EL001 Northern Lights

- Receiving and permanent storage of CO_2

Plan for development, installation and operation

Part II - Impact Assessment

October 2019

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TOTAL

equinor

Preface

Gassnova SF (Gassnova) is Norway's enterprise for CCS – carbon capture and storage – and is responsible for implementing concept studies and front-end engineering of the Norwegian full-scale CCS project. In June 2017, Gassnova awarded Equinor ASA (then Statoil) the assignment to study potential locations for an onshore facility for receiving, intermediate storage and further pipeline transport of CO_2 for permanent storage under the seabed on the continental shelf.

Equinor's scope of work was expanded in the autumn of 2017 to also include studying and planning a solution for ship transport of liquid CO_2 from carbon capture players in Eastern Norway (Fortum Oslo Varme from the waste-to-energy facility at Klemetsrud in Oslo, and the Norcem cement plant in Brevik) to the onshore terminal in western Norway.

Storage of CO_2 on the continental shelf is subject to the "Regulations relating to exploitation of subsea reservoirs on the continental shelf for storage of CO_2 and relating to transportation of CO_2 on the continental shelf" (the CO_2 Storage Regulations). The study and planning work includes preparing a Plan for Development and Operation (PDO) and a Plan for Installation and Operation (PIO), with associated impact assessment (IA) for the storage part of the full-scale CCS project. Pursuant to the provisions of the CO_2 Storage Regulations, ship transport of CO_2 is not covered by the IA, PDO and PIO requirements.

In October 2017, Equinor signed a partnership agreement with A/S Norske Shell (Shell) and Total E&P Norge AS (Total), which meant that Shell and Total would join as equal partners, while Equinor will lead the project.

The Ministry of Petroleum and Energy stipulated the study programme for the IA for Northern Lights in a letter dated 13 August 2019. The present impact assessment has been prepared by Equinor on behalf of the partners. Shell and Total have contributed with quality assurance of the impact assessment. Submission of the PDO and PIO is planned for the spring of 2020, after conducting consultation and processing of the statements concerning the impact assessment.

Equinor ASA hereby submits the impact assessment for Northern Lights for public consultation and comment. The consultation bodies are hereby given an opportunity to assess the current description of the environmental and social effects the development may have, including identified mitigating actions.

As of 4 October 2019, work on the impact assessment has been concluded. Any changes with regard to licences and permits after this date are not reflected or taken into consideration in the document. The document is, however, up to date as regards the latest developments concerning the London Protocol and export of CO_2. The parties to the London Protocol reached agreement on Friday, 11 October 2019 to allow temporary use of the amendment to the Protocol from 2009, which allows export of CO_2 for storage purposes.

The partners have developed a website for the Northern Lights project (English only), see https://northernlightsccs.com/ and https://northernlightsccs.eu/

Equinor, 21 October 2019

Sverre Overå
Project Director, Northern Lights

Abbreviations and terms

A

AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable (risk reduction principle)
ASD	Ministry of Labour and Social Affairs
AUV	Autonomous Underwater Vehicle

B

Barg	gauge pressure (overpressure)
BAT	Best Available Techniques
BOP	Blow-out preventer
BTA	Gross area
BOV	Decision to Continue

C

Capex	Capital Expenditure (Investeringskostnader)
CCS	CO_2 capture and storage
CO_2	Carbon dioxide
CH_4	Methane

D

DG	Decision Gate (beslutningspunkt)
DSB	Norwegian Directorate for Civil Protection
DP	Dynamic positioning
DFU	Defined hazard and accident situations
DWT	Deadweight tonnes (dødvekttonn)

E

EL	Exploitation licence (utnyttelsestillatelse)
ESD	Emergency shut down (nødavstengning)

F

FAR	Fatal Accident Rate
Fm.	Formation

H

HAZID	Hazard Identification (Fareidentifikasjon)
HAZOP	Hazard and Operability (Fare- og installasjons-/driftsanalyse)
HDD	Horizontal Directional Drilling (retningsboring)
HIPPS	High Integrity Pressure Protection System
HSE	Health, safety and the environment

I

IDLH	Immediately Dangerous to Life or Health
IMO	International Maritime Organisation
IPPC	Integrated pollution prevention control
ISPS	International Ship and Port Facility Security Code

K

KLD	Ministry of Climate and Environment
KMD	Ministry of Local Government and Modernisation
IA	Impact assessment
KW	Kilowatt (thousand watt)
KWh	Kilowatt hour (one kilowatt hour)

M

MEG	Monoethylene glycol
Mt	Megatonne (= million tonnes)
MSL	Mean Sea Level (middelvannnivå)
MW	Megawatt (1000 kilowatt = 1 million watt)
MWh	Megawatt hour

N

NH_3	Ammonia
Nm / nm	nautical mile (= 1852 metres)
NNSN	Norwegian National Seismic Network
NOFO	Norwegian Clean Seas Association for Operating Companies
NOROG	Norwegian Oil and Gas Association
NOx	Nitrogen oxides

O

NPD	Norwegian Petroleum Directorate
OD	Outer diameter (ytre diameter)
MPE	Ministry of Petroleum and Energy
Opex	Operating Expenditure (Driftskostnad)
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic

P

PIO	Plan for Installation and Operation
PBA	Planning and Building Act
PCO	Pipeline Commissioning (previously RFO)
PLEM	Pipeline end module (rørlednings endemodul)
PLONOR	Pose Little or No Risk to the Environment
PRM	Permanent Reservoir Monitoring
PSA	Petroleum Safety Authority Norway
ppm	parts per million
PSD	Process Shut Down (prosessnedstengning)
PSV	Pressure Safety Valve (trykksikringsventil)
PDO	Plan for Development and Operation

R

RVA	Risk and vulnerability analysis
ROV	Remote Operated Vehicle (fjernstyrt undervanns-fartøy)

S

SOx	Sulphur oxides
SVO	Especially valuable and vulnerable areas

T

APA	Awards in Predefined Areas
TRA	Total Risk Analysis
TSS	Traffic Separation Scheme

U

UHF	Ultra High Frequency

V

VHF	Very High Frequency
VSD	Variable Speed Drive (hastighetsregulator)

Å

AADT	Annual Average Daily Traffic

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Summary

Norway has signed the Paris Agreement on reduction of CO_2 emissions to limit anthropogenic (human-caused) climate change to less than 2ºC, and preferably limited to 1.5ºC, compared with the pre-industrial level. The Agreement entails international obligations to implement major reductions in CO_2 emissions. Together with the EU, Norway has committed to achieving a 40% reduction in CO_2 emissions by 2030 compared with the 1990 level. In 2018, Norwegian emissions were 52.9 million tonnes of CO_2 equivalent, where CO_2 accounts for about 83% of this.

Gassnova SF is Norway's enterprise for CCS – carbon capture and storage – and is responsible for implementing concept studies and front-end engineering and design of the Norwegian full-scale CCS project which encompasses capture, transport and storage of CO_2 (CCS). In the summer of 2017, Gassnova awarded Equinor ASA (then Statoil) the assignment to study and plan a ship solution to transport cold CO_2 from industrial capture players, a facility for receiving liquid CO_2 from ships, intermediate storage, further pipeline transport, injection and permanent storage approximately 3 000 meters under the seabed on the continental shelf, all of this in a safe manner. Equinor established the Northern Lights project, and in late summer 2017 entered into a project collaboration with A/S Norske Shell (Shell) and Total E&P Norge AS (Total) for implementation of the study work.

On 11 January 2019, the King in Council resolved to award Exploitation Licence no. 001 (EL001) for CO_2 storage on the Norwegian shelf to licensee Equinor. Equinor has been designated operator of EL001. The awarded area is unlicensed in relation to the Petroleum Act, and comprises blocks 31/4 (part), 31/5 (part), 31/7 (part), 31/8 and 31/9 (part).

Transportation and storage of CO_2 on the continental shelf is subject to the "Regulations relating to exploitation of subsea reservoirs on the continental shelf for storage of CO_2 and relating to transportation of CO_2 on the continental shelf" (the CO_2 Storage Regulations). Pursuant to these Regulations, a Plan for Development and Operation (PDO) shall be prepared, as well as a Plan for Installation and Operation (PIO), with associated impact assessment (IA). The plan is to submit the PDO and PIO in April 2020 for the authorities' project approval process.

The plan calls for establishing the onshore facility for intermediate storage and further pipeline transport of CO_2 for geological storage in the Johansen Formation south of the Troll field (approximately 75 km from land) in Naturgassparken in Øygarden municipality about 30 km northwest of Bergen. A phased development is planned for Northern Lights. Development Phase 1 has a planned capacity of 1.5 million tonnes of CO_2 per year from late autumn 2023, with an operating period of 25 years. Development Phase 2 has a planned capacity of up to 5 million tonnes of CO_2 per year, with realisation contingent on contractual access to CO_2 for geological storage.

A decision has been made to drill a confirmation well for the purposes of verifying well and reservoir assumptions that form the basis for development of the project based on storage in the Johansen Formation. The well will be drilled in November 2019 using water-based drilling chemicals, and well testing will be conducted. No vulnerable environmental assets have been identified in the area.

An approximately 100-km long pipeline (12¾") will be installed from the onshore facility to the injection well, which will be ploughed/jetted into the seabed in the fishery-intensive area southwest of Troll A. The transport capacity of the pipeline is sufficient to handle the project's Development Phase 2. The umbilical system from Oseberg A for supplying hydraulic fluids and MEG, electricity and signals to the well's subsea facilities will cross fishery-intensive areas and will be ploughed/jetted into the seabed along the entire route to the well. Construction work will take place in autumn 2019 (installation of the Subsea Injection Satellite – SIS in conjunction with drilling the well), and in the summer seasons in 2021, 2022 and 2023. The subsea facility that will be designed and constructed in accordance with regulatory requirements will have a shape and

design that deflects trawls, and Equinor does not see a need for establishing a permanent safety zone where fishing is prohibited.

Oseberg A has been selected as the offshore host installation for the umbilical system, hydraulic and MEG systems, as the installation has available capacity in these systems. An open, water-based hydraulic system with return to sea has been selected for operating valves on the subsea facility on the injection well. Hydraulic fluid has been placed on the substitution list for Oseberg A, with planned phase-out and substitution by 2027.

No environmental or social consequences have come to light that would indicate that the project should not be carried out. The most severe negative environmental effect is associated with the aesthetical and landscape consequences as a result of establishing a facility with storage tanks on land. The geological CO_2 storage will be monitored with the aid of seismic surveys prior to start-up of CO_2 injection and at intervals of a few years during and after injection ends. Seismic is considered to entail some negative consequences for fish, marine mammals and fisheries in the affected areas offshore. As regards other environmental and cultural study topics, the consequences are largely deemed to be in the categories minor or insignificant change. Development and operation of the project is considered to entail improvement of the factors related to tourism and business development in the area. For the purposes of safeguarding consideration for third parties and safety during the operations phase, the zoning plan for the facility has established zones requiring special consideration based on criteria from the Norwegian Directorate for Civil Protection, as well as the performed spread and risk analyses.

The development and construction phase of the project is estimated to entail emissions of about 39 170 tonnes of CO_2 and 742 tonnes of NOx, including drilling the confirmation well in winter 2019/2020. In the operations phase (25 years for Development Phase 1), the facility will be connected to the power grid on land and will also supply the transport ships with onshore power during their time at quay and offloading of CO_2.

Sufficient construction power is available from the existing BKK power grid station in Naturgassparken. Updated dialogue with BKK Nett in autumn 2019 yielded information indicating that tie-in of new consumption in the region may be difficult until Statnett has concluded its ongoing studies in 2020. This also applies for connection of Northern Lights with approximately 10 MW to BKK Nett's regional grid.

Preliminary estimates indicate that operation of the Northern Lights facility and permanent CO_2 storage on the Norwegian shelf will entail emissions in the order of 720 tonnes of CO_2 per year. This amounts to about 0.05% of the receiving capacity of 1.5 million tonnes of CO_2 per year for Development Phase 1. Development Phase 1 has a handling and injection capacity that represents 3% of overall Norwegian CO_2 emissions in 2018, or 11% of the CO_2 emissions from industry and mining in Norway. For Development Phase 2 (5 million tonnes of CO_2 per year), the capacity represents 11% of the total CO_2 emissions, or 44% of the CO_2 emissions from Norwegian industry and mining.

As of today, no functional market has been established for purchase and sale of CO_2 for receiving and permanent storage. Consequently, there is also no complete, self-financing value chain with functioning market mechanisms for permanent storage of third-party CO_2. Therefore, there is a need for partial State financing to establish and operate such a facility in Norway. The financial framework conditions for the project have not yet been clarified as of the consultation period for the present IA, and consequently no calculations have been made regarding socio-economic profitability.

Taking a basis in concept costs from 2018, the investment costs for Development Phase 1 in spring 2019 have been adjusted to reflect concept changes that will be covered by the IA, PDO and PIO, and the preliminary estimate (+/- 30% uncertainty) is 6.35 billion NOK (2018) for development of Northern Lights. This takes account of factors such as Oseberg A as subsea control system host installation, transport ships for CO_2 shall not be included and removal costs are included. A preliminary estimate of annual operating costs amounts to 179 MNOK (2018). The Norwegian share of the value creation is estimated at approximately 57% during the construction phase, which is equivalent to approximately 3.5 billion NOK (2018). Estimates indicate

that this will lead to a national employment effect of approximately 2 100 full-time equivalents, which includes direct and indirect effects as well as consumption effects. The regional value creation is relatively limited, estimated at approximately 6%, which is equivalent to approximately 380 MNOK (2018). Operation of the facilities is expected to lead to an annual employment effect of approximately 46 full-time equivalents at the national level, 9 full-time equivalents at the regional level and 18 full-time equivalents at the local level.

Environmental risk associated with a potential leak from the Aurora storage reservoir is negligible/low. The environmental risk is considered low/negligible for CO_2 emissions to air from the facility and low/negligible for emissions of LNG from the transport ship while moored at the quay at the facility. The environmental risk in the water column and on the seabed for minor leaks from the pipeline is considered low. The environmental risk on the sea surface for major leaks from the pipeline is assessed as low to moderate.

1 Introduction

1.1 Carbon capture and storage is part of the climate solution

The Paris Agreement lays out ambitious goals for reduction of CO_2 emissions to limit anthropogenic (human-caused) climate change to less than 2º C, and preferably limited to 1.5º C, compared with the pre-industrial level. Equinor, Shell and Total all acknowledge the impact of climate change, while also affirming that access to fossil energy continues to play an important role in helping humans to achieve and maintain good quality of life and a good standard of living.

Carbon capture and storage (CCS) is one of the technologies where both Equinor, Shell and Total are targeting efforts as a part of the companies' climate commitment. CCS is considered to be an important long-term measure for reducing global CO_2 emissions. This is also supported by the Energy Technology Perspective Report from the IEA (International Energy Agency), 2017. IEA assumes in the 2-degree scenario that 6 billion tonnes of carbon will be captured and stored each year, by 2050.

All three companies in the Northern Lights partnership agree that, at this moment in time, CCS is the most important and leading technology for decarbonisation of fossil fuel, and the only developed technology that can yield major reductions in CO_2 emissions from industrial processes (e.g. in connection with steel and cement production).

Equinor, together with its partners Shell and Total, will develop the part of full-scale carbon capture and storage that relates to transport and storage of CO_2. Through this project, the three partners will further develop and apply the companies' respective expertise and experience within the field of CCS in cooperation with authorities and other industry partners in the chain, and thereby use learning and transfer of knowledge to promote CCS as an important climate instrument. The CCS chain being studied has the flexibility to accommodate expansion. This can lower the entry barrier for industry players and nations in Europe that want to realise their first CCS projects.

The CCS technology has been tested, but a solid commercial framework must be set up that can stimulate use in the scope necessary to achieve climate goals. The Government's implementation of concept studies and front-end engineering of full-scale CCS in Norway will, through public-private partnerships, seek to demonstrate a commercial framework that is attractive for both the industry and the authorities.

Development of CCS can also contribute to establish a hydrogen market. Hydrogen is an emission-free energy carrier that can be used for purposes such as generating electricity, heating and as fuel. In connection with production of hydrogen from natural gas, the CO_2 that is formed in the process can be safely captured and stored.

Based on their respective circumstances and positions, the companies that are collaborating in Northern Lights have nuanced approaches to the climate challenge and CCS. Company-specific sections have been included in the following to reflect this.

Equinor views the changes that are taking place in the oil and gas industry, energy markets and international policy as opportunities to shape and improve the energy sector of the future. Equinor targets its work as an energy company to be part of the solution to the world's energy and climate challenges. The company wants to set an example for how the oil and gas industry must develop, show leadership and blaze a trail to better solutions. Equinor's climate roadmap describes how we are developing our activity to be part of the solution to the world's energy and climate challenges. Equinor's climate commitment and climate roadmap are described in more detail in the following link:
https://www.equinor.com/no/how-and-why/sustainability.html

Equinor has been working with the innovative CCS technology since the 1990s and has some of the world's largest projects in the CCS field. To date, the company has captured and stored more than 20 million tonnes of CO_2 on Sleipner and Snøhvit on the Norwegian shelf. This has given Equinor more than 20 years of experience in operating CCS, and has positioned the company as a world leader in this field. Equinor continues to work toward the goal of commercialising CCS, and constantly assesses the possibility of further reducing our own CO_2 emissions.

Equinor has started work to verify technical and financial factors for hydrogen value chains with CCS and to assess the potential of such concepts over the longer term. The CO_2 storage facility is an important building block in these value chains that could contribute to Europe achieving its climate goals in a long-term perspective.

Shell intends to play a role in facing the energy challenges by exploring and applying solutions within its areas of technical expertise. In Shell's opinion, CCS will become a critical low-carbon technology that must be spread internationally if the world is to achieve the ambition of zero emissions.

Shell sees a huge advantage in cooperating with Equinor and Total as partners in the Northern Lights project. The companies' respective experiences are a significant benefit for project implementation and can accelerate development of a market for CCS.

The value chain in Northern Lights is unusual because it is based on transporting CO_2 using ships. Through Shell Trading and Shipping (Stasco), Shell possesses unique expertise and comprehensive experience within LNG, which has analogies with CO_2 transportation. The company also operates the world's largest LNG fleet. Participation in the Northern Lights project can stimulate and increase the likelihood of Shell expanding its low-carbon activity by searching for new business opportunities.

Shell is involved in many CCS demonstration projects around the globe.

- Together with the Canadian government, Shell has developed, constructed and is now operating the integrated CCS Quest at commercial scale, which captures, compresses and stores about 1 million tonnes of CO_2 per year.
- Gorgon, the world's largest CCS operation, and with Lula CCS together with Petrobras.
- Shell led the development and completed front-end engineering of the integrated, commercial-scale CCS project called Peterhead, which was cancelled by the UK government.

Shell is involved in a number of CCS industry cooperation activities and CCS R&D programmes. More detailed information about Shell's work on handling the climate challenges is available in this link: https://www.shell.com/sustainability/environment/climate-change.html

Total integrates climate challenges into its strategy, which aims to limit global warming to less than 2°C by 2100, compared with the pre-industrial level. The company has been actively involved in CCS projects for many years. This includes:

- Participates as partner in Norwegian CCS projects (Snøhvit, Sleipner and in Technology Centre Mongstad - TCM)
- Lacq pilot project from 2010-2013 in France. This project helped provide Total with relevant competence, particularly in connection with the process for regulatory authority approval, and CCS storage licences.
- Total's CCS R&D budget has tripled over just two years, and is expected to account for 10% of the company's total R&D budget, excluding R&D for special chemicals.

- Total takes part in the Oil and Gas Climate Initiative (OGCI), which gathers 10 of the world's largest oil and gas companies in a single organisation. OGCI Climate Investment will earmark about half of its financing of USD 1 billion to CCS technology.

A successful CCS industry requires cooperation between the public and private sectors, and across industries. Total's participation in the Norwegian full-scale CCS project is in line with this approach. Additional information and examples of integrating climate into Total's strategy are available at this link: https://www.total.com/en/commitment/environmental-issues-challenges/climate-change%20

1.2 National climate policy, carbon capture and storage

Norway has signed the Paris Agreement on reduction of CO_2 emissions to limit anthropogenic (human-caused) climate change to less than 2ºC, and preferably limited to 1.5ºC, compared with the pre-industrial level. The Agreement entails international commitments to major CO_2 emission reductions. Together with the EU, Norway has committed to achieving a 40% reduction of the CO_2 emissions in 2030 compared with the 1990 emission level. Total Norwegian emissions in 2018 were 52.9 million tonnes of CO_2 equivalent, where CO_2 accounts for about 83% of this.

In the Government's Sundvolden declaration (/1/) the Solberg government stated that it would *"pursue a broad commitment to develop a cost-effective technology for capture and storage of CO_2..."*. The Government's strategy for CCS work was submitted in connection with the Fiscal Budget for 2015 (Prop. 1 S (2014-2015)) (/2/). The strategy encompassed a wide range of activities, including work on potential full-scale CCS projects in Norway.

In July 2016, the Ministry of Petroleum and Energy (MPE) published a report that summarises feasibility studies of full-scale CCS implemented in Norway (/3/). Gassnova SF (Norway's CCS enterprise) is the designated responsible party for an overarching value chain consisting of three sub-studies (capture of CO_2 from selected industrial facilities, ship transport of CO_2, as well as receiving, intermediate storage and transport of CO_2 for injection on the continental shelf). The relevant full-scale CCS project that is now being studied in Norway is the world's first CO_2 capture, transport and storage project (CCS) that can handle CO_2 from multiple independent CO_2 sources. Existing CCS projects handle CO_2 from a single (own) source, such as injection and storage of CO_2 from the wellstream from Sleipner (since 1996, approximately 1 million tonnes of CO_2 annually) and Snøhvit (since 2008, approximately 0.7 million tonnes of CO_2 annually) on the Norwegian shelf.

In the government platform from Jeløya (January 2018) (/4/) the Solberg II government stated that it will "*Contribute to develop a cost-effective technology for capture, transport and storage of CO_2. The Government will present a comprehensive assessment of full-scale CCS to the Storting no later than in connection with the revised national budget, RNB 2018, and will have the ambition of realising a cost-effective solution for full-scale CCS facilities in Norway, given that this yields technological development in an international perspective."*

In RNB 2018 (Prop. 85 S 129 (2017-2018), the Government presented the status of the work on a full-scale CCS project for capture and storage of CO_2. Norway's climate goals are also summed up here, see box below (text from page 129 in Prop. 85 S).

"Norway has ambitious climate targets:
1. By 2020, Norway will cut global greenhouse gas emissions corresponding to 30 per cent of Norway's emissions in 1990.
2. Norway has taken on a conditional commitment of at least a 40 per cent emission reduction in 2030 compared with 1990.
3. Norway will be climate-neutral in 2030.
4. Norway has adopted a statutory target of becoming a low emission society in 2050.
5. Reduced emissions of greenhouse gases from deforestation and forest degradation in developing countries, in accordance with sustainable development.
6. Political objectives for society to be prepared for and adapted to climate change."

The Government states the following in Prop. 85 S (2017-2018), page 129: In addition to being one of five priority areas for the Government's climate policy, capture and storage of CO_2 is also part of the Government's strategy for green competitiveness and the Government's ocean strategy.

The Government platform from Granavolden (January 2019) (/5/) *continues its prevailing policy concerning capture and storage of CO_2 (page 86): The Government will:*

- *"Contribute to develop technology for capture, transport and storage of CO_2, and have the ambition of realising a cost-effective solution for full-scale CCS in Norway given that this yields technological development in an international perspective."*

1.3 Early concepts considered – prior to establishing the Northern Lights collaboration

Gassnova SF is Norway's enterprise for CCS. In May 2015, Gassnova completed a pre-feasibility study of potential full-scale CCS projects in Norway, which identified several emission sources and storage locations that could be technically suitable for CCS and industrial players that may be interested in participating in further studies. In the autumn of 2015, the Government decided to continue the project in a feasibility study phase (/3/). The Ministry of Petroleum and Energy (MPE) had the overall responsibility for the work on the feasibility studies. Gassnova SF acted as coordinator with responsibility for the capture and storage parts of the project, while Gassco AS had responsibility for the transportation part.

The MPE's feasibility study (2016) (/3/) provides a general summary of which alternative CCS chains with solutions for development and operation of a permanent storage facility were assessed in the work. The feasibility study also recommends that a potential continuation of the project should be based on the following main concept:

The transport ships transport cold, pressurised and liquid CO_2 from capture players to a receiving and intermediate storage facility on land in western Norway. Cold and liquid CO_2 is stored intermediately before it is pumped through an export pipeline for injection for permanent storage in one or more new injection wells in suitable geological reservoirs in the Smeaheia area east of the Troll field.

Reference is made to Appendix A for a more detailed description of the storage locations and development concepts that were assessed in the MPE's feasibility study.

The current IA will not include more detailed impact assessments of the alternative solutions that were considered before Gassnova awarded the study contract in the summer of 2017, and the Northern Lights collaboration was established.

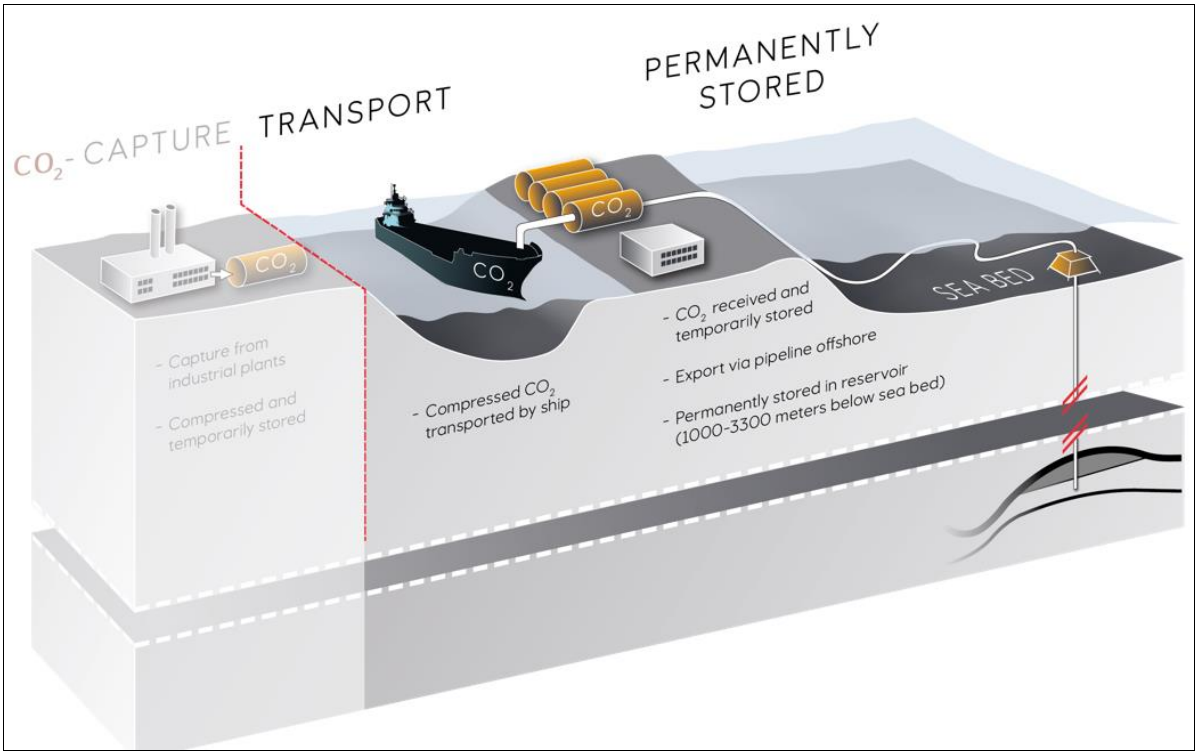
1.4 Full-scale transport, receiving and storage of CO_2

Gassnova is responsible for implementing concept studies and front-end engineering of full-scale CCS, which includes capture, transport and storage of CO_2. In June 2017, Gassnova awarded a study contract to Equinor (then Statoil) for implementation of concept and front-end engineering studies for a development solution in line with the recommendation from the feasibility study. Equinor established the Northern Lights project and entered into a project collaboration with Shell and Total in late summer 2017 to implement the study contract.

Equinor ASA (then Statoil) has received the assignment from Gassnova to study and plan a ship solution to transport cold CO_2 from the capture players, a facility to receive liquid CO_2 from ships, intermediate storage, further transport via pipeline, injection and permanent storage 1000-3300 metres under the seabed on the continental shelf – all in a manner that is both safe and secure. This makes up the transport and storage part of a total value chain as illustrated in Figure 1-1.

Ship transport of bulk CO_2 is exempt from the impact assessment requirement (cf. Chapter 1.6), and will not be subject to further consideration in the existing IA.

Figure 1-1 Illustration of overall value chain for CO_2 capture, transport and storage in Norway. CO_2 transport and storage is part of Equinor's scope of responsibility (grey).



1.5 EU requirement for impact assessment

The impact assessment requirement is laid down in the EU regulations which Norway has incorporated and reflected in the Norwegian statutory framework, such as the Pollution Control Act, the Planning and Building Act and sector legislation, including the Petroleum Act and the CO_2 Storage Regulations. Council Directive 97/11/EC of 3 March 1997 amending Council Directive 85/337/EEC requires impact assessment of the effects

of certain public and private projects that may have significant environmental and/or socioeconomic consequences.

1.6 Statutory requirements for impact assessment

The CO_2 storage initiative in question is subject to a study obligation pursuant to several statutes.

- The Regulations relating to exploitation of subsea reservoirs on the continental shelf for storage of CO_2 and relating to transportation of CO_2 on the continental shelf (CO_2 Storage Regulations). Section 4-5 of the Regulations stipulates a requirement for a plan for development and operation (PDO) of the subsea reservoir for injection and storage of CO_2, which shall contain a description of the development and an impact assessment. Sections 4-7 and 4-8 provide more detailed descriptions of the content of the study programme and the impact assessment, respectively. Section 6-1 similarly confirms that an application shall be prepared with a plan for installation and operation (PIO) of facilities, which must contain a description of the project and an impact assessment, if application for such a licence does not follow as part of the PDO. Ship transport of CO_2 is not covered by the Regulations' requirements for IA, PIO and PDO, cf. Section 1-6 (i) of the Regulations.
- The Planning and Building Act (PBA), Chapters 4 and 14, stipulates rules for when an initiative triggers an impact assessment obligation under the law, cf. Regulations relating to impact assessments (pursuant to PBA).
- The Regulations relating to impact assessments (IA Regulations), Chapter 2 establishes rules for which initiatives are subject to a study obligation and how the process shall be implemented, cf. Appendix I no. 23 and Appendix II no. 10i.
- The Act concerning protection against pollution and concerning waste (Pollution Control Act), Section 13 provides more detailed provisions regarding impact assessments for activity that can entail major pollution at a new site. The pollution control authority may stipulate that the party planning reportable activity shall perform an impact assessment to map the effects of such pollution.
- The Regulations relating to pollution control (Pollution Regulations), Section 35-5. Applications for a licence to inject and store CO_2 shall include an impact assessment for the activity.
- The Act relating to the management of biological, geological and landscape diversity (Nature Diversity Act) applies to Norwegian land territory and in Norwegian territorial waters. Certain of the statute's provisions also apply on the continental shelf insofar as they are appropriate. The statute contains provisions on the knowledge base and use of the precautionary principle as a basis for decisions, and entails important principles that are relevant for preparation of impact assessments.

1.7 Relationship to the zoning plan pursuant to the Planning and Building Act

Section 1-2 (1) and (2) of the Planning and Building Act confirms that *"Unless otherwise provided, the Act applies to the entire country, including river systems. In marine areas, the Act applies to a zone extending one nautical mile beyond the baseline of the territorial sea."* Pursuant to Section 1-3 of the Act, marine pipelines for the transport of petroleum are not subject to the Planning and Building Act. Marine pipelines for transport of CO_2 are not covered under this exemption from the statute. The initiative triggers a requirement for a zoning plan pursuant to Section 12 of the Planning and Building Act. This interpretation of the law has been confirmed by both the Ministry of Petroleum and Energy (MPE) and the Ministry of Local Government and Modernisation (MLGM), and is used as a basis for preparing detailed plans for the initiative.

The Northern Lights project is subject to the impact assessment requirement under the provisions of the Planning and Building Act and the IA Regulations within the scope of the Planning and Building Act. The initiative triggers IA requirements pursuant to the IA Regulations for both the onshore facility and the CO_2 pipeline, cf. Sections 6 and 8 of the Regulations, and Appendix I and Appendix II to the Regulations:

- Appendix I no. 23 – *"Storage facilities for geological storage of CO_2, i.e. a specific area …… and associated surface and injection installations."*
- Appendix II no. 10 i – *"Pipelines for transport of CO_2 streams with a view toward geological storage."*

Consequently, an impact assessment must be prepared as part of the detailed zoning plan for the initiative. The project is also subject to the impact assessment requirement in the provisions of the CO_2 Storage Regulations, which comprises the entire project, including the reservoir for geological storage and injection wells.

1.8 Zoning plan process

The following process has been implemented for the zoning plan with impact assessment pursuant to the provisions of the Planning and Building Act.

Start-up meeting
A start-up meeting was held with Øygarden municipality on 13 November 2017 and with Fedje municipality on 4 January 2018.

Start-up notice
A letter was sent to affected parties and announcements were printed in local newspapers to provide notification regarding start-up of the planning work and public consultation concerning the planning programme on 9 February 2018, with a 6-week deadline for comments in the consultation process. The planning programme was confirmed by the municipal council in Øygarden municipality on 13 June 2018 and by the executive committee in Fedje municipality on 28 June 2018.

Participation
An information meeting regarding the planning work was organised at Kystmuseet Ovågen in Øygarden municipality on 5 March 2018. Around 70 people attended, and questions were asked regarding how the onshore facility and the pipeline will affect the surrounding area, and what risk this entails for both people and marine life.

Based on the planning work for potential landing of umbilicals at Fedje, an information meeting was organised in the multipurpose hall on Fedje on 17 October 2018. There were around 20 attendees at this meeting. Strong local resistance was voiced against the landing of cables. The solution involving landing of cables was subsequently abandoned.

Zoning plan with impact assessment
Several interim meetings have been carried out with Øygarden municipality during the course of the work to prepare plan proposals. Interim meetings have also been carried out with Fedje municipality. The completed proposed zoning plan (plan proposal) with IA incorporated in the plan description was formally submitted to Øygarden municipality and Fedje municipality in December 2018 for initial plan processing.

Consultation and public inspection
In accordance with Section 12-10 of the Planning and Building Act, the detailed zoning plan for Northern Lights was submitted for consultation and public inspection following the initial processing in the municipalities. The deadline for statements was set at 7 May 2019.

Approval
The schedule for processing the zoning plan has been clarified with Øygarden municipality and Fedje municipality as the local planning authorities. The zoning plan was approved by both municipalities in late September 2019.

1.9 Purpose, process, procedure and schedule for impact assessment

1.9.1 Purpose of the impact assessment process

The impact assessment process, including a proposed study programme and the actual impact assessment, must ensure that factors related to the environment and society, including individual people, the natural environment, natural resources, cultural heritage, businesses and other socio-economic factors of local, regional and national significance are subject to examination in the planning work on an equal basis with technical, financial, operational, safety and working environment factors. This also includes assessment of mitigating measures to avoid or reduce negative effects for the environment and society, as well as the possibility of reinforcing the positive social effects of a development.

The impact assessment process is an open process which shall ensure that players who have viewpoints regarding the development receive sufficient information about the project and have an opportunity to express their opinion, for example regarding potential other consequences and possible alternatives to those assumed by the developer, including alternative measures to avert negative effects and reinforce positive effects.

The impact assessment process is thus an integral part of the planning process and shall discuss issues that are relevant both for the internal decision processes on the part of the developers and the external approval process.

1.9.2 Process, procedure and schedule for impact assessment

Before the licensee of a subsea reservoir (storage location) for injection and storage of CO_2 can develop such a reservoir, the licensee must submit a plan for development and operation (PDO) of the subsea reservoir to the authorities for approval. Before installation and operation of facilities, a plan for installation and operation (PIO) of such facilities must be submitted for the authorities' approval, unless this is covered by the PDO. PDOs and PIOs for storage and transport of CO_2 are governed by the CO_2 Storage Regulations of 5 December 2014.

PDOs and PIOs consist of a development/installation part and an impact assessment part. The impact assessment (IA) must be considered by relevant authorities and other stakeholders, and the licensee must describe how consultation submissions have been taken into consideration, before the development/installation part of the PDO and PIO is submitted for processing by the authorities. Based on the PDO and PIO (including IA and edited consultation comments), the MPE will draw up a proposition to the Storting (St. Prop.) which is submitted to other ministries and approved by the King in Council before it is passed on to the Storting.

The MPE and the Ministry of Labour and Social Affairs (ASD) have prepared guidelines for PDOs and PIOs, including IAs, the most recent version from March 2018 (/10/). As a point of departure, the guidelines were developed for petroleum-related projects, but they also apply for PDOs and PIOs that are prepared in accordance with the provisions of the CO_2 Storage Regulations. Therefore, insofar as suitable, the guidelines have been used as a basis for the work on the IA for Northern Lights. The IA has been prepared based on a study programme stipulated by the MPE. As the responsible authority, the MPE determines what is required based on an evaluation of the submissions received in the consultation process for the programme.

The project is subject to an impact assessment requirement pursuant to the provisions in Chapters 4 and 6 of the CO_2 Storage Regulations. A schedule has been set for the impact assessment process in the project in consultation with the MPE, see Table 1-1.

Table 1-1 Schedule for the impact assessment process

Description	Timeline
Public hearing on proposed programme for impact assessment (9-week submission deadline)	5 February – 9 April 2018
Prepare Supplement to Proposed programme for impact assessment (*)	June – July 2018
Public hearing on Supplement to proposed programme for impact assessment (8-week submission deadline)	17 July – 11 September 2018
Stipulated study programme for impact assessment	13 August 2019
PDO and PIO - Part 2 Impact assessment submitted for public hearing	22 October 2019
Public hearing IA (12-week submission deadline)	22 October – 15 January 2020
Submitting PDO and PIO, Part 1 Technical and financial plan	30 April 2020

(*) Due to moving the storage location from Smeaheia to the Johansen Formation south of the Troll field, the need to prepare a Supplement to the proposed study programme and implement a public hearing of this was clarified with the MPE.

The operator distributes the IA for consultation to affected authorities and professional and industrial bodies, and also secures statements from these stakeholders. At the same time, an announcement is published in the Official Norwegian Gazette *(Norsk Lysningsblad)* to the effect that the IA has been submitted for public hearing. The impact assessment and relevant supporting documentation is published on the operator's website: https://www.equinor.com/no/how-and-why/impact-assessments.html

Equinor will summarise the result of the consultation process and submit this to the MPE. The MPE will handle the further processing of the IA and make a determination as to whether the study obligation is deemed to be fulfilled. The mitigating measures identified and described in the IA will be followed up and incorporated in the further project work.

1.10 Authorities' continuing procedure

Capture players Fortum Oslo Varme and Norcem send their front-end engineering reports to Gassnova. Equinor and the partners also send their front-end engineering report for the transport and storage part (Northern Lights) to Gassnova in autumn of 2019. Gassnova compiles the documentation for the complete CCS chain in the Norwegian full-scale CCS project and makes its recommendation to the MPE.

For the transport and storage part, Equinor and its partners Shell and Total will make their internal company decisions to implement (DTI) the project by the end of March 2020. In late April 2020, the companies will make a conditional investment decision, where the condition linked to participation in the project is dependent on the State, represented by the Storting, making a positive investment decision. The PDO and PIO for Northern Lights will be sent to the authorities for processing on 30 April 2020.

Based on the impact assessment, PDO and PIO, as well as consultation submissions regarding the IA and the recommendation from Gassnova for the overall project, the MPE will present the case to the Government after the State's external consultants have carried out quality assurance of the overall project (QA2/KS2) due to the State financing. The project must be reviewed by the Storting, and the MPE will draw up a Proposition to the Storting which will be addressed by the King in Council before it is sent to the Storting for further processing. Consideration by the Storting is expected in late autumn 2020 in connection with processing the Fiscal Budget for 2021.

1.11 Transboundary transport, injection and storage of CO_2

Development and operation of a geological CO_2 storage facility on the Norwegian shelf will put the physical trappings into place and thus facilitate receiving and permanent storage of CO_2 from countries other than Norway. The estimated CO_2 volumes from Oslo Fortum Varme and Norcem in Brevik (estimated at 400,000 tonnes of CO_2 per year from each of the facilities) will only exploit about 53% of the planned facility's capacity of 1.5 million tonnes of CO_2 per year in Development Phase 1.

Through the work on Northern Lights, there has been extensive dialogue with potential foreign suppliers of CO_2 for permanent storage (users or customers of the storage solution), cf. Chapter 11. A letter of intent concerning delivery and storage of CO_2 was signed in September 2019 between seven foreign industrial companies and Equinor, on behalf of Northern Lights.

Both the EU CO_2 Storage Directive and the Norwegian CO_2 Storage Regulations allow for such transboundary transport, as well as storage of CO_2. However, transboundary transport, injection and storage of CO_2 is covered by international conventions which currently prohibit this, for the time being (/11/, page 10).

On Friday, 11 October 2019, the parties to the London Protocol agreed to allow temporary application of the amendment to the Protocol of 2009 which permits export of CO_2 for storage purposes. The decision is an international breakthrough for capture, transport and storage of CO_2 across national borders, and it can also lead to more rapid development of carbon capture and storage as climate technology (press release from the MPE:
https://www.regjeringen.no/no/aktuelt/eksport-av-co2-for-offshore-lagringsformal-tillates/id2673809/).

1.12 Other statutes, regulations, licences, approvals and consents

1.12.1 Other statutes and regulations

Other than the CO_2 Storage Regulations, several other statutes and regulations will apply to the Northern Lights project. The Framework Regulations, the Management Regulations, the Facilities Regulations and the Activities Regulations (the HSE regulations) are joint regulations for multiple authorities that have their legal basis in several different statutes, including the Pollution Control Act. As regards requirements linked to HSE factors, the CO_2 Storage Regulations point to several sections in the Framework Regulations, even though these Regulations have not been asserted for transport and injection of CO_2 on the continental shelf. The working environment regulations are incorporated in the above-mentioned regulations. The Cultural Heritage Act and the Nature Diversity Act are also central statutes in the IA work for projects on land, the Norwegian shelf and infrastructure near the coastline.

Health, environment and safety
Particular reference is made to Section 11 (2) of the Framework Regulations and Section 2 (3) of the Pollution Control Act; "Efforts to avoid and limit pollution and waste problems shall be based on the technology that will yield the best results in the light of an overall evaluation of current and future use of the environment and economic considerations."

Based on the Framework Regulations, the Petroleum Safety Authority (PSA) is currently working on new safety regulations for transport and injection of CO_2. As of the hearing of the current IA, it is not known when the new regulations will be adopted and take effect.

The operator must select the technical, operational and organisational solutions which yield the best results, based on an overall assessment. Reference is also made to Section 36-8 of the Pollution Regulations and principles in connection with application of best available techniques (BAT), efficient energy utilisation and that discharges of health and environmentally harmful chemicals of defined priority shall be reduced or stopped insofar as technically and financially feasible.

Cultural Heritage Act

The Cultural Heritage Act defines cultural artefacts as all traces of human activity in our physical environment, including places associated with historical events, beliefs and traditions. Cultural artefacts can be found both on land and in maritime areas. The Cultural Heritage Act protects all types of vessels and harbour locations with cultural layers older than 100 years in the sea sediments (Sections 4 and 14 of the Cultural Heritage Act). The developer is responsible for clarifying the relationship to marine cultural artefacts that may be affected by the initiative.

Nature Diversity Act

The Nature Diversity Act shall ensure that nature, with all its biological, landscape and geological diversity and ecological processes, is safeguarded through sustainable use and protection, also such that it provides a basis for human activity, culture, health and well-being, now and in the future, also as a basis for Sami culture. The statute applies on Norwegian land territory and in Norwegian continental waters, excluding Svalbard and Jan Mayen. Some of the statute's general principles are also applied to the continental shelf and in the economic zone. The statute contains provisions on knowledge base and use of the precautionary principle as a basis for decisions, and establishes important principles relevant for preparation of the IA. The impact assessment safeguards many of the principles laid down in the statute.

Planning and Building Act

The Planning and Building Act shall promote sustainable development in the best interests of the individual, the society and future generations. Planning according to the statute shall contribute to coordinate national, regional and municipal obligations and provide a basis for decisions on use and protection of resources. Planning and decisions shall ensure transparency, predictability and involvement for all affected interests and authorities. Emphasis shall be placed on long-term solutions, and consequences for the environment and society must be described. Consideration for the formative conditions for children and young people and aesthetical shaping of the surroundings shall be safeguarded in the planning.

Water Framework Directive

The Water Framework Directive shall ensure protection and sustainable use of the aquatic environment and, if necessary, implement preventive or corrective environmental measures to ensure the state of the environment in freshwater, ground water and coastal waters. Established environmental targets shall be concrete and measurable. Water management shall be comprehensive, from mountain to fjord, coordinated across sectors, systematic, knowledge-based and organised for broad participation. The Directive applies out to one nautical mile outside the baseline, which corresponds with the Planning and Building Act.

1.12.2 Licences, approvals and consents

Various licences will have to be obtained from the authorities in order to implement the development plan. Some of these will have to be acquired in the planning phase, while other licences are not required until the development phase. Some licences are only relevant for the shutdown phase. Which licences must be obtained in the different phases will be clarified in the continuing hearing and procedural process for the IA, cf. Section 4-8 (c) of the CO_2 Storage Regulations.

Table 1-2 provides a preliminary overview of some key applications and permits in connection with development and operation of Northern Lights. The overview is not exhaustive.

Table 1-2 Overview of selected key applications and licenses in connection with development of Northern Lights (not exhaustive).

