs with seven European industry actors to develop CCS value chains.<sup>1</sup> The MoUs were signed with Air Liquide, Arcelor Mittal, Ervia, Fortum Oyj, HeidelbergCement AG, Preem and Stockholm Exergi. They entail cooperation on potential CCS in industries with high CO<sub>2</sub> emissions and transport to Northern Lights.

*Air Liquide* is a leading European industrial company in the field of gases, technologies and services for industry and health. Air Liquide is also part of the Antwerp@C consortium, which is a collaboration between Antwerpen Port and surrounding industry. The consortium's ambition is to halve current emissions of around 18 million tonnes of CO<sub>2</sub> by 2030. Antwerp@C applied for funding from the EU's Connecting Europe Facility (CEF) this spring, and during the Northern Lights Summit 2020, they communicated that they want to send the first delivery of CO<sub>2</sub> to Northern Lights as early as in 2025.

*ArcelorMittal* is the biggest steel manufacturer in Europe, Africa and the USA. The company's ambition is to become carbon neutral in Europe by 2050. The MoU entails cooperation on a number of joint activities, including the development of logistics, exploring potential commercial models and advocating carbon capture, utilisation and storage as an important step towards successful decarbonisation of European industry. ArcelorMittal has collaborated with Northern Lights at three of their factories in Dunkirk, Ghent and Hamburg, respectively, as part of a Project of Common Interest (PCI).

*Ervia* is responsible for the Irish national gas and water infrastructure. Ervia aims to have a net zero emission gas network by 2050. CCS is a critical element to achieving this ambitious goal. Ervia is working on a feasibility study to assess

the role of CCS in decarbonising the gas network. This study will among other things look at the storage possibilities in the Irish Kinsale Head gas field and CO<sub>2</sub> exports to Norway and the Northern Lights project.

*Preem* is the biggest fuel company in Sweden. It is currently implementing a demonstration project at its refinery in Lysekil, using technology from Aker Carbon Capture. Part of the project is to implement a value chain analysis for the whole CCS value chain with transport to Northern Lights. The project has been awarded funding from Norwegian and Swedish authorities, with around NOK 10 million in funding from CLIMIT and around SEK 9 million from the Swedish Energy Agency.

*Stockholm Exergi* produces district heating for customers in the Stockholm area. The City of Stockholm owns 50 per cent and Fortum owns 50 per cent of the company. Stockholm Exergi, with funding from the Swedish energy authorities, has developed a test pilot and conducted a test campaign at Värtaverket in Stockholm. An industrial-scale facility at Värtaverket would be able to capture around 800,000 tonnes of CO<sub>2</sub> per year. Stockholm Exergi expects a facility to be ready for operation in 2025.<sup>2</sup>

The agreements with *HeidelbergCement* and *Fortum Oyj* were entered into on a group level. These two agreements therefore also state that the groups will further build on experience from developing the carbon capture projects at Norcem (Heidelberg) and Fortum Oslo Varme (50 per cent ownership by Fortum) to identify and develop more capture projects in their portfolios.

<sup>1</sup> <https://www.equinor.com/en/news/2019-09-cooperation-carbon-capture-storage.html>

<sup>2</sup> <https://www.stockholmexergi.se/nyheter/kvv6/>

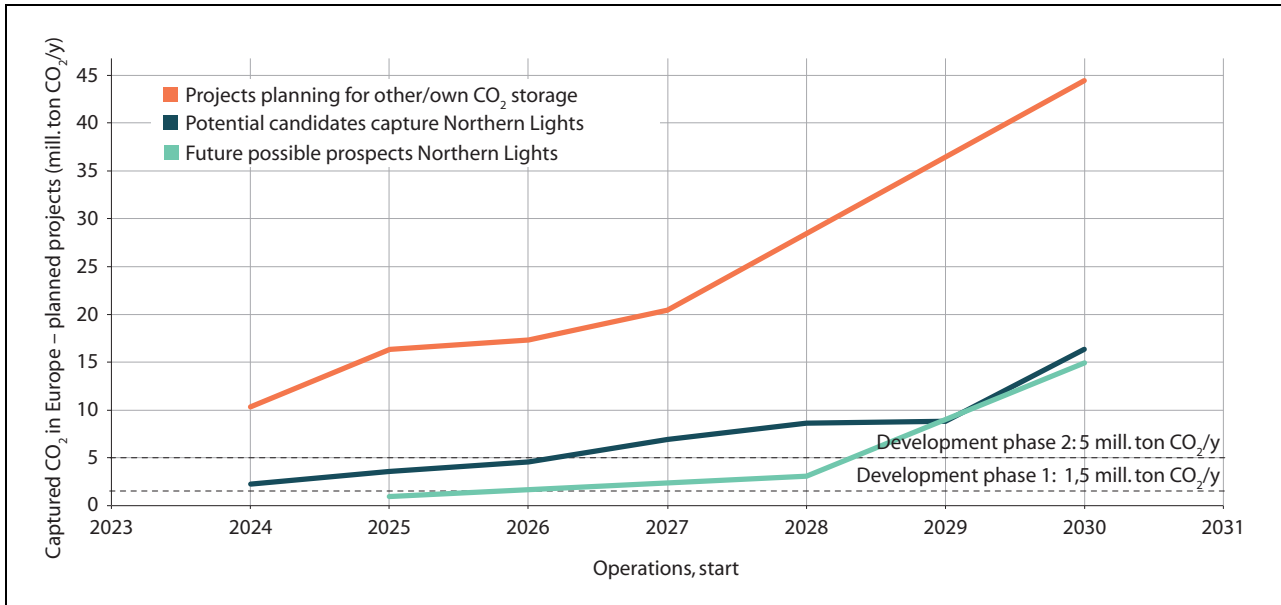


Figure 4.9 Market potential of Northern Lights’ transport and storage infrastructure leading up to 2030, according to Carbon Limits and Thema [25]

Source: Carbon Limits/Thema

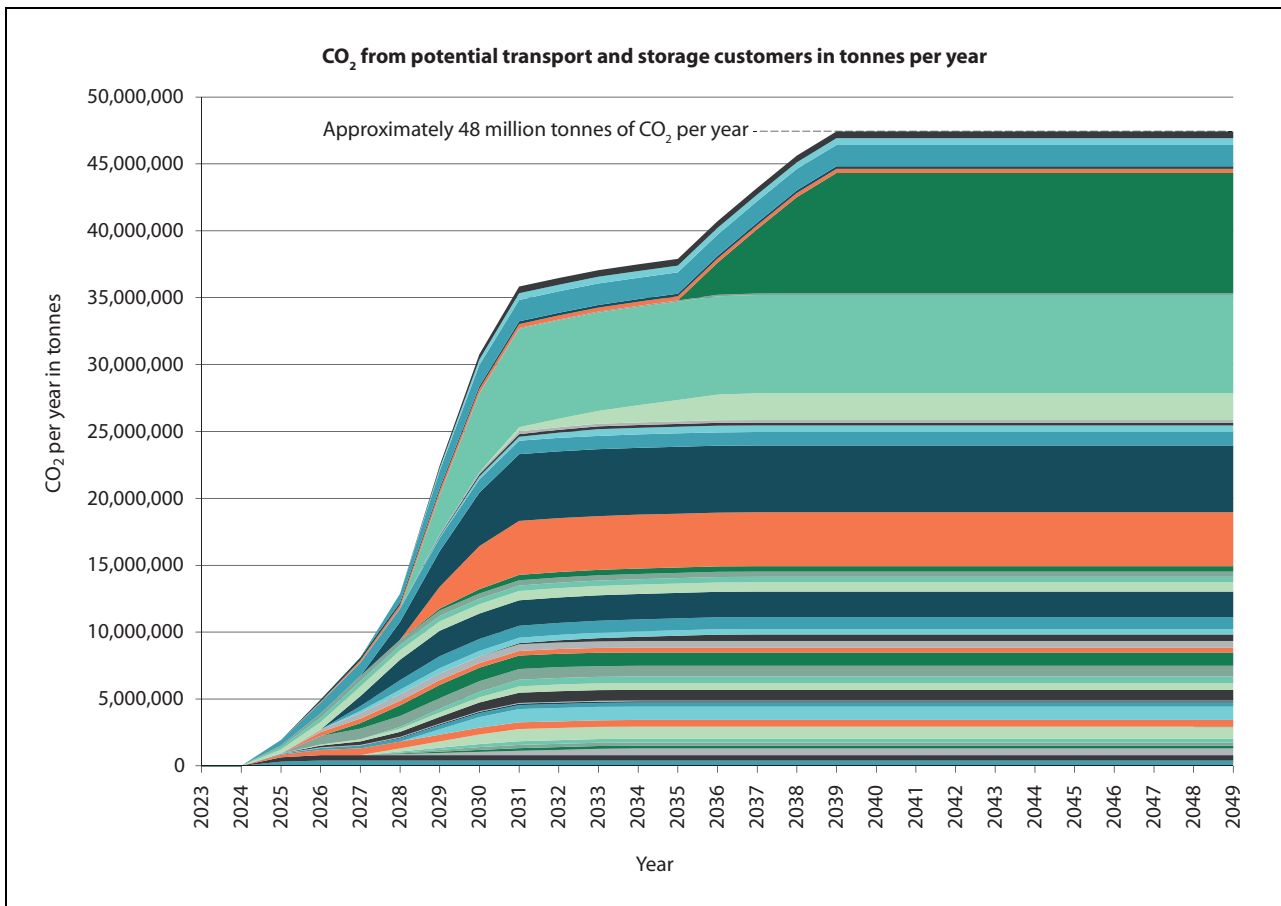


Figure 4.10 Market potential in Europe for the transport and storage infrastructure

Source: Northern Lights

#### 4.2.6 Frameworks for investment and operation

The Ministry has negotiated with the companies involved in Longship for several years on the distribution of costs and risk during the investment and operational phase. In these negotiations, the Ministry has placed emphasis on the companies having incentives to make good industrial decisions throughout the project, and that the risk in the project is to be distributed between the state and industry. The companies will bear some of the costs and risks associated with the project.

Notification of state aid for investment and operations as negotiated in the agreements with the actors and the framework for the project has been submitted to the EFTA Surveillance Authority (ESA). On 17 July 2020, ESA made a decision on the state aid arrangements for the project, which it found to be in accordance with the EEA Agreement and therefore had no objections [54]. In the event of changes to the negotiated arrangements, it may be necessary to obtain a new approval from ESA.

##### 4.2.6.1 Carbon capture

Negotiations with Norcem and Fortum Oslo Varme have taken place in parallel with the same draft contracts.

The most important instrument for cost and risk distribution is the model for investment funding and operational funding. The state has committed to covering all costs up to a threshold. Above this point of impact, the state will cover 75 per cent of the costs, while the companies will cover 25 per cent. This model was chosen, among other things, to give the companies good cost control incentives. The Ministry considers that 25 per cent of all costs above the threshold will provide sufficient incentives in the range where the company has the possibility to influence costs. A similar model was chosen for operating costs. The funding period is set to ten years from the start of operations. The threshold is part of the companies' tenders.

Norcem and Fortum Oslo Varme's direct profit from the project will come from savings on CO<sub>2</sub> emissions. The actors compete in sectors with relatively low margins. They are nonetheless willing to bear a share of the costs and risk, and their costs will increase if the project's overall costs increase more than anticipated.

To limit the state's responsibility, a maximum cost has been agreed. As part of the FEED phase, the companies developed a cost and uncertainty

analysis, which shows the probability distribution of estimated costs. The maximum cost is equivalent to an estimated 85 per cent probability of the costs remaining within that amount. It is also the level the state normally uses as the cost frame for state investment projects. Neither of the parties is obliged to implement the project if the maximum cost is reached, but if one of the parties chooses to complete or both parties agree to complete the project, the other party is obliged to perform their remaining rights and obligations under the contract.

Through the negotiations, additional funding was agreed for CO<sub>2</sub> that is not included in the EU ETS, whereby the funding recipient receives funding equal to the allowance price for each tonne of CO<sub>2</sub> captured. If the emissions are subject to a tax, the value of the carbon tax will be subtracted from the allowance price in the EU ETS, resulting in the additional funding amount being the difference between the carbon tax and allowance price. The additional funding also applies to CO<sub>2</sub> from biogenic sources.

Certain adjustments have been made to the agreement with Fortum Oslo Varme that reflect the conclusion on co-financing from other sources and how the risk is to be distributed given the Government funding. If the start-up of Fortum Oslo Varme is later than in 2024, this also entails a shorter funding period for operating costs.

##### 4.2.6.2 CO<sub>2</sub> storage

Negotiations on the framework for investment and operation of the CO<sub>2</sub> storage facility were carried out with Equinor, in cooperation with Shell and Total (Northern Lights).

A cost distribution was agreed for the project whereby the state covers 80 per cent of the investment costs and the companies cover 20 per cent. In the operational phase, the state will cover 95 per cent of the costs for the first year of operation, 90 per cent the second year, 85 per cent the third year and then 80 per cent from the fourth year of operation and the remainder of the funding period, which is ten years from the start-up of operations. If a second well and/or third ship is needed, the state will cover 50 per cent of these costs, with the maximum amount of funding limited to NOK 830 million. The state will also bear a share of the cost risk for unexpected incidents; see section 6.2.3.

In the same way as in the carbon capture agreements, a maximum cost has been included to prevent the state's obligation to cover costs

from exceeding the level corresponding to an 85 per cent probability of the costs remaining within that amount. Through the funding model, Northern Lights will cover a share of the operating costs and risk by storing CO<sub>2</sub> from Norcem and, potentially, Fortum Oslo Varme's facilities. Northern Lights has no revenues from storing CO<sub>2</sub> from the Norwegian project, which gives incentives to sell capacity to other carbon capture projects. The effect of this is evident, for example through the MoUs they have signed with seven European companies on the development of CCS value chains; see Box 4.1.

After a CO<sub>2</sub> storage facility has been discontinued, all obligations relating to monitoring and corrective measures will be transferred to the state in accordance with the Regulations relating to exploitation of subsea reservoirs on the continental shelf for storage of CO<sub>2</sub> and relating to transportation of CO<sub>2</sub> on the continental shelf (the transfer of responsibility and regulation is covered in more detail in section 4.3).

#### 4.2.7 Evaluation and ranking of Norcem and Fortum Oslo Varme

Since the feasibility study phase, the framework for developing carbon capture has been structured to resemble a tender process. This was done among other things in order to avoid allocating more state aid than necessary and to have a clear framework for assessing subsequent projects.

Gassnova announced a competition for concept selection and FEED studies in 2016 based on the societal and impact goals for the project. The tender documents set out delivery requirements and evaluation criteria. The competition and evaluation criteria were also considered by the ESA in connection with the notification of state aid for concept selection and FEED studies [46]. Norcem and Fortum Oslo Varme conducted feasibility studies, concept selection studies and FEED studies within the

framework of the competition. Both companies have also negotiated the investment and operation framework with the Ministry since 2017. The Ministry has assessed the projects on the basis of the FEED reports and the results of the negotiations. Gassnova and the Ministry together set out the following criteria for the competition:

1. Capture capacity, the facility's suitability
2. Submitted progress schedule
3. Ability to execute the project
4. The state's risks and costs
5. Contribution to technology development
6. Facilitation of knowledge transfer

Norcem and Fortum Oslo Varme's FEED reports submitted in October 2019 form the basis for the Ministry's and Gassnova's assessment and evaluation of the projects. In connection with the investment and operation framework negotiations, both actors submitted tenders for their own contribution to the project, based on a draft contract that is identical for both actors.

Gassnova has conducted an evaluation of Norcem and Fortum Oslo Varme's projects, comprising four parts:

1. Technical evaluation
2. Assessment of the quality of the actors' cost estimates
3. Evaluation of contribution to benefit realisation
4. Ranking

Gassnova's ranking was based on the technical evaluation. The quality of the cost estimate and the actors' contribution to benefit realisation were also taken into account in the final ranking. This means that of the six criteria established to assess the projects, Gassnova assessed the technical criteria 1–3 followed by an assessment of benefit realisation in accordance with criteria 5 and 6. Gassnova did not assess the actors under criteria 4 'the state's costs and risks'. Gassnova allocated points to the actors on a scale from 1 to 5, where 1 is 'unsatisfactory', 3 is 'as expected' and 5 is 'excellent'. Successful

Table 4.2 The results from Gassnova's technical evaluation [55]

Gassnova's technical evaluation at maturity level DG3					
Main criteria	Weighting	Fortum Oslo Varme		Norcem	
		Points	Weighted points	Points	Weighted points
Capture capacity, the facility's suitability	25 %	3	0.8	4	1
Submitted progress schedules	15 %	3	0.5	4	0.6
Ability to execute the project	60 %	3	1.8	4	2.4
Total score			3		4

implementation of the project is a prerequisite for expedient demonstration of CCS as a climate measure. Gassnova has therefore placed considerable weight on the industry actors' ability to execute the project in its evaluation. Table 4.2 summarises Gassnova's technical evaluation.

Gassnova's evaluation concludes that both Fortum Oslo Varme and Norcem's projects have good technical solutions and that the projects are sufficiently mature for implementation. The technical evaluations show that Norcem scored 4 'good' on all technical criteria. Fortum Oslo Varme scored 3 'as expected' on the technical evaluation. Gassnova also concluded in the assessment of the quality of the actors' cost estimates and the evaluation of their contribution to benefit realisation, that Norcem scored somewhat higher than Fortum Oslo Varme, but that both had delivered as expected or better.

Gassnova therefore ranks Norcem above Fortum Oslo Varme from an overall perspective. Gassnova recommends that both Fortum Oslo Varme and Norcem's projects can be continued as they are described in the FEED reports.

The Ministry drafted contracts based on negotiations with Norcem and Fortum Oslo Varme, which formed the basis for inviting the two actors to submit tenders for funding for construction and operation of carbon capture facilities. Norcem accepted the draft contract, while Fortum Oslo Varme's offer was conditional upon certain amendments to the contract wording. The proposed changes would have led to somewhat higher cost and interface risks for the state than originally envisaged in the Ministry's draft contract.

The Ministry's assessment is that the state's costs and risks are clearly lower for Norcem's project than Fortum Oslo Varme's project, and it therefore ranks Norcem above Fortum Oslo Varme on criteria 4 'the state's costs and risks'.

