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Industrial opportunities and employment prospects in large-scale CO_2 management in Norway

Authors: Sigmund Ø. Størset, Grethe Tangen, Ove Wolfgang og Gunnar Sand

Special advisors:
Johan E. Hustad, NTNU, Director of NTNU Energy and
Nils A. Røkke, Executive Vice President Sustainability- SINTEF

Oppdragsgivere:
Confederation of Norwegian Enterprise (NHO), the Confederation of Trade Unions (LO), the United Federation of Trade Unions, the Federation of Norwegian Industries, the Norwegian Oil and Gas Association and the Industri Energi trade union.

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Preface

The report *Industrielle muligheter og arbeidsplasser ved storskala CO_2-håndtering i Norge*, (Industrial opportunities and employment prospects in large-scale CO_2 management in Norway) was written by SINTEF with the assistance of NTNU on behalf of the Confederation of Norwegian Enterprise (NHO), the Confederation of Trade Unions (LO), the United Federation of Trade Unions, the Federation of Norwegian Industries, the Norwegian Oil and Gas Association and the Industri Energi trade union. The objective of this work was to demonstrate the potential opportunities for industry linked to a realisation of full-scale CO_2 management in Norway.

The work was carried out within specified time and cost restraints, with consequent limitations. Emphasis has been placed on obtaining input from Norwegian industrial operators. In spite of this, it has not been possible to obtain well-documented figures applying to all the aspects we were interested in. This means, among other things, that estimates have been used in cases where reference data are lacking. We have made a point of specifying this in the report.

Our studies show that it is possible to improve the competitiveness of existing jobs and create new ones by investing in full-scale CO_2 management. How big the impact will be depends on to what extent one assumes that CO_2 management will be implemented in Norway and Europe. To demonstrate the potential effects of Norwegian commitment to CO_2 management, we have studied the potential linked to three different scenarios whereby the CO_2 market in Europe may develop; a "low-level" scenario in which CO_2 is only implemented in power-intensive industry in Europe, a "moderate-level" scenario based on the 2-degree scenario of the IEA, and a "high-level" scenario based on the IPCC's 2-degree scenario, in which CO_2 management plays a crucial role.

Nils A. Røkke
Executive Vice President Sustainability, SINTEF

Johan E. Hustad
Director, NTNU Energy

Sigmund Ø. Størset
Project Manager, SINTEF

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1 Executive Summary

The world needs CO_2 management (CCS – Carbon Capture and Storage) if it is to achieve the ambitions of the Paris Agreement. The degree of emission reduction which must be achieved by means of CO_2 management varies from one analysis to another, but according to the International Energy Agency (IEA) and the United Nations Intergovernmental Panel on Climate Change (IPCC) it is between 12% and 20%, and increases if we progress from the 2-degree goal to the 1.5-degree goal. Alternative ways of achieving the same emission reductions are uniformly more expensive, if at all existing. Some industrial emissions cannot be curbed in any other way than by means of CO_2 management.

Global emissions of greenhouse gases increased by 1.4% in 2017, and a number of major countries will not reach their emission peak until after 2020. This will make the task even more challenging, and will call for political proactivity which is crucial for success. Norway has endorsed the Paris Agreement, is a participant in the EU's quota system and has committed itself to achieving the climate goals for 2030 in co-operation with the EU. This means that Norwegian emissions of greenhouse gases must be reduced by at least 40% by 2030. The country's obligations towards the EU, which are also legally established in the Norwegian Climate Act, will establish the basis of Norwegian policy in coming years. The long-term and even more ambitious goals for emission reductions in the EU roadmap for 2050 acquire special importance in the light of the need for CCS.

The Norwegian full-scale project for CO_2 management is planned to store up to 1.4 million tonnes of CO_2 per year and is unique in a global context. It will be the first project that captures CO_2 from both process industry and waste management, and combines several emission sources using ships for transport between emission sources and CO_2 storage facilities. The project could potentially be the first step towards the establishment of the Norwegian continental shelf as a large-scale centralised storage facility for European CO_2. This in itself can become a significant business area. In future CCS projects, concepts developed for the full-scale project may be duplicated and combined in new ways.

The socio-economic profitability of the full-scale project could be affected by a number of factors, among them the cost of alternative climate initiatives, economies of scale and learning effects. CO_2 management may also contribute to prolonging the market for Norwegian natural gas by creating framework conditions for realising the clean, full-scale production of hydrogen. In this feasibility study we attempt to quantify the industrial opportunities that investment in CO_2 management may present, assuming that Norway, Europe and the rest of the world achieve the ambitions of the Paris Agreement and that CCS becomes a part of the climate solution, as described by the IPCC and IEA. To do so, we have defined three scenarios for the development of CCS in Europe and have studied the scope of opportunity for Norwegian operators in these scenarios. The opportunities will be linked to:

- **The Norwegian process industry,** whose goal is to achieve zero emissions in 2050 while doubling productivity. CO_2 management in Norway is a prerequisite for achieving the goal. The realisation of such an ambition will increase the competitiveness of more than 30,000 existing jobs in Norway. It could also contribute to an increase in indirect employment from about 60,000 at present.

- **Norway as a host nation for international industry.** With the proximity of infrastructure for CO_2 management, Norway can become an attractive host nation for industry, thanks to the greater potential for manufacturing emission-free products. In combination with the availability of reasonably-priced renewable energy, this will potentially form the basis for new industrial establishment in Norway at a time when the proportion of costs resulting from the workforce is dropping.

- **Hydrogen production from natural gas using CCS***.* In Norway, investment in hydrogen production from natural gas using CCS can result in sales of NOK 220 billion in 2050, and between 25,000 and 35,000 employed. A precondition for realising a hydrogen value chain is, among other things, that adequate storage capacity for CO_2 is established in the North Sea.

- **A market for CO_2 management in Europe,** which will potentially involve from 30,000 to 40,000 jobs directly linked to CO_2 management in 2030 and from 80,000 to 90,000 in 2050. Norwegian industrial actors are well-equipped to increase their value generation in such a market.

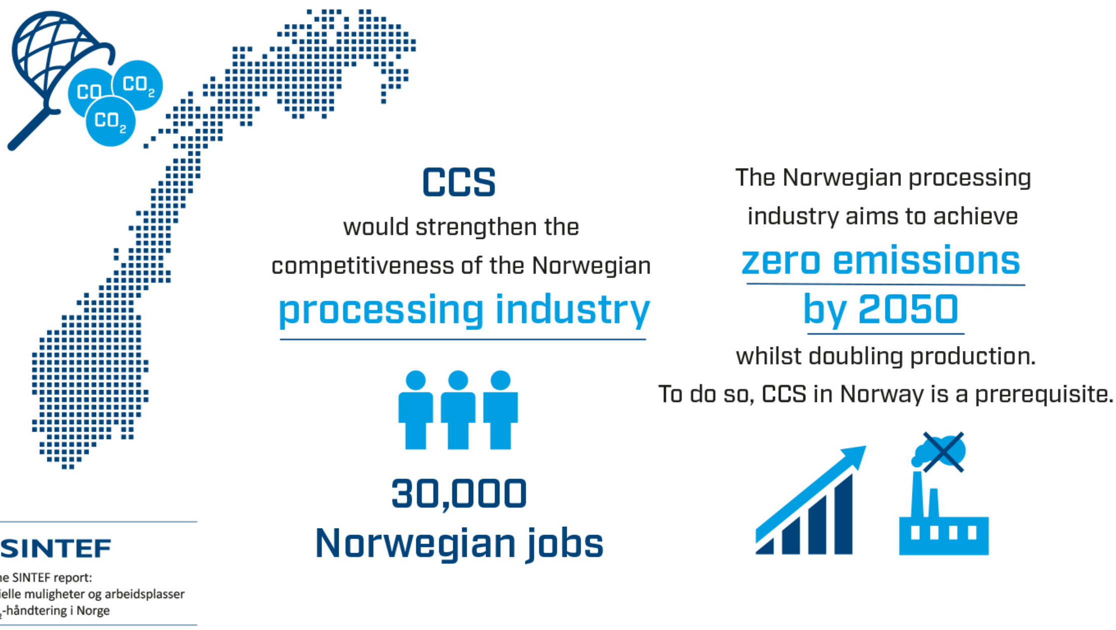
- **A centralised storage facility for CO_2 in the North Sea** consisting of several storage locations, which can contribute significantly in the petroleum industry in which Norway has already invested considerably and generated enormous revenues and in which investment is needed to maintain value generation as oil production declines. In 2050, Norway may have more than 10,000 jobs directly linked to CO_2 storage in the North Sea, while the ripple effects of the industry could employ a further 5,000 to 10,000 people in Norway.

- **Transport of CO_2 by ships,** which in 2050 can entail a need for a fleet of more than 600 vessels and can provide employment for 8,000 to 10,000 people. Norwegian shipbuilders, shipping companies and associated service activities are well placed to participate in this market.

- **The market for CO_2 capture technology and installations,** which can reach a scale of over NOK 450 billion in Europe in 2050 and employ more than 40,000 people. Norwegian-developed technology will be capable of competing in this market, and also has a potential for global expansion.

- **The value generation in the full-scale project itself.** In addition to the ripple effects, the Norwegian full-scale project itself will be capable of employing up to 5,000 full time equivalent years, mainly in jobs in Norway. Technology development through the full-scale project will potentially position Norwegian operators in relation to the international market and give them competitive advantages compared with operators in countries that do not have a domestic market for such technology. There is considerable potential for proliferation of technology and know-how from the full-scale project, which will provide crucial lessons for the development of the next generation of CO_2 management projects.

All in all, CCS stands out as a necessary condition for securing value generation and jobs in Norway at a time when the international community has committed itself to limiting global warming to 2 degrees or preferably lower. An early commitment to CO_2 management in Norway will be an investment in infrastructure for industrial development leading to a low-emission society and will potentially enhance the future competitiveness of Norwegian industry. Norway has natural advantages in the form of geological structures in the North Sea that can sequester a large part of Europe's CO_2, industrial advantages through its strong maritime and offshore-related industry, and expertise-related advantages as a leader in several aspects of the value chain related to CO_2 management.



2 Full-scale CO_2 management in Norway can pave the way for a green transition

2.1 CCS is an important aspect of the climate change solution

The United Nations Intergovernmental Panel on Climate Change (IPCC) maintains that the world in all probability needs a rapid and comprehensive development of CCS (Carbon Capture and Storage) if there is to be any possibility of avoiding global warming by more than 2 degrees (the 2-degree target)[1]. A large proportion of the emission reductions must take place in industry, with the solution being new process technology and the use of CCS.

Norway has been a pioneer in the field of CO_2 management and has more than 20 years' experience in the capture and storage of CO_2 on an industrial scale through the Sleipner and Snøhvit field developments (Attachment A2). In collaboration with industry, the authorities have played a leading role in developing know-how and technology, among other things by way of Test Centre Mongstad (TCM) and the CLIMIT programme for research and innovation, managed by the Research Council of Norway and Gassnova (Attachment A2).

A solid knowledge base, combined with significant storage capacity for CO_2 on the Norwegian continental shelf and a petroleum industry with infrastructure and expertise directly applicable to CCS, puts Norway in a position to develop new concepts for the capture and storage of CO_2. This is essential for the reduction of greenhouse gas emissions in Norway and internationally. Norwegian industry is also ready for the necessary transition to emission-free products, whether they be cement, fertiliser or energy[2]. CCS can be crucial to enhancing the competitiveness of Norwegian industry in a low-emissions society.

2.2 The Norwegian full-scale project for CO_2 management

The Norwegian Government's ambition is to realise at least one full-scale demonstration installation for CO_2 management, cf. the Sundvollen declaration. The feasibility study presented by the Ministry of Petroleum and Energy (OED) in 2016 recommends a model that will provide robustness and flexibility; capture of CO_2 from three industrial sources, transport by ship from sources to hubs, interim storage at Kollsnes and pipeline transport to an offshore storage location in the North Sea[3], see Figure 1.

[1] IPCC Fifth Assessment Report, IPCC. 2014.
[2] Veikart for prosessindustrien (Road-map for the process industry), the Federation of Norwegian Industries. May 2016.
[3] Mulighetsstudier av fullskala CO_2-håndtering i Norge (Feasibility study for full-scale CO2 management in Norway), OED. 2016.

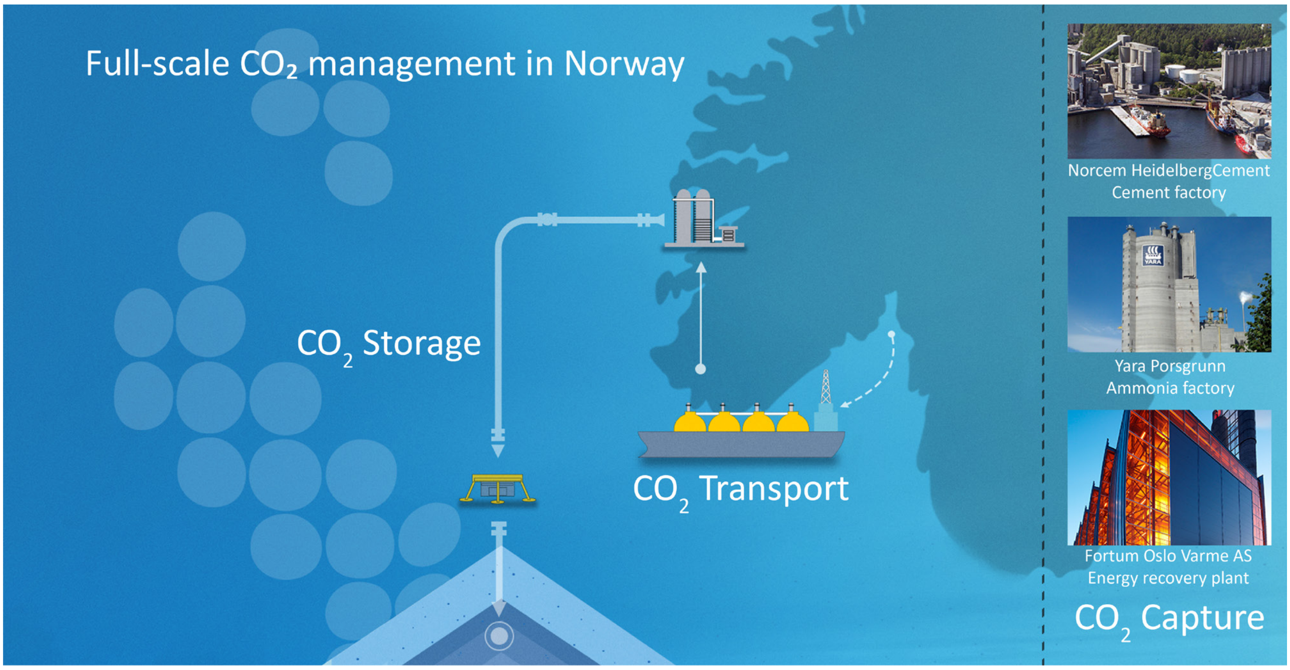


Figure 1. Illustration of the Norwegian full-scale project for CO_2 management (Source: Gassnova).

The Norwegian full-scale project is the world's first CCS project intended to manage CO_2 from several independent sources for permanent storage, amounting to 1.4 million tonnes of CO_2 annually. The project has a number of other elements that make it unique:

The world's first cement factory using CCS and with potential for zero-emission products
Norcem (Norcem Brevik/Heidelberg Cement) has commenced a full-scale project to capture 400,000 tonnes of CO_2 per year from cement production at the factory in Brevik[4]. This constitutes about 50% of the factory's emissions. The project has been in progress since 2010. From 2013 to 2017, Norcem carried out a large test project with support from Gassnova/CLIMIT in which four different technologies were tested on actual exhaust gas emanating from cement production. The vision is zero emissions from concrete products throughout the life cycle of the products by 2030. Based on the results of the CLIMIT project, Norcem has decided to go ahead with a concept based on amine technology for CO_2 capture from exhaust gas. The technology has been developed by Aker Solutions and tested for more than 8,000 hours at the factory in Brevik. The use of surplus heat from the production process makes this an energy-efficient carbon capture installation. Norcem has used significant amounts of bio-based fuel for many years. If the use of bio-based fuel in production is increased further, Norcem's goal of zero CO_2 emission from its products will be within reach.

[4] Presentation by Per Brevik, Norcem, at the Federation of Norwegian Industries' Carbon Capture Seminar. 19 March 2018.

Figure 2. The Klemetsrud plant is one of three industrial CO_2 sources in the Norwegian full-scale project. (Source: Fortum Oslo Varme)

The first energy recovery installation for waste treatment with full-scale CCS and contribution to negative CO_2 emissions

The CCS project at Klemetsrud (Fortum Oslo Varme) plans to remove 90% of CO_2 emissions from the incineration of biological (58%) and fossil fuel material[5]. Its capacity is 400,000 tonnes per year, with potential for increase. In the feasibility study, Klemetsrud assessed two capture technologies tested on an industrial scale at TCM: amine scrubbing and scrubbing with chilled ammonia. Both incorporate heat recovery to maintain or increase deliveries to the district heating system and energy integration for optimal energy consumption. CO_2 capture from waste incineration leads to a net reduction in CO_2 and results in negative emissions in accounting. Globally, 1.3 billion tonnes of domestic waste are produced annually and the amount is on the increase. There is therefore significant potential for reducing total global emissions by using CCS in waste incineration. Climate-friendly treatment of residual waste may also potentially be a key to meeting the challenges connected with global urbanisation, because all towns and cities will need to find solutions to this problem.

Sustainable fertiliser production crucial to food production for a growing population

Yara is an international company that produces fertiliser and has produced ammonia in Porsgrunn for 50 years. The raw material, ethane, is converted to hydrogen, which is the active element in ammonia (NH_3). Some ethane is also combusted to produce reaction heat. A total of 800,000 tonnes of CO_2 are produced annually from two point sources: exhaust gas and process gas. Of this, about 200,000 tonnes are recovered, purified and sold for industrial use, among other things in foodstuffs. The conceptual studies indicate that about 300,000 tonnes can be recovered for CCS purposes. The capture installations will be very large and must be integrated closely into existing factories while production is in progress. Because of this the development of only one of the point sources has been considered within the framework of the full-scale project. The process gas source can be recovered using known technology. The exhaust gas can be recovered by absorption using chilled ammonia, but the installation must be upgraded in relation to the existing plant. The concept studies show that the installations for producing CO_2 in liquid form and CO_2 tanks for interim storage involve investment costs which are almost as high as that of the CO_2 capture installation itself.

[5] Presentation by Pål Mikkelsen, Fortum Varme Oslo, At the Federation of Norwegian Industries' Carbon Capture Seminar. 19 March 2018.

Figure 3. Transport of CO_2 by ship provides flexibility (Source: Larvik Shipping).