Application / licence	Legal framework	Responsible authority
Plan for development and operation (PDO) and plan for installation and operation (PIO), including impact assessment (IA)	CO_2 Storage Regulations	Ministry of Petroleum and Energy
Consent for drilling	Management Regulations	Petroleum Safety Authority
Approved zoning plan	Planning and Building Act	Øygarden municipality and Fedje municipality
Marine rock deposit and establishing quay facilities	Harbour Act	Port of Bergen and Norwegian Coastal Administration
Laying pipelines in fairways in internal waters	Harbour Act	Norwegian Coastal Administration
Discharge permit for construction work on land and at sea in connection with establishing onshore facility, including drilling of landfalls, dredging and disposal.	Pollution Control Act	County Governor of Vestland
Consent to use pipelines	Management Regulations	Petroleum Safety Authority
Consent to build facility to handle hazardous substances	Regulations on handling hazardous substances	Norwegian Directorate for Civil Protection
Consent to start operation of onshore facility	Regulation on handling hazardous substances and Management Regulations	Norwegian Directorate for Civil Protection / Petroleum Safety Authority
Consent to use seabed facilities	Management Regulations	Petroleum Safety Authority
Licence to use frequencies for telecommunication	Electronic Communication Act	Norwegian Communications Authority
Discharge permit for drilling	Pollution Control Act	Norwegian Environment Agency
Discharge permit from pipelines in connection with preparation for operation	Pollution Control Act	Norwegian Environment Agency
Application for discharge permit for operation	Pollution Control Act	Norwegian Environment Agency
Application for carbon offsets	Greenhouse Gas Emission Trading Act	Norwegian Environment Agency
Consent for injection and storage of CO_2	CO_2 Storage Regulations	Ministry of Petroleum and Energy and Ministry of Labour and Social Affairs
Licence for permanent storage of CO_2	Pollution Regulations	Norwegian Environment Agency
Report on hazardous substance	Regulation on handling hazardous substances	Norwegian Directorate for Civil Protection
Consent for handling hazardous substances	Regulation on handling hazardous substances	Norwegian Directorate for Civil Protection
Cessation plan (including IA)	CO_2 Storage Regulations	Ministry of Petroleum and Energy
Notice of marine operations in the Royal Navy's training area in Hjeltefjorden	Planning and Building Act, zoning plan w/instructions	Norwegian Armed Forces
Notice of marine operations near the coastline		Fedje Sea Traffic Station
Construction licence to build and operate high voltage facility inside the onshore facility	Energy Act	Norwegian Water Resources and Energy Directorate (NVE)

2 Assessed development solutions and choosing the present solution

With reference to Section 4-8 (1) of the CO_2 Storage Regulations, the impact assessment must describe alternative development solutions the licensee has investigated and substantiate its choice of development solution and injection strategy (see Chapter 3.8) as well as explain the criteria for the choice that has been made.

Here we will describe the most relevant alternative solutions, as well as the fundamental characteristics of the processes and criteria that form the basis for the choices made leading to the solution for development and operation, which is described in more detail in Chapter 3, and which form the basis for preparing the PDO and PIO. Consequences of the chosen development solution are assessed and described in more detail in Chapters 5, 6 and 7.

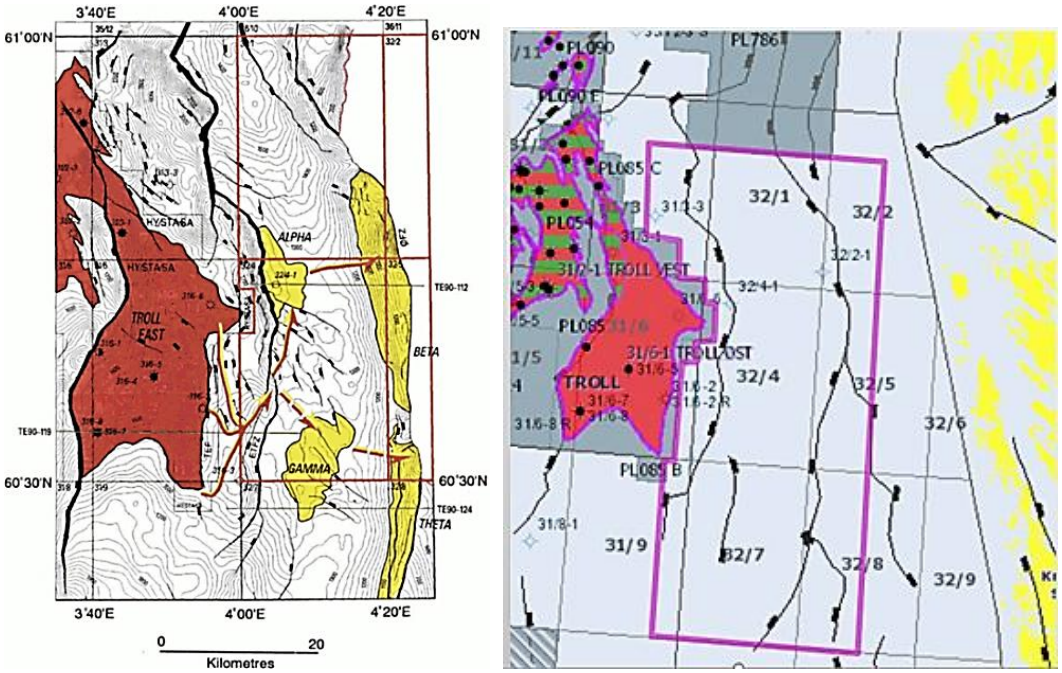
2.1 Assessments following establishment of the Northern Lights project

As regards assessments carried out in the early phase prior to establishment of the Northern Lights project, please refer to Chapter 1.3 and Appendix A.

2.1.1 Subsurface geological storage location

In 2017, the project was based on permanent storage of CO_2 in a geological reservoir in the Smeaheia area east of the Troll field in the North Sea, see Figure 2-1.

Figure 2-1 Location of the Smeaheia area east of the Troll field.



In spring 2018, the decision was made to move the storage location from Smeaheia to the Johansen Formation south of Troll; see Chapter 2.1.1.1 for a more detailed description.

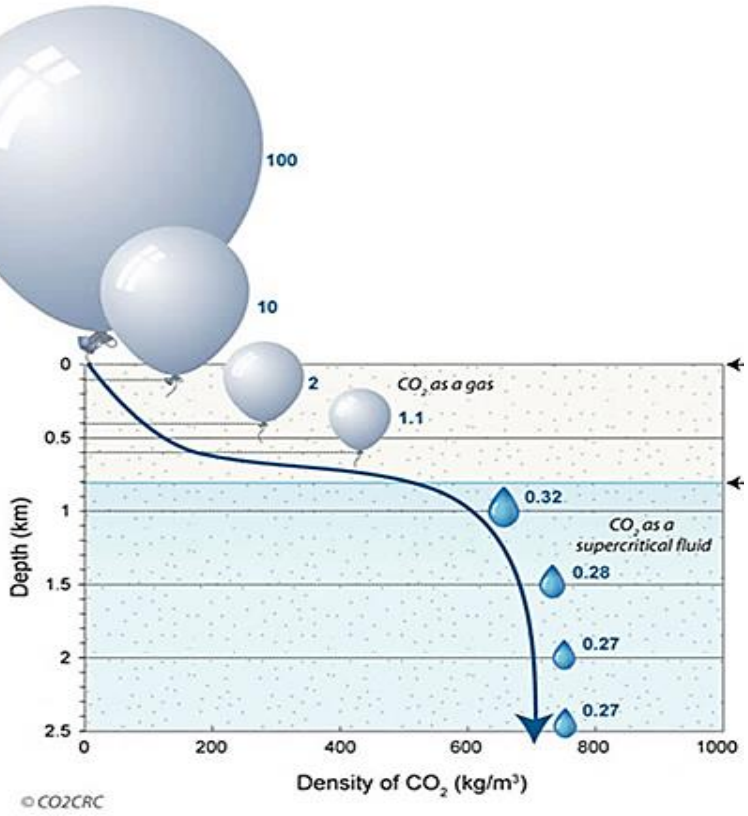
The subsurface geological storage location is now planned in the southern part of the Johansen Formation south of the Troll field, cf. Figure 3-1, and is outside the scope of the Planning and Building Act. Equinor and the partners have given the area the project name "Aurora", which references both Roman mythology (the goddess of dawn) and the Latin term for northern lights - "*Aurora borealis*".

2.1.1.1 Background and criteria for moving from Smeaheia

Long-term production of vast oil and gas volumes from the Troll field has led to reduced pressure in the Troll reservoir. Pressure communication between the Troll reservoir and Smeaheia is considered highly likely. This also entails that Smeaheia could experience reduced reservoir pressure over time. Gas production from Troll will be increased further through Troll Phase 3. In Phase 3, the gas above the oil column in Troll Vest will be produced while also continuing the production of oil. The Plan for Development and Operation (PDO) for Troll Phase 3 was approved in December 2018. Production of the gas resources through Phase 3 is expected to result in a further reduction in reservoir pressure. Troll Phase 3 will extend Troll's lifetime to 2050.

In an effort to illustrate the above, we can look at a CO_2 volume for permanent storage that is injected in the liquid phase against a reservoir pressure. Depending on pressure and temperature conditions, some of the CO_2 volume will dissolve in the formation water over time. Lower reservoir pressure will entail that the injected CO_2 volume will expand (reducing its density in kg/m^3) and require more space in the reservoir. This means a reduction in the reservoir's capacity to store CO_2 compared with the same reservoir at higher reservoir pressure. The density of CO_2 will increase along with increasing reservoir pressure. The phase transition between liquid and gas, and volume expansion as a result of lower CO_2 density are illustrated in Figure 2-2, where changes in the size of droplets and balloons, respectively, demonstrate the relative change in volume per unit of weight at the changed density as a result of reduced pressure and depth. Lower reservoir pressure will mean that injected CO_2 is not compressed as much as it would have been at a higher reservoir pressure, which entails that one tonne of stored CO_2 will require a greater storage volume than it would at a higher reservoir pressure.

Figure 2-2 Transition from liquid to gaseous phase, and relative volume expansion at lower density (kg/m³) as a result of variable reservoir depth.



A new and up-to-date assessment has been carried out as regards storage capacity in the Smeaheia area east of Troll, which also comprises an assessment of the likelihood of migration[1] between the Alpha and Beta structures in Smeaheia, cf. Figure 2-1. The available storage capacity in the Alpha structure in Smeaheia at a reduced reservoir pressure is considered to likely be insufficient to ensure permanent storage in the Alpha structure of the CO_2 volumes slated for injection in Phase 1 of the storage project. It is considered likely that CO_2 with a lower density and greater volume requirements could migrate to the east in the reservoir, to the Beta structure, cf. Figure 2-1. The Beta structure is closer to potential structural fractures near the Øygarden fault west of Øygarden. An exploration licence for petroleum activity in the Gamma structure south of Alpha was also awarded in the APA 2017 round. Overall, as of spring 2018, Smeaheia emerged as less suitable for permanent storage of CO_2 than what was assessed previously.

In spring 2018, the project concluded that the uncertainties associated with the location's storage capacity were too extensive and required too much technical work to mature the project to an investment decision within the timeframe of the project. The project's timeframe is determined by the national political authorities, which are also safeguarding harmonisation and coordination of the completion of the capture players' carbon capture facilities. It is important that the CO_2 storage facility is ready to receive and inject CO_2 when the capture players are ready to deliver the captured CO_2. Splitting the timeframe for the storage part from the other parts of the Norwegian full-scale CCS project is not considered to be expedient.

[1] Migration is defined as follows in Section 1-6 (q) of the CO_2 Storage Regulations: *"Migration, movement of CO_2 in the storage complex."*

2.1.1.2 Aurora – CO_2 storage location in the Johansen Formation

The Norwegian Petroleum Directorate (NPD) describes the Johansen Formation in its grid-based CO_2 atlas[2], and the following is based on this description. The Johansen and Cook Formations are primarily separated by shale and siltstone, but due to the parallel faults, they will be treated as a single aquifer. The sandstone in the Johansen Formation has good reservoir properties in multiple wells in the Troll field, and seismic data indicate that the sand distribution is the same as in the overlaying Sognefjord Delta[3]. The Cook Formation and the underlying Statfjord Formation extend to the Tampen Spur. The upper part of the Dunlin Group in the Troll area consists of the thick Drake shale formation, which makes up the primary seal in the area.

The Johansen Formation is deeper than the Smeaheia area, and storage can take place at depths up to 3,300 metres below the seabed. The Johansen Formation is also deeper than the Troll field, and extends over a considerable geographic area, which also comprises the Troll reservoir. In 2007, the Johansen Formation south of the Troll field was proposed as a potential storage location for CO_2 from Mongstad, and multiple studies have been conducted to qualify this aquifer for CO_2 storage. The NPD and Gassnova have collected 3D seismic for the most promising area. The studies indicate that the formation has sufficient capacity to store the CO_2 volumes from Mongstad, but a well will be important in order to clarify the reservoir and seal properties in the area south of Troll. CO_2 migration to the surface is unlikely due to the considerable capacity in the Sognefjord Delta aquifer. The capacity in the Johansen and Cook aquifer depends on the communication internally in the aquifer, and whether or not it communicates with the Statfjord and/or Sognefjord Delta aquifer across major faults.

Please refer to Chapter 3.14 for a more detailed description of Aurora as a storage location.

2.1.2 Receiving and intermediate storage facility on land – choice of location

The study agreement between Equinor and Gassnova defines certain decisions that must be made collectively by the agreement partners, when these decisions must be made, as well as the relevant decision-making process. The choice of location for an onshore plant for receiving, intermediate storage and injection of CO_2 is defined as a collective decision between the parties.

Based on objective technical assessment criteria and commercial negotiations, the agreement partners made a decision on the choice of location in consultation with the authorities on 9 November 2017. **Naturgassparken in Øygarden** has been chosen as the location for a land-based facility for receiving and intermediate storage of CO_2, given the Storting's approval of the development project.

The process leading to the choice of location will be described in more detail in the following sections. The location process was carried out in two phases, where Phase 1 was carried out with the aid of an external consultant. Equinor established assessment criteria and criteria to grade the suitability, while the external consultant collected data and other information, and assessed the suitability in relation to the defined criteria. Equinor also conducted internal studies of potential pipeline routes (a total of 11 pipeline routes) (/14/). Assessments carried out in Phase 1 are described in more detail in the following, while assessments in Phase 2 are described in more detail in Chapter 2.1.2.2.

[2] http://gis.npd.no/themes/co2storageatlas/

[3] The NPD refers to Smeaheia as the Sognefjord Delta.

2.1.2.1 Choice of location – Phase 1

A total of 19 alternative locations along the coast from Kårstø (Tysvær municipality in Rogaland County) to the South, to Lutelandet (Fjaler municipality in Sogn og Fjordane County) to the North have been assessed, cf. Figure 2-3.

The port to receive CO_2 by ship must be sheltered within the archipelago to ensure satisfactory access for the high number of port calls planned. Factors such as wind, waves and swells in the approach to the port and at the actual quay are decisive factors for high regularity, not least regarding safety in all operation scenarios.

Assessment criteria

The following 8 objective assessment criteria were established for assessment in Phase 1 of the location of an onshore plant; they were assessed with the same weighting (unweighted) in Phase 1 of the process:

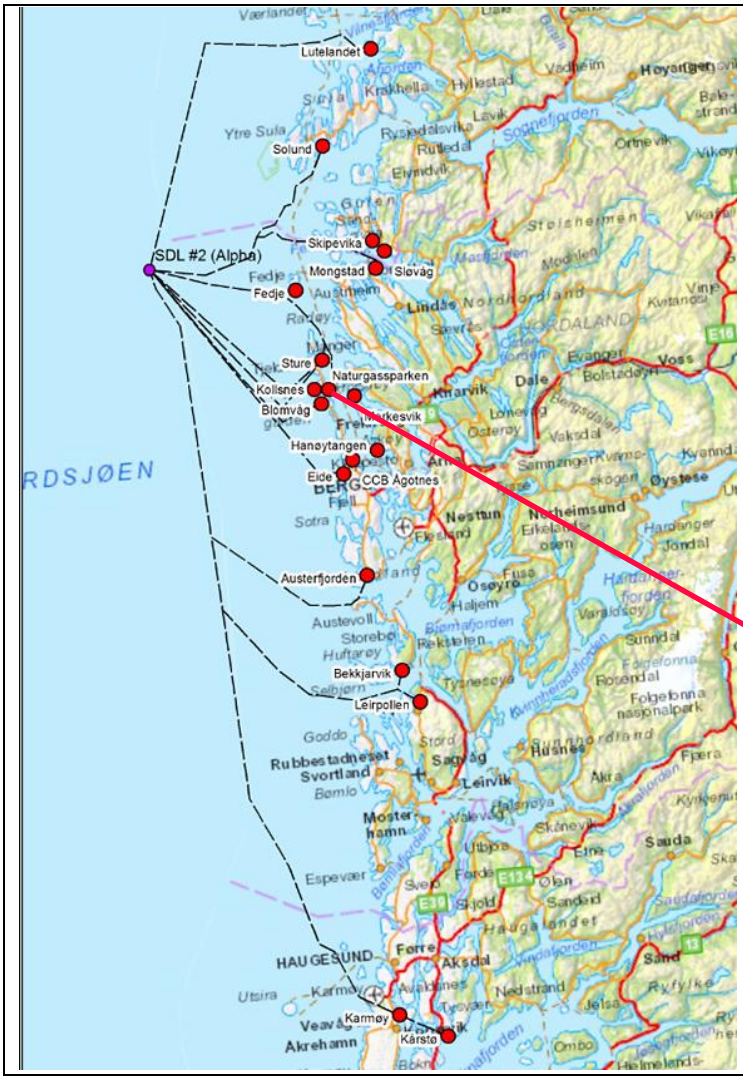
- Maritime conditions and quay conditions
  - Vessel sizes – quays (length of up to 210m, draft 14m, 1 quay + opportunity for 1 extra quay)
  - Regularity is important (safe approach and manoeuvring area, avoid sea waves/swells)
- CO_2 pipeline from terminal (known sea routes yield the best grade, onshore routes may be more complicated)
- Land development (a developed lot or land consisting primarily of exposed rock yields the best grade, while proximity to residential areas yields the poorest grade due to noise conditions)
- Infrastructure (proximity to densely populated areas and an airport yield the best grade, while little infrastructure and a need for ferry transport yield the poorest grade)
- Zoning status in relation to municipal master plan and/or zoning plan
- Property factors (presumed to be equal for all alternatives in Phase 1 for screening)
- External environment: Natural assets (Naturbase [nature type mapping service/database - transl.] – Norwegian Environment Agency) and cultural artefacts (Askeladden - Directorate for Cultural Heritage). No registration in these databases yields the best grade, while registration nearby yield poorer grades.
- Costs (differential costs for pipeline. Naturgassparken is defined as zero position / reference)

Grades in the assessment of the locations' suitability in relation to the defined criteria can be found in
.

Table 2-1 Grades for the assessment of the locations' suitability.

Grade	Colour	Suitability
A	Green	Well-suited
B	Yellow	Suitable
C	Orange	Poorly suited
D	Red	Unsuitable

Figure 2-3 Map of assessed locations for an onshore facility for CO_2 storage. Chosen location indicated in red.



Location	Municipality
Lutelandet	Fjaler
Solund	Solund
Skipevika	Gulen
Sløvåg	Gulen
Mongstad	Lindås
Fedje	Fedje
Sture	Øygarden
Kollsnes	Øygarden
Naturgassparken	Øygarden
Merkesvik	Askøy
Blomvåg	Øygarden
Hanøytangen	Askøy
CCB Ågotnes	Fjell
Eide	Fjell
Austefjorden	Sund
Bekkjarvik	Austevoll
Leirpollen	Fitjar
Hydro Aluminium	Karmøy
Kårstø	Tysvær

As regards to locations where the maritime conditions and quay conditions, and/or CO_2 pipeline out from the terminal are assessed as "Unsuitable" (D – Red), no further assessment was undertaken in relation to the other assessment criteria. This is because the maritime conditions and quay conditions are considered to be so critical for the operation and regularity of an onshore facility that these factors override the others.

Based on these assessments, the following locations were deemed "Unsuitable" based on these criteria: Lutelandet, Solund, Fedje, Kollsnes, Merkesvik, Blomvåg, Hanøytangen, Eide and Kårstø.

Phase 1 assessment was completed when the external consultant recommended proceeding with four alternative locations for more detailed assessments in Phase 2 of the location process (Skipevika, Mongstad, Sture and Naturgassparken).

2.1.2.2 Choice of location – Phase 2

The four alternative locations, Skipevika, Mongstad, Sture and Naturgassparken, combined with various alternatives for the pipeline route, were assessed in more detail in Phase 2 of the location process.

The assessment criteria for the location in Phase 2 were defined as follows with associated weighting:

- Maritime conditions and quay conditions (25% weight)
- Infrastructure (25% weight)
- Costs (25% weight)
- CO_2 pipeline out from the terminal/onshore facility (10% weight)
- Zoning status, property factors and external environment for the onshore plant (10% weight)
- Land development (5% weight)

Based on the results in Phase 2, the external consultant recommended in September 2017 to proceed with Mongstad in Lindås municipality, Sture and Naturgassparken in Øygarden municipality as alternative candidates. This means that these candidates are considered to be technically and environmentally equal as regards the placement of an onshore facility for receiving, intermediate storage and injection of CO_2.

Commercial negotiations were carried out in autumn 2017 with the owners of Sture, Mongstad and Naturgassparken. The last part of Phase 2 was carried out internally at Equinor and partners Shell and Total. Equinor and its partners provided their recommended decision to Gassnova. Agreement parties Equinor and Gassnova made a joint decision in November 2017 to select Naturgassparken in Øygarden as the location for the onshore plant.

Final choice of location

Based on objective technical assessment criteria and commercial negotiations, the agreement partners made a decision on the choice of location in consultation with the authorities on 9 November 2017. Naturgassparken in Øygarden has been chosen as the location for a land-based facility for receiving and intermediate storage of CO_2, given the Storting's approval of the development project.

2.1.3 Pipeline to export CO_2 – choice of preferred solution

CO_2 in intermediate storage must be transported via pipeline from the onshore plant to the injection well(s) in the reservoir on the continental shelf for permanent geological storage. The pipeline must be designed to transport the relevant CO_2 volume from both Development Phase 1 (demonstration project with 1.5 million tonnes of CO_2 per year) but, must also be able to transport the increased CO_2 volumes in the development of Phase 2 (with up to 5 million tonnes of CO_2 per year). The transport system must be designed such that the CO_2 is always kept in liquid phase, without transitioning to either gas or solid form (dry ice), thus preventing multiphase flow or plugs occurring in the transport system.

2.1.3.1 Pipeline dimension

The choice of pipeline dimension affects both transport capacity and investment costs for the storage project. Multiple dimensions between 8″ and 14″ nominal diameter have been considered. The decision was made in April 2018 to engineer a pipeline with a 12″ nominal diameter (12 ¾″ OD). This will be sufficient for Phase 1 of the storage project, with transport and injection of up to 1.5 million tonnes of CO_2 per year. It will also provide sufficient transport capacity for a future Phase 2 of the project, with up to 5 million tonnes of CO_2 per

year, with a maximum transport distance of 160 km. This will require a somewhat higher operating pressure than at Phase 1, but the pipeline will be engineered and dimensioned for this.

2.1.3.2 Criteria for identifying routes for the pipeline and umbilical

The following general criteria for identifying routes have been used as a basis for the work on suitable routes for the CO_2 pipeline and umbilical:

- Route length should be reduced to the extent possible
- Likelihood of human activity/impact and environmental consequences should be reduced.
- The number of curves on the route should be minimised, while the radius of curves should be maximised.
- The extent of free spans (free-hanging between two local peaks) and large bending moments should be minimised.
- The need for seabed intervention (such as the use of rockfill) should be reduced to the extent possible.
- Installation work should be optimised to achieve the most time and cost-effective solutions.
- Pipelines and cables should cross areas with significant bottom trawling activity as perpendicular as possible to the prevailing direction of trawl to reduce disadvantages for fishery activities.
- Existing pipelines and cables should be crossed as perpendicular as possible.

Identification of well-suited routes is particularly challenging in areas with complex seabed topography with very steep slopes and/or tight corridors and canyons, combined with proximity to existing pipelines and cables. Detailed seabed mapping at high resolution combined with analyses of seabed topography are important tools in the effort to find the most suitable routes.

2.1.3.3 Reuse of the Mongstad Gas Pipeline (MGP)

In connection with establishing the gas-fired combined heat and power (CHP) plant at Mongstad in 2010 (Mongstad Power Plant), a 12-¾" (OD) pipeline was installed from the Kollsnes processing plant over land to Helleneset at Osundet in Øygarden municipality (Mongstad Gas Pipeline – MGP). From there, the pipeline goes north in the sea in Hjeltefjorden to Fedje, where it curves into Fensfjorden and goes east to Mongstad. The pipeline has transported feed gas to the CHP. The combined heat and power plant at Mongstad with associated gas pipeline from Kollsnes is planned to be shut down and decommissioned in late 2018 /early 2019.

An assessment has been made as regards the technical feasibility of reusing parts of this pipeline to transport CO_2. This requires a technical re-qualification and approval by the authorities, as well as reaching a commercial agreement with the owners of the pipeline. MGP is owned by the MGP partnership (the license), consisting of Petoro (56%), Equinor (30.58%), Shell (8.10%), Total (3.69%) and ConocoPhillips (1.62%).

A number of factors have been taken into consideration in the assessments of potential reuse of parts of the Mongstad Gas Pipeline (MGP), e.g.

- Technical qualification of MGP to transport liquid CO_2, as well as a method for cutting and connecting the old and new pipeline
- Commercial negotiations with the MGP license regarding finances, taking over obligations and commitments
- New pipeline routes have been identified as technically feasible for a storage location on the shelf
- Costs and capacity associated with reuse of MGP versus cost and capacity of the new pipeline
- Risk factors associated with removal obligations for MGP

- Risk factors associated with a pipeline on land versus directly into the sea from the onshore facility for future Phase 2
- Risk factors associated with pipeline capacity and maximum transport distance in relation to an uncertainty in the location of storage for future Phase 2 CO_2 volumes. Reuse of MGP provides less flexibility.
- Possibility of future utilisation of a complete pipeline system between Kollsnes and Mongstad is maintained. MGP could potentially be cut on land at Hellevatnet, and both parts of the pipeline can be extended by approximately 1 km to Naturgassparken.

Conclusion concerning reuse

Following a comprehensive assessment of the various factors identified above, Equinor and its partners Shell and Total decided that the Mongstad Gas Pipeline (MGP) will not be reused to export CO_2 for permanent storage on the continental shelf. Gassnova SF as has endorsed this decision as principal.

2.1.3.4 Alternative routes for new pipeline to storage location – choice of route

A considerable number of alternative pipeline routes from the onshore plant to the storage location have been assessed through multiple steps in an extensive process, from selecting the location of the onshore facility to the final choice of well location. Moving the storage location from Smeaheia to the Johansen Formation in early summer 2018 has led to the assessment of new pipeline routes in addition to the alternatives to Smeaheia. Challenging seabed topography is highly determinant for the routing in the considered route corridors.

A final decision has been made on the following route:

From Naturgassparken north in Hjeltefjorden, south and west of Fedje, south of Troll A to the well location in Aurora in the Johansen Formation.

Because a zoning plan must be prepared for the pipeline in the sea out to one nautical mile (nm) outside the baseline (scope of the Planning and Building Act), the pipeline route up to this point will be decided first. The further route from one nm off the baseline to the well location will be decided later.

Moving the storage location about 54 km to the south-west to a preliminary well location results in the need for a longer pipeline, and identification of partially new pipeline routes. Due to demanding seabed topography, the pipeline routes in question from the onshore plant on Ljøsøyna to about one nm off the baseline (scope of the Planning and Building Act) will not be changed as a result of the new well location. The direction of the pipeline route does not shift toward the preliminary well location in Johansen until it crosses the baseline.

The final well location was not set until April 2019, about 15 km north of the preliminary well location in Aurora in the Johansen Formation, which led to the final adjustments to the relevant chosen pipeline route.

A considerable number of alternative pipeline routes have been assessed from the receiving plant to the storage location. The process for choosing the pipeline route has been extensive and underwent multiple steps over a lengthy period (cf. Figure 2-4 and Figure 2-5 for an illustration of alternative routes). The most important steps are listed in the following items:

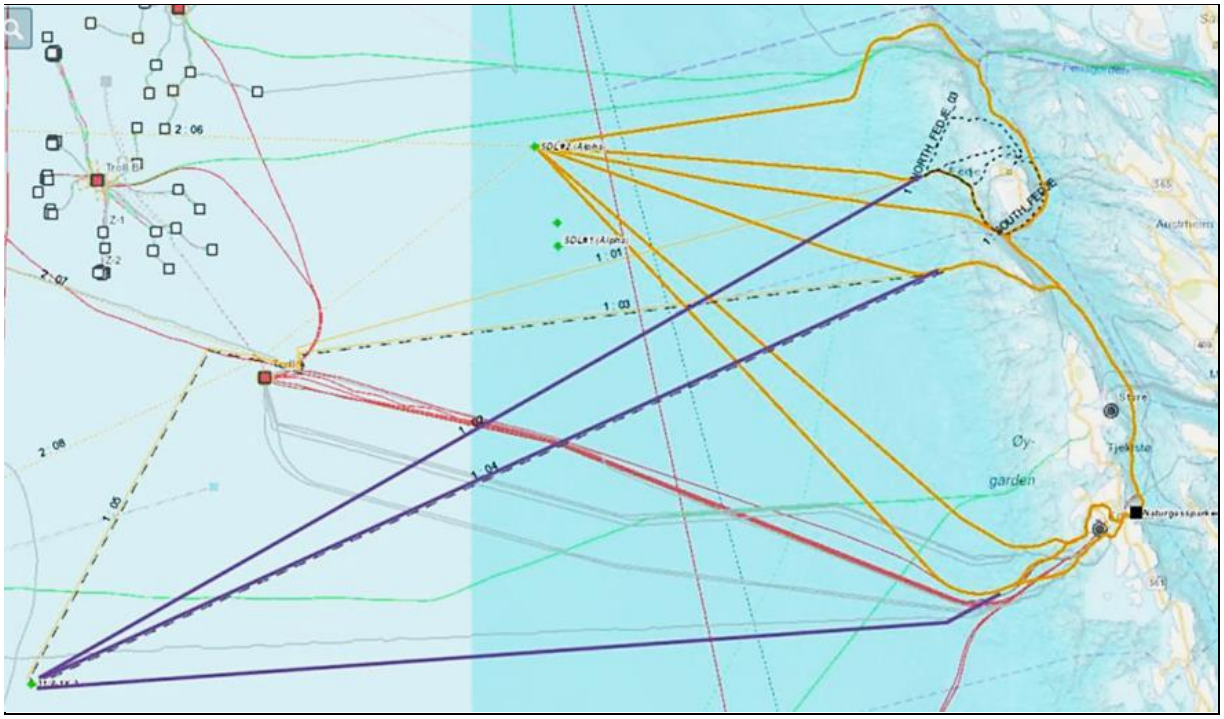
- General route corridors are identified in connection with choosing the location of the onshore facility
- The primary solution (concept) for a pipeline directly out into Hjeltefjorden from the onshore facility (to the north) is chosen, alternatives over land to the west toward Kollsnes and further in the sea were abandoned in May 2018, cf. Chapter 2.1.3.5

- Route corridor north of Fedje is abandoned
- The alternatives South of Fedje and South of Sulo are kept open, work on zoning plan comprises both alternatives
- Storage location is moved to a preliminary well location in the Johansen Formation, new route alternatives outside the baseline are considered
    - one primary alternative based on the South of Fedje solution, with one alternative running north of the Troll A installation and one alternative running south of Troll A
    - one primary alternative based on the South of Sulo solution, with one alternative running north of the Troll A installation and one alternative running south of Troll A
- The South of Fedje route is selected, and the alternative South of Sulo is abandoned, a route out to a "fixed point" regardless of well location is chosen for route alternatives north and south of Troll A installation
- The final well location is chosen (moved approximately 15 km north in relation to preliminary placement), the route from the "fixed point" is changed to reflect the new well location
- The final comprehensive route for the pipeline from receiving plant to the injection well is chosen

Final comprehensive pipeline route, cf. Figure 2-6.

From Naturgassparken north in Hjeltefjorden, south and west of Fedje, south of Troll A to the well location in Aurora in the Johansen Formation.

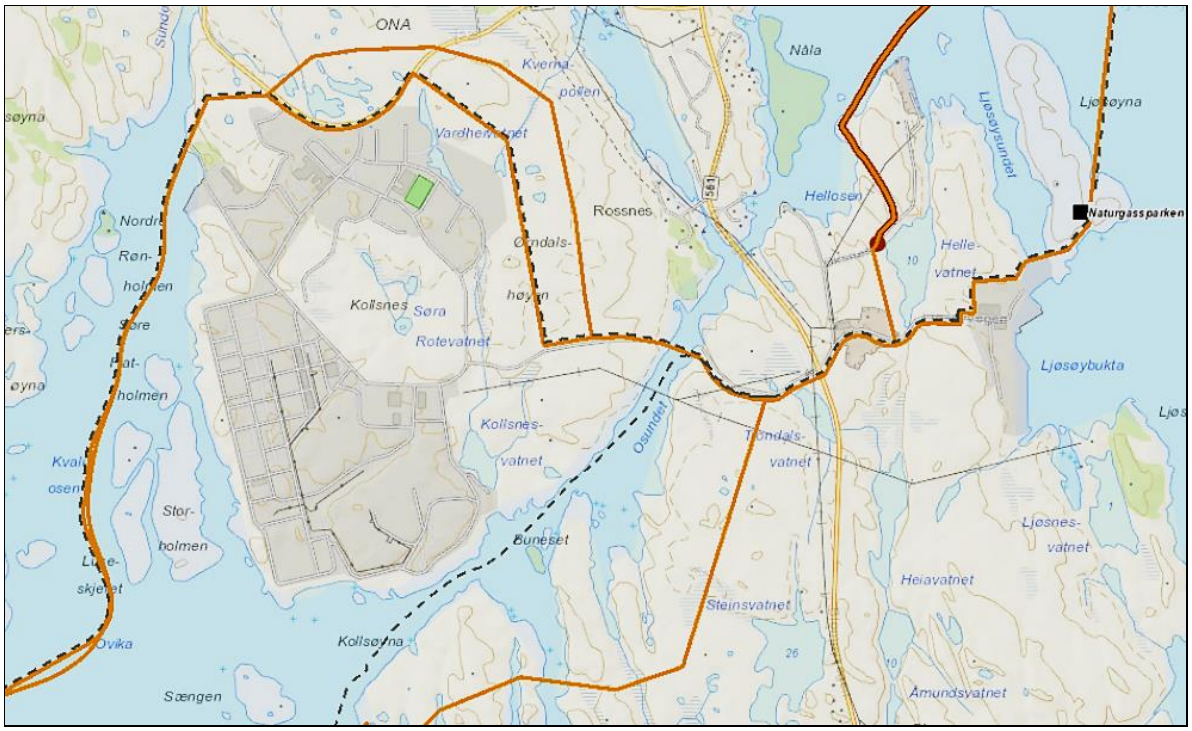
Figure 2-4 Alternative pipeline corridors to Smeaheia (orange) and the Johansen Formation (purple). Existing gas pipelines (red), oil pipelines (green) and cables (grey).



2.1.3.5 Technical assessment of pipeline alternatives within the baseline

Installation of the pipeline, and potential umbilical, in trench on land to the west from Naturgassparken toward the Kollsnes processing plant has been assessed with two alternative routes, north and south of Kollsnes, cf. Figure 2-5.

Figure 2-5 Alternative route corridors for the pipeline (solid orange line) and umbilical (broken black line) from an onshore facility in Naturgassparken (black square) on land. The thick orange line shows the existing Mongstad Gas Pipeline which was considered for possible reuse.



A technical assessment of alternative pipeline routes is shown in Table 2-2. A score of 5 is the best. See Figure 2-4 and Figure 2-5 for maps of the route alternatives.

- Scores of 1-2 are indicated in red – which demonstrates a technical challenge with the route alternative
- A score of 3 is indicated in yellow – which shows a technically feasible route, with certain identified comments making the route solution is less attractive
- Scores of 4-5 are indicated in green – which shows a fully feasible technical route

Table 2-2 Technical feasibility of alternative pipeline routes within the baseline.

	Weight	South of Kollsnes (P06)	North of Kollsnes - southern alt. (P03)	North of Kollsnes - northern alt. (P08)	South of Sulo	**South of Fedje**	North of Fedje
Criterias / Total score		2,3	2,6	2,7	3,8	**4,5**	3,8
Effects from discharge of CO_2	20 %	3	2	2	4	5	5
Environmental sensitive areas	15 %	2	3	3	3	4	4
Crossing of and/or influence on other infrastructure	10 %	3	3	4	3	3	3
3rd Party activities	20 %	2	3	3	4	4	4
Seabed topography conditions	15 %	2	3	3	4	5	2
Design, installation, operation and maintenance	20 %	2	2	2	4	5	4

The alternative South of Fedje was assessed as the best solution from a technical standpoint, with the alternatives South of Sulo and North of Fedje in shared second place. A route North of Fedje would have posed considerable challenges as regards seabed topography and would have been technically demanding, combined with a longer pipeline with increased investment costs.

The route alternatives with a pipeline to the west on land attains a low score and ranking, which reflects the challenges associated with pipeline routes on land, but also challenges in the beach and coastal zones as regards seabed topography, "technical constructability" and installation of the pipeline. Compared with the route alternatives to the north in Hjeltefjorden, one could not, from a technical point of view, recommend proceeding with the route alternatives in the direction of Kollsnes. The decision was made to abandon these alternatives in May 2018.

The highly demanding and challenging seabed topography west of Øygarden is the primary reason why all existing pipelines from the North Sea to and from the onshore facilities at Kollsnes and Sture are installed in long undersea tunnels (up to 3 km long). It is not considered to be appropriate and sufficiently safe to install a new pipeline in existing tunnels while oil and gas pipelines are in operation. The layout and securing in the tunnels toward the sea are not adapted for a pipeline as small as 12¾".

2.1.4 Umbilical with control station – choice of solution and route

Umbilical and power cable will have to be installed for controlling and monitoring the subsea facility in order to supply necessary electric power, hydraulics and monoethylene glycol (MEG)[4] as well as control and monitoring signals for valves and other equipment in the subsea facility and in the well. Multiple alternative solutions and routes have been considered for the umbilical and power cable with associated control station.

The chosen solution is to use Oseberg A as an offshore host installation for the tie-in of the umbilical system with associated control station.

[4] MEG is a type of antifreeze, used here primarily as a medium for leak testing valves in the subsea facility.

2.1.4.1 Land-based solution

Several land-based solutions have been assessed for a control station to monitor and control the well and subsea system, with associated umbilical and power cable.

- The original plan was to include the control station in the onshore plant, and lay cables along the same route as the pipeline from Naturgassparken to the injection well.
- Due to technical and financial factors, certain attempts were made to move the starting point for the cables away from Naturgassparken and closer to the well location.
- Kollsnes was considered as a possible location for a land-based control station. The alternative was abandoned due to future cables, which entailed little available room and an unfavourable cable route.
- One proposed solution was to establish a land-based control station on Fedje, with cables to the Johansen well location and running parallel along the pipeline starting west of Fedje.
- In order to establish a land-based control station for the cables, a sector within an area already zoned for commercial activity on the west side of Rongsvågen bay was assessed, with a less suitable alternative on the east side of the bay. Local resistance was significant, including from Fedje municipality as planning authority.
- Alongside the maturing of a land-based solution on Fedje, work was under way to find a suitable offshore host installation with a satisfactory technical solution.
- The land-based solution on Fedje was abandoned in early November 2018 in favour of choosing the Oseberg Field Centre as offshore host installation. The chosen solution entails lower investment costs than a land-based solution.

2.1.4.2 Assessment of alternative offshore host installations

An effort was under way from the outset of the contract work for Gassnova to identify a technically feasible solution with a control station on a suitable offshore host installation. This results in a considerably shorter route for the umbilical system than in a land-based solution. Use of both Troll A and one of the Oseberg platforms as host installation was considered even before the storage location was moved from Smeaheia to Aurora. Troll A was eliminated due to a lack of available J-tubes for pull-in of umbilical and cable, in addition to use of a type of MEG that cannot be used for technical reservoir reasons. The new subsea facility on Troll Phase 3 also lacks available connection points beyond its own needs.

Installations near Aurora with sufficient remaining operating periods are all located on the Oseberg Field Centre and Troll. This is summarised in Table 2-3, which also indicates the installations' remaining lifetimes and distance to the preliminary well location in Johansen at the time of assessment (June 2018).

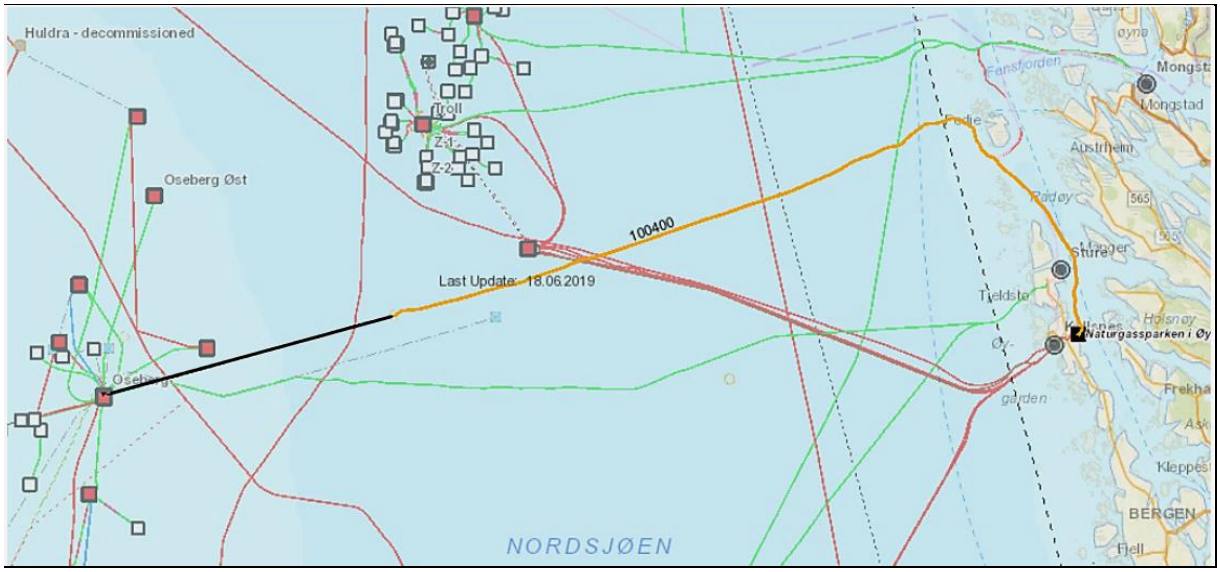
Table 2-3 Alternative assessed offshore host installations.

Installation	Approved remaining lifetime	Distance to well in Johansen, km	Comment
Brage	2030	23	
Oseberg Field Centre (A, B and D)	**2039**	**33**	**Oseberg Field Centre is chosen**
Oseberg Sør (South)	2039	35	
Oseberg Øst (East)	2031	39	
Troll A	2066	20	Solution was abandoned early due to lack of technical suitability. MEG type not compatible with relevant reservoir.

Identification of a technically feasible solution using the Oseberg Field Centre as host installation leads to abandoning Fedje as a solution in November 2018. Oseberg A's planned operating period extends to 2039 and the platform has available capacity to handle control and monitoring of the subsea facility in collaboration

with the receiving plant in Naturgassparken. Oseberg A is chosen as host installation for the umbilical and power cable, cf. Figure 2-6.

Figure 2-6 Chosen route for pipeline (orange line) from Naturgassparken to the injection well and chosen route for umbilical (black line) from Oseberg A to the injection well. Existing gas pipelines (red) and oil pipelines (green). The baseline is indicated by the broken line near the coast.



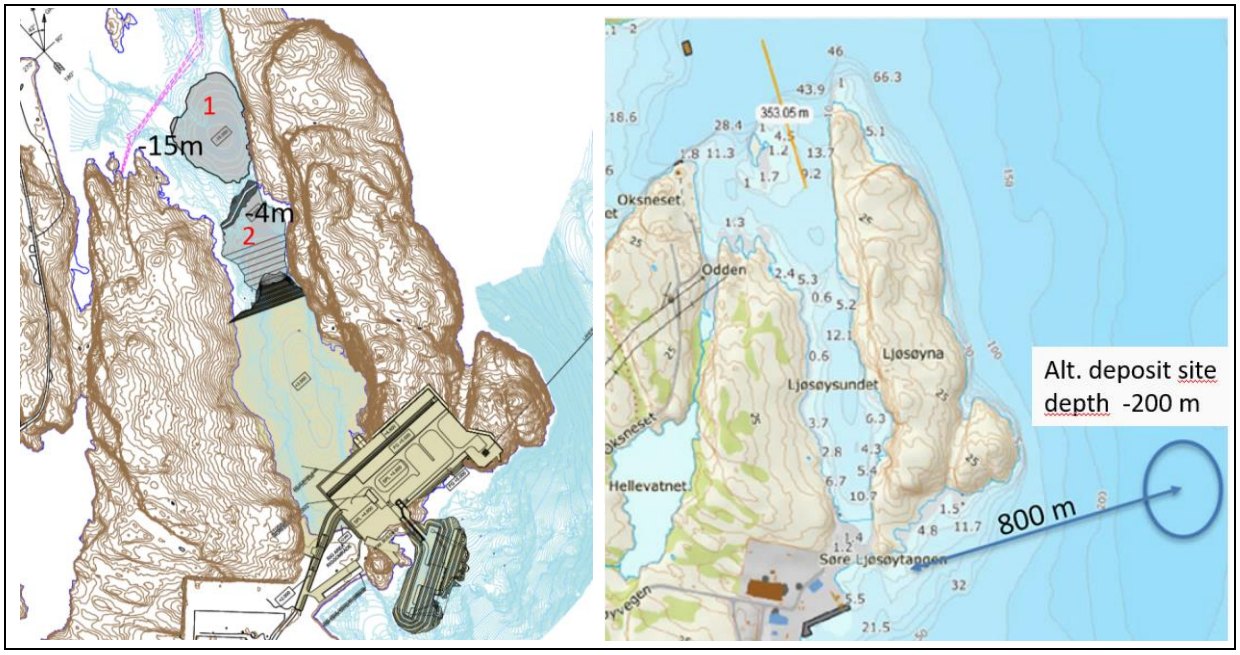
2.1.5 Assessment of alternative locations for depositing dredging materials

The relevant land use part of the Øygarden municipal master plan shows the southern part of Ljøsøysundet strait as a commercial area, based on depositing of surplus rock in the strait for new land area, cf. Chapter 7.2. This land use has been used as a basis in the recently revised zoning plan for Naturgassparken (approved in December 2018). This land use was also continued and incorporated into the zoning plan for Northern Lights, which was submitted for first reading in December 2018. This plan sets the stage for depositing surplus blasted rubble in the southern part of Ljøsøysundet to establish new commercial area.

Soil surveys were carried out in Ljøsøysundet in January 2019 (/15/), which clarified the occurrence of a wet layer of clay that must be removed in order to ensure satisfactory completion of the terminal's access zone on rockfill. The volume of dredging materials in this area is calculated at 30,000 m^3, which due to the soil survey is higher than the estimate in a previous project phase. Some of these dredging materials contain pollutants. The results of the soil surveys and the environmental condition are described in more detail in Chapter 5.3.5.1. In addition to this volume, there is a need to deposit 10,000 m^3 of dredging materials from the quay area in Ljøsøybukta bay. Total dredging materials are estimated at approximately 40,000 m^3.

Multiple alternative solutions and locations were assessed in spring 2019 for the establishment of a deposit site for dredging materials from the construction work. Transporting dredging materials on public roads to an onshore deposit site is assessed as unsuitable. Figure 2-7 shows locations at Ljøsøyna, outside the deposit site for surplus rock, which has been assessed in more detail as a potential deposit site for dredging materials.