Atkins and Oslo Economics have quality assured the projects in accordance with the framework agreement under the KS quality assurance scheme, and the QA2 report [56] is based among other things on the companies' FEED reports and Gassnova's evaluations. Atkins and Oslo Economics have not therefore assessed the criteria for the competition for state aid, but have carried out assessments relevant to the Ministry's assessment. One of the main conclusions of the QA2 report was that it may be better to implement one carbon capture project rather than two, since this makes a greater storage volume available to other carbon capture projects, and because it reduces

the cost without necessarily lowering the learning effects significantly. QA2 states that Norcem's carbon capture facility is preferable to that of Fortum Oslo Varme, primarily due to lower life cycle costs.

Overall, the Ministry is of the opinion that both projects are possible to implement. The project can therefore be implemented with two carbon capture projects. At the same time, Norcem clearly ranks highest based on the criteria set for the competition.

### 4.3 Relevant regulations

Effective and comprehensive regulation of capture, transport and storage of CO<sub>2</sub> is an important prerequisite for the establishment of CCS projects. Clear regulations and frameworks must be in place for commercial companies to decide to invest in projects. This is also necessary to assure the authorities, industry and civil society that CCS takes place under proper, safe conditions.

There are several international and national laws and regulations that set out the framework for CCS in Norway. The most important of these are described below.

#### 4.3.1 International and regional frameworks

##### *The London Protocol*

In international environmental law, the Protocol of 7 November 1996 (the London Protocol) to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 29 December 1972, forms the basis for allowing CO<sub>2</sub> storage beneath the seabed.

In principle, the London Protocol prohibits the intentional dumping or storage of wastes or other matter at sea, on the seabed or in sub-seabed geological formations. An amendment was made to the protocol in 2006, which added storage of CO<sub>2</sub> in sub-seabed geological formations to the list of 'permitted dumping'. The amendment entered into force in 2007.

The London Protocol nonetheless contains a prohibition on export of all wastes and other matter to other states for dumping or incineration at sea. In 2009, the parties to the Protocol adopted an amendment that opens for export of CO<sub>2</sub> to other states for storage purposes on certain conditions. This amendment has not formally entered into force, since too few of the parties to the Protocol have ratified it.



Norway approved the amendment in 2010. The fact that the 2009 amendment has not formally entered into force is a legal obstacle to cross-border cooperation on CCS. Norway is working to encourage more countries to ratify the 2009 amendment so that it will enter into force for all parties to the London Protocol.

In 2019, the parties to the London Protocol supported a Norwegian–Dutch proposition to allow provisional application of this amendment<sup>10</sup> while awaiting ratification by two-thirds of the 53 parties. Countries that so wish can make arrangements for transport of CO<sub>2</sub> across national borders by submitting a declaration to the International Maritime Organization (IMO). In June 2020, Norway submitted a declaration of provisional application of the 2009 amendment. The declaration enables cross-border cooperation on capture and permanent geological storage of CO<sub>2</sub>.

According to the 2009 amendment, bilateral agreements between the countries cooperating on transport and storage of CO<sub>2</sub> are also required. Such agreements must confirm and make reference to obligations to provide individual permits for transport and storage of CO<sub>2</sub>. These obligations follow from the London Protocol and other applicable international law.

In order for Norway to be able to enter into cross-border cooperation on transport and storage of CO<sub>2</sub>, it is therefore necessary that the collaborating country declares formal provisional application of the 2009 amendment to the London Protocol to the IMO, and that Norway and the collaborating country enter into a bilateral agreement. Furthermore, it is an advantage if the collaborating country ratifies the 2009 amendment. The Ministry of Petroleum and Energy will follow this up according to regular procedures with the authorities of countries in which industry actors are interested in exporting CO<sub>2</sub> to Norway for storage on the Norwegian continental shelf.

#### *The Oslo-Paris Convention (OSPAR)*

The objective of the OSPAR Convention is to protect and conserve the marine environment. In 2007, the OSPAR Commission adopted amendments to the appendix to the OSPAR Convention to allow storage of CO<sub>2</sub> in geological formations beneath the seabed. In connection with the

amendments to the Convention, OSPAR has adopted a decision to ensure environmentally safe storage of CO<sub>2</sub> in geological formations and OSPAR Guidelines for Risk Assessment and Management of Storage of CO<sub>2</sub> Streams in Geological Formations.

The OSPAR Commission has also adopted a prohibition on storage of CO<sub>2</sub> in the water column at sea and on the seabed due to the potential negative environmental impacts of such activities.

#### *The UN Intergovernmental Panel on Climate Change's Guidelines*

Under the UN Framework Convention on Climate Change, Kyoto Protocol and the Paris Agreement, the UN Intergovernmental Panel on Climate Change's Guidelines apply to greenhouse gas emissions accounting.<sup>11</sup> In accordance with the guidelines, the amount of CO<sub>2</sub> emissions and injected CO<sub>2</sub> at each storage facility for permanent storage of CO<sub>2</sub> in geological formations is reported on an annual basis.

#### *The European Emissions Trading System*

Norway participates in the European Emissions Trading System (EU ETS) and is subject to Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading (the EU ETS Directive), which was incorporated in the EEA Agreement in 2007. The EU ETS Directive is implemented in Norwegian legislation through *Act No. 99 of 17 December 2004 relating to Greenhouse Gas Emission Allowance Trading and the Duty to Surrender Emission Allowances (the Greenhouse Gas Emission Trading Act)* and pertaining regulations (*the Greenhouse Gas Emission Trading Regulations*). Operators conducting activities that are incorporated in the EU ETS must annually surrender allowances corresponding to the total amount of emissions that are subject to the trading system.

Operators can subtract CO<sub>2</sub> that has been captured and stored from activities subject to the EU ETS from their emissions accounting. This means that they do not need to surrender allowances for this volume. Norcem will be an example of this when this project has been implemented.

Fortum Oslo Varme's activities are not subject to the EU ETS, but the Norwegian Tax Adminis-

<sup>10</sup> The Vienna Convention on the Law of Treaties allows for provisional application of parts of a treaty pending formal entry into force, if the negotiating states have in some other manner so agreed; see Article 25.

<sup>11</sup> 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

tration has conducted a public consultation on a proposal for a Storting resolution concerning a carbon tax on waste incineration. If the proposal is adopted, a carbon tax will be introduced on the part of the emissions produced by combustion of fossil sources. In such case, Fortum Oslo Varme will not have to pay the tax if its emissions are captured and stored.

The Norwegian project entails that captured CO<sub>2</sub> will be transported by ship to the storage actor's reception terminal. This has raised certain legal issues with regard to the EU ETS, since the EU ETS regulations explicitly regulate transport by pipelines, but make no mention of transport by ship.

In July 2020, the European Commission endorsed Norway's interpretation of the regulations, which entails that the capture facilities will be able to subtract CO<sub>2</sub> from their emissions accounting when CO<sub>2</sub> is transferred from the ship to the reception terminal. The capture operator may not subtract allowances for CO<sub>2</sub> that leaks during transport and must thus surrender allowances for these emissions. The financial loss that results from such leakages during transport can be regulated in private legal contracts between the operators. Each capture facility must have detailed and adapted monitoring plans developed in consultation with the Norwegian authorities that regulate leakage and emissions of CO<sub>2</sub> during transport.

CO<sub>2</sub> emissions from biomass (biogenic CO<sub>2</sub>) are not included in the EU ETS and such emissions are counted as zero in the emissions accounting. This also means that it is not possible to subtract biogenic CO<sub>2</sub> that is captured and stored in the emissions accounting. The EU ETS regulations thus do not provide any incentives to capture biogenic CO<sub>2</sub> or for what is known as negative emissions.

Capture and storage of CO<sub>2</sub> from biomass is included in most of the UN Intergovernmental Panel on Climate Change's emission pathways aimed at achieving the temperature goals set out in the Paris Agreement [3]. It is therefore a challenge that there are currently no incentives to capture biogenic CO<sub>2</sub>.

The European Commission will assess how incentives for bioenergy with carbon capture and storage can be developed in its ongoing work under the European Green Deal. The European Commission has initiated a process to assess potential incentives for nature-based solutions for CO<sub>2</sub> removal, including using CCS on emissions produced from biogenic sources.<sup>12</sup>

#### 4.3.2 National regulations

Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide (the Storage Directive) sets out the legislative framework for the environmentally safe storage of CO<sub>2</sub> within the EEA. The Directive aims to ensure that there is no significant risk of CO<sub>2</sub> leakage or harm to health or the environment, as well as to prevent negative effects on the safety of the transport network or CO<sub>2</sub> storage facilities. The Storage Directive stipulates requirements for, among other things, the establishment of a licensing scheme for exploration for storage locations, monitoring of stored CO<sub>2</sub>, financial security and third-party access to pipelines that transport CO<sub>2</sub> and to storage locations.

The Directive was incorporated in the EEA Agreement in 2012, and the Ministry of Petroleum and Energy, the Ministry of Labour and Social Affairs and the Ministry of Climate and Environment are responsible for different parts of the Directive in Norwegian legislation. The Directive was implemented through new regulations, *The Regulations relating to exploitation of subsea reservoirs on the continental shelf for storage of CO<sub>2</sub> and relating to transportation of CO<sub>2</sub> on the continental shelf (the CO<sub>2</sub> Storage Regulations)*, a new chapter in *Regulations No. 931 of 1 June 2004 on pollution control (the Pollution Control Regulations)*, and a new chapter in *Regulations No. 653 of 27 June 1997 relating to petroleum activities (the Petroleum Regulations)*. Together with *Regulations No. 186 of 25 February 2020 relating to safety and working environment for transport and injection of CO<sub>2</sub> on the continental shelf (the CO<sub>2</sub> Safety Regulations)*, these make up a comprehensive regulatory framework for transport and storage of CO<sub>2</sub> in Norway.

The CO<sub>2</sub> Storage Regulations include inter alia provisions concerning the conditions for the transfer of responsibility to the state (Section 5-8), financial security for obligations pursuant to the Regulations during the operational period and a subsequent period until the transfer of responsibility (Section 5-9), financial contribution to cover the state's costs for a period after the transfer of responsibility (Section 5-10), and third-party access to facilities for transport and storage of CO<sub>2</sub> (Section 5-12). Section 7A in Chapter 35 of the Pollution Control Regulations set out partially overlapping provisions.

<sup>12</sup> <https://etendering.ted.europa.eu/cft/cft-display.html?cftId=6709>

The Ministry's assessment of these matters for the project planned for implementation under Exploitation Licence 001 are detailed below. This does not entail a limitation of the Ministry's competence or stipulate guidelines for future administrative practice.

#### Transfer of responsibility to the state (Section 5-8)

Following closure of a storage site, all obligations concerning monitoring and corrective measures are transferred to the state in accordance with the CO<sub>2</sub> Storage Regulations. Section 5-8 of the CO<sub>2</sub> Storage Regulations sets out four conditions for transferring responsibility to the state.

The first condition is that all available information indicates that the stored CO<sub>2</sub> will remain completely and permanently contained. To fulfil this condition, the operator must e.g. be able to document that the actual behaviour of the injected CO<sub>2</sub> conforms with the modelled behaviour, that leakage cannot be proven, and that the storage site is evolving towards a condition of long-term stability.

The second condition is that a minimum period determined by the Ministry has elapsed. This minimum period shall be no shorter than 20 years, unless the Ministry, upon application from the operator before or at this time, is convinced that the requirement in the first condition is complied with before the expiry of this minimum period.

The third condition is that the financial obligations mentioned in Section 5-10, which are detailed below, have been fulfilled.

The fourth condition is that the storage site has been prudently abandoned and the injection facilities removed.

The state will not stipulate a longer minimum period than necessary to determine that the first and second conditions of the first paragraph in Section 5-8 are fulfilled. The state will not object to a transfer of responsibility if it is clear that the conditions set out in the first paragraph in Section 5-8 have been fulfilled.

More specific stipulation of the criteria for transferring responsibility and the length of the minimum period must take into account experiences from operation of the storage facility. This must take place through dialogue between the storage operator and the relevant authorities. Through this process, it will be possible to clarify the details concerning transfer of responsibility well before the closure of operations. It is natural to base this dialogue on experience from the

established monitoring plans developed by the operator in accordance with the requirements in Appendix II to the CO<sub>2</sub> Storage Regulations. The monitoring plan must be updated every five years and after closure of the storage site. When responsibility is transferred to the state, the operator must present an updated plan demonstrating the requirements set out in the CO<sub>2</sub> Storage Regulations.

If the operator believes that the conditions of the Regulations have been met, the operator can submit an application to transfer responsibility to the state. In the Ministry's assessment, the basis for such an application will generally be in place after the first five-year period. Pursuant to the CO<sub>2</sub> Storage Regulations, it is nonetheless not decisive how much time has passed, but that the conditions for the transfer of responsibility have been met.

Assessments made pursuant to Section 5-8 concerning the transfer of responsibility, length of the minimum period and any transfer of responsibility before this period has expired will be based on all information available at the time of assessment.

#### Financial security (Section 5-9)

Section 5-9 of the CO<sub>2</sub> Storage Regulations stipulates financial security requirements. In applications for permission for injection and storage of CO<sub>2</sub> pursuant to Chapter 35 of the Pollution Control Regulations, the operator shall document that appropriate dispositions can be made in the form of financial security or equivalent to ensure that all obligations arising from the Pollution Control Regulations can be fulfilled. The documentation is based on more specific provisions prescribed by the Norwegian Environment Agency. The financial security shall be valid and effective before injection starts. The Ministry of Climate and Environment and the Ministry of Petroleum and Energy will jointly assess the financial security.

Chapter 35 of the Pollution Control Regulations sets out partially overlapping provisions in Section 35-15, which also stipulates a financial security requirement to ensure that all obligations pursuant to Chapter 35 can be fulfilled, including those that follow from the provisions concerning procedures for closure of the storage site, operation after the storage site has been closed and any obligations that follow from *the Act relating to Greenhouse Gas Emission Allowance Trading and the Duty to Surrender Emission Allowances (the Greenhouse Gas Emission Trading Act)*. The finan-

cial security is periodically adjusted to take account of changes to the risk of leakage and the estimated costs. When a storage site has been closed after the conditions have been fulfilled or on application, the financial security shall remain valid and effective until the responsibility for the storage site has been transferred to the state in accordance with the Regulations. When a permit has been withdrawn, the financial security shall be valid and effective until a new permit has been issued or the storage site has been closed and the state's costs have been covered in accordance with the Regulations.

How the financial security is designed and what security mechanisms are accepted will depend on a specific assessment of e.g. what obligations are to be covered, what conditions apply to the product, how the state's right to coverage has been addressed, and the operator's financial soundness and liquidity. When delimiting the amount, an appropriate assessment will be made based on the size of the estimated costs that can be expected after a reasonable assessment in relation to e.g. monitoring programmes, any corrective measures, closure, post-closure operations, and the cost of allowances in the event of leakage. The size of the financial security will be assessed at regular intervals and adjusted to any changes in the assessed risk of leakage and estimated costs of all obligations. In the assessment of what is considered adequate coverage of allowance costs in the event of leakage, the state will consider what is deemed probable based on the knowledge available when the financial security is provided, with subsequent adjustments.

The scope of the financial security for this project must also take into account that through the funding agreement, the state is responsible for a significant share of the potential costs related to injection of 1.5 million tonnes of CO<sub>2</sub> each year and CO<sub>2</sub> emissions from the state-funded CO<sub>2</sub> capture project. There is a need for dialogue between Northern Lights and the authorities to determine the content and scope of the financial security.

#### Financial mechanism (Section 5-10)

Section 5-10 of the CO<sub>2</sub> Storage Regulations stipulates the requirement that the operator shall make a financial contribution available to the State, represented by the Ministry of Petroleum and Energy, as specifically decided by the Ministry before the transfer of responsibility takes place. The contribution shall take into account the crite-

ria mentioned in Appendix I to the CO<sub>2</sub> Storage Regulations, as well as elements that relate to the historical storage of CO<sub>2</sub> of relevance for the determination of obligations after the transfer. The financial contribution shall, as a minimum, cover anticipated monitoring costs for a period of 30 years. The contribution may be used to cover the state's costs after the transfer of responsibility to ensure that the CO<sub>2</sub> is safely stored after the transfer of responsibility.

The size of the financial contribution will in principle be determined on the basis of expected monitoring costs for a 30-year period, based on what is deemed to constitute a necessary monitoring programme following an appropriate technical assessment. Following a specific assessment in accordance with Section 5-10, other elements may also provide grounds for increased contributions. Monitoring requirements after the transfer of responsibility must be based on the knowledge available and risk assessment conducted when the transfer of responsibility is imminent, based in particular on the experience gained from the storage site's operating period. In principle, the financial contribution should not be greater than what is deemed necessary, following an appropriate assessment, to cover the expected costs for the state after the transfer of responsibility.

Costs will be related to identifying future risks at the time responsibility is transferred. The size of the financial contribution will be decided when responsibility is transferred, but must as a minimum cover the costs of data collection that can provide a good picture of the stored CO<sub>2</sub>. The data collection must be based on recognised methods and available technology at the time of application.

Dialogue between Northern Lights and the authorities on these matters will be necessary in the course of the operational period to ensure that, through this process, the details concerning the financial mechanism are clarified well before responsibility is transferred.

#### Third-party access to facilities for storage of CO<sub>2</sub> and storage sites (Section 5-12)

Section 5-12 of the CO<sub>2</sub> Storage Regulations stipulates that agreements on the use of facilities and storage sites that are covered by Section 4-5 concerning the Plan for development and operation of a subsea reservoir for injection and storage of CO<sub>2</sub>, or by *Act No. 72 of 29 November 1996 relating to petroleum activities* (the *Petroleum Act*) shall be submitted to the Ministry for approval. The Ministry may, in connection with approval of

agreements or if an agreement is not reached within a reasonable time, as well as in connection with instructions pursuant to the regulations, stipulate tariffs and other conditions or subsequently change the conditions that have been approved or set, in order to ensure that storage of CO<sub>2</sub> is implemented based on the consideration for resource management and that the owner of the facility is afforded a reasonable profit, e.g. based on investment and risk. Section 6-3 of the CO<sub>2</sub> Storage Regulations also states that the Ministry may impose conditions on a licence to install and to operate facilities and tariffs for use of the facility.

A condition for the project's success is that it contributes to the implementation of more CO<sub>2</sub> capture projects in Europe. Key policy instru-

ments to achieve this are to establish a storage facility with the capacity to receive volumes of CO<sub>2</sub> in addition to the agreed volumes from Norcem and potentially Fortum Oslo Varme, that the storage companies manage this capacity, and that the storage companies are able to earn a reasonable profit from storing volumes of CO<sub>2</sub> from Europe.