Flexible infrastructure with the world's first network for transport of CO_2 by ship
In connection with the full-scale project, CO_2 will be transported aboard ships in liquid form at moderate pressure (15 bar pressure and -26°C) from the source locations to a CO_2 hub at Kollsnes, west of Bergen. From here the CO_2 will be temporarily stored and transported by pipeline to the reservoir where it will be injected. Norcem's and Yara's plants are located close to docks. A process installation will be set up at each plant to cool the CO_2 to liquid form. There will also be storage tanks in which to store the liquid CO_2 until the next ship departs. Similar infrastructure will be established in Oslo to handle CO_2 from the Klemetsrud plant. Here, CO_2 will be transported in zero-emission road tankers or pipelines to the quayside. An interim storage facility will also be needed at Klemetsrud.

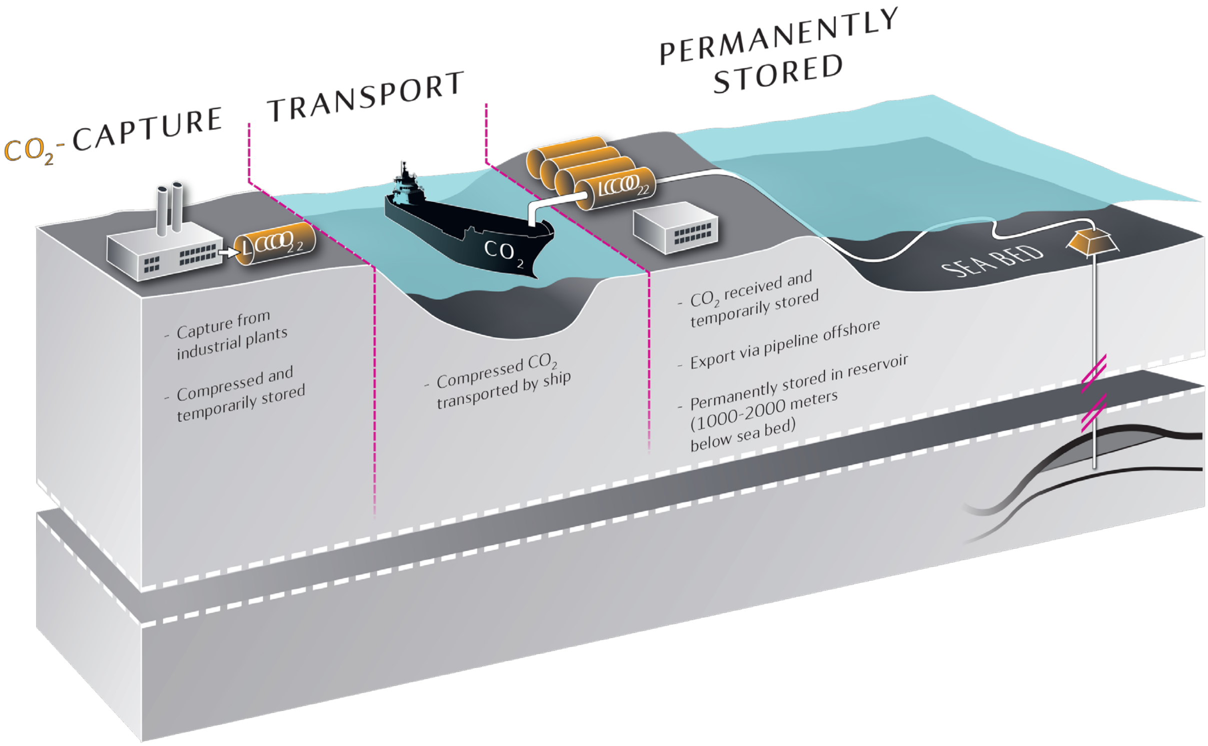


Figure 4. Illustration of CO_2 capture, transport and storage in Norway (Source: Statoil).

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First steps towards establishing centralised CO_2 storage on the Norwegian continental shelf

The storage concept of the full-scale project will be developed by Statoil in collaboration with Shell and Total[6]. Smeaheia, to the east of the Troll field, is an area of porous, water-saturated sedimentary rocks, so-called saline aquifers, suitable for permanent CO_2 storage. Harder rocks above the porous formations function as a cap rock. An application will probably be submitted to use this reservoir, pursuant to the provisions of the storage regulations, but the use of other locations in the area is also being considered. The 2016 feasibility study indicates that Smeaheia can store up to 100 million tonnes of CO_2, but the anticipated hydrocarbon production from the Troll field may result in reduced storage capacity.

The potential for acquiring European clients will be an important success criterion for a Norwegian storage project. Statoil has also recently received approval for an application to the EU for a Project of Common Interest (PCI) relating to CO_2 transport using ships between the UK, the Netherlands and the North Sea[7]. A PCI is an instrument aimed at supporting the establishment of European infrastructure projects in the energy sector involving several countries (see Chapter 4, European funding mechanisms).

For a selected storage location, one or more wells will be drilled with the necessary equipment and subsea installations for injection of liquid CO_2. Temporarily stored CO_2 must be transported by pipeline from the onshore facility to the injection well and a number of possible routes are being considered. Pipelines are designed for a technical life-span of 25 years and the likely diameter will be from 8 to 14 inches.

A phased development of the storage project is planned, including the construction of an onshore facility with interim storage and a pipeline. The capacity for reception and handling in Phase 1 is 1.5 million tonnes of CO_2 per year, with a possibility of expansion in Phase 2 to 4 million tonnes. Available infrastructure with additional capacity can facilitate the reception of CO_2 from other countries, development of existing industry and the establishment of new industry in Norway. Storage of 4 million tonnes of CO_2 per year entails operation for almost 25 years if the storage capacity is approaching 100 million tonnes. In comparison, 1 million tonnes of CO_2 are stored annually at the Sleipner field, and 0.7 million tonnes at Snøhvit, and to date more than 20 million tonnes of CO_2 have been stored in these projects.

In the long term, the amount of CO_2 Captured from Norwegian and in time European sources could exceed 4 million tonnes per year. This will demand further expansion of the reception and handling capacity. The Norwegian Petroleum Directorate has documented that the North Sea in particular lends itself well to the storage of large amounts of CO_2[8]. The storage capacity can be expanded by developing more storage locations which in combination will form a centralised storage facility for CO_2 on the Norwegian shelf.

The status of the full-scale project

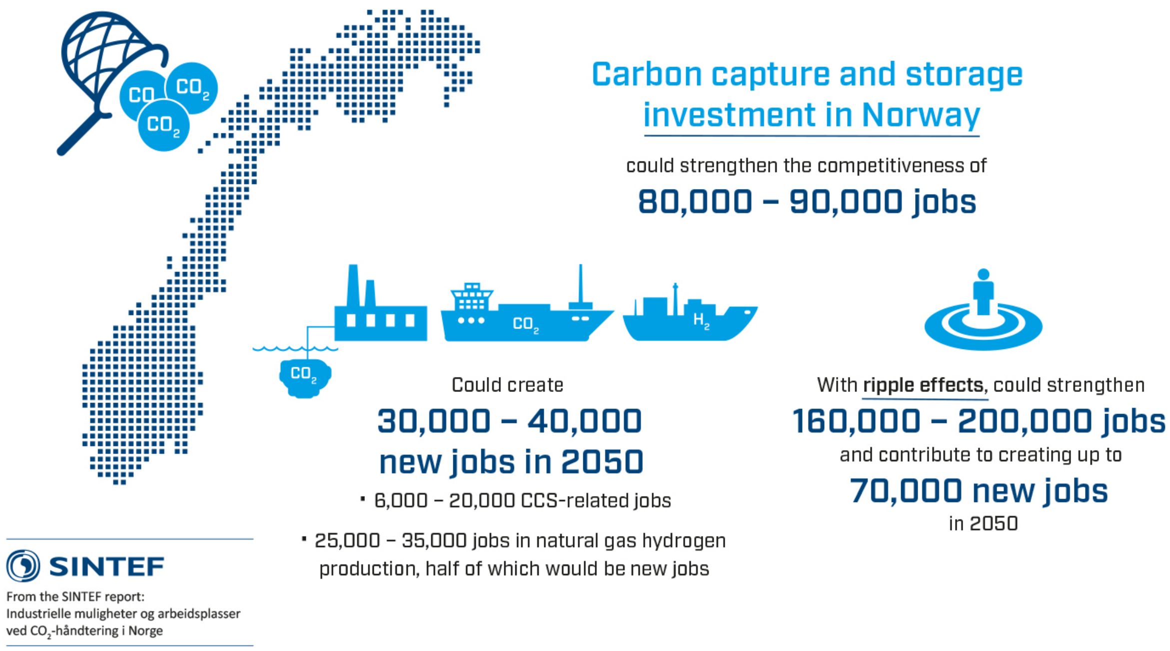
The 2016 feasibility study shows that CO_2 capture is technically feasible at the three industrial sources. In the autumn of 2017, the capture operators submitted their concept studies, while Gassco submitted a study for ship transport. In June 2017, Statoil was assigned to study possible locations for a reception facility, as well as for interim storage and pipeline transport of CO_2 to permanent subsea storage. In the autumn of 2017 the assignment was expanded to include transport by ship of liquid CO_2 from the capture operators' local temporary storage. A joint venture agreement between Statoil, Shell and Total for the implementation of the planning project was signed in October 2017.

[6] Northern Lights – Reception and permanent storage of CO_2, Shell, Total, Statoil. January 2018.
[7] Projects of Common Interest, Global CCS Institute. September 2017.
[8] CO_2 Storage Atlas for the Norwegian continental shelf, the Norwegian Petroleum Directorate. May 2014.

In connection with the Norwegian National Budget for 2018 it was decided that the Government would submit the full-scale project in its entirety to Parliament no later than the presentation of the revised budget in May 2018. An assessment will then be performed of how the project shall be continued. The original project plan is based on the completion of the decision-making foundations for capture, transport and storage by the autumn of 2018, so that Parliament can make an investment decision in the spring of 2019. It is planned that the installation shall then be put into operation in 2022.

3 CCS for increased value generation and employment in Norway

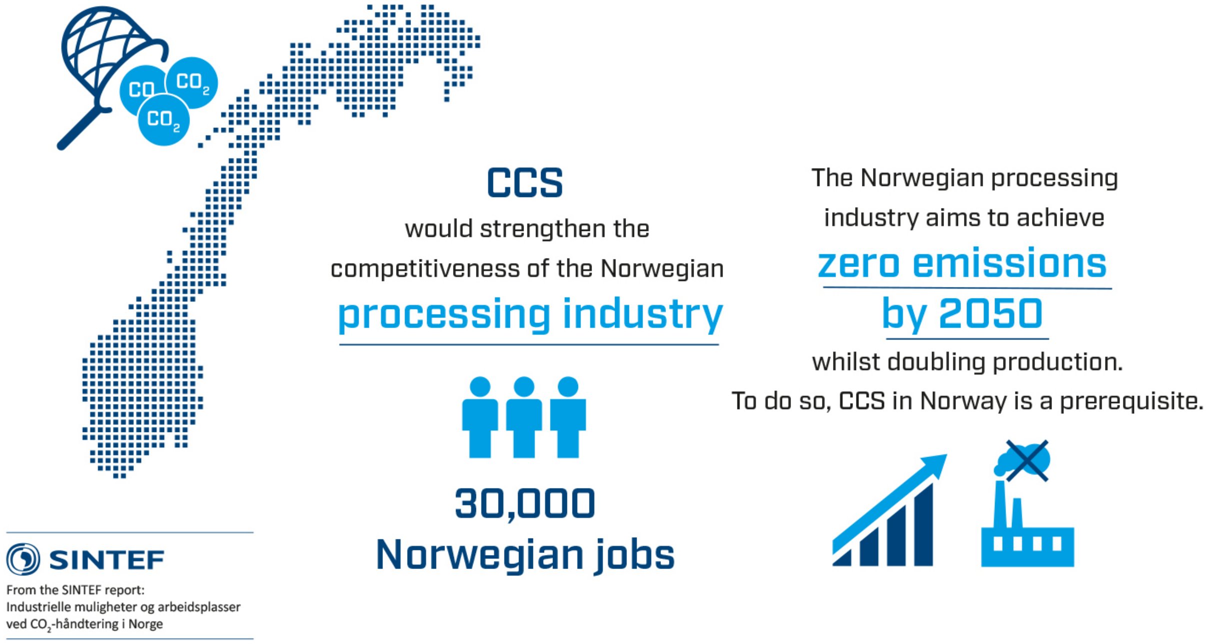
A commitment to CO_2 management in Norway could improve the competitiveness of between 80,000 and 90,000 existing jobs in Norway in the process industry, natural gas operations and shipping. If we include jobs indirectly linked to these industries, the project could strengthen the competitiveness of a total of between 160,000 and 200,000 jobs (direct and indirect employment). It could create between 30,000 and 40,000 new jobs in the period up to 2050. Between 6,000 and 20,000 of these could be linked to the CO_2 management industry and technology among Norwegian industrial actors. Between 25,000 and 35,000 could be connected with the production of hydrogen from natural gas using CO_2 management. Half of these could be connected with natural gas operations, while the remainder would be new jobs linked to the production of hydrogen and CO_2 management. The total number of jobs in Norway directly and indirectly linked to these new industries could be close to 70,000 in 2050.



3.1 Industrial opportunities resulting from a commitment to CCS in Norway

CO_2 management for increased industrial productivity and zero emissions in the process industry

The goal of the Norwegian process industry is to achieve zero emissions in 2050 while doubling production. CO_2 management in Norway is a prerequisite for achieving the goal. The realisation of such an ambition will increase the competitiveness of more than 30,000 existing jobs in Norway. It could also contribute to an increase in indirect employment from about 60,000 at present.



The Norwegian process industry is among the best in the world. Since 1990, it has cut its emissions by 40%, while production has increased by 37%.[9] In the same period, overall emissions of greenhouse gases in Norway have increased. This demonstrates an ability for readjustment and increased competitiveness in the process industry. The industry is making a major socio-economic contribution in Norway: The Norwegian process industry is responsible for 1.7% of Norway's Gross National Product (GNP) and employs just over 30,000 people, or 1.2% of the Norwegian workforce – many of these through cornerstone companies in local communities.

At the present time, the Norwegian process industry is responsible for around 20% of total Norwegian greenhouse gas emissions, just over 11 million tonnes of CO_2 equivalents (2014)[10]. In May 2016, a work group set up by the Federation of Norwegian Industries published a roadmap for the process industry which provided input to the Government's expert committee on green competitiveness[9]. According to the roadmap, the goal of the industry is zero emissions in 2050, while productivity increases to approach twice the current level. CO_2 management is a precondition for achieving these goals: according to the roadmap, 60% of emission reduction shall take place by means of CCS, and this will become a condition for continued growth in the process industry.

A significant part of CO_2 emissions do not originate in power and heat generation, and cannot therefore be removed by using renewable energy generation or biofuels. An example is cement production, in which almost two-thirds of the emissions result from the refining of the raw material, limestone. The same applies to the incineration of sorted residual waste which cannot and should not be subjected to material recycling. Capture of CO_2 from the production process is the only technology that can eliminate such emissions. If Norway establishes infrastructure for CO_2 management that can be used by the process industry, it will present entirely new opportunities for the production of climate-friendly competitive products.

CO_2 management in Norway can therefore contribute to the retention of 30,000 jobs in the process industry. Growth of the industry approaching a doubling in productivity in 2050 can also contribute to the

[9] Veikart for prosessindustrien (Road-map for the process industry), the Federation of Norwegian Industries. May 2016
[10] The report of the Norwegian Government's expert committee on green competitiveness. October 2016.

creation of new jobs. At the same time, doubled productivity could result in an approximate doubling in sales, which could both provide increased revenue to the Norwegian state by way of taxes and levies, and contribute to increased sales and employment in associated industries. At present, the Norwegian process industry employs about 60,000 people indirectly in Norway by way of buying and selling services in other sectors[11].

In recent decades, the process industry has demonstrated its ability to reorganise and to assert itself in a sector with tough international competition. The operators are now showing that they also wish to transition toward zero emissions. Several other operators in addition to Norcem, Fortum Oslo Varme and Yara are considering the potential for associating themselves with the CO_2 infrastructure in the full-scale project. These are industrial companies such as Eramet, the Eyde cluster (representing almost 50 companies, 15 of which are in the process industry), Elkem, the CCS cluster at Øra and the CO_2 hub in Nordland county[12], co-ordinated by *Mo Industripark* (with 7 members of the process industry, such as Alcoa and Celsa). Also operators in Norway's neighbouring countries, such as the Preem refinery in Lysekil in Sweden, are considering the possibility of linking themselves to Norwegian CO_2 infrastructure[13]. This broad interest shows that the operators believe that CO_2 management is necessary in order to maintain competitive industry.

Although the price of products from the process industry could increase significantly as a result of CO_2 management, the impact on the price of the finished products will be more limited. For example, the cost of a building using emission-free cement (cement manufactured at a plant where CO_2 emissions are captured and stored) will be about 0.5%, higher than that of a building constructed with conventional cement[14]. Similarly, there will be price increase of less than 0.5% for a car manufactured from emission-free steel[14]. In other words, only a modest investment will be necessary on the part of the end-user to acquire products based on emission-free materials. If Norway becomes the first country in the world to realise infrastructure for managing CO_2 from industrial sources, the Norwegian process industry will gain a competitive advantage by being the first to offer emission-free products. In this connection, public procurement, rules and standards will represent important tools for creating a market for low-emission materials for use in buildings and other infrastructure. With the climate-change policy pursued in many Norwegian cities in 2018, such a transition may be attractive also because emission-free products may become a requirement for sales within industrial sectors and regions.