Figure 2-7 Left: Alternative sea deposit sites in Ljøsøysundet outside rock deposit site. Right: deepwater deposit site in Hjeltefjorden. Alternative solutions and maps prepared by Multiconsult.



Chosen solution

The choice of solution is based on the following criteria:

- Minimising consequences for the environment and third parties
- Minimising risk of harm to personnel and equipment during transport and depositing
- The measure is kept within the proposed action levels in the zoning plan
- Predictable use and utilisation of the area with deposited surplus masses
- Efficient and predictable project execution

The chosen solution for depositing dredging materials to deposit them under the deposit of surplus blasted rock in the southern part of Ljøsøysundet.

The solution is considered to be in compliance with the zoning plan for Northern Lights. The chosen solution has been discussed with both CCB Kollsnes (landowner for Naturgassparken) and the County Governor of Vestland in May and June 2019, neither of which had substantive comments on the chosen solution. The solution is described in more detail in Chapter 3.7.3.2. The following alternative solutions and locations have been assessed:

Chosen solution - Southern part of Ljøsøysundet, depositing under deposit of surplus rock

Dredging materials can be deposited during the planned depositing of blasted rock. Pollutants have been proven in one sample series in the deep area of the planned deposit area. The depositing of rock could result in disturbing polluted fine particles from this area, but with the planned dispersion-limiting measures (silt curtain), the fine particles will re-sediment in the deposit area and remain under the blasted rock without spreading out of the area. In the dredging area, pollutants have been proven in one of four samples. By first dredging and depositing the polluted sediments, they will subsequently be covered by clean dredging materials before further depositing of blasted rock. This solution is considered to have a number of benefits, e.g. short transport, isolating the polluted dredging materials, and depositing the dredging materials in accordance with the zoning plan for Northern Lights. The greatest disadvantage is considered to be the uncertainty surrounding how settling will affect the use of the area, as it is challenging to simulate the behaviour of dredged materials.

Alternative deposit solutions that have been considered:

Sea deposit site in northern Ljøsøysundet and independent of rock deposit

- Alternative 1 – Deep area at the mouth of Ljøsøysundet

The mouth of Ljøsøysundet has a natural depression in the seabed which is suitable for a sea deposit site. The greatest depth is 21 m. It must be documented that current conditions are such that the masses will remain in place and not erode away. The alternative is considered to have a few benefits, for example that dredging materials will not affect the use of the deposit area. However, the disadvantages are both greater and more numerous, as areas outside the action level in the zoning plan are utilised, the location is more exposed to weather and it is more challenging to shield the area and prevent the dispersion of sediments.

- Alternative 2 – Just north of planned rockfill in Ljøsøysundet

A sea deposit site can be established just outside the planned rockfill. It features a natural ridge that forms a threshold outside the rockfill. It must be documented that current conditions are such that the masses will remain in place and not erode away. This alternative has a number of benefits, the dredging materials will not affect the use of the rockfill area, and that the area is shielded with little wave impact and few weather delays. The strait can be closed off to prevent dispersal of particles and pollutants. The disadvantages are considered to outweigh the benefits, as areas outside the action limits in the zoning plan are affected, and a sea deposit site here will limit the area's potential to later be filled with blasted rock and used for commercial purposes pursuant to the land use part of the municipal master plan.

Sea deposit site off Ljøsøysundet

In order to prevent conflict between the sea deposit site and areas zoned and/or planned for commercial development, two other locations have been considered outside the zoning plan area for Northern Lights.

- Alternative 3 – Deepwater deposit site in Hjeltefjorden east of Ljøsøyna

A sea deposit site can be established at a considerable depth (approximately 200 m) in Hjeltefjorden, east of Ljøsøyna (approximately 800 m outside the quay area). It must be documented that current conditions in the area are such that the masses will remain in place and not erode away. This alternative has a few benefits; depositing can occur independent of the depositing of blasted rock, and the dredging materials will not affect the use of the deposit area in the strait. The disadvantages are both greater and more numerous, areas outside the action levels in the zoning plan are affected, the water depth is considerable and a suitable method for depositing materials must be assessed. There is a fishing ground in the area, the area is exposed to wind and waves, and one must expect more weather delays than would be the case with more shielded solutions.

- Alternative 4 – West side of Øygarden, south of Kollsøyna

There is a sea deposit site on the west side of Øygarden which was used to dump rock in connection with "Troll pre-compressor 3 and 4" (TPC 34) at Kollsnes. The area is exposed to waves from the North Sea and is also exposed to wind. Experience from TPC 34 indicates that the depositing experienced significant weather delays, and low efficiency. The alternative has a few benefits; the area is in an approved and existing deposit site, depositing can take place independent of the depotsition of blasted rock in Ljøsøysundet. The alternative's disadvantages are both greater and more numerous; areas outside the action levels in the zoning plan are affected and transport routes are long. The waters are narrow, winding and challenging as regards passing Kollsøyna, with a risk of being forced to sail in open sea and exposed to rough weather conditions.

Receiving facility on land

- Alternative 5 – Existing deposit site at Eide

Franzefoss Gjenvinning's facility at Eide near Ågotnes (approximately 33 km south of Naturgassparken) could be a potential receiving facility. The solution involves transport on public roads or at open sea. Road transport presumes intermediate storage on land to de-water the materials before loading them into vehicles for transport. The alternative has a few benefits, such as use of an existing approved deposit site, sea areas outside the zoning plan are not affected, and the dredging materials will not affect use of the deposit area. The alternative has a number of significant disadvantages; long transport distances on public roads and a depositing fee must be paid, which results in a very costly solution. As regards road transport, intermediate storage must be established for de-watering with a cleaning and sedimentation system. Alternative maritime transport at open sea is subject to extensive weather delays and low efficiency.

3 Plans for development, installation and operation

3.1 Licensees and licence history

In June 2017, the Norwegian State, represented by Gassnova SF, tasked Equinor (then Statoil) with studying and planning permanent storage of CO_2 in offshore reservoirs, with associated onshore facility for receiving and intermediate storage, export and offshore injection solutions.

In October 2017, Equinor (then Statoil) signed a partnership agreement with A/S Norske Shell (Shell) and Total E&P Norge AS (Total), which entails that Shell and Total become equal partners, while Equinor will lead the project. The partners all have a share of 33.33%, and will provide personnel, experience and financial support to the project. The agreement presumes that any development and operation will take place jointly with participation from all three partners, with the assumption of positive investment decisions.

From a regulatory standpoint, transport and storage of CO_2 on the continental shelf is subject to the Regulation relating to exploitation of subsea reservoirs on the continental shelf to store CO_2 and relating to transport of CO_2 on the continental shelf - "the CO_2 Storage Regulations".

The award of an exploitation licence confers exclusive rights associated with the specified area, and an operator will be designated. A plan for development and operation (PDO) and plan for installation and operation (PIO) must be submitted for authority approval.

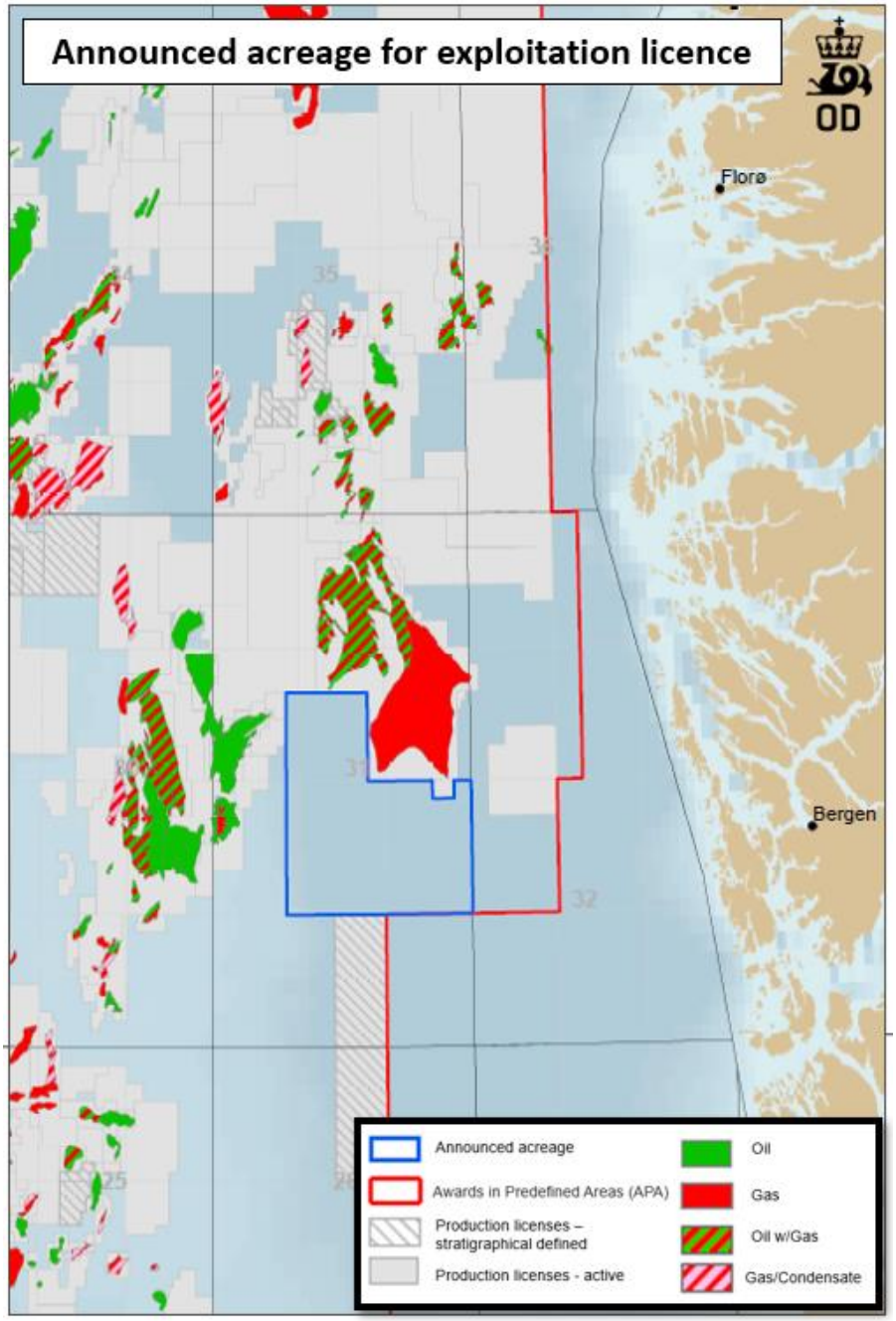
On 5 July 2018, the Ministry of Petroleum and Energy (MPE) announced the first acreage available for application for an exploitation licence to store CO_2 on the Norwegian continental shelf (press release from the MPE). The MPE states that: *"The purpose of the announcement is to invite players to submit applications for award of an exploitation licence for the storage of CO_2. Once the applications have been processed, the aim is to award an exploitation licence in 2018."* Equinor submitted an application to for award of an exploitation licence to the authorities on 6 September 2018. The MPE has stated that this is the only application it has received for award of an exploitation licence.

On 11 January 2019, the King in Council decided to award exploitation licence no. 001 (EL001) for CO_2 storage on the Norwegian shelf to licensee Equinor (press release from MPE). Equinor has been designated the operator for EL001. The MPE forwarded exploitation licence no. 001 to Equinor in its letter of 14 January 2019. The awarded acreage is unlicensed pursuant to the Petroleum Act, and comprises **blocks 31/4 (partial), 31/5 (partial), 31/7 (partial), 31/8 and 31/9 (partial).** The award letter is enclosed as Appendix B.

The area is located south and west of Troll, and borders PL785 S in block 31/11 to the south. A map of the announced acreage for applications for award of an exploitation licence, as well as the awarded acreage, is shown in Figure 3-1. The awarded acreage is in accordance with the acreage announced and applied for.

Even though Equinor alone has been awarded the exploitation licence (pursuant to the application) and given the rights as licensee and operator, the underlying assumption is that the three companies Shell, Total and Equinor will negotiate an agreement, if possible, which entails that all companies participate as partners in a future development solution, with Equinor as operator. Negotiations are under way on the establishment of a joint venture (JV) company. When such a JV agreement is entered into, the plan is to apply to the MPE to transfer EL001 from Equinor to the new company, which will then be the licensee and operator once the transfer is complete.

Figure 3-1 Announced acreage for applications for award of an exploitation licence is shown with a blue outline.



The exploitation licence entitles the licensee to store CO_2 within the area covered by the licence:

Field no.	Block no.	Acreage, km^2
31	4 (partial)	50,861
31	5 (partial)	271,260
31	7 (partial)	76,779
31	8	511,902
31	9 (partial)	494,762
Total acreage		**1,405,564 km^2**

3.2 CO_2 storage as part of the full-scale CCS chain – interfaces

The full-scale value chain for CO_2 capture, transport and storage (CCS) includes the Klemetsrud waste recovery plant in Oslo (Oslo Fortum Varme) and the Norcem cement factory in Brevik. These players will capture and provide intermediate storage for CO_2 in liquid form in dedicated tanks on existing quay facilities. Both players plan to capture 400,000 tonnes of CO_2 per year for transport to the receiving plant in Øygarden for permanent storage in the reservoir on the continental shelf; a total of 800,000 tonnes of CO_2 per year.

Custom-made transport vessels will load liquid CO_2 into tanks from the capture players, and then ship the cargo along the coast to a receiving and intermediate storage facility at Naturgassparken in Øygarden municipality northwest of Bergen. Here CO_2 will be pumped into tanks for intermediate storage before it is exported via the pipeline to the storage location and injection for permanent subsurface storage on the continental shelf.

The plan calls for consistent, transport and storage conditions for CO_2 throughout the value chain. The following pressure and temperature conditions have been assessed:

- High pressure: CO_2 in liquid form at a pressure of approximately 45 barg and temperature of 10ºC
- Intermediate pressure: CO_2 in liquid form at a pressure of approximately 15 barg and temperature of -30ºC
- Low pressure: CO2 in liquid form at a pressure of approximately 6-8 barg and temperature of -50ºC

Gassnova, as principal for the complete value chain, has chosen to use the intermediate pressure as a basis for a consistent, shared design assumption. **The transport and storage part (Northern Lights) of the full-scale project is slated to be based on a pressure of 15 barg and temperature of approximately -26 ºC.**

The capture of CO_2 by the industrial sources is not covered by the CO_2 Storage Regulations. Section 1-6 (i) of the Regulations defines facility as follows: *"installations, plants and other equipment for exploitation of subsea reservoirs for storage of CO_2, but excluding supply and utility vessels or vessels that transport CO_2 in bulk. Facility also includes pipelines and cables unless otherwise determined."*

As a result of this, the present impact assessment, as well as the PDO and PIO for Northern Lights, does not include activities of the capture players or ships transporting CO_2. The impact assessment will cover the geographical area from the immediate area in Hjeltefjorden at Naturgassparken, relevant land areas, the receiving and onshore facility including quays, alternative route corridors assessed for the export pipeline and umbilical system, subsea facility, injection well and offshore reservoir for permanent storage of CO_2.

3.3 Comprehensive schedule for Northern Lights

Northern Lights is the transport and storage part of the Norwegian full-scale CCS project. Plans for decisions, approval and construction of Northern Lights have therefore been coordinated with the plans for approval and construction of the capture players' CO_2 capture facilities.

The project's main plan, which was used as a basis for development, installation and operation of Northern Lights is outlined below. The plan is based on the licensee and partners approving the investment on 29 April 2020 (conditional investment decision, where the condition is linked to the State's partial funding being adopted by the Storting), and that the storage project is ready for operation in the 4th quarter of 2023.

- Study contract with the State (represented by Gassnova) awarded 30 June 2017
- Consultation for IA as part of PDO and PIO October 2019 – January 2020

- Drilling of verification well in Aurora November – December 2019
- Combined concept choice (DG2) and investment decision (DG3) 29 March 2020
- Conditional investment decision by licensee and partners 29 April 2020
- PDO and PIO submission 30 April 2020
- Official investment decision and approval of PDO and PIO 15 December 2020
- Onshore construction work starts Q1 2021
- Early rock installation before pipeline installation Q2 2021
- Offshore pipeline and cable installation Q2 2022
- Connecting pipeline to subsea facility and well Q3 2023
- Receiving facility ready to export CO_2 for injection Q4 2023 / Q1 2024

3.4 Composition of CO_2 to be received and stored

The CO_2 gas captured by the capture players will have different origins, and could therefore have somewhat differing chemical compositions, i.e. contain small amounts of chemical compounds other than CO_2. Equipment components such as pipes, valves, metering instruments, pumps, injection and well equipment, in the receiving, intermediate storage, export and injection chain must be designed and constructed with a material quality adapted to and suitable for the physical and chemical properties of the expected composition of received CO_2. The chemical composition and purity of the liquid CO_2 to be received for geological storage is very important as regards avoiding corrosion and impaired material quality in the receiving, process, transport and injection system.

As part of the work on the Norwegian full-scale CSS project, limit values have been defined for the chemical composition of the CO_2 to be received for permanent geological storage through the project in collaboration with Gassnova and the capture players, Norcem and Fortum Oslo Varme. Limit values for the composition of CO_2 for receiving and permanent storage are shown in Table 3-1.

Table 3-1 Limit values for the composition of CO_2 for receiving and permanent storage.

Component	Concentration limit value, ppm (mol)
Water, H_2O	≤ 30
Oxygen, O_2	≤ 10
Sulphur oxides, SO_x	≤ 10
Nitrogen oxide/nitrogen dioxide, NO_x	≤ 10
Hydrogen sulphide, H_2S	≤ 9
Carbon monoxide, CO	≤ 100
Amines	≤ 10
Ammonia, NH_3	≤ 10
Hydrogen, H_2	≤ 50
Formaldehyde	≤ 20
Acetaldehyde	≤ 20
Mercury, Hg	≤ 0.03
Cadmium, Cd Thallium, Tl	≤ 0.03 (sum)

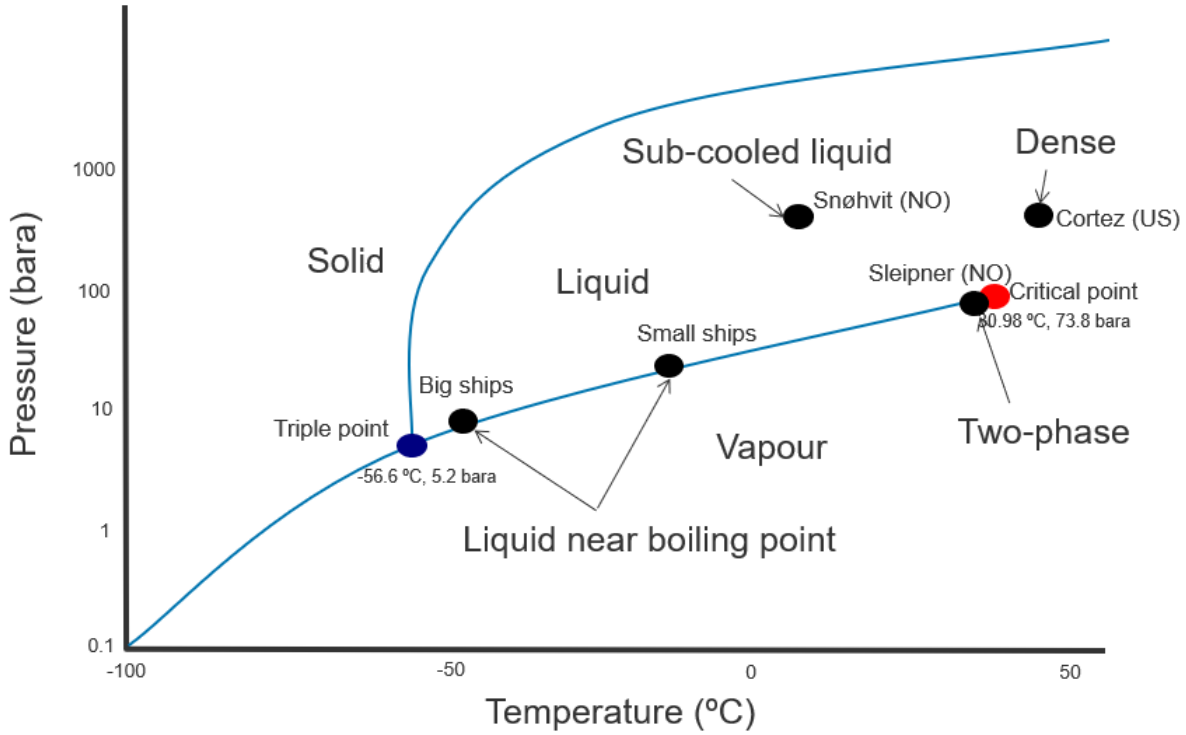
New players delivering CO_2 for permanent storage to the receiving plant must document that the composition of the CO_2 in question satisfies the defined limit values for content and composition before they are approved as suppliers. If there are discrepancies in relation to the specified limit values, a risk assessment must be carried out as to whether the discrepancy constitutes a risk potential for installations or the personnel at the receiving plant. Operational procedures will be established to ensure that these factors are safeguarded. A

local laboratory for sampling and testing of the quality of the received CO_2 cargoes is planned in connection with the technical facilities at the receiving plant, cf. Chapter 3.18.

3.5 Special properties of CO_2

As all other substances, CO_2 can present in three different phases (solid form, liquid and gas), depending on pressure and temperature. CO_2 in solid form is called dry ice. At room temperature and atmospheric pressure, CO_2 is an odourless and colourless gas. A phase diagram for CO_2 ("the CO_2 envelope") showing the transition between the different physical phases of CO_2, is shown in Figure 3-2.

Figure 3-2 Phase diagram for CO_2.



The thermodynamics of phase transitions between the solid, liquid and gaseous phase of CO_2 can be explained using the pressure-temperature diagram ("phase diagram") shown in Figure 3-2. The diagram shows the line for the boiling point between the triple point and the critical point at variable pressure conditions. Below the boiling point line, CO_2 presents in gas form, while above the line it is in liquid form. There is no boiling point line above the critical point, and CO_2 presents in a so-called "supercritical" phase, with properties between gas and liquid. At the triple point, the solid form, liquid and gas coexist as one. The transition line between liquid and solid form, and the transition line for sublimation (direct phase transition) between gas and solid form converge at the triple point.

As opposed to hydrocarbon gas (natural gas), CO_2 is neither flammable nor explosive. To the contrary, the gas is used as an extinguishing agent due to its ability to displace oxygen. As a result of this, CO_2 gas in large concentrations can therefore cause asphyxiation and death. The gas is heavier than air and will "run downhill" and settle in depressions in the terrain, particularly in weather situations with stable air and no wind.

When CO_2 gas under pressure is quickly depressurised, the temperature will drop rapidly, which may lead to the formation of dry ice (solid substance). Chilling and frost injuries could therefore amount to an HSE risk for

personnel in proximity who are exposed directly. The formation of dry ice inside process equipment could pose a risk due to the temperature dropping below design conditions. Dry ice can also clog equipment and thus lead to a risk of shut-in volumes, which in turn could result in a pressure build-up exceeding design pressure.

Under changing pressure and temperature conditions, pressurised CO_2 in process, piping and injection equipment could present in more than one phase at once (both gas and liquid, and potentially solid / dry ice). This will entail particular challenges as regards materials and operations.

The special properties of CO_2 could pose challenges associated with HSE at the facility, and particular consideration will be given to this through the further development and engineering work in the project. Operating procedures will be prepared which safeguard HSE-related factors during receiving, operation and maintenance of the facilities in question. Reference is made to Chapter 3.15 for a more detailed description of these factors. In order to safeguard the consideration for third parties outside the actual receiving facility, special consideration zones will be established on the basis of dispersion and risk analyses, with restrictions on nearby activity, cf. Chapters 8.2 and 8.3.

3.6 Brief description of shipping solution for CO_2 transport

Sea transport of liquid CO_2 along the coast from the capture players to the receiving plant in Naturgassparken is not included in the present IA and will not be covered by the plan for development, installation and operation (PDO-PIO). This follows from the provisions of the CO_2 Storage Regulations and the MPE's clarifications, cf. Chapter 3.2. The shipping solution will nevertheless be described in brief and general terms in the following, see Figure 3-3, to provide a comprehensive presentation of the entire delivery chain for CO_2. The shipping solution will not be addressed or impact-assessed further in the present IA.

Figure 3-3 Planned ship for transport of liquid CO_2

Conversion of existing ships and new construction have been assessed based on the design for transport of liquid CO_2. The preferred solution is new construction of tankers, based on standardised solutions with the fewest possible deviations from established and available equipment deliveries. This approach is considered to be the most robust and will reduce the risks associated with costs and implementation of the ship construction.

At the time of consultation for the IA, no decision has been made as regards ownership and operation of the transport ships, nor as regards who will contract the construction of the vessels. It is presumed that two capture players will supply liquid CO_2 from tanks at quay.

The ship solution is based on existing and known ship concepts for the food industry and LPG transport. The plan is to build and operate two transport ships for liquid cooled CO_2, with the following properties:

- Tank capacity of 7,500 m^3 of CO_2, distributed across two type-C storage tanks of 3,750 m^3 each
- The storage tanks will be designed for the following transport conditions: pressure 19 barg and -35°C
- **Operating conditions for storage tanks: pressure 15 barg and temperature - 26°C**
- LNG (liquid natural gas, tank placed on deck) as fuel during transport, use of onshore power at quay calls, and option of approximately 45 minutes of battery operation during approach/departure to/from port
- Ship length of 130 metres
- Draught of 8 metres
- Thrusters both fore and aft
- Offloading CO_2 with the aid of offloading arms (capacity of 800m^3/hour)
- The ships will be registered in Norway

The transport ships will be designed and constructed to use LNG as fuel. Gasnor AS has an LNG production facility at Naturgassparken, based on importing natural gas from Gassco's gas terminal at Kollsnes.
Despite this, the plan is not for the vessels to fill LNG locally while they are at quay at the receiving facility in Naturgassparken. This is caused, in part, by the cost of routing LNG to the Northern Lights import quay, and in part a desire to avoid introducing hydrocarbons to a facility otherwise free of hydrocarbons. The plan is therefore for the ships to fill LNG from existing LNG facilities located along the transport ships' routes to and from Naturgassparken.

3.7 Receiving and intermediate storage facility on land

In November 2017, Equinor as contractor, along with Gassnova as principal and the Ministry of Petroleum and Energy (MPE), decided that a facility for receiving and intermediate storage of CO_2 would be placed in Naturgassparken in Øygarden municipality in Hordaland County, given that the Storting endorses the development and realisation of the project. Øygarden municipality is located northwest of Bergen, see Figure 2-3 and Figure A-1.

The onshore facility for receiving and intermediate storage of CO_2 is planned to be developed in at least two phases, depending on the volume of CO_2 to be received:

- **Phase 1, with capacity to receive, export and inject up to 1.5 million tonnes of CO_2 per year in permanent storage on the shelf.**
- Potential future Phase 2, with a receiving, export and injection capacity of up to 5 million tonnes of CO_2 per year.

Efforts are under way vis-à-vis multiple Norwegian and international capture players to provide available receiving and injection capacity to 3rd party players (cf. Chapter 11).

The technical process and system plants will be designed to allow for expanding receiving capacity as needed. It must be possible to establish at least one future quay at the facility in addition to the one to be constructed as part of Development Phase 1, in order to allow for future expansions in a Development Phase 2.

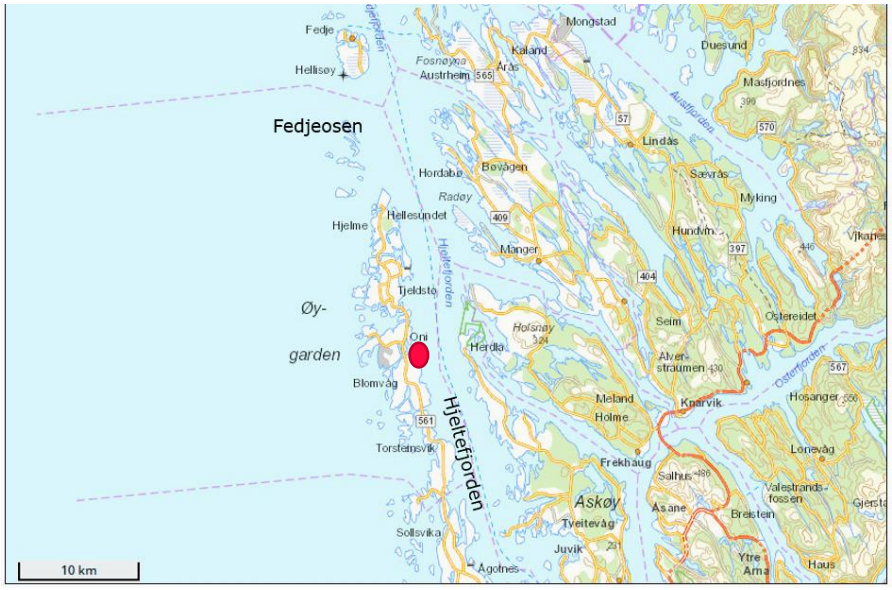
- As regards Development Phase 1, a plot will be developed on land totalling approximately 35,000 m^2 (access road and rock deposit in sea for the quay are not included)
- As regards a future Development Phase 2, the plan is to develop an additional plot on land totalling 15,000 m^2
- Total plot area on land, Phase 1 + Phase 2: Approximately 50,000 m^2 (access road and rock dposit in sea for the quay are not included)

3.7.1 Naturgassparken in Øygarden

Naturgassparken in Øygarden is owned by Coast Center Base AS (CCB) and Øygarden municipality, through the company CCB Kollsnes AS, which also operates the industrial estate. Øygarden municipality owns an ISPS-approved deepwater quay in a central location in this area, which is operated by CCB Kollsnes (www.ccb.no/vaare-baser/kollsnes/).

Naturgassparken is located on the east side of Blømøyna island in Øygarden municipality (land no. 41, title nos. 180, 190, 195 and 194, etc.), and is placed at Ljøsøybukta bay on the west side of the northern part of Hjeltefjorden, 12 nm south of the Fedjeosen sea area and 10 nm north of CCB in Ågotnes, see Figure 3-4. Naturgassparken is located about 3 km east of the gas terminal at Kollsnes and about 7.5 km south of the oil terminal at Sture.

Figure 3-4 Overview map of Hjeltefjorden and Fedjeosen. Naturgassparken is indicated in red.



The area where the onshore facility will be located within Naturgassparken is shown in Figure 3-5. Gassco and Equinor's gas processing plant at Kollsnes is located outside the left edge of the photo.

Figure 3-5 Naturgassparken, facility for receiving and intermediate storage of CO_2 is planned in an area within the red oval on Ljøsøyna. Photo (May 2015) was obtained from www.norgeibilder.no

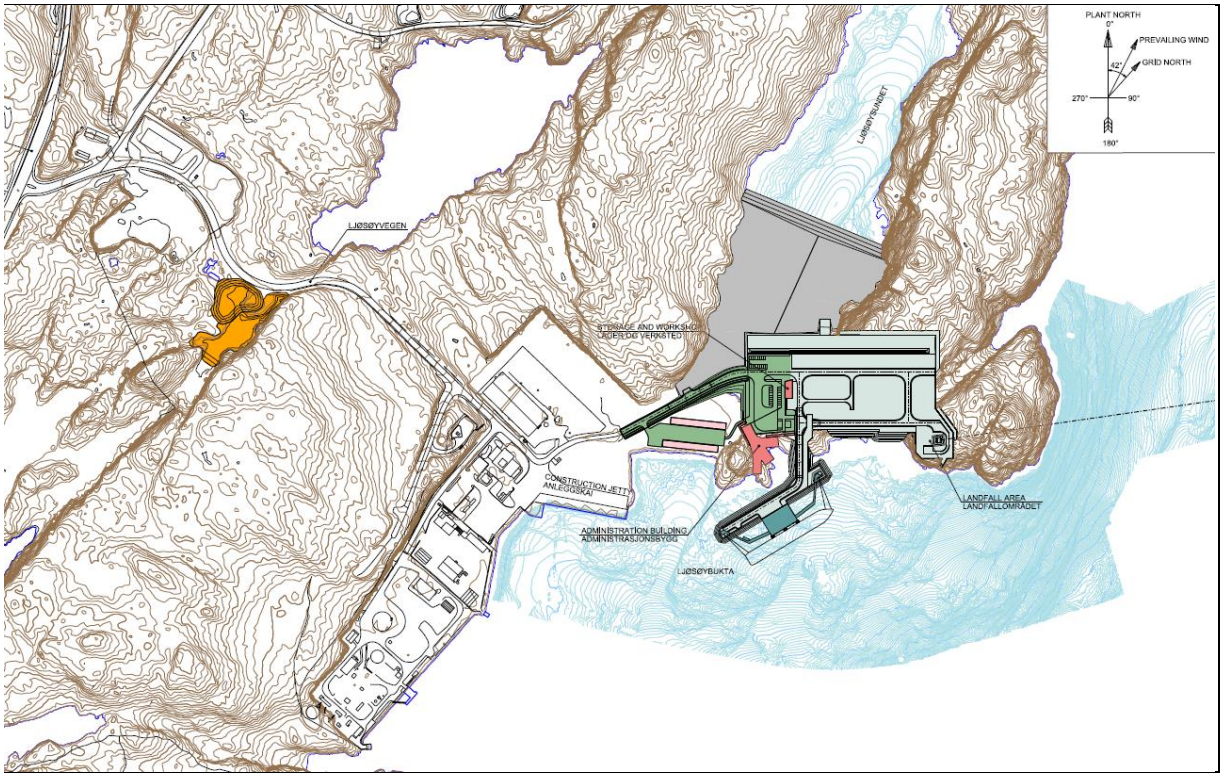
3.7.2 Onshore construction work and land development

Traditional construction work such as blasting, levelling and landscaping of the site will be carried out for the receiving facility. Construction activities will mainly consist of the following work:

- Cutting and removing trees
- Removing uncompacted materials, soil and vegetation
- Drilling and blasting in solid rock
- Handling and moving blasted rock
- Directional drilling of tunnel (24" diameter) as landfall solution for CO_2 pipeline (12-3/4" diameter). The tunnel will be approximately 540 metres long and will end on the seabed at a depth of approximately 260 meters.
- Crushing blasted rock into suitable fractions for use in landscaping the site
- Backfilling and compressing crushed rock on the construction site
- Establishing internal infrastructure (road, water, sewerage, power supply, drainage, fencing, etc.)
- Constructing an administration building with an open area for visitors to the facility, as well as a warehouse and a workshop building
- Landscaping and planting vegetation
- Paving roads, constructing fencing and lighting

Soil and uncompacted materials dug from the terrain before the blasting work will be transported to a local deposit site for uncompacted materials at Naturgassparken, about 700 metres from the construction area, see Figure 3-6 (shown in orange). This area is included in a larger area (total of 17.9 decares) indicated as a deposit area for excess material in the approved zoning plan for Naturgassparken. The deposit site for soil and uncompacted materials is located south of Ljøsøyvegen, with run-off toward the south-west to sea. The plan is to deposit surplus blasted rock in the southern part of Ljøsøysundet strait, cf. Figure 3-6 (grey) and Chapter 3.7.3.

Figure 3-6 Overview of planned development of receiving facility with quay and depositing of blasting rock in Ljøsøysundet. Deposit site for soil and uncompacted materials (orange) at Naturgassparken. Drawing: Multiconsult.



A comprehensive overview of the volume of materials and mass balance associated with the planned construction work onshore and at sea is shown in Table 3-2.

Table 3-2 Volume of materials and mass balance in the construction work for Northern Lights.

Description	Soil and uncompacted materials onshore, transport to soil deposit site (m^3)	Uncompacted materials at sea, dredging and transport to sea deposit site (m^3)	Solid rock, for blasting and materials handling (m^3)	Deposit volume for developing land area and quay (m^3)	Surplus rock, to deposit site in Ljøsøysundet (m^3)
Landscaping construction site, quay and approach area	13,000	40,000	480,000	170,000	575,000
Area on land for HDD landfall tunnel	1,000		25,000	3,000	35,000
Total, m^3	**14,000**	**40,000**	**505,000**	**173,000**	**610,000**

3.7.3 Construction work at sea

Construction work must be carried out at sea in order to establish the quay facility with mooring arrangements in Ljøsøybukta. This mainly consists of the following activities:

- Dredging uncompacted materials (to ensure stability for the deposit)
- Deposit rock to establish a quay facility
- Piling in the deposit for foundation work for quay facility

- Rock pitch the deposit with large rocks for wave protection
- Installing mooring arrangements on piles
- Depositing dredging and surplus rock at sea

Dredging and depositing of dredging materials is subject to an application pursuant to the Pollution Control Act, and an application will be submitted to the County Governor of Vestland for this purpose. Dredging will also be subject to an application pursuant to the Harbours and Fairways Act.

Multiconsult has conducted a soil survey as regards the physical and chemical content and composition of the sediments (/15/), as a basis for assessments and proposals for the handling of dredging materials and surplus blasted rock. The plan is to deposit surplus blasted rock, approximately 610,000 m^3, in the southern part of Ljøsøysundet, and this is incorporated in the zoning plan for the measure. The deposit will be completed with a gentle, stable slope to the north.

3.7.3.1 Dredging soft materials

There is a need to dredge soft uncompacted materials in two partial areas at sea near Ljøsøyna. The receiving facility will be located at the far south of Ljøsøyna. The majority of the facility will be on the levelled area on land, while the access and parking area will be on the blasted rock deposit to the far south in Ljøsøysundet. In order to obtain sufficient stability and quality for the deposit, about 30,000 m^3 of soft sediments must be removed in parts of the deposit area before depositing takes place. A quay is planned in Ljøsøybukta, and in front of the quay there will be a need for some dredging (estimated at 10,000 m^3) to achieve sufficient deposit stability for the quay establishment. The total dredging volume is calculated at approx. 40,000 m^3 of uncompacted materials/sediments to establish the terminal areas. A more detailed description of the sediments and environmental condition is provided in Chapter 5.3.5.

Distribution of types of dredging materials

Based on the soil surveys, the dredging materials with a planned volume of 40,000 m^3 are assessed with a composition as follows (please note that the distribution is subject to considerable uncertainty):

- Gyttja/organic material: 5,000 m^3
- Shell sand: 20,000 m^3
- Soft clay/silt: 15,000 m^3

3.7.3.2 Plan for depositing dredging and surplus materials in Ljøsøysundet

The southern parts of Ljøsøysundet are shown as future commercial areas in the land use part of the municipal master plan, cf. Chapter 7.2. In the revised zoning plan for Naturgassparken (approved in December 2018), the southern part of Ljøsøysundet is zoned as a commercial area, based on rock deposit in the strait. This has been followed up and incorporated in the zoning plan for Northern Lights. The southern parts of Ljøsøysundet are considered to be the best alternative for depositing the surplus rock presumed to be levelled for potential industrial application in the future. The area for the deposit in Ljøsøysundet is estimated at approx. 60,000 m^2 (60 decares).

Multiple alternative solutions have been assessed for depositing dredging materials; these are discussed in Chapter 2.1.5. The solution involving depositing dredging materials under the rock deposit in the southern part of Ljøsøysundet is considered to be the best solution. The area in question is well-sheltered and has calm wave conditions. A silt curtain will be established during the depositing at the northern estuary to prevent the movement of sediments and mud out of the strait to the north. The deposit solution in the southern part of Ljøsøysundet is addressed in more detail in the following.

Dredging deposit site under rockfill in Ljøsøysundet

With a dredging volume of about 40,000 m^3, the dredging materials will cover an area of approximately 15,000 m^2 and achieve a deposit elevation of between 0 and 6 m in Ljøsøysundet. Pollutants have been proven in one sample series in the deep area of the planned deposit area (see Chapter 5.3.5.1). The depositing of rock could result in disturbing polluted fine particles from this area, but with the planned dispersion-limiting measures (silt curtain), the fine particles will re-sediment in the deposit area and remain under the blasted rock without spreading out of the area. Pollutants have been proven in the planned dredging area which exceed the stage-1 limit values in one of four samples. By first dredging and depositing the polluted sediments, they will subsequently be covered by clean dredging materials before further filling of blasted rock. The filling will, in part, take place with the aid of strategic and systematic backfill from a barge, and in part with the transportation of materials from levelled land. As the deposit area will also be delimited by a silt curtain such, thus ensuring that particles cannot spread from the area, the planned development is not considered to entail a risk of dispersing pollutants to surrounding areas. Neither will there be a risk of disseminating pollutants once the depositing takes place.

In order to contribute to the drainage of existing uncompacted and deposited materials, a layer of blasted rock will be deposited on the existing seabed with a thickness of approximately 2 m. This will entail an acceleration of natural sedimentation. These sedimentations will be caused by settling of the existing seabed materials, dredging materials and deposited masses. This settling is expected to continue for an extended period of time. The deposit will be stabilised to the north by completing it with a gentle angle of the deposit. The entire depositing operation is within the action level for the zoning plan.

Based on the extent and duration of the settling, this could result in restrictions on use as an area zoned for industrial activity. Once the settling is complete, the extent of settling must be registered, and development of the area must be considered on the basis of the readings.

3.7.4 Receiving facility with quay

The receiving plant will be designed and devised for a technical lifetime of 25 years, while the quay and various loadbearing and supporting elements (typically concrete) will have a lifetime of 50 years. A general illustration drawing of the establishment of the land area and quay for the receiving plant is shown in Figure 3-7. The area for a future Development Phase 2 is shown to the right (east) of the main area.

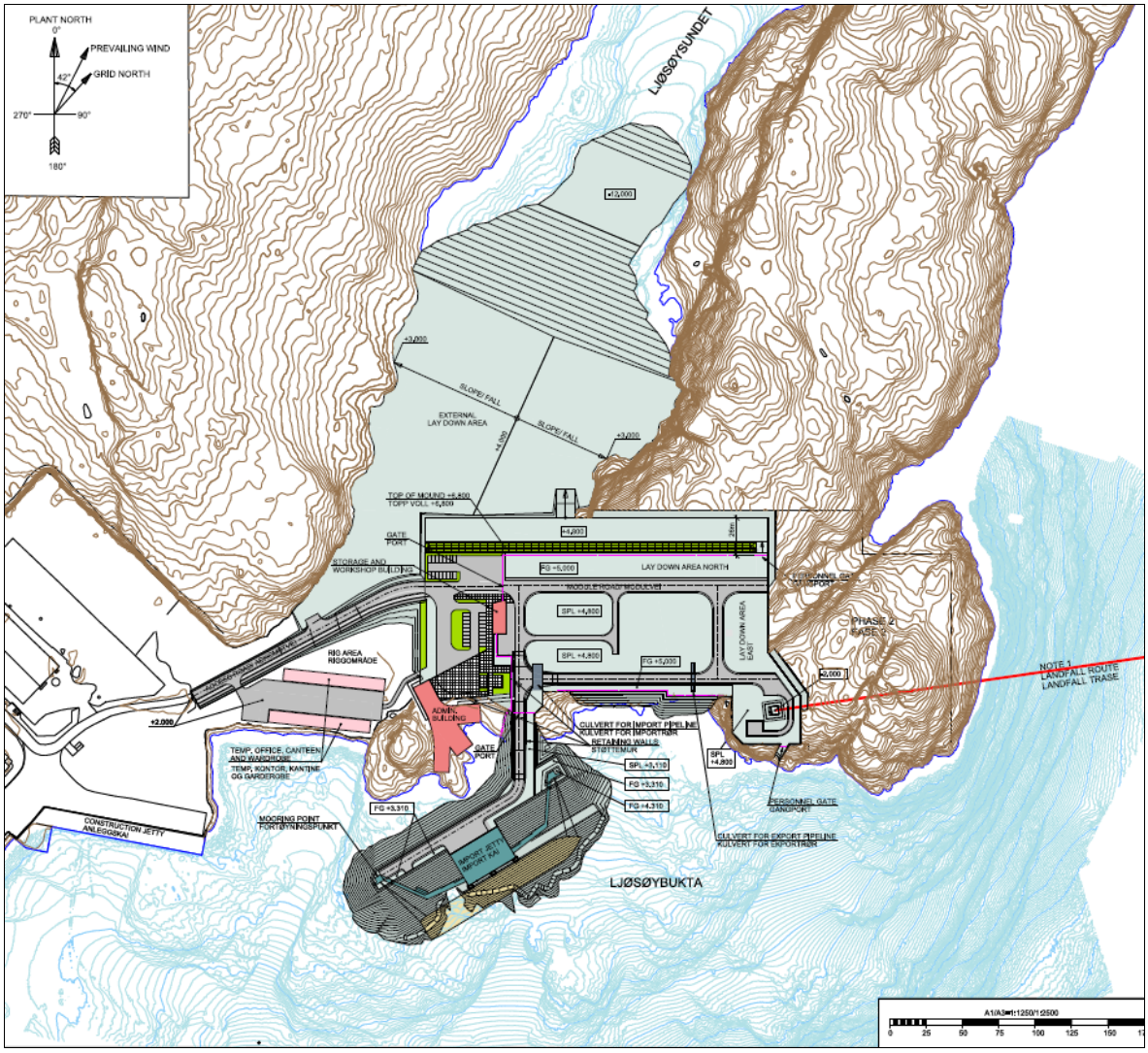
During the work of blasting and landscaping for Development Phase 1, blasting and development will also take place for sufficient area for the facility's Phase 1 to ensure that further expansion for Phase 2 can be implemented without the receiving facility having to shut down normal operations. The quay facility will be established on rockfill at sea, where the surface will be rock pitched. Parts of the natural coastal contours will remain to reduce the impact on the landscape. The pipeline will be routed through an approximately 540-metre-long drilled tunnel to the seabed at a depth of approximately 260 metres.

The plan is for the receiving plant to consist of the following main elements:

- Quay facility with offloading arms, piping and valve arrangement to receive liquid CO_2 from ships
- Piping and equipment to transport liquid CO_2 from the quay to the storage tanks
- Storage tanks (12 vertical) for intermediate storage of CO_2 (capacity; one ship cargo of 7,500 m^3). The tanks will be insulated to avoid cold loss and the need to vent CO_2 in gaseous phase to air.
- Process system required to return CO_2 in gaseous phase from storage tanks to transport ship during offloading to balance pressure on the ship tanks
- Process system to change the pressure and temperature of pipeline export and injection of CO_2
- Electric pumps for export via pipeline for injection in the reservoir
- Internal piping and valve systems
- Power supply and local power distribution

- Administration building with an open area for visitors to the facility and a workshop and warehouse building
- Metering systems for CO_2
- Monitoring, management and control systems

Figure 3-7 Illustration of the establishment of land area and quay for the receiving facility. Area for future Development Phase 2 to the right (east) of the main area. Efforts will be made to conserve parts of the natural coastal contour. Landfall tunnel and CO_2 pipeline are indicated by the red line. Drawing: Multiconsult.



Offloading/loading arms will be installed on the import quay (Figure 3-11) which will connect the ship's manifold system to the pipe transfer on the quay used to transfer CO_2 between the ship and receiving facility:

- 1 offloading arm to transfer liquid CO_2 from the ship to tanks (12", capacity 800m^3 per hour)
- 1 loading arm for return transfer of CO_2 in gas form from tanks to ship (6", capacity 800m^3 per hour). This is necessary to balance and maintain the pressure in the tanks on the ship.
- 1 shared spare offloading/loading arm to ensure uptime and regularity for receiving capacity (12", capacity 800 m^3 per hour), with isolation valves to ensure conversion between loading and offloading functionality.