A prerequisite for the companies accepting a share of the costs is that they are given an opportunity to generate revenues from selling storage capacity, which affords a reasonable profit. If the real return for the transport and storage companies is higher than ten per cent during the funding period, the funding agreement entitles the state to part of the profit.

## 5 Gassnova and the external quality assurer's assessment

### 5.1 Gassnova's assessment

Gassnova's 2015 pre-feasibility study recommended that the demonstration project for full-scale carbon capture and storage (CCS) should be implemented in accordance with established industry practice.

Gassnova's overall tasks in the planning phase have been to ensure the development of a CCS value chain that satisfies the state's maturity requirements that apply at the end of the various project phases, and to contribute to providing the state with a sufficient basis on which to decide whether it will grant funding to the implementation of full-scale CCS. Gassnova has emphasised utilising the significant CCS expertise it has built over many years from previous CCS projects, as the administrator of the state's ownership in Technology Centre Mongstad and through the research and development programme CLIMIT. During the concept selection and FEED phase, Gassnova, following a mandate from the Ministry of Petroleum and Energy, evaluated and ranked the capture projects, ensured that the transport and storage project was carried out in line with the study agreement, coordinated the CCS chain, coordinated and carried out work related to benefit realisation, and conducted socioeconomic assessments of the project in cooperation with DNV GL.

#### 5.1.1 Gassnova's evaluation of the capture projects

Gassnova's evaluation concludes that the projects of both Fortum Oslo Varme and Norcem have good technical solutions and that they are sufficiently mature for implementation. Gassnova ranks Norcem in first place and Fortum Oslo Varme in second place. The evaluation of Fortum Oslo Varme and Norcem's capture projects was concluded in December 2019 and was based on the capture actors' FEED reports.

Gassnova has conducted a technical evaluation, an assessment of the quality of the actors' cost estimates, and an evaluation of their contributions to benefit realisation. Successful implemen-

tation of the project is a prerequisite for expedient demonstration of CCS as a climate measure, and Gassnova's evaluation has therefore placed emphasis on the industry actors' ability to execute the project. This includes an assessment of, among other things: Planned organisation and implementation of the project, the HSE and quality management systems, risk management, and elements that affect how easy it is to plan the construction phase and construct the project. Gassnova has also conducted an assessment of the design of the carbon capture facility, documentation of the selected technology's maturity and the progress schedules submitted.

Based on the actors' FEED reports, Gassnova's assessment is that Norcem will be in the best position to implement a carbon capture project. Norcem is considered to have a more thorough implementation plan than Fortum Oslo Varme and has come further in its preparations for relevant approvals from the respective authorities. Norcem also provided a better description of its methods for construction and installation of the carbon capture facility and has better documentation that the technical elements of the project work well at their facility.

With a few exceptions, both Norcem and Fortum Oslo Varme have matured the basis for their basic cost estimates to the right level for an investment decision. This is due to the long time interval from the FEED was completed until the investment decision, and that funding agreement negotiations with the state had not been concluded at the end of the FEED phase.

Based on Norcem and Fortum Oslo Varme's equipment lists and stated quantities of pipes and steel, a cost analysis was performed by comparing these with other industry projects. The main conclusion from this analysis is that the estimates appear to be at the right level for Norcem, while Fortum Oslo Varme's estimate is somewhat high.

Both actors have done a good job when it comes to their contribution to benefit realisation. Demonstrating that carbon capture is feasible within a cost level that is considered acceptable is an important contribution to benefit realisation.

This means that if the cost becomes too high, the value of the CCS demonstration will be lower, or potentially negative. The cost of the measure is higher for Fortum Oslo Varme than Norcem, and therefore, seen in isolation, implementing Fortum Oslo Varme's project will have a lower demonstration value than implementation of Norcem's project.

However, Fortum Oslo Varme has identified more potential subsequent projects than Norcem, has received a very high number of visitors to its facility and actively shares knowledge. Gassnova considers these to be positive factors.

Both Fortum Oslo Varme and Norcem have continued their work on selected activities after the concluded FEED study.

Fortum Oslo Varme has also adjusted the layout of the capture facility in order to facilitate the establishment of a new potential incineration line in the energy recovery facility. This has led to a reduction in the estimated costs of Fortum Oslo Varme's project. Gassnova has evaluated this information and believes that the changes are not of such a nature to influence the conclusion of the evaluation.

Both actors have identified their biggest risks in connection with construction and operation of their facilities. Risks to indicate that it would not be possible to implement the CCS chain did not emerge during this process.

### 5.1.2 Gassnova's assessment of the CO<sub>2</sub> transport and storage project

In Gassnova's assessment, the CO<sub>2</sub> transport and storage project has been sufficiently studied to enter the implementation phase. Gassnova regards the overall CO<sub>2</sub> transport and storage system developed by Northern Lights as suitable to manage CO<sub>2</sub> from Norcem and Fortum Oslo Varme, as well as being capable of receiving CO<sub>2</sub> from other actors. The basis for the basic cost estimates for the CO<sub>2</sub> transport and storage project has matured to the right level for an investment decision to be made.

It has been verified that the Aurora area is highly suitable for CO<sub>2</sub> storage. This has been verified by inter alia drilling a combined verification and injection well, and developing a good plan for monitoring the storage facility. Overall, Gassnova considers that these activities have reduced the technical risk of the CO<sub>2</sub> transport and storage project to an acceptable level.

Northern Lights has developed a ship design for CO<sub>2</sub> transport that enables safe and efficient transport of CO<sub>2</sub> from the capture facility to the

interim storage in Øygarden. Thorough efforts have also been made to select the location for the onshore facility and pipeline route. The fact that Northern Lights has chosen to reuse the oil and gas infrastructure at the Oseberg A platform for managing and monitoring the well has reduced the cost estimate for the project.

Northern Lights has performed thorough work on benefit realisation. It has worked systematically to identify subsequent projects and on sharing knowledge and technology development. Gassnova's assessment emphasises that several elements of the CO<sub>2</sub> transport and storage project facilitate further technology development in the field of CO<sub>2</sub> transport and storage. Examples include the development of cost-effective installations on the seabed, and bigger ships for more efficient transport of liquefied CO<sub>2</sub> over longer distances.

### 5.1.3 Gassnova's overall assessment

In Gassnova's opinion, the state can achieve CCS demonstration by realising a CCS chain with Norcem's and/or Fortum Oslo Varme's project. Both capture projects have been studied to a level that is sufficient to enter an implementation phase for industrial projects. Gassnova has also assessed Northern Lights' CO<sub>2</sub> transport and storage project and concludes that it is complete, of high quality and studied to the right level for implementation.

Both the UN Intergovernmental Panel on Climate Change and the IEA indicate that CCS must become a technology that can be quickly and widely deployed in order to reach international climate ambitions. Early demonstration projects will generate learning and experience that can reduce barriers and lead to cost reductions for subsequent projects. Developing a CCS project takes a long time, particularly the identification and qualification of a suitable and safe CO<sub>2</sub> storage location. Gassnova believes that Norway has a good possibility of realising a good demonstration project, and that this will have an impact on future technology development internationally.

The work on identifying subsequent projects and sharing experience and knowledge with relevant actors, particularly internationally, has been carried out expediently by all of the actors involved in the project. The Northern Lights project has additional capacity in its transport and storage infrastructure, which makes it possible to recruit new carbon capture projects. Northern Lights has made systematic efforts to this end.



In Gassnova's assessment, a good foundation has been established for subsequent projects that wish to utilise the transport and storage infrastructure. It will probably be necessary for the projects, during a transitional period, to utilise new EU funding schemes, as well as those of certain nation states. Gassnova believes that utilisation of the infrastructure is the most important contribution to reducing future CCS costs.

In cooperation with DNV GL, Gassnova has updated the socioeconomic analysis that Atkins and Oslo Economics carried out as part of the state's quality assurance process in 2016 (QA1).

The updated analysis shows that CO<sub>2</sub> reductions in sectors not included in the European Emissions Trading System (EU ETS) may be of more value to Norway than CO<sub>2</sub> reductions in sectors included in the EU ETS, since Norway has separate domestic targets for this sector. From a global perspective, however, every tonne of CO<sub>2</sub> emissions prevented has the same value, regardless of the origin of the stored CO<sub>2</sub>.

The updated socioeconomic analysis concludes that a CCS value chain with both one and two capture projects can be economically profitable, but that the profitability of the project will depend on whether future international climate policy is pursued in line with the adopted targets. In a situation where international climate policy is moving in the direction of the goals in the Paris Agreement, the analysis shows that implementation of Norcem's project will generate greater socioeconomic value than implementation of Fortum Oslo Varme's project, mainly due to the differences in the project costs.

## 5.2 The external quality assurers' assessment

The project has been quality assured in accordance with the state's project model. Atkins and Oslo Economics carried out the quality assurance process. Quality assurance of the concept selection study was completed in 2016 (QA1). Quality assurance of the specific projects (QA2) was carried out in two parts to adapt to the industry projects' progress schedules. QA2 Part 1 was submitted in 2018, and QA2 Part 2 was submitted in summer 2020.

In the QA2 report [56], Atkins and Oslo Economics highlight that the measure has matured through the FEED phase and appears to be adequately documented and feasible to implement, but with some uncertainty remaining in a number

of processes. In the quality assurers' opinion, systematic work has been conducted on all of these remaining processes.

The quality assurers consider the costs to be high. The overall expected investments for the project (P50) will be somewhere between NOK 12.9 and 17.1 billion, depending on whether it is decided to invest in one or two capture facilities. Corresponding annual operating costs are expected on average to be between NOK 570 and 800 million during the ten-year funding period (P50). The overall cost estimate for investment and operation is between NOK 18.7 and 25.1 billion (P50). The external quality assurers estimate the state's costs, including ten years of operation, to be between NOK 14.4 and 21.1<sup>1</sup> billion (P50) depending on how many and which capture projects are implemented.

The quality assurers state that the project may be beneficial from a socioeconomic perspective, given an ambitious climate policy in line with the global temperature goals in the Paris Agreement. The external quality assurers have not performed an independent socioeconomic analysis in connection with QA2, but base their assessment on Gassnova's analyses and reviewed methods and assumptions. The quality assurers believe the most important factor of whether subsequent CCS facilities are developed to be the cost of CO<sub>2</sub> emissions in relation to the cost of CCS.

There is great uncertainty about the benefits and the measure may therefore turn out to be very unprofitable. Third-party funding is necessary for the implementation of subsequent facilities. According to the quality assurers, it may be better to implement one capture project rather than two, since a greater volume of storage is then available to other capture projects, and because it reduces the cost without necessarily lowering the learning effects to any degree.

On the basis of the quality assurers' assessment, Norcem's capture facility would appear to be preferable to that of Fortum Oslo Varme, primarily due to it having lower lifetime costs. The quality assurers highlight in particular the importance of the transport and storage project's role in the work on benefit realisation and creating a market for CCS in Europe.

In general, the quality assurers also believe the management and organisation plans to be

<sup>1</sup> The figures cover any additional funding for carbon capture in sectors not included in the European Emissions Trading System. The figures have been updated after the QA2 report was published on 24 June 2020.

expedient, although somewhat immature on the part of the state. The actors have extensive experience with major investment projects. The project may be challenging to manage, particularly if changes are required. The funding agreements

with the industry actors appear to be well drafted and mechanisms to address expedient establishment and operation of the project have been established.

## 6 Benefits and costs of Longship

### 6.1 Benefits

Longship's goal is to contribute to Norway and Europe achieving their long-term climate targets at the lowest possible cost. The purpose of the benefit realisation work is to enable the project to generate the greatest possible benefits. Section 3 described market failure for the development of carbon capture and storage (CCS) and showed the potential cost reductions that would follow from more CCS projects being developed. This section deals with how Longship will address market failure and contribute to enabling cost reductions for subsequent projects.

The potential benefits of Longship can be divided into two main categories: 1) Climate effects and 2) Business development. These categories can also be seen in the impact goals, where climate effects correspond to impact goals 1–3 and business development corresponds to impact goal 4.

The extent of these benefits will depend, among other things, on future European climate policy and whether the emission reduction targets are followed up with policy instruments and measures. The business development effects are thus dependent on the climate effect being recognised and in demand. At the same time, successful demonstration of a full value chain for carbon capture, transport and storage will demonstrate a realistic solution for reducing emissions from important industries that have no alternatives to CCS. Longship will therefore make it easier to follow up the political ambitions for emission reductions with concrete measures, and therefore contribute to achieving Europe's climate targets.

#### 6.1.1 Climate effects

The climate effects of Longship come both directly in the form of emission reductions in Norway and indirectly through cost reductions generated by demonstration and development of CCS, and the development of infrastructure for subsequent projects; see section 3 on market failure.

The direct national emission reductions from the project will initially be around 400,000 tonnes of CO<sub>2</sub> per year when Norcem's capture project becomes operational, and will increase to around 800,000 tonnes of CO<sub>2</sub> if Fortum Oslo Varme's project is implemented as well. Of these, around 200,000 tonnes of CO<sub>2</sub> from Fortum Oslo Varme can be counted under Norway's obligations to the EU on reductions in sectors not included in the European Emissions Trading System (EU ETS). Norcem's cement factory falls under a sector that is subject to the EU ETS and its emission reductions under the system will in time be countered by increased emissions in other areas within the maximum emissions stipulated by the EU ETS.

Indirectly, the project will generate climate effects by demonstrating a full and flexible CCS value chain, and the establishment of CO<sub>2</sub> transport and storage infrastructure will contribute to reducing costs for subsequent projects [41]. This is illustrated in Figure 3.1. Longship contributes to reducing costs in several ways.

Firstly, learning and technology development from the project at Norcem and, if applicable, Fortum Oslo Varme, will contribute to reducing costs and risk for subsequent projects. DNV GL's report on expected CCS cost reductions estimates reductions of around 10 per cent for each cumulative doubling of the CO<sub>2</sub> volume captured [41]. Establishing carbon capture will contribute to this process. The cost reduction potential from the first projects is also greater than is the case when more projects have been developed. As such, the first projects contribute a relatively greater share of the cost reductions [25].

Secondly, establishing CO<sub>2</sub> transport and storage infrastructure will also contribute to reducing costs. Establishing CCS infrastructure will also assure actors with industry emissions considering carbon capture that they can actually store CO<sub>2</sub>. It is therefore necessary to establish infrastructure in order to establish a market for CCS. A number of actors planning carbon capture in Europe are considering storing CO<sub>2</sub> in a Norwegian storage facility. Proximity to the CO<sub>2</sub> storage facility and the flexible transport solutions that sea transport

provides, make Northern Lights' infrastructure attractive for a number of emission sources around the North Sea. The infrastructure Northern Lights establishes has the potential to trigger carbon capture projects both in Norway and the rest of Europe.

Thirdly, establishing a carbon capture facility at Norcem with transport and storage provided by Northern Lights will also demonstrate a full value chain. A successful project will reduce the risk for subsequent projects, both because they will see that the solutions actually work and because specifications and procedures have already been developed. A failed project with high costs can have a negative effect since it may scare off future projects.

These effects enable industry to direct their efforts towards developing carbon capture, and more testing and utilisation of technology will result in a faster innovation cycle. More users can shorten the innovation process for new technologies, and new technologies can lower the threshold for using carbon capture technologies. The road towards achieving a critical mass of carbon capture projects that can create a cycle of technology development and use is long, but can be shortened by establishing a full carbon capture, transport and storage value chain.

International cooperation is imperative to solving global climate challenges and the Norwegian Government wants Norway to be a driver in international climate work.

Establishing a full carbon capture, transport and storage value chain will also demonstrate that CCS is an available climate measure, and will lower the threshold for the realisation of new carbon capture projects that can connect to Northern Lights. This will make it easier to follow up policy measures and instruments because the solutions have been implemented and are available. As such, it could be argued that the project also has a vital political demonstration effect.

Based on DNV GL's analysis and the IEA's expected CO<sub>2</sub> price for the power and industry sectors in advanced economies in 2030 and 2040, CCS may be profitable from a business economics perspective between 2030 and 2040, depending among other things on how many carbon capture facilities have been established [41].

Investment in hydrogen is a key element of achieving the targets of the European Green Deal for a climate neutral Europe. Hydrogen can contribute to lower emissions from industry, transport, power production and buildings across Europe.

The European Commission launched a new hydrogen strategy on 8 July 2020 [57]. The strategy sets out how the EU can implement this potential through investments, regulation, market development, research and innovation. In the strategy, the EU prioritises hydrogen produced from renewable power, but in the short and medium term, there will be a need for large quantities of hydrogen from other sources.

Around 90 per cent of all hydrogen currently produced in Europe comes from reformation of natural gas without CCS. For the sake of comparison, only 4 per cent of hydrogen is produced from electrolysis of water, and only parts of this electrolysis is based on clean renewable energy.

Establishing CO<sub>2</sub> storage infrastructure will make it possible to produce hydrogen with almost no emissions in Europe, produced from natural gas with CCS. Access to storage infrastructure has the potential to accelerate European hydrogen initiatives and reduce high CO<sub>2</sub> emissions from existing and future hydrogen production. Gas produced efficiently with low emissions on the Norwegian continental shelf could contribute to covering the need for gas to produce low-emission hydrogen in Europe.

The Government presented its hydrogen strategy on 3 June 2020. The strategy, which is the first of its kind in Norway, sets out the basis for further work on hydrogen. Longship makes it possible to produce hydrogen from natural gas with low overall emissions. Longship is thus an important contribution to the success of the EU's ambitious hydrogen strategy. The Government will follow-up the hydrogen strategy and Longship with a dedicated roadmap for hydrogen.

### 6.1.2 Business development

In addition to the climate effects described above, Longship may also have a positive effect on business development in Norway [9]. How such effects increase value creation in Norway is difficult to measure and will depend, among other things, on whether the world and Europe implement policies and measures in line with the global climate goals of the Paris Agreement. Longship aims to contribute to developing a measure that is necessary to achieve the global climate targets at the lowest possible costs.

It will be extremely challenging for the EU to achieve its long-term target of climate neutrality by 2050 without CCS being adopted in many areas. CCS must also contribute to large-scale negative emissions [17, 18].

**Box 6.1 CCS and Norwegian industry**

A number of actors have assessed the role of CCS in relation to Norwegian industry and jobs.