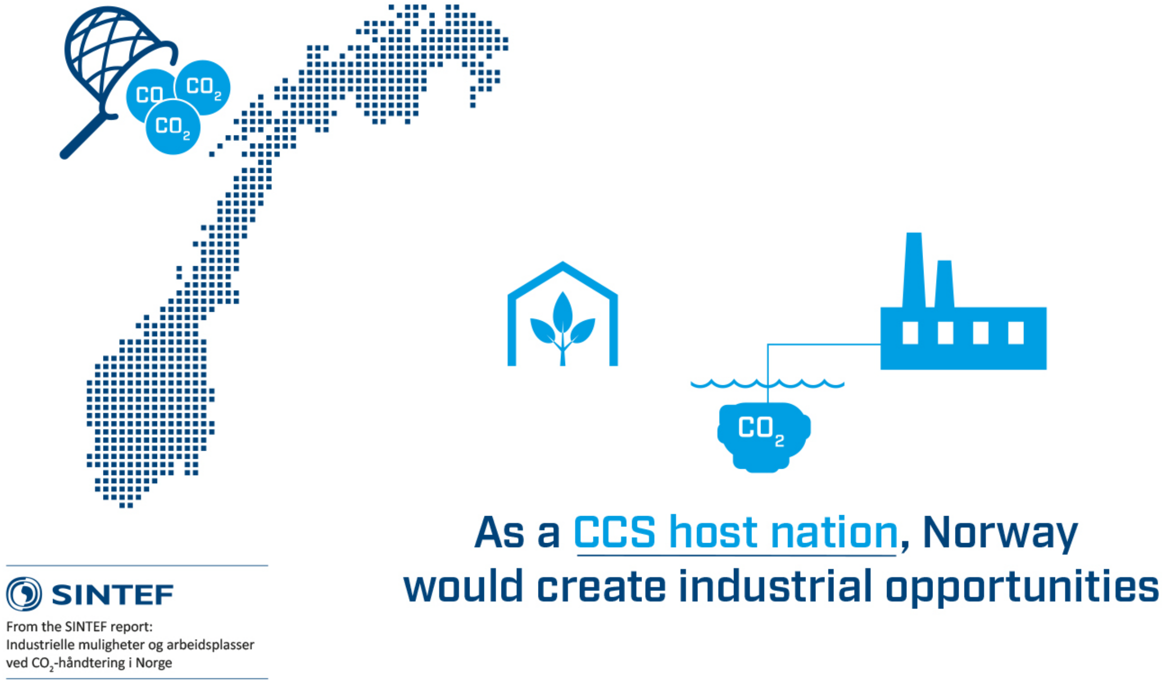
[11]The number of indirect jobs has been calculated by estimating ripple-effect multipliers based on input-output accounting from the National Accounts published by Statistics Norway, using data from 2016. The employment multiplier for sectors in the Norwegian process industry is approximately 2 – in other words, two indirect jobs per direct job in the industry.

[12] Prosessindustri i regionalt$_2$-prosjekt (Process industry in regional CO_2 projects), Mo Industripark AS. October 2017.

[13] Preem is considering carbon capture at the Lysekil refinery, Gassnova. February 2018.

[14] J. Rootzén, F. Johnsson: Technologies and policies for GHG emission reductions along the supply chains for the Swedish construction industry, ECEEE. May 2017.

Norway as an attractive host nation for international industry



With the proximity of infrastructure for CO_2 management, Norway can become an attractive host nation for industry, thanks to the greater potential for manufacturing emission-free products. In combination with the availability of reasonably-priced renewable energy, this will potentially form the basis for new industrial establishment in Norway at a time when the proportion of costs resulting from the workforce is dropping.

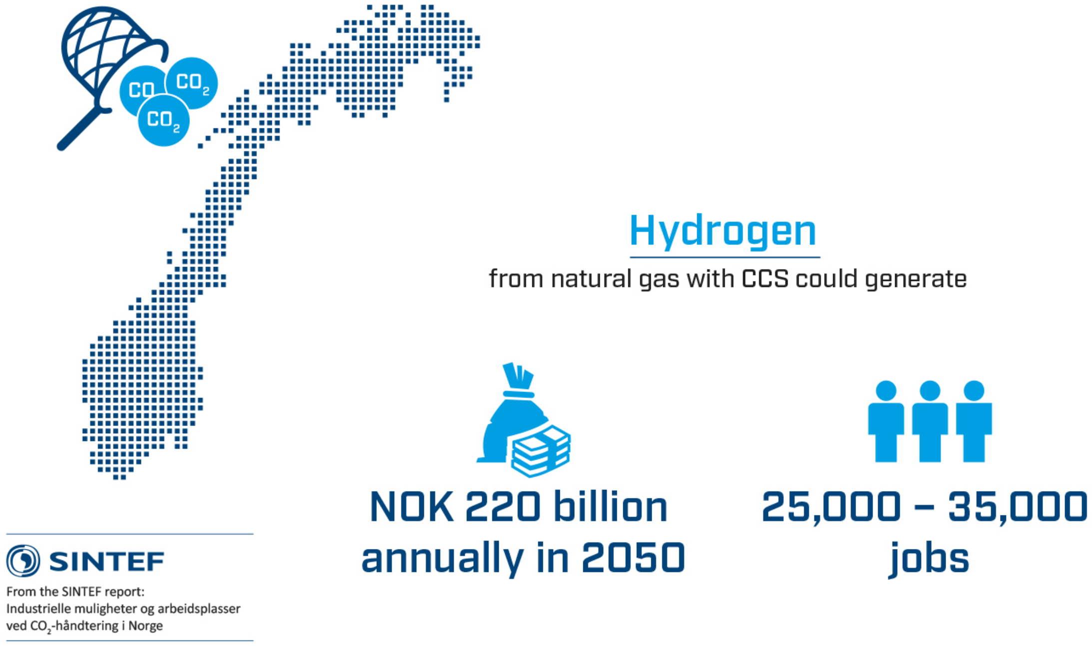
Access to reasonable priced hydroelectric power has been a competitive advantage for Norway in comparison with other countries and has made Norway an attractive host nation for energy-intensive industry. The establishment of infrastructure for CO_2 management can result in similar competitive advantages by allowing the manufacture of products without emission of CO_2. This can be attractive also for international industry looking for opportunities to manufacture emission-free products. The combination of reliable access to renewable energy and CO_2 management facilities will be unique in a global context. A specific example is operators wishing to produce hydrogen from natural gas in Norway, in view of the fact that CO_2 emissions from the process can be captured and stored[15].

Access to CO_2 and infrastructure for handling it may also create new opportunities for business development in the Norwegian regions. *Naturgassparken Vest AS*, which owns the site at which the CO_2 hub is planned at Kollsnes, is already reporting interest from local operators which see opportunities linked to access to CO_2. These opportunities can be linked to the production of carbon materials, operation of the reduction in the CO_2 content of raw materials for the smelting industry or cultivation of algae to be used as fish feed. *Naturgassparken Vest* also describes considerable interest from Øygarden Municipality and the local community. If, for example, a small amount of pure CO_2 can be used in the production of algae, which in turn is used as feed at an adjacent fish-farming facility[16], this can potentially lead to the development of

[15] Hydrogenvei til Japan (Hydrogen road to Japan), Energi og klima. June 2016.
[16] Nytt forskningssenter vil utnytte CO_2 til fiskefôr (New research centre will use CO2 to produce fish feed), University of Bergen. June 2014.

new industry and new jobs which benefit local communities. In this way, a CO_2 capture project will not only benefit the cornerstone business, but will also provide a basis for new businesses, often instead of resorting to the import of foreign products. However, it is important to point out that such use of captured CO_2 will not provide climate benefits, since the use of CO_2 in products means that sooner or later the CO_2 will be emitted into the atmosphere, rather than being removed from the carbon cycle, as would be the case if the CO_2 is stored permanently.

Hydrogen production from natural gas using CCS may develop into an industrial boom for Norway



Investment in Norway in hydrogen production from natural gas can result in sales of NOK 220 billion in 2050, and between 25,000 and 35,000 new jobs. A precondition for this is, among other things, that adequate storage capacity is developed for CO_2 in the North Sea.

Hydrogen as a low-carbon energy carrier can become an important supplement to the role natural gas plays today, and will become complementary to intermittent renewable energy. Hydrogen can be used in energy generation, heating and cooling, as a fuel (especially in the marine sector), and as an ingredient in energy-intensive industries such as steel production. Several major projects are being assessed: In the Netherlands, Equinor, Vattenfall and Gasunie are studying the potential for converting the Magnum Power Station to a hydrogen gas plant that will supply 1,200 MW of pure power to the consumer market[17]. The potential for replacing natural gas with hydrogen in the gas distribution system[18] to provide emission-free heating is being assessed in Leeds in the UK. A CO_2 storage facility in the North Sea, which is a precondition for a commitment to hydrogen production from natural gas using CCS, can present interesting opportunities and contribute to an extension of the market potential for Norwegian natural gas resources,

[17] Intensjonsavtale for å konvertere naturgass til hydrogen (Agreement in principle to convert natural gas to hydrogen), Statoil. July 2017.
[18] H21 Leeds City Gate, Northern Gas Networks. July 2016.

especially in view of the fact that the EU has set climate goals which in practice mean zero CO_2 emissions from the energy sector by 2050.

The Hydrogen Council's roadmap estimates that hydrogen can satisfy 18% of the world's overall energy needs in 2050, and provide 30 million jobs[19]. At present, natural gas supplies 22% of the energy requirement[20]. Based on this, a possible scenario for Europe in 2050 may be that hydrogen satisfies about 80% of the energy need that is served by natural gas today. The market price is uncertain, but the price for hydrogen produced from natural gas using CCS will be higher than the price of natural gas, since energy and processing are needed to produce the hydrogen. If we assume a market price equal to twice the current natural gas price, this corresponds to a market volume for hydrogen for energy generation, heating and industrial use in Europe approaching NOK 1,200 billion[21] in 2050.

It should be added here that the realisation of value chains based on hydrogen will call for more than one CO_2 storage facility. The investments will be considerable and customers must be willing to pay a higher price than for natural gas. Alternatively, the authorities must stimulate the use of hydrogen by way of purpose-designed incentives and framework conditions.

If Norway in 2050 produces the same volume of natural gas as in 2017 (122 billion Sm^3, or about 1,350 TWh[22]), but with 80% conversion to hydrogen power to meet the development described above, this will correspond to hydrogen production and export of around 750 TWh[23]. The market value will be approaching NOK 220 billion. In comparison, the export value of all Norwegian natural gas was NOK 200 billion in 2017. Maintaining production volume of natural gas in 2050 may be too high an estimate, but it is used below as an illustrative example.

In 2016 about 148,000 people were directly employed in Norwegian oil and gas operations[24]. This includes employees of operating companies and suppliers with direct deliveries in the oil and gas value chain[25]. Of these, more jobs are linked to oil than to gas, because oil production calls for higher labour intensity and gas is typically produced from a small number of large installations. If we assume that natural gas operations on the Norwegian continental shelf represent between 20% and 30% of the jobs[26], this results in something of the order of 30,000 to 40,000 jobs. If 80% of Norwegian gas is converted to hydrogen in 2050, we can ascribe somewhere between 25,000 and 35,000 jobs in the natural gas industry to the hydrogen market. Since the gas which is converted to hydrogen and CO_2 must be separated and stored, hydrogen will require greater labour-intensiveness per unit than natural gas does. This is also a contributory factor in the higher price for hydrogen than for natural gas. Based on the assumption that the price of hydrogen will double relative to that of natural gas, hydrogen will call for twice as many jobs as the production of natural gas does today.

So far, the example does not take into account the effect that efficiency improvement and automation in the gas industry will have on the need for manpower in the years up to 2050, which will probably be

[19] Hydrogen, scaling up, Hydrogen Council. November 2017.
[20] IEA. 2017.
[21] Assuming a natural gas price of NOK 1.6 per Sm^3 and double price for hydrogen per unit of energy content.
[22] Export volumes and market value of Norwegian natural gas, provided by the official Norwegian website Norsk Petroleum.
[23] Assumed degree of efficiency of the process of transitioning from natural gas to hydrogen, including 70% CO_2 management.
[24] Utvikling i direkte petroleumsrelatert sysselsetting 2014 – 2020 (Development of directly petroleum-related employment 2014-2020), IRIS. March 2016.
[25] According to source 24): "Petroleum-related operations can be divided into "direct" and "indirect". "Direct" operations can be defined as supplies of goods and services with direct applications in the value chain of the petroleum industry (seismic, drilling, maintenance, etc.) while "indirect" operations will be all other activities (hotels, restaurants, auditing, etc.)."
[26] The distribution of jobs is based on a best estimate. We have not been able to find a reference relating to this.

substantial. The process industry in Norway is a good example of this. Productivity has increased by almost 40% since 1990, while the number of people employed has dropped significantly. If we assume a corresponding development in the gas industry approaching 2050, for example an improvement in efficiency of 50% linked to the number of employees, in this scenario about 25,000 to 35,000 jobs will be directly connected with the production of hydrogen from natural gas using CO_2 management in Norway.

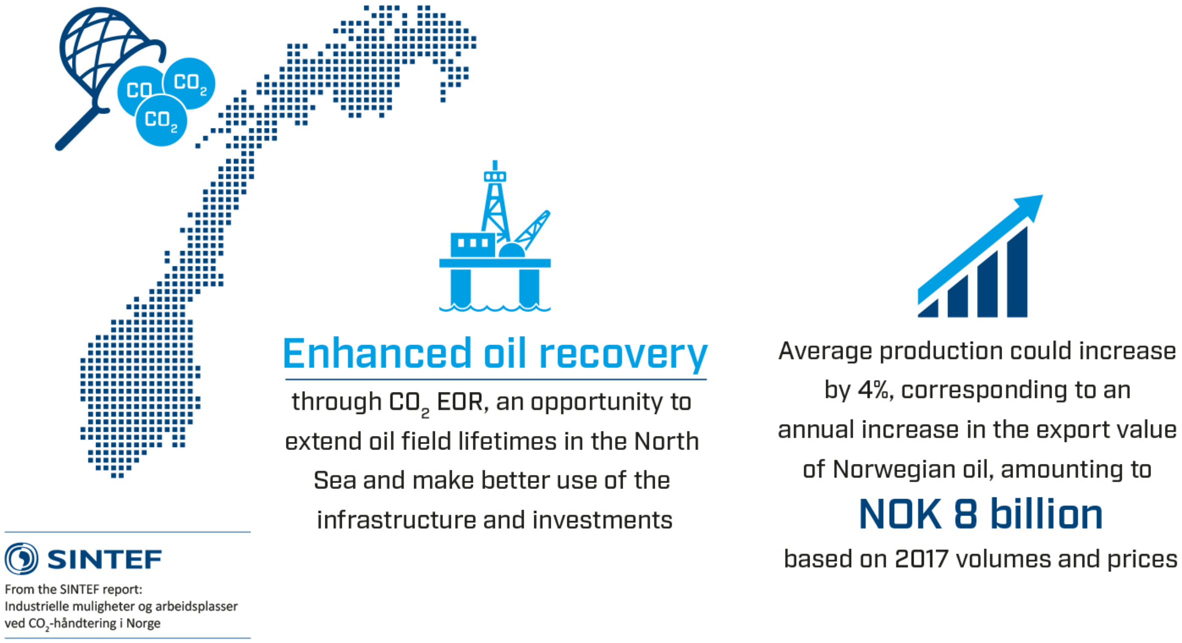
IRIS has estimated that the sum of direct and indirect jobs in the oil and gas industry in Norway is 1.8 times the number of directly employed people[27] (see Attachment B). The total number of people employed in Norway in connection with the export of hydrogen from natural gas in 2050 could be between 50,000 and 60,000. This corresponds to just over 2% of the Norwegian workforce in 2017.

So far, at least a third of the estimated recoverable reserves of natural gas on the Norwegian shelf have been produced[28]. Commitment to the production of hydrogen from natural gas in Norway could potentially maintain the value of the gas reserves in a future market by considerable restrictions in CO_2 emissions. Adaptation to hydrogen production can protect jobs in the Norwegian oil and gas industry while establishing a large number of new jobs. Moreover, Norway has commercial operators in the field of hydrogen technology, such as NEL Hydrogen and Hexagon. If hydrogen is produced in large volumes from natural gas, this will augment their markets and potential sales of hydrogen technology.

A Norwegian commitment to hydrogen technology will also be capable of reinforcing entire industries which need concepts for low-emission energy carriers. A good example is the Norwegian maritime industry, where hydrogen is of interest as a fuel for ships[29]. The UN's International Maritime Organization (IMO) has recently adopted an ambition to reduce emissions from world shipping by 50% by 2050[30]. A commitment which provides access to large volumes of hydrogen will potentially contribute to improving the competitiveness of the Norwegian maritime and shipping industries in the transition to zero-emission transport. This could be comparable to the way in which access to LNG (liquefied natural gas) has assisted Norwegian shipping in becoming a world leader through the transition to LNG as a fuel. The Norwegian maritime industry currently employs about 110,000 people[31], about 15,000 of them in the shipping industry[32].

[27] Based on employment figures from Industribyggerne (The industry builders), IRIS. March 2015.
[28] According to figures from Norsk Petroleum, 2017.
[29] World's First Hydrogen-Powered Cruise Ship Scheduled, The Maritime Executive. October 2017.
[30] UN body adopts climate change strategy for shipping, United Nations International Maritime Organization. April 2018.
[31] According to figures from the Norwegian Government website Regjeringen.no. 2018.
[32] Figures from Statistics Norway. May 2017.

Increased oil recovery using CO_2 EOR



Norway has a clear policy to increase hydrocarbon recovery and the efficient use of resources in the oil and gas fields on its continental shelf. Access to large volumes of CO_2 opens for enhanced Oil Recovery (EOR) with CO_2. CO_2 EOR may provide potential for extending the lifespan of petroleum fields in the North Sea, thereby making better use of existing infrastructure and providing greater returns on investments made on the continental shelf. The average increase in production can be around 4%, which corresponds to an annual increase in the export value of Norwegian oil of NOK 8 billion, based on 2017 volumes and prices. CO_2 EOR can also represent a financial incentive for the establishment of CO_2 infrastructure in Europe.

The Norwegian sector of the North Sea is a mature petroleum province and production is declining at a number of oil fields. The recovery rate on the Norwegian shelf is 46%, which is high compared with the global average. However, it can be increased further using various enhanced recovery methods. The most common method is to inject water to provide pressure support. In the United States, EOR with CO_2 has been used onshore to enhance oil recovery for 40 years, but so far offshore CO_2 EOR has not been attempted on the Norwegian continental shelf. The fact that CO_2 has not been available in adequate amounts at fields where it would be appropriate has been a serious impediment. If CO_2 becomes available by way of an established CCS chain at the right stage of an oil field's lifetime, using CO_2 for EOR can improve the profitability of the CCS project, while simultaneously disposing of CO_2.

The establishment of a combined CCS and CO_2 EOR chain will provide flexibility whereby CO_2 is available for EOR when needed and otherwise is injected for permanent storage. In this way, CO_2 EOR in the North Sea can stimulate the development of infrastructure for CO_2 management and thereby accelerate the realisation of CCS from European sources.