The steel tanks for intermediate storage of liquid CO_2 at the onshore facility have the following properties/characteristics:

- 12 vertical cylinder tanks
- Storage capacity 625 m^3 per tank (+ 10% margin), total of 7,500 m^3 (corresponds to tank capacity on the ships)
- Fully insulated and surface-treated from the factory
- Design pressure: 21.8 barg
- Minimum design temperature: - 46 °C
- Wall thickness 35 mm, including 2.5 mm of corrosion protection
- Estimated weight per tank: 200 tonnes
- Internal diameter: 6.1 m
- Height: 35 m

It will be possible to connect the tanks in groups using a valve arrangement, or isolate and operate them independently of the other tanks. This entails significant flexibility as regards optimising operations and managing the CO_2 volume in intermediate storage at the facility at any given time. The arrangement also allows for certain tanks to be isolated for inspection and maintenance work while maintaining operation in other tanks.

Work platforms and the valve arrangement will be installed on top of the tanks. Work platforms and walkways will be connected so that all tank tops are accessible to personnel without having to climb down and back up for each tank.

The process plant will consist of the following main elements in addition to the tanks:

- Heating element to heat CO_2 in liquid phase to CO_2 in gaseous phase for vapour return to ship
- Export heating element for potential heating of liquid CO_2 to be exported in the pipeline to the injection well. Placed after the export pumps and heats the CO_2 export stream to an output temperature of 1 °C to avoid freezing the seawater in the landfall tunnel and the surroundings around the pipeline on the seabed.
- Booster pumps. The booster pumps are between the tank manifold and export pumps and increase the liquid CO_2 pressure from the pressure in the tank up to the export pumps' required suction pressure on the inlet side.
- Export pumps operate in parallel with one booster pump each. Export liquid CO_2 via the export heating element in the export pipeline to the injection well. The pump configuration ensures optimisation and flexibility as regards flow conditions and injection rate throughout the system. The export pumps are equipped with a variable-speed drive (VSD) to optimise power consumption.
- Temporary launcher arrangement for cleaning pigs with associated valve system (pig launcher), used in connection with preparing the pipeline for operation.
- Necessary connection and valve arrangement for future expansion of storage capacity.

Shut-off valves

Multiple valves with somewhat different functions will be installed in various places in the receiving and process facility to control the storage and process conditions, isolate plant sections and to avoid undesirable incidents and potential escalation of such incidents.

- Emergency shutdown (ESD) valves are placed on the interface to the export pipeline and on the gas and liquid side for CO_2 pipes on the import quay. They will automatically close in an emergency situation, such as confirmed gas detection.
- There are process shutdown valves upstream and downstream on the liquid side of the storage tanks that close automatically if the level is too high or too low. There is also a check valve on the liquid side, upstream of the storage tanks toward the quay.

- There are motor-operated valves on the gas and liquid side for each of the 12 storage tanks. They can be closed from the control room and will be able to isolate one tank from the others, e.g. in the event of a leak.
- There are safety valves on top of each storage tank. There are also pressure relief valves on all liquid volumes that could be isolated in a shutdown situation. They will open and release CO_2 if the pressure is too high due to heating from the surroundings, and then close when the pressure is reduced to an acceptable operating pressure.

All valves in the receiving plant will be electrically operated and remote-controlled from the local control room at the facility or a central control room in a different location. Please refer to Chapter 3.17 for a more detailed description of the operating philosophy and operating model.

Figure 3-8 Illustration of receiving facility with administration building to the left of the quay, seen toward the northeast. Illustration: Multiconsult.

The following infrastructure will be connected to the facility:

- Access road and internal road system
- Electrical infrastructure
- Telecommunications (fibre cables, etc.)
- Water and drainage system

New infrastructure for water and drainage will be connected to existing connection points centrally at Naturgassparken. The receiving facility will have the following capacity needs within existing developed capacity in the park:

- Firewater supply: 50 l/s
- Drinking water supply: 4 l/s
- Drainage water: 4 l/s supplied in existing sludge separator and drainage network

Brief description of the process at the receiving facility

Once the transport ship is moored at the quay, it will be connected to onshore power to supply power to consumers on board, including the ship's electric CO_2 export pumps. Offloading/loading arms on the quay will be connected to the ship's CO_2 manifold, and offloading can start at a maximum rate of 800 m^3 per hour.

Nothing will be added to and no components will be removed from the CO_2 composition received at the facility. This is therefore a relatively small and simple process facility, which is designed to avoid venting CO_2 to air during normal operating conditions. The only things that will happen at the facility are intermediate storage, a change in pressure and temperature, as well as export for injection.

- Cooled CO_2 in liquid phase will be pumped to the isolated storage tanks at the receiving facility for intermediate storage. The same volume of CO_2 gas will be received at the same time to balance and equalise the pressure in the ship tanks.
- From the storage tanks, booster pumps will increase the liquid pressure, and the CO_2 stream will be led through valves to
    a) the export pumps (the majority of the liquid stream)
    b) the heating element to achieve a transition from liquid to gas to return CO_2 gas to the transport ship. Surplus gas beyond the ship's need to balance the pressure in the ship tanks will be routed back to a storage tank on land.
    c) if there is a need to vent CO_2, this will be routed back to a storage tank on land, and not to air.
- The export pumps will pump CO_2 in liquid phase to the export heating element with planned heating of the liquid stream, and further on into the pipeline for export to the injection well in Aurora.
- CO_2 gas will be transferred to the ship tanks via the loading arm and manifold on the transport ship.

The storage tanks at the facility are insulated to avoid increases in temperature and a transition from liquid phase to gaseous phase with subsequent pressure increase, where the gas phase will have to be re-condensed to liquid or vented to air through the valve system on the top of the tanks. No cooling system will be installed on the tanks to avoid heating and transition to gas. If injection is stopped for any reason, the temperature in the storage tanks will slowly increase, and an increasing volume of liquid will undergo a physical phase transition to gas.

It has been calculated that, with a full ship load of CO_2 (7,500 m^3) in intermediate storage in the tanks at the facility, injection can be stopped for up to 5 days before there will be a need to vent CO_2 to air. Such a lengthy stoppage of injection with a full ship load in the tanks is considered very unlikely.
Figure 3-9 shows an illustration of the receiving facility viewed toward the south-east.

Figure 3-9 Illustration of receiving facility with administration building and visiting area on the right, warehouse building by the car park and parts of the tanks with power grid station to the left. Viewed toward the southeast. Illustration: Multiconsult.

The tanks and process facility are described above. The receiving facility will also comprise the following elements:

Access zone with parking
The access zone will consist of the following main elements:

- Access road with pavement to the facility
- Bus stop shelter
- Bus, car and bicycle parking
- Vegetation
- Gates and access control
- Shelter for waste containers

Administration building with an open area for visitors to the facility
An administration building is planned in the facility's access zone. In addition to offices and a control room, the building will also contain an open area for visitors in order to receive guests at the facility, see Figure 3-9 and left part of Figure 3-10.

Figure 3-10 Left: Administration building. Right: Warehouse building. Illustrations: Ark Arkitektur and Multiconsult.

The administration building will be designed as a modern building, but, based on local traditions such as heather burning in the use of materials and colours. In order to create the most environmentally friendly building possible, a significant portion of natural materials such as rocks, wood and glass, are used. Wood and rock are also the most frequently used materials in local architecture. The administration building will have two main functions:

- Closed administration and control area
- Open area for visitors to the facility

The open area will feature a presentation of CCS and the Northern Lights project in one of the two presentation rooms, before the guests are taken on a tour of the actual facility. The closed administration part will be for the employees who operate the facility with a control room, office space and a meeting room. Both areas will have necessary WC and locker room facilities. An access control system will be installed in addition to video surveillance. The building will have a lifted fresh air intake and airlock in the entryway to prevent CO_2 penetration in the event of a potential incident with emission of large volumes of CO_2.

Warehouse building with minor workshop functions
The storage building will also contain workshop functions for minor repairs, and will be on the south side of the main gate, separate from the administration building, see the right part of Figure 3-10 and Figure 3-9. The building will be a single-story building with no public access, and it will be integrated as part of the security fence to ensure direct access from the building to the facility. The building will consist by a storeroom, a small

laboratory, a small workshop and a few office workplaces. The building will use the same types of materials and details as the administration building. An access control system will be installed in addition to video surveillance.

The plan is for both the administration building and storage building to be heated (and cooled as needed) with the aid of a heat exchanger plant, based on use of seawater as energy carrier.

Power grid station and electrical building
A power grid station will be established inside the facility to receive and distribute electric power to the process plant and quay. Small local substations will be established in the facility to distribute power to local consumers.

The power grid station will contain the following main components for the electrical system:

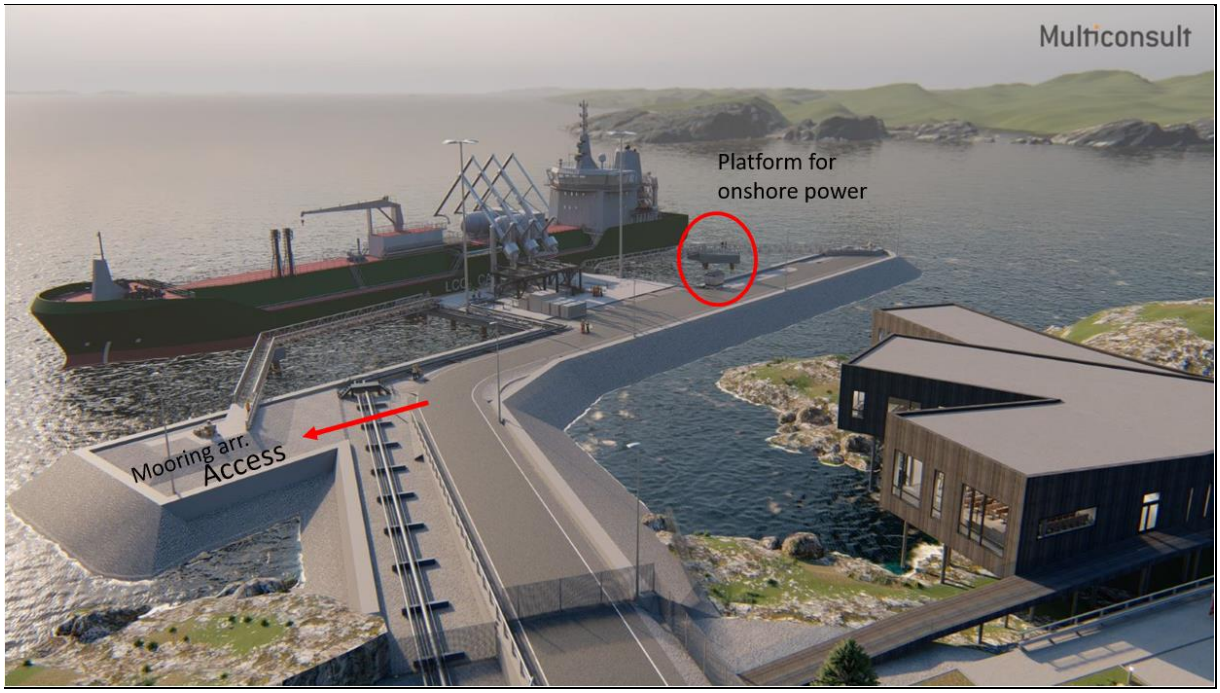
- Main power supply (22 kV) from BKK Nett will be connected to the 22 kV switchgear
    - 22 kV switchgear
    - 6.6 kV switchgear
    - 400 V switchgear
    - Frequency inverter (from 50 to 60 Hz) to supply onshore power to transport ships at quay
    - Direct current uninterruptible power supply to control the switchgear
- Power will be distributed to the entire facility from the 22 kV switchgear, and the voltage level is stepped down as needed to 6.6 kV, 0.69 kV or 0.4 kV and distributed via respective distribution panels. Onshore power will be supplied at the quay at a voltage of 0.69 kV.

All transformers will be placed outdoors, and will be designed to collect any liquid leaks.
Power cables to and within the facility will be installed as underground cables or placed in a culvert, and no new overhead power lines will be established. The application for a plant licence pursuant to the Energy Act to the Norwegian Water Resources and Energy Directorate (NVE) will provide a more detailed description of the electrical system.

The electrical building will contain a room for the telecommunications equipment. The building will also contain a central equipment room for various monitoring, control and management systems at the facility.

Import quay with supply of onshore power
The import quay with walkways and mooring arrangement will be established on rockfill in the sea, see Figure 3-11, and the surface of the rockfill will be rock pitched toward the sea. Foundations for the quay itself will be piled through the rockfill, and the quay surface will be cast on-site with prefabricated concrete girders.

Figure 3-11 Import quay for transport ships with liquid CO_2 to the facility. Illustration: Multiconsult.



A facility will be installed on the import quay to supply onshore power for the transport ships.

- The ships' power need is estimated to be 1 MW
- Power will be supplied at a voltage of 690 V, 60 Hz
- Connects to the ship's power system through a "plug and outlet" solution.

Lighting

Various forms of outdoor lighting will be established at the facility, where design and height will be adapted to the lighting needs.

- Light poles (local), height 6 m
- Street light poles, height 10 m
- Floodlight poles, height 25 m

The tanks will be equipped with warning lights pursuant to the Regulations relating to reporting, registration and marking of aviation obstacles to ensure aviation safety.

3.8 Injection strategy

Maintaining a situation with continuous export and injection from the receiving facility is desirable for multiple reasons. In part, this is due to flow factors in the pipeline, subsea facility with wellhead and in the well, but also because it is the most favourable as regards integrity and flow conditions in the well and reservoir. Continuous flow will prevent a situation where the well is constantly shut down and started up, and the risk of dry ice forming in the system. An injection strategy based on continuous injection is considered to be more robust than batch-wise injection with frequent stops and starts.

Optimising the management of CO_2 at the facility will have to take multiple operational factors into account:

- Continuous injection at an injection rate that ensures single-phase flow in the transport system and well
- The ships' call frequency, so that there is sufficient tank capacity available when a new ship is ready to offload
- Offload rate from ships, where the need to return CO_2 gas from the receiving facility to the ship is also taken into account

With 7,500 m^3 of CO_2 in the ship tanks and full utilisation of offloading capacity (800 m^3/hour), it will take about 9.5 hours of effective offloading time to offload the entire CO_2 cargo. This is in addition to the time spent in approach and departure, quay and mooring operations.

The export pressure supplied from the export pumps will vary between 45 – 100 barg. The lowest export pressure needed to maintain CO_2 flow in single-phase as a liquid is calculated at 45 barg. The export pumps will be equipped with variable-speed drives (VSDs), to optimise pump speed and energy consumption with a variable injection rate and volumes of CO_2 received at the facility. The use of VSDs is considered to represent the best available techniques (BAT).

3.9 Pipeline

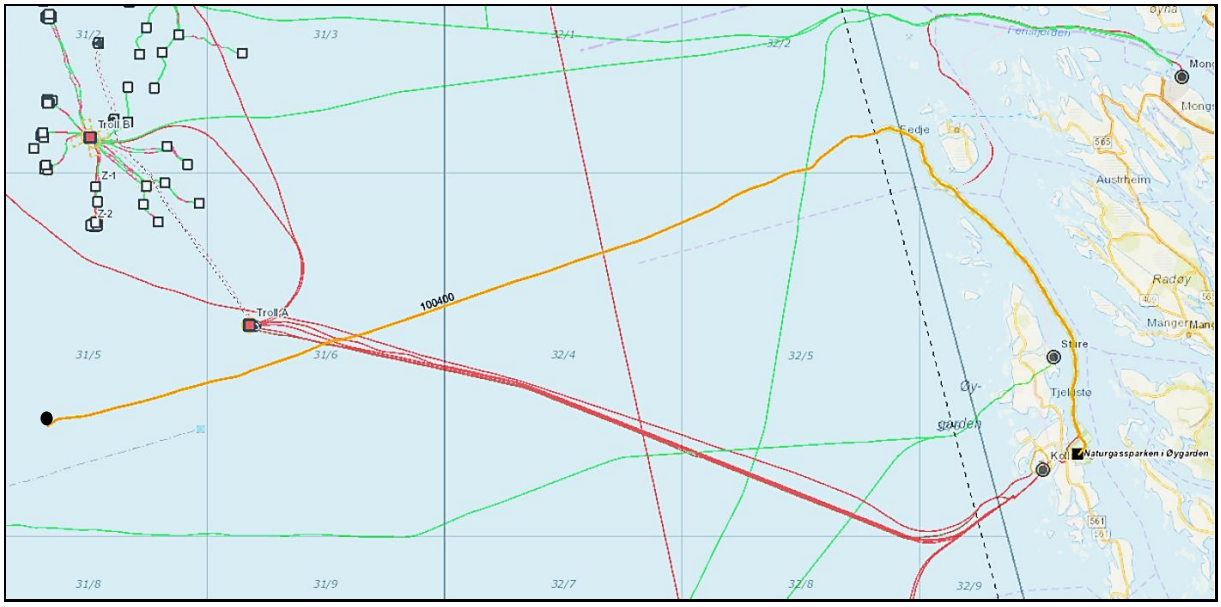
CO_2 in intermediate storage must be transported via pipeline from the onshore plant to the injection well(s) in the reservoir on the shelf for permanent geological storage. The pipeline will be designed to transport the relevant CO_2 volume from both Development Phase 1 (demonstration project with 1.5 Mt of CO_2 per year), but must also be able to transport the increased CO_2 volumes in the development of Phase 2 (with up to 5 Mt of CO_2 per year). The transport system must be designed such that the CO_2 is always kept in liquid phase, without transitioning to either gas or solid form (dry ice), thus preventing multiphase flow or dry ice plugs occurring in the transport system.

Pipeline system:

- Total pipeline length: 100.4 km
- Directional-drilled landfall tunnel: Diameter 24", length 540 m, emerges on the seabed at a depth of 260 m
- Design pressure: 290 barg
- Minimum design temperature: - 30 °C (first 7 km), - 20 °C (rest of the pipeline)
- Outer diameter: 12¾" (323.9 mm)
- Wall thickness: 17.5 mm (first 7 km) and 15.9 mm
- Outer corrosion protection (coating): 3-layer polyethylene, in the landfall tunnel, a coating of neoprene rubber will be used in addition to polyethylene.
- Cathodic protection of the pipeline system:
    - Sacrificial anodes (aluminium) in the sea and in landfall tunnel (anode mass of about 30 tonnes)
    - Isolation joint on dry land for electrical isolation of the pipeline in the sea
- The pipeline on land will be installed in air, and a solar resistant coating will be applied for corrosion protection

A map of the pipeline route from the receiving facility to the injection well is shown in Figure 3-12.

Figure 3-12 Route for CO_2 pipeline from Naturgassparken to the injection well is shown in orange. Existing pipelines are shown, for gas (red) and oil (green). The scope of the Planning and Building Act is delimited by the broken line off the coast.



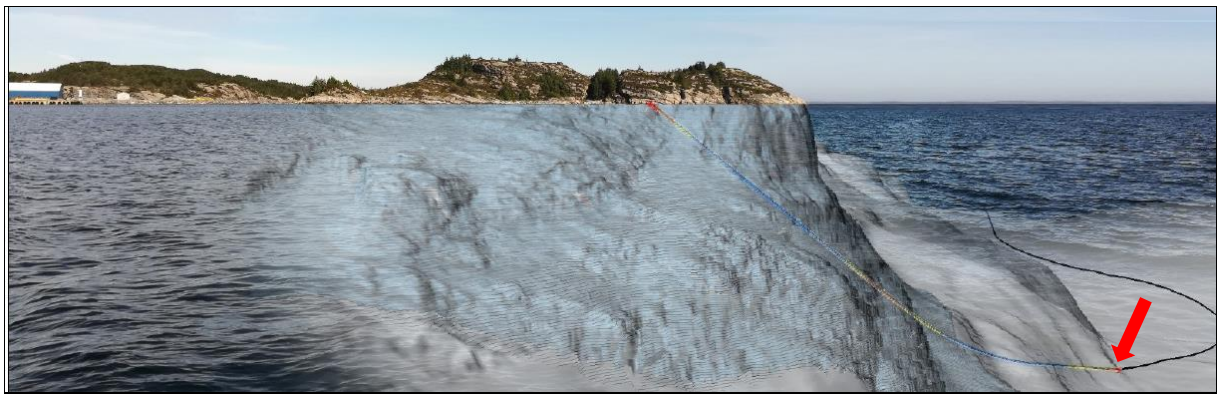
Landfall solution

The seabed topography off Ljøsøyna is demanding and poorly suited to establish a sufficiently stable solution for the pipeline in a landfall trench toward the receiving facility. The chosen solution for landfall for the pipeline is therefore directional drilling (HDD) of an about 540 m long landfall tunnel (diameter 24″), from land out to a depth of approximately 260 metres, cf. Figure 3-13. The pipeline will be pulled through the borehole from the pipelaying vessel just northeast of the southern end of the island using a winch on land.

The lower part of the landfall tunnel will be open to the sea, and the tunnel will be filled with seawater. A sump pit will be established at the upper end of the tunnel, and a small seawater pump will be installed to pump a steady stream of water out of the upper part of the tunnel and discharge the water to sea. This will ensure that the seawater in the tunnel is replaced with fresh seawater, thus establishing circulation in the tunnel. This has the following purpose:

- Water quality and conductivity. The sacrificial anodes on the pipeline in the tunnel will emit ions to the seawater. It is important to ensure constant replacement of the seawater in the tunnel in order to avoid changes in the seawater's chemical composition and electric conductivity over time.
- Prevent the seawater in the tunnel from freezing. Constant replacement of the water in the tunnel will ensure that it does not freeze if liquid CO_2 is exported at temperatures below the freezing point of seawater. A constant replacement of tunnel water will contribute to reduce the need for energy-demanding heating of the CO_2 stream from the export pumps.

Figure 3-13 Illustration of directional-drilled landfall tunnel on Ljøsøyna and the pipeline coming out from the tunnel near the red arrow.



Once the pipeline is attached on land, the pipelaying vessel will start laying the pipeline to the north in Hjeltefjorden, cf. Figure 3-14. The pipeline will be laid to the north along the west side of Hjeltefjorden in parallel with the existing Mongstad gas pipeline. Just to the northeast of Ljøsøyna, the pipeline will be laid to the east of fish farming locality 14435 Ljøsøy N, but due to seabed topography factors, the plan is to install it between the actual fish farm facility and the two outermost eastern anchors. Practical handling of this during the pipelaying operation is described in more detail in Chapter 6.2 and Chapter 9.2.

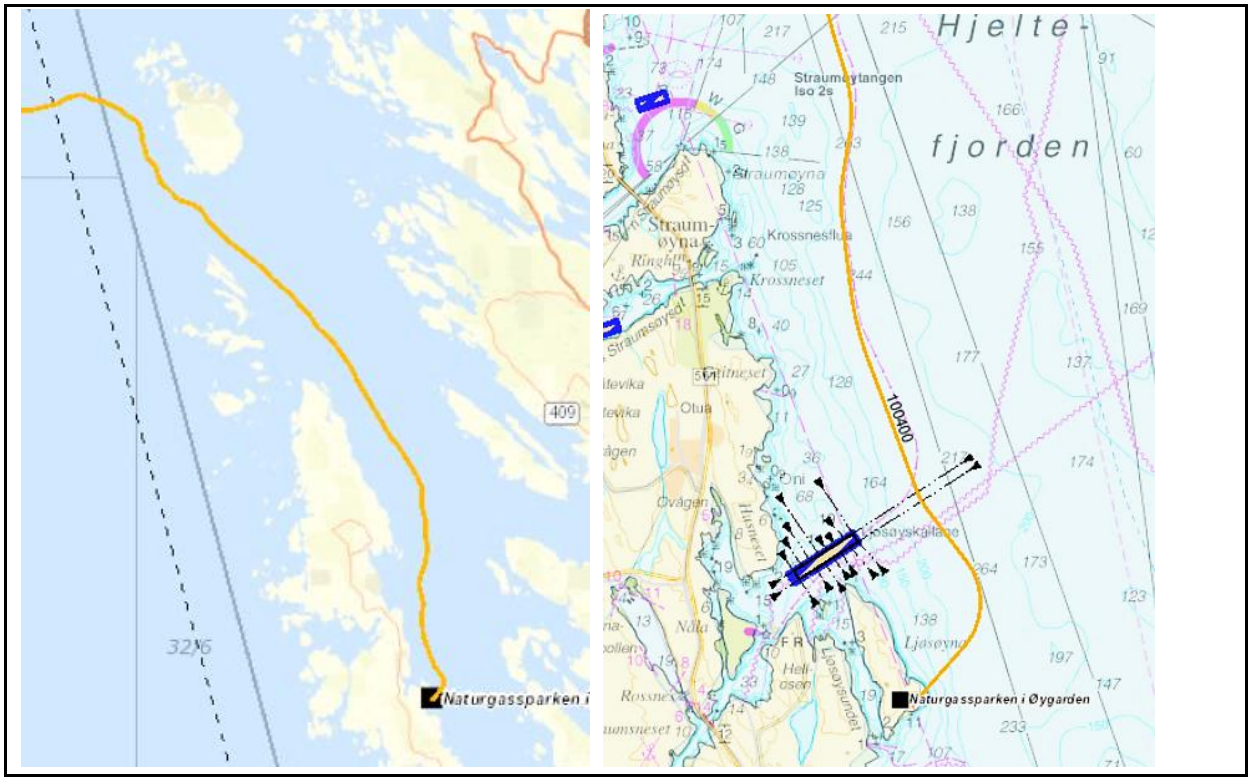
From about 8 km north of the Sture plant, the new CO_2 pipeline will also follow along the existing Vestprosess pipeline to Mongstad for a distance of about 7 km. The distance to existing pipelines will vary somewhat, but the minimum distance will be about 10 metres.

In the area south of Fedje, the CO_2 pipeline will continue to the northwest, and run to the south and west of Fedje, further north of the wreckage of submarine U-864 with mercury cargo, with a minimum distance of approximately 1,100 metres from the wreckage (600 metres outside the restriction zone). The seabed topography south and southwest of Fedje is very steep and challenging. At one nautical mile west of the baseline, the pipeline leaves the scope of the Planning and Building Act, and continues south-southwest toward the injection well. The pipeline route within the scope of the Planning and Building Act is illustrated in Figure 3-14. In the fishery-intensive areas southwest of Troll A and up to the injection well, the pipeline will be jetted into the seabed for protection against damage from bottom trawling.

Rock installation

Some places it will be necessary to install rock (10-12.5 cm) on the seabed to avoid free spans, to ensure a stable surface with sufficient load capacity for the pipeline, and in part for protection. When established infrastructure such as pipelines and cables are crossed, rock will be installed for separation and protection. The plan is to install a total of approximately 40,000 m^3 of rock, which covers the need associated with the pipeline, umbilical system and crossings of existing infrastructure. Of this, about 34,000 m^3 will be in connection with the pipeline and crossings along it. The remaining rock volume will be installed for the umbilical system, partially near Oseberg A and partially in connection with crossing existing infrastructure. The overall volume of rock was considerably reduced during the front-end engineering of the pipeline compared with the concept phase.

Figure 3-14 Left - Route for new CO_2 pipeline is shown with the thick orange line. The limit of the scope of the Planning and Building Act is shown with the broken line off the coast. Right – route detail shown on sea chart north of Ljøsøyna.



3.10 Umbilical with control station

Communication/Power cable and umbilical (umbilical system) will be installed for the subsea facility on the injection well in order to supply necessary electric power, fluids, as well as control and monitoring signals for valves and other equipment in the subsea facility and in the well. The cables will be designed for a technical lifetime of 25 years. The umbilical system to the subsea facility will cover the following functions:

- Transferring electric power and signals (via optical fibre) for monitoring and control of equipment on the subsea facility and in the injection well
- Transferring fluid to barrier test valves (MEG)
- Transferring hydraulic fluid to operate valves

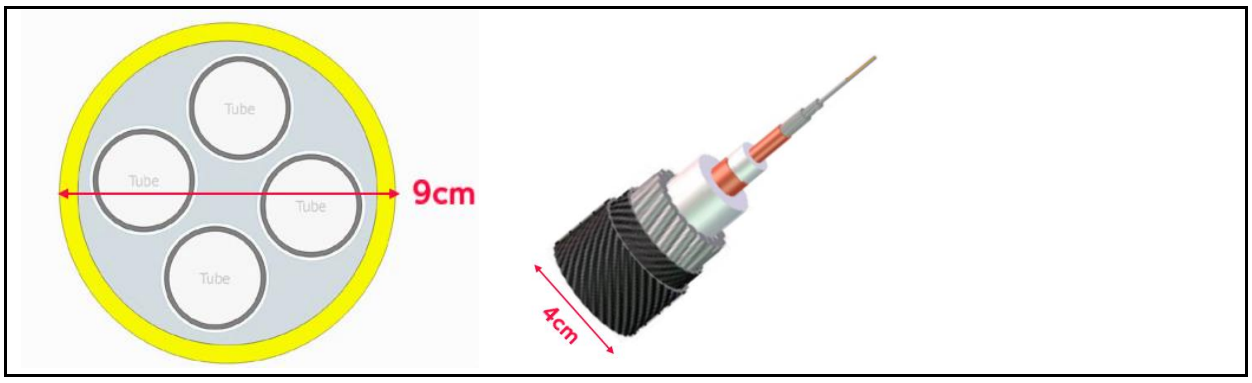
The control system will be designed so that it can be extended to any future injection wells in addition to the injection well currently planned in the Johansen Formation. Two alternative concepts have been considered for the umbilical, and a split solution has been chosen.

- **One cable for power and fibre optics (DC/FO), and one umbilical with necessary fluid lines**
- One shared, fully integrated cable, containing all necessary functions

The chosen solution with two separate parallel systems along the same route is considered to be the most robust solution from a technical standpoint, which also has a lower investment cost compared with a fully integrated cable solution.

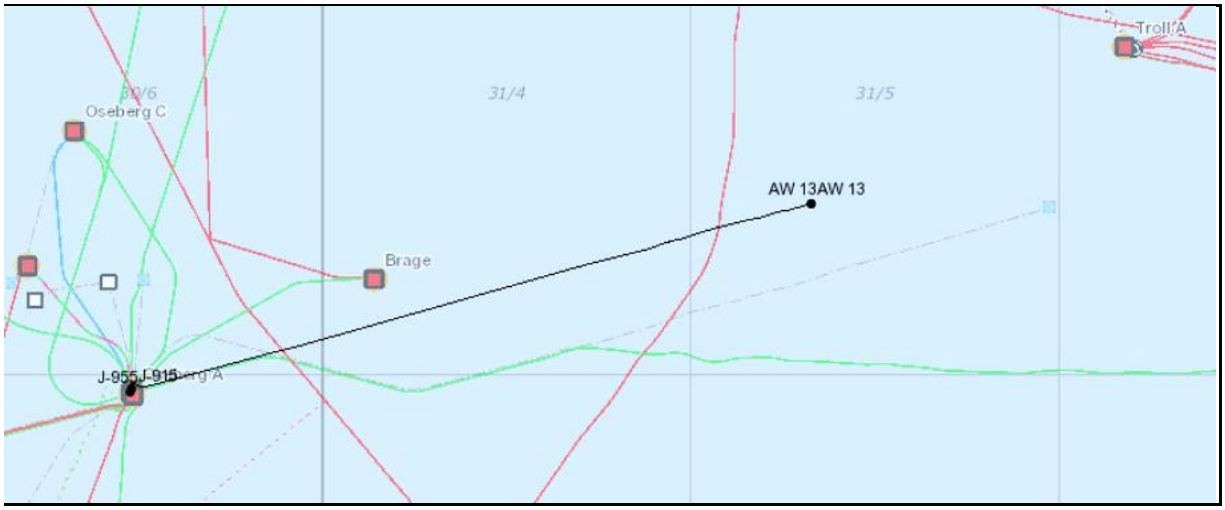
The umbilical for fluids (diameter 9 cm) is flexible with 4 smaller pipes inside, used to transport and inject environmentally friendly (green and yellow) chemicals. The power cable (diameter 4 cm) for power supply and transmitting signals (fibre optics) has a fibre optic cable integrated alongside the power cable. An example of the typical structure and cross-section of cables in a split solution is shown in Figure 3-15.

Figure 3-15 Typical structure and cross-section of fluid cable (on the left) and power and signal cable (on the right).



There must be a control station with tanks and equipment to supply power, signals and fluids through the umbilical system. Oseberg A has been chosen as host installation. The plan is to plough the cables into the seabed, potentially protected with rock/jetting where ploughing is not possible (such as for crossings of existing infrastructure). The relevant cable route is about 35.6 km long and is illustrated in Figure 3-16.

Figure 3-16 The route for umbilicals (fluids cable and combined power and signal cable) from Oseberg A to injection-well is indicated with a black line. Gas pipelines are shown with red lines and oil pipelines with green.



3.10.1 Modifications to Oseberg A

Oseberg A will be the host installation for umbilical system that supply service fluids (hydraulic fluid and MEG), electric power and signals to monitor and control the Northern Lights subsea facility and well control, see Figure 3-17. A tie-in agreement with the Oseberg license is expected to be completed in January 2020.

Figure 3-17 Oseberg Field Centre, with Oseberg A in the middle. Oseberg B to the left and Oseberg D to the right.

The subsea well(s) will be controlled and monitored both from the local control room on the Oseberg A platform (OSA) and from the local control room at the facility at Naturgassparken, and it will also be possible to remotely operate them from the central control room at Sture or Kollsnes. OSA will operate the well during shutdown and start-up of injection, while the onshore control room (local at Naturgassparken or central at Sture/Kollsnes) will control the injection rate using the choke valve on the subsea well during normal operations. The well will be connected to OSA through the umbilical system that transmits electric power, fibre optic signals, hydraulic control fluid and MEG from corresponding supply units placed on OSA.

The following work will be carried out on OSA in order for it to function as host installation for the control station for the Northern Lights well(s):

- Removing a decommissioned nitrogen station to make room for a new MEG supply unit
- Connecting to OSA's operating system (SAS) and OSA's electric power supply system
- Expanding an existing hydraulic power supply unit so that it can also operate Northern Lights
- Pulling in and connecting a cable for electric power and fibre optic signals
- Pulling in and connecting an umbilical for hydraulic power and MEG

The modification work on Oseberg A will be described in more detail in the plan for development and operation (PDO) of the project.

3.11 Overpressure protection for the transport systems

The design of the technical solutions for the transport systems for Northern Lights has integrated various solutions to avoid overpressure in the facilities.

The pipeline from the receiving facility to the injection well has a design pressure of 290 barg. The normal operating pressure for Development Phase 1 will be 45-100 barg. When the well is started up after a long shutdown, higher pressure will have to be used in certain instances to start the injection. The maximum operational pressure from Naturgassparken for Phase 1 will therefore be 140 barg. The pressure from the export pumps for Phase 1 will be much lower than the maximum pressure for the pipeline and subsea system. The pumps on the onshore facility therefore cannot entail any risk of overpressure in the pipeline and subsea system.

The pipeline will be designed to transport larger volumes of CO_2 in the future (Development Phase 2, up to 5 Mt of CO_2 per year). The export pressure will then be higher, but still within design pressure, and will require the installation of an acceptable pressure safety system for the pipeline.

MEG from Oseberg Field Centre: Another high-pressure source into the transport system will be MEG used as a service fluid on the subsea facility. The MEG system will be located on Oseberg with a dedicated MEG tank for Northern Lights totalling 6 m^3. The plan is to use MEG with the subsea system and the well, and no operations are planned in connection with the pipeline. The fluid umbilical has a design pressure of 345 barg. The maximum operational pressure for the MEG system will be 245 barg. A conventional pressure safety system with two barriers will be used for pressure protection. This corresponds to a pressure of 345 barg at the wellhead, and this pressure is lower than the acceptable pressure for the entire transport system (umbilical, pipeline, PLEM, spool, subsea manifold, X-mas tree and well).

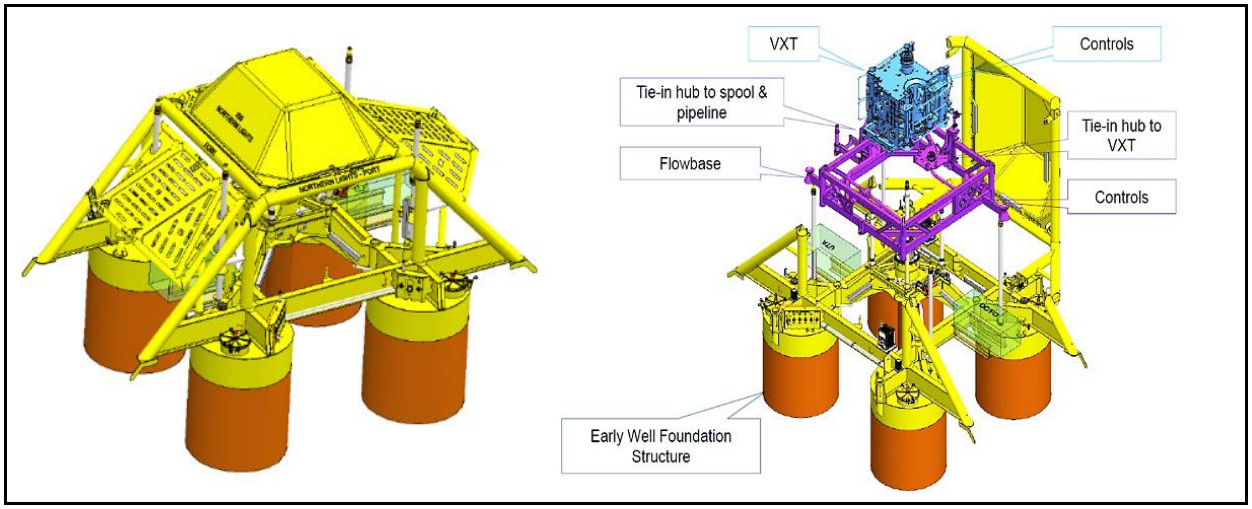
The injection well in the reservoir is expected to meet a reservoir pressure of approximately 276 bar. A pressure build-up of approximately 20 bar in the reservoir is expected over time. A reservoir pressure of 296 bar has been used to calculate the maximum shut-in pressure at the wellhead. The maximum pressure from the reservoir is 120 bar at the wellhead. The reservoir will not constitute the greatest pressure source in the system. The well will be secured with two barriers against the reservoir pursuant to authority requirements, the same as for other wells on the Norwegian shelf. The well will also be designed to withstand maximum pressure from the other pressure sources; MEG and CO_2.

3.12 Subsea facility

The subsea facility will be established in connection with the injection well on the Norwegian Continental Shelf, where the pipeline, X-mas tree and control system with umbilical and power/communication cable will be connected to the well, and will be installed inside a trawl-resistant protective structure. The size of the structure will be 20.4 m x 12.4 m, with a total height of 16 m including the depth of suction anchors. The weight will be 146 tonnes. The subsea facility will be designed and built with a technical lifetime of 25 years, and will consist of the following main components, see Figure 3-18 for illustration.

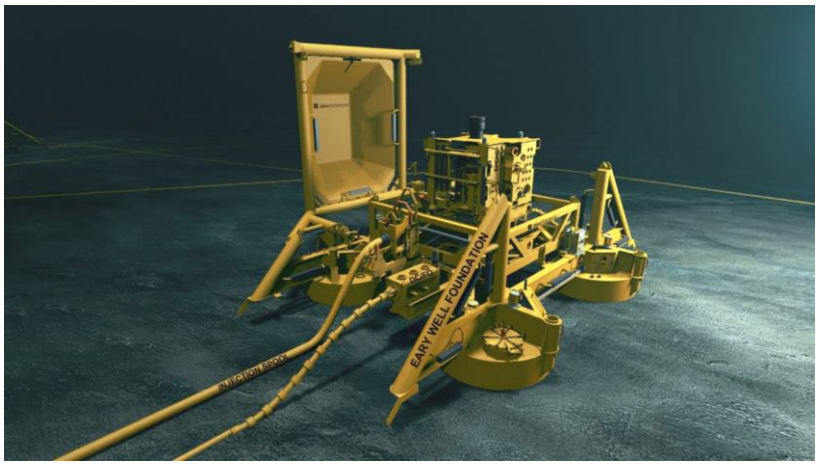
- Wellhead
- X-mas tree
- Choke module
- Flowbase
- Protective structure
- Control system
- Power cable and umbilical

Figure 3-18 Single-well satellite (closed and open protective structure) with vertical X-mas tree.



A model of the subsea facility viewed from the side with an open protective cover is shown in Figure 3-19.

Figure 3-19 Model of the subsea facility with an open protective cover.



Oseberg uses an open hydraulics system for some of its wells, and the system has available capacity. This system is based on using the water-based hydraulic fluid Oceanic HW443ND with return to sea. Northern Lights will use available capacity in this system on Oseberg and will thus use an equivalent hydraulics system for well control. Hydraulic fluid and MEG will be supplied through an umbilical from Oseberg A. The hydraulic fluid is in the yellow colour category (Y2) due to low biodegradability as a result of an additive but is not acutely toxic.

In open systems, hydraulic fluid will be discharged to sea during the following operations upon each opening of the remote-controlled valves:

- Normal valve operations
- Internal consumption from control unit
- Normal seepage/sweating from various connection points

Total discharges of hydraulic fluid from the Northern Lights subsea facility will be approximately 2,000 litres per well per year. Discharges will be somewhat higher the first year due to more frequent testing of the barrier valves. The project's Phase 1 (1.5 Mt of CO_2 per year) is planned to start with one injection well and have a

second well in reserve if the first well does not have sufficient injection capacity. If the project's Phase 2 is realised with a total injection capacity of 5 Mt of CO_2 per year, the number of wells will have to be increased to provide an injection rate of 5 Mt of CO_2 per year.

At the start-up of Phase 1 (1.5 Mt of CO_2 per year), the project will only have one injection well. If the project's Phase 2 is realised with a total injection capacity of 5 Mt CO_2 per year, the number of wells could be increased to a presumed five injection wells.

A discharge permit pursuant to the provisions of the Pollution Control Act will be sought for the planned operational discharges in the normal manner.

For an environmental assessment of the use of an open hydraulics system with return and discharge to sea, reference is made to Chapter 5.10 concerning BAT assessments.

3.13 Drilling and well – 31/5-7 Eos

Eos with her dead son Memnon (from Greek vase painting).

In Greek mythology, **Eos** is the goddess of the dawn, personified as a beautiful, young woman. Her tears fell to Earth and became morning dew. Every morning, she rises from the sea in a chariot pulled by two horses. She was the daughter of Titans Theia and Hyperion, and her siblings were Helios, god of the sun, and Selene, goddess of the moon. She was married to temperamental god of the wind Aiolos and together they bore the children Boreas, Euros, Notos and Zefyros. Aphrodite accused her of nymphomania, and she was punished for her love of Ares. She was forced to marry the Trojan prince Tithonus, a mere mortal. They had two children; Memnon, who was killed in the Trojan War by Achilles, and Emathion, who was killed by Heracles. Eos asked Zeus to make her new husband immortal, but forgot to ask for his eternal youth. He became older and older and the other gods eventually took pity on Eos and turned Tithonus into a cicada. The counterpart to Eos in Roman mythology is **Aurora**. (**https://Wikipedia.no)**.

3.13.1 Eos – purpose

In order to verify the well and reservoir assumptions that form the basis for developing the project based on storage in Aurora in the Johansen Formation, a decision has been made to drill an early confirmation well. The well will be drilled in November 2019, and well testing will be carried out. Due to the pressure conditions, the formation water will be pumped up to the rig to carry out the testing (like a production test). Results from the well testing will be incorporated in the plan for development and operation (PDO) for the geological CO_2 storage. The verification well's objectives are

- Confirm/verify that the reservoir sandstone is suitable to store CO_2
- Data acquisition
- Updating the geological model
- Can subsequently be converted and used as an injection well

The well will be drilled by the West Hercules drilling rig with planned start-up in November 2019.

The primary objective of Eos is to prove sandstone and storage potential in the Johansen Formation and the Cook Formation and investigate the seal properties of the shale in the Drake formation (all in the Dunlin Group) in Eos, as well as to collect data for reservoir understanding. The Johansen and Cook formations are expected to be water-filled. No structural traps where hydrocarbons could accumulate have been identified in the area surrounding Eos. Therefore, no hydrocarbon accumulations are expected at the Eos location. Aurora is described in more detail in Chapter 3.14.

3.13.2 Location

Verification well 31/5-7 Eos is planned at position **60° 34' 35.14'' N and 003° 26' 36.13'' E** (ED50, UTM 31N, CM 3° E), and will be drilled through a single-well satellite structure. The well is located on the Horda platform, approximately 15 km west of 31/6-1 (Troll Øst) and 17.5 km southwest of 31/5-2 (Troll Vest). The distance to shore is approximately 72 km. The distance to the sector boundary with the United Kingdom is about 82 km. Water depth at the well location is 307 m MSL.

3.13.3 West Hercules drilling rig

The West Hercules rig (owned and operated by Seadrill) will drill the verification well. The rig was built in 2008, totals 40,000 DWT and can accommodate 180 people on board. The rig has already been contracted to drill multiple wells for Equinor. West Hercules has been designed as a "tight rig" as regards any leaks or spills on deck and handling thereof.

The average diesel consumption in connection with power generation on West Hercules is estimated at 44 tonnes per day, and the planned operation has an estimated duration of 75 days (including a 29-day well test). An application for an emission permit pursuant to the provisions of the Pollution Control Act was submitted to the Norwegian Environment Agency on 28 June 2019 (/18/). An application was also submitted for a permit to discharge a small volume of radioactive tritium to use as a tracer in well testing (/19/). The Norwegian Environment Agency and the Norwegian Radiation and Nuclear Safety Authority issued the necessary emission and discharge permits in letters of 25 September and 30 September 2019, respectively.

West Hercules will drill the confirmation well and carry out well testing in the winter of 2019/2020, and then plug and abandon the well. If the test results confirm suitable well and reservoir properties, a different rig will come to the well location in summer 2023, reuse the upper parts of the well, drill a side-track over the plug in the reservoir and complete this, and then the well will be converted into an injection well. The injection well will be abandoned with the necessary barriers installed and will be ready for the injection of liquid CO_2 in 2023.

3.13.4 Well design

The plan is to drill the Eos well with the following design.

- Pilot hole

The plan is to drill a 8-1/2" pilot hole to determine whether there is shallow gas present. The plan is to drill with seawater and high-viscosity pills.

- 36" and 26'' well sections

The top two hole sections will be drilled with seawater. In order to clean the hole, high-viscosity liquid pills with bentonite/polymer will be pumped as needed to clean the hole (only PLONOR chemicals). In order to stabilise reactive clay, the plan is to pump a water-based drilling fluid system with KCl before pulling out from the 26" hole. 30" conductor and 20" casing will be run and cemented in throughout. Cuttings and any surplus cement will be discharged on the seabed, as no riser will be installed.