In connection with the work of the Expert Committee on Green Competitiveness, the Norwegian processing industry drew up a roadmap for 2050, where value creation in the industry increased at the same time as the industry could contribute to negative CO<sub>2</sub> emissions by 2050 [14]. According to the roadmap, for Norwegian industry to achieve its long-term national climate targets, as much as 33 per cent of planned emission reductions would come from CCS and around 20 per cent from CCS combined with combustion of biogenic matter.

In 2018, SINTEF, on assignment for the Confederation of Norwegian Enterprise (NHO), the

Confederation of Norwegian Trade Unions (LO), Fellesforbundet, the Federation of Norwegian Industries, the Norwegian Oil and Gas Association and Industri Energi, prepared the report 'Industrial opportunities and employment prospects in large-scale CO<sub>2</sub> management in Norway' [58]. The report summary focuses on the most optimistic picture for the scope of CCS and Norwegian opportunities relating thereto. The report also shows that even low estimates for development of CSS can create jobs in Norway. The number of jobs varies from a few thousand to many tens of thousands, depending on the extent of CCS implemented in Europe and the share of the market taken by Norwegian industry.

Norway is the only country in Europe that currently stores CO<sub>2</sub>. We have developed great expertise, and Equinor is at the international forefront of offshore CO<sub>2</sub> storage. Other European countries considering or planning CO<sub>2</sub> storage are the Netherlands, the UK, Ireland and Denmark. This will generate demand for knowledge and experience of CCS that can lead to positive effects in Norway in three areas: 1) Transition of Norwegian industry to a low-emission society; 2) Business development that is dependent on access to CO<sub>2</sub> storage and further development of the petroleum and energy supply and service industries; and 3) State revenues from CCS-related activities.

As described in section 2, some industries, such as cement and waste management, are unlikely to find alternatives to CCS that can substantially reduce their CO<sub>2</sub> emissions. For other sectors, CCS can be a competitive alternative to other climate measures.

CCS can contribute to maintaining industry jobs that would otherwise be at risk in the transition to a low-emission society. These jobs are distributed across the country, because the processing industry and other activities that generate CO<sub>2</sub> emissions are spread all over Norway. The industry cluster around Mo Industripark in Norland (including Alcoa Mosjøen, Elkem Rana and Elkem Salten), the Eyde cluster and several activities in the Øra area of Fredrikstad (including Borregaard in Sarpsborg and Saugbrugs in Halden)

are examples of enterprises considering the development of carbon capture at their facilities and utilising Northern Lights' transport and storage infrastructure.<sup>1</sup> Returkraft in Kristiansand, together with Northern Lights and others, have applied for EU funding for studies on CO<sub>2</sub> transport for storage in a potential Norwegian storage facility.

Development and operation of carbon capture and storage facilities will facilitate jobs and business development in Norway. The project is expected to employ around 1,500–3,000 full-time equivalents during the construction phase, and create around 170 jobs during the operational phase. Norway has developed a knowledge community and a supply industry with a high level of expertise in carbon capture, transport and storage over the course of more than 25 years. This has been based on a long-term focus on research, new technology and business development. In a future global CCS market, the Norwegian supply industry will be a strong contender to win contracts and take international market shares. This effect will be enhanced by having a head start. Participation in European projects will generate assignments for the Norwegian supply industry, strengthen Norway's competence base, and further develop Norwegian business and industry in the field.

<sup>1</sup> <https://www.mip.no/2018/lanserer-co2-hub-nordland-og-far-millionstotte-til-co2-fangst-og-lagring/>

### Box 6.2 Aker Carbon Capture

Aker Carbon Capture is an example of a supplier that has utilised Norwegian policy instruments to develop carbon capture technology. In 2008, Aker Solutions together with SINTEF started planning a research programme, 'SOLVIt', to develop an environmentally-friendly capture technology with low energy requirements. The programme was funded by CLIMIT and lasted for eight years. While the SOLVIt programme was ongoing, they started construction of a mobile test facility and were awarded a contract to construct an amine capture facility at Technology Centre Mongstad (TCM). Here, Aker tested several different amine compounds on an industrial scale for two years. Aker Solutions' mobile test facility has been used in several places in Europe and the USA, and tested carbon capture from different emission sources. The facility is

currently in Sweden to test Aker's technology at PREEM's refinery in Lysekil.<sup>1</sup>

Aker Solutions has also developed a modular and standardised capture facility called 'Just Catch'. In 2019, Aker Solutions won a contract for carbon capture at a waste incineration facility in Twence in the Netherlands.<sup>2</sup> In the summer of 2020, Aker Solutions decided to spin off its CCS activity to a new company, Aker Carbon Capture. Aker Carbon Capture was listed on the Merkur Market operated by the Oslo Stock Exchange on 26 August 2020.

<sup>1</sup> <https://www.akersolutions.com/news/news-archive/2020/aker-solutions-starts-ccs-test-program-at-preem-refinery-in-sweden/>

<sup>2</sup> <https://www.twence.nl/en/twence/news/2019/aker.html>

In its work on attracting third-party customers to the CO<sub>2</sub> storage facility, Northern Lights has been in contact with actors that are considering moving to or starting new business activities in Norway as a result of access to CO<sub>2</sub> transport and storage infrastructure. Dialogue is at an early stage and factors other than access to CO<sub>2</sub> storage are decisive for the localisation of industry.

Examples of such industrial actors are CCB and ZEG Power, which have received funding from Enova to establish an industrial pilot facility for hydrogen production with CCS. The facility will be established near Northern Lights' onshore facility.<sup>2</sup>

The project facilitates infrastructure development that can lead to substantial CO<sub>2</sub> storage capacity in Norway. Sections 4 and 8 outline how CO<sub>2</sub> transport and storage infrastructure will be developed in phases to enable the capacity to be increased. Northern Lights' assessment of market potential is also outlined.

Assuming more projects follow suit, Longship and our investment in CCS over a long period of time will give Norway an advantage through its

expertise, established infrastructure and the fact that Norwegian authorities and companies are in key positions in relevant international networks.

The state does not intend to be co-owner of the CO<sub>2</sub> storage facility in development phases 1 and 2. The state's role is primarily to provide financial support and share the risk as set out in the agreement. The state does not have costs related to development phase 2, nor does it receive any direct income from CO<sub>2</sub> storage during these phases. If Northern Lights' real return on invested capital exceeds 10 per cent, then part of the profit during the funding period including part of any profit from development phase 2, will accrue to the state.

If the capacity for the annual amount of CO<sub>2</sub> stored is expanded after development phase 1 and 2, the established infrastructure will have to be further developed and further investment made in new infrastructure (development phase 3). The state may decide to initiate negotiations on ownership of the established infrastructure. In the event of high demand, new storage licenses will be required pursuant to the CO<sub>2</sub> Storage Regulations. In accordance with the CO<sub>2</sub> Storage Regulations, the state is entitled to enter into the partnership if new licenses are granted.

<sup>2</sup> <https://www.vnr.no/far-stotte-til-pilotanlegg-for-hydrogenproduksjon/>

## 6.2 The state's costs and risks

### 6.2.1 Cost overview

The state covers a large share of the actual costs of the project. The cost and risk distribution in the negotiated agreements entail a percentage distribution of actual costs. The cost overview in this section is therefore an estimate based on the front-end engineering design (FEED) reports and agreements. The state's actual costs will depend on the actual costs of the project and will therefore increase if project costs increase, up to the agreed maximum limit. See section 4.2.6 for details about the funding agreements.

In Proposition No 1 to the Storting (2020–2021), the Ministry of Petroleum and Energy will propose to the Storting that the project be implemented with Norcem as the first carbon capture project followed by Fortum Oslo Varme's carbon capture project, conditional on sufficient own funding and funding from the EU or other sources. Fortum Oslo Varme must clarify whether it wishes to implement the project on these conditions within three months of the funding decision from the second round of calls issued by the EU's Innovation Fund, but no later than 31 December 2024. State aid awarded to Fortum Oslo Varme is limited to a maximum of NOK 2 billion in investments and NOK 1 billion in operating costs. This proposal will have overall expected costs for the state of NOK 16.8 billion and a Parliament's cost frame for investment support of NOK 13.1 billion and operating support of NOK 6.1 billion.

The figures do not include potential additional funding during the operational phases from 2024 for compensation for captured CO<sub>2</sub> that is not

included in the EU ETS. Carbon capture from non-fossil sources will not reduce costs or provide income for Norcem or Fortum Oslo Varme. The funding agreement therefore facilitates additional funding for capture of CO<sub>2</sub> equal to the allowance price in the EU ETS per tonne of captured CO<sub>2</sub> that is not included in the trading system.

The Norwegian Tax Administration has distributed a proposal for consultation concerning the introduction of a carbon tax on waste incineration. A tax will reduce the amount of additional funding. If a carbon tax is introduced on waste incineration, around half of the Fortum Oslo Varme facility's emissions (those from fossil sources) will be subject to the tax. If the tax is introduced, carbon capture will reduce costs for Fortum Oslo Varme in that it will have to pay less tax. If the tax is lower than the allowance price, Fortum Oslo Varme will receive the difference between the tax and allowance price, while if the tax is higher than the allowance price, the difference will be deducted from the additional funding for CO<sub>2</sub> from biogenic sources.

Around 12 per cent of Norcem's emissions are not subject to the EU ETS because they come from biogenic sources and will therefore form the basis for additional funding.

If the state realised both Norcem and Fortum Oslo Varme without EU funding, the expected costs for the state would be around NOK 20 billion (P50<sup>3</sup>). This includes the state's share of investment costs and share of the ten-year operating costs. The difference in costs between Norcem and Fortum Oslo Varme is around NOK 2 billion.

<sup>3</sup> P50 is the estimated cost level for which there is an estimated probability of 50 per cent of not exceeding.

Table 6.1 Estimated expected costs and Parliament's cost frame for Northern Lights, Norcem and Fortum Oslo Varme

Bill, 2021 NOK with exchange rates at 2 June 2020	Expected costs (P50)		Parliament's cost frame (P85)	
	Total QA2 <sup>1</sup>	Industry/ other sources	State aid	State aid
Northern Lights	14.2	3.8	10.4	
Norcem	4.5	0.7	3.8	
Fortum Oslo Varme	6.4	3.8 <sup>2</sup>	2.6 <sup>3</sup>	
Total	25.1	8.3	16.8	Investments: 13.1 Operation: 6.1

<sup>1</sup> Construction and ten years' operation.

<sup>2</sup> Based on the external quality assurers' estimate excluding the Government's recommendation

<sup>3</sup> Based on the external quality assurers' estimate excluding the Government's recommendation



Table 6.2 External quality assurers' cost estimate

Overall costs and industry's share at P50:				
Mill. 2021 NOK with exchange rates at 2 June 2020	Expected costs (P50)			Industry's share in pct.
	Total	Industry	State aid	
1. Norcem, transport and storage	18,700	4,500	14,200	24 pct.
2. Fortum OV, transport and storage	20,700	4,500	16,200	22 pct.
3. Two capture facilities, transport and storage	25,100	5,100	20,000	20 pct.

Overall costs and industry's share at P85:				
Mill. 2021 NOK with exchange rates at 2 June 2020	Parliament's cost frame (P85)			Industry's share in pct.
	Total	Industry	State aid	
1. Norcem, transport and storage	20,700	5,000	15,700	24 pct.
2. Fortum OV, transport and storage	22,800	5,000	17,800	22 pct.
3. Two capture facilities, transport and storage	27,600	5,800	21,800	21 pct.

In the agreement with Equinor on behalf of Northern Lights, the state commits to provide funding for cessation, monitoring and removal of up to 80 per cent of the costs of the proportional share of captured CO<sub>2</sub> from the demonstration facility for full-scale CCS in Norway after ten years of operation. Monitoring costs are not included in the cost estimates. If the transport and storage operator does not manage to obtain third-party customers and the storage facility is therefore shut down without storing CO<sub>2</sub> from sources other than Fortum Oslo Varme and Norcem, the state is obliged to cover 80 per cent of the costs related to cessation, monitoring and removal.

If the transport and storage operator is able to attract customers and continue commercial operation beyond the ten-year funding period, the proportional share of the stored CO<sub>2</sub> from Norcem and, if applicable, Fortum Oslo Varme will gradually be reduced. The state's share of the costs related to cessation, monitoring and removal will in such case be reduced and may reach zero if Northern Lights achieves a certain minimum return during the course of operations.

### 6.2.2 Funding from other sources

In addition to the share covered by industry companies in the negotiated agreements, the Ministry has looked into other co-funding possibilities for the project. The project will contribute to enabling

industry and actors in the EU to reduce their emissions at a lower cost. Particular efforts have therefore been made to secure co-funding from the EU.

The biggest potential source of EU funding is the Innovation Fund. This fund is financed by the sale of allowances from the EU ETS. The fund can grant funding of up to 60 per cent of the relevant investment and operating costs of projects. See more about the Innovation Fund in Box 2.6.

The EU's first round of calls for proposals was issued in July 2020 with a deadline for applications of 29 October 2020. Projects applying for funding in the first round can expect to receive a funding decision from the Innovation Fund in the last quarter of 2021. In the application, the actors must indicate whether they expect financial support from the national authorities. The Government's proposal to implement the project gives Fortum Oslo Varme such an indication.

### 6.2.3 Risk

#### Cost risk

Based on the negotiated agreements, the state will cover around 80 per cent of the actual project costs. The state covers 80 per cent of investment costs related to development phase 1 of Northern Lights, with the exception of a potential additional ship and additional well, where the state covers a

maximum of 50 per cent of the costs. The draft contract with the capture actors states that the state will cover 75 per cent of all costs above a given level. However, none of the parties will be obliged to cover investment costs that exceed the agreed level (P85). The project is complex, which is evident by the extensive funding agreements. Box 6.3 provides an overview of cost and risk distribution in the agreements.

There are certain exceptions from the maximum cost for transport and storage with potentially unlimited cost exposure for the state. If an extraordinary incident should occur, with a risk of leakage from the storage facility or harm to the environment or life and health, the state is required to cover 80 per cent of the costs of preventive and corrective measures related to the volume stored in phase 1 of the project (up to 1.5 million tonnes of CO<sub>2</sub> per year). This responsibility applies throughout the storage facility's operational period and is not limited by the maximum limit for the state's cost responsibility stipulated in the agreement.

In the event of CO<sub>2</sub> leakage from the storage facility, including after the funding period, the state's costs will be 80 per cent of the costs related to the CO<sub>2</sub> volume from Norcem and, if applicable, Fortum Oslo Varme. These costs will depend on the size of the leakage and the price of allowances. For the remaining 20 per cent, the state has also committed to assuming some of the risk for increased allowance prices by covering the allowance cost above EUR 40 per tonne of CO<sub>2</sub>.

There is a very low probability of CO<sub>2</sub> leaking from the storage facility.<sup>4</sup> Any CO<sub>2</sub> emitted from other sources must be covered in full by Northern Lights. Responsibility will be distributed proportionately based on the total amount of CO<sub>2</sub> deposited at the specific time.

However, this does not apply if the leaks are due to gross negligence or willful misconduct, or omissions by personnel in managerial, supervisory or particularly independent positions in Northern Lights or someone for whom they are responsible. The funding recipients will in such case cover all costs related to the leaks.

After a storage facility has been shut down, all obligations relating to monitoring and corrective measures pursuant to the regulations will be transferred to the state represented by the Ministry of Petroleum and Energy or a party authorised by it. The transfer of liability is regulated by the

*Regulations relating to exploitation of subsea reservoirs on the continental shelf for storage of CO<sub>2</sub> and relating to transportation of CO<sub>2</sub> on the continental shelf* (the CO<sub>2</sub> Storage Regulations). The rights and obligations of the state and operators pursuant to the Regulations are detailed in section 4.3.

External quality assurers have emphasised uncertainty in some of the remaining processes. Emission licences constitute one such process. This applies to all three actors, but Gassnova and the external quality assurers highlight this uncertainty as being greatest for Fortum Oslo Varme's facility, since at the time of assessment, they had not completed all of the necessary documentation for the emission licence.

Fortum Oslo Varme has since obtained the necessary documentation. Gassnova has followed this work closely and on the basis of tests carried out at the pilot facility, the Statement of Qualified Technology from DNV GL, and the diffusion and trickle down calculations that have been conducted, it believes that there is a high probability that the emissions will satisfy the requirements the Norwegian Environment Agency is expected to stipulate to issue an emissions licence.

It is not common for an emissions licence to be issued before an investment decision has been made for a project. However, the fact that the emissions licence has not been issued poses uncertainty that can lead to delays and/or increased costs.

#### Interface risk

A basic principle in the project, based on the results of the pre-feasibility study, is that the state assumes the role of intermediary between Norcem and, if applicable, Fortum Oslo Varme and Northern Lights. This entails an interface risk that can lead to high costs for the state if, for example, project completion in part of the chain is delayed. The state must in such case cover the costs for the actor that has to wait for other actors in the chain. This also increases the risk of higher costs during the operational period if CO<sub>2</sub> from the capture actors does not meet the specifications, or they do not deliver CO<sub>2</sub> as expected. In the same way, the state's costs may increase if Northern Lights cannot receive the CO<sub>2</sub> that has been captured, which must instead be emitted; see Box 6.3. With certain exceptions, the impact on the other parts of the chain are generally the responsibility of the state. The interface risk makes good project management essential on the part of the state.

<sup>4</sup> The Petroleum Directorate's assessment of the plan for development, installation and operation. See section 8.

### Box 6.3 Risk matrix – the state’s costs, responsibility and risks

The state’s costs

– funding model

Transport and storage

Capture

*Investment costs*

The state is required to provide the following funding to establish transport and storage:

*Basic investment funding:* The state will cover 80 per cent of the costs of establishing an onshore facility, pipeline and two ships, up to the maximum budget.

*Additional investment funding:* The state will in addition cover 50 per cent of the costs of establishing a third ship and, on certain conditions, also drilling an additional well, up to the maximum budget.

The state is required to provide the following funding to establish capture facilities:

*Investment funding:*

*Norcem:* The state will cover costs up to a stipulated level. Above this level, the state will cover 75 per cent of the costs up to the maximum budget.

*Fortum Oslo Varme:* Fortum Oslo Varme will cover costs up to a stipulated level. The state will cover 75 per cent of the costs above this level and up to the maximum budget. The state’s maximum investment funding for Fortum Oslo Varme is NOK 2 billion.