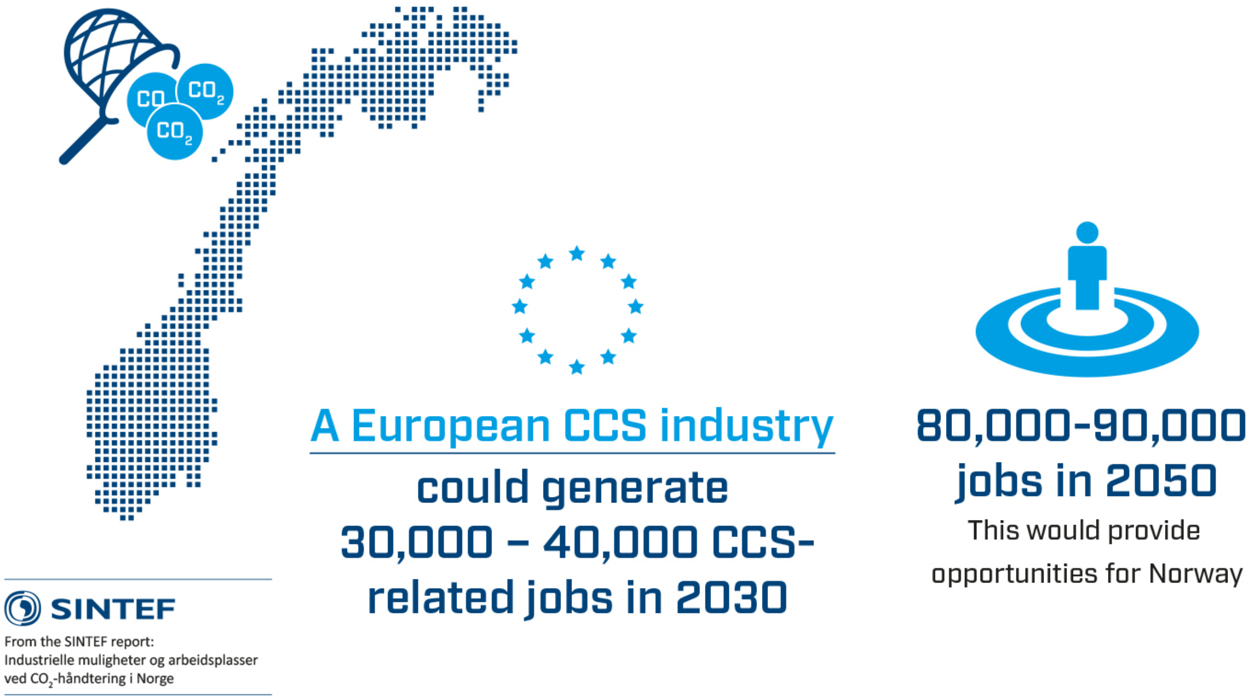
A study carried out by the Norwegian Petroleum Directorate (NPD) presents CO_2 EOR figures calculated for 23 fields in the Norwegian sector of the North Sea over a period of 40 years[33]. More than 300 million Sm^3 of additional oil could be produced. Total oil production on the Norwegian continental shelf in 2017 was

[33] V. Pham, E. Halland: Perspective of CO_2 for Storage and Enhanced Oil Recovery (EOR) in Norw. North Sea, GHGT-13. November 2016.

approximately 92 million Sm^3, with an export value of NOK 209 billion, so the study indicates significant potential for enhanced recovery. In all, increasing production by 300 Sm^3 represents a value of NOK 680 billion, based on the export value of Norwegian oil in 2017. Another, more detailed, analysis in the same study indicates that CO_2 EOR can result in an average increase in production of 4% while also storing 70-100% of the injected CO_2. In 2017, a 4% increase in production will represent an annual increase in export amounting to just over NOK 8 billion. The analysis assumed access to 1-3 million tonnes of CO_2 annually and showed that CO_2 is more effective than, for example, methane which is used for EOR in some fields.

The profitability of CO_2 EOR will to a large extent depend on the price of oil, the cost of obtaining CO_2 and additional costs connected with modification of infrastructure, especially if new wells and production interruptions are necessary in connection with modification. An alternative strategy for optimal use of the infrastructure may be to inject CO_2 for EOR for the first years and when the potential additional oil production has been achieved, to shut down oil production and use the reservoir for storage of CO_2. Aker Solutions has developed and is about to qualify subsea technology for CO_2 EOR[34]. A pilot project for offshore testing of CO_2 EOR may be a potential expansion of the Norwegian full-scale project, and will be the first of its type in the world[35].

3.2 The market for CO_2 management in Europe may be considerable



The market for CO_2 management in Europe will potentially involve from 30,000 to 40,000 jobs directly linked to CO_2 management in 2030 and from 80,000 to 90,000 in 2050. Norwegian industrial actors are well-equipped to increase their value generation in such a market.

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[34] P.H. Nøkleby: Taking CO_2 EOR offshore. Workshop "Driving CCS forward in Norway". 2015.

[35] Presentation by Oscar Graff, Aker Solutions, at the Federation of Norwegian Industries' Carbon Capture Seminar. 19 March 2018.

The Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) in 2014 analyses 1200 scenarios for emission of greenhouse gases and indicates that CCS plays a decisive role in 114 of 120 scenarios where global warming is limited to 0.9-2.3 °C[36]. The IEA's scenario for limiting global warming to 2 degrees confirms this and estimates that CCS must contribute to 12% of cumulative emission reductions up to 2050. This represents 95 billion tonnes of CO_2 captured and stored during this period. If we are to further improve the likelihood of limiting warming to 2 degrees, an even larger proportion of the CO_2 emissions must be eliminated. This is reflected in several of the IPCC's 2-degree scenarios in which the amount of CO_2 eliminated through CCS is far greater – more than 20 billion tonnes per year in 2050. Cumulative emissions in Europe in 2015 amounted to 4,450 million tonnes of CO_2 equivalents[37], which is 20% lower than in 1990. The EU's goal of 80% reduction in emissions relative to the 1990 level by 2050 (see Attachment A3), calls for further reduction by around 3,300 million tonnes of CO_2 equivalents.

If we are to limit global warming to 2 degrees and CCS is to play the role envisaged for this technology in the scenarios as described above, there will be a considerable market for CO_2 management in Europe and the rest of the world. To illustrate this scope of possibility we have defined three scenarios for how the CO_2 market in Europe may appear in 2030 and 2050: the Low CCS, Moderate CCS and High CCS scenarios. These scenarios are shown in Figure 5. The two first are based on the IEA's 2-degree scenario[38]. "Moderate CCS" represents the complete IEA scenario in which there is a 50% probability of limiting global warming to 2 degrees[39]. "Low CCS" is based on the same IEA scenario, but includes only emissions expected to be captured and stored from industry (Low CCS does not include CO_2 management in the power generation sector or from hydrogen production from natural gas). The "High CCS" scenario is based on selected IPCC 2-degree scenarios that ascribe major importance to CCS and therefore result in larger volumes of captured and stored CO_2 per year in the years up to 2050.

Figure 5 shows how much CO_2 must be captured and stored in Europe in 2030 and 2050 for each of the three scenarios. The figure also shows the assumed cost development for CO_2 management in terms of NOK per tonne of CO_2, and the estimated size of the total costs linked to CO_2 management in Europe in the scenarios. We have used these figures as a basis for estimating the number of jobs in Europe directly linked to CO_2 management. Our method of calculating employment figures is based on cost and employment estimates for the Norwegian full-scale project, assuming that all three capture projects are realised, i.e. 1.4 million tonnes of CO_2 stored per year, at a cost of around NOK 1,400 per tonne[40]. Using this as a starting point we have scaled up the employment figures in proportion to the scale of future CO_2 management. Then we have scaled down the employment figures in proportion to the expected falling cost of CO_2 management in the future (as discussed in Chapter 4). Falling costs in the future will also to some extent be driven by a reduction in the need for manpower as a result of automation and improved efficiency, and are taken into account by the model. The complete method and assumptions on which the calculations are based are presented in Attachment B.

[36] IPCC Fifth Assessment Report, IPCC. 2014.
[37] Total greenhouse gas emissions by countries, Eurostat. 2016.
[38] The 2-degree scenario as calculated by IEA, in terms of amounts of stored CO_2 per world region. Here the volumes assumed for OECD countries in Europe are used as a basis for calculating European market size. Moderate CCS is equivalent to the full IEA scenario while Low CCS includes only the volumes of CO_2 expected to be captured and stored from the process industry in Europe in 2030 and 2050. Presented in 20 years of carbon capture and storage, IEA. November 2016.
[39] This scenario is based on a selection of the IPCC scenarios in which warming is limited to 2 degrees and in which CCS is ascribed major importance. The relative proportion of CCS in Europe used as the basis for this scenario is the same as that assumed in the IEA scenario. The data have been obtained from the AR5 Scenario Database, which contains the data used as the basis for the IPCC Fifth Assessment Report, IPCC. 2014.
[40] Kvalitetssikring (KS1) av KVU om demonstrasjon av fullskala fangst, transport og lagring av CO_2 (Quality assurance (QA1) of the concept selection study for demonstration of full-scale capture, transport and storage of CO_2), Oslo Economics and Atkins. 2016.

Based on this method our estimate shows that there is potential for between 80,000 and 90,000 new jobs in Europe in 2050 directly linked to the emergence of a market for CO_2 management. The sum of directly and indirectly linked jobs may approach 150,000 in 2050, assuming the same proportion between direct and indirect jobs in the CO_2 management industry as for the oil and gas industry. Figure 6 shows our estimates for employment in Europe according to the first three scenarios. The figure also shows the number of people employed in the capture, transport and storage, respectively, of CO_2, based on the estimated distribution of costs among these industries (see Attachment B).

If the Norwegian full-scale project is realised, Norwegian operators could be well prepared for the competition in a future market for CO_2 management in Europe. As shown in Figure 5, sales *linked only to CO_2 management* could be between NOK 65 and 400 billion in 2030 and between NOK 190 and 900 billion in 2050. In comparison, Norway exported oil and gas for a value of NOK 414 billion in 2017[41]. The actual market potential for CO_2 could be greater, since these figures do not, for example, take into account any profits in the market resulting from high CO_2 quota price, or future higher prices for products with a lower CO_2 footprint. However, several variables exist here. Such a market will potentially provide a basis for increased value generation for Norwegian industry in a European market. Figure 7 shows estimated employment figures for Norwegian operators in a European market for CO_2 management. These figures are discussed below.

[41] Norsk olje- og gasseksport, (Norwegian oil and gas exports) published by Norsk Petroleum.

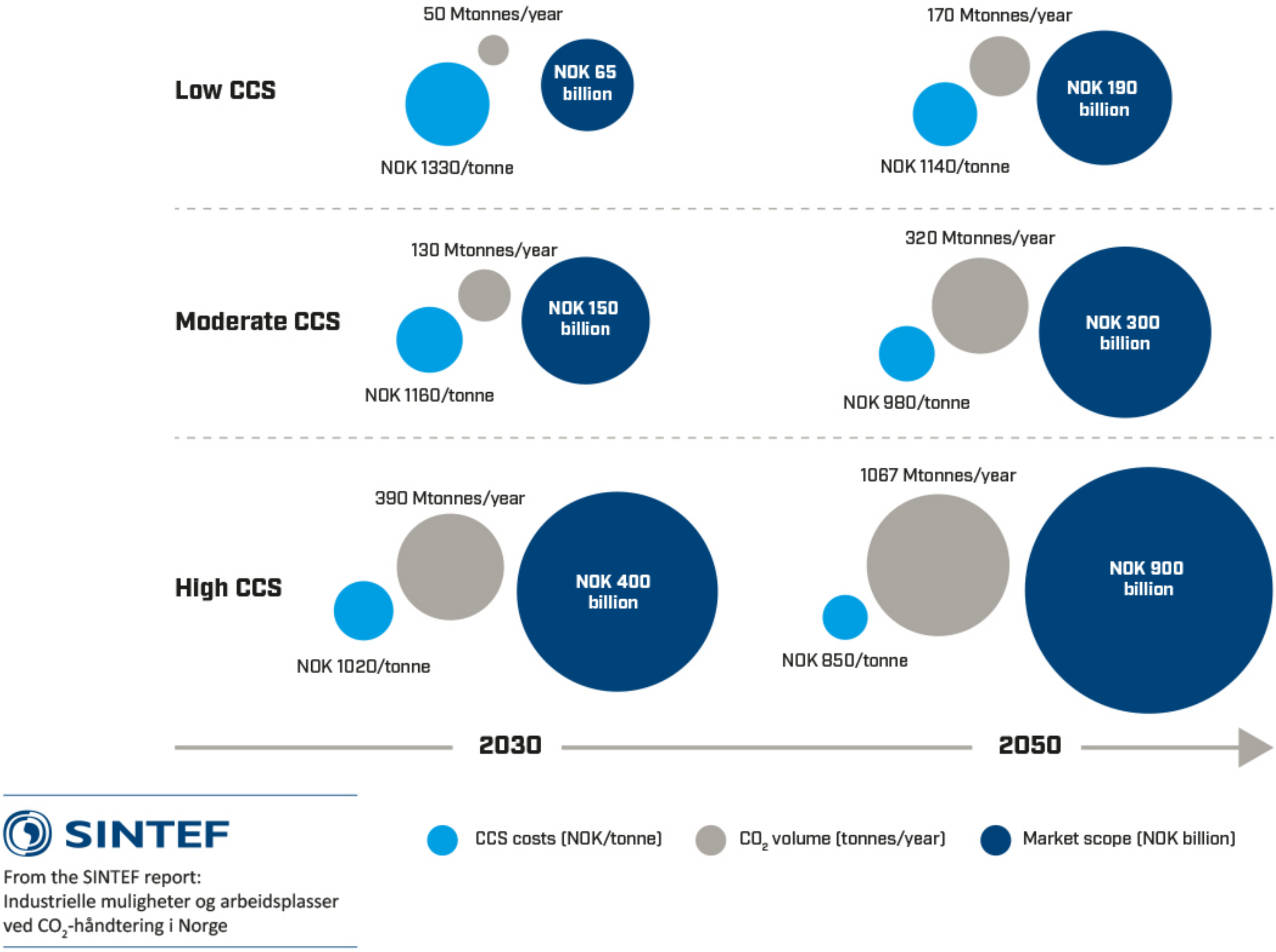


Figure 5. Three scenarios for CO_2 management in Europe: Low CCS[38], Moderate CCS[38] and High CCS[39]. Costs for CO_2 management [NOK/tonne], amount of CO_2 captured and stored [Mtonne/year] and market size [NOK billion] 2030 and 2050.

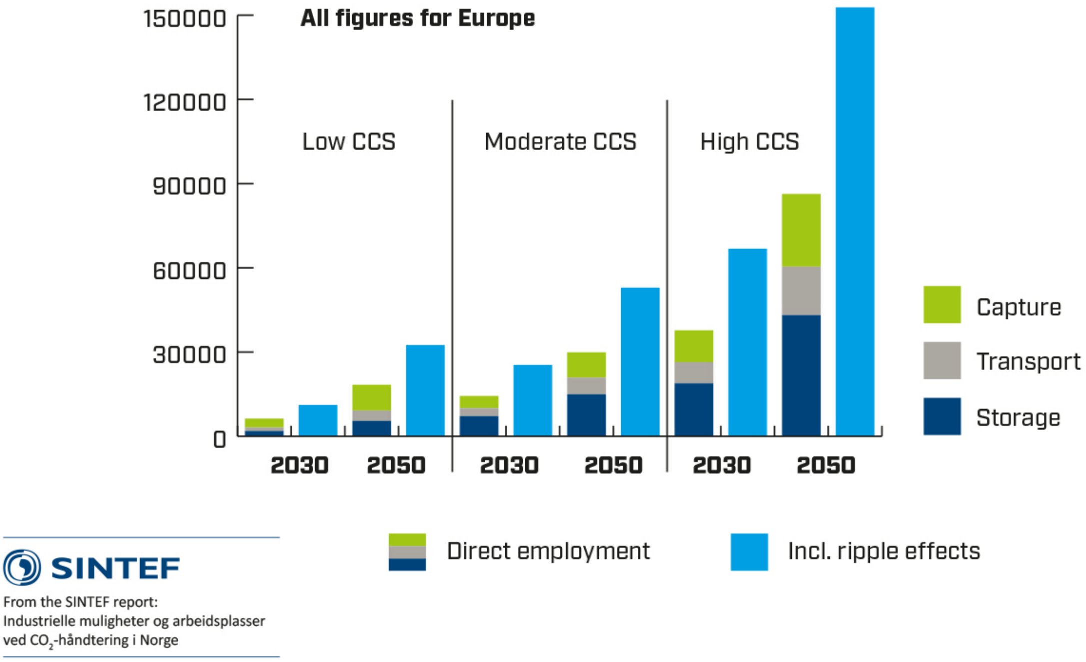


Figure 6. Estimated employment figures for directly linked jobs and total number (direct and indirect) of jobs in the field of CO_2 management in Europe in 2030 and 2050 for the Low CCS[38], Moderate CCS[38] and High CCS[39] scenarios.