The deeper well sections (17½", 12¼" and 8½") will be drilled with a water-based drilling fluid system. Cuttings will be returned to the surface via the facility's riser, cleaned and separated over the shaker before discharge to sea. The drilling fluid will primarily consist of green PLONOR products. Surplus drilling fluid will be sent to shore.

- 17½" well section

As regards the 17-1/2" section, 13-5/8" casing will be run, and the plan is to cement back to 400 metres above the setting depth.

- 12¼" well section

As regards the 12¼" section, 9-5/8" extension tubes will be run, and the plan is to cement back to 400 metres above the setting depth. Data acquisition will be carried out in accordance with a separate programme before the next section.

- 8½" well section

Data acquisition will be carried out in accordance with a separate programme before permanent plugback and the well will be abandoned.

Drilling fluid and handling of cuttings

The plan only calls for consumption and discharge of drilling fluid in the yellow and green categories. The products in the drilling fluid are green PLONOR chemicals where the only yellow product is Glydril MC. This works as a formation stabilising agent.

A total of 1,689 m^3 of drilling fluid will be discharged to sea. From the pilot hole and the upper sections, 241 m^3 of water-based cuttings will be discharged to the seabed. From the other sections, 261 m^3 of water-based cuttings will be taken up to the rig, cleaned and separated over the shaker on board before cuttings with adhering substances are discharged to sea. Total volume of cuttings to sea is 502 m^3, which includes cuttings from drilling the sidetrack for the injection well.

Overall permit volumes for consumption and discharge

Table **3-3** lists the permit application volumes for consumption and discharge.

Table 3-3 Total permit volumes for consumption and discharge in the drilling and well testing of Eos. /18/.

Type of chemical	**Consumption in application** [tonnes]	**Discharges to sea in application** [tonnes]
Total volume of green substances	5617	2228
Total volume of yellow substances (excl. Y2)	211	109
Total volume of yellow Y2 substances	8	1
Total volume of red substances *	23	0.00432 **
Total volume of black substances*	10	0

** The majority of consumption of red and black chemicals is related to potential replacement of a major volume of hydraulic fluid. ** Discharges of tracers in connection with well testing.*

Environmental risk and emergency preparedness

No hydrocarbons (oil or gas) are expected to be found on Eos. There will therefore be no blowout-related environmental risk associated with the drilling or any need for an oil spill preparedness analysis for Eos. See Chapter 3.13.1 and Chapter 3.14 for a more detailed description of the geology at the location and probability of discovering hydrocarbons. All clean-up fluids and any hydrocarbon liquids from the well testing will be collected and transported to shore for further treatment. West Hercules is designed as a "tight rig" as regards leaks and spills on deck, and leaks will be collected and handled in accordance with this.

Drilling of the Eos well as a "non-hydrocarbon-bearing well" is included in the drilling programme for drilling ordinary exploration wells for hydrocarbons. The rig will be set up with normal HSE emergency preparedness with personnel, equipment and chemicals to handle incidents involving discharge of hydrocarbons. Any environmental consequences of a minor point source discharge from the rig will be considered minimal and brief. The well is planned in an area that is well-mapped in connection with previous activities and monitoring programmes carried out in the region, cf. Chapter 5.3.5.3. No vulnerable environmental assets have been identified in the area. The Eos well is part of the offshore area included in the area preparedness arrangement for Troll-Oseberg.

3.13.5 Assessments and measures if hydrocarbons are encountered

Northern Lights does not entail any drilling in known petroleum-bearing layers (Eos or subsequent wells), extraction or transport of hydrocarbons as would be the case in a traditional oil or gas project. Therefore, there is no expectation that hydrocarbons will be encountered in connection with drilling the verification well or subsequent drilling of the sidetrack to convert into an injection well. Ongoing assessments of the potential of encountering hydrocarbons during the drilling indicates a very low discovery potential, but the likelihood of this so far cannot be entirely ruled out. The planning of the drilling takes into account that gas could theoretically be encountered, and an 8½" pilot hole will be drilled to determine whether any shallow gas is present.

Different measures will be relevant depending on where in the well (relevant depth in relation to the cap rock for the storage reservoir) any hydrocarbons are encountered. Any relevant measures will also depend on whether the potential presence of hydrocarbons is considered to be able to affect the reservoir's suitability as permanent geological CO_2 storage. Well testing will be carried out as part of the drilling and well operation in winter 2019/2020. The test equipment used to carry out the well testing will be set up to handle potential occurrences of hydrocarbons. As regards Eos, hydrocarbons will not be produced to the surface in the normal way, and the equipment will only be installed as backup. The presence of some natural gas naturally dissolved in the water cannot be ruled out. If so, these volumes will be minor. All clean-up fluids and any hydrocarbon liquids will be collected and transported to shore for further treatment.

3.14 Subsurface geological storage – Aurora

In Roman mythology, **Aurora** was the personification of dawn, and was the Roman counterpart to the Greek Eos. She was a beautiful woman who flew across the sky announcing the arrival of the Sun. Aurora had two siblings – her brother, the Sun, and her sister, the Moon – and she had many husbands and sons. Four of her sons were the four winds, Aquilos (the north wind), Favonius (the west wind), Auster (the south wind) and Eurus (the east wind). Morning dew is the tears of Aurora. She weeps for her dead sons and lovers. Aurora's counterpart in Greek mythology is **Eos**. (www.wikipedia.no).

3.14.1 Geological description of the storage unit

Exploitation licence EL001 is located south of the Troll field and east of the Brage field, cf. Figure 3-1.

The chronostratigraphic strata in the area are shown in Figure 3-20. The Dunlin Group is the primary storage unit. The plan is to inject CO_2 in water-filled porous and permeable sandstone in the Johansen Formation (Fm.), and it will be stored here and in the overlaying Cook Formation. Tight, impermeable shale in the Drake Formation represent the primary seal for the storage. All three formations are part of the Dunlin Group and occur regionally in wells.

Water-filled sandstone in the overlaying Brent and Viking groups is considered to present potential future injection and storage opportunities. Tight shale in the Brent and Viking Group, such as the Ness, Heather and Draupne formations, will act as additional seal layers. The Draupne Formation is known as the seal for the Troll field and other hydrocarbon fields in the North Sea, and is considered to be a reliable seal for CO_2. The Northern Lights project has no concrete plans to store CO_2 in the shallower units, but due to the vast potential, it may be relevant over the long term to store CO_2 in these sandstone units.

Figure 3-20 Chronostratigraphy overview.

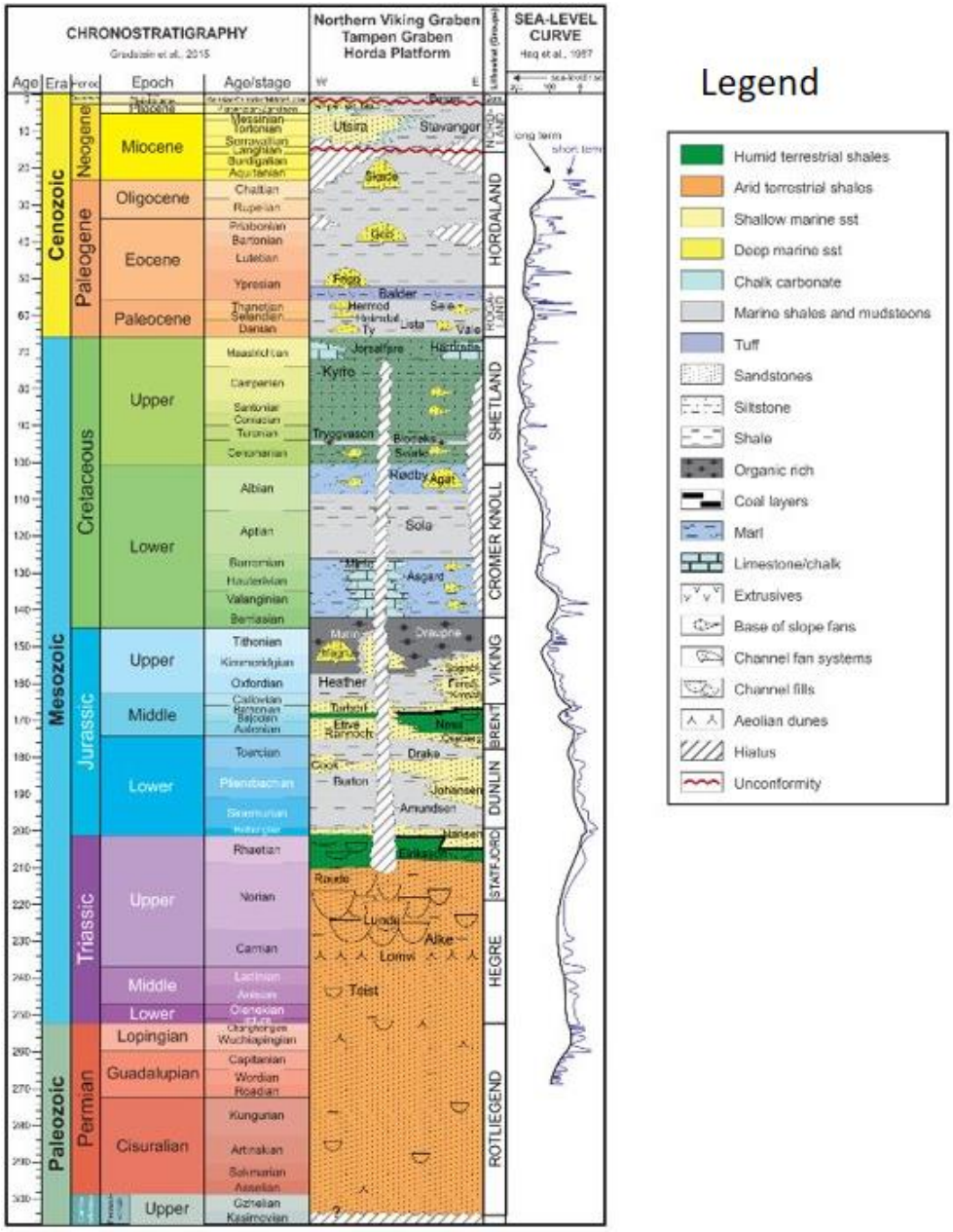
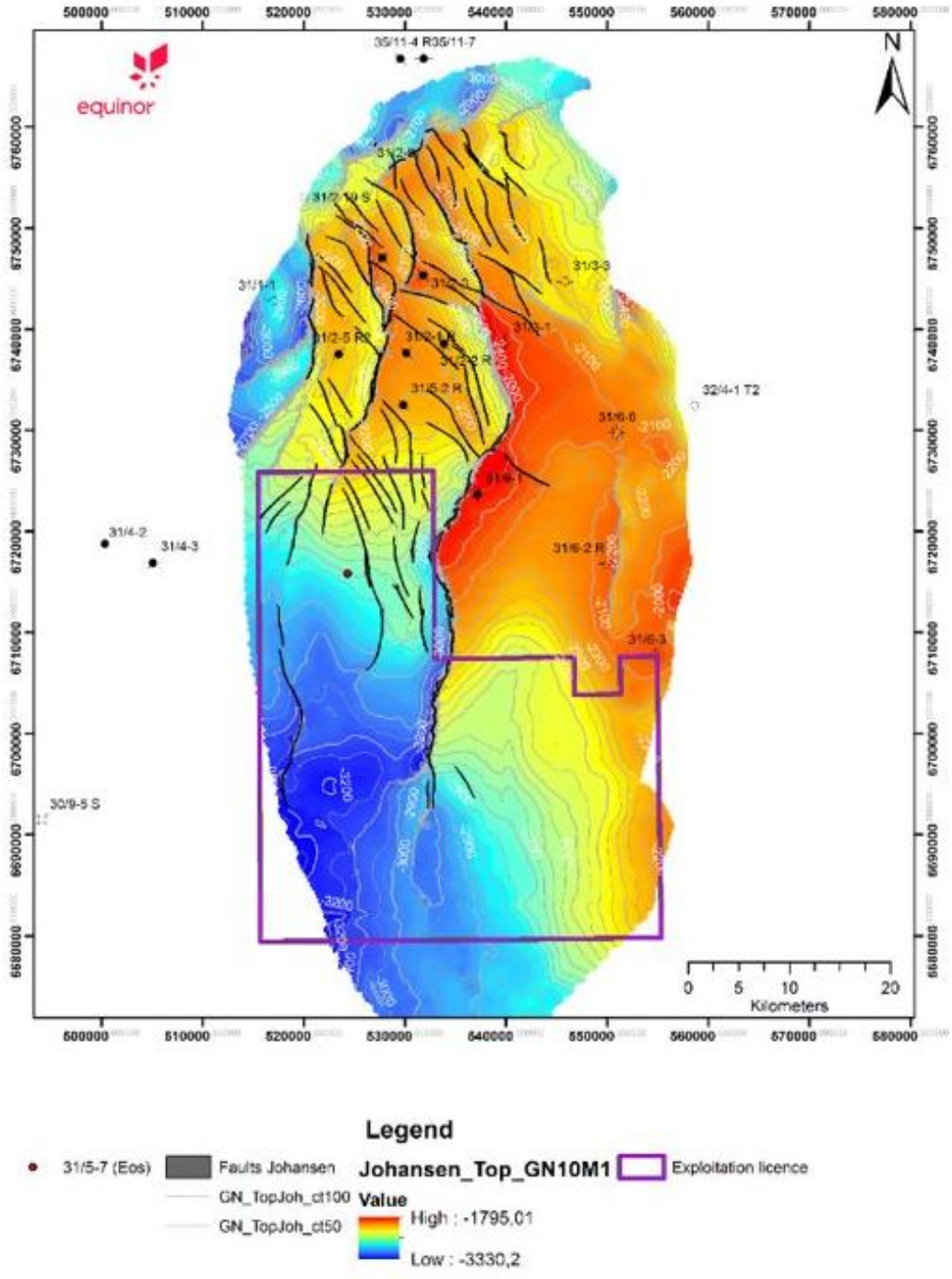


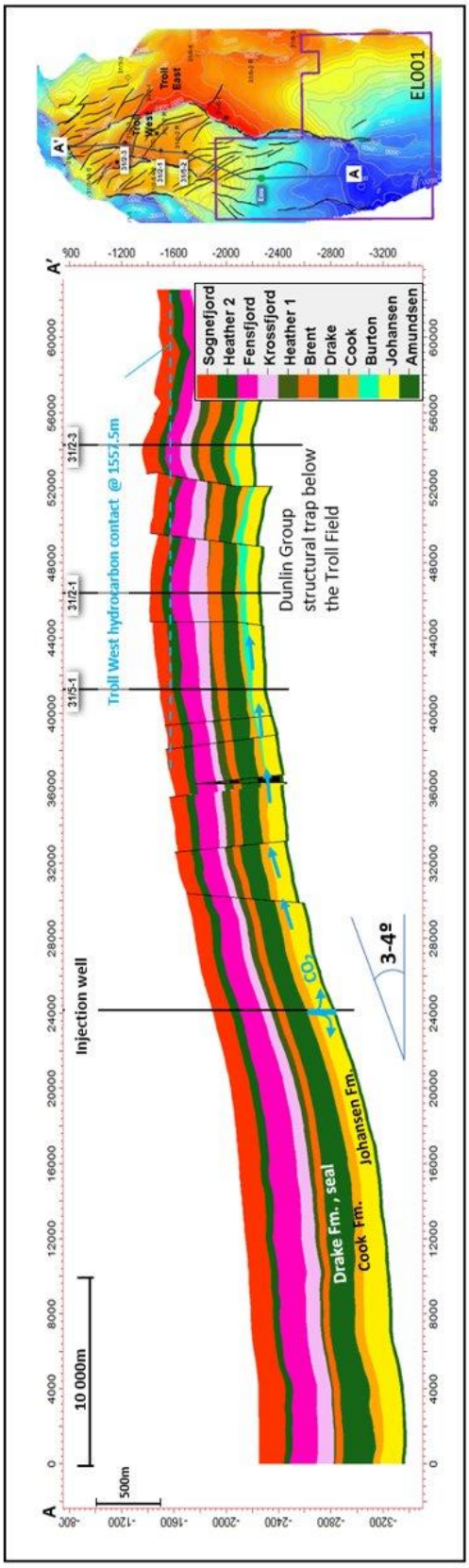
Figure 3-21 shows a structural depth map of the top of the Johansen Formation based on seismic data. The location of the planned 31/5-7, Eos well, is indicated in red. The well will be drilled in 2019 as a verification well and will, if suitable for this, be converted and used as an injection well when injection starts up.

Figure 3-21 Top of Johansen structural depth map. Colder colours (blue) indicate greater depths, while warmer ones (red) indicate lesser depths. The map show depths varying from -3,330 to -1,795 metres below the seabed.



The planned injection point is located at a vertical depth of about 2,660 m below sea level. The planned injection point is located downflank from the Troll structure, in an incline rising to the north. The Cook Formation is deposited above the Johansen Formation and follows the same structural shape as the top of the Johansen Formation, see Figure 3-22.

Figure 3-22 Structural cross-section from north to south through the Viking, Brent and Dunlin groups.



Two different fault patterns can be observed in the area; the main faults on the Troll field with a primarily N-S direction and faults with a NW-SE direction (cf. Figure 3-21). In the injection area (northern part of EL001), the mapped faults have a relatively small throw, meaning that the sandstone reservoirs or the primary seal layer in the Dunlin Group are not fully separated across the faults.

As of September 2019, there is no well data from the Johansen, Cook and Drake formations from exploitation licence EL001. Based on surrounding wells, the reservoir quality for CO_2 injection and storage is presumed to be good, with porosity around 20% and permeability values around 150 mDarcy in the Johansen Formation.

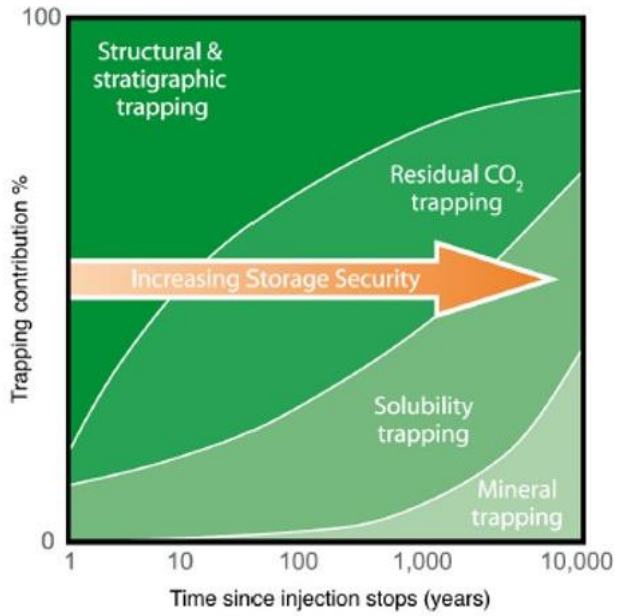
The Drake Formation is expected to be an effective seal with a presumed thickness of about 100 m. Pressure data from surrounding, older exploration and production wells indicate hydrostatic pressure in the Johansen and Cook formations, which indicates that there was no communication with producing fields at the time of sampling (most recent pressure measurement from 2012, 17 years after start-up of the Troll field). The expected pressure is 275.6 bar and expected temperature is 121.1°C for the top of Johansen prognosis of a vertical depth of 2,665 m below the seabed. The Eos well will be drilled in November 2019, and will provide important information to verify reservoir quality, formation pressure and seal quality before Equinor, Shell and Total make an investment decision in spring 2020.

3.14.2 Storage mechanisms for CO_2 in the subsurface

With the expected reservoir pressure and temperature, CO_2 will present with a density of around 500-600 kg/m^3, while water has a density of about 1,000 kg/m^3. The pore volume in the sandstone in the reservoir rock contains formation water. Due to the difference in density, CO_2 will move upward in the sandstone layers until it encounters a seal that stops it.

Both physical and chemical processes have an influence as storage mechanisms for CO_2 in a geological reservoir (IPCC 2005) (/21/). Figure 3-23 shows a schematic of the relative importance of different storage mechanisms over time.

Figure 3-23 Storage mechanisms for CO_2 in the subsurface and how they work over time (IPCC 2005). Increasing storage security over time.



- **Structural & stratigraphic storage**: A high capillary inlet pressure for CO_2 in geological strata (in this instance the Drake Formation) or faults constitute a seal and prevent CO_2 from migrating out of the storage location.
- **Residual storage**: Part of CO_2 trapped permanently in the pores (immobile condition).
- **CO_2 dissolution in formation water**: This mechanism will occur immediately after injection. It is difficult to assess the speed of the process as multiple factors such as pressure, contact surface with formation water, temperature and the salt content of formation water will play a role.
- **Mineralisation**: CO_2 reacts with the minerals in the reservoir rock and chemical components in the formation water and will precipitate as solid minerals.

It is presumed that all the mechanisms described above will contribute to secure storage of CO_2 for this project. By injecting in a sandstone package, the CO_2 will move upward in the structure toward shallower levels due to the difference in density with water. As regards Northern Lights and the Eos well, this means a movement to the north from the injection point. Continuous access to "new" formation water as the CO_2 moves, will help dissolve parts of the injected CO_2 to store it in the water. In the same way, access to new pore volume will help ensure that residual storage will also be an important storage mechanism. It is presumed that CO_2 injected in the Johansen Formation will migrate up to the Cook Formation and then collect under the tight Drake Formation, which is a regional barrier (presumed to be about 100 m thick). Irregularities in the bottom of the Drake Formation can form small, local structural traps where CO_2 is stored. The remaining CO_2 not stored in the ways mentioned above will, after a few decades and over a longer period of time (hundreds of years), move toward the major structural trap under the Drake Formation below the Troll field (cf. Figure 3-22). Over time, mineralisation and precipitation of solid minerals will be of increasing importance.

With the planned injection volumes, it is likely that, after a period of time, from a few hundred to a few thousand years, a significant proportion of the injected CO_2 will be dissolved in formation water or trapped in minerals.

3.14.3 Preliminary presumed storage capacity

The reservoir conditions for injection and storage in the Dunlin Group are considered to be good and the planned well is expected to verify this. The well is located about 10 km south of the licence boundary to the north.

The first development phase in Northern Lights is based on injecting up to 1.5 Mt of CO_2 per year over a period of 25 years, totalling 37.5 Mt. Preliminary studies show that the majority of the injected CO_2 is expected to be stored within exploitation licence EL001 during the injection period and the immediate time period following completion of the injection. A lesser proportion of the injected volume could potentially cross the licence boundary with Troll before 2050, but would then be at a greater depth than the reservoir interval in Troll (5-600 m). This will be assessed in more detail on the basis of results from the well testing in January/February 2020. The aim is to include updated assessments of the storage capacity in the PDO for the project in spring 2020.

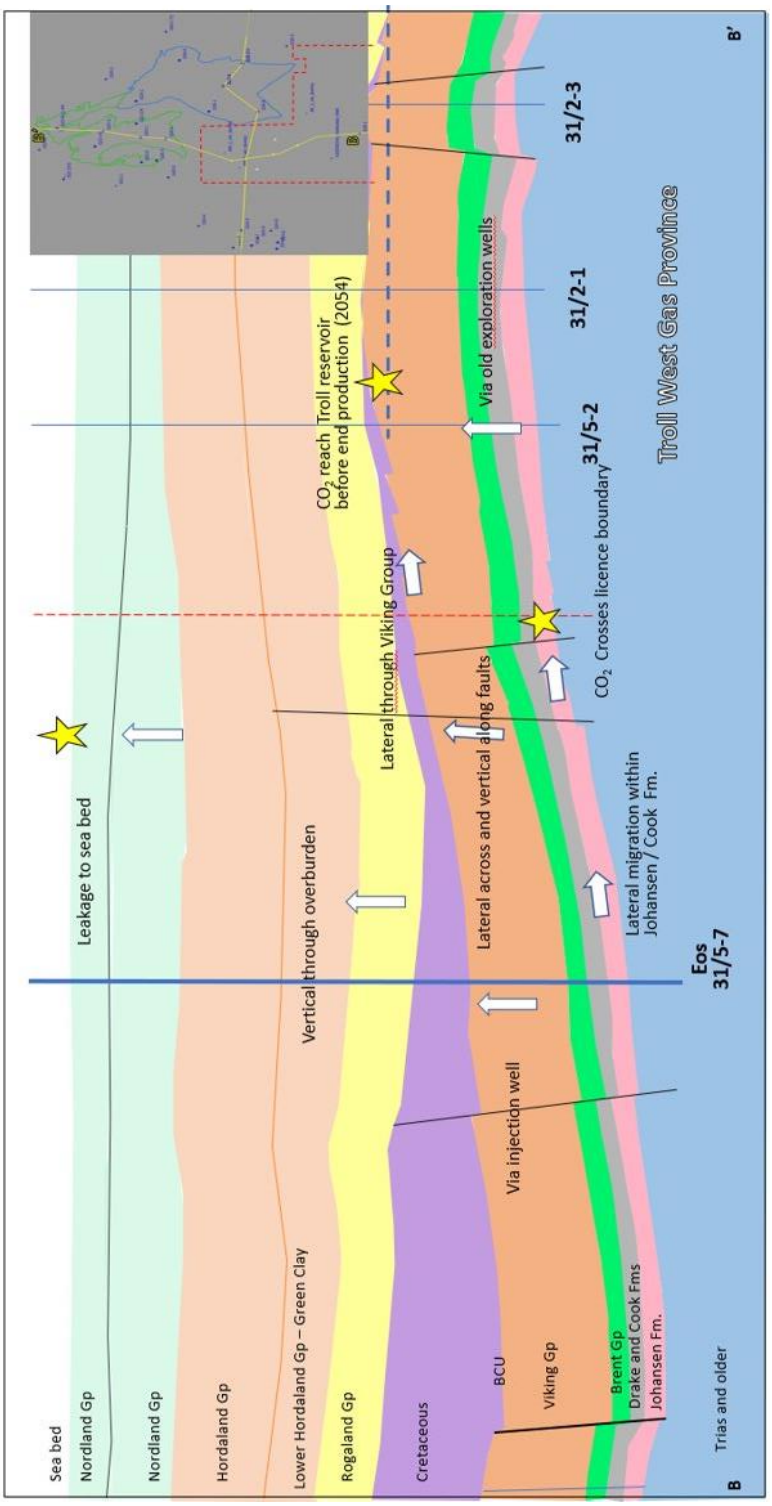
3.14.4 Assessment of leaks and impact on surrounding hydrocarbon reservoirs

Section 1-6 (m) of the CO_2 Storage Regulations defines *leakage* as: *"release of CO_2 from the storage complex"*, and Section 1-6 (k) defines *storage complex* as a: *"storage location and the geological surroundings that may be of significance for the security of the storage"*.

Potential migration and leakage routes for CO_2 are shown in the schematic in Figure 3-24. Should barriers or corrective measures implemented for identified needs potentially fail, the effect of CO_2 moving along these routes could be a leak to the seabed or migration of injected CO_2 to producing intervals in the Troll field before the field is shut down.

Leakage to the seabed could theoretically occur through geological strata and faults or via wells. Leakage via geological strata is considered highly unlikely. In addition to the defined primary and secondary seals, there are multiple tight layers in the 2-km sedimentary layer package above these seals and they will act as barriers for CO_2. Permeable intervals could also store CO_2 that potentially migrates up through the layer package.

Figure 3-24 Schematic figure showing potential migration and leakage routes for CO_2.



Leakage via faults is also considered highly unlikely. Faults in the injection area can be compared with the faults on the Troll field. After being filled with hydrocarbons, the Troll structure has undergone both tectonic and seismic activity (Goldsmith P.J. 2000) (/20/) without breaking the seal. This shows that the faults do not leak vertically. The planned placement of the injection well is 600 m away from faults visible in seismic. Modelling of possible reactivation of faults, as a result of injecting cooled CO_2, shows that this is unlikely.

The completed leakage risk analysis shows that, in general, the risk of leakage to sea is minor, and that the risk of geological weakness zones is less than that of wells. Leakage to the seabed via wells has been considered. Figure 3-24 shows the exploration wells in the Dunlin Group. The condition of the well barriers has been assessed. The well barriers between the Johansen and Sognefjord formations in the area CO_2 could reach over time, are considered to be good. Leakage from the Dunlin Group to shallower levels or to the seabed is therefore considered highly unlikely.

Weak barriers from the Sognefjord Formation and up to the seabed have been identified in two of the old exploration wells: 31/5-2 and 31/2-1. In order for these wells to constitute a risk of leakage to the seabed, CO_2 will have to migrate into the Sognefjord Formation, which is considered highly unlikely. Seismic monitoring of CO_2 could identify whether CO_2 should nevertheless move out of the Dunlin Group, and measures can be implemented to reduce the risk of leakage. Relevant risk-reducing measures will depend on assessments of the results from the seismic monitoring, and at the time of IA consultation, it is too early to predict the outcome of the assessments. For a description of plans to monitor the geological storage location, please see Chapter 10.1.

As shown in Figure 3-21, injected CO_2 will move to the north in the mapped structure. The producing reservoirs in Troll Vest are located 15-20 km north of the injection point and are hundreds of vertical metres shallower than the Johansen and Cook formations, cf. Figure 3-22. The likelihood of injected CO_2 reaching this hydrocarbon zone before the Troll field closes down has been assessed. Simulation of how CO_2 moves over time shows that this is very unlikely.

East of the injection well, the structure slopes toward a deeper area (cf. the blue colour in Figure 3-21), which prevents the migration of CO_2 toward Troll Øst. The same applies correspondingly for migration to the west and the Brage and Oseberg Øst fields. The Johansen Formation thins out and disappears to the west and is not found in the two fields. The Cook Formation has a greater extent and is found here, but due to the structural scenario, injected CO_2 will not migrate to the west toward these fields, but rather follow the same structural scenario as the top of the Johansen Formation, and migrate toward shallower levels to the north.

3.14.5 Assessment of earthquake risk as regards storage integrity

It is known that parts of the coast off Western Norway have seismic activity. Seismic activity in Norway is monitored by the Norwegian National Seismic Network (NNSN) at the University of Bergen. NNSN consists of 34 seismic stations placed in Norway and on the Norwegian Arctic islands. Most of the stations transmit data in real time and the data is processed together to detect and locate earthquakes in Norway and nearby areas. NNSN will be expanded in the near future with permanent seabed stations to monitor oil and gas operations. The expansion comprises stations on Oseberg and Grane (about 40 and 200 km, respectively, from Aurora), and will entail a certain improvement in the detection level for seismic monitoring of the Aurora area compared with the current situation.

Since the Troll field started up in 1995, there have been a limited number of minor earthquakes in the area, primarily related to the Øygarden fault, which is located about 40 km from the Troll/Aurora area. There are no observations to indicate that oil and gas production on the Troll field has been affected by these quakes. As Aurora is deeper than the Troll reservoir, we presume that the storage integrity can be presumed to be equivalent to or better than the integrity of the Troll reservoir. We therefore consider it unlikely that the integrity

of Aurora will be compromised due to natural seismicity. The strategy and plans for monitoring the CO_2 storage in Aurora are described in more detail in Chapter 10.1.

3.15 Health, safety and the environment (HSE) during development and operation

3.15.1 Introduction

Equinor is Gassnova's agreement partner, and will study and plan ship transport and permanent facilities for CO_2 storage, with associated onshore facility, export and injection system. Shell and Total have joined as equal partners in the project, with Equinor as the leader of the study efforts. Regulatory requirements and Equinor's management system with requirements for safety, security, health and sustainability will be used as a basis for work in the project.

Equinor has specific requirements for safety, security, health and sustainability which are incorporated in all commercial activities in the company and in the project's governing documents. Equinor's vision for HSE is **zero harm to people, the environment and assets**. In order to achieve this, multiple HSE activities will be carried out in the concept and engineering phase of the project. This e.g. includes preparing an HSE programme and HSE activity plan, establishing project-specific acceptance criteria, preparing CO_2 dispersion analyses and risk analyses, noise predictions and noise assessments.

Equinor's activity will be planned, designed, built and operated in a manner which ensures that accidents and serious incidents do not occur, in addition to avoiding or limiting negative consequences for people, the environment and society. This applies for all phases in a project. Implementation of mitigating measures is therefore considered continuously in order to avoid, prevent or limit negative impact. It is also a goal to create lasting values and implement measures that can further reinforce the positive ripple effects of a development.

Alternative measures are considered systematically, matured and followed up in all phases of the project development. Regulatory requirements will be minimum requirements. Use of the ALARP principle (as low as reasonably practicable) and comprehensive assessments for all types of environmental aspects is mandated by internal procedures. In addition to using BAT (best available techniques), measures to avoid and reduce negative consequences will be considered according to a prioritised measure hierarchy.

3.15.2 Equinor's management principles and requirements for safety, security, health and sustainability

Equinor's objective is to transform natural resources into energy for people and progress for society. Our goal is to use natural resources efficiently and to prevent harm to the environment such as habitats and the basis to sustain life for people, plants, animals and other organisms. We work actively to minimise emissions of greenhouse gases from our activities. Equinor's vision for safety and security is zero harm. Equinor's strategy – **always safe, high value and low carbon** – positions Equinor to deliver values in a long-term perspective in a low-carbon future.
Equinor uses the terminology safety and sustainability. The term HSSE (health, safety, security and the environment) is included in this terminology.

Safety and security in Equinor comprise the management of health, safety and the working environment, security, emergency preparedness and crisis management. The terms security and safety can be described as [5]:

[5] This is a simplified description and not an exhaustive definition.

- Security of personnel, information and facilities against outside man-made threats (acts with malicious intent).
- Safety for personnel, facilities and third parties against accidents and other incidents with a risk for life and health, and which are caused by natural circumstances, own facilities and activities.

Sustainability comprises a responsible, social, environmentally friendly and financial conduct which facilitates robust and viable activities. Our approach to sustainability includes resource efficiency and safeguarding biodiversity, protecting the local environment, creating local opportunities, human rights and transparency.

It is important for Equinor to maintain an open dialogue with society about the choices made, and to maintain close follow-up of our suppliers to ensure compliance with our goals and ambitions. These obligations are integrated in Equinor's management system.

Equinor, as operator in the development and operations phase, has specific requirements for safety and sustainability which are incorporated in all commercial activity in the company, and thus also in the project's governing documents and in the decision processes for planning, implementation and operations. The project's HSE programme comprises general goals and strategies and defines special project requirements. The programme will be updated in the different planning phases of the project, in the implementation phase and in operations. Equinor's activities in development and operations will be carried out in a manner which prevents accidents and serious incidents, as well as avoiding or limiting negative consequences for people, the environment and society. Alternative measures are considered systematically, matured and followed up in all phases of the project development. The measures are prioritised according to a hierarchy, from measures to avoid consequences, via measures to limit negative impacts, to finally comprising measures to compensate for or replace permanent losses.

Safety and sustainability have also been key in the choice of alternative solutions for Northern Lights. This applies from general choices, to assessment and selection of the best technical solutions according to the ALARP and BAT principles. The following are examples of a few general choices:

- Safe harbour conditions in the placement of the onshore facility
- Pipeline route with the least possible exposure in relation to 3rd parties in the event of a leak
- LNG as fuel for the CO_2 transport ships
- Not plan for local LNG supply at the receiving facility at Naturgassparken (avoid hydrocarbons)
- Supplying onshore power for CO_2 vessels when they are at quay at the receiving facility
- Using variable speed drives (VSDs) on the CO_2 export pumps at the onshore facility to optimise power consumption

Human rights

Human rights are the basic rights and freedoms enjoyed by all people, regardless of gender, age, religion or nationality. Equinor's activities shall be carried out in accordance with the UN's guiding principles for businesses and human rights and shall support the ten principles laid down in the UN's "Global Compact".

Equinor is concerned with safeguarding human rights for its own employees and contracted personnel, suppliers and, not least, in local communities where Equinor is active. Nevertheless, breaches of human rights may occur in work carried out both directly and indirectly for Northern Lights. This is why active efforts are in place to identify any risk of potential violations of human rights. Regular training and skills development take place under this topic to ensure that Equinor makes decisions and implements actions which ensure respect for all internationally recognised human rights, in our activities and for affected parties.

The various suppliers and their sub-suppliers in construction and operation of the project may have different requirements and practices in relation to human rights. In order to avoid potential breaches, Equinor therefore

uses standardised contract provisions as regards respecting human rights. These provisions are included in all new contracts regardless of contract value. Based on risk assessments, Equinor carries out follow-up activities vis-à-vis suppliers to ensure compliance with the contract provisions. This could mean e.g. that the potential risk of human rights violations is discussed in management meetings or that verifications are carried out at the supplier, where personnel working for the supplier are interviewed about their working conditions. Such verification activities are carefully monitored by the Equinor team following up the contract, particularly when nonconformities are identified.

Appeal mechanisms

Based on Equinor's own requirements, the project will have established non-judicial appeal and compensation mechanisms for parties affected by our activities, whether they be individuals or local communities, so that they can express their concerns and/or appeals.

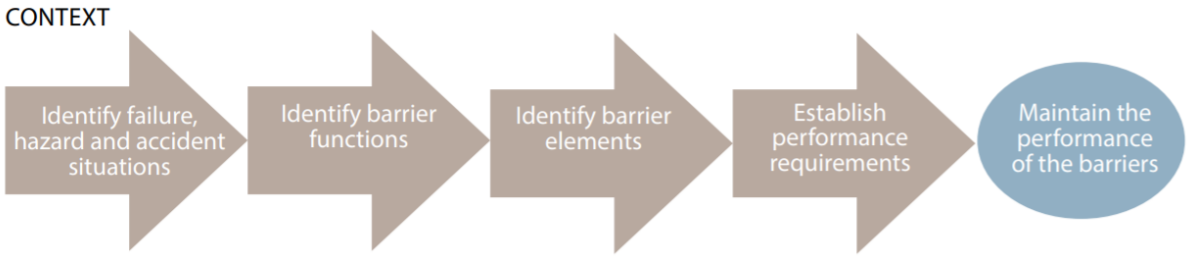
Dialogue has been established with the Norwegian Fishermen's Association, and the aim is to continue the dialogue in the ongoing work to reduce the disadvantages for fisheries as a result of project implementation. Dialogue has also been established with affected neighbouring businesses within and just outside Naturgassparken, and the plan is for this dialogue to continue in the further work on engineering, development and operation. Open information and dialogue meetings will be considered for the development and construction phase, where the public will be invited to voice their experiences, views and concerns. Concrete appeal mechanisms will be considered, adapted to local conditions and needs, in the project's HSE programme.

Barrier management

Barrier management involves systematically and continuously ensuring that the necessary barriers are identified, present and operative to protect against and in the event of errors, hazard and accident situations. These situations will be linked to the risk picture at a specific facility or a plant, or to a concrete area at the installation or plant. According to Section 5 of the Management Regulations, barriers are measures that must, at an early stage, discover errors, hazard and accident situations, reduce the likelihood of these developing, as well as limit harm and disadvantages that may result from such situations.

Barrier management is the coordinated activities carried out to establish and maintain barriers such that they maintain their function at all times, see Figure 3-25 below.

Figure 3-25 Main points in barrier management



Source: PSA

The barrier's function is handled by the barrier elements, which can be technical or non-technical (organisational or operational). Furthermore, barrier management is about ensuring that the various barrier elements have the properties necessary for them to collectively prevent, protect against and limit the scope of harm in incidents with a risk for life and health, harm to the environment and its functions for humans and animals, and incidents that may result in loss of facilities and assets.

Installation and area-specific safety strategies (barrier strategies) and performance requirements will be prepared for the barriers.

3.15.3 Technical safety, risk analyses and consideration for 3rd parties

The risks of handling CO_2 are associated with pressure, thermodynamic conditions that may lead to the formation of dry ice, freezing, clogging and pressure increase beyond design limits in the event of loss of control. If water is present, there is also a risk of corrosion, and one must also take into account the fact that CO_2 is a solvent. In the event of an emission, the consequences will be dispersion of very cold, asphyxiant gas, loss of visibility due to fog formation (water and dry ice). These factors have been used as a basis in the selection of materials, systems to monitor and verify process conditions, ventilation, systems to detect and limit leaks and preparedness systems, as well as equipment and procedures to bring undesirable incidents and potential accidents under control.

CO_2 is not flammable, which means that a risk of fire and explosion at the onshore facility will be minor, and associated with auxiliary systems such as transformer oil, hydraulics systems, lube oil and limited volumes of chemicals in connection with laboratories and maintenance. Safe design of the facility and safety barriers will be based on authority requirements, results from risk analyses, as well as standards for safety in general and CO_2 specific standards in particular.

3.15.3.1 Acceptance criteria for safety

Acceptance criteria have been established for safety for Northern Lights. These include semi-quantitative criteria described in a risk matrix and are in line with Equinor's recommended criteria. Quantitative acceptance criteria have also been established for the onshore facility. The criteria provide requirements for acceptable risk levels for operating personnel, critical safety functions and 3rd parties, and are in line with Equinor's recommended criteria for onshore facilities that handle hydrocarbons. These criteria include the Directorate for Civil Protection's (DSB's) recommended risk acceptance criteria for 3rd parties, cf. Chapter 8.3.

DSB's recommended criteria stipulate that 3 risk contours must be calculated for the facility. The 3 contours represent the annual probability of lethal exposure as 10^{-5}, 10^{-6} and 10^{-7}. The risk contours are the point of departure for establishing so-called special consideration zones in the zoning plan with restrictions on 3rd party establishment and activity, cf. Chapter 8.3 and Table 8-1. The connection between acceptance criteria and acceptable statistically likely recurrence of an incident is shown in Table 3-4.

Table 3-4 Connection between acceptance criteria and acceptable statistical probability of recurrence, number of years.

Acceptance criterion - highest acceptable probability per year	Acceptable statistical probability of recurrence, number of years
1x 10 $^{-1}$	10 years
1x 10 $^{-2}$	100 years
1x 10 $^{-3}$	1000 years
1x 10 $^{-4}$	10,000 years
1x 10 $^{-5}$	100,000 years
1x 10 $^{-6}$	1,000,000 years
1x 10 $^{-7}$	10,000,000 years

This means that statistically lethal exposure is not acceptable at a frequency of more than once every 100,000 years for neighbouring facilities and once every 10 million years for schools, day care facilities, nursing homes, etc.

3.15.3.2 Qualitative risk analyses

Systematic hazard identification and qualitative risk assessments have been carried out for the onshore facility, export pipeline and subsea systems. No hazards have been identified which entail high risk. Actions

and recommended measures from these risk assessments have been documented and are followed up through risk registers and actions in the ongoing engineering work.

Total Risk Analysis (TRA)

A quantitative risk analysis (TRA) has been carried out for the onshore facility including the ESD valve (emergency shutdown valve) against the export pipeline and the part of the pipeline located on land, as well as offloading and presence of the transport ship at quay. The TRA calculates the probability and consequences of leaks from any equipment that could constitute major accident risk for people in and outside the facility, based on e.g. available statistics from relevant databases. Available weather statistics for the area have also been taken into consideration. Planned barriers in relation to leak detection, automatic or manual shutdown, etc. also take this into account where relevant.

Gas dispersion calculations are included as part of the risk analysis and are important results in the calculation of risk contours. They were carried out using the CFD code Kameleon Fireex (KFX). The calculations cover the dispersion of accidental emissions of CO_2, and take into account the direction of the emission, obstacles and the effect of the terrain.
Selected calculations have been carried out of LNG discharges from the transport ship's fuel tanks while at quay, but these do not contribute to the risk contours in the TRA due to a low probability of discharges.

3.15.3.3 Primary findings of the total risk analysis

The risk for operators at the facility is calculated to be acceptable with a good margin. The FAR[6] value for the most exposed group is estimated at 1.4, which is far below the criterion of FAR<25. The average FAR value (including visitors) is calculated at 0.8.

CO_2 is a heavy gas, and the low temperature involved in a potential emission will increase the effect. The gas will follow the terrain toward low-lying areas and could settle in low points in the terrain with poor air replacement. The calculations show that the concentration will be higher, and the extent of hazardous gas concentrations will be greater at elevations of 0.5 m compared with 1.5 m above ground. The protective effect of the high rock cut behind (north of) the onshore facility is considerable, and the gas will not disperse upwind of the cut.

As regards the loss of critical safety functions (main muster area and local control room), the administration building has an acceptable risk level compared with the acceptance criterion. Even if high concentrations from accidental emissions of CO_2 could reach the building (which is situated higher than the storage and process area), the ventilation intake is placed so high (8.5 m above ground level) that it is in a safe height area. The gas concentration at greater elevations is considerably lower than on the ground. The lower parts of the building could be exposed to concentrations higher than IDLH (Immediately Dangerous to Life or Health)-with a frequency higher than 10^{-4} per year. Parts of the administration building are on pilings above the terrain, and the gas will also disperse under the building and out over the sea instead of clinging to the building. Measures to secure the administration building against incursion of CO_2 have been identified in the security strategy, see Chapter 3.15.3.4.

Risk contours have been calculated as a basis for special consideration zones around the onshore facility and the land part of the export pipeline to safeguard considerations for 3rd parties (see Chapter 8.3). The contribution to these risk contours is solely from emission of CO_2, as the other hazard potentials (including LNG discharges from the transport ship's fuel tanks) is so minor that they do not contribute to the contours. Comparing the risk contours (10^{-5}, 10^{-6} and 10^{-7} contours) with the DSB's acceptance criteria (see Table 8-1), yields the result that the risk is acceptable.

[6]FAR = Fatal Accidental Rate, statistically expected number of fatalities per 100 million exposed hours. The FAR value can be calculated based on accident statistics or based on results from risk analyses.

Even though the risk is acceptable with a good margin, a few risk-reducing measures have nevertheless been proposed in the total risk analysis to further reduce the risk. This includes e.g.:

- improved system for overfilling control on storage tanks
- ensuring that the transformers constitute a low fire and explosion hazard
- using a compact flange or all-welded connection downstream of the ESD valve on the export pipeline

The measures will be assessed in more detail in the detailed engineering of the facility according to the ALARP principle.

3.15.3.4 Safety strategy for the onshore facility

Secure design and safety barriers to prevent, detect, verify and limit accident risk at the facility are briefly summarised below:

- The area with storage tanks, process equipment and landfall for the export pipeline is north and northeast of the administration building with a control room and muster area. The prevailing wind direction is south-southeast, (Figure 5-1), so the major CO_2 volumes are primarily downwind of the building.
- The administration building is situated at a higher level in the terrain than the storage and process area.
- Design of equipment in accordance with internationally recognised standards, including standards focusing on the risks represented by CO_2.
- Various systems to detect leaks, including gas detectors. The detectors are expected to be placed at potential leak points, and at low elevations above ground.
- Process monitoring and systems to detect and control process conditions outside the design limits. This is very important due to the risk of dry ice formation if design limits are exceeded.
- Pressure relief systems, including so-called thermal safety valves on volumes that could be shut-in in the event of an ESD situation (emergency shutdown).
- Emergency shutdown including an automatic stop of offloading from ships and preventing the vast volumes in the export pipeline from flowing back.
- Alarm and communications systems for emergency situations.
- Emergency preparedness procedures which also include visitors to the facility. The procedures will be more detailed in the next phase of the project.
- Personal protective equipment, which will include equipment with breathing air easily available, including in the event of escaping from a major gas emission.
- Secure area in the administration building. Placing the air intake at a high elevation, with gas detectors in the intake. Confirmed gas detection in the air intake will close dampers in the ventilation system so that gas cannot flow inside in the event of emissions of CO_2. An airlock in the building's entryway will prevent the incursion of CO_2 through the entrance.