*Operating costs for the funding period (10 years)*

The state is required to provide the following funding for transport and storage operations for a ten-year operational period:

*Operational funding:* The state will annually cover a gradually decreasing share from 95 per cent to 80 per cent (average 83 per cent) of the operating costs of the facility with an annual capacity of 1.5 million tonnes of CO<sub>2</sub> up to a ten-year maximum budget.

*Extraordinary costs:* The state will also cover 80 per cent of certain extraordinary and unanticipated costs relating to the subsurface that exceed the maximum budget. This liability is unlimited.

*Sharing of operating costs:* By increasing the annual capacity above 1.5 million tonnes of CO<sub>2</sub>, the total operating costs will be distributed in line with the total amount of CO<sub>2</sub> stored. This may reduce the state’s costs.

The state is required to provide the following funding for operation of the capture facilities for the funding period, which for Norcem is ten years. The funding period for Fortum Oslo Varme depends on when the facility becomes operational.

*Norcem:* The state will cover 100 per cent of all annual operating costs up to an agreed level. The state will cover 75 per cent of all operating costs above the agreed level, up to the ten-year maximum budget.

*Fortum Oslo Varme:* Fortum Oslo Varme will cover all costs up to a stipulated level. The state will cover 75 per cent of all costs from this level up to the maximum budget. The state’s maximum funding for the operational period is NOK 1 billion.

*Additional funding:* The state will also pay additional funding for CO<sub>2</sub> that is not subject to the EU ETS. The additional funding will correspond to the allowance price, but any savings ascribed to a carbon tax will be deducted. If the carbon tax is equal to the allowance price, the additional funding will therefore be zero. If the carbon tax is higher than the allowance price, the difference will be deducted from the additional funding for any CO<sub>2</sub> volumes that are not subject to the carbon tax, e.g. those from biogenic sources.

## Box 6.3 (cont.)

The state's costs  
– funding model

## Transport and storage

## Capture

*Costs after the operational period has expired*

The state is required to cover the following costs accrued after the ten-year operational period has expired:

*CO<sub>2</sub> emissions:* In the continued commercial operation of transport and storage, the state will continue to cover a fixed share of the costs of CO<sub>2</sub> emissions received from Norcem and, if applicable, Fortum Oslo Varme, that are stored in the course of the funding period (but not for other CO<sub>2</sub>).

*Cessation funding:* When operations have been concluded, the state will provide funding for cessation, monitoring and removal corresponding to 80 per cent of a proportionate share of volume from Norcem/Fortum Oslo Varme in the funding period and the overall amount of stored CO<sub>2</sub> (the state's share of the costs will thus be reduced with increased commercial volumes). This funding obligation lapses if Northern Lights reaches an agreed level of return on investment.

The state is not required to cover costs after the operational period has expired (except in the event of the state terminating the agreement before expiry).

*Profit sharing during the funding period*

If Northern Lights in the course of the ten-year period of operation achieves a defined return on investment level 1, 50 per cent of the net cash flow from that point in time is to be shared with the state. If the returns exceed a defined return on investment level 2, 75 per cent of the net cash flow will go to the state.

This is similar to the system in place for transport and storage, but with the distinction that when the level of return on investment is initially reached, the operational funding is reduced and eventually stopped entirely. Fifty per cent of net cash flow over and above the agreed level of return 1 is shared with the state and 75 per cent of net cash flow over and above level of return 2 is shared with the state.

*Guarantee*

Each of the three participants in Northern Lights must furnish a guarantee to secure Northern Lights' obligations under the funding agreement. The guarantees have a maximum guarantee amount each of NOK 1 billion, which is gradually reduced throughout the operational period.

Norcem will furnish a guarantee to secure its obligations under the funding agreement. The guarantee has a maximum guarantee amount equal to their share of the maximum budget for establishment and operation, with a gradual reduction throughout the operational period. Fortum Oslo Varme will also furnish a guarantee on similar principles.

## Box 6.3 (cont.)

## The state's costs

– funding model

Transport and storage

Capture

*Scenarios that influence the state's costs**Higher construction costs*

Increases the state's costs since the state must cover 80 per cent of construction costs up to the agreed maximum budget.

Increases the state's costs since the state must cover 75 per cent of construction costs above a stipulated level up to the agreed maximum budget.

*Delayed completion*

Delays will normally lead to higher construction costs and thus increase the state's costs; see the point above. Delayed completion in one part of the chain (either capture or transport/storage) will also mean that Norcem and Northern Lights' ten-year funding periods will no longer correspond. This will require a longer funding period for the other part of the chain not subject to a delay, thus increasing the state's costs. If the capture actors are delayed, the state must cover 100 per cent of Northern Lights' additional costs.

The same as for transport and storage. If Northern Lights is delayed, the state must also provide funding to cover all of the capture facilities' emissions costs.

*Higher operating costs*

Increases the state's costs since the state will on average cover 83 per cent of operating costs up to the agreed maximum budget.

Increases the state's costs since the state must cover 75 per cent of operating costs above a stipulated level up to the agreed maximum budget.

*Larger quantities of CO<sub>2</sub>*

Impacts the state's costs to a limited degree since operational funding is provided independent of the quantity of CO<sub>2</sub> received and stored, within the agreed capacity of 1.5 million tonnes of CO<sub>2</sub> per year. By increasing the annual capacity above 1.5 million tonnes of CO<sub>2</sub>, the total operating costs will be shared in line with the total amount of CO<sub>2</sub> stored (which may reduce the state's costs).

Increases the state's costs for additional funding up to the maximum limit of 400,000 tonnes of CO<sub>2</sub> per year (thus reducing the state's costs for additional funding for lower quantities of CO<sub>2</sub>).

## Box 6.3 (cont.)

The state's costs – funding model		
	Transport and storage	Capture
<i>CO<sub>2</sub> emissions</i>	<p>Leads to additional costs for the state since the state commits to covering 80 per cent of the costs of emissions from the storage facility for volumes from Norcem and, if applicable, Fortum Oslo Varme, that have been stored during the operational period.</p> <p>The state will also cover 100 per cent of the costs over and above an allowance price of EUR 40 per tonne of CO<sub>2</sub> for CO<sub>2</sub> emissions from Norcem and, if applicable, Fortum Oslo Varme, that have been stored during the operational period. This entails a limitation to Northern Lights' responsibility.</p> <p>These obligations to cover emission costs continue into a subsequent period of commercial operation, but the state's responsibility will not then increase further.</p>	<p>Will not in principle lead to additional costs for the state, since this is Norcem/Fortum Oslo Varme's responsibility (with the exception of emissions caused by the transport and storage operator's failure to receive CO<sub>2</sub>; see below).</p>
<i>No or limited delivery of CO<sub>2</sub> from the capture actor</i>	<p>May increase the state's costs since any additional operating costs will lead to higher operational funding. The state therefore bears the largest part of this risk (interface risk).</p>	<p>It is not possible to claim compensation from Norcem/Fortum Oslo Varme for increased transport and storage costs due to failure to deliver CO<sub>2</sub>. It will not be necessary to pay any additional funding, but Norcem/Fortum Oslo Varme will otherwise be entitled to operational funding. The state therefore bears the largest part of this risk (interface risk).</p>
<i>Failure to receive CO<sub>2</sub> on the part of Northern Lights</i>	<p>In the event of Northern Lights failing to receive CO<sub>2</sub>, the state may reduce operational funding by the same amount as the state must pay in compensation to Norcem/Fortum Oslo Varme. There is an annual limit to how much operational funding may be reduced. In the event of force majeure or other matters that provide exemption from liability (including extraordinary weather conditions and maintenance), the state is not entitled to reduce funding. There are also certain other limitations to the right to reduce funding. Overall, this means that the state bears the largest part of this risk (interface risk).</p>	<p>Failure to receive the agreed amount of CO<sub>2</sub> will increase the state's costs since the state has committed to compensate Norcem/Fortum Oslo Varme for financial losses in connection with having to emit CO<sub>2</sub>. The state's responsibility applies regardless of whether Northern Lights is held liable, and means that the state bears the largest part of this risk (interface risk).</p>

## Box 6.3 (cont.)

The state's costs		
– funding model	Transport and storage	Capture
<i>CO<sub>2</sub> deliveries that fail to meet specifications</i>	May increase the state's costs since any additional operating costs will lead to higher operational funding. The state therefore bears the largest part of this risk (interface risk).	Norcem/Fortum Oslo Varme's responsibility for CO <sub>2</sub> deliveries that fail to meet specification requirements is limited to NOK 15 million per year. The capture actors are not entitled to pay compensation for transport and storage costs over and above this. This means that the state bears the largest part of this risk (interface risk).
<i>Instructed changes</i>	The state is obliged to cover 100 per cent of additional costs accrued due to changes instructed by the state related to the establishment or operation of transport and storage facilities.	The state is obliged to cover 100 per cent of additional costs accrued due to changes instructed by the state related to the establishment or operation of capture facilities.
<i>Breach of contract on the part of the funding recipient</i>	In the event of breach of contract on the part of Northern Lights, the state's right to reduce funding will be limited to the following: During the establishment period, basic investment funding and additional investment funding may be reduced by a maximum of NOK 500 million. During the operational period, operational funding may be reduced by a maximum of NOK 40 million per year.	In the event of breach of contract on the part of Norcem/Fortum Oslo Varme, the state's right to reduce funding will be limited to the following: During the establishment period, investment funding may be reduced by a maximum of NOK 75 million. During the operational period, operational funding may be reduced by a maximum of NOK 15 million per year.
<i>Regulatory amendments, delays or amendments to licences</i>	Increased costs resulting from delayed licences or amendments to public law regulations/awarded licences will increase operating costs and thus increase funding.	The same as for transport and storage.
<i>Exchange rate fluctuations</i>	The agreement allows for inflation adjustment of the maximum budget. Otherwise no exchange rate adjustments.	Funding is adjusted for changes in exchange rates. The mechanism entails that the exchange rate risk is divided proportionately between the parties by their share of the costs. A similar mechanism applies to adjustments to operating costs caused by changes in power prices and inflation during the operational period.



## Box 6.3 (cont.)

The state's costs – funding model		Transport and storage	Capture
<i>Force majeure</i>	The state may not reduce funding for delays or non-performance of the agreement due to obstacles that constitute force majeure. Force majeure does not entail a right to funding over and above what follows from the funding model, but increased costs resulting from force majeure will increase the state's costs. The maximum budget still applies.		The same as for transport and storage.
<i>Covid 19 force majeure</i>	No separate regulation.		In principle, the same procedure as ordinary force majeure. The state may not reduce funding for delays or non-performance of the agreement due to obstacles that constitute Covid 19 force majeure, and increased costs will lead to increased funding in accordance with the funding model. If Covid 19 force majeure leads to the maximum budget for construction costs being exceeded, Norcem/Fortum Oslo Varme may also demand the maximum budget to be adjusted corresponding to the excess costs resulting from Covid 19 force majeure.
<i>Other unforeseen circumstances</i>	Unforeseen circumstances may lead to increased costs, which in general may lead to increased operational funding. Northern Lights (and in principle also the state) may request re-negotiation of the agreement in the event of unforeseen circumstances, the consequences of which cannot be avoided/overcome, and that lead to imbalance in the agreement.		The same as for transport and storage.
<i>Termination on the part of the state</i>	The state does not have the right to terminate the funding agreement with Northern Lights and is thus obliged to provide funding as agreed for establishment and ten years of operation of the facility.		The state may terminate the agreement but is obliged to cover the following costs in the event of termination during the establishment period: The state will cover 100 per cent of accrued construction costs. The state will cover 100 per cent of the costs of removal of the capture facility. In the event of termination during the operational period, the state is obliged to cover a proportionate share of the company's own contributions for establishment and removal costs.

Box 6.3 (cont.)		
The state's costs		
– funding model	Transport and storage	Capture
<i>Major cost increases</i>		
<i>Construction costs reach the maximum budget</i>	<p>If the costs of basic investments (onshore facility, pipeline and two ships) reach the agreed maximum budget, neither of the parties are required to contribute further financing or complete the project.</p> <p>Unless the parties agree to continue, or one of the parties assumes sole responsibility to finance completion of the project alone, the project will be abandoned and each of the parties will bear its own costs.</p> <p>If Northern Lights assumes responsibility to finance completion of the project, the state is obliged to provide operational funding in accordance with the agreement.</p>	<p>The same as for transport and storage. See the exceptions relating to Covid 19 force majeure and exchange rate adjustments above.</p>
<i>Operating costs reach the maximum budget</i>	<p>If the operating costs reach the maximum budget, the parties will meet to discuss the situation. However, Northern Lights is not entitled to halt operations or discontinue the project.</p> <p>See the exceptions for extraordinary costs above.</p>	<p>If operating costs reach the maximum budget, Norcem and, if applicable, Fortum Oslo Varme have the right to adapt operations and, if necessary, stop operation of the capture facility.</p>

Other matters that entail risk in the project

*Health, safety and the environment*

The industry actors have stated that mapping and management of HSE risk has been well studied and conducted in accordance with good practice. A serious HSE incident is unlikely, but if such an incident should occur, it may in addition to the serious direct consequences damage the state's reputation.

*The industry actors downscale activities*

The carbon capture projects are dependent on industry activity being maintained at the facilities. Both Norcem and Fortum Oslo Varme are in a situation where downscaling is unlikely. The funding agreements require the companies to operate their capture facility, but in the event that meeting

the funding agreement entails an unreasonable burden, they may demand re-negotiation.

*Problems during start-up*

Injection of CO<sub>2</sub> in the storage location is dependent on a generally stable flow of CO<sub>2</sub>. If the flow is unstable, it may mean that the facility needs to stop and start more often, which will lead to higher costs. This is a likely risk during the start-up phase, but this will be reduced in step with more capture facilities and with operational experience.

*Patent risk*

The company International Energy Consortium (IEC) has had a CCS patent approved. IEC has contacted Gassnova and Equinor several times

concerning alleged infringement of their patent in connection with the Norwegian project.

Objections have been made in relation to the patent, and the case is under consideration by the European Patent Office (EPO).

The patent bureau Zacco, on behalf of Gassnova, sent an objection concerning the IEC's patent for full-scale CCS to the EPO on 10 October 2018. A further two objections were submitted before the deadline, among others from Equinor. The grounds for the objections are unlawful amendments, insufficient feasibility and insufficient novelty/inventive merit. These are separate conditions, and will therefore be assessed individually.

The EPO convened an oral hearing in the Netherlands on 24 March 2020. In the summer of 2019, the EPO issued its provisional (non-binding) assessment of the patent based on the three objections, the IEC's response and the comments submitted to the response.<sup>5</sup> The EPO's provisional assessment of the case supports the objectors' position to a great extent. The EPO's consideration of the case has been postponed until 2021 due to the coronavirus situation.

In Zacco's assessment, there is a high probability that the EPO will either retract its approval of the patent or narrow its scope so that it does not conflict with the interests of the CCS actors.

## 6.3 Measures to manage risk in the project

### 6.3.1 The industry's incentives in the agreement

The most important risk management measure in the project is the clear responsibility of the companies to own and develop the carbon capture, transport and storage projects, and that they cover a share of the actual costs when they accrue. The companies therefore have incentives to keep the costs at a minimum. The companies also have incentives to complete their projects on schedule since a delay will increase their costs and delay the revenues or savings they generate.

Northern Lights' business model is to provide CO<sub>2</sub> transport and storage services to industry companies with CO<sub>2</sub> emissions in return for negotiated tariff payments. Northern Lights will not generate revenue from CO<sub>2</sub> storage from Norcem

and, if applicable, Fortum Oslo Varme, and without commercial volume, Northern Lights will operate at a continuous loss. Northern Lights therefore has a strong incentive to develop the market for CO<sub>2</sub> storage and to offer tariffs that industry companies are capable of paying.

Norcem and Fortum Oslo Varme will generate savings by reducing the need to buy emission allowances, tax obligations and additional funding per tonne of captured CO<sub>2</sub>. They therefore have strong incentives to operate their carbon capture facilities efficiently.

### 6.3.2 Project management

Longship is complex and therefore challenging to manage. The project requires good follow-up by the state and particular attention to any changes in the sub-projects. The industry actors in the project are international companies with established project management and quality assurance procedures. This also includes processes to establish risk-reducing measures. The funding agreements between the state and the actors regulate obligations, liability and rights.

The state's risk is regulated by the agreements. The industry actors' compliance with the agreements will be important to the outcome. This means that the state will exercise its access and audit rights provided for in the agreements. It is nonetheless likely that cases will arise where the state and industry disagree about specific technical assessments, and this must be resolved by dialogue with the companies.

There are no commercial agreements between Norcem and, if applicable, Fortum Oslo Varme, and Northern Lights. The state's representative must therefore be qualified to manage the interface between the actors since this risk is mainly borne by the state. The state also has the right of instruction in cases where measures are needed in part of the chain to reduce costs in another part. The state must in such case bear the cost consequences of the instruction. The state's cost and risk exposure mean that the state will need to follow up more than payments and funding.

The Ministry of Petroleum and Energy will be responsible for following up the funding agreements. Steps have been taken to allow Gassnova on behalf of the state to follow up the actors' project management through agreed reporting. According to the plan, Gassnova will also coordinate the work on benefit realisation and facilitate the sharing of relevant experience with other projects and stakeholders.

<sup>5</sup> <https://register.epo.org/application?documentId=E3E8L43G3541DSU&number=EP12830562&lng=en&npl=false>

### Box 6.4 Scenarios in the socioeconomic analyses

Two different scenarios have formed the basis for Gassnova's analysis and QA2; the 'Paris Agreement' and 'Current European climate policy'. The difference between the scenarios is primarily expected price pathways for CO<sub>2</sub> and the number of subsequent projects.

The Paris Agreement scenario is based on the assumption that the Paris Agreement's temperature goals will be achieved, and that policy instruments and measures are implemented that correspond to the targets Norway, the EU and the world have stipulated for climate efforts. The scenario has a price pathway for CO<sub>2</sub> emissions that reflects what it will cost to limit the average temperature increase to 1.5–2 degrees Celsius by 2100. The price pathway is the median of all SSP (Shared Socioeconomic Pathways) scenarios that correspond to the 1.5 and 2 degree target [60]. The scenario also assumes a CCS project development rate leading up to 2050 in line with the IEA's 'Sustainable Development' scenario. In this scenario, projects are developed that capture and store 735 million tonnes of CO<sub>2</sub> per year in 2030 and 2,748 million tonnes of CO<sub>2</sub> per year in 2050 in addition to the amount captured and stored today.