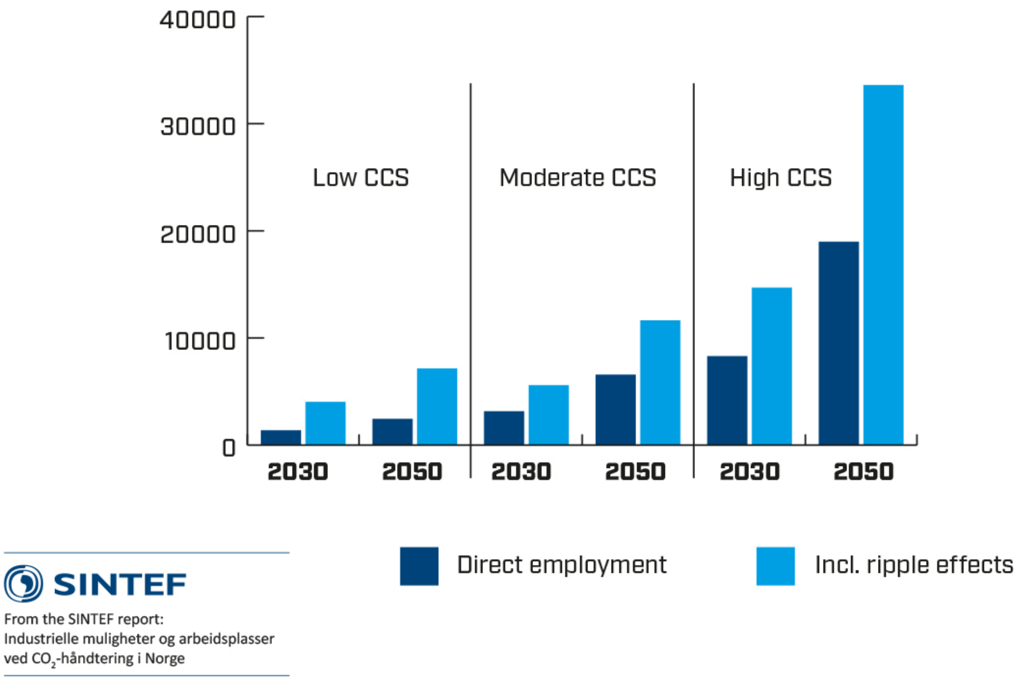
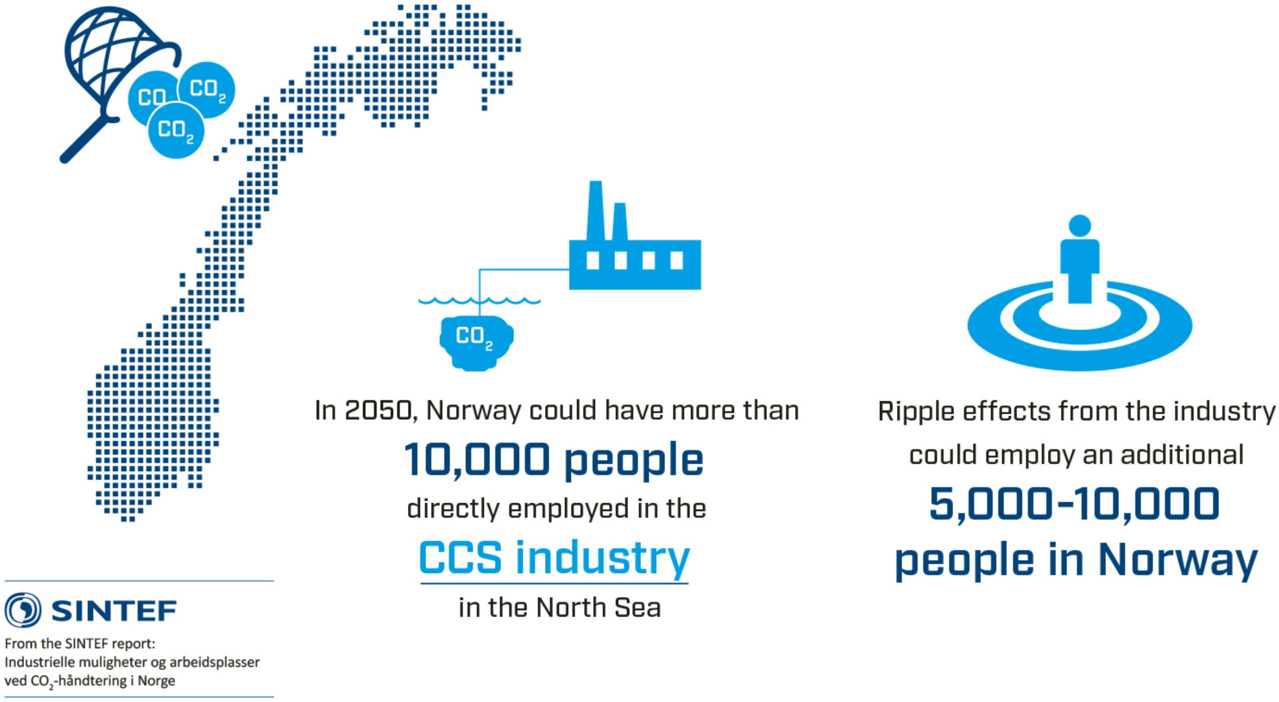


Figure 7. Estimated employment figures for directly linked jobs and total number (direct and indirect) of jobs in the field of CO_2 management in Europe in 2030 and 2050 for the Low CCS[38], Moderate CCS[38] and High CCS[39] scenarios.

A CO_2 storage industry in the North Sea



A centralised storage facility in the North Sea consisting of several storage locations for CO_2, which can make a significant contribution in the petroleum industry in which Norway has already invested considerably and earned major revenues and in which investment is needed to maintain value creation as oil production declines. In 2050, Norway may have more than 10,000 jobs directly linked to CO_2 storage in the North Sea, while the ripple effects could employ a further 5,000 to 10,000.

CO_2 storage has many characteristics in common with petroleum operations. Mapping storage locations resembles exploration for petroleum reservoirs and CO_2 to be stored is pumped through wells down to porous rock formations which have previously contained oil, gas or water. The Norwegian Petroleum Directorate has studied the storage potential on the Norwegian shelf and its CO_2 Atlas shows that it is theoretically possible to store 80 Gtonnes of CO_2. Most is in the North Sea where the capacity of water-saturated sandstone aquifers is 48 Gtonnes and 24 Gtonnes in depleted oil and gas fields.[42] Geological formations on the Norwegian shelf can thus store CO_2 in quantities that can be significant in an international context. If 100 million tonnes are injected annually for 50 years, this corresponds to the storage of 5 Gtonnes of CO_2.

As shown in Figure 6 we estimate that the number of jobs connected with CO_2 storage can vary from around 2,000 in 2030 for the Low CCS scenario to around 25,000 in 2050 for the High CCS scenario. The UK has an estimated storage capacity of 78 Gtonnes[43], Denmark 18 Gtonnes, Sweden 15 Gtonnes[44], and the Netherlands 2.5 Gtonnes[45], so in simple terms we can assume that Norway possesses about 40% of the

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[42] CO_2 Storage Atlas for the Norwegian continental shelf, the Norwegian Petroleum Directorate. May 2014.
[43] M. Bentham et al.: CO_2 Storage evaluation Database. The UK's online storage atlas (2014) GHGT-12. Link
[44] K.L. Anthonsen et al.: CO_2 storage potential in the Nordic region (2012). NORDICCS Conference Link
[45] F. Neele et al: Independent assessment of high-capacity offshore CO_2 storage options. Report (2012) Link

storage capacity in northern Europe. It may therefore be reasonable to assume that Norway can command a corresponding share of the market for CO_2 storage in Europe. This involves from 2,000 to 2,500 jobs connected with CO_2 storage in 2050 according to the Low CCS scenario and just over 10,000 according to the High CCS scenario. This will provide ripple effects connected with indirect employment, so that the sum of directly and indirectly employed people linked to CO_2 storage in Norway could be between 15,000 and 20,000 in 2050, according to the High CCS scenario. By assuming a role as an early mover by way of the full-scale project, Norway will have an opportunity to acquire an even larger share of the market.

Several countries in Europe are considering the North Sea for future storage of CO_2[46]. The Netherlands, Germany, France and the United Kingdom all produce considerable CO_2 emissions and have adopted ambitious climate change targets that can be difficult to achieve without the use of CCS (See Attachment A3). Apart from the United Kingdom and to a certain extent the Netherlands, these countries have little suitable storage capacity and they are dependent on storage in other areas, primarily Norway and the United Kingdom if they are to include CCS as a climate mitigation technology. Sweden's goal is net zero emissions of greenhouse gases in 2045, and although the country has identified some storage capacity, association with a Norwegian CCS chain may be attractive, enabling Sweden to achieve this goal more rapidly. The Global CCS Institute reports considerable interest from many of its international members in the Norwegian full-scale project, and particularly for the potential for accepting CO_2 from international operators in the North Sea[47]. This potential will lower the barriers for other European countries and in particular provide opportunities for towns and regions which want to facilitate CCS independently of access to national infrastructure for CO_2 management. Specific projects which could affiliate themselves with a Norwegian storage system in the North Sea in the short term are Eemshaven[48] and the Teesside projects[49].

Like Norway, the United Kingdom has considerable potential for CO_2 storage on its continental shelf. A study of commercial opportunities linked to CO_2 management in the United Kingdom[50] estimates that the British balance of trade would have a deficit of around GBP 100 billion in the period 2020-2060 if the United Kingdom were to ship its CO_2 for storage in another country rather than allowing British operators to deal with this industry. On the other hand, the British balance of trade will be improved if the United Kingdom itself is able to accept CO_2 from other countries which must pay to dispose of their CO_2. Overall, the study concludes that establishing CO_2 storage facilities in the United Kingdom would have a positive effect on the UK economy, compared with shipping for storage in another country. These results could also be significant for Norway, if the country were to be the first to offer central storage facilities for CO_2 in the North Sea with large enough capacity to accept CO_2 from other countries.

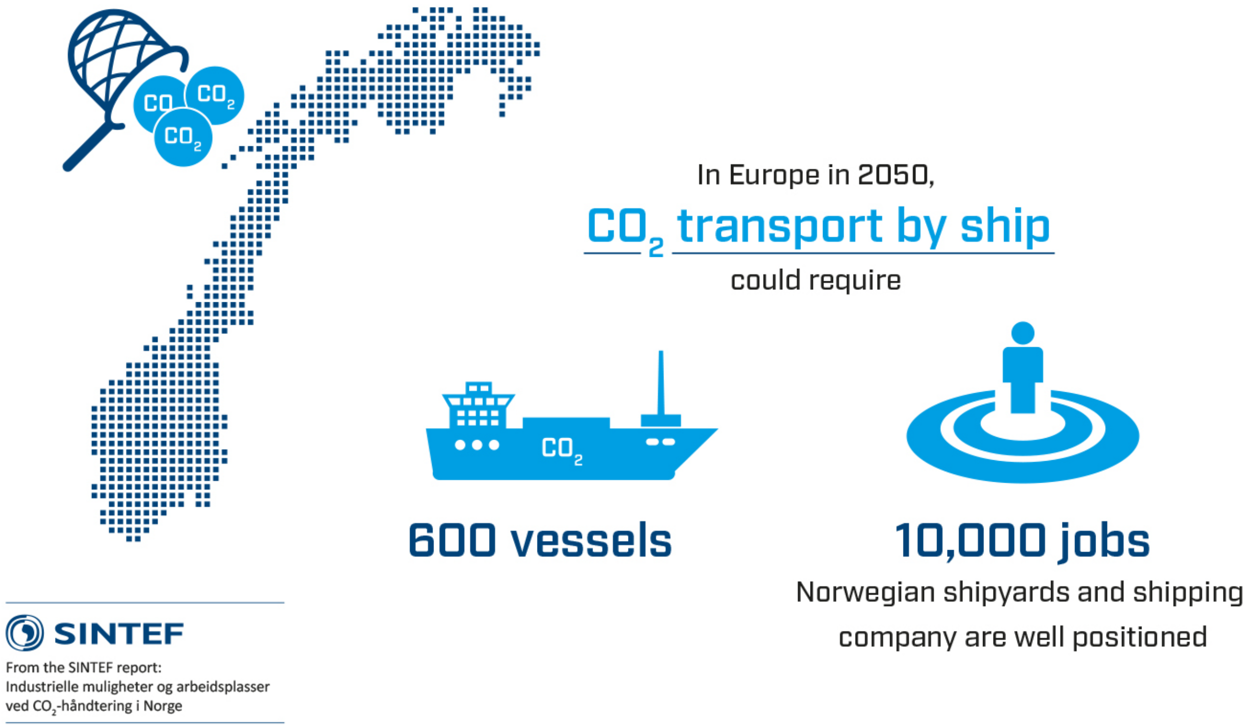
With an oil and gas industry among the best in the world as regards cost-effectiveness, Norway is in a unique position to build up a competitive offshore CCS industry. The expertise, technology and infrastructure necessary to establish a chain for CO_2 storage already exists, including surveying and detailed subsurface assessment, well drilling, infrastructure construction, gas injection, monitoring of subsurface fluids and shutting down wells. By investing in a CO_2 storage industry it is possible to maintain enough jobs to compensate for those lost as a result of the decline in oil and gas production. Hence employment can be maintained in those regions which are hardest hit by reductions. In addition, the time scale will probably be longer than that of the present-day oil and gas industry, since storage will continue for significantly longer than the decades of continued oil production that are anticipated. Development of CO_2 storage as an

[46] North Sea to the Rescue: The commercial and industrial opportunities of CO_2 storage in the North Sea, Bellona. December 2015.
[47] Based on personal communication with the Global CCS Institute.
[48] Projects of Common Interest, Global CCS Institute. September 2017.
[49] Teesside Collective.
[50] Clean Air, Clean Industry, Clean Growth: How Carbon Capture Will Boost the UK Economy, CCS Association. October 2017.

industry can also be significant in using infrastructure which otherwise would have to be dismantled and removed.

In addition to this there will be opportunities linked to the export of subsea equipment, monitoring technology, CO_2-resistant materials, drilling technology, leak detection instruments, pressure-control devices, etc.

The Norwegian maritime industry can transport Europe's CO_2



In 2050 there could be a need for a fleet of more than 600 ships for transporting CO_2 in Europe, with a potential for employing 8,000 to 10,000 people. Norwegian shipbuilders, shipping companies and associated service activities are well placed to acquire shares in this market.

Norwegian commercial operators are particularly well qualified for transporting CO_2 in ships. Larvik Shipping is unequalled in Europe, with more than 30 years' experience. This shipping company is unique as regards both the ships used for transporting CO_2 and the company's and crews' experience in this type of transport. Transport of CO_2 with ships also has clear similarities with the transport of liquid natural gas (LNG), where Norwegian shipping companies and shipbuilders are in prominent positions. Norway as a maritime nation will be strongly placed in the competition for the CO_2 transport market in Europe, especially if a centralised storage facility is established in the North Sea, which is the home turf of the Norwegian shipping industry.

The shipping and shipbuilding industries have already demonstrated their ability to create new markets and will be able to increase value generation through the emerging market for transport of CO_2 in Europe. Norwegian shipbuilders have also demonstrated high levels of competitiveness, particularly in industrial sectors involving demanding technology and complex systems. The maritime communities have also demonstrated considerable ability to turn their hands to new markets. Norwegian shipping companies have in many cases chosen to build their ships at Norwegian shipyards[51], something which could also be the case in an emerging CO_2 market. Moreover, the Norwegian full-scale project will contribute to qualifying more Norwegian operators and positioning them well in relation to the CO_2 market, thereby providing a competitive advantage compared with international competitors. As an example of the interest among Norwegian operators, Larvik Shipping and Knutsen OAS Shipping have collaborated with Gassco to assess potential concepts for vessels that would be of interest in connection with the Norwegian full-scale project.[52]

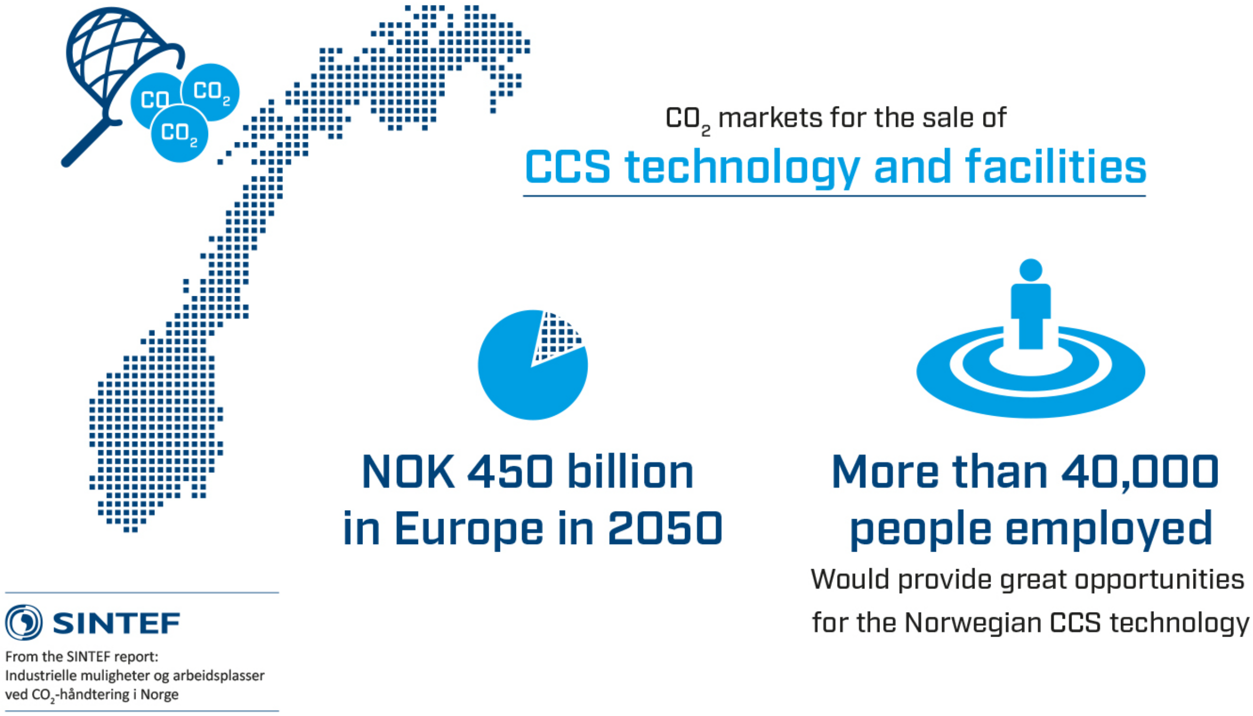
Several ship concepts have been assessed in the full-scale project, with the largest having a capacity of 9,000 tonnes of liquid CO_2. It will cost around NOK 900 million if it is built at a shipyard in western Europe[53]. The full-scale project itself will need several such ships. If half of all the CO_2 in Europe in 2050 according to the High CCS scenario were transported by sea, this will require a fleet of more than 600 ships (with an estimated average round-trip travel time of four days[54]). With the same assumptions, there will already be a need for at least 200 ships in 2030. In comparison, 50 gas tankers (LNG ships) sailed under Norwegian flag in 2016[55].

According to our model, the combined market for the transport of CO_2 in Europe can amount to NOK 15-80 billion in 2030 and to NOK 40-180 billion in 2050. By comparison, the total sales of Norwegian shipping companies in 2015 were around NOK 300 billion[55]. If we assume that CO_2 transported by ship represents half of the total transport market for CO_2 in 2050 (the rest being transported by pipeline), this will form the basis for between 1,500 and 8,000 to 10,000 jobs in Europe according to the Moderate CCS scenario in 2030 and the High CCS scenario in 2050 respectively.

In periods of much investment in, and building of, ships the employment figures could be far higher, since our model is based on the average number of employed people throughout the operational period of each CCS project (See Attachment B). In 2017 around 110,000 people were employed in the entire maritime industry in Norway[56]. Of these around 15,000 were employed in shipping[57]. This shows that if Norwegian shipping companies are able to command significant shares of the emerging market, this will potentially result in growth in several sectors. As is the case for the storage industry, the transport industry will also experience the ripple effects of the emerging market connected with the number of indirect jobs which could approach a doubling of employment figures[27].

[51] Hurtigruten to Build Up To Four New Explorer Vessels, Hurtigruten. April 2016.
[52] Gassco tildeler studiekontrakter for CO_2-transport (Gassco awards study contracts for CO_2 transport), Gassco. February 2016.
[53] Fullskala CO_2-transport med skip, rapportnummer PG23-NR.RF-17.138360 (Full-scale CO_2 transport using ships, Report No. PG23-NR.RF-17.138360), Gassco. November 2017.
[54] As described in reference 53): In the full-scale project the optimal round-trip time is estimated at four days, which is equivalent to one round-trip from Oslo, along the coast to Kollsnes and back.
[55] Maritim verdiskaping (Maritime value generation), Maritimt Forum. March 2016.
[56] According to figures from the Norwegian Government website Regjeringen.no. 2018.
[57]Figures from Statistics Norway. May 2017.