3.15.4 Security-related assessments and measures in more detail

It is a regulatory requirement that the licensee must implement and maintain security measures to contribute toward preventing deliberate attacks on facilities as well as have emergency response plans for such attacks at all times, (Section 10-3 of the CO_2 Storage Regulations). An internal security analysis has been prepared as regards undesirable malicious acts and incidents aimed at operation of the onshore receiving facility. This is confidential in order to avoid exposing the assessments and relevant measures considered for implementation at the facility. The security analysis will be kept up-to-date in relation to changes in the threat scenario.

Security in Equinor

Equinor's security function shall ensure that we can achieve our goals by securing employees, assets and activities. Equinor takes a comprehensive approach to security, which covers three different areas: physical security, information security and personnel security. There is an interaction between these three areas which forms a strong system, where each area protects against weaknesses in the other, and ensures a combination of deterrence and detection (www.equinor.com).

- Physical security

Physical security measures aim to protect our employees, prevent unauthorised persons from entering our facilities, and protect against eavesdropping, sabotage, damage and theft.

- Information security

Information security aims to ensure the confidentiality, integrity and availability of our information. We have a risk-based approach to information security which focuses on employees, processes and technology.

- Personnel security

Personnel security protects against those who exploit legitimate access to our property for unauthorised purposes.

Factors have been identified which could constitute a risk of an undesirable incident occurring. Due to the nature of the matter, the assessments' sensitivity and preventive considerations, these threats will not be described in more detail. The correct authorities will nevertheless receive information about these assessments as needed through suitable channels.

An RVA analysis (risk and vulnerability analysis) has been carried out as part of the zoning plan for the project. This is described in more detail in Chapter 7.5. The following is quoted from the RVA analysis (/22/).

General security

General security comprises physical safety at the facility and risks associated with inadvertent attacks and theft of sensitive information from other nations, activists (particularly environmental activists) and cybercrime. Equinor’s onshore facilities often experience security challenges as regards physical security due to large areas on the properties, shared facilities with considerable traffic and multi-purpose use of areas. On this basis, it is necessary to highlight what is considered to constitute a general security risk for the planned facility at Naturgassparken.

A 2.4-metre security fence with gates will be established around the facility. The security fence will encircle the terminal area, the administration building, as well as the warehouse and workshop building. All buildings will be equipped with card readers for access control. Real-time video surveillance of the facility will be established, with transmission to a manned control room.

Based on the Norwegian Police Security Service's (PST's) unclassified threat assessment for 2019 (/23a/), general security-related assessments can be summarised as follows:

- It is considered very likely that other countries will attempt to acquire sensitive information from major stakeholders in Norway. There is a risk of other countries attempting to recruit employees or consultants and use them as a source and resources to gain access to information.
- Like other major stakeholders, Equinor is considered to be exposed to cybercrime, where international cyber criminals are considered the greatest threat.
- Certain nations are increasing their activities against infrastructure, industrial and automated control systems. Stakeholders associated with the petroleum and energy sector will have to expect that they will be at risk of advanced operations against their computer networks.
- PST considers a terrorist attack in Norway to be likely, but neither Equinor nor its partners Shell and Total fit the target group described by PST.
- In May 2019, PST published its assessment of the national threat level at Moderate ("One or more players could have the ability and willingness to carry out terror in Norway"). Moderate is level 3 on a scale from 1 to 5. "The likelihood of being affected by terrorism in Norway is low."

Port and quay facility - ISPS

The receiving facility is designed and will be built with a special dedicated quay facility to receive CO_2 from custom-built transport ships. The ship cargoes could come from both Norwegian and foreign capture players and port facilities. The Regulations relating to port facility security consider all ships with an international ship security certificate (ISSC) to be in international traffic at all times. This means that all port facilities that receive ships with ISSCs must be ISPS certified pursuant to the Regulations relating to port facility security. The transport ships will be able to load CO_2 at ISPS certified quay facilities at CO_2 capture players (such as Norcem in Brevik).

The quay facility at the receiving facility will therefore be designed and secured to satisfy the requirements for an ISPS port pursuant to the ISPS Code[7]. The Norwegian Coastal Administration[8] is responsible for implementing the ISPS Code and port security regulations (Regulations relating to port security) at all Norwegian ports and port facilities covered by these regulations. Equinor will establish dialogue with the Norwegian Coastal Administration as regards relevant measures for implementation of the regulations. The existing quay facilities at Naturgassparken are ISPS areas today.

3.15.5 Safety zones and fishery activity in more detail

The provision in Section 10-4 (1) of the CO_2 Storage Regulations stipulates that *"There shall be a safety zone around and above facilities unless the Ministry of Labour and Social Affairs decides otherwise. In hazard and accident situations, the Ministry may create provisional emergency and exclusion areas to the extent this is deemed necessary to prevent or limit adverse effects. The extent of zones as mentioned in the first and second sentences shall be determined by the King. This provision does not apply for pipelines and cables."*

As regards general requirements for health, safety and the environment, the CO_2 Storage Regulations refer to the relevant parts of the Framework Regulations. The operator will use the Framework Regulations as a basis for the offshore part of Northern Lights until the PSA's work on a new regulation on security for transport and injection of CO_2 is implemented, see Chapter 1.12.

Section 45 (2) of the Framework Regulations establishes requirements for the design and function of development solutions, which are used as a basis for development solutions for transport and storage of CO_2 on the shelf: *"Subsea facilities and pipeline systems shall also be designed and installed such that the facilities can withstand mechanical damage caused by other activity, and such that they do not damage fishing gear or obstruct fishery activity to an unreasonable extent."*

Unless the Ministry of Labour and Social Affairs (ASD) decides otherwise, a safety zone shall be established around the seabed facility. As a point of departure, fishery activity will not be allowed within the safety zone, but the ASD may decide that fishery activity may nevertheless take place in all or parts of the zone, if this is not deemed to pose a threat to security or prevent storage of CO_2. The subsea facility will be designed and built in line with regulatory requirements, and Equinor sees no need to establish a permanent safety zone with a fishery ban around the facility.

Assessments are under way as regards monitoring the geological storage in the subsurface, cf. Chapter 10.1. One of the measures considered is a small, permanent or semi-permanent system of seismic nodes on the seabed (PRM). If this is implemented, the system must be protected against harm from fishery activity. As regards assessments linked to consequences for fishery activity, please refer to Chapter 6.1.

[7] ISPS - International Ship and Port Facility Security Code.

[8] Norwegian Coastal Administration – port security: https://www.kystverket.no/Maritim-infrastruktur/Havnesikring/Fakta/

3.16 Preparing for operation

3.16.1 Receiving facility

During completion, testing and preparing the receiving facility for operation, the aim is to minimise venting of CO_2 from the facility. No emissions of CO_2 are expected during completion and testing of the facility at all, because the plan is to use nitrogen gas for gas flushing and testing. The plan is to use the first ship cargo of liquid CO_2 for final preparations, filling, cooling and testing of the facility before starting to fill the CO_2 pipeline and furthermore to start up injection in the reservoir. During filling and cooling of the facility, larger volumes of CO_2 gas could form than the transport ship can take in return to balance the volume in the ship tanks, and a need could thus arise to vent this "surplus volume" of CO_2 gas to air. The start-up philosophy and procedures will be developed in more detail in the detailed engineering of the facility.

3.16.2 Pipeline and subsea facility

Once the entire pipeline and other components of the transport system have been installed, the different parts will have to be connected and prepared for operation. The transport system will also have to be connected to the wellhead and injection well. The transport system must be cleaned, pressure-tested, dried and filled with liquid CO_2 before the injection well is started up.

The pipeline will have a total volume of about 6,800 m^3. It will be installed in summer 2022, and the plan is for it to be filled with chemical-treated water from when it is installed until summer 2023, when the connection to the subsea facility is scheduled. Oxygen scavenger will be added to the water that will be inside the pipeline after the pipelaying is complete to prevent algae growth and fouling in the pipeline. A dye will also be added to the water in the pipeline to more easily discover any leaks during pressure-testing of the pipeline. This water will be discharged to sea at the injection well upon start-up.

During preparation of the pipeline, the plan is to use chemicals classified in the green (PLONOR) and yellow (environmentally acceptable) environmental category, see Table 3-5. The colour category refers to the categorisation of chemicals used offshore in Section 63 of the Activities Regulations. Chemical-treated water and nitrogen will be discharged to sea at the injection well at a depth of about 300 m in July/August 2023. When the pipeline is cleaned after being laid in 2022, only small volumes of monoethylene glycol (MEG) will be discharged to sea.

Table 3-5 Chemicals scheduled for use in preparing the CO_2 pipeline.

Chemical	Colour category
OR-13 (oxygen scavenger)	Green
RX-9022 (dye)	Yellow
MEG (antifreeze)	Green
Nitrogen	Green

Multiple cleaning and installation plugs ("pigs") will be used during this operation. Chemical-treated water will be introduced in the pipeline from land at Naturgassparken. Treated water will be discharged at the injection well. The drying operation will be carried out a sufficient number of times for the transport system to be dry enough that there is no risk of corrosive carbonic acid forming when CO_2 is introduced in the system. No discharges to sea are planned in coastal waters. An application will be submitted to the Norwegian Environment Agency for permission to use and discharge the relevant chemicals that will be used during preparation of the system.

3.17 Operating philosophy, operating organisation and base services

3.17.1 Operating philosophy and operating organisation

For a more detailed description of the receiving facility as well as illustrations, please refer to Chapter 3.7.

Operating philosophy

The receiving facility will be a partially manned facility, designed for low basic staffing. There will be a local control room at the facility, so this can be manned and operated locally. The facility will largely be automated, and equipped such that it can also be remotely operated from a central control room based on 24/7 staffing. There are multiple alternative locations for a central control room; both Kollsnes and Sture are being considered in more detail. The Oseberg Field Centre will have a few local monitoring and control functions associated with the control station for the subsea facility on the injection well. The Oseberg Field Centre will operate the well during shutdown and start-up of injection, while the onshore control room will control the injection rate using the choke valve on the well during normal operations. Both the control room on Oseberg and onshore will have continuous monitoring of the well.

Technical and operational support will be supplied from the nearby facilities at Kollsnes and Sture, cf. Figure 3-26. These facilities both have terminal operations and handle hydrocarbon gas in liquid phase. Both facilities are operated by personnel from Equinor. The preferred model for organising a technical/operational/maintenance organisation will be assessed in more detail in late autumn 2019.

Operational support could include, but is not limited to the following:

- Quay, vessel services and offloading operations
- Technical/maintenance
- Laboratory personnel
- Waste management
- Control room expertise
- HSE and emergency work

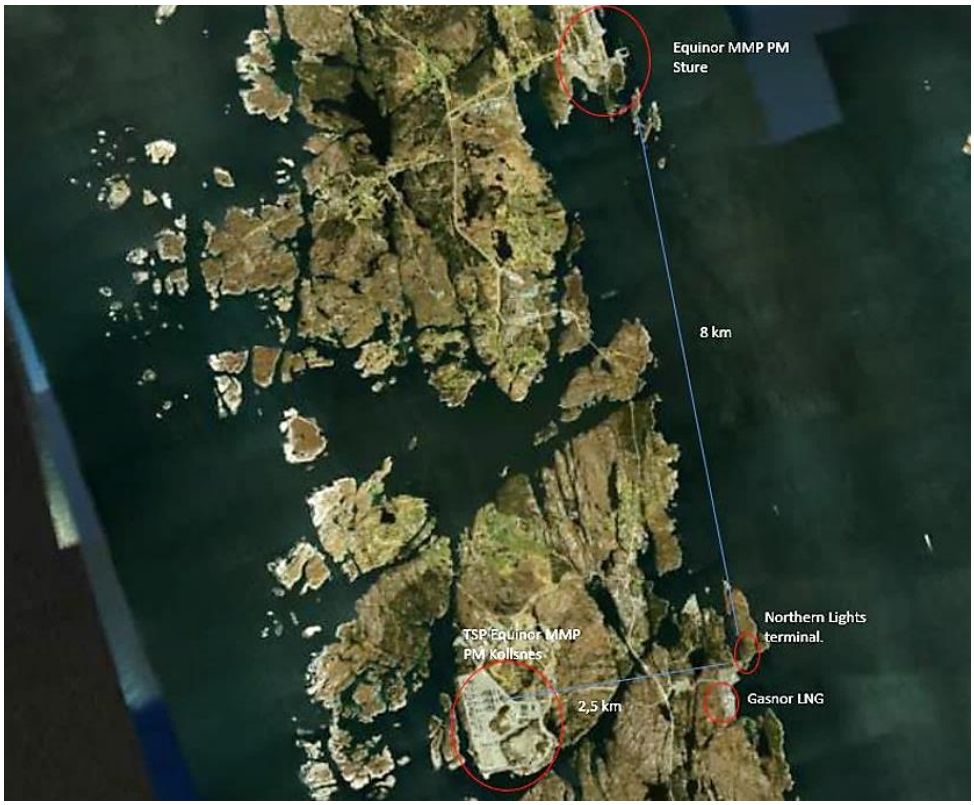
Operating organisation

A preliminary model has been prepared for an operating organisation for Northern Lights. The preliminary organisation will be updated leading up to the investment decision and submission of the PDO and PIO in spring 2020.

As accounted for in Chapter 3.1, an application will most likely be submitted to transfer exploitation licence EL001 from Equinor to a newly established joint venture company as licensee and operator. The joint venture company will then be listed as the owner of the Northern Lights facilities. The company will most likely purchase technical operations and support functions from Equinor as technical service provider, in a manner similar to Gassco's gas terminal at Kollsnes (which is owned by Gassled, with Gassco as operator, but the facility is operated by Equinor as technical service provider).

Within Equinor, the NES (New Energy Solutions) unit will have "organisational ownership" of the Northern Lights facilities during operation. Personnel from NES will be responsible for the administrative operations management of the facilities, with technical operations and maintenance personnel from the organisational unit that operates other onshore facilities (MMP PM). This unit will also be responsible for technical integrity at the facilities on land and on the seabed, while the operating organisation on the Norwegian shelf (DPN) will be responsible for the well(s).

Figure 3-26 Location of nearby facilities – Kollsnes (gas terminal), Sture (oil terminal) and Gasnor LNG.



Staffing

- During start-up period:

Management and administration (NES): 3-4 positions
Staffing during start-up, based on 24/7: 6-8 positions
Total staffing during start-up phase: 9-12 positions

- **During stable operations:**

Management and administration (NES): 3-4 positions
Technical operations personnel from service provider (24/7): 4-6 positions
Anticipated total staffing in operations phase: 7-10 positions

There could also be a need for some support from Equinor's central control room, as well as central professional communities within the disciplines of reservoir and subsurface, drilling and well and subsea facility.

The operating organisation will safeguard a number of administrative and technical functions, such as;

- Management and administration, incl. HSE
- Planning, logistics and port functions
- Terminal operations, monitoring the receiving facility, pipeline, well and injection
- Operators, HSE, laboratory work, maintenance, etc.
- Service from Equinor's Norwegian operating organisation for pipelines and wells as needed

The control room operations could include, but are not limited to monitoring and controlling the following;

- Quay and mooring operations

- Offloading operations
- Operating the receiving facility
- Pipeline
- Subsea facility
- Well control (via Oseberg Field Centre)
- Reservoir

Communication
The receiving facility will have to communicate with ships, the central control room and operators on the quay and out in the facility. Normal communication equipment at the facility will be: Maritime VHF, UHF, telephone and mobile phone, as well as fibre cable.

3.17.2 Base services

During the development phase, there will be a certain need for storage and base services from an onshore supply base. There are currently supply bases at CCB Ågotnes in Fjell municipality (Fjell will be incorporated into the new Øygarden municipality in January 2020) and CCB Mongstad base in Lindås municipality (will be incorporated into the new Alver municipality in January 2020). CCB Kollsnes can also provide quay and storage services at Naturgassparken for use during the construction phase in cooperation with CCB Ågotnes. The need for base services during development and operation is expected to be very moderate compared with ordinary oil and gas activity.

- Development phase

During the development phase, the plan is to use the existing ISPS quay at Naturgassparken as a construction quay, to offload larger machinery and plant components directly over the quay. This will help reduce the need for transport on public roads. The drilling and well operations will require a few base and supply services, most likely from CCB Ågotnes. The need for base services associated with marine operations during the installation and survey campaigns will presumably be very moderate.

If a coiling vessel is chosen as the installation method for the pipeline, the laying vessel will have to make more trips to shore to coil up the welded pipeline. The different installation contractors have their own spool bases, some in Norway and some abroad. Depending on which pipelaying contractor is chosen, the laying vessel will then go to a Norwegian or foreign base to coil up new lengths of pipeline pre-welded on land.

- Operations phase

The need for base services during the operations phase is considered to be minor. The need is presumed to be primarily associated with marine operations during inspection, service and maintenance of the well, subsea facility and pipeline. The purchase and delivery of chemicals to the Northern Lights subsea facility will be part of the continuous operation of the Oseberg Field Centre. This will account for a small part of the base and supply logistics for Oseberg, which is presumed to not be affected to any particular extent.

3.18 Metering philosophy

The metering philosophy is based on the project's understanding of and assumptions regarding the regulatory and commercial requirements set for metering and metering accuracy. There will be a dialogue with regulatory authorities to ensure that the design of the metering philosophy is in accordance with the relevant regulatory framework and requirements.

The following system is planned as regards metering of received and injected CO_2:

- Volumes (or mass) will be measured by the capture players while CO_2 is loaded on the ship for transport.
- Level gauging in ship tanks to measure CO_2 volumes offloaded at Naturgassparken.
- Online analyses of O_2, H_2O, H_2S and sampling of received CO_2 will be undertaken at the intake to Naturgassparken, in part to protect material quality in the facilities and in part to document the composition of the injected volumes stored.
- Volumes vented to air and fugitive emissions will be estimated, or based on metering the tank volume where this is relevant.
- A flow meter will be installed on the subsea facility to measure volume and rate at the well. Subsequent injection wells will also be equipped with such meters to measure both volumes, as well as contribute to monitoring and control of the reservoir.

In addition to the volume metering to be implemented at start-up, space has been allocated at the receiving facility for two additional future metering stations that can be installed if this is considered necessary.

- Space at the inlet to Naturgassparken has been allocated for a "fiscal" metering system to measure commercial 3rd party volumes beyond the volumes from Norcem and Fortum Oslo Varme.
- Space at the outlet from Naturgassparken has been allocated to establish a metering station to measure exported volumes from the facility for injection.

The need for these extra metering points and necessary technical requirements in connection with this will be studied in more detail and confirmed in the ongoing front-end engineering. Technology qualification is considered necessary for both these metering points.

3.19 Cost estimate for investment and operation

The overall preliminary investment costs for development of the Northern Lights CO_2 storage in Aurora and construction of the onshore receiving facility, as well as necessary infrastructure includes the following main elements:

- Engineering and project management
- Drilling and well operations for verification well, which will subsequently be converted to an injection well
- Purchase and development of land area at Naturgassparken
- Purchase and installation of plants, equipment and components for the onshore receiving facility
- Steel purchase and fabrication of pipeline, manifolds, spools and valves
- Subsea facility with associated umbilicals and control system for well control
- Necessary new plants and modifications on the Oseberg A installation
- Marine operations incl. pipe and cable installation, ploughing/jetting, rock installation and connections
- Projected cessation costs
- Insurance, amount to hedge against market adjustments and reserve

The cost estimates are based on Development Phase 1, with a receiving and injection capacity of 1.5 million tonnes of CO_2 per year for 25 years, a total of 37.5 million tonnes of CO_2.

In late autumn 2018, the investment estimate for the transport and storage project totalled about NOK 6.4 billion (2018 prices), based on technical concept studies and with an uncertainty of +/- 30%, and this was submitted to Gassnova as principal. The concept estimate included ship costs, and was based on umbilicals to Fedje, which was later changed to Oseberg as host installation. With a point of departure of NOK 6.4 billion, the estimate was adjusted in relation to the scope of the project to be covered by the IA, PDO and PIO. Ship costs have been deducted, the concept change with umbilicals to Oseberg has been taken into account, front-end engineering costs (FEED) and costs for removing the subsea facility and onshore receiving facility once

operations are completed are included. The adjusted concept estimate totals NOK 6.35 billion (2018) with an uncertainty of +/- 30%.

Subsequent updates of the cost estimates and contract signings could lead to changes in the estimates, and the uncertainty in the estimates will be reduced. For more information about investments and costs, please see Chapter 7.17. Updated unbiased investment and operating expenses used as a basis for the licensee's investment decision will be presented to the authorities through submission of the PDO and PIO in April 2020.

3.20 Financial assessments

As of today, there is no functioning market for the purchase and sale of CO_2 for receiving and permanent storage. This means that there is also a lack of a self-funding whole value chain with functional market mechanisms for permanent storage of 3rd party CO_2. Mechanisms have therefore not been established to ensure commercial profitability for a full-scale CCS value chain where multiple independent financial players are involved. This means that there is a need for partial state funding of the establishment and operation of such a facility in Norway. This must take place within the confines of the EEA Agreement and the Public Procurement Act. Such partial state funding will also be subject to monitoring and verification by the EFTA Court.

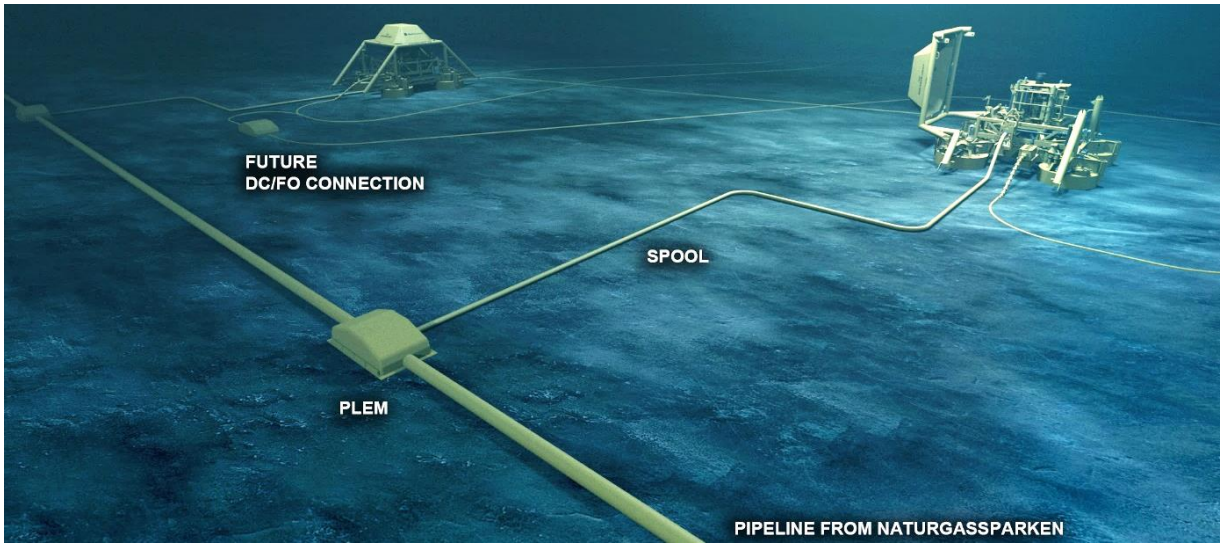
The financial framework conditions for investment in and operation of a facility for receiving and permanent storage of CO_2 will be clarified in autumn 2019 (during consultation of the present IA) between the Norwegian State, represented by the MPE, and Equinor with partners. There is thus no basis for or ability to provide preliminary financial assessments at the time of consultation for the present impact assessment. It is presumed that the financial framework conditions for development, construction and operation of a CO_2 storage solution with infrastructure will be finally clarified before Equinor and its partners Shell and Total make their conditional investment decisions in spring 2020. This will form the basis for submitting the PDO and PIO in April 2020.

3.21 Potential future Phase 2 with expanded receiving and injection capacity

3.21.1 Wells and subsea facility

In Development Phase 1, the plan is to develop the geological CO_2 storage with the aid of a single-well satellite structure. If additional injection wells are needed, the most suitable well structures will have to be installed. The power, signal and control system established in the first Development Phase is designed to allow for easy expansion up to five injection wells. The satellites will be connected with power cables and umbilicals, and individual wells can be monitored and controlled from land, as well as from the Oseberg Field Centre (cf. Chapter 3.17.1). Figure 3-27 illustrates the principle behind such an expanded system.

Figure 3-27 Illustration of a potential future expansion of the subsea facility, with connection of an extra single-well satellite with spool and power and hydraulics cables.



3.21.2 Pipeline

The Phase 1 pipeline (12¾") will be designed to transport up to 5 million tonnes of CO_2 per year, equivalent to Phase 2. Transport capacity beyond 5 Mt of CO_2 per year requires installation of a new pipeline. The route selection for the pipeline for Phase 1 also took into account the opportunity of laying a potential extra future pipeline (up to 20") along approximately the same route. With additional injection wells, "intra-field" pipelines will have to be installed between the CO_2 pipeline from land and the new satellite structures, so that CO_2 can be injected in each individual well independent of other wells. This will take place by connecting to the PLEM unit installed at the end of the pipeline in Phase 1, where new valve arrangements and branching opportunities will be established on the system as needed, cf. Figure 3-27 for illustration. The individual satellite structures will be connected to the pipe system using pre-fabricated spools, in the same manner as for the first well.

3.21.3 Receiving facility at Naturgassparken

The following will briefly describe necessary measures associated with the receiving facility in order to expand the receiving and injection capacity in a potential Development Phase 2.

Zoning plan. The zoning plan for Development Phase 1 covers a sufficient area for a subsequent Development Phase 2 as well. However, a zoning change will be needed to incorporate the up-to-date footprint for the expanded facility and road structure, a future Quay 2 and revised special consideration zones as a result of updated risk analyses based on a changed footprint and changed CO_2 volumes at the facility.

Quay 2. A Quay 2 will have to be built northeast of Quay 1 to increase the capacity for calls from CO_2 transport ships.

New tanks. Extra tanks will most likely have to be installed to expand intermediate storage capacity at the receiving facility. The tanks for Phase 1 will be adapted to this in that necessary valve and connection arrangements have been installed for "seamless" connection of new tanks.

New export pumps. New export pumps will have to be installed in order to increase the injection pressure and injection rate, and thus utilise the already existing (5 Mt of CO_2 per year) transport capacity in the pipeline system.

Extra auxiliary systems. Extra auxiliary and control systems to handle increased CO_2 volumes at the facility, including a system for necessary heating of CO_2. It will be natural to consider using heat exchange against seawater as one of multiple alternative solutions.

The blasted and developed land area for Phase 1 will include a sufficiently large sub-area for a future Phase 2 to maintain the necessary safe distance to additional blasting of Phase 2 land area. This means that receiving and operation at the receiving facility in Phase 1 can be maintained during the work on further blasting, land development, construction, installation and connection of Phase 2 of the facility.

3.22 Cessation of CO_2 storage activity

Before the licence to exploit the subsea reservoir for CO_2 storage and special permit for construction and operation of facilities expire, the licensee shall present a cessation plan to the MPE for approval (Section 7-1 of the CO_2 Storage Regulations). The cessation plan shall comprise proposals for continued storage of CO_2 or shutdown of the storage location and disposal of facilities, and shall contain a disposal part and an IA.

Once injection activity is complete and the storage is shut down, the wells will be plugged and finally abandoned, and facilities on the seabed will be removed in accordance with OSPAR Decision 98/3. Pipelines and cables will be handled and disposed of according to the prevailing relevant regulations at the time in question. The guidelines in Report No. 47 (1999–2000) to the Storting - Disposal of disused pipelines and cables, which the Storting endorsed, apply for pipes and cables. As a general rule, pipes and cables can be abandoned when they are not or cannot be a disadvantage or constitute a risk for demersal fishery, assessed on the basis of the cost of burial, covering or removal.

The decommissioning of seabed installations, the pipeline and cables is many years in the future (planned operating period of 25 years), and well before the activities are ceased, a plan will be prepared which covers clean-up and waste management, including an impact assessment of the decommissioning activities. Handling of the pipelines upon cessation of the field will be based on national policy at the time in question. In line with current practice, it is presumed in the planning of the development that the pipeline will be abandoned after cleaning as well as securing the ends through burial or covering with rock/gravel to avoid future risks to fishery activity.

The cessation plan shall also describe plans for monitoring the reservoir and CO_2 storage once injection is completed. It must be possible to verify that the injected CO_2 volumes behave as expected, so that it can be documented that there is no leakage from the storage to the seabed and surroundings. According to the provisions in Section 35-14 of the Pollution Control Regulations and Section 5-8 of the CO_2 Storage Regulations, the Norwegian State, represented by the MPE, shall, upon application from the operator, take over long-term responsibility for monitoring and corrective measures for the permanent CO_2 storage pursuant to these regulations, given that the conditions for this have been satisfied. For a description of the preliminary strategy for monitoring the CO_2 storage, please refer to Chapter 10. The PDO will contain a more detailed description of the strategy and plan for monitoring the storage both during injection, but also once injection is complete.

4 Summary of consultation comments and how they have been taken into account

Three separate public consultation hearings have been implemented as a basis for the study programme/planning programme and framework for this impact assessment.

- Proposed study programme for impact assessment (consultation period 5 February – 9 April 2018) (/23/)
- Proposed planning programme for detailed zoning plan with impact assessment (consultation period 9 February – 23 March 2018) (/24/)
- Supplement to proposed study programme for impact assessment (consultation period 17 July – 11 September 2018) (/25/)

The planning programme for the detailed zoning plan with impact assessment within the scope of the Planning and Building Act was adopted by Øygarden municipality on 13 June and Fedje municipality on 19 June 2018. Table 4-3 indicates where the topics in the approved planning programme are addressed in this IA. .

4.1 Thematical grouping of comments

The consultation comments are grouped and addressed according to the following thematical breakdown:

A. General remarks regarding the IA programme and the IA process, incl. zoning plan process
B. Environmental assets and knowledge about these
C. Cultural artefacts
D. Climate, emissions to air, power solution and BAT (best available techniques)
E. Consequences for marine environment – use of chemicals, discharges to sea and BAT, physical interventions, subsea noise, etc.
F. Safety (incl. security), environmental risk and storage security
G. Fisheries and other business interests
H. Framework conditions and use of policy instruments
I. Social effects, incl. drinking water
J. Infrastructure (aviation, road transport, coastal traffic, electricity and water supply)
K. Landscape and outdoor recreation

An overview of which chapters in this IA deal with which study topics is shown in Table 4-1.

Table 4-1 Overview of where submission statements are addressed in the impact assessment.

Topic	Topic description	Impact assessment, Chapter reference
A	General comments regarding the IA programme and the IA process, incl. zoning plan process	1
B	Environmental assets and knowledge about these	5.4, 5.5
C	Cultural artefacts and knowledge about these	5.7
D	Climate, emissions to air, power solution and BAT (best available techniques)	5.8, 5.10, 7.9
E	Consequences for marine environment, use of chemicals, discharges to sea and BAT, physical interventions, subsea noise, etc.	5.4, 5.5, 5.9
F	Safety (incl. security), environmental risk and storage security	3.14, 3.15, 7.5, 7.6, 10.2
G	Fisheries and other business interests	6
H	Framework conditions and use of policy instruments	Not relevant in IA
I	Social effects, incl. drinking water	7
J	Infrastructure (aviation, road transport, coastal traffic, electricity and water supply)	7.4, 7.9
K	Landscape and outdoor recreation	5.6

4.2 Overview of consultation comments

Table 4-2 shows an overview of which study topics have been addressed by each specific consultation body. The table summarises and distributes the consultation input by study topic in the following three public consultation hearings:

- Proposed study programme for impact assessment (marked X in the table)
- Supplement to proposed study programme for impact assessment (marked Y in the table)
- Proposed planning programme for detailed zoning plan with impact assessment (marked Z in the table)

Table 4-2 Overview of consultation comments. X: Statement re Proposed study programme, Y: Statement re Supplement to proposed study programme, Z: IA-relevant statement re planning programme for detailed zoning plan with IA.

CONSULTATION BODY	COMMENTS RE SUMMARY TOPICS **A** General re process, IA study programme, IA and zoning plan **B** State of the environment **C** Cultural artefacts, **D** Climate, emissions to air and BAT **E** Consequences for marine environment – Discharges to sea and BAT, **F** Safety-security/ Environmental risk/Storage security **G** Fishery and other business interests **H** Framework conditions and use of policy instruments **I** Social effects, incl. drinking water **J** Infrastructure **K** Landscape and outdoor recreation												
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**		No comments
National and regional authorities													
Norwegian Labour Inspection Authority													X
Port of Bergen										XY			
Directorate for Cultural Heritage			X										
Ministry of Transport and Communications					Y	Y				X			
Norwegian Public Roads Administration	X									X			Y
Norwegian Coastal Administration, headquarters					Y	Y							
Hordaland County Authority	X		Y				Y	X	X	Y	Y		
Directorate of Fisheries						X	XY						
Norwegian Directorate for Civil Protection						X							
Norwegian Environment Agency				X	X	X							
Bergen Maritime Museum			X										
Ministry of Justice and Public Security						XY							
Norwegian Water Resources and Energy Directorate (NVE)										X			
Ministry of Labour and Social Affairs (ASD) and the Petroleum Safety Authority (PSA)						Y							X
Ministry of Foreign Affairs													X Y
County Governor in Hordaland	X	X			X	X			X				Y
Local authorities													
-													
Business, employer and employee organisations													
Norwegian United Federation of Trade Unions (consultation via LO)													X Y
Trade unions in Statoil (joint statement from Tekna, Industri Energi, SAFE, NITO, Lederne)	X												
Norwegian Fishermen's Association							Y						

CONSULTATION BODY	COMMENTS RE SUMMARY TOPICS **A** General re process, IA study programme, IA and zoning plan **B** State of the environment **C** Cultural artefacts, **D** Climate, emissions to air and BAT **E** Consequences for marine environment – Discharges to sea and BAT, **F** Safety-security/ Environmental risk/Storage security **G** Fishery and other business interests **H** Framework conditions and use of policy instruments **I** Social effects, incl. drinking water **J** Infrastructure **K** Landscape and outdoor recreation												
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**		No comments
Norwegian Confederation of Trade Unions (LO)	X			X				X	X				Y
Norwegian Society of Chartered Technical and Scientific Professionals (TEKNA)	X							X					
Environmental, nature and public interest organisations													
Zero	X			X				X		X	X		
Others													
-													
Study programme for IA - No. of comments within summary topics	7	1	3	3	4	9	4	4	3	7	2		9
Consultation bodies that have delivered submissions to the hearing of the planning programme for the detailed zoning plan with IA (PBA), which is also relevant for the IA study programme													
Bergen Klatreklubb (climbing club)											Z		
Fiskarlaget Vest (fishermen's association)							Z						
Hordaland County Authority	Z		Z	Z	Z		Z			Z	Z		
Invest in Bergen									Z				
Coastal Administration West					Z	Z				Z			
Norwegian Food Safety Authority, South and West Regions					Z				Z				
Sanden Velforening (residents' association)						Z	Z			Z			
Sulo Krins Ve og Vel	Z					Z	Z						
Trond Gunnar Nilsen		Z		Z		Z							
Planning programme for zoning (PBA) – no. of comments within summary topics for IA	2	1	1	2	3	4	4	0	2	3	2		0
Total no. of statements summarised for study programme for IA, distribution by summary topic	**9**	**2**	**4**	**5**	**7**	**13**	**8**	**4**	**5**	**10**	**4**		**9**

In a letter dated 13 August 2019, the Ministry of Petroleum and Energy stipulated the study programme for the IA for Northern Lights. A copy of the letter with stipulated programme is enclosed as Appendix D.

4.3 Approved planning programme for zoning plan with impact assessment – handling of study topics for IA

TableTable 4-3 states where the topics in the approved planning programme for the zoning plan are addressed in this impact assessment.

Table 4-3 Study topics in approved planning programme for zoning plan with IA, and how this is handled in the existing impact assessment.

Study topic	Basic material / Known knowledge	Assessment method	Addressed in IA, chapter reference
Fisheries	Known knowledge from earlier nearby pipeline project. Databases (Yggdrasil) with information on activity and registered assets/occurrences	Collection of basic data, i.e. supplemental registration. Assessment of value and potential scope of impact.	6.1 9.1
Aquaculture (fish farming)	Known knowledge from earlier nearby pipeline project. Databases (Yggdrasil) with information on activity and registered assets/occurrences.	Collection of basic data, i.e. supplemental registration. Assessment of value and potential scope of impact.	6.2 9.1
Marine biological diversity	Known knowledge from earlier nearby pipeline project. Databases (Environmental status) with information on registered assets/ occurrences.	Collection of basic data, i.e. supplemental registration. Assessment of value and potential scope of impact.	5.4 5.5 9.1 9.3
Landscape and outdoor recreation	Known knowledge from earlier nearby pipeline project. Databases with information. Core agricultural area. Landscape analyses carried out.	Collection of basic data, i.e. supplemental registration. Inspection. Use of 3D model and photomontages to assess distant effect. Assessment of value and potential scope of impact.	5.6 9.1
Natural environment and biological diversity on land	Known knowledge from earlier in the nearby area. Databases with collection of basic data, i.e. supplemental registration. Field registration. Area will be inspected. Detailed zoning plan for receiving, intermediate storage and export facility for information on registered assets/occurrences.	Collection of basic data, i.e. supplemental registration. Field registration. Area will be assessed according to the principles laid out in Sections 8 through 12 of the Nature Diversity Act.	5.4.1 9.1 9.3
Cultural environment and cultural artefacts on land – field archaeological for surveys (Hordaland County Authority)	Registration work performed previously and good knowledge of cultural artefacts in the area. Databases Directorate for Cultural Heritage - Askeladden.	Collection of basic data, potential supplemental archaeological registration for areas not previously investigated. Assessment of value and potential scope of impact.	5.7 9.1
Socio-economic and social consequences, also in relation to settlement and business development	Earlier registrations. Cost profile for the project. Analyses from similar facilities.	Collection of basic data, i.e. supplemental registration. Assessment of value and potential scope of impact.	7 9.1

Study topic	Basic material / Known knowledge	Assessment method	Addressed in IA, chapter reference
ROS analysis • Rising sea level and extreme weather • Traffic safety • CO_2-leakage and diffusion • Chemical leaks • Fire and explosion hazard • Noise load for third parties • General safety	Report: "Sea level change for Norway Past and Present Observations and Projections to 2100". Available traffic data. Municipal ROS analyses County ROS Analyses from similar facilities.	Identify which incidents may occur as well as size and scope. The analysis shall also illustrate how various measures can reduce risk and/or vulnerability. Dispersion analysis and simulation based e.g. on terrain formations and design of facilities. Climate impact with potential uncertainty.	7.5 9.1
Seismic activity - CO_2-pipeline	Registration of seismic activity (NNSN).	Study of seismic activity. Seismic data included in analysis of data basis for design the pipeline.	5.3 9.1
Marine archaeological assessments (Bergen Maritime Museum)	Knowledge of earlier registrations along pipeline routes	Collection of basic data, i.e. supplemental registration. Assessment of value and potential scope of impact.	5.7 9.1
Climate	Discussion of the effects of the project on climate	Assessment of value and possible scope.	5.8 9.1

4.4 Participation in and influence on key choices in the project

The open processes with public meetings, hearings and the opportunity to provide input to the project at various points in time have enabled a broad-based opportunity to participate from stakeholders and citizens who may be affected in various ways. This participation has, in many ways, contributed to influence the basis for important choices in the project in relation to safeguarding local considerations, as well as the outcome of these choices. The most key choices can be summarised in the following points:

- Pipeline route over land. A decision was made in May 2018 to abandon the alternative involving a pipeline over land from Naturgassparken westward, to the north and south of the Kollsnes gas terminal, respectively. Safeguarding considerations for neighbours, catchment areas for drinking water, important natural assets with the occurrence of Eurasian eagle-owls were among the factors taken into consideration in addition to technical and financial aspects of the alternative.

- Umbilical to Fedje. A decision was made in September 2018 to abandon the proposed solution involving routing the power cable and umbilical to Fedje, with establishment of an associated control station on land in Rongsvågen cove. Safeguarding considerations for significant local opposition among both the population and the municipality as planning authority were among the factors that were emphasised. Also, a technically feasible solution using the Oseberg field centre as offshore host installation was identified. The selected solution also entailed reduced costs compared with landing.

- Pipeline route in the sea south of Sulo. A decision was made in October 2018 to abandon the route alternative south of Sulo (through the Sulesundet strait), and to continue work to engineer and optimise a route for the pipeline south and southwest of Fedje (south of Fedje). Safeguarding considerations related to use of the recreational buildings on land near Sulesundet and consideration for local fishing areas were among the factors that were emphasised, in addition to technical challenges associated with the alternative.

5 Environmental impact assessment

5.1 Method and supporting documentation

Several supporting expert reports have been prepared as a basis for this impact assessment, as well as various technical and project-related reports. Key supporting reports include:

- Kaurin, M., Braathen M. and Eilertsen, M. 2018: Northern Lights - Konsekvensvurdering med hensyn på fiskeri, havbruk og marint biologisk mangfold. (*Impact assessment relating to fishery activities, aquaculture and marine biodiversity*), Technical report Rambøll. /6/
- Hettervik, G.K., Oftedal A. and Hetlelid A., 2018: Northern Lights - Konsekvensvurdering med hensyn på landskap, friluftsliv, kulturminner og kulturmiljø. (*Impact assessment relating to landscape, recreational activities, cultural heritage sites and cultural environment*), Technical report Rambøll. /7/
- Hansen, C.B., Hartveit, K.J. and Winberg J., 2018: Northern Lights - Konsekvensvurdering med hensyn på samfunnsmessige forhold. (*Impact assessment concerning social considerations*), Technical report Rambøll. /8/
- Eilertsen, L. 2018: Northern Lights – Konsekvensvurdering med hensyn på naturmiljø og biologisk mangfold på land. (*Impact assessment relating to the natural environment biodiversity on land*), Technical report, Rådgivende Biologer, rapport 2758. 2018. /9/
- Oddane, B. H. 2019: Kartlegging av hubro på Ljøsøyna i Øygarden kommune - Registrering av territoriehevdende hanner 2019. (*Survey of Eurasian eagle-owls in Ljøsøyna in Øygarden municipality – Registration of territorial males*), Ecofact report. /26/
- Braathen M. and Sømme, H.O. 2019: Northern Lights – Konsekvensvurdering med hensyn på fiskeri og marint biologisk mangfold vest for grunnlinjen. (*Impact assessment relating to fishery activities and marine biodiversity west of the Baseline*), /27/
- Hartveit, K.J., Andersen, J.S. and Rosenberg Nielsen J., 2019: Northern Lights - Vurdering av samfunnsøkonomiske forhold (*Assessment of socio-economic conditions*). Technical report Rambøll. /28/
- DNV GL 2019: Miljørisiko for EL001, Northern Lights, mottak og permanent lagring av CO_2 (EL001 *Environmental risk, Northern Lights, receiving and permanent storage of CO_2*), /29/

To prepare their supporting reports, the consultancy firms Rambøll and Rådgivende Biologer used the following manuals from the former Norwegian Directorate for Nature Management (now the Norwegian Environment Agency).

- DN Manual 11 - Game Surveys (2000)
- DN Manual 13, second edition, Surveying Nature Types - Valuation of Biodiversity (2007)

In their supporting reports to this impact assessment, Rambøll and Rådgivende Biologer applied the method description for non-monetised impact as described in more detail in the Norwegian Roads Administration Handbook V712 Impact Assessments 2018 (/30/). The method can be briefly summarised as follows:

- **Value assessment:** An assessment of the importance of an area in a national perspective
- **Assessment of the impact of a project:** An assessment of the impact a defined project has on the same area. The impact is assessed in relation to the reference situation, which in this case is the current situation.
- **Assessment of consequences**: Consequences are established by comparing value and impact. Consequence is an assessment of whether a defined project will entail improvement or deterioration in an area.

After identification and description of the current conditions relating to various topics in the assessment area, they are assessed according to their value. The areas in question are assigned a value based on defined value criteria for the various topics. The value is determined by applying a five-point scale ranging from negligible to very high value (Negligible – Some Value – Medium Value – High Value – Very High Value).

When evaluating the impact, an assessment will be made of the project's impact on the reference situation, and whether the condition will deteriorate or improve, based on the information from the value assessment. A new project will have an impact on an area through direct intervention or proximity to the project area. The location/position of the project will be assessed, as well as its dimension/scale and design. The impact assessment will focus on the operations phase and any measures in the construction phase that will result in permanent changes. The total impression of the scale will be further differentiated using a five-point scale ranging from major deterioration to improvement (Major Deterioration – Deterioration – Some Deterioration – Negligible Deterioration – Improvement).

The value estimation and the impact will be entered into a table, and the results will show the consequences of the project on the reference situation/current situation. Any negative consequences are related to a value reduction of an area, whereas any positive consequences are contingent on an increase in value for the area following completion of the project. The consequences are assessed and assigned a degree of consequence. The scale of consequences ranges from minus 4 to plus 4, cf. Table 5-1.

Table 5-1 Impact assessment of the area/assessment topic. Translated from Manual V712 /30/.

Scale	Magnitude of impact	Explanation
- - - -	4 minus (- - - -)	The most severe environmental damage that might be caused to the subarea. Only applicable for subareas holding high or very high value.
- - -	3 minus (- - -)	Severe environmental damage for the subarea.
- -	2 minus (- -)	Substantial environmental damage for the subarea.
-	1 minus (-)	Some environmental damage for the subarea.
0	None/Negligible (0)	Negligible environmental damage for the subarea.
+/++	1 plus (+) 2 plus (++)	Environmental gains for the subarea: Some improvement (+), substantial improvement (++)
+++/ ++++	3 plus (+++) 4 plus (++++)	Mainly used for subareas holding negligible or some value that experiences a very high value increment caused by the measure.

The methodology applied in the V712 Manual was developed for onshore facilities or facilities in coastal waters. Thus, some adaptations will be necessary for open-sea facilities. This has been taken into consideration in the assessments.

In this impact assessment (IA), the assessments of consequences are mainly outlined using a qualitative description. The description is based on underlying plus and minus values, as indicated in Table 5-1.

Socio-economic consequences are assessed using preliminary cost estimates for the concept phase. The estimates are from late autumn 2018 and most cost components have an uncertainty of +/- 30%. Costs are aggregated to composite entries, based on key cost elements and a presumed Norwegian and regional share of delivery. There is great uncertainty relating to the estimates due to uncertainty relating to the cost estimates, the expected Norwegian share of deliveries as well as uncertainty in the calculation models.

Throughout the project development, efforts have been made to include early conclusions and recommendations from the supporting reports and we have made active use of the reports in order to select the most beneficial solutions for the environment and society.