The scenario 'Current European climate policy' is based on the application of policy instruments in line with what is currently implemented and a less ambitious 2050 target than that adopted by the EU in December 2019. This scenario distinguishes between sectors included in the EU ETS and those that are not.

Sectors not included in the EU ETS are subject to national obligations to the EU and ambitions to cut national emissions towards 2030, as expressed in the Granavolden platform. Until 2030, the CO<sub>2</sub> price in sectors not included in the EU ETS increases from the current level to NOK 2,000 in 2030. This figure was selected on the basis of an anticipated alternative cost to meet national climate targets.

For sectors included in the EU ETS, the expected allowance price in the EU ETS is used as a price pathway up to 2030. A tightening of the allowance market as a consequence of the European Green Deal is not taken into account. In this scenario, the CO<sub>2</sub> price leading up to 2050 moves towards a level corresponding to the expectation that the EU will achieve an 80 per cent emissions reduction by 2050.

This scenario assumes a development rate of carbon capture and storage projects up to 2050 based on the IEA's scenario 'Stated Policies'. In this scenario, projects are developed that capture and store 43 million tonnes of CO<sub>2</sub> per year in 2030 and 126 million tonnes of CO<sub>2</sub> per year in 2050 on top of the amount captured and stored today.

<sup>1</sup> The assumptions of current European climate policy were made before the *European Green Deal* was presented and before the meeting of the European Council adopted the goal of climate neutrality.

## 6.4 The project's socioeconomic profitability

Several assessments have been made of the socioeconomic profitability of Longship. In QA1, external quality assessors conducted an assessment of socioeconomic profitability [45]. On the basis of the QA1 analysis, Gassnova together with DNV GL conducted an updated assessment of the project's socioeconomic profitability ahead of QA2 [59]. External quality assessors have not conducted an independent socioeconomic analysis as part of QA2, but have based their analysis on that of Gassnova/DNV GL and reviewed methods and assumptions [56].

A socioeconomic analysis should in principle be limited to the effects on groups in Norway. However, a global perspective has been used in this case since the project is designed to reduce emissions and realise cost reductions that may also be generated at the international level.

Gassnova's analysis and QA2 show the same picture. The project is socioeconomically profitable if based on a climate policy in line with the global temperature goals of the Paris Agreement. The need for many projects to follow suit shows the importance of European countries following up Norway's project with their own initiatives. In a scenario with current European climate policy, the project is not socioeconomically profitable and

the analysis shows negative net quantified effects of the project.

The quantified socioeconomic cost of realising the project is the sum of investment and operating costs and the tax-financing cost. The analysis is based on the project having a lifetime of 25 years, while tax-financing costs are only for the ten years of state aid in addition to investment costs.

The socioeconomic benefits of implementing the project have two quantified elements: The value of emission reductions and productivity effects. Productivity effects mean that subsequent CCS projects can be implemented at lower costs as a result of the implementation of this project. Productivity effects can again be divided into two parts: Effects that follow from learning and knowledge transfer (learning effect) and effects that follow from increased use of the CO<sub>2</sub> storage capacity (scale effect). The QA2 report assesses the productivity effects as option values. This means that the effects depend on others also making decisions, beyond implementing the project addressed in this report, in order for them to have an impact. Specifically, the benefit realisation effect is dependent on other projects making investment decisions and being realised. The analyses show that subsequent projects in Europe and globally are prerequisites for CCS becoming an efficient and competitive climate policy instrument.

In addition to the quantified benefits, Gassnova's analysis and the QA2 report identify and assess a number of non-quantified effects. The project will demonstrate that CCS is a feasible and safe climate measure, it will have a facilitating effect on subsequent projects and provide regulatory and commercial learning.

Longship will also facilitate utilisation of the storage capacity on the Norwegian continental shelf and facilitate low emissions from the use of Norwegian natural gas through conversion to hydrogen with CCS.

Table 6.4 summarises the assessment of the project's socioeconomic profitability in the QA2 report. The non-quantified effects are assessed on a scale from +++++ (large-scale positive effect of major importance to society) to — (large-scale negative effect of major importance to society).

In the scenario where the world achieves the global temperature goals of the Paris Agreement,

the alternative where only Norcem is realised and the alternative where Norcem and Fortum Oslo Varme are realised have almost the same socioeconomic profitability. If option values are included, the project is highly socioeconomically profitable in this scenario.

In the scenario 'Current European climate policy', the project is very unprofitable from a socioeconomic perspective, but the alternative with Fortum Oslo Varme is least unprofitable. This is because the scenario distinguishes between sectors included and not included in the EU ETS, and the CO<sub>2</sub> prices it is based on are much higher in sectors not included in the EU ETS than those that are.

The QA2 report indicates that the project can be socioeconomically profitable, given an ambitious international climate policy that results in CO<sub>2</sub> prices that are around ten times higher than current allowance prices. The assumed point in time that CO<sub>2</sub> prices reach a level ten times higher than the current level is vital to the analysis. Table 6.4 shows the situation where CO<sub>2</sub> prices are ten times higher in 2040 than today. This indicates a very socioeconomically profitable project after option effects. If a flat CO<sub>2</sub> price is assumed for the first ten years followed by prices rising to ten times as high in 2050, the project is marginally socioeconomically profitable after option effects. There will at the same time be other effects that also influence profitability, such as the size of cost reductions that stem from the project and the number of subsequent projects. The effect of Norway's project is that the next projects will require a lower CO<sub>2</sub> price to be profitable, and that these projects will be socioeconomically profitable without CO<sub>2</sub> prices that are ten times the current level.

The QA2 report also provides an analysis of how much these results change if the assumptions are changed. These analyses show that the measure can also be very unprofitable if based on lower, but still rising, CO<sub>2</sub> price pathways, if the lifetime is limited to ten years or if a purely national perspective is used in the analysis, or if fewer facilities follow and utilise learning from the project. In the analysis of sensitivity to higher CO<sub>2</sub> prices, the project becomes more socioeconomically profitable.

Table 6.3 Assessment of the socioeconomic profitability of the project from the QA2 report

	Current European climate policy			The Paris Agreement		
	Alt. 1: Transport and storage 1.5 mt, Capture Nor- cem 0.4 mt.	Alt. 2: Transport and storage 1.5 mt, Capture FOV 0.4 mt.	Alt. 3: Transport and storage 1.5 mt, Capture Nor- cem and FOV 0.8 mt.	Alt. 1: Transport and storage 1.5 mt, Capture Nor- cem 0.4 mt.	Alt. 2: Transport and storage 1.5 mt, Capture FOV 0.4 mt.	Alt. 3: Transport and storage 1.5 mt, Capture Nor- cem and FOV 0.8 mt.
Investment costs	10,840	11,690	14,580	10,840	11,690	14,580
Operating and maintenance costs	7,540	8,900	10,490	7,540	8,900	10,490
Tax financing costs	2,520	2,780	3,420	2,520	2,780	3,420
<i>Overall costs</i>	<i>20,900</i>	<i>23,370</i>	<i>28,490</i>	<i>20,900</i>	<i>23,370</i>	<i>28,490</i>
Value of emission reductions	4,910	11,030	15,940	9,340	9,840	19,180
<i>Net quantified benefits before option effects</i>	<i>-16,000</i>	<i>-12,340</i>	<i>-12,550</i>	<i>-11,560</i>	<i>-13,530</i>	<i>-9,310</i>
Productivity effects (learning effects)	2,800	2,800	2,800	19,140	19,140	19,140
Scale effect in connection with full utilisation of storage capacity (1.5 million tonnes)	4,610	4,510	2,510	4,610	4,510	2,510
<i>Net quantified benefits after option effects</i>	<i>-8,580</i>	<i>-5,030</i>	<i>-7,240</i>	<i>12,190</i>	<i>10,120</i>	<i>12,340</i>
Demonstrate carbon capture and storage as a feasible and safe climate measure	++++	++++	+++++	++++	++++	+++++
The project's facilitating effect	+++	+++	+++	++	++	++
Regulatory learning	++	++	+++	+++	+++	++++
Commercial learning	+	+	++	++	++	+++
Utilisation of Norway's geological resources	++	++	++	++++	++++	++++
Innovation and application of carbon capture and storage	+	+	++	++	++	+++
Competence-raising and supplier industry for carbon capture and storage	++	+	++	+++	++	+++
Increased value of Norwegian gas	+	+	+	++++	++++	++++
Environmental impact	-	-	--	-	-	--

Source: Gassnova, and Atkins and Oslo Economics

## 7 How do we make CCS successful?

### 7.1 Phases of market development

A wide range of factors will impact the development rate of carbon capture and storage (CCS) in Europe and the rest of the world. The different phases of CCS will entail different needs for financial support and political frameworks.

The first CCS projects in Europe will require the EU and individual states to make substantial contributions. The EU's state aid guidelines<sup>1</sup> allow states to cover up to 100 per cent of the costs. Agreements have been negotiated in the project where the state covers around 80 per cent of the costs. It is unlikely that states will want to cover costs that enable the operator of a CO<sub>2</sub> storage facility to make a significant return in this less mature phase. There will be relatively few carbon capture projects, little CO<sub>2</sub> available for storage, and investment and operating costs will be relatively high given the small volumes these costs must be distributed between.

DNV GL has prepared an analysis of how CCS costs may develop when the infrastructure is utilised and more carbon capture facilities are built; see section 3. The analysis shows that subsequent projects will still require state aid, but that these projects will be able to increasingly compete for funding from more general funding schemes. Enova, for example, administers general funding schemes where future CCS projects can compete with other climate technologies for funding. The EU's Innovation Fund may also make significant contributions to projects. The demand for CO<sub>2</sub> storage will increase during this phase, while the learning from subsequent facilities may reduce costs. CCS may require some state facilitation and knowledge-sharing even after it becomes more widespread. The Government recommends that any additional Norwegian carbon capture facilities must compete for investment and operational funding from general funding schemes. The state will not engage in direct negotiations on state aid with individual actors.

In a mature phase, costs will be sufficiently reduced to enable CCS projects to become commercial and receive sufficient incentives through general policy instruments, such as CO<sub>2</sub> prices and higher prices for climate-friendly products. The demand for CO<sub>2</sub> storage will increase during this type of phase, and operators of storage facilities will be able to expect a commercial return on investment. The level of return is uncertain, however, and will depend, inter alia, on the number of CO<sub>2</sub> storage operators, developments in the price of CO<sub>2</sub> emissions and the actual cost reductions for CCS. It is during the mature phase that the commercial impact discussed in section 6.1 will be independent of state subsidies.

Sections 3.2 and 6.1 illustrate how Longship will contribute to cost reductions for subsequent projects. The project will thus also contribute to developing CCS as a climate measure. The success of the development of CCS depends on other projects following the Norwegian project's lead. If CCS is to become an efficient and competitive climate policy instrument, new projects must be initiated in Europe and worldwide.

### 7.2 Other countries must support CCS

Concrete policy instruments and measures must be implemented for the world to achieve international and national climate ambitions and climate targets. It must also be possible to implement these policy instruments and measures in an effective manner. As illustrated in section 7.1, more countries and the EU must support CCS projects to enable CCS to become an effective climate measure internationally and in Europe in particular. Other projects are under development in Europe, but they will require additional funding [25, 56].

The European Green Deal and the EU's climate targets represent ambitious goals for reducing emissions at the EU level. However, the EU must follow up these policies with concrete policy instruments and measures. Thema and Carbon Limits indicate that tightening the allowance mar-

<sup>1</sup> <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52014XC0628%2801%29&from=EN>



### Box 7.1 Development of Sweden's CCS policy

Sweden's long-term emissions target is to reduce net greenhouse gas emissions to zero by 2045 and to subsequently achieve negative emissions. Sweden's national energy and climate plan highlights CCS as a means of achieving negative emissions. An official study was conducted in conjunction with the development of the Swedish policy on 'The road to a climate-positive future' [61] in which bio-CCS is highlighted as an important measure. The Swedish authorities have introduced funding mechanisms for projects relating to CCS through the Swedish Energy Agency. Sweden has also recently decided to ratify the 2009 amendment to the London Protocol that allows CO<sub>2</sub> export to other states for storage purposes.

ket may contribute to more CCS, particularly if new measures are introduced to combat what is known as carbon leakage [25]. In their view, the current funding schemes are not enough to trigger a large-scale rollout of CCS projects, unless they are supplemented by measures specifically targeting carbon capture and storage.

International cooperation is also imperative. Cooperation between Norway and other parties in Europe is key to the continuation of Longship and further developing various technologies that are relevant to carbon capture, transport and storage.

The CO<sub>2</sub> Storage Regulations regulate the relationship between the state and the operator performing the activity; cf. section 4.3. Sources outside Norway can only utilise a CO<sub>2</sub> storage facility on the Norwegian continental shelf if the country that wishes to export CO<sub>2</sub> to Norway enters into a bilateral agreement with the Norwegian authorities. The London Protocol also requires the involved countries to have a bilateral agreement in place. Such bilateral agreements must regulate responsibility for CO<sub>2</sub> and technical elements such as when this responsibility is transferred from the emission source country to Norway and how potential disagreements can be resolved.

The Climate Convention and the Paris Agreement assume that each country is responsible in international law for CO<sub>2</sub> emissions within their

territory. The storage of CO<sub>2</sub> from emission sources outside Norway is recognised as an emission reduction in the country in which the emission sources are located. The same volumes must be reported and recognised as 'non-emitted CO<sub>2</sub>' by Norway. Any leakage from a CO<sub>2</sub> storage facility on the Norwegian continental shelf will be recognised under Norway's air emissions account, and Norway will be liable in international law for costs associated with the emissions, including improving and securing the facility, and Norway must make corresponding emission cuts. This means that Norway faces a disadvantage when storing CO<sub>2</sub> from sources outside Norway. This liability will lie with the storage facility operator during the funding period and post-operational phase, while Norway will assume liability once the storage facility is returned to the state. The more CO<sub>2</sub> Norway imports, the greater the liability. Pursuant to the CO<sub>2</sub> Storage Regulations, the operator is liable for the costs and risks involved in CO<sub>2</sub> storage activities during the operational phase and until the storage facility is returned to the state.

## 7.3 The road ahead for the Government's work on CCS

The Government will contribute to developing technology for carbon capture, transport and storage. Longship will make a significant contribution to this development, but also underlines the need for and value of international cooperation on developing technology and reducing emissions.

### 7.3.1 Research, development, demonstration and international work

The implementation of Longship is not enough alone to make CCS a cost-effective climate measure. The project must be followed up with research, development and international work to enable more projects to be implemented and thus CCS to be developed as a climate measure. The academic literature shows that technology and measures are developed most expediently by repeating processes involving a combination of research, development and demonstration [62].<sup>2</sup> This is conducive to reducing costs and will make the measure more effective.

<sup>2</sup> Almost all technology development theory is built on Schumpeter's ideas. He divided the technological process into three parts: Invention, innovation and diffusion.

The Government already supports a comprehensive portfolio of measures in research, development and demonstration, Technology Centre Mongstad (TCM) and international work, and it will continue to do so. The CLIMIT programme and the Norwegian CCS Research Centre (NCCS) are the national cornerstones of research, development and demonstration. The CLIMIT programme plays an important role in supporting actors that develop new and more effective carbon capture technology and the early planning phase of CCS projects. Participating in international and European CCS research programmes and activities is also important and the Government will continue these initiatives.

A decision has been made to continue TCM until the end of 2023. TCM still plays a key role in the Government's CCS work. The centre and the knowledge base that has been built up around it will facilitate the further development of various carbon capture technologies. The state on its part wishes to increase industry participation and funding of TCM.

International cooperation is key to making CCS an effective climate measure. The Ministry is following up several international CCS initiatives (see section 4.1.3) and the Government will continue this work. The work on research, development and demonstration, TCM and international cooperation are important means of deriving the greatest possible benefits from the project.

### 7.3.2 Further work on industrial-scale CCS

Section 6.3 discusses the concrete project follow-up. To ensure society derives the greatest possible benefits from the project, it is important that the state facilitates active benefit realisation work in close cooperation with the industry actors and their suppliers. The benefit realisation plan in the project is discussed in section 4.2.5.

The learning, development and improvements generated by the project must be shared with subsequent projects. Established instruments such as CLIMIT, TCM and international work will be key to this part of the benefit realisation work, together with technology diffusion through e.g. patents. Gassnova will coordinate the work on benefit realisation, and an important responsibility rests with the industry actors and their suppliers. Experience from the implementation of the project and use of regulations must be included in further work on the framework for CCS, both in Norway and in Europe.

Knowledge diffusion and value creation will also be generated through Norwegian actors' and suppliers' participation in future CCS projects internationally. The policy instruments for advancing business interests internationally, including Norwegian Energy Partners, can play an important role in facilitating international business development, including for CCS technology markets.

Although the Government is not participating in Northern Lights, it is in society's interest that the storage facility is realised and utilised. Many of the projects Northern Lights are in contact with are outside Norway. Norway will continue to facilitate the development of CCS projects in Europe through knowledge diffusion and by facilitating the utilisation of Northern Lights' CO<sub>2</sub> storage facility.

As indicated in section 7.1, the success of the development of CCS depends on other projects following the Norwegian project's lead. If CCS is to become a cost-effective and competitive climate policy instrument, new projects must be initiated in Europe and globally. A number of projects, as shown in section 2.5, are under development in Europe, several of which are dependent on third-party funding. CCS has to be able to compete with other measures if it is to become an effective climate measure. Actors that plan to use CCS as a means of reducing their emissions in Norway must apply for funding from general funding schemes in Norway and abroad, including CLIMIT, ENOVA and the EU's Innovation Fund.

### 7.3.3 The Government will contribute to developing technology for carbon capture, transport and storage

The Government will also work to further develop established policy instruments and schemes and will:

- Participate in designing policy and instruments at the European level to facilitate CCS in Europe.
- Continue CLIMIT and Technology Centre Mongstad as key instruments for the CCS efforts.
- Follow up the benefit realisation work in Longship in close cooperation with the industrial companies and take steps to ensure that knowledge, learning and efficiencies from the project make positive contributions to the development of CCS in Europe and the rest of the world.

- Contribute to the possibility of using the CO<sub>2</sub> storage infrastructure in other projects through enhanced cooperation with relevant European countries.
- Require that any future CCS projects in Norway will have to compete for investments and

operational funding from general funding schemes, such as Enova and the EU's Innovation Fund. The state will not engage in direct negotiations on state aid with individual stakeholders.