Norwegian suppliers can sell technology for CO_2 capture in an international market



The market for CO_2 capture technology and installations can reach a scale of over NOK 450 billion in Europe in 2050 and employ more than 40,000 people. Norwegian-developed technology will be capable of competing in this market, and also has a potential to spread globally.

In 2030 the market for CO_2 capture in Europe could amount to between NOK 75 and 200 billion. In 2050 it could rise to between NOK 155 and 450 billion. Globally, the size of the market could be NOK 8,500 billion in 2050 according to our model. The number of jobs directly connected with the construction and operation of CO_2 capture facilities in Europe could exceed 40,000 in 2050.

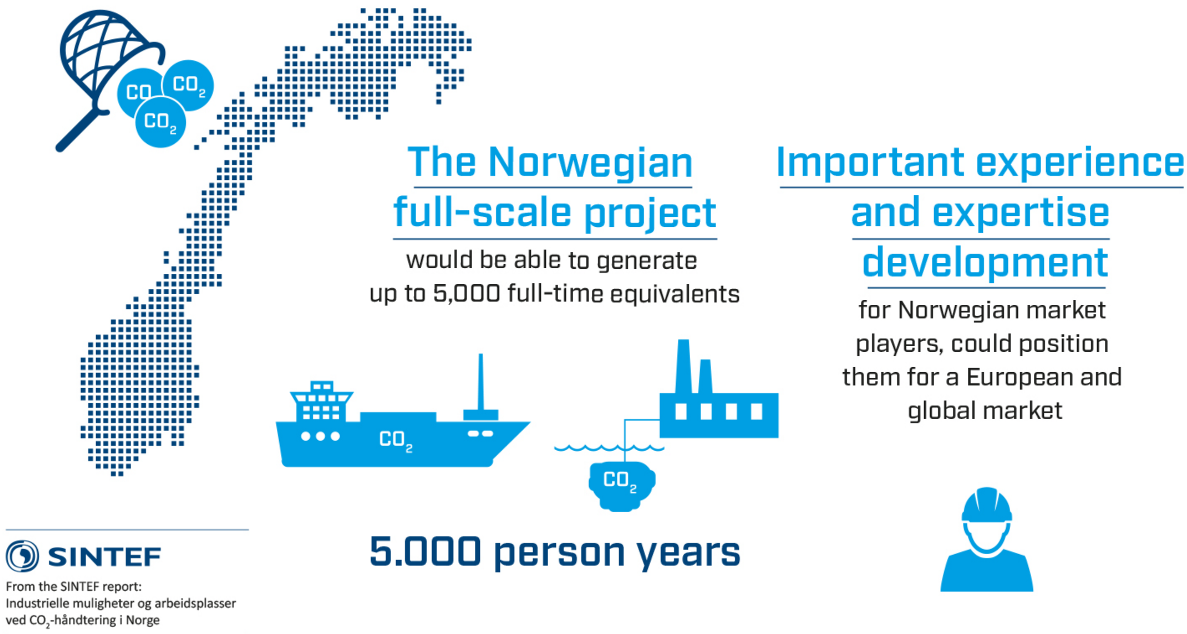
Norwegian operators, particularly Aker Solutions, but also others, have developed their own technology which could potentially be strong contenders for the European market. Aker's technology has been tested and validated on an industrial scale, among other things at Test Centre Mongstad and at Norcem's cement plant, and could become qualified for the world market through the full-scale project. Hydrogen Mem-Tech is another Norwegian company that is developing membranes for separating CO_2 and hydrogen from natural gas. This technology has been tested and demonstrated at Statoil's methanol production plant at Tjeldbergodden. Other Norwegian operators such as Air Products Kristiansand and Compact Carbon Capture AS are also showing interest in the CO_2 capture market.

However, Norwegian operators in this market will meet considerable competition from outside Europe, with Fluor and Mitsubishi, for example, already being established commercial suppliers on the world market. If Norwegian suppliers nevertheless succeed in establishing a market share of 10% of the European market, this will correspond to 4,000 jobs in 2050, and a market volume of around NOK 45 billion per year according to the High CCS scenario.

CCS project development and implementation
Through the realisation of a full-scale chain for CO_2 management it is expected that the commercial operators involved will build up experience that will be relevant to future facilities. Concept studies are being implemented for all elements of the chain. Comprehensive theoretical work is accompanied by testing of technological concepts from laboratory to industrial scale in order to validate selected concepts and reduce uncertainty in financial estimates. Implementation of the projects presupposes close interaction between industrial operators, suppliers and service providers. In this way, Norwegian operators can obtain experience through the full-scale project which will qualify them to sell services in future projects in Europe, based on their expertise in the planning, implementation and management of complex CCS projects.

The full-scale project will provide the industry with experience in the technical concepts and costs of capture, transport and storage. It could also form an important showcase for involved operators in connection with the development of future projects. The interaction between industry and the authorities provides important lessons in the planning and implementation of corresponding development projects, in the form of contract design, operational philosophy and operational agreements. As the first CCS chain in the world dealing with capture from different industrial sources, flexible sea transport and permanent offshore storage, the project will potentially provide unique experience in the realisation of an integrated CCS chain.

3.3 Industrial opportunities connected with the realisation of the Norwegian full-scale project



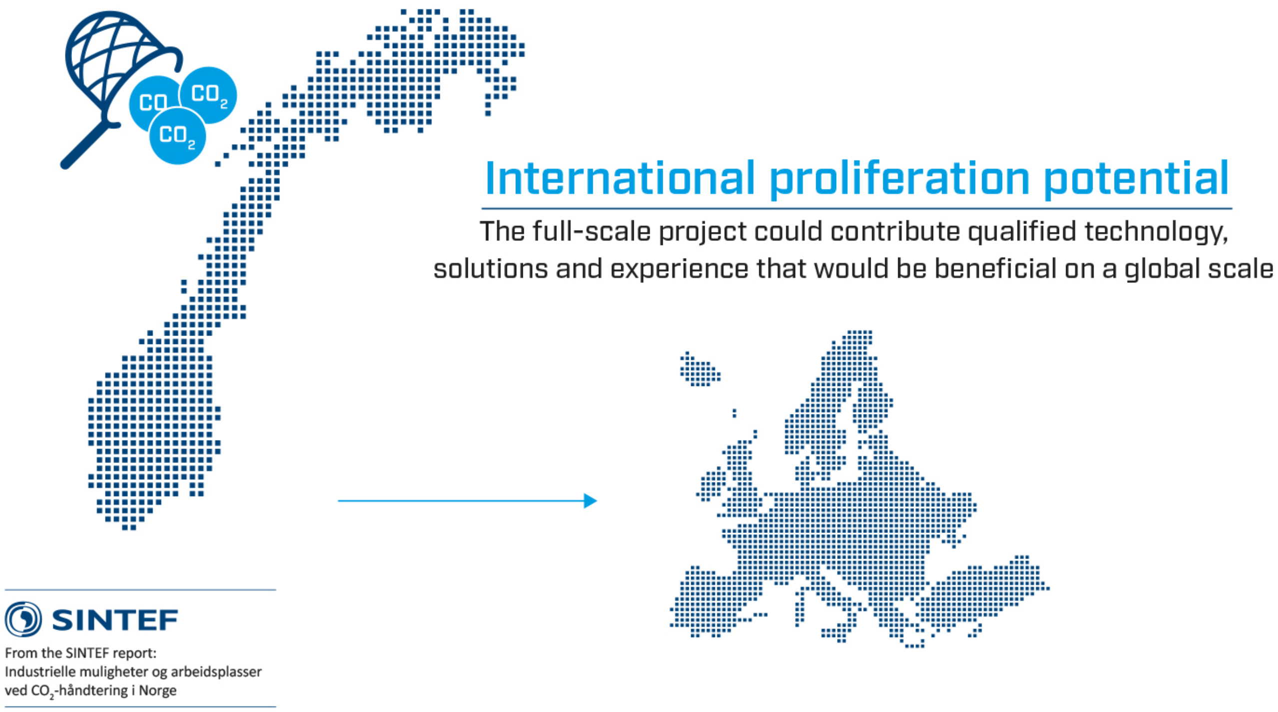
The Norwegian full-scale project could create employment corresponding to up to 5,000 full time equivalent (FTE) years directly connected with the project, mainly jobs in Norway. Technology development and qualification through the project could position Norwegian operators and provide competitive advantages in the international market. There is considerable potential for proliferation of technology and know-how, which will provide crucial lessons for the development of the next generation of CO_2 management projects.

Employment, technology development and technology qualification

The Norwegian full-scale project could create employment corresponding to up to 5,000 FTE years, comprising 650 FTE years per year for the four years of the construction period and just under 100 FTE years per year throughout the 25-year operating period, assuming that all three capture projects are realised (see Attachment B). Immediate ripple effects will arise in connection with indirect employment, which will increase the employment figure by a factor of just under 2 and increase the number of FTE years to between 8,000 and 9,000[27]. Thanks to the proximity of the Norwegian market, it is reasonable to assume that most of these FTE years will be won by Norwegian businesses.

However, for Norway the most important aspect of the full-scale project, apart from its contribution to limiting emissions of CO_2 from Norwegian industry, will be the development of experience and expertise acquired by Norwegian operators. Norwegian suppliers and centres of expertise will be actively represented in all phases of the full-scale project, connected with capture (Norwegian capture technology), transport (shipping companies operating CO_2 ships, and the possible building of CO_2 ships at Norwegian shipyards), storage (Equinor in collaboration with Shell and Total, and a number of suppliers) and management of the entire CO_2 chain (contractors and engineering companies). The full-scale project will provide these operators with unique experience in contributing to the planning, implementation and operation of CO_2 management infrastructure. In addition, the three industrial operators Norcem, Fortum and Yara will possess unique expertise and experience linked to gas scrubbing in their industrial sectors. The full-scale project as a whole will contribute to giving Norwegian operators prominence in the European and global markets.

Potential for proliferation



The full-scale project includes capture from three different industrial sources and based on the extensiveness of similar process industry plants in the world there is reason to believe that the selected concepts may have significant potential for proliferation by way of future projects. Two examples from the full-scale project are:

- **Cement**: The cement industry is responsible for 5-6% of global CO_2[58] emissions and considerable potential therefore exists for reducing emissions by means of capture and storage. HeidelbergCement in Belgium is currently testing other technologies for CO_2 capture than those tested by Norcem[59]. The company is the world's second largest cement and construction materials producer and has 80 cement factories in Europe alone.

- **Waste incineration:** Globally, 1.3 billion tonnes of domestic waste are produced annually and the amount is on the increase. A large proportion of this is organic material, which potentially makes a significant negative contribution to overall global emissions, i.e. the need to remove more CO_2 than is emitted. Sweden has considerable emissions from biomass, and the large-scale establishment of CO_2 capture and storage can therefore contribute significantly to reduction in their negative effect. Fortum is a participant in the full-scale project with its energy recovery plant at Klemetsrud in Oslo, and has a total of 23 combined power and heating plants of which four are located in Sweden.

Such examples illustrate that the Norwegian full-scale project can contribute qualified technology, concepts and experience which can make a difference on a global scale. The precondition is that enough qualified storage space exists, and here the full-scale project can also play an important role. The establishment and qualification of CO_2 storage on the Norwegian continental shelf will provide new insight into the nature of the subsurface which can be crucial to the development of a European centralised storage facility. Limited information is available regarding the geological formations that have not been exploited offshore in petroleum production, and mapping is carried out largely by way of seismic methods and a few exploration wells. The drilling of injection wells and any monitoring wells provides additional knowledge about the formations, and forms the basis for more reliable estimates of the storage capacity and optimal strategies for exploitation of storage facilities. Data collected in the course of the project, before, during and after injection, will also be relevant. Data collected at Sleipner and Snøhvit have been extensively shared with industrial and research groups, playing a decisive role in international knowledge enhancement in the last 20 years.[60].

Knowledge sharing is an important element of the plan for realising the benefits of the full-scale project and the participants must practise it in all parts of the chain. Knowledge acquired during the project will be valuable to participants in future projects, to academic communities co-operating with industry to develop the next generation of technologies, and to authorities deciding on possible public funding.

At the time of writing of this report, Sweden is accelerating its efforts to define its ambitions for CO_2 management. On 25 April 2018, large parts of Swedish industry will submit a plan for green competitiveness to the Swedish Prime Minister. Nine so-called "roadmaps" specifically describe how the transition to fossil-fuel free technology and improved competitiveness shall take place. Several of the Swedish roadmaps point out the importance of developing CCS concepts, for example in the mining industry: The Swedish mining industry is the largest in the EU and is responsible for 8% of Sweden's CO_2 emissions[61]. One of the industry's three important expectations of the politicians is the desire for commitment to research and development into fossil-fuel free production processes and CCS, including test plants and upscaling.

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[58] Bigger Climate Action Emerging in Cement Industry, United Nations Climate Change Conference. October 2017.
[59] HeidelbergCement hosts ground breaking ceremony for Calix carbon capture pilot project at Lixhe cement plant, Global Cement. February 2018.
[60] An example of knowledge sharing. S. Hagen: Sleipner: Knowledge sharing in CCS projects. 2012.
[61] LKAB et al.: Nu gör vi gruvan fossilfri (We are now making our mines fossil-fuel free), Dagens Industri. April 2018.

The interest of Swedish industry in CCS is shared by the country's government. The white paper "En klimatstrategi för Sverige" (A climate strategy for Sweden) submitted by the Government to Parliament on 12 April 2018, documents the intention to assess CCS as a possible initiative in a proposed study of how Sweden shall achieve net negative emissions after 2045[62]. The focus is on industries such as iron and steel, cement and refining, as well as biogenic emissions from burning biomass, for example in waste incineration plants If the development is as described in Sweden, this could involve potential for value transfer from the Norwegian full-scale project. Sharing of experience, expertise and technology will be highly relevant.

Norwegian infrastructure for CO_2 management: a competitive advantage for Norwegian industry
Infrastructure unites the country and provides industrial opportunities for the regions. Current examples are the national electricity grid and the ferry-free E39 highway project[63] which connects the country's regions and lowers barriers to industrial development in districts. A CO_2 management infrastructure will also potentially provide opportunities for industrial development. The CO_2 management chain planned in the full-scale project covers the Norwegian coast from Oslo to Kollsnes and could be expanded to the rest of the country. It will represent an important investment in infrastructure which could result in widespread ripple effects in the form of new business and development of existing commercial operations.

An important question in this context is to what extent the establishment of CO_2 infrastructure in Norway will improve the competitiveness of Norwegian industry, compared with a situation in which Norwegian industry must ship its greenhouse gases to other countries. An obvious effect is that the geographical proximity will reduce transportation costs. Norwegian commitment to infrastructure will also contribute to the development of the products of Norwegian suppliers, so that the industry can make use of Norwegian tenderers when setting up its own CO_2 capture projects. The operators of Norwegian CO_2 infrastructure will probably be to a large extent Norwegian.

The ability of Norwegian industry to collaborate with other Norwegian businesses involved in CO_2 management could represent a competitive advantage in itself. The reasoning behind this is that the Norwegian commercial model is characterised by high productivity and trust at the level of both business and society[64]. Mutual trust among companies reduces transaction costs as a result of more efficient collaboration. Norwegian industry will benefit from this and it will contribute to lowering the barriers for Norwegian industry connected with CO_2 management, compared with a situation where other countries are the first providers of CO_2 infrastructure.

[62] En klimatstrategi för Sverige (A climate strategy for Sweden), Government white paper. April 2018.
[63] The cost of the ferry-free E39 project is estimated at NOK 340 billion, which is around 15 times the cost of the Norwegian full-scale project.
[64] Report No. 37-2016 on behalf of the Norwegian Ministry of Education and Research, Socio-economic analysis. 2016.

4 The socio-economic profitability of CO_2 management

CO_2 management is necessary to limit global warming in accordance with the goals of the Paris Agreement. However, many sources of uncertainty exist when socio-economic profitability is to be estimated for a specific project: Will the international community comply with the Paris Agreement and cut emissions sufficiently to achieve its goals? In that case, what will the future quota price be? Will the demonstration of full-scale CCS in Norway result in the construction of other full-scale installations? How will the cost of full-scale CCS develop? Many undefined factors influence such estimates of profitability.

Quality management of the concept selection study for the full-scale project

To ensure the effective use of the community's resources, external assessments are carried out of the quality management of concept selections for Norwegian government investments. Two assessments have been completed of quality management of the Norwegian full-scale project for CO_2 management[65,66]. According to estimates carried out in these assessments, the full-scale project is not socio-economically profitable. The deficit of the "basic scenario" is NOK 20.7 million, resulting in a cost per tonne of stored CO_2 of around NOK 1,400.

Important conditions which influence the socio-economic assessments in the quality management are:

- Linear extrapolation of the quota prices (cf. the Thompson Reuters curve in Figure 8), which results in a much lower quota price than that which IPCC claims is necessary to achieve the 2-degree goal (cf. the IPCC 2-degree curve in Figure 8).

- The full-scale project will be the first and last of its type.

In an alternative 2-degree scenario, with a higher quota price and where we benefit from technological learning because the full-scale project is followed by more CCS-projects, the deficit is reduced from NOK 20.7 billion to NOK 1.8 billion. Unpriced impacts are not discussed further in the assessments. It should be noted in particular that the full-scale project will increase international awareness that CO_2 management is a viable and safe climate-change initiative ("the demonstration effect").

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[65] Kvalitetssikring (KS1) av KVU om demonstrasjon av fullskala fangst, transport og lagring av CO_2 (Quality assurance (QA1) of the concept selection study for demonstration of full-scale capture, transport and storage of CO_2), Oslo Economics and Atkins. 2016.

[66] Kvalitetssikring (KS2) av demonstrasjon av fullskala fangst, transport og lagring av CO2 Rapport fase 1 og 2 (Quality assurance (QA1) of the demonstration of full-scale capture, transport and storage of CO_2: Report Phase 1 and 2), Oslo Economics and Atkins. February 2018.