The current IA uses the terms "within the scope of the PBA" and "outside the scope of the PBA". This is because parts of the planned project are comprised by the scope of the Norwegian Planning and Building Act (PBA) as the scope of the act extends one nautical mile beyond the Baseline and are thereby comprised by the statutory requirement that demands a zoning plan. An impact assessment is required pursuant to the Regulation of impact assessment as stipulated in the PBA. To improve readability with regard to the scope of the Planning and Building Act and the requirement for a zoning plan with an IA, descriptions of value and impact assessments have been divided accordingly in the following.

5.2 Demarcation of the project and influence areas

The project area consists of all areas that are directly and physically affected by implementation of the planned project and associated activities, whereas the influence area also comprises adjacent areas that may be affected by the project. The onshore project area comprises area occupation on Ljøsøyna. In the sea, the project area includes a zone of 250 meters on either side of the centre of the pipeline corridor, 100 meters on either side of the centre of the umbilical route, as well as a 250-metre-wide radius encircling the well location. The drilling rig will be anchored during drilling, with an anchor pattern consisting of eight anchors set in a circle with a radius of approximately 2 kilometres.

The influence area may vary depending on the relevant assessment topic. As for biodiversity, affected areas will vary both geographically and with regard to nature types and relevant species. As regards vegetation and nature types, the influence area is estimated to be located 100 meters from any technical interventions. The influence area is considered to be significantly larger for the bird and mammal species that require large land areas, due to disruptions during the construction phase. For biodiversity on land, the map shows an influence area of 500 meters for ecological function areas for species. The influence area is set at 150 m from the pipeline and cable route and 500 m from the facility. This is based on historical particle dispersion figures from similar construction work.

The assessment area is the area directly comprised by the present assessment and includes both the project and the influence area.

5.3 Area description

5.3.1 The onshore environment

Eilertsen, 2018 (/9/), describes the onshore environment. The bedrock in the area consists of various types of gneiss. This is a hard, oligotrophic rock type that supports little vegetation. In addition, there is little uncompacted material in the influence area. The island of Ljøsøyna consists mainly of open, barren firm ground.

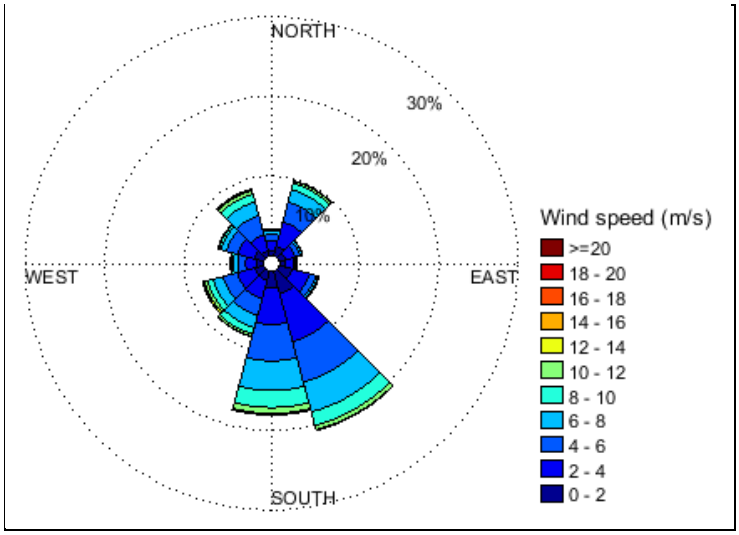
The onshore project area is situated in a coastal landscape with sparse vegetation cover and barren ground. The vegetation consists of a mosaic of coastal heathland vegetation and small sections of poor fens. Coastal heathlands are an anthropogenic vegetation type, maintained through grazing and burning. The vegetation in the relevant area is in poor condition, consisting of sections of coarse, old heather, some trees and bushes and, in some areas, large sections of the alien species mountain pine. The vegetation is very poor in species.

5.3.2 Weather and wind conditions

Øygarden municipality has an oceanic climate with relatively high annual precipitation, mild winters and cool summers. Annual mean precipitation is 1400 mm (1961-1990, Kollsnes, eKlima). The average summer temperature is 12.9°C in July (1961-1990, Kollsnes, eKlima). February is the coldest month with a mean temperature of 1.8°C (1961-1990, Kollsnes, eKlima). The annual mean temperature is 7.2 °C.

As part of the pre-engineering, wind measurements were conducted at Naturgassparken for one full year, see the wind rose in Figure 5-1. The prevailing wind direction is south-southeast, with regular wind speeds of up to 10-12 m/s (strong breeze). The local wind system is affected by the fjord system, particularly Hjeltefjorden.

Figure 5-1 Wind rose for Naturgassparken - all year.



5.3.3 The environment in the fjord system

Rambøll (/6/) has described and assessed the marine areas in the fjords, as well as the value of and impact on these areas. Hjeltefjorden stretches from Fedjeosen in the north to Knarrvika in the south leading in to Mangersfjorden, Herdlefjorden and Byfjorden. The fjord is 3-5 km wide and 50 km long. In the north by Fedjeosen, the fjord opens out to the North Sea at a water depth of 500 m. North and east of the construction site at Ljøsøyna the water depth increases rapidly to 250 m. Hjeltefjorden is described as a protected fjord. The planning area is characterised by a medium tidal range and saline water masses, which is normal for coastal waters.

The seabed topography in Hjeltefjorden is moderately undulating with varying benthic conditions. Alternating shallow outcrops and deep basins extend the entire length of the area. The benthic substrate on the outcrops consists of rock and coarser substrate. Surveys of the deep fjord channel outside Sture showed predominantly firm and fine-grained sediments with substantial clay sediments.

5.3.4 The environment in the open maritime zone outside the Baseline

Seabed habitat

The seabed in the assessment area consists of sediments and sand/mud interspersed with a varying degree of gravel, sand, and partly exposed rock near the shore by Fedje. The seabed in the Norwegian Trench

consists primarily of silt, gradually containing more sand/gravelly mud/silt leading up to the Oseberg Field Centre. There are also large sections of sand and gravelly sand surrounding the Oseberg fields.

Benthic fauna
The composition of the benthic fauna community varies geographically and can be explained by factors such as the sediment particle size, water depth, organic content, any environmental toxins and sea temperature. Currents also affect the species distribution, as most benthic species have larvae that will drift with the water currents. The benthic fauna is an important food source for fish and is also important for the dispersion of sediment organic material.

5.3.5 The environmental condition in the sea

5.3.5.1 Ljøsøysundet strait and Ljøsøybukta bay

In January 2019, new surveys were conducted of the environmental quality of the sediments in Ljøsøybukta and Ljøsøysundet, where construction work in the sea is due to take place (/15/). A map of sampling stations is included in Appendix C.

1. Ljøsøybukta – dredging for filling into sea

Surveys and bathymetric studies have been conducted at the planned excavation site near the new quay at Ljøsøybukta. The studies indicate the presence of ridges/crags consisting of bare rock/a thin layer of uncompacted material with interspersed channels covered by a thick layer of sediments. The sediments are presumed to consist mainly of shell sand. One of four samples from the planned dredging area detected total PAH16 and some PAHs in concentrations corresponding to environmental condition class II. None of the samples contained concentrations above the level 1 limit values (PR15, PR18, PR19, PR20). From a pollution point of view, environmental measures will therefore not be required in connection with dredging or depositing in this area.

2. Ljøsøysundet – area for depositing and filling

Sediments at the southernmost point of Ljøsøysundet strait are presumed to contain shell sand over presumed moraine over rock. In some places, the shell sand will presumably contain some sand and gravel. Sediments in the top layer contain some organic material/gyttja. Clay has been detected under the shell sand in the section leading up to the deep end of the strait. Clay has also been detected under several metres of shell sand in the area of the planned rock fill completion in the north. There is a softer layer of clay and argillaceous silt under the shell sand. This has a high lime content (93%). Rock depths vary between approximately 0 in border areas, and depths of up to 8.3 m have been registered at the centre of the Ljøsøysund strait.

In the area of the planned rock fill dam at the filling's completion in the north, the content of fine particles (<63 µm) in the top sediments is 11.6%. The content of total organic carbon (TOC) is 4.0% Two deeper samples, taken at a depth of 0.2-0.5 m and 0.5-0.7 m, showed that the content of fine particles was 3.0-3.2%, whereas the TOC content was 0.7-0.9%. At the southernmost point of Ljøsøysundet, the content of fine particles in top layer sediments was 16.5-36.9%, whereas the TOC content was 1.4-7.1%.

In PR22E, located in the planned dredging area at the southernmost point of Ljøsøysundet, copper of environmental condition class V (very poor) was detected as was class III zinc (moderate). In the top sediments (0-0.1 m) in PR103, located at the deepest section of Ljøsøysundet, several class III and IV PAH compounds were detected (moderate to poor), whereas the concentration of total PAH16 was in condition class II. The PAH concentration decreased as the water got deeper. The sample taken at a depth of 0.25-0.5

m showed that only one of the PHA compounds was above the level 1 limit value (detected in condition class III).

In PR103, concentrations of TBT corresponding to condition class V (very poor) were detected in the sample taken at a depth of 0.25-0.5 m. The deepest sample (0.7-0.9 m) showed that the concentration decreased to condition class II (good). The top sediment sample (0-0.1 m) was classified as condition class IV (poor). TBT corresponding to environmental condition class III was also detected in PR1 and PR3 (both in the planned dredging area in the southern section of Ljøsøysundet), as well as in PR101 (8-9 µg/kg), however, below the level 1 limit value (35 µg/kg).

We have no knowledge of any depositing or dredging activities or any other activity that would stir up the sediments in Ljøsøysundet. The contaminated sediments are therefore expected to be limited to sediments deposited during the industrial era and presumed limited to the top 0.3-0.5 metres. Most of the sedimentation has taken place in the deepest section.

5.3.5.2 Hjeltefjorden and the sea areas west of Fedje

In their marine supporting report prepared for this IA, Rambøll described the environmental condition in the sea territory inside the Baseline (/6/). The influence area is situated within the water bodies Hjeltefjorden-Northern section (0261030201-1-C) and Fedje West (0261000035-2-C). The ecological condition in Hjeltefjorden-Northern section is moderate, whereas the chemical condition is poor (Vann-nett, 2018). Due to insufficient data, the reliability of this condition classification is low. The reduced ecological condition is due to increased values of total phosphorous and nitrogen, as well as exceedance of limit values (limit good/moderate in the M-608 guideline) for the substance group PFOS (Vann-nett, 2018). The chemical condition is reduced due to exceedance of various polycyclic aromatic hydrocarbons (PAHs) in the sediment. The condition classification of environmental toxins in the sediment is only based on 1-2 sampling points. Thus, it is highly uncertain whether this is representative for the entire water body. Water exchange in the fjord is satisfactory and measurements have proven high oxygen values in the bottom water (Vann-nett, 2018).

The northern section of Hjeltefjorden is affected by aquaculture activities as well as discharges from point sources. However, only to a very limited degree (Vann-nett, 2018). Gasnor Kollsnes and BKK Produksjon are located in the vicinity of the planning area. Both enterprises discharge cooling water and Gasnor has permission to discharge oily water (<5 mg/l), amine residue and a gas treatment chemical. BKK discharges minor quantities of hydrocarbons, TOC (total organic carbon) and cooling water. Five minor mechanical treatment plants discharge to the fjord (Miljøstatus, 2018), and there is an onshore wrasse fish farm in Naturgassparken, which discharges nutrient salt and organic substances to Hjeltefjorden. There are also several aquaculture facilities in Hjeltefjorden. Studies of the kelp forest around Ljøsøyna have indicated siltation of the kelp forest in the northern section of Ljøsøysundet, with significant on-growing filiform algae.

The ecological condition of the Fedje West water body is considered poor, whereas the chemical condition is unknown (Vann-nett, 2018). Due to insufficient data, the reliability of this condition classification is low. The water body is contaminated by mercury from a submarine wreck near Fedje (Vann-nett, 2018). Monitoring of pollution in the sediment near the submarine indicates that the mercury pollution extends maximum 150 metres from the wreck. Thus, increased values are not expected in the planning area. The ecological condition is considered poor as parts of the water body are contaminated by mercury (Vann-nett, 2018).

5.3.5.3 Open waters

The Eos well is located in monitoring region III (regional environmental monitoring, sediment monitoring), situated approximately 12 km west of the TOGI location, 20 km vest of the Troll A facility and 20-25 km east

of the Brage field). The closest regional monitoring station is REGIII-06, situated approximately 10-12 km east of Eos. Production started from Troll A, Brage and TOGI in the 1990s (TOGI was shut down in 2002) and they have been part of the Region III monitoring programme since 1998. The area surrounding these fields is therefore well known as regards physical, chemical and biological composition of the sediments. No valuable environmental resources have been identified in the area.

The Eos well is located in the deep section of Region III (the Norwegian Trench) and is situated at a water depth of 307 metres. Sediments in this area are characterised by a high pellyite content (> 90%), low content of fine sand (<5%) and a high concentration of total organic carbon (>15%) (Akvaplan-niva 2016) (/31/). The benthic fauna is dominated by bristle worm constituting 79% of the total number of species and 52% of the total number of registered taxa (Regional stations - Akvaplan-niva 2016). The nearest subsea installation is TOGI, which came on stream in 1991 and was shut down in 2002. The first post-activity study was conducted in 2013 and the second one in 2016, after the subsea template had been removed. The results from the 2013 and 2016 studies showed that the sediment at the TOGI stations contained a low concentration of THC, below the Limit of Significant Contamination (LSC), and that the benthic fauna was undisturbed. Results from the 2019 region III environmental monitoring will not be available until 2020.

In some sections of the area near Oseberg Field Centre, the benthic community was adversely affected by environmental toxins in 2016. However, the benthic community at the TOGI (Troll Oseberg Gas Injection) station was unaffected. The regional station REG-6 is situated south-east of TOGI, at a depth of 295 m. The benthic community at the station was in satisfactory condition. The station is situated near the project area and is thus the most representative for the injection well. REG-08 is located north of TOGI on the Troll field. The benthic community here was in a satisfactory condition in 2016.

5.3.6 Seismic activity – CO_2 pipeline and onshore facility

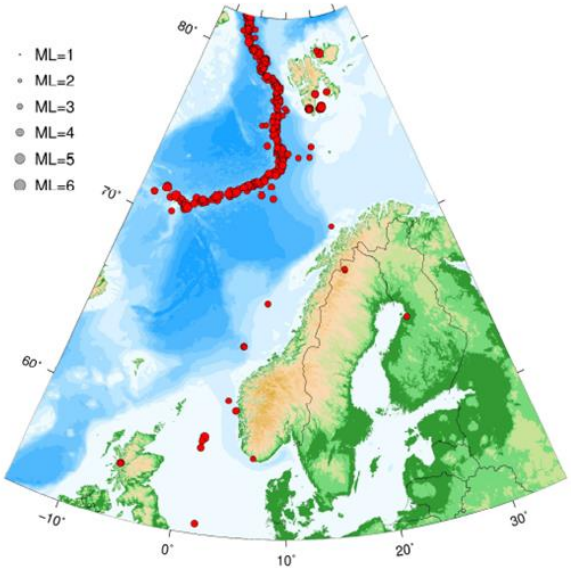
In Norway, seismic activities are monitored by the Norwegian National Seismic Network (NNSN) at the University of Bergen. The network comprises 34 seismic stations located throughout Norway and the Norwegian Arctic islands. Most of the stations transfer data in real time, and data are processed and analysed together to detect and localise earthquakes in Norway and nearby areas. Seismic activity in Norway is particularly linked to tectonic plate movement along the Mid-Atlantic Ridge, cf. Figure 5-2 showing earthquake epicentres in 2017 with a magnitude of 3 or higher (magnitude on the Richter scale)[9].

Some sections off the coast of Western Norway are known to have seismic activity. On 7 November 2017, an earthquake was registered approximately 5 km west of Øygarden. The earthquake had a magnitude of 3.8 and a depth of 12.8 km. The earthquake was much closer to the shore and much deeper than the deepest parts of the area currently being considered for permanent storage of CO_2. Noticeable quakes have also previously been registered in this area, to be exact five times in the last 25 years (magnitude above 3.5).

The Troll reservoir is situated just north of the planned storage site, and the reservoir has contained oil and gas for millions of years. The Troll production monitoring system shows no indication of impact from the earthquake that took place on 7 November 2017, nor from any other earthquakes that have occurred during production from Troll (from 1995). It is therefore unlikely that the planned storage site will be significantly affected by any earthquakes in the nearby area.

[9] (Ref: Annual report for the Norwegian National Seismic Network 2017).

Figure 5-2 Distribution of epicentre of earthquakes in 2017 with a magnitude of 3 or higher. (Ref: Annual report for the Norwegian National Seismic Network 2017).



The southern part of the North Sea is more exposed to earthquakes than the northern part. In 2017, 13 earthquakes were registered in the southern part of the North Sea. The strongest took place on 30 June and had a magnitude of 4.5. The quake was reportedly felt in North East Scotland, on the Shetland and Orkney Islands, as well as in Stavanger, Norway. On the North Sea Sleipner A facility, the earthquake felt like "a powerful wave had hit the platform".

Subsea facilities, oil and gas installations and pipelines are designed and constructed to be able to withstand the forces and stress associated with seismic activity in the areas. This also applies to the CO_2 pipeline that runs from the onshore facility in Øygarden to the storage facility in the Johansen formation south of the Troll field. In some areas, rocks (10-12.5 cm) are installed on the seabed to prevent free span and ensure a stable foundation with sufficient load carrying capacity for the pipeline. Seismic activity is taken into account when calculating and assessing how much rock to use. This includes activity with a magnitude and statistical probability of recurrence every 10,000 years.

All existing pipelines on the Norwegian Continental Shelf, and between petroleum installations on the shelf and onshore facilities (such as Mongstad, Sture and Kollsnes), have been designed and installed to be able to withstand the forces and stress exerted on them as a result of seismic activity. Seismic activity has been registered and reviewed as part of the design basis and commissioning of the processing facility, storage tanks and other equipment at the onshore facility. This also applies to the facility's foundation and all its equipment. The entire site will be prepared using crushed and compressed rock material layered on top of solid rock. Parts of the access and parking area will be built on a rock fill in the sea.

Chapter 3.14.5 describes the risk of earthquakes with regard to the integrity of the geological storage complex.

5.4 Natural and environmental assets within the scope of the PBA

This chapter describes the impact of the planned development and operation of the Northern Lights project on natural and environmental assets within the scope of the Norwegian Planning and Building Act. The

descriptions and assessments are largely based on the publicly available supporting reports prepared specifically for this project, cf. references /6/, /9/, /26/ and /27/. An environmental risk assessment has also been conducted related to the impact on environmental assets of a major CO_2 emission /29/, see Chapter 10.2.1 for a more detailed description.

5.4.1 Onshore areas - biodiversity

5.4.1.1 Landscape-ecological connections – current condition and value assessment

Landscape ecology explores changes in the distribution (mosaic) of relatively homogeneous landscape elements (forests, bogs, watercourses, roads, semi-natural sites and urban areas), and how this affects living conditions, interaction and dispersion of organisms. According to the development plan, the onshore facility will be located close to an existing industrial area and will impact a natural area in the southern part of Ljøsøyna. Habitat variation is minimal in the influence area, providing limited living conditions for various species. The areas adjacent to the planned onshore facility are divided into infrastructure and built-up areas (cf. Figure 3-5). The majority of important nature types and wilderness areas are limited to the area south of the project area. The influence area is considered to have some landscape-ecological value, as it may function as a wildlife corridor/migration corridor for species. There are no technical interventions in the project area. However, there is some established industry in the influence area. There is little variation in landscape elements/habitats, though they may have a local function as habitats/migration corridors for birds and game. Landscape-ecological connections are estimated to have **some value**.

5.4.1.2 Important nature types – current condition and value assessment

There are no previously registered nature types in the project and influence areas. The closest registered nature types are a coastal moor and a coastal pine forest situated approximately 500 meters south of the planned onshore facility, cf.Figure 5-3 (left). A coastal moor is a nature type contingent on grazing and/or burning. The project area in question consists of barren land dominated by exposed bedrock and coastal heathland at risk of overgrowing. The quality is thus considered to be too low to be classified as an important nature type. Important nature types are assessed to have **no value**.

5.4.1.3 Ecological function areas - current condition and value assessment

The game study for Øygarden classified the forest area at Ljøsneset, south of the planned onshore facility, as an important function area for game. Ordinary game fauna is likely to be present throughout the influence area, consisting of, e.g., an increasing deer population that has been exposed to hunting since 1979. Several migration corridors have been demarcated in all directions of the adjacent areas, but none of them cross the influence area for the planned onshore facility.

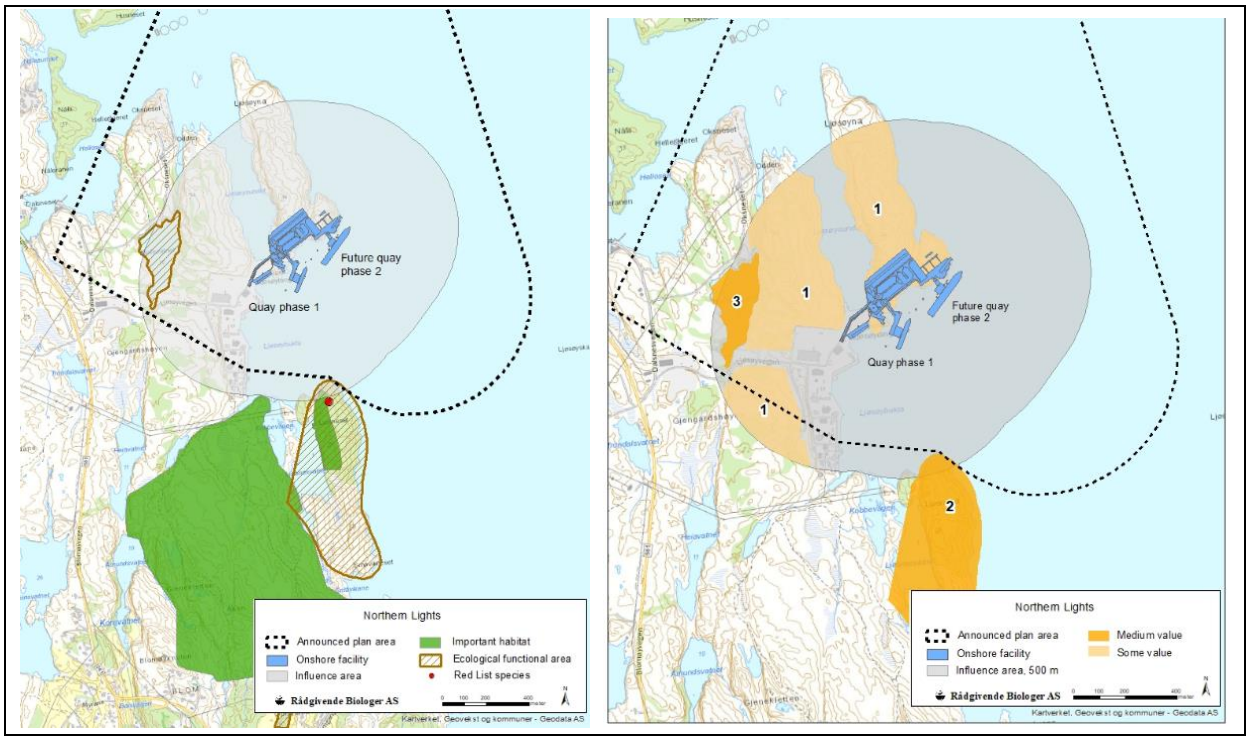
Species maps have registered a sighting of goshawk (NT, near threatened) in the forest near Ljøsneset just outside the influence area, and presence of the species has been registered, but not publicly shared, about 650 meters from the project. There is also information about a potential parliament of Eurasian eagle-owls (EN, endangered) in the area, but the exact location and the type of function areas have not been specified. The County Governor of Vestland has not registered any important localities for Eurasian eagle-owl in this area but does not rule out that the species hunts and mates in the area.

It is highly likely that eels (VU, vulnerable) are present in Hellevatnet lake (non-anadromous watercourse), as there are eels in the nearby lakes of Heiavatnet and Trondalsvatnet. As a potential habitat for eels, Hellevatnet has value as an ecological function area, and ecological function areas for species are considered to be of **medium value.**

5.4.1.4 Overall biodiversity – summary of value

Few important areas for biodiversity have been registered in the project and influence areas for the planned onshore facility, cf. Figure 5-3, right. The land areas are estimated to have **some value** in a landscape-ecological context. Two ecological function areas for species are registered inside the influence area, and have been estimated to be of **medium** value, cf. the map in Figure 5-3, (right). (2) Ljøsneset - game area just inside the influence area and 3) Hellevatnet – a potential function area for eel. The general influence area is marked as 1 on the map in Figure 5-3).

Figure 5-3 Left – Important nature types and ecological function areas. Right - Biodiversity value map. From /9/.



5.4.2 Overall biodiversity - overall assessment of impact and consequence

There may be several negative effects of the same nature during the construction and operations phases, and negative effects may be greater during the construction phase. For a limited period, the construction work may cause significant interruption.

<u>The construction phase</u>

- Noise and traffic

An increase in noise and traffic may disturb birds and mammals, particularly during the breeding and nesting period in springtime. Most species have a relatively high tolerance for temporary increases in noise levels, but particularly larger birds of prey are sensitive to disruptions. Although there is already some noise and traffic in the area, the construction work, and blasting in particular, may have an adverse effect on birds during the breeding period. Modelled noise maps, (cf. Figure 7-6) show that the noise load will be greatest in the project area itself. Noise load is estimated at maximum 90 dB, but noise levels gradually reduce as distance from the project increases. Noise levels at the outer sections of the 500-metre influence area will be between 55 and 60 dB. The noise in the areas where breeding birds may be present is not particularly loud. However, as some species are highly sensitive to noise, there is a risk that the construction work may disrupt breeding. The noise maps are considered conservative, and the noise load is presumably less than indicated.

- Run-off and dispersion from construction areas

In general, construction work involving blasting may lead to dispersion of silica dust and blasting agent residue, and run-off from construction areas often leads to discharges of nitrogen to watercourses and wetlands. However, no run-off to watercourses is expected in connection with the Northern Lights construction work.

The operations phase

- The 0 alternative (reference situation)

The 0 alternative presents the current situation in the project and influence areas without implementation of the project, but allowing for factors in approved measures and natural developments in the area. The onshore facility will be constructed in an area zoned for industrial purposes. This means that the industrial area will be expanded regardless of realisation of the onshore facility. In total, the 0 alternative is likely to have a slightly negative impact on biodiversity in the influence area.

- Impact and consequence of the onshore facility.

The planned onshore facility will result in permanent area occupation and reduced habitats for species. The onshore facility is considered to result in a **minor** reduction of function and migration possibilities. Only two ecological function areas for species have been demarcated (Figure 5-3, right) inside the influence area and none of these will be directly affected by the facility. Operational noise will gradually abate as the distance from the terminal increases, cf. Figure 7-7. Ljøsneset (loc. 2) will be located in a zone ranging from below 40 to maximum 48 dB (A). The recommended noise limit in quiet areas/recreational areas is 40 dB. Noise in the operations phase is considered to have minor effect on location 2. Overall, the project is considered to result in **negligible** changes to the ecological function areas for species.

Overall assessment of the impact on nature

Area occupation associated with the planned onshore facility will entail minor deterioration of natural areas with a local landscape-ecological function. The project will have an insignificant impact on important nature types and species. The overall impact of the onshore facility in Naturgassparken is considered to be **slightly negative with regard to biodiversity**.

The construction work is not likely to result in failed breeding attempts among goshawk just outside the influence area and mitigating measures are not considered necessary.

Reduction of uncertainty with regard to biodiversity

The consultancy firm Rådgivende Biologer (/9/) found that the data sources for most of the subtopics were sufficient, but pointed out that no specific studies had been conducted with regard to birds. They point to uncertainty relating to knowledge and existence of Eurasian eagle-owls (EN, endangered), and the species' use of the area, and recommend follow-up studies in February and March. The studies should involve the use of listening devices to reduce uncertainty and increase knowledge about Eurasian eagle-owls in the area. This should be done by a biologist with experience from such studies.

During the period 20 February – 4 March 2019 (/26/), a Eurasian eagle-owl specialist from Ecofact Sørvest conducted registrations of calls from male Eurasian eagle-owls near Naturgassparken. Three special recording devices were tuned into the relevant frequency domain for Eurasian eagle-owls during the period. The devices were placed at strategic locations based on the topographical conditions, as well as at sites where Eurasian eagle-owls are known to breed.

Ecofact summarises the study as follows /26/: None of the recordings registered Eurasian eagle-owls. The devices were in place at the locations at a suitable time for catching the sound of Eurasian eagle-owls. There are known Eurasian eagle-owl territories both north and west of the planning area. Based on maps and aerial photographs, there is a likely Eurasian eagle-owl territory between Osundet and Ulvsundet. This is supported by registrations of calling Eurasian eagle-owls dating a few years back.

"There is already significant disturbance in the planning and influence areas. This makes the area less suitable as a breeding ground for Eurasian eagle-owls, although not unsuitable. Based on the overall results from the study, and the fact that there are several potential breeding grounds outside the influence area, we find that it is highly unlikely that Eurasian eagle-owls breed inside the planning and influence area. However, it is likely that the planning area is part of a habitat hosting a territorial pair of Eurasian eagle-owls. Further follow-up studies to locate nests in summer are not considered necessary."

5.4.3 Areas in the sea – current condition and value assessment

The seabed topography in Hjeltefjorden is moderately undulating with varying benthic conditions. Alternating shallow outcrops and deep basins extend the entire length of the area. The benthic substrate on the outcrops consists of rock and coarser substrate. Surveys of the deep fjord trench outside Sture showed predominantly firm and fine-grained sediments with high clay contents.

The area near Ljøsøysundet, around Ljøsøyna and in Ljøsøybukta were surveyed by a ROV in 2017. Images showed that sweet kelp forest was dominant in hard-bottom areas at a depth of 1-15 metres. In the inner sections of Ljøsøysundet, there were fewer kelp deposits and dominant vegetation of seaweed species and filiform algae. At the deposit site, there was no seaweed or kelp, only algae. Large expanses of shallow maritime sedimentary seabed are also common.

5.4.3.1 Important marine nature types

Marine nature types – coral

There are no known species of coral inside the area comprised by the zoning plan (within 1 nm of the Baseline) or in the project's influence area. However, coral has been detected 4-6 km west of the Baseline, west of Fedje (cf. Chapters 5.5.1.1).

Marine nature type - kelp forest

In 2017, an ROV was used to register kelp forest near the shore in some parts of Ljøsøybukta, Ljøsøysundet and the area off Ljøsøysundet. The sweet kelp forest is a critical habitat, nursery and feeding ground for a multitude of algae, crustaceous species, fish and seabirds. In the North Sea it is red-listed as a vulnerable (VU) nature type. Although there are patches of sweet kelp forest, the sweet kelp forest in the area is considered important (Value B). Registrations showed sweet kelp and mixed kelp forest covering an area of 90 decares, but the area is likely to be larger as the whole area was not mapped in detail. The kelp deposits are considered to be of a **high** value. There are several kelp forests of national importance northwest of Fedje (Naturbase.no).

Marine nature type - scallops

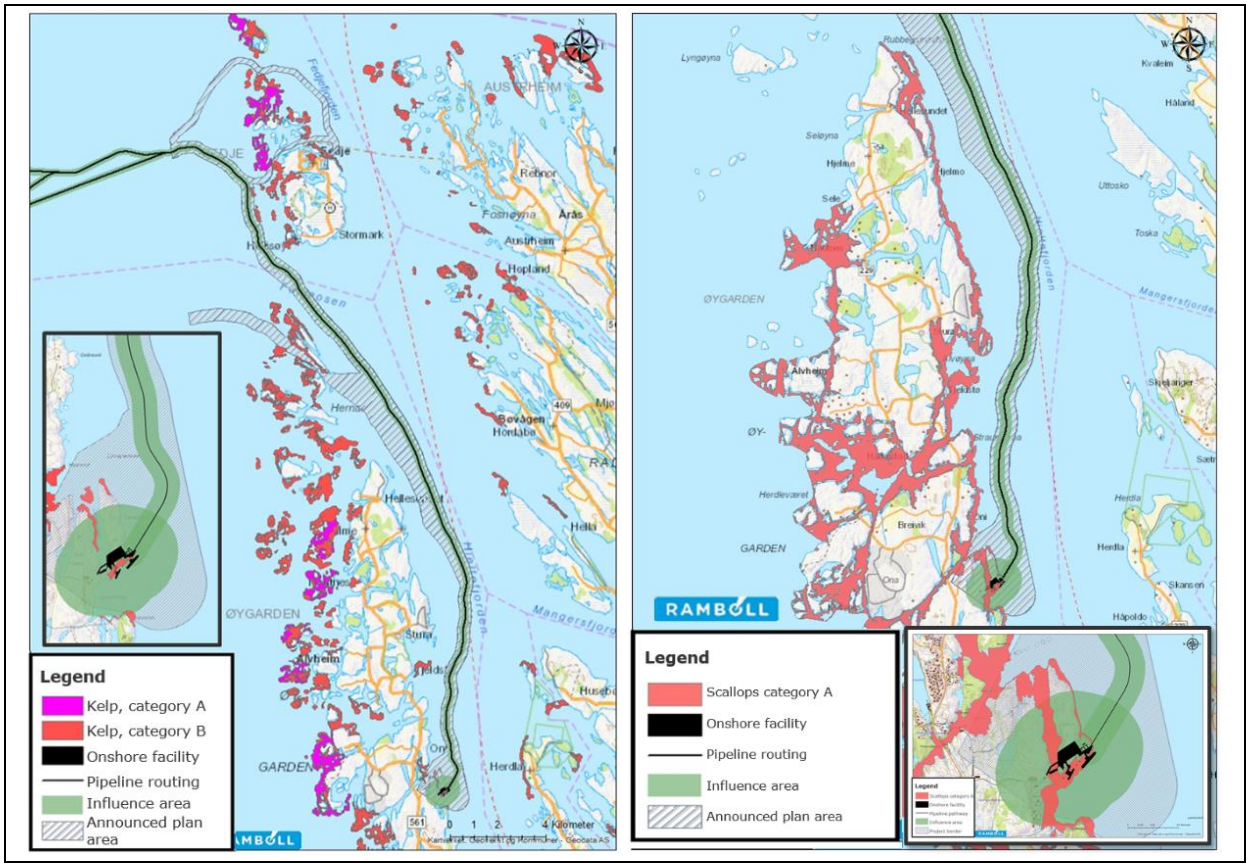
Naturbase has registered a major nature type locality consisting of large scallop populations, referred to as the Stor-Sotra (I14). Demarcation of the area comprises the whole of Sotra and is based on video observations performed by the Norwegian Institute of Marine Research during the period 2010-2014. The nature type locality is considered very important (Value A) and is therefore classified as **very high** value. The areas partially overlap with the notified planning and influence areas. Table 5-2 indicates the values in the area, and Figure 5-4 shows their locations.

Table 5-2 Value of important nature types From Rambøll /6/.

Location	Type	Value
Sweet kelp forest around Ljøsøyna island.	Red-listed and important nature type	High value (Category B)

Location	Type	Value
Store Sotra-Scallops	Important nature type	Very high value (Category A)
Kelp forest of national importance - Hatlenipa - Fiskholmskjæret	Red-listed and important nature type	High value (Category B)
Kelp forest of national importance - Fedje	Red-listed and important nature type	High value (Category B)

Figure 5-4 Populations of kelp forest (left) and scallops (right) near and inside the announced zoning plan demarcation (shaded area) and the influence area (green area). A cable to Fedje and a pipeline south of Sulo are no longer relevant options. From Rambøll /6/.



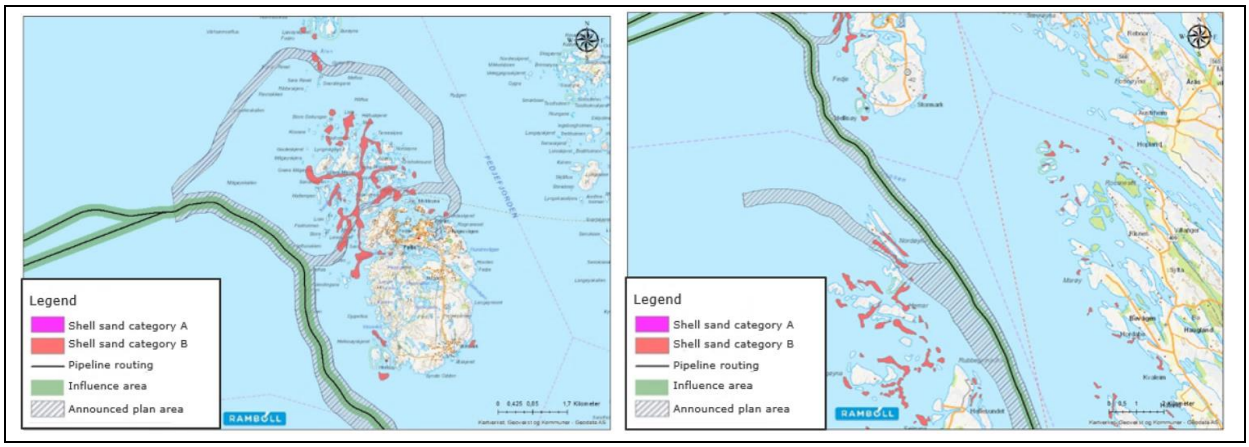
5.4.3.2 Shell sand

Shell sand is classified as an important marine nature type consisting of partially disintegrated calcified shells from shellfish and other marine organisms. Shell sand is a habitat rich in soft bottom fauna. It functions as a spawning and nursery ground for several species of fish. Large crustaceous species use shell sand banks as mating grounds and during ecdysis. They are also an important subsistence source. As a resource, shell sand is regulated pursuant to the Continental Shelf Act, and a licence is required for exemptions. There are several minor shell sand deposits on both sides of Hjeltefjorden and some larger deposits between the islands in Fedjeosen and northwest of Fedje. The deposits are indicated on the maps in Figure 5-5.

Value assessment

All deposits (Blomøy, Nordøy and Fedje north) are important nature types and considered to be of **high value.**

Figure 5-5 Shell sand deposits near and inside the announced zoning plan demarcation (shaded area) and the influence area (green area). A cable to Fedje and a pipeline south of Sulo are no longer relevant options. From Rambøll /6/.



5.4.3.3 Plankton

The pelagic system in the fjord area is presumed to be part of the typical pelagic system in the Central North Sea. There is a rapid burst of phytoplankton growth in spring attributed to large inputs of nutrient salts. At the same time, a stabilisation of the surface layer occurs, and sunlight provides the energy necessary to start the spring bloom. The zooplankton are varied, with a number of species living planktonically throughout the life cycle, as well as larvae from a multitude of species living their adult lives on the seabed or in the littoral zone (echinoderms, coelenterates, barnacles, molluscs, etc.).

Value assessment
Plankton are considered to have **some value** in the entire fjord system.

5.4.3.4 Benthic fauna

The benthic fauna is an important food source for fish and is also important for the dispersion of sedimented organic material. Studies of the bottom-fauna community have mainly concentrated on the area off the Sture Terminal, where regular studies of the deep areas have taken place since 1997. In 2013, 78 species were detected (on 0.5 m^2), but in the period leading up to 2010, as many as 90 species were detected (unknown area). The area is consequently considered relatively rich in species. The community is mainly dominated by mussels (*Abra nitida*) and bristle worms (*Hetromeastus filiformis*). The deep-water shrimp *Pandalus borealis* and the bristle worm *Owenia borealis* are species for which Norway has a special responsibility. These species were detected at the station in 2013 (Naturbase, 2018). The species are classified as species of particularly high conservation priority.

Value assessment
The benthic fauna community in the Hjeltefjorden water body is considered good to very good, based on data collected outside Sture in 2013 (Vann-nett, 2018). The area is considered to be of medium **value** for the benthic fauna, based on the discovery of two Norwegian responsibility species in the area.

5.4.3.5 Marine mammals

Porpoises and springers (collective designation for small dolphins such as the white-nosed dolphin and the Atlantic white-sided dolphin) are autochthonous to the area whereas minke whales migrate to the area for food. They are most numerous in the northern and western parts of the North Sea. In Naturbase, two whale species, killer whale and porpoise, have been registered in or near the influence area. The species are species for which Norway has a special responsibility and are classified as species of a particularly high conservation priority. Porpoise is a small toothed whale. On the western coast of Norway, the porpoise survives on a diet of primarily pelagic fish and lanternfish. Porpoise have been observed during migration and reproduction in the area. They are also likely to be foraging for food in the area. There are killer whales in all maritime zones, but the species is most commonly found in high-productive, coastal areas. Killer whales hunting for food have been observed in the area.

There are two species of seal in the North Sea: common seal and grey seal. Both are autochthonous and stay close to the shore. There are observations of both species near the influence area. It is therefore possible that seal use the area as a foraging area.

There are several registrations of otters near Hjeltefjorden and in Fedje. Otters breed north of Fedje, and there is one registration of otter near Ljøsøyneset in the southern part of Ljøsøybukta. There are strong indications that otters use the influence area as a foraging area. Otter is classified as a vulnerable (VU) species in the Red List. They predominantly eat yearling fish. They are not strictly territorial but live in habitats of varying expansion.

Value assessment
As function areas for whale, Hjeltefjorden and Fedjeosen are considered to be of **medium value,** as porpoise and killer whale are Norwegian responsibility species and should therefore be classified as medium value. As function areas for seal, the fjords are estimated to have **some value.** As breeding grounds for otters, Hjeltefjorden, Fedjeosen and northern Fedje are considered to be of **high value**, as they are classified as red-listed species in the category vulnerable (VU).

5.4.3.6 Fish stocks

In Norway, the North Sea, coast and fjords have substantial fishery resources and are important habitats, nursery and spawning grounds for fish, as well as important areas for commercial and local fishing activities. The main commercial species include cod, saithe, mackerel, herring, Norway Pout, sandeel and shrimp. Stocks are managed through comprehensive and systematic monitoring, and most stocks are at sustainable levels. Please see Chapter 5.5.1.5 for a brief description of the various species.

Coastal areas and fjords such as Hjeltefjorden and Fedjeosen are important habitats and nursery grounds for fish (www.miljøstatus.no). Coastal codfish spawn near the coast and in the fjord basin. However, none of the registered spawning grounds are located inside the project's influence area. Sprat is the only red-listed species registered in Heltejorden and Fedjeosen with the red-list status near threatened (NT). Several minor spawning grounds for cod and herring have been registered on the Norwegian Directorate of Fisheries' map (www.kart.fiskeridir.no), both in the eastern and western part of Øygarden. However, these are situated outside the influence area.

Value assessment
Hjeltefjorden and Fedjeosen are habitats, nursery and spawning grounds for common species and ordinary NT species, and thus classified as an ecological function area of **some value**. It is difficult to establish general demarcations for habitats, nursery and spawning grounds for fish in the area.

5.4.3.7 Anadromous salmon species

In the salmon register Lakseregisteret, no anadromous watercourses are registered in the influence area. There are several small sea trout streams in Øygarden, Askøy, Meland and Radøy, and fish from these streams and other watercourses in the region may use Hjeltefjorden as a grazing area. Smolt may also migrate from significant salmon populations in the rivers of Vosso, Daleelva, Storelva, Loneelva, Ekso and Modalselva to Herdlefjorden and the outer part of Hjeltefjorden on their way to the sea.

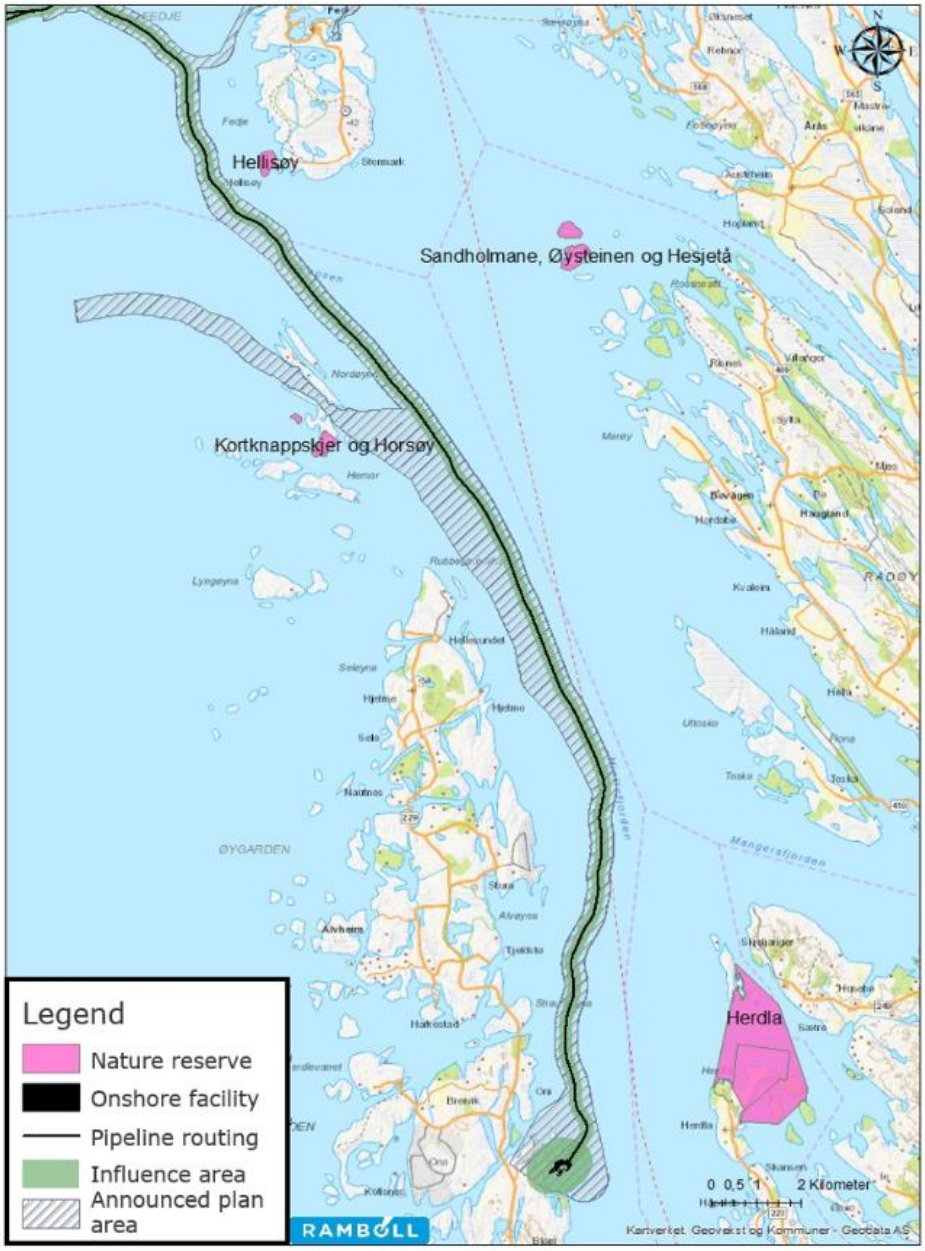
Value assessment

The salmon stock in question is threatened by several factors, and the stock size varies from relatively good in Loneelva and Storelva to very poor in Vosso (national salmon watercourse system). Hjeltefjorden and Fedjeosen are migration corridors for Vosso salmon and other anadromous populations and are consequently considered to be of a **very high value** as an **ecological function area** for anadromous salmon.