## 8 Development plan for Northern Lights

### 8.1 Plan for development, installation and operation

#### 8.1.1 Introduction

On 30 April 2020, the Ministry of Petroleum and Energy received a combined plan for development and operation (PDO) and plan for installation and operation (PIO) for the Northern Lights project. On 6 May 2020, the Ministry received a letter stating that the companies had made a positive investment decision and a request for approval of the PDO/PIO. The investment decision has been made among other things on the condition that the Storting makes a positive investment decision for the whole project without stipulating costly

conditions and that the state aid agreement is completed and approved.

Northern Lights will receive captured CO<sub>2</sub> that is transported on ships and delivered to an onshore reception facility in Øygarden municipality. The CO<sub>2</sub> will be stored there temporarily before it is pumped through a pipeline to an injection well on the seabed.

The subsea reservoir where the CO<sub>2</sub> is to be stored is covered by exploitation licence 001, which was awarded to Equinor ASA by the King in Council on 11 January 2019. This is the first licence for carbon injection and storage on the Norwegian continental shelf awarded under the CO<sub>2</sub> Storage Regulations. The area covered by the licence is south-west of the Troll field and east of

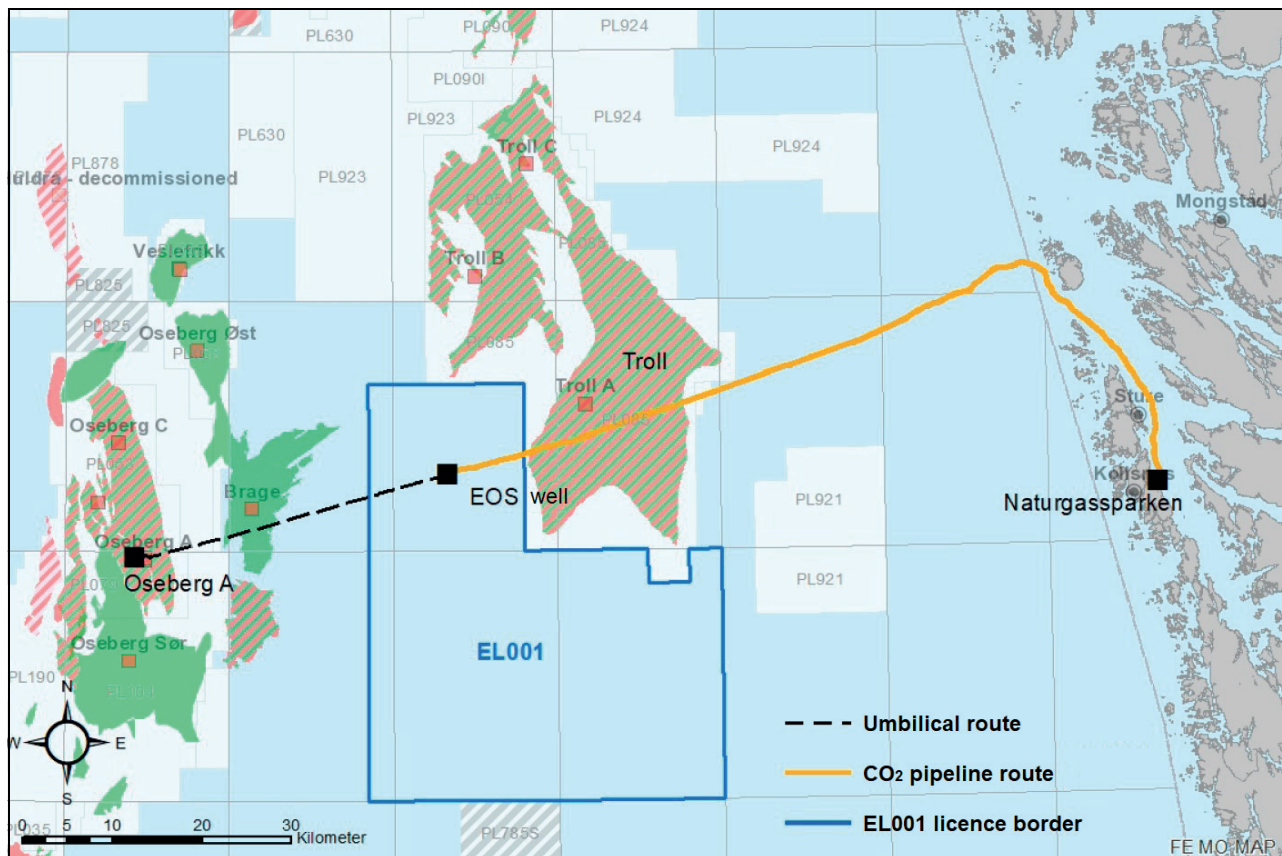


Figure 8.1 Location of exploitation licence EL001 with pipeline route and route for control cables

Source: Northern Lights' plan for development, installation and operation Part I – Main document

the Oseberg field in the northern part of the North Sea.

Equinor has entered into a cooperation agreement with A/S Norske Shell (Shell) and Total E&P Norge AS (Total), and it is these three companies that are behind the Northern Lights project. The intention is that Equinor, Shell and Total will together establish a general partnership with shared liability, which will be responsible for the development and operation of the project. The company is in an establishment phase and will go under the name Northern Lights DA. A participants' agreement has been drawn up between the three companies in the project, which regulates the establishment of Northern Lights DA and ownership and operation of the project. This agreement shall be approved by the Ministry of Petroleum and Energy; cf. the CO<sub>2</sub> Storage Regulations Section 4-1 sixth paragraph.

Equinor will be licensee and operator until the new company has been formally established. An application will then be submitted to transfer these responsibilities to Northern Lights DA.

### 8.1.2 Development solution

The development solution comprises ships to transport CO<sub>2</sub>, an onshore facility for reception and temporary storage of the CO<sub>2</sub>, transport by pipeline, and an injection well and permanent storage in a reservoir on the continental shelf.

#### Ships

The shipping solution for transporting CO<sub>2</sub> is not part of the PDO/PIO; cf. the CO<sub>2</sub> Storage Regulations Section 1-6 (i) and (t). The solution is nonetheless part of the total scope of the project and is included in the support agreement with the state. It is therefore briefly outlined in the PDO/PIO.

The plan is initially to build two dedicated tankers to transport liquid, cooled CO<sub>2</sub>. The ships will be owned by Northern Lights DA. The carbon capture actors will deliver liquid CO<sub>2</sub> from tanks at the agreed quay. The ships will be 130 metres long. If Northern Lights secures more CO<sub>2</sub> storage customers, more ships will have to be built.

#### Onshore facility for reception and temporary storage of CO<sub>2</sub>

The onshore facility will be established at Naturgassparken in Øygarden municipality. The facility will have a quay with loading arms for unloading ships, 12 storage tanks for temporary storage of

CO<sub>2</sub>, a process system for heating and increasing CO<sub>2</sub> pressure prior to transport by pipeline, quality control of CO<sub>2</sub>, buildings for electrical equipment and control systems, an administration building with a control room, office and visitor facilities, and a workshop and storage building. The control room at the onshore facility will be used during the start-up period, while the plan is to use the control room at the Sture terminal during the operational period to reduce operating costs and staffing needs.

The storage tanks' capacity will correspond to the ships' capacity, such that they have the capacity to store the CO<sub>2</sub> discharged from one ship. The capacity will enable a continuous flow of CO<sub>2</sub> from the onshore facility to the storage reservoir.

The area where the onshore facility is to be built will be blasted and levelled before construction commences. It will be possible to expand the onshore facility if the need arises in the future, including an additional quay.

#### Pipeline and installation on the seabed

A 100-km pipeline will be installed from the reception facility out to the installation on the seabed with pertaining injection well. The pipeline will be constructed to enable a branch pipe to be established to alternative storage locations in the future in the area east of Troll and for pipes to be connected from the industrial area at Mongstad.

A well, Eos, has been drilled, and is intended to be used for injection of CO<sub>2</sub>. Parts of the installation on the seabed were established in connection with the drilling of this well. The control cables for the well will come from the Oseberg A platform. The well will be managed and monitored from the Oseberg A platform, from the control room at the onshore facility and from the Sture terminal. The control rooms will have different tasks, but they will all continuously monitor the well. It will be possible to trawl over the installation and control system on the seabed.

A system will be implemented to identify any leakages in the entire storage chain, from the onshore facility to the injection well. An overarching monitoring plan has also been drawn up for the whole project, which, among other things, describes the monitoring of the storage complex. This will take place by monitoring pressure and temperature in the well and by active and passive seismic monitoring.

The CO<sub>2</sub> volumes will be injected into the Johansen formation and be stored there and in the Cook formation above it. The shale in the for-

mation above will act as a sealing cap rock. Data from the Eos well confirmed the presence of high-quality sandstone in the reservoir. The well hit a 75-metre layer of sealing shale above this with sufficient integrity for CO<sub>2</sub> injection. The well results support previous assessments that the volumes of CO<sub>2</sub> included in phase 1 of the project can, with high probability, be injected into the reservoir.

### 8.1.3 Volume, timeline and development phases

The plan is to develop Northern Lights in phases.

Phase 1 is planned with an estimated capacity of 1.5 million tonnes of CO<sub>2</sub> per year. The completion of phase 1 is scheduled for 2024, and it will have a planned operational period of 25 years. The facility will then be able to receive CO<sub>2</sub> from Norcem and, if applicable, Fortum Oslo Varme, totalling around 0.8 million tonnes of CO<sub>2</sub> per year. The residual capacity may be sold to other carbon capture actors. If the entire capacity of 1.5 million tonnes of CO<sub>2</sub> is filled per year throughout the planned operational period, the total amount of stored CO<sub>2</sub> for development phase 1 will be 37.5 million tonnes.

The potential of the storage complex is assumed to be much greater. The operator considers it probable that up to 100 million tonnes of CO<sub>2</sub> could be stored inside the exploitation licence in a potential second phase of the project, but the uncertainty in the build-up of pressure and the lack of well data mean further maturation is required. Experience from the operation of phase 1 will be decisive in determining how much CO<sub>2</sub> can be stored in total in the reservoir.

It may be relevant to drill an additional well during phase 1. This will depend on how the injection in the first well performs and how the CO<sub>2</sub> is distributed in the reservoir. The cost allocation and criteria for triggering state aid for an additional well are regulated in the agreement on state funding for investment and operation. A potential additional well will require consideration by the authorities subject to the CO<sub>2</sub> Storage Regulations Section 4-5 last paragraph.

A potential second phase of Northern Lights, with increased treatment and storage capacity of 5 million tonnes of CO<sub>2</sub> per year is discussed in the plan, but a decision has not been made to implement phase 2. This will not therefore be included in the authorities' consideration of the PDO/PIO for Northern Lights.

### 8.1.4 Investments and economics

The operator estimates the total investments under the development plan to be 5,975 million 2020 NOK. The estimate includes one injection well. An additional investment for an additional well may be necessary during phase 1, estimated to cost 1,140 million 2020 NOK.

The average annual operating costs are estimated to be around 370 million 2020 NOK.

The state's share of investments, operating costs and any additional investments is regulated in the funding agreement, cf. sections 4.2. and 6.2.

The project currently has no expected income. Any income will derive from commercial customers with third-party volumes that buy CO<sub>2</sub> storage capacity from Northern Lights. A potential income stream will depend on when contracts are entered into, the amount of CO<sub>2</sub> transported and stored, and the level and nature of tariffs paid for third-party volumes.

Intergovernmental agreements will have to be entered into on CO<sub>2</sub> received from other countries, which, among other things, set out the division of responsibility in the event of CO<sub>2</sub> leakage, and responsibility for monitoring the storage facility after it shuts down, cf. section 4.3. The project is making active efforts to market the storage facility to potential customers.

Delivery agreements cannot be entered into before the Storting has reached a positive investment decision and the funding agreement has been signed.

The operator estimates the pre-tax present value, without the state's contribution to be -7,941 million 2020 NOK, and the internal rate of return to be negative. The potential additional investment in an additional well is not included in the estimate. Nor does it include the potential income from third-party use of the facility.

### 8.1.5 Shutdown and disposal

Shutdown and removal costs are estimated to be 426 million 2020 NOK. This estimate will increase by a further NOK 179 million if an additional well is necessary.

Shutdown and disposal of the facilities, including the onshore facility, will be outlined in a cessation plan for Northern Lights, and will be conducted in accordance with the regulations applicable at that time. The final plan for the post-operational phase is scheduled to be submitted at the same time as the cessation plan. The equipment

located on Oseberg A will be included in the platform's cessation plan.

### 8.1.6 Impact assessment

An impact assessment (IA) has been conducted for the project. The proposal for the IA programme was distributed for public consultation on 5 February 2018 and the final date for consultative submissions was 9 April 2018. Since the storage location changed from Smeaheia to the Johansen formation, an addition to the IA programme was distributed for public consultation on 17 July 2018 and the final date for consultative submissions was 11 September 2018. The Ministry of Petroleum and Energy adopted the impact assessment programme on 13 August 2019 based on the consultation documents, the consultative submission received and the operator's comments to the aforementioned.

The operator has prepared an IA based on the adopted IA programme. It was distributed for public consultation on 22 October 2019 and the final date for consultative submissions was 15 January 2020. Twenty-five submissions were received.

A zoning plan process, including an IA, has been conducted subject to the Planning and Building Act for the onshore facility and the part of the pipeline covered by the scope of this act. The zoning plan was approved by Øygarden and Fedje municipalities at the end of September 2019.

The main features of the impact assessment are outlined below.

#### 8.1.6.1 Main features of the impact assessment

The petroleum resources the area around in the storage location are highly valuable for Norway. It is likely that the CO<sub>2</sub> will migrate over time into the production licence for the Troll field. However, it is highly improbable that significant volumes will migrate there as long as the Troll field is in production. The CO<sub>2</sub> will in such case be captured in deeper formations and is not expected to come into contact with hydrocarbons in the field. It is deemed highly improbable that CO<sub>2</sub> will migrate to other fields.

The pipeline from the onshore facility to the injection well will largely run through an area where there is limited fishing activity. In areas where the pipeline will lie in a fisheries-intensive area, it will be jetted into the seabed. The control cables will be ploughed or jetted into the seabed along the entire route. It will be possible to trawl over the installation on the seabed.

During the construction and installation period at sea, a restricted/safety zone will be established around the area where the pipeline and cables are to be installed. The operator does not consider it necessary to establish a permanent safety zone around the installation on the seabed.

The storage location will be monitored by means of seismic surveys. The plan is to collect seismic data immediately prior to the start-up of injection, and every few years during the operational period.

The onshore facility is located in an area with existing industrial and development activity. The biggest negative environmental impact, in the opinion of the operator, is linked to the consequences of the establishment of the onshore facility and tanks on land for people's views and enjoyment of the area. To mitigate this, the project will ensure that parts of the outer section of the terrain and coastline remain untouched, to shield the area from the fjord.

The consequences are largely considered to be in the categories minor or no change for other environmental and culture-related assessment topics.

To ensure that third parties and safety are taken into account during the operational phase, zones requiring special consideration have been established in the zoning plan for the reception facility, based on criteria from the Directorate for Civil Protection, and dispersion and risk analyses.

CO<sub>2</sub> and NO<sub>x</sub> emissions will be low during the development and construction phase; estimated at 0.04 million tonnes and 0.1 thousand tonnes, including drilling of the Eos well. Annual CO<sub>2</sub> emissions during the operational phase are estimated to be under one thousand tonnes. An application will be submitted for an emissions permit under the Pollution Control Act in the ordinary manner for all planned, minor discharges to sea related to operations.

Coral deposits have been registered along the west side of Fedje in an area the pipeline must cross. To mitigate this, a survey of the seabed will be conducted in connection with the pipe laying operation, and the route may be altered to avoid conflicts with confirmed coral reefs in the vicinity. The impact is regarded as insignificant.

The development and operation of Northern Lights will generate activity for Norwegian suppliers. The Norwegian share of investments during the construction phase is estimated to be equivalent to 57 per cent. This is estimated to generate an employment effect at a national level of 2,100 full-time equivalents, including direct and indirect



effects. This includes an estimated regional employment effect of 250 full-time equivalents during the construction phase. The operation of the facilities is expected to generate an annual employment effect of around 46 full-time equivalents at a national level, of which 9 full-time equivalents will be at a regional level and 18 at a local level.

The IA includes a summary of the mitigating measures built into the project.

## 8.2 Assessments of the plan for development, installation and operation

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The operator has sent the plan for development, installation and operation to the Ministry of Petroleum and Energy (MPE), the Ministry of Labour and Social Affairs (MLSA) and the Ministry of Climate and Environment (MCE), with a copy to the Norwegian Petroleum Directorate (NPD), the Petroleum Safety Authority (PSA) and the Norwegian Environment Agency (NEA); cf. the CO<sub>2</sub> Storage Regulations sections 4-5 and 6-1. The plan has also been sent to the Ministry of Justice and Public Security (MJPS) since the Directorate for Civil Protection (DCP) is the supervisory authority for large parts of the onshore facility.

The MLSA has submitted the plan to the PSA, which has considered the PDO/PIO within its area of responsibility and pursuant to the CO<sub>2</sub> safety regulations. The PSA has also been in dialogue with the NPD and DCP during its consideration to clarify, among other things, interfaces, total risk analysis and regulations.

The PSA has recommended approval of the plan, but has highlighted a few unclear elements in the development which may impact safety. The PSA will follow this up with the operator during the planning and implementation phase. The MLSA has stated that these are important factors that must be followed up by the operator. The MLSA otherwise refers to the PSA's assessment and has no further comments.

The MJPS has submitted the plan to the DCP. The DCP provided input to the operator at an earlier stage of the process concerning the land use plan and the description of the DCP's official responsibility. The DCP finds that this has been followed up expediently and that any other factors will be followed up in connection with processing of the application for consent for the onshore facility, which the project plans to submit to the DCP in the fourth quarter 2020. The DCP has no further comments. The MJPS endorses the DCP's statement.

The MCE and the NEA have made no comments on the final version of the PDO/PIO. Pursuant to Section 13 of the Pollution Control Act, the pollution control authorities may order a party planning an activity that may cause significant pollution to conduct an impact analysis to map the impact of the pollution. The MCE concludes that the conducted impact assessment is sufficient and that further impact analyses pursuant to the Pollution Control Act are therefore not necessary.