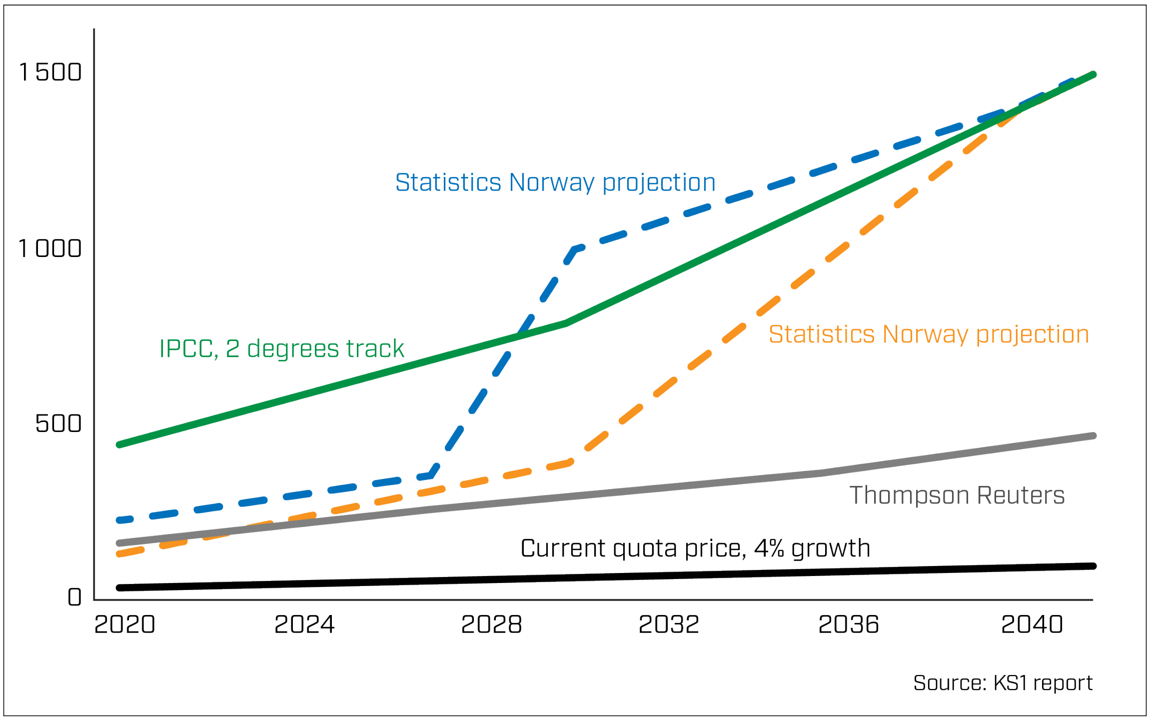

Figure 8. Extrapolated quota prices (NOK/tonne) according to QA1[65] (Source: Oslo Economics).

Several other conditions will potentially affect socio-economic profitability.

Achieving the 2-degree goal will be more expensive without CCS

The cost of other climate-change initiatives than CCS will be far more expensive than the cost of reducing emissions of greenhouse gases. IPCC's analyses indicate that achieving the 2-degree goal without using CO_2 management will be 140% more expensive. Several studies, including that of the IEA, maintain that it will not be possible to achieve the 2-degree goal without using CCS. Some industrial emissions cannot be handled in other ways because CO_2 is a natural result of the industrial process. Looking further ahead there will also be a need for net negative emissions which will remove CO_2 from the cycle. The only known way of doing this is by means of Bio-CCS, which entails the capture of CO_2 from the combustion of biomass. A successful full-scale project may also be a step in the direction of Bio-CCS.

The most important environment-related motive for the full-scale facility is that the project can promote the building of corresponding facilities, through the demonstration effect. If the full-scale project is successful it may in this scenario become socio-economically profitable even if the priced effects of the project should be negative.

Expected falling costs

In a 2-degree scenario involving significant development of CCS, the quality management reports indicate that the technological lessons from the full-scale project will result in a cost-reduction for all future projects of NOK 3.5 billion, or approximately 14% of the cost of the full-scale project.

If it is realised, the project will be the third offshore storage project, after Sleipner and Snøhvit. However, at the present time there are no examples of projects involving capture from several independent industrial sources with flexible infrastructure and geological storage of CO_2 without EOR. The full-scale project will therefore be the first of its type. Other projects involving the capture of CO_2 from industry are Quest in

Canada which captures CO_2 from hydrogen production and the Illinois Industrial CCS project which captures CO_2 from ethanol production. However, both of these projects have only one source and storage takes place onshore. The same applies to the Gorgon project being built in Australia, where 3.5-4 million tonnes of CO_2 from natural gas processing will be stored without EOR onshore.

The Boundary Dam Project with CO_2 capture from coal-fired power generation is also the first of its type. Here the learning effect is estimated to be high, and the cost of a subsequent facility will be 20-30% lower than what has now been built[67]. Lessons from Boundary Dam have thus been taken into account from Project 1 to Project 2. Experiences from the development of renewable energy technologies point in the same direction. Present-day solar cell panels cost a fraction of what they did 20 years ago. Developments in battery technology have resulted in a reduction in costs of 7% per year since 2010, and the costs are expected to fall by a further 6% per year until 2025.

Effects of scale

Development of infrastructure for the transport and storage of CO_2 represents a substantial part of the cost of the full-scale project. With some adjustments this infrastructure could be used to store CO_2 from several sources. The NORDICCS project[68], which studied the implementation of CCS in a Scandinavian perspective, revealed that the cost per installation of establishing ships and storage infrastructure in the North Sea falls sharply as the number of installations increases, as compared with a small number of projects which have to bear this cost alone.

European funding mechanisms

Opportunities for European funding do not affect the socio-economic profitability of the project from a global or European perspective, but could make the project more attractive from a Norwegian perspective. In 2017 four CCS projects were added to the European list of qualified Projects of Common Interest (PCIs). Three of the four PCIs are linked to Norwegian CO_2 storage in the North Sea. When a project has qualified it can apply for funding from the Connecting Europe Facility (CEF), an infrastructure fund totalling EUR 30 billion[69]. Of this amount EUR 5.35 billion is available for projects in the energy sector, including CCS.

The EU has recently adopted a revision of its Emissions Trading System (ETS), which is to apply from 2021[70]. In this context, the establishment of an innovation fund is being considered which will be financed through the sale of greenhouse gas emission quotas[71]. The size of the fund will depend on the quota price, but according to estimates it could exceed NOK 40 billion[72]. The fund shall contribute to the commercialisation of climate technology by assisting the establishment of large-scale demonstrations, and will apply to three main categories of technology: renewable energy, low-emission technology in energy-intensive industry and CO_2 management. The fund could potentially be of considerable importance for the financing of CCS projects in Europe.

[67] Carbon Capture and Sequestration Technologies program at MIT, MIT. September 2016.
[68] Marit Mazzetti, Nils Røkke and Nils Eldrup, NORDIC CCS Roadmap. December 2015.
[69] Connecting Europe Facility, INEA. April 2018.
[70] Kvotehandelsdirektivet (the Quota Trading Directive), Europalov. April 2018.
[71] Public Consultation on the Establishment of the Innovation Fund, European Commission. January 2018.
[72] Høringssvaret fra den danske regjeringen (Consultation response from the Danish Government), the Danish Government. March 2018.

Better resource use in developed fields

Petroleum operations are capital intensive and it is important to achieve effective resource use in operating fields. The use of CO_2 to enhance recovery from existing fields by way of CO_2 can provide revenue to a CO_2 management project. Petrobras' project at the Lula oil field in Brazil is the only offshore CO_2 EOR project in the world and stores 700,000 tonnes of CO_2 per year. The Norwegian full-scale project using three industrial sources will handle up to 1.4 Mtonnes of CO_2 per year. Past studies indicate that this is probably too little to make EOR a source of revenue on the Norwegian shelf in the short term, since EOR at oil fields in the North Sea will require stable supplies of several million tonnes per year[73,74].

The value of Norwegian natural gas

CCS can contribute to an increase in the value of Norwegian natural gas in a future in which Europe's use of fossil energy sources is declining. Two mechanisms make this particularly relevant from a Norwegian perspective:

- If the CO_2 content of the natural gas is not handled using CCS this can affect strategic decisions both at the political level and among major industrial operators in the EU, which in turn could contribute to a reduction in demand and therefore a lower price for natural gas.

- Without CCS the future quota price will probably be very high if the quota limit is set according to a 2-degree scenario. In isolation, this factor will contribute to reduced profitability for natural gas because of its CO_2 content.[75] With CCS the quota price will be reduced.[76]

Hydrogen produced from natural gas using CO_2 management will represent an energy carrier with a low CO_2 footprint. It can be used in hydrogen power generation plants, for the production of heat, as an ingredient in the process industry and as a fuel in the marine and onshore transport sector, replacing natural gas or other fossil fuels.

[73] The Norwegian Petroleum Directorate: Muligheter for gjennomføring av CO_2 injeksjonsprosjekt for økt utvinning på norsk sokkel (Potential for implementing CO2 injection projects for enhanced recovery on the Norwegian shelf). 2005.
[74] Willie Reid: A Selective Literature Review of CO_2 EOR in the UK North Sea Continental Shelf. 2015.
[75] One complicating factor here is the relative profitability of different fossil fuels.
[76] With CCS it is the price of the CCS service which is important for profitability, but the price of a CCS service will probably be based on the quota price if the market mechanisms are allowed to function and regulatory price control is not imposed. One complicating factor is the relative profitability of different fossil fuels.

Attachment A: Full-scale CO_2 management in Norway – background data

A1. CCS as a climate change initiative

What is CO_2 capture and storage?

CCS (Carbon Capture and Storage) is a collective term for technologies which reduce emissions of CO_2 from industrial installations to the atmosphere. The technologies include capture, transport and storage. Capture takes place by separating CO_2 from other gases in the emission stream using chemical or physical processes. The gas is compressed to a liquid state which is transported by pipeline or in ships or road tankers to a suitable storage location where the CO_2 is injected into porous rock formations in the substrata, covered by impermeable rocks which prevent leakage of CO_2. CCS technologies are of interest in reducing emissions from power stations based on coal, oil and gas combustion, from cement factories and from other industrial operations.

Three areas of application for CO_2 capture

CO_2 capture has traditionally been studied as a solution enabling coal and gas fired power stations to generate electricity with significantly reduced emissions. In Norway this will be of interest for power generation aboard petroleum platforms, which is almost entirely based on the use of gas turbines.

In recent times, CO_2 capture from energy-intensive process industry has received greater attention. In such industries, such as cement production, CO_2 originates both from fuels creating the heat necessary for the process and from refining the raw materials, which in the case of cement production is limestone. A cement factory cannot be made emission-free without the use of CO_2 capture, even if the energy requirement is satisfied by renewable energy and biofuels.

What the two CCS projects in Norway, Sleipner and Snøhvit have in common is that the CO_2 that is captured accompanies the natural gas from the reservoir, so-called "associated CO_2". The CO_2 must be removed if the natural gas is to be sold. At Sleipner and Snøhvit, CO_2 is transported and injected into the substrata for permanent storage. At other facilities the associated CO_2 is released after separation from natural gas.

International CCS status

The number of full-scale CCS projects has increased worldwide in recent years. A total of 17 facilities are in operation while 5 are being constructed [77,78]. In combination these projects will contribute to the storage of approximately 38 million tonnes of CO_2 annually. These projects are spread throughout the world and the portfolio includes processes that capture CO_2 from a wide range of sources. Among them is the capture of CO_2 from coal-fired power generation at Boundary Dam in Canada, from iron and steel production in Abu Dhabi, from hydrogen production at Quest in Canada, from fertiliser production at several locations in the USA, from production of bioethanol in Illinois in the USA, and from natural gas processing in the Norwegian Sleipner and Snøhvit projects. Among projects under construction are CCS at an oil refinery in Alberta, Canada and two plants in China producing chemicals from coal using CCS.

15 projects are being planned and 8 of these are in China or South Korea. Apart from the Norwegian full-scale project the remaining projects are in the USA (2), Australia (2) and the UK (2). As regards installations

[77] Large-scale CCS facilities, Global CCS Institute. April 2018.

[78] The GCCSI's definition of a full-scale project: For coal-fired power generation: >800 million tonnes of CO_2 per year, for industry: >400 million tonnes of CO_2 per year. This assumes injection of CO_2 into a dedicated storage facility and/or as pressure support for enhanced recovery (CO_2 EOR), and permanent storage must be documented. A lack of adequate monitoring of CO_2 storage results in many CO_2 EOR projects not being included in the database.

being planned, more of these involve CCS in power generation than in industry, but the projects also include industrial processes such as the manufacture of chemicals and fertiliser. The combined storage potential for projects being planned is around 27 million tonnes of CO_2 per year.

In Europe, two Norwegian CCS projects are in operation, at Sleipner and Snøhvit. In addition to the Norwegian full-scale project, two British CO_2 management projects are being planned:

- The Teesside Collective: Capture of 800,000 tonnes per year from industry from the outset, but with the ambition of increasing this to 10 million tonnes per year, with offshore storage in the North Sea and anticipated start-up in 2025.

- Caledonia Clean Energy Project: Capture of 3 million tonnes of CO_2 from gas-fired power generation, with storage in the Scottish sector of the North Sea and anticipated start-up in 2024.

Feasibility studies are being carried out for full-scale CCS chains in the UK, Ireland and the Netherlands[79]. In 2012 the European Commission established a programme to support the development of key projects for energy infrastructure for the member nations, known as Projects of Common Interest (PCIs)[80]. The scheme includes the establishment of infrastructure for CO_2 transport across national boundaries. In 2017 the EU included four CO_2 projects in its list of PCIs which qualify for funding and which support several of the feasibility studies. One of the PCI projects is being managed by Statoil and addresses the transport of CO_2 from the Teesside Industry Cluster and Eemshaven in the Netherlands (Nuons Magnum project) and its storage on the Norwegian shelf. In all the PCI projects, CO_2 is intended to be stored in different parts of the North Sea.

The GCCSI’s database also includes 85 pilot and demonstration projects throughout the world. 23 of these are in operation, 15 are being planned or constructed and the rest have been completed. These projects have been important in validating and demonstrating technology to obtain operational experience in the design and development of full-scale projects. A Norwegian example is the facilities for testing capture technology at Norcem’s cement factory at Brevik. A comprehensive test programme carried out from 2013 to 2017 forms the basis for concept selection in the full-scale project. A number of test centres have been set up at which research institutes and industry are collaborating in developing and testing new technology. Norwegian examples are the Test Centre at Mongstad for capture technology which can promote cost-reduction and the CO_2 field laboratory at Svelvik (CO_2FieldLAb) for the development of monitoring technology[81].

[79] Norges bidrag til et europeisk nettverk for CO_2-fangst og -lagring (Norway's contribution to a European network for CO_2 capture and storage), Bellona. March 2018.
[80] Projects of Common Interest, Global CCS Institute. September 2017.
[81] Barrio, M. et al.: CO_2 Migration Monitoring Methodology in the Shallow Subsurface: Lessons Learned From the CO2FIELDLAB Project, TCCS-7. June 2013.

A2. The status of CCS in Norway in 2018

Existing projects

Norway has been a pioneer in commercial CO_2 storage through the Sleipner and Snøhvit projects. The introduction of a CO_2 tax and a desire to test new technology were important driving forces behind the associated investment decisions. The development of CCS in Norway, commercially, technologically and in relation to the regulatory conditions, is the result of close collaboration between authorities, industry and research institutions. Both projects have been implemented as planned and no leakage of CO_2 has been observed.

Figure 9. The Sleipner platform with the CO_2 separation unit in the centre (Source: Statoil)

Sleipner CO_2 capture and storage

Sleipner, which came into operation in 1996, is the world's first commercial CO_2 storage project. Natural gas from the Sleipner West field contained up to 9% CO_2. To comply with the sales specifications the content had to be reduced to 2.5%. The CO_2 was separated from the natural gas aboard the offshore platform, compressed and injected through a well into the Utsira sandstone formation. CO_2 from the Gudrun gas field has been stored in the same formation since 2014. Around 850,000 tonnes of CO_2 is injected annually at Sleipner, and in all 17 million tonnes have been stored. If Statoil, as the operator of the Sleipner field, had decided to release the CO_2 instead of storing it, this would have resulted in an annual cost of NOK 481 million based on the prevailing rate of CO_2 tax[82].

The Sleipner project demonstrated that CO_2 storage is technically possible. It provided comprehensive know-how about full-scale storage, especially connected with monitoring of the reservoir. Know-how and data from Sleipner have been extensively shared with national and international operators and form a reference for research and development.

[82] Stortingsvedtak om CO_2 -avgift i petroleumsvirksomheten på kontinentalsokkelen for budsjettåret 2018 (Parliamentary resolution relating to CO_2 tax in petroleum operations on the continental shelf for the 2018 budgetary year), Lovdata. December 2017.

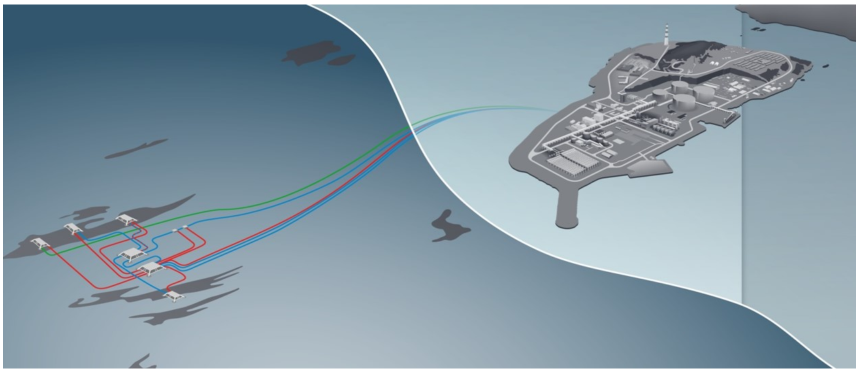

Figure 10. The Snøhvit concept for CO_2 capture from natural gas shipped ashore on Melkøya. CO_2 is transported by pipeline out to the field and is injected beneath the seabed (Source: Statoil).

Snøhvit CO_2 capture and storage

Production of liquefied gas (LNG) based on natural gas from the Snøhvit field in the Barents Sea started on Melkøya near Hammerfest in 2007. The gas contains 5-8% CO_2 which is separated out by means of amine technology after the gas has been transported ashore by pipeline. From Melkøya the CO_2 is transported back to the field in the world's first offshore CO_2 transport pipeline (150 km), and is injected more than 2000 metres beneath the seabed into the Tubåen sandstone formation, and into the Stø formation since 2011. Under normal operations, 1,800 tonnes of CO_2 are injected per day and 700,000 tonnes per year. In total, more than 4 million tonnes of CO_2 from the Snøhvit field have been stored.

The Snøhvit project was based extensively on know-how and experience acquired at Sleipner. An important lesson from the project was the integration of advanced geophysical methods and knowledge of injectivity for optimal exploitation of the storage capacity.

Figure 11. Test Centre Mongstad (Source: Statoil).

Technology Centre Mongstad (TCM)

Norway has assumed a leading role in technology development connected with CO_2 capture through Technology Center Mongstad (TCM). TCM was established in 2012 as a joint venture project between the Norwegian Government, Statoil, Shell and Total. The plant includes two units for CO_2 capture following incineration: one designed for use with amine-based solvents and one using chilled ammonia. TCM has sufficient capacity to handle 100,000 tonnes of CO_2 per year and is therefore the world's largest plant for the development and testing of capture technologies. The facility is located at the Mongstad refinery, north-west of Bergen, and provides realistic conditions. TCM's flexible design facilitates testing for a range of industrial processes in addition to gas and coal-fired power stations.