The MPE has submitted the plan to the NPD. The NPD has considered the PDO/PIO within its area of responsibility pursuant to the CO<sub>2</sub> Storage Regulations, i.e. downstream of and including discharge to temporary storage.

The NPD considers it highly probable that the CO<sub>2</sub> volumes included in phase 1 of the project can be injected. The cap rock above the selected reservoir has excellent sealing properties and the risk of leakage to the seabed is deemed very low. The development solution is largely based on known technology and has been extensively assessed. The chosen solution has the flexibility to allow for subsequent expansion.

The NPD has considered the costs of the pipeline, installation on the seabed and well by comparing them with data from other development projects on the Norwegian continental shelf. The estimates are, in the NPD's view, on a par with other projects on the continental shelf.

The petroleum resources in the area are highly valuable. The NPD assumes that the CO<sub>2</sub> will migrate over time into the Troll field production licence. Like the operator, the NPD considers it highly improbable that significant volumes will migrate there as long as the Troll field is in production. The CO<sub>2</sub> will in such case be captured in deeper formations and the NPD does not expect it to come into contact with hydrocarbons in the field. The NPD considers it highly improbable that CO<sub>2</sub> will migrate to other fields.

The NPD highlights certain shortcomings in the reservoir model that are imperative to establishing a sound monitoring plan, predicting CO<sub>2</sub> migration and instigating any mitigation measures in time. The NPD therefore recommends that an approval is subject to a condition that reservoir models are updated. The NPD also recommends that an effective information and cooperation platform is established between the companies and the authorities both during the development and operational phase.

The NPD recommends that the development plan be approved.

### 8.2.1 The Ministry's assessment of the development plan

The Ministry has been in dialogue with the operator about the project prior to the submission of the development plan. The objective of this dialogue has been to ensure that the chosen solution leads to good resource management and that it meets the authorities' requirements.

The Ministry makes references to the comments submitted by the MLSA, MCE and MJPS and recommends that the developer follow up the comments from the PSA, and that the operator incorporates the DCP's input during the planning and implementation phase.

The Ministry also makes reference to the NPD's assessment of the PDO/PIO. Since the project is covered by the state's external quality assurance scheme, cf. section 5, neither the Ministry nor the NPD has conducted their own calculations of the profitability of the Northern Lights subproject. A more detailed assessment of the economy of the project is provided in section 6. The NPD has proposed making it a condition that an updated geological reference model and pertaining dynamic reservoir model are developed. The Ministry agrees with this, and will make this

a condition in the event that the Storting gives its approval following consideration of this white paper and pertaining budget consequences.

The development is not expected to have significant negative impacts on the environment. The development itself will entail a relatively small increase in emissions to air, and, during the operational phase, the project will make it possible to reduce emissions to air from potential emission sources in Norway and abroad. Based on the impact assessment, the public consultation thereto and the operator's comments to the consultative submissions, the mitigating measures are considered acceptable. No factors have come to light to indicate that the development plan should not be approved. The MPE deems the assessment obligation to be met. The principles of sections 8–10 of the Nature Diversity Act are reflected.

Based on the above discussion, the Ministry of Petroleum and Energy endorses the approval of the Northern Lights development. The project can be implemented within acceptable frameworks with respect to health, the environment, safety and fisheries' interests.

## 9 The Ministry of Petroleum and Energy's assessment

According to the UN Intergovernmental Panel on Climate Change and other authoritative sources, carbon capture and storage (CCS) will be necessary to reduce emissions from industry and power production and contribute to negative emissions, thereby reducing global greenhouse gas emissions in line with climate targets along the least-cost path. There are currently relatively few facilities in operation on a global basis, and to make CCS an effective and competitive climate measure, it is necessary to lower costs and improve efficiency. More and new projects that bring learning, technological development and economies of scale will reduce costs.

The current market does not provide industry with sufficient incentives to implement and develop CCS. This is partly due to high investment costs, low income potential in the short term and high risk. Furthermore, the price of emitting CO<sub>2</sub> is lower than the cost of CCS, and the development of climate technology is a public good where those bearing the costs of technology development must share the profits with others. The current state of technology and the market make it necessary for states to contribute to the development of CCS. A Norwegian project will further develop CCS technology and through this reduce costs for future facilities. It will also make it possible to create a market for CCS.

Norway is in pole position to contribute to the development of CCS. For many years, various governments have supported the testing of technology, test and pilot projects, and communicated the role of CCS as an important tool in international climate negotiations. The Government has followed up this work and made targeted efforts in line with the government's strategy for CCS since 2014. These efforts have been fruitful and in this report, the Government now presents a decision-making basis to the Storting for a robust and mature project for full-scale carbon capture, transport and storage in Norway.

The project has followed an industry project maturation process. In line with this process, extensive work has been conducted through different assessments and studies, comprising pre-

feasibility studies, feasibility studies, concept selection studies and front-end engineering design studies. The industrial companies have matured their projects with financial support from the state. A step-by-step approach of this kind means that the project has become more thoroughly defined and specified for each project phase, while reducing uncertainty and establishing more precise cost estimates. In 2018, the Government presented the project to the Storting in Proposition No 85 to the Storting (2017–2018). It was decided that the project would be continued into the front-end engineering design phase. The Government also pointed out important factors to be evaluated in conjunction with the final investment decision:

- Information from the front end engineering and design phase, including cost development, risk, learning effects in relation to use of resources, and whether a carbon capture and storage project in Norway will be an effective contribution to the overall global climate efforts.
- The budgetary constraints that makes it challenging to finance the project without significant funding from other sources.
- That equivalent spending on other climate measures can give much larger emission reductions.

The Ministry believes that the project has matured to the level required for an investment decision. The companies will own and develop the project. The project the Government intends to realise has been named Longship, and comprises carbon capture from Norcem's cement factory in Brevik in Porsgrunn municipality as the initial capture facility, transport of CO<sub>2</sub> by ship to a reception terminal in Øygarden municipality, and by pipeline to a well, in which CO<sub>2</sub> will be injected into a storage formation beneath the seabed. Northern Lights, which is a collaboration between Equinor, Shell and Total, has planned the CO<sub>2</sub> transport and storage part of the project. The Government also wants to realise the carbon capture facility at Fortum Oslo Varme's waste incineration

facility in Klemetsrud in Oslo municipality, on the condition that Fortum Oslo Varme contributes a sufficient amount of own funding and funding from the EU or other sources.

The companies will own and develop the project. State aid agreements have been negotiated regulating cost and risk sharing between the state and the companies. These have been designed to provide good incentives for keeping costs low and keeping to the schedule.

The results of the front-end engineering design (FEED) show that all parts of the project are feasible. Realising carbon capture at Norcem will contribute to developing carbon capture in the cement industry, which represents around seven per cent of global CO<sub>2</sub> emissions. The use of residual heat from cement production reduces energy needs, and it thereby contributes to important technology development. Based on the set criteria for the project, the Ministry of Petroleum and Energy ranks Norcem significantly higher than Fortum Oslo Varme.

Fortum Oslo Varme also contributes important elements to the development of CCS by demonstrating carbon capture in waste incineration, where a large share of emissions come from the combustion of biogenic matter. The project will thus demonstrate how CCS can lead to negative emissions. CCS from Fortum Oslo Varme will also reduce emissions in a sector not included in the European Emissions Trading System, where Norway has ambitious targets.

The economic room for manoeuvre is weakened in the long term by the ongoing Covid-19 pandemic. However, the Government still recommends prioritising Longship. The basis for the Government's decision also shows that the Norwegian CCS project contributes to lowering the long-term costs of reducing climate emissions.

The Government therefore believes that implementing Longship is an effective way for Norway to contribute to reducing global greenhouse gas emissions in the long term at the lowest possible cost. However, the project also entails significant risks and uncertainty. The Government nonetheless believes the risks and uncertainty associated with not implementing the project to be higher.

In the Ministry of Petroleum and Energy's Proposition No 1 to the Storting (2020–2021), the Government will recommend that the Storting allocate funds to ensure the implementation of Longship. The Government will recommend that state aid be awarded in accordance with the negotiated agreements. Furthermore, the Government

recommends implementing Longship with Norcem as the initial carbon capture project, followed by Fortum Oslo Varme's carbon capture project, on the condition that they receive sufficient own funding and funding from the EU or other sources. Fortum Oslo Varme must clarify whether it wants to implement the project on these conditions within three months of the funding decision from the second round of calls issued by the EU's Innovation Fund, but no later than 31 December 2024. State aid awarded to Fortum Oslo Varme is limited to a maximum of NOK 2 billion in investments and NOK 1 billion in operating costs. The Government will also propose necessary authorisations.

The total costs for the project are estimated to be NOK 25.1 billion. The Government's recommendation will have overall expected costs for the state of NOK 16.8 billion with a cost frame of NOK 13.1 billion and operating support of NOK 6.1 billion. This means that the state expects to cover around two thirds of the project costs.

Longship is complex. The costs are high and the state bears risk through funding agreements with the industrial companies. There is also uncertainty beyond the state's control that affects whether the project succeeds, including developments in the climate policy of other countries and the number of subsequent projects implemented.

Risk is still associated with a number of factors, despite the fact that the technology in the individual parts of the project has been rigorously tested. The state bears a substantial share of this risk. There will be risk associated with the interfaces between the different parts of the project. There will also be risk related to cost development, project schedules and whether all parts of the project function as intended. It is a matter of striking a balance between reducing risk and keeping costs at a minimum. If Longship is to have a good demonstration effect, the costs must be kept as low as possible. We must therefore expect, for example, to run into problems in connection with start-up of operations and to experience periods with low capture rates. The learning achieved from resolving such problems will form an important part of the project.

At the same time, a successful Norwegian project for carbon capture, transport and storage will make a significant contribution to the development of CCS as an effective climate measure, and lead to technological development in an international perspective. Longship demonstrates that CCS is safe and feasible, it facilitates learning and cost reductions for subsequent projects and it

Table 9.1 Estimated expected costs for Northern Lights, Norcem and Fortum Oslo Varme (P50)<sup>1</sup>

Bill. 2021 NOK with exchange rates per 2 June 2020	Expected costs (P50)			Parliament's cost frame (P85)
	Total QA2 <sup>2</sup>	Industry/ other sources	State aid	State aid
Northern Lights	14.2	3.8	10.4	
Norcem	4.5	0.7	3.8	
Fortum Oslo Varme	6.4	3.8 <sup>3</sup>	2.6 <sup>4</sup>	
Total	25.1	8.3	16.8	Investments: 13.1 Operation: 6.1

<sup>1</sup> Expected costs do not include additional funding for captured CO<sub>2</sub> that is not subject to the European Emissions Trading System, equivalent to the allowance price per tonne CO<sub>2</sub> excluding a potential Carbon tax per tonne CO<sub>2</sub>.

<sup>2</sup> Construction and ten years' operation.

<sup>3</sup> Based on the external quality assurers' estimate excluding the Government's recommendation

<sup>4</sup> Based on the external quality assurers' estimate excluding the Government's recommendation

establishes infrastructure that other projects can use. Hence, the threshold for establishing new carbon capture projects will be lowered. Longship can also facilitate business development through protecting, restructuring and creating new industry and business activities in Norway. The project will employ around 1,500–3,000 full-time equivalents in the construction phase, depending on whether Fortum Oslo Varme is implemented. According to industry stakeholders, the project will create around 170 jobs during the operational phase.

If the world is to reach the global temperature targets, there is a need for international cooperation on technological development and emission reductions. This is also important in order for Longship to have the desired effect. The project is a contribution to an international collective effort to develop a necessary climate measure, and will only succeed if subsequent projects use the infrastructure and learning it generates.

The project should first and foremost be considered on the basis of whether it contributes to reaching the targets set for the project and the Government's work on CCS. In the short term, this could be measures that lead to a greater reduction in emissions for equivalent spending, but a short-term national emissions reduction is not the main aim of the project. A number of analyses show that CCS is a necessary and cost-effective climate measure in the long term. The Ministry is of the opinion that Longship facilitates cost reductions that can contribute to making CCS an effective climate measure if other countries also

follow suit with concrete policies. The project underlines the need for and value of international cooperation on technological development and emission reductions.

Northern Lights' work on creating a market for CCS in Europe demonstrates that several projects are considering using the infrastructure Norway has developed. The state aid agreement for the transport and storage part of the project has been designed to bring in new projects. All Northern Lights' revenues will come from CO<sub>2</sub> storage from new projects. Northern Lights therefore has a strong incentive to develop the market for CO<sub>2</sub> storage. The Ministry considers it important that Northern Lights' capacity is utilised by industry stakeholders that are not financed directly by the Norwegian state. If this succeeds, it will be clear evidence that the project has had the desired effect.

We are dependent on the EU and other European nations also contributing to developing CCS as a climate measure. The Government therefore has a clear expectation that Europe will now follow suit and that the remaining capacity in the storage facility will be utilised by third parties that are not directly financed by the Norwegian state.

The Government will continue to contribute to developing technology for carbon capture, transport and storage. The Government will also work to build on established policy instruments and schemes and will:

- Participate in designing policy and instruments at the European level to facilitate CCS in Europe.

- Continue CLIMIT and Technology Centre Mongstad as key instruments for the CCS efforts.
- Follow up the benefit realisation work in Longship in close cooperation with the industrial companies and take steps to ensure that knowledge, learning and efficiencies from the project make positive contributions to the development of CCS in Europe and the rest of the world.
- Contribute to the possibility of using the CO<sub>2</sub> storage infrastructure in other projects through enhanced cooperation with relevant European countries.
- Require that any future CCS projects in Norway will have to compete for investment and

operational funding from general funding schemes such as Enova and the EU's Innovation Fund. The state will not engage in direct negotiations on state aid with individual stakeholders.

- Follow up the hydrogen strategy and Longship with a dedicated roadmap for hydrogen.

The Ministry of Petroleum and Energy

r e c o m m e n d s :

that the recommendation from the Ministry of Petroleum and Energy on Longship carbon capture and storage, dated 21 September 2020, be submitted to the Storting.

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**Appendix 1****XVI**

**Power of attorney to enter into agreements and incur obligations for the state for Longship (Carbon capture and storage)**

The Storting agrees that the Ministry of Petroleum and Energy in 2021 may:

1. enter into agreements with Norcem and Northern Lights to establish and operate their parts of Longship (Carbon capture and storage) within a total cost frame of a. 14 700 mill. 2021 NOK in investments (CAPEX) b. 6 600 mill. 2021 NOK in operating expenses (OPEX) for up to ten years.
2. enter into agreements where the expenses are to be shared between the state, Norcem and Northern Lights in accordance with the principles described in more detail in Chapter 1840 Carbon capture and storage, item 72 Longship – Carbon capture and storage and in Meld. St. 33 (2019–2020) Report to the Storting (white paper) Longship – Carbon capture and storage, where the share of the state as a maximum constitutes up to
  - a. 11 100 mill. 2021 NOK in investments (CAPEX)
  - b. 5 100 mill. 2021 NOK in operating expenses (OPEX) for up to ten years with the addition of potential additional funding for captured CO<sub>2</sub> that is not subject to the European Emissions Trading System, equivalent to the allowance price per tonne of CO<sub>2</sub> excluding any potential carbon tax per tonne of CO<sub>2</sub>.
3. enter into an agreement with Fortum Oslo Varme conditional on sufficient own funding and funding from the EU or other sources in accordance with the principles described in more detail in Chapter 1840 Carbon capture and storage, item 72 Longship – Carbon capture and storage and in Meld. St. 33 (2019–2020) Report to the Storting (white paper) Longship – Carbon capture and storage, where the share of the state as a maximum may constitute up to
  - a. 2 000 mill. 2021 NOK in investments (CAPEX)
  - b. 1 000 mill. 2021 NOK in operating expenses (OPEX) for up to ten years with the addition of a potential additional funding for captured CO<sub>2</sub> that is not subject to the European Emissions Trading System, equivalent to the allowance price per tonne of CO<sub>2</sub> excluding any potential carbon tax per tonne of CO<sub>2</sub>.
4. enter into an agreement with Northern Lights to incur obligations for the state for costs in the event of CO<sub>2</sub> emissions of up to 80 per cent of the allowance price up to and including 40 EUR per tonne and 100 per cent of the part of the allowance price that exceeds 40 EUR per tonne of CO<sub>2</sub>, for the proportionate share of captured CO<sub>2</sub> in the funding period of up to ten years from Norcem and, if applicable, Fortum Oslo Varme of the total amount of stored CO<sub>2</sub> in the storage.
5. enter into an agreement with Northern Lights to incur obligations for the state in the funding period of up to ten years for up to 80 per cent of the costs of preventive and corrective measures for the agreed annual storage volume of 1.5 million tonnes of total storage capacity for CO<sub>2</sub>, in the event of extraordinary events with the risk of CO<sub>2</sub> leakage from the storage or damage to the environment or life and health.
6. enter into an agreement with Northern Lights to incur obligations for the state after cessation of operations of the CO<sub>2</sub> storage, for the proportionate share of captured CO<sub>2</sub> during the funding period of up to ten years from Norcem and, if applicable, Fortum Oslo Varme of the total amount of stored CO<sub>2</sub> in the storage, with up to 80 per cent of the costs of
  - a. any preventive and corrective measures in the event of extraordinary events with the risk of CO<sub>2</sub> leakage from the storage or damage to the environment or life and health
  - b. cessation, monitoring and removal after closure of the storage.

**Petition Resolution**

18. The Storting charges the Government to initiate negotiations to enter into the transport and storage partnership with state ownership shares in the event of a possible expansion of the infrastructure to more than 1.5 mill. tonnes of CO<sub>2</sub> per year.
  19. The Storting requests the Government to report to the Storting on how the state may take part of the income from future exploitation permits for CO<sub>2</sub> storage. The assessment shall include taxation and alternatives for state ownerships, including the SDFI model.
  20. The Storting requests the Government to report to the Storting how Longship is organised, who owns the technology that is developed and demonstrated, and how to facilitate for the society to get the most out of the technology being developed and demonstrated through state funding.
  21. The Storting charges the Government to facilitate so that as much as possible of the technology that is being developed and demonstrated in Longship and other learnings from the project will be utilised in Norway.
  22. The Storting requests the Government to closely monitor the cost and risk control in Longship, in such a way that potential significant negative deviations in the projects are identified early, and that the Government utilises the agreement's room for manoeuvre to keep the state's costs as low as possible.
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