TCM collaborates with Norwegian and international technology suppliers. Among the technologies tested is an amine process from Aker Solutions (formerly Aker Clean Carbon). Aker specialises in the development and sale of technology for CO_2 capture. In addition to test campaigns on behalf of a number of suppliers, TCM has carried out its own campaigns in collaboration with several different operators.

Norwegian expertise in the field of CO_2 management

Norwegian industrial and technological operators

Norwegian operators have experience and expertise which provides competitive advantages in a future market for the transport and storage of CO_2. Statoil has safely stored CO_2 offshore for more than 20 years and is in a class of its own internationally. Statoil's pipeline to Snøhvit is the world's first offshore pipeline for CO_2. Safe overland transport of CO_2 also has a long history, particularly in North America. Larvik Shipping has transported CO_2 in liquid form from Yara's ammonia plant at Herøya to the European market since 1988 and hence has 30 years' experience as almost the only provider of this service in Europe.

Aker Solutions is in a special position among Norwegian operators in the field of CO_2 capture and has developed its own amine-based technology over many years, among other things in collaboration with SINTEF in the SOLVit programme, financed by Gassnova and others. Aker's capture technology has been tested at TCM and at Norcem's cement factory at Brevik. Aker Solutions is of interest as a supplier of capture technology to the operators involved in the full-scale project.
There are also other, smaller companies in the CO_2 market. Hydrogen Mem-Tech AS (a subsidiary of Reinertsen New Energy) and CoorsTek Membrane Sciences are developing membrane technology in Norway for separating CO_2 from hydrogen. Both are collaborating with Norwegian research groups. Hydrogen Mem-Tech has tested its technology at a pilot scale at Statoil's methanol plant at Tjeldbergodden. OCTIO AS is a technology company in the field of geophysical monitoring, offering 4D gravimetry and subsidence data to the oil and gas industry. The technology has been used in connection with CO_2 storage.

Figure 12. Aker Solutions has designed and constructed a mobile test unit for amine scrubbing which has been tested in the USA, Scotland and Norway (Source: Aker Solutions).

Research groups and centres of expertise
The CLIMIT programme, under the auspices of the Research Council of Norway and Gassnova, has supported research and development in CO_2 management since 2005, with annual grants of NOK 50-200 million going towards research and pilot projects. In the period 2009-2016 the Research Council also supported the Norwegian Centres for Environment-Friendly Energy Research (CEERs), BIGCCS, managed by SINTEF, whose work covered the entire CCS value chain, and SUCCESS, managed by Christian Michelsen Research, which focused on CO_2 storage. In 2016 the Norwegian CCS Research Centre (NCCS) (2017-2024), a CEER also supported by the Research Council of Norway, was initiated. The budget for each of the centres is of the order of NOK 300-500 million.

Norwegian research groups are world leaders in this field and are attractive joint venture partners in an international context. Norwegian participants have a solid involvement in the EU's framework programme for research (now Horizon 2020). At the largest scientific conference on CO_2 management (GHGT, last held in Lausanne in 2016), Norwegian research scientists were co-authors in 16% of all papers. On a global basis, Norwegian research scientists have been responsible for about 5% of all scientific publications in the last ten years, Norwegian research groups are therefore well-equipped to contribute to technological development and research advances not only in the Norwegian full-scale project.

A3. Climate goals and political considerations

National and international climate agreements

At the UN climate summit in Paris in December 2015, 195 countries agreed to reduce emissions of greenhouse gases to limit global warming to between 1.5 and 2 degrees Celsius by the end of the present century. All the countries endorsing the agreement undertake to prepare national plans defining how they will reduce their emissions and will report on their emission reductions every five years starting in 2023. Countries that continue to increase their emissions shall reach a maximum as soon as possible, and by 2030 at the latest, after which the volume of emissions shall fall. At some time between 2050 and 2100, the countries shall be “climate neutral”.

Norway is one of the signatories to the Paris Agreement. Through climate consensuses in Parliament, Norwegian politicians have also approved targets for Norwegian climate change initiatives and agreed on how the goals shall be achieved. The agreement contains goals for emission reductions in 2020 and a long-term goal of converting Norway to a low-emission society. Specifically, by 2020 Norway shall reduce its emissions of greenhouse gases by an amount equivalent to 30% of emissions in 1990. Norway shall be carbon neutral by 2050.

Major parts of the EU’s environmental and climate policy are incorporated into Norwegian law as a result of the EEA agreement. The EU has defined a goal of reducing emissions of greenhouse gases by 80% by 2050, relative to the level in 1990. 40% of the reductions shall take place by 2030. Norway is signed up to the EU’s quota system, which covers around half of Norway’s emissions, and our intention is to meet the climate target for 2030 along with the EU. In the industrial sectors not subjected to quotas, each country shall reduce emissions relative to the 2005 level, calculated on the basis of GNP per head of the population. Norway’s target has provisionally been set at 40%. The EU is in a good position to achieve the target of 20% reduction in greenhouse gas emissions relative to the 1990 level by 2020.

Power generation stands out as the sector with the greatest potential for emission reduction in the EU, and the EU has set a goal of clean power supplies by 2050. Renewable energy and CCS are put forward as the most important means to achieve the target. The IEA and IPCC maintain that extensive use of CCS is key to achieving the climate targets. The international community cannot succeed in phasing out fossil fuels to the required extent within the time frame available without CCS.

Consequences of an ambitious climate policy

How is Norway to achieve the emissions goals of the Paris Agreement and the climate consensus? This is also a crucial issue in the context of Norwegian CCS strategy. The IEA and IPCC make it clear that the international community cannot achieve the climate targets without CCS. The extent of emission reductions which must be achieved by means of CCS varies among the different projections, but generally lies between 14% and 20% of the total and increases when we progress from the 2-degree goal to the 1.5-degree target. Also in Norway, CCS is a necessary element of the range of initiatives for achieving the emissions targets. It is difficult to see how we shall achieve the targets in any other way within the time-frame referred to.

Attachment B: Estimating the effects of CCS on employment

About the estimates

The following is a description of the method we have used to estimate the effects on Norwegian and European employment of CCS in different future scenarios. In view of various elements of uncertainty as regards the future it is difficult to make precise estimates of employment numbers. Our aim is therefore somewhat more modest, being to provide an indication of what can be a realistic order of magnitude in various scenarios.

The Norwegian full-scale project

We estimate the number of people employed in the full-scale project ("Three sources" in QA1[83]) by dividing wage costs in the full-scale project by the assumed wage cost per employee. Table A.1 shows the basic figures and calculation of the total number of jobs in the full-scale project. The cost figures (see Footnotes 1 and 2 to the table) and the proportion of them that is represented by wages (Footnote 3) are obtained from the QA1 report. Assumed wage costs per FTE year is based on discretionary estimate whose basis is described in Footnotes 4 and 5.

The cost-based estimate gives a total of 89 employees per year in the operational phase and 2,560 altogether in the investment phase. These estimates will be sensitive, particularly to the proportion of the estimated wages.

Table B.1: Cost-based estimate of the number of FTE years and persons employed in the full-scale project for CO_2

	Operations	Investment
Cost	NOK 893 million per year[1)]	NOK 12,800 million [2)]
Proportion of wages[3)]	10%	20%
Wage costs[4), 5)]	NOK 89 million	NOK 2,560 million
Cost per FTE year	NOK 1 million	NOK 1 million
Total FTE years	89 per year (2,233 in all over 25 years)	2,560 FTE years

1) Table 9-3 Page 57 QA1.
1) Table 10-5 Page 73 QA1.
3) Page 64 QA1: "The operators have stated that the proportion … represented by manpower costs is somewhere between 10 and 20 per cent of the total costs. We have assumed that 20 per cent of investment, implementation and planning costs is wage costs and that 10 per cent of overall operating costs is wage costs."
4) SSB: "The average cost of one FTE year in petroleum production and mine operations was NOK 1.2 million in 2012".
5) For industry, cf. the same website as for 4), wage costs are approximately NOK 650,000 per FTE year. The CO_2 value chain probably includes elements of both. Wage growth has been limited in recent years. We assume an average cost of NOK 1 million per FTE year.

Since we are to use estimated employment figures to scale up from the full-scale project to a situation with many CCS projects, we estimate the number of jobs over 25 years. From Table B.1 we see that the average number of employees over 25 years is: 89 + 2560/25 = 191.

The estimated total number of FTE years in the CCS value chain (191 per year) is distributed among the various parts of such a value chain according to proportions based on a brief literature review, cf. Table B.2. Note that the distribution of costs between the elements in Table B.2 is different from that in the

[83] Kvalitetssikring (KS1) av KVU om demonstrasjon av fullskala fangst, transport og lagring av CO_2 (Quality assurance (QA1) of the concept selection study for demonstration of full-scale capture, transport and storage of CO_2), Oslo Economics and Atkins. October 2016.

Norwegian full-scale project. This is because the proportion of costs for capture is expected to fall with time (result from literature review).

Table B.2: Distribution of average number of people employed per year over 25 years

	Share	People employed
Capture	50%	96
Transport	20%	38
Storage	30%	57
Total	100%	191

Future CCS quantity

The values in Table B.3 are figures obtained from the IEA[84] and IPCC[85], and are formulated as three scenarios, respectively: Low CCS, Moderate CCS and High CCS. The first two are based on the IEA's 2-degree scenario[86]. "Moderate CCS" represents the complete IEA scenario in which there is 50% probability of limiting global warming to 2 degrees[87]. "Low CCS" is based on the same IEA scenario, but includes only emissions expected to be captured and stored from industry (Low CCS does not include CO_2 management in the power generation sector). The "High CCS" scenario is based on selected IPCC 2-degree scenarios that ascribe major importance to CCS and therefore result in larger volumes of captured and stored CO_2 per year in the years up to 2050.

Table B.3: CCS quantities in the world and Europe

All numbers in Mtonnes CO_2/year	2030	2050
Low CCS		
The world	500	1,800
Europe	50	170
Moderate CCS		
The world	1,500	6,000
Europe	130	320
High CCS		
The world	4,500	20,000
Europe[1)]	390	1,067

1) IPCC does not include specific values for Europe. Here we have used the same proportion as in the IEA's 2-degree scenario for 2050 (our *Moderate CCS*), i.e. 8.7% in 2030 and 5.3% in 2050.

[84] 20 years of carbon capture and storage, IEA. November 2016.
[85] The data have been obtained from the AR5 Scenario Database, which contains the data used as the basis for the IPCC Fifth Assessment Report, IPCC. 2014.
[86] The 2-degree scenario as calculated by IEA, in terms of amounts of stored CO_2 per world region. Here the volumes assumed for OECD countries in Europe are used as a basis for calculating European market size. Moderate CCS is equivalent to the full IEA scenario while Low CCS includes only the volumes of CO_2 expected to be captured and stored from the process industry in Europe in 2030 and 2050. Presented in 20 years of carbon capture and storage, IEA. November 2016.
[87] This scenario is based on a selection of the IPCC scenarios in which warming is limited to 2 degrees and in which CCS is ascribed major importance. The same relative proportion of CCS in Europe has been used as the basis for this scenario as is assumed in the IEA scenario. The data have been obtained from the AR5 Scenario Database, which contains the data used as the basis for the IPCC Fifth Assessment Report, IPCC. 2014.

CCS costs

The reports connected with quality management of the full-scale project[83] (QA1 and QA2) use a method for determining the future cost of CCS in which the cost is reduced by 8% each time the capacity of CO_2 capture and storage is doubled on a global basis. Moreover, the cost when the installed CCS capacity in the world reaches 1,800 billion tonnes of CO_2 has been estimated at NOK 1000 per tonne. This corresponds well with an estimated cost of the full-scale project of NOK 1,400 per tonne. We use these figures as conditions for our model, so that:

$$P_E = 1000 \cdot \left(\frac{T_V}{1800} \right)^{\frac{\ln(1-8\%)}{\ln(2)}} = 2458 \cdot T_V^{-0.12} \tag{1}$$

$$P_{GE} = \frac{1}{T_V} \int_{u=0}^{T_V} \left(2458 \cdot u^{-0.12} \right) du = \frac{P_E}{0.88} \tag{2}$$

$$P_E = 1000 \cdot \left(\frac{T_V}{1800} \right)^{\frac{\ln(1-8\%)}{\ln(2)}} = 2458 \cdot T_V^{-0.12} \tag{1}$$

$$P_{GE} = \frac{1}{T_V} \int_{u=0}^{T_V} \left(2458 \cdot u^{-0.12} \right) du = \frac{P_E}{0.88} \tag{2}$$

Where:

P_E= CCS costs in Europe for new projects (NOK per tonne, present value)
P_{GE}= Average CCS cost in Europe (NOK per tonne, present value)
T_V= Stored CO_2 in the world (million tonnes per year)

The values of T_V are obtained from Table B.3.

At any given time, the postulated future scenarios will be for installations in operation that have been established in different years. We assume linear phasing-in from 2020 to 2030, and continuing from 2030 to 2050. The cost of new installations and the average cost of established installations for different years and scenarios are shown in Table B.4.

Table B.4: CCS costs for different scenarios (NOK per tonne)

	New installations according to Equation 2	Average according to Equation 3
Low CCS		
2030	1,167	1,326
2050	1,000	1,136
Moderate CCS		
2030	1,022	1,162
2050	865	983
High CCS		
2030	896	1,018
2050	749	851

Future employment in the European CCS industry

We use the estimated employment in the full-scale project as the basis for estimating employment in CCS, assuming this will become a major industry in Europe. We scale up the total number of jobs in proportion to the number of tonnes stored, but reduce the number of jobs according to the expected cost reduction for CCS in a 2-degree scenario:

$$S_E = S_F \frac{P_E}{P_F}\frac{T_E}{T_F} \quad (3)$$

$$S_E = S_F \frac{P_E}{P_F}\frac{T_E}{T_F} \quad (3)$$

Where:

S_E= Total number of people employed in CCS in Europe
S_F= Total number of people employed in the full-scale project
P_E= CCS cost in Europe (NOK per tonne, present value)
P_F= CCS cost in the full-scale project (NOK per tonne, present value)
T_E= Stored CO_2 in Europe (million tonnes per year)
T_F= Stored CO_2 in the full-scale project (million tonnes per year)

The number of people employed in the full-scale project is estimated in Table B.2, the future amount of CO_2 for our scenarios is specified in Table B.3 and the average CCS cost for these scenarios is specified in Table B.4. We can thereby calculate Equation (3) for different scenarios, cf. Table B.5.

Table B.5: Number of people employed in different future scenarios

Scenario	Year	CCS in Europe (Mtonnes per year)	Average CCS cost (NOK per tonne)	Persons employed in Europe according to Equation (1)
The full-scale project		1.4	1,400	191
Low CCS	2030	50	1,326	6,304
Low CCS	2050	170	1,136	18,364
Moderate CCS	2030	130	1,162	14,364
Moderate CCS	2050	320	983	29,911
High CCS	2030	390	1,018	37,752
High CCS	2050	1,067	851	86,316

Employment in Norway

The assumptions regarding the Norwegian share of European employment in each of these categories are ours, cf. Table B.6. As regards storage, the same market share is assumed as the Norwegian share of the total storage capacity in Europe. As regards capture and transport, the market shares are our assumptions. The share of the transport market is higher than for capture, based on an implicit assumption that a Norwegian central storage facility is established in the North Sea and that a significant part (around half) of the CO_2 will be transported using ships. This will result in a large quantity of CO_2 transported by ship in the North Sea, where the Norwegian maritime industry will be able to play an important role. Based on Tables B.5 and B.6, we estimate the number of people employed in Norway in the fields of capture, transport and storage.

Table B.6: Shares of employment

	Share for CCS chain	Norwegian share of European share
Capture	50%	10%
Transport1)	20%	25%
Storage	30%	40%

1) Includes transport both by ship and by pipeline.

Table B.7: Norwegian employment in different future scenarios for CCS

Scenario	Year	Capture	Transport1)	Storage	Total
Low CCS	2030	315	315	757	1,387
Low CCS	2050	981	981	2,204	4,040
Moderate CCS	2030	718	718	1,724	3,160
Moderate CCS	2050	1,496	1,496	3,589	6,580
High CCS	2030	1,888	1,888	4,530	8,306
High CCS	2050	4,316	4,316	10,358	18,989

1) Includes transport both by ship and by pipeline.

Ripple effects

By "ripple effects" of CCS we mean employment linked to or ascribable to CCS operations which are not part of the CCS chain (capture, transport and storage) directly. This could be supplied by sub-vendors to businesses belonging to the CCS chain, supplies to these sub-vendors, etc. Such estimates are often based on input-output analyses that follow the business chain step by step. In connection with this project we have not had an opportunity to apply such models for the petroleum industry. For this reason, we base assumptions on openly available information related to petroleum operations.

According to analyses carried out by IRIS in the report "*Industribyggerne*" (The industry builders), the number of people directly and indirectly employed in the petroleum industry was 330,000 in 2014[88]. The number directly employed in that year was 186,000. In other words, the ratio between directly employed and the sum of directly and indirectly employed was 1.8.

Since offshore CCS has many similarities with the petroleum industry, we use the same factor when estimating the ripple effects of CCS, cf. Table B.8.

Table B.8: Norwegian employment (direct and indirect) in different future scenarios for CCS

Scenario	Year	Direct employment	Including ripple effects
Low CCS	2030	1,387	2,455
Low CCS	2050	4,040	7,151
Moderate CCS	2030	3,160	5,593
Moderate CCS	2050	6,580	11,647
High CCS	2030	8,306	14,701
High CCS	2050	18,989	33,611

[88] Industribyggerne (The industry builders), IRIS. March 2015.

One should be aware that the estimated ripple effect is the number of jobs directly or indirectly linked to CCS. This can also be referred to as "the gross effect".[89] This does not necessarily mean that the number of jobs in Norway increases by this estimate (or that unemployment is reduced correspondingly). For example, it can be envisaged that many of those employed would have obtained other jobs if the CCS industry did not exist. What we can refer to as the "net effect" is therefore smaller. It is also possible that the factor which applies to petroleum operations is a somewhat high estimate in the case of CCS, as a result of the high profitability of petroleum operations. On the other hand, our estimate of NOK 1 million per direct employee is based on the cost figures applying in the petroleum industry.

[89] Greaker and Rosendahl: Petroleumsvirksomhet i Barentshavet sørøst – om klima, økonomi og sysselsetting (Petroleum operation in the south-east Barents Sea – regarding climate, economy and employment), Energi og klima. August 2017.

SINTEF