5.4.3.8 Seabirds

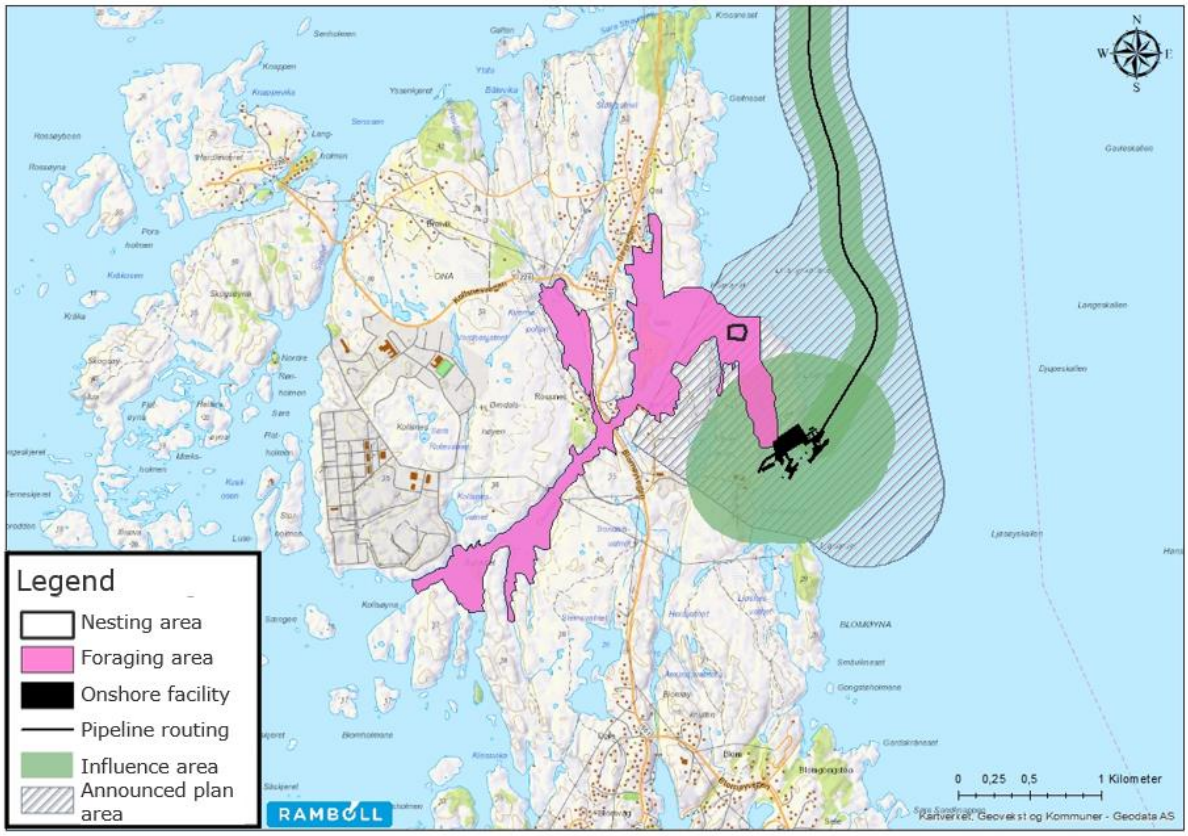
Seabirds are an important part of the coastal and marine environment, not least as a highly visible element on top of long food chains. Population development, survival and reproduction among seabirds are good indicators of the condition of marine ecosystems. The are several areas of significance for seabirds in Hjeltefjorden and around Fedje. The areas are for instance used as breeding and nesting areas for terns and seagulls. Some of the areas are small nature reserves, and thus protected, and four of them are in proximity of the influence area, cf. Figure 5-6. No breeding has been registered for many years in Sandholmane, Øysteinen and Hesjå nature reserves, nor in several of the other areas (Naturbase, 2018). There are relatively few colonies of other seabirds in the region. In some periods, there may be some auks, cormorants and bay ducks in Hjeltefjorden, but they rarely occur in large numbers. There are also some migration and overwintering locations with a relatively high diversity of marine ducks, and, in some periods, a high number of eider ducks, red-breasted mergansers and black scoters.

Figure 5-6 Seabird nature reserves near the announced zoning plan demarcation (shaded area) and the influence area (green area). An umbilical to Fedje and a pipeline south of Sulo are no longer relevant options. From Rambøll /6/.



The islet in Osundet, west of Ljøsøyna's northern point, is a breeding and nesting site for common terns (EN, endangered) and Arctic terns (LC, least concern), eider ducks (NT, near threatened), black-backed gulls (LC, least concern), oystercatcher (LC, least concern) and redshanks (LC, least concern). The situation is currently critical regionally (and locally) for several of these species, which means the outer section of Ljøsøysundet is of a **very high** value (Figure 5-7). Breeding and nesting on the islet are already affected by the nearby fish farm activities and marine traffic through the Osundet strait. Three species have been registered foraging for food in the influence area around Ljøsøyna. These species are of a particularly high conservation priority (black-backed gulls (LC, least concern), kittiwake (EN, endangered) and shag (LC, least concern). In addition, two species of particularly high conservation priority have been registered; black scoter (NT, near threatened) and eider ducks (NT, near threatened). It is also likely that other nesting birds forage for food in the area.

Figure 5-7 Foraging and nesting area for seabirds in proximity of the Northern Lights terminal and quay facility. Announced zoning plan demarcation (shaded area) and influence area (green area). From Rambøll /6/.



Value assessment

The value of seabirds is classified as **very high**, as protected areas and ecological function areas for endangered species (EN) must be classified as **very high**.

5.4.3.9 Particularly valuable areas (PVA)

As part of the work on integrated management plans for the North Sea and Skagerrak, particularly valuable areas (PVA) were identified. These are areas that, based on natural-scientific studies, are of key significance for biodiversity and biological production and where any adverse impact will have long-term or irreversible effects. **No PVA areas** have been registered in the influence area within the scope of the Norwegian Planning and Building Act.

5.4.4 Areas in the sea – assessment of impact and consequences

5.4.4.1 Important marine nature types

Coral

There are no known species of coral inside the area comprised by the zoning plan (within 1 nm of the Baseline) or in the project's influence area. However, coral deposits have been proven 4-6 km west of the Baseline, west of Fedje (see Chapter 5.5.1.1). A pre-lay survey will be conducted in connection with the pipe

installation operation, and the need for minor adjustments of the pipeline route will be considered in more detail, in order to avoid conflict with any proven coral reefs in the vicinity.

Kelp forest

Kelp forest has been registered in some areas near Osundet, in Ljøsøysundet, around Ljøsøyna and in Ljøsøybukta. In Ljøsøybukta, the sediment is relatively coarse and water speeds high. Increased turbidity in the construction phase is not expected to have any significant impact on the kelp forest off Ljøsøysundet. Water speeds are lower in Ljøsøysundet, the bottom sediment is more fine-grained and the volumes of material that will be deposited are higher. A silt curtain will be installed in the project area to contain the dispersion of particles outside the deposit site. However, a slight increase in turbidity may still reduce the quality of the kelp forest inside, and potentially outside, the silt curtain. The kelp forest is expected to return to its original condition relatively soon after completion of the construction work.

Depositing of rock in Ljøsøybukta in connection with the rock fill for the quay facility is likely to reduce kelp forest areas. However, large sections of the rock fill will be under water, where the kelp forest is likely to recover. Kelp forest re-establishes itself about every ten years. The long-term kelp forest loss is therefore expected to be 1-2 decares. In addition, approximately 4 decares of kelp forest is expected to be lost in Ljøsøysundet, but seaweed is likely to be re-established on the subsea foundation at the northern end of the deposit site. It has previously been estimated that the area of kelp forest around Ljøsøyna is approximately 90 decares. However, this may be larger as there are unmapped areas. Based on this, we estimate a 4% loss of kelp forest in the area, but this figure is highly uncertain. The project will consequently be categorised as causing some deterioration of this kelp forest.

Scallops

The influence area also comprises some minor parts of a large area of scallops. Scallops are filtering organisms which thrive in strong currents. The shells are generally found on flat seabed with strong currents or in undulating seabed terrain consisting of a mixture of rocky or sandy bottom. There is no risk of existing scallops being buried, as they are able to move over short distances. Filtering organisms are often affected by high turbidity in the water columns. However, as the construction period is of limited duration, this is unlikely to have any significant impact on the scallop population inside the influence area. The Store Sotra scallop area consists of a total area of 88,316 decares. Loss of scallop habitat is estimated at 80-1000 m^2. That makes up less than 1 ‰ of the area, which is considered insignificant impact, with no consequences for scallops.

The total impact on important marine nature types is estimated to cause "some environmental degradation to important marine nature types", based on a loss of high value important marine nature types as a result of the development.

5.4.4.2 Shell sand

Installation of a pipeline in Sulesundet south of Sulo and umbilical landing points at Fedje are no longer relevant alternatives. Development along these routes would have had adverse impact on shell sand deposits. The current solution is to install the umbilical entirely offshore, and the selected pipeline route will have no impact on shell sand deposits. Project implementation will have no impact on or consequences for shell sand deposits.

5.4.4.3 Plankton

An estimated 3400 kg of nitrogen will be introduced to the sea areas in connection with the construction work. Water exchange in Ljøsøybukta is good and the release of nitrogen is not expected to have any effect, whereas water exchange in Ljøsøysundet is slower. Introduction of nitrogen in connection with the

construction phase will only make up a minor part of the increased supply of nutrients to the area from the existing fish farm north of Ljøsøyna and will thus be of little significance compared to the existing impact in the area. During the initial operating phase, nitrogen will be flushed from the Ljøsøysundet rock fills. However, these will be small quantities compared to the annual supply of nutrients from the fish farm north of Ljøsøyna. The release of nitrogen will only constitute a minor part of the total recipient load, and flush-out of nitrogen from the rock fills will gradually abate and make up a decreasing part of the total annual nitrogen contribution for the recipient.

The installation of the pipeline is not expected to affect plankton, as these operations will only cause very limited resuspension of sediment and only in deep waters. Concentrations of environmental toxins released from the sediment are not expected to be high enough to have an impact. During the construction phase, only very limited impact is expected in the influence area near the construction site. As the impact is short-term, easily reversible and only will affect a very limited part of the function area, the impact is considered negligible, and with no consequences for the plankton community.

5.4.4.4 Benthic fauna

Dispersion of particles, and thus environmental toxins, is expected to be low in connection with the pipeline installation, and only limited suspension of sediments is expected as a result of depositing of rock material along the pipeline. Consequently, no impact is expected on the benthic fauna. Benthic fauna conditions in Ljøsøysundet will be affected by the depositing activities in the strait. However, this will be limited in the depositing area and areas adjacent to the depositing site. The benthic fauna will also be affected at the import quay deposit site in Ljøsøybukta.

Drilling of the pipeline landfall tunnel from shore to the seabed will generate around 100 m^3 of drill cuttings that will end up on the seabed. This will result in sediment coverage of the benthic fauna in some small areas and is likely to cause temporary loss of benthic fauna in the area. The area will gradually recolonise. However, if this leads to a change of grain size, it might cause some changes to the benthic fauna in the area. The impact of such coverage is still considered insignificant, as only a small area will be affected, there are no known red-listed or important species and the area will recover in the long term.

Installation of rock along the pipeline and crossings will affect the habitat in the installation area. Rock installation along the pipeline south of Fedje and out to 1 nm outside the Baseline, is expected to affect an area of approximately 5,500 m^2. However, the benthic fauna is not specific to the area and the species are present at several locations along the coast. The areas that will be covered by rock are limited. No impact is anticipated on responsibility species, nor is biodiversity in the area likely to be reduced. Furthermore, there are no known rare species in the areas that will be lost in connection with rock filling near the construction area. Consequently, the impact is considered insignificant, with no consequences for the benthic fauna.

5.4.4.5 Marine mammals

Marine mammals may be negatively affected by subsea blasting. Blasting will only take place on land, not in the sea, and sound waves from the blasting will fade away as they travel towards the sea. The blasting work is likely to have little impact on marine mammals. Porpoise and common seal are known to keep away from piling areas, at a distance of 20-25 km. Some piling work will take place during construction of the quay. However, this will be of very limited duration. There are no permanent habitats or whelping areas for seal close to the construction area, and impact on marine mammals is considered to be negligible. There is currently heavy maritime traffic and noise in the area, and an increase in maritime traffic linked to the onshore facility is not expected to have any significant impact on marine mammals.

Increased turbidity in the water column due to depositing and work at sea, may reduce visibility for fish foraging for food, and potentially keep them away from the area. Marine mammals have been known to

mistake plastic for food, and a large intake of plastic over an extended period may affect the intake of nutrients. However, addition of plastic from the construction work is marginal compared to existing volumes in the sea. Given the very limited size of the area affected by the construction phase and the duration of the work, no impact on marine mammals is expected.

Otters live partially on land but have not been observed in the influence area near Naturgassparken, and the impact from the construction phase is considered negligible. Increased activity in the area and consequently maritime traffic, may affect potential otters in the area. However, no otter habitats have been registered in the influence area. Should otters nevertheless exist in the area, studies conducted by the Norwegian Institute for Nature Research (NINA) in connection with the much larger Ormen Lange development (Nyhavna in Aukra municipality), indicate that the number of otters remained at a representative level. There may have been a slight increase in local turnover of otter individuals, potentially mainly attributed to roadkill. The number of otters killed by vehicles is not expected to increase to any significant degree, as most of the transport in and out of the area will take place by ship. Around 195 extra ships are expected to call during the operational period, but there is already ship traffic in the area. Thus, there is no likely additional impact on marine mammals. Overall, the construction and operations phases are considered to have insignificant impact on marine mammals in the fjord areas as an ecological function area, and consequences are considered **negligible**.

5.4.4.6 Fish stocks

Fish stocks may be affected by construction phase activities due to traffic and noise. There may also be a risk of dispersion of fine particles, nutrient salts and environmental toxins. Fish are sensitive to sound pressure and particle movement. Adult fish are highly mobile and readily capable of swimming away from (flight/flight response) disturbing areas, as opposed to larvae and spawn that are less mobile. The construction and installation activities will entail a small increase in maritime traffic in the affected waters, in addition to existing traffic. The pipelaying operation will progress gradually at an average speed of approximately 4 km per 24 hours. This means that noise and disturbance related to the activities will move on as the pipeline work progresses. Each area will therefore only be affected for a very limited period. Pipelaying and rock installation before and potentially after the pipelaying may result in some local dispersion of small amounts of fine particles and nutrients close to the seabed, as well as of any environmental toxins in the sediments in Hjeltefjorden. These will resediment relatively quickly.

Maritime traffic to and from the Ljøsøyna itself will cause most noise for fish, as the work at the reception plant will be ongoing for a couple of years. Most studies indicate that damage caused by noise exposure does not have an adverse effect on fish stocks. The construction phase is temporary and no seismic, sonar or detonation activities will take place during the construction phase that will cause significant damage to fish, spawn or larvae. The negative effects from dispersion of fine particles, nutrient salts and environmental toxins in the construction phase are considered to cause insignificant changes to fish stocks. The construction phase of the project is not likely to have any effects or cause any damage that will affect recruitment of fish stocks and will cause only **negligible** impact on and environmental degradation to fish and fish stocks. Fish stocks are not considered likely to be affected by operation of the terminal or the pipeline. Overall, the project is considered to have **negligible** consequences for fish stocks in the relevant fjord areas.

5.4.4.7 Anadromous salmon species

Anadromous salmon species may be affected by construction phase activities due to traffic and noise. There may also be a risk of dispersion of fine particles, nutrient salts and environmental toxins. The construction and installation activities will entail a small increase in maritime traffic in the affected waters, in addition to existing traffic. Salmon and sea trout are fast-swimming species, and in the relatively wide fjord of Hjeltefjorden, it should be unproblematic for smolt and spawners to avoid vessels and vessel noise. Impact on migrating salmon in such open waters as Hjeltefjorden is consequently considered to be an insignificant

problem. Pipelaying and rock installation before and potentially after the pipelaying may result in some local dispersion of small amounts of fine particles and nutrients close to the seabed, as well as of any environmental toxins in the sediments in Hjeltefjorden. These will resediment relatively quickly. Construction work in the sea off Ljøsøyna will partly take place in sheltered areas, and partly be implemented in such a way that dispersion across the construction areas is reduced. Anadromous salmon migrate and feed in the upper layers of the sea. Dispersion of fine particles, nutrients and environmental toxins in the construction phase is considered to have insignificant impact on migrating anadromous fish.

There will be no operational discharges to sea during the facility's operations phase, neither from the onshore facility, nor from the pipeline, and the increase in maritime traffic in the fjord system caused by the facility system will be marginal. Operations are considered to have insignificant impact on anadromous salmon. Overall, the project is considered to have **negligible** consequences for anadromous salmon.

5.4.4.8 Seabirds

The pipelaying and rock depositing in the pipe route are considered to have negligible impact on seabirds, and impact on the nature reserves along Hjeltefjorden is consequently described as insignificant. It has been registered that several red-listed seabird species nest in the outer part of Ljøsøysundet. It is also an important foraging area for red-listed species. The construction work (blasting and piling in particular) will be disruptive for seabirds, particularly in the breeding season (May until the end of July). The construction will take place in the southern part of Ljøsøyna and in southern parts of Ljøsøysundet, whereas the rest of Ljøsøyna will function as noise reduction. Preliminary noise maps (cf. Figure 7-6) indicate that noise will not be a significant problem for nesting sea birds during the construction phase.

Increased turbidity due to dredging and depositing may make it more challenging for birds to find food if the operations take place during vulnerable periods of the breeding season. Several seabird species use Ljøsøysundet as a foraging area, but there are also several nearby foraging areas that will limit any potential impact. In some cases when searching for food, seabirds mistake pieces of plastic for food. Ingestion of very small segments of plastic such as detonation cords may constitute a risk that could cause death by starvation in seabirds. The construction phase may impact the breeding and nesting area in Ljøsøysundet causing reduced breeding and production of offspring. The area is considered somewhat deteriorated. Impact on the foraging area in Ljøsøysundet is estimated to be somewhere between negligible and some deterioration, as parts of the foraging area will be inaccessible to birds for a period of time.

Ljøsøysundet is part of an important foraging area for several red-listed species in the area, such as the eider duck, common tern, Arctic tern, black-backed gull, oystercatcher and redshank. Depositing in the southern part of Ljøsøysundet will cause permanent loss of some sections of the foraging area. However, a significant area will remain available for foraging during the operating phase. Consequently, the area's function as a foraging area for seabirds will be **somewhat deteriorated**. Operating noise from the terminal may increase noise levels for breeding birds in Ljøsøysundet somewhat. However, preliminary noise maps for the operating phase indicate that the noise will not be at a disturbing level for breeding seabirds (cf.Figure 7-7). As a breeding ground, the area is still considered to become **somewhat deteriorated** due to more activity in the area in general. For seabirds, the total impact is classified as **some environmental degradation**, as breeding and foraging areas in Ljøsøysundet may be affected, both in the construction and operations phase.

5.4.4.9 Particularly valuable areas (PVA)

No areas within the scope of the PBA have been defined as particularly vulnerable areas. The project will therefore not have any impact on particularly vulnerable areas.

5.5 Natural and environmental assets outside the scope of the PBA

The description and assessments in the following are largely based on a publicly available supporting report prepared for the current IA, cf. reference /27/. An environmental risk assessment /29/ has also been prepared related to the impact on environmental assets from a large emission of CO_2, see Chapter 10.2.1 for a more detailed description.

5.5.1 Current condition and value assessment

The seabed in the assessment area consists of sediments and sand/mud with a varying degree of gravel, sand, and partly exposed rock near the shore by Fedje. The seabed in the Norwegian Trench consists primarily of silt, gradually containing more sand/gravelly mud/silt leading up to the Oseberg Field Centre. There are also large sections of sand and gravelly sand surrounding the Oseberg fields.

5.5.1.1 Important marine nature types - coral

There is still insufficient knowledge about fauna communities in and above the seabed, particularly with regard to distribution of the larger species, such as sponges, sea pens and coral reefs. These grow on the seabed and are thus vulnerable to bottom trawling and other physical impact. Coral occurence have been discovered along the western coast and on the western slope of the Norwegian Trench, near Tampen. The coral occurence consist of the red-listed species Lophelia pertusa (near threatened, NT), which is the only reef-forming coral in Norwegian waters.

Many of the known coral occurences have been mapped on seabed maps prepared by operators on the shelf as part of their development projects. Equinor's seabed mapping of the Johan Sverdrup oil pipeline route to Mongstad registered coral occurence along the western part of Fedje. The Northern Lights pipeline route must traverse the same area in a south-westerly direction, with a certain probability of discovering new and previously undiscovered coral presence. In the spring of 2019, seabed mapping was conducted along the pipeline route, registering both coral and potential shipwrecks, cf. Figure 5-8.

Figure 5-8 Potential coral deposits registered west of Fedje during the seabed mapping for the planned Northern Lights pipeline (solid orange line), potential coral reefs and coral gardens are shown as green areas. The Johan Sverdrup pipeline to Mongstad is indicated by a green line. Screenshot of Equinor's map database.

Several potential coral gardens and coral reefs have been registered near the initial planned pipeline route. A pre-lay survey will be conducted in connection with the pipelaying operation, and the need for minor adjustments of the pipeline route will be considered in more detail, in order to avoid conflict with any proven coral reefs in the vicinity.

Value assessment
The coral deposits west of Fedje are red-listed and important for biodiversity in the area, and thus estimated to be of **some** value.

5.5.1.2 Benthic fauna

The composition of the benthic fauna community varies geographically and can be explained by factors such as sediment particle size, water depth, organic content, any environmental toxins and sea temperature. Currents also affect the species distribution, as most benthic species have larvae that will drift with the water currents. The benthic fauna is an important food source for fish and is also important for the dispersion of sedimented organic material.

Value assessment
The deep-sea sediments in the Norwegian Trench are important to bristle worm and mussels. They are key elements of the food chain and are estimated to be of **some** value.

5.5.1.3 Plankton

There are two types of plankton: phytoplankton and zooplankton. Phytoplankton need sunlight for photosynthesis and usually grow in the upper 30 m of the water column. Zooplankton are more mobile and often migrate vertically in the water column throughout day. There is a rapid burst of phytoplankton growth in March/April attributed to access to nutrient salts. At the same time, a stabilisation of the surface layer occurs, and sunlight provides the energy necessary to start the spring bloom.

Value assessment
Plankton are very important in the food chain but float freely in the ocean. The assessment area is not of special importance for plankton compared with adjacent areas, and plankton are considered to have **some** value.

5.5.1.4 Marine mammals

Except for the Norwegian Trench, the North Sea is a shallow sea, with depths of 50-200 metres in the northernmost areas. This makes the area less suitable as a habitat for large whale species. Three smaller whale species are often seen in the North Sea: minke whale, porpoise and white-nosed dolphins. They occur in large areas of the North Sea and live off fish such as sandeel, herring and mackerel, but also zooplankton. Porpoises and springers (collective designation for white-nosed dolphins and Atlantic white-sided dolphins) are autochthonous to the area whereas minke whales migrate to the area for food. They are most numerous in the northern and western parts of the North Sea.

There are two species of seal in the North Sea: common seal and grey seal. Both are autochthonous, stay close to the coast and are classified as least concern. Seals are consequently not likely to live inside the offshore assessment area, but they may use the area to forage for food. None of the dominant sea mammal species in the North Sea are red-listed.

Value assessment
The whole area comprises the pipeline, umbilicals and the well, and has dispersed populations of sea mammals that use the area to forage for food. The area is estimated to be of **some** value.

5.5.1.5 Fish stocks

Below is a short list of the key fish species in the assessment area. It is based on information from the Norwegian Institute of Marine Research and the Norwegian Environment Agency. The ascribed status indicates whether it is under or above the precautionary level as stipulated in the 2013 Integrated Management Plan for the North Sea and Skagerrak and the report from the Monitoring Group; 2018 Status of the environment in the North Sea and Skagerrak. See Figure 5-9 for a map of the dispersion and spawning grounds.

The North Sea herring is a pelagic species. It swims in shoals and is found in nursery habitats in the south-eastern section of the North Sea and Skagerrak - Kattegat. It spawns from August to February. The autumn-spawning North Sea herring, which is the dominant species, has full reproduction capacity and fishing of the species is sustainable. Considered to be above the precautionary level.

Sandeel is a fish that swims in shoals and lives in shallow sandy substrates in the central and southern parts of the North Sea. They live on zooplankton and are a key species in the food chain, as they provide important nourishment for species such as cod, saithe, herring and seabirds. Sandeel have a close association with one locality and are dependent on specific types of sand in which they burrow at night. Possible depletion of the sandeel stocks has led to restrictions on sandeel fishing. In recent years, stocks have increased significantly in the southernmost localities, though stocks remain low in the northern section of the North Sea (Viking Bank). Sandeel stocks are considered to be below the precautionary level.

North Sea cod live in habitats along the coast and in the North Sea. Spawning takes place in the North Sea from January to May. There are several cod stocks, but they are considered as one. Cod is often caught in mixed fisheries. Recruitment is poor and cod is listed as vulnerable (VU) worldwide. The species is considered to be below the precautionary level.

Saithe is a pelagic fish as well as a demersal fish and is found in the North Atlantic Ocean. Saithe live in habitats in the North Sea and west of Scotland. It spawns near the Egga shelf edge, from west of Shetland to the Viking Bank west of Oseberg and near the Egersund Bank. Saithe is usually caught by trawling. It then stays in nursery habitats along the entire coast, in fjords and in areas past the Baseline for 1-3 years. Saithe stocks are considered to be above the precautionary level.

Haddock is a demersal fish. It lives in the North Sea-Skagerrak area and spawns in the northern and central parts of the North Sea from March to May. Nursery grounds for haddock are close to the shore. Haddock is mainly caught by bottom trawling, but also in mixed fisheries with cod, whiting and crawfish. Spawning stocks are above the precautionary level, but recruitment is low. Today, the largest stocks are in the northern part of the North Sea. The North Sea haddock is considered to be above the precautionary level.

Mackerel is a pelagic shoal fish with nursery grounds in the North Sea, west of the British Isles and Portugal. The Norwegian coast was an important nursery ground for mackerel from 2016-2017. Mackerel spawns in the central part of the North Sea from May to July. Stocks of mackerel are considered to be good. The fish is harvested using purse seines and trawl nets. Considered to be above the precautionary level.

Norway Pout is a small cod fish that swims in large shoals. It has its spawning ground and habitat in the northern part of the North Sea. Spawning takes place from January to May. Norway Pout is an important food source for large fish and sea mammals. Recruitment of the species has been good in recent years but varies considerably from year to year. Norway Pout stocks are considered to be above the precautionary level.

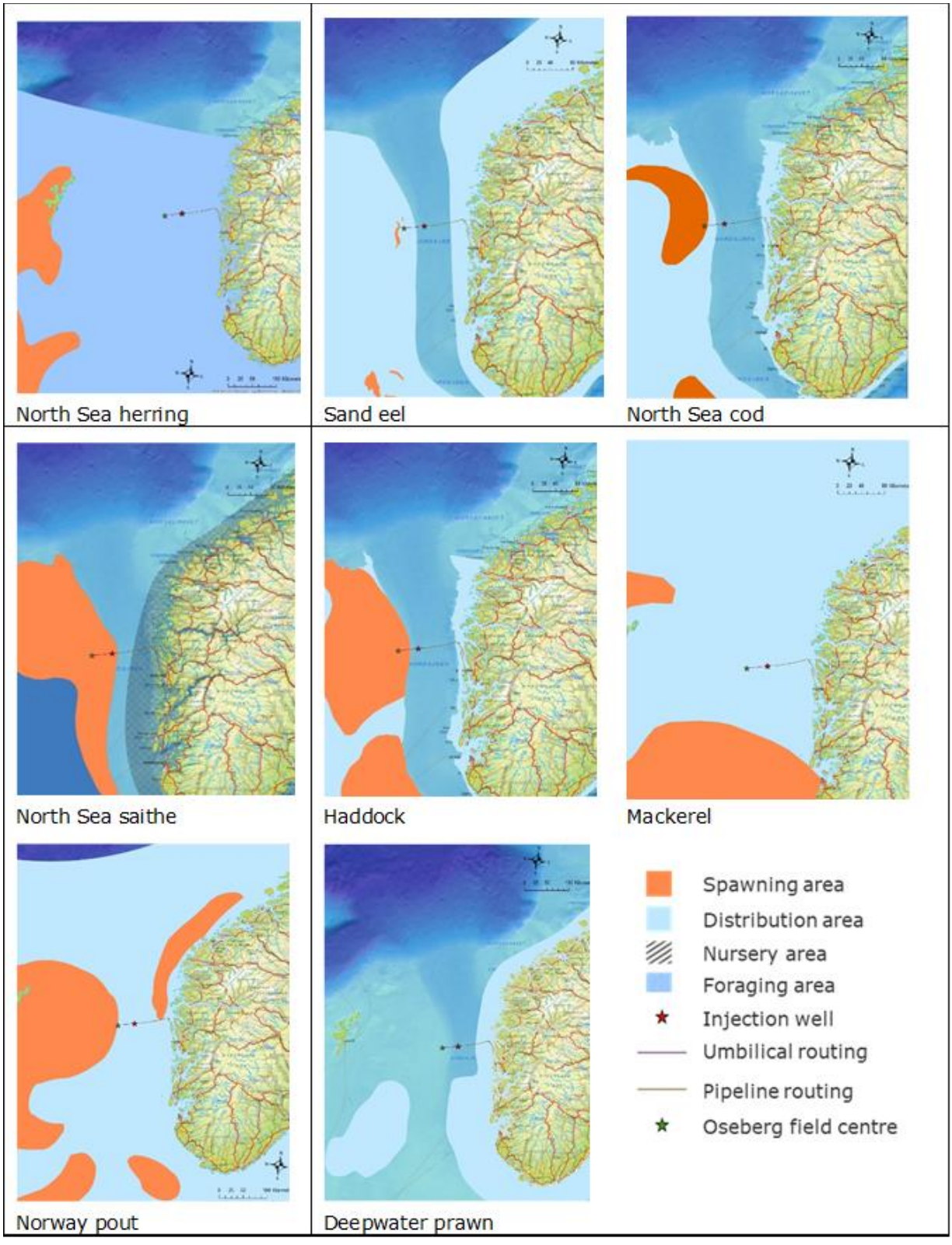
Deepwater prawns live mostly in deep waters, usually below 70 meters. The species is found from Skagerrak and northwards, along the entire coast of Norway and all the way up to the north of Svalbard. The prawn is an important prey for several species of demersal fish, particularly cod. Prawn stocks in the North Sea are considered to be below the precautionary level.

Spawning periods for the various fish species are presented in Table 5-3. North Sea herring does not spawn near the Northern Lights project. However, the species is present throughout the area and is important for fishery as well as for the marine food chain.

Table 5-3 Spawning periods for some key fish species in the North Sea.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North Sea herring	■	■						■	■	■	■	■
Sand eel	■											■
North Sea cod	■	■	■	■	■							
North Sea saithe	■	■	■	■								
Haddock			■	■	■							
Mackerel					■	■	■					
Norway pout	■	■	■	■	■							
Deepwater prawn										■	■	

Figure 5-9 Fish and prawns with spawning grounds near or inside the Northern Lights assessment area. Due to varying data availability, the map information varies between the different fish species. From Rambøll /27/.



Value assessment
The various areas are considered to be of slightly variant value for the stocks. The east side of the Norwegian Trench and the deepest areas of the Trench (which include the pipeline) are habitats for prawns and considered to be of **some** value. The western slope of the Norwegian Trench (which includes the well and cables) is a spawning and nursery ground for saithe and Norway Pout, and is considered to be of **some** value. The shallow bank areas west of the Norwegian Trench (which includes cables) are spawning and nursery grounds for several important species of fish and are thus considered to be of **medium** value.

5.5.1.6 Seabirds

Seabirds in the North Sea mainly breed in Southern Norway and in the north-eastern parts of the United Kingdom. Many seabird populations native to the north-eastern parts of the UK migrate across the North Sea after the breeding season. The area also attracts large populations of seabirds both from the Norwegian Sea and the Barents Sea. Consequently, many seabird species have important migration, resting and overwintering sites in the area. In 2018, seabird populations in the Norwegian section of the North Sea and Skagerrak were estimated at 133,000 and 101,000 nesting pairs, respectively.

In general, population trends for seabirds in the North Sea and Skagerrak show a decline in species that graze in the open sea (pelagic species). The condition of a number of seabird populations around the North Sea area is under severe pressure as breeding attempts have failed several years in a row. Seabird species feeding on small shoal fish, such as sandeel, are particularly vulnerable, including the kittiwake, common tern, guillemot and puffin. Many coastal species are also under threat, but the situation is more varied for this group. Populations of newly established species such as the northern gannet and great cormorant (the subspecies phalacrocorax carbo sinensis) are on the increase, whereas populations of the common gull, kittiwake, common tern, puffin and guillemot are declining. Red-listed seabirds in the assessment area include the common tern and the northern fulmar (endangered - EN). Both the common tern and the northern fulmar subsist on surface water organisms.

Value assessment
The western parts of the assessment area consist of open waters, the well and umbilicals. The areas are used as feeding areas and are of particular importance to pelagic diving species, and are thus considered to be of **some** value.

5.5.1.7 Particularly valuable areas (PVA)

Particularly valuable areas (PVA) were identified as part of the work on integrated management plans for the North Sea and Skagerrak. These are areas that, based on natural-scientific studies, are of key significance for biodiversity and biological production and where any adverse impact may have long-term or irreversible effects.

Value assessment
The northern sandeel area is considered to be of **high value.**

5.5.2 Assessment of impact and consequences

5.5.2.1 Important marine nature types - coral

Several potential coral gardens and coral reefs have been registered near the planned pipeline route in the area west of Fedje. A pre-lay survey will be conducted in connection with the pipelaying operation, and the need for minor adjustments of the pipeline route will be considered in more detail, in order to avoid conflict with any proven coral reefs in the vicinity. No need has been identified for installation of rock along the pipeline in the area with registered potential coral occurence. The coral Lophelia pertusa spawns during the period February-March. The pipeline will be installed during the summer months which means there is very little risk of mud build-up on nearby coral. No coral or seabed conditions for coral growth have been registered further west or near the well location.

Implementing minor route adjustments during the pipelaying to avoid area occupation and conflict with any confirmed adjacent coral reefs is considered to yield negligible impact on coral, and with no environmental degradation during the construction phase. Coral deposits will not be affected during the pipeline operation but could provide a suitable substrate for future coral colonisation.

5.5.2.2 Benthic fauna

Anchor handling, rock installation and trenching/jetting of cables and western sections of the pipeline will have an impact on some bristle worm and mussel populations along the pipe routes and near the injection well. However, this is considered to have little and relatively short-term impact on the populations. The impact is considered to be in the category *some deterioration* for both the pipeline and the injection well, whereas it is considered *negligible* for the umbilical and cable route.

The hydraulic fluid from the subsea facility is classified as a yellow (Y2) chemical as it has low biodegradability due to the use of an additive, but it is not acutely toxic. Xmas tree discharge volumes are limited. Discharges take place throughout the year and are not considered to have any significant impact on the benthic fauna. The impact is considered to be *negligible*. The western pipeline sections, the umbilical and cable will mainly be jetted into the sediments, and rock will be installed along some parts of the pipeline route, thus causing some impact at the installation site. The area is, however, limited. Thus, the installation is considered to cause *some deterioration*.

Filtering organisms are vulnerable to suspension of sediments and particles as a result of drilling. Consequences for seabed habitats (except coral) and benthic fauna during the construction phase are classified as *minor* environmental degradation, as the adverse effect is considered to be limited. The discharge of yellow category hydraulic fluid in the operations phase is not acutely toxic, is limited and is distributed over a period of one year. Consequences are therefore considered negligible.

5.5.2.3 Plankton

The installation of the pipeline or umbilical and cable is not expected to affect plankton, as these operations will only cause very limited resuspension of sediment and only in deep waters. Furthermore, the drilling rig will be anchored in deep waters by eight anchors. Cuttings and water-based drilling fluid will be discharged to the sea during drilling of the injection well. Top hole cuttings and chemicals in the green category will be deposited on the seabed close to the well. This will cause increased turbidity up to 500 m from the drilling location. From the lower well sections, cuttings will be brought up to the drill floor and released to the sea, after the drilling fluid has been cleansed using shakers. This will dilute the drilling fluid considerably and disperse cuttings over a larger area.

Plankton are unlikely to be affected by discharges of cuttings to the seabed or suspension of sediments caused by anchor handling, as plankton live in the water column above the discharge and the seabed. Discharges of cuttings from the drill floor may increase turbidity somewhat. However, this is considered to have *little* impact on plankton due to the discharges being heavily diluted, of limited volume (one well) and of short duration.

When preparing for commissioning, the CO_2 pipeline must be prepared and made ready for operation. This entails using chemically treated water. The chemicals that will be used are mainly in the green category, and some in the yellow category. During the construction phase, plankton conditions are expected to deteriorate somewhat near the injection well, but the impact is short-term, quickly reversible and will only affect a very limited part of the assessment area. Used hydraulic fluid (approximately 2 m^3 annually) will be regularly discharged from the subsea facility valves. The water-based hydraulic fluid is in category yellow (Y2, low biodegradability due to use of an additive) but is not acutely toxic. Any effects are presumed to be of a highly local and short-term nature, and impact is considered to be negligible.

The total impact on plankton during the construction phase is classified as *minor environmental degradation*, due to the discharges being highly diluted, of limited volumes and of short duration. For the operations phase, total impact is considered *negligible*, as discharges will consist of minor operational discharges of water-based, non-toxic hydraulic fluid.

5.5.2.4 Marine mammals

During the construction phase, marine mammals may be affected by noise from maritime traffic and increased turbidity. The installation of pipelines and cables, as well as rock fills along the pipeline route, is expected to produce some noise. However, the work will take place at different locations over a limited period of time. Marine mammals will also be able to migrate out of the area during the construction work. Thus, the work is not expected to have any adverse impact. As there is considerable maritime traffic in the area already, maritime traffic is not expected to have any significant impact on marine mammals during the construction phase.

The well drilling will produce noise and increased turbidity in the water column. This may result in marine mammals avoiding the area. Consequently, marine mammals are not expected to be significantly affected by the drilling, and impact is considered **negligible** for the pipeline, umbilical and cable and well.

In connection with CO_2 reservoir monitoring, seismic shooting will take place for about two months prior to initial injection (for baseline and comparison purposes), and subsequently every two years, for an estimated period of around one month. Seismic activity may cause direct harm to fish and mammals but mitigating measures can reduce the risk for individual specimens and populations (see Chapter 9.2 for a description of mitigating measures). Direct damage to the animals' auditory organ is limited to the immediate surroundings, a few hundred metres from the source. There is nothing to indicate that this will have any impact on populations. Porpoise, grampus and minke whale tend to be more evasive at lower levels than many other species. Seismic shooting may therefore affect marine mammals in the area. Seismic shooting is consequently considered to cause **some deterioration** in the area of the injection well and the reservoir area north of this. Most pipeline and cable routes will be unaffected by the seismic activity. Consequently, the Northern Lights project is considered to have negligible impact on marine mammals in the vicinity of the routes during the operations phase.

For marine mammals, the total impact is estimated to cause *minor* environmental degradation during the construction phase, as seismic shooting will take place prior to injection. For the operations phase, the total impact is classified as causing *some* environmental degradation, as seismic shooting will occur every few years.

5.5.2.5 Fish stocks and prawns

Noise and disturbance connected with the pipe laying operation will move with the installation and will thus only have an impact for a very limited period of time. Consequently, there is no anticipated adverse effect on fish stocks associated with the operation. Dispersion of fine particles during installation of the pipeline and rocks along the pipeline route, is not expected to cause any significant harm to fish. The sediments in the immediate vicinity of the Oseberg Field Centre are considered to be contaminated. Demersal fish and fish close to the seabed may therefore be affected by dispersed contaminated sediments during installation of the umbilical and cable in this area. This will take place over a very limited period of time, and the area is already heavily affected by human activity. The regional monitoring reference stations indicate that the sediments in the other sections of the assessment area contain very low contamination. Impact on fish stocks is considered to be of little significance, due to the short exposure time and limited dispersion.

The injected CO_2 will be monitored in the reservoir by conducting seismic surveys during the summer season. Prior to injection, a baseline seismic survey will be conducted, which will provide a basis for comparing the subsequent CO_2 monitoring. The area covered by the survey will be around 550 km^2 and the surveying is scheduled to last for about two months. The seismic activity may have an impact on spawn and fish larvae if it takes place during the spawning season, or immediately after. The spawning and distribution areas for the main fish species are shown in Figure 5-9, and spawning seasons for some key species are shown in Table 5-3. None of the key species' spawning grounds are close to the well. Chemically treated water from the preparation of the pipeline will be discharged near the well. The discharges are scheduled to take place in July and August. Mackerel spawn during the period May-July, whereas North Sea herring spawn during the period August-February. The spawning grounds for both species are located far from the well area, and discharges of chemical-containing water are likely to be diluted rapidly and have insignificant impact on drifting eggs and spawn.

The operations phase

The CO_2 pipeline is of a relatively small dimension. It is not considered to present any obstacles or affect fish stocks in the area. During the operations phase, approximately 2 m^3 of yellow hydraulic fluid per well (Y2 because of its low biodegradability due to the use of an additive, but it is not acutely toxic) will be discharged to the sea from the subsea facility valve assembly. The injection well is not in close proximity to the registered spawning grounds, and minor discharges of used water-based non-toxic hydraulic fluid used for testing and operation of valves, are considered to have negligible adverse impact and consequences for fish eggs and spawn.

Throughout the operations phase, seismic surveys of the reservoir area will take place in summer with some years' intervals, to monitor how CO_2 is dispersed in the reservoir. The area in question is around 200 km^2. Seismic activity may cause direct harm to fish and mammals, but the method of implementation can reduce any adverse effects. Adult fish are highly mobile and readily capable of swimming away from (flight/flight response) disturbing areas, as opposed to larvae and spawn that are less mobile. The seismic activity will have a soft start in order to scare off any fish and marine mammals in the area, thus preventing any harm. After some time, the effect of the seismic shooting will be increased, and noise-sensitive species will presumably have left the area. Seismic shooting repeated at intervals of a few years, will have a temporary effect on fish stocks in the affected area. The impact is consequently classified as *some deterioration* as fish are abundant in the area.

During the construction phase, well drilling will increase turbidity over a short period. However, this is not expected to have any significant impact on fish stocks in the area. Seismic shooting during the operations phase will cause disturbance to areas that are important to several species of fish. The total impact on fish stocks is considered *negligible* during the construction phase and *some environmental degradation* is expected during the operations phase.

5.5.2.6 Seabirds

Several seabird species use the Northern Lights assessment area as a feeding area. However, the assessment area makes up only a small part of the total feeding area for seabirds. During the construction phase, seabirds may be frightened away from the area. There is, however, heavy maritime traffic in the areas and the impact from the installation activity is not likely to be distinguishable from other traffic in that respect. The installation of the pipeline and cables is considered to have very limited effect on seabirds in the area, as the installation will take place in deep waters. During the well drilling period when cuttings are discharged to the sea from the drill floor, turbidity will also increase in the upper water layers. During this period, seabirds are likely to use other nearby foraging areas. The impact is therefore considered to be negligible.

The total impact for seabirds, is considered negligible, both for the construction and operations phases, as operation of the facility is unlikely to affect the seabird population in the area.

5.5.2.7 Particularly valuable areas (PVA)

The PVA Viking Bank, including the northern sandeel area, is considered to be of high value, but will not be affected by development or operation of the project. The umbilical and DC/FO cable start near Oseberg Field Centre, situated approximately 7 km east of the northern sandeel area. The pipeline will pass through the PVA previously known as the coastal zone. In April 2019, a proposal was put forward to no longer define the coastal zone as a PVA, as there is no scientific basis for identifying the entire coastal zone as a particularly valuable and vulnerable area. The total impact on PVA areas is regarded as negligible, both for the construction and operations phases, as none of the areas will be directly affected by the facility and as fish from the Viking Bank sandeel area are not likely to be significantly affected during the construction phase.

5.6 Local environment, landscape and outdoor recreation

This chapter describes consequences for local environments, landscape and outdoor recreation linked to the relevant areas and planned activities for development and operation of Northern Lights. The description and assessment are largely based on the publicly available assessment prepared especially for this project (cf. /7/).

Landscape and the area's impact on the natural scenery
The natural scenery is defined as "the visual and spatial structure of the landscape and how the landscape is experienced as a physical form." This comprises the visual distinctive features or characteristics of an area; how the landscape is experienced spatially and on the basis of its surroundings. With regard to natural scenery, the influence area will be defined by the project's visibility, and the assessment of the influence area will be made based on an analysis of where the project will be seen from.

The area is situated in a landscape region classified as the Coastal Districts of Western Norway. It is an open coastal landscape situated between the large expanse of sea in the west and the mountainous fjord landscape in the east. The sea areas play a dominant role in the overall natural scenery, characterised by the landscape types wide fjords, fjord confluences and open fjord estuaries. Skerries and the strandflat are dominant and characteristic features of this flat and open coastal landscape, and disruptions to the landscape are clearly visible at long distances. A multitude of coves and straits create several small and sheltered "spaces" in the landscape, in areas such as where the east-western flowing Osundet strait conjoins Hjeltefjorden in the east with the North Sea in the west. The open landscape provides expansive views, and from the hills there are wide views in all directions.

5.6.1 Øygarden

The project area in Øygarden municipality is situated in a flat and open coastal landscape, which forms a transition between the large sea area in the west and the mountainous fjord landscape in the east. The dominant rock type is oligotrophic gneiss which, combined with few patches of soil, creates an image of poor vegetation in the area. Agriculture and settlement in the area is dependent on thin layers of marine deposits.

The coastal landscape in the area tells a story characterised by a building environment and a cultural landscape which reflects the combined fishing and farming activities which have been the main source of livelihood in the area. This was the landscape of the fisherman farmer, and the land use and buildings from this time are still visible in the cultural landscape. The project area in Øygarden and the fjord landscape are currently dominated by the large industrial plants at Kollsnes and Sture. There are also large protruding overhead power lines in the landscape.

Current condition and value
The project area is situated in an open, wide coastal landscape, with some smaller terrain features in prominent landscape structures in the north-south direction, and the area makes up a small-scale landscape. Combined with the coastline with its variation between bare rock-faces and steep rocky walls, the main topographic features are highly important for the landscape's visual appearance. With the exception of the quay facility near Naturgassparken in Ljøsøybukta and the quarry in Oksneset the coastline represents a long uninterrupted stretch of important visual characteristics. Much of the area is zoned for industrial purposes, but only a small section has so far been developed, consisting of industrial plants, roads, quay facilities, rock cuts and fills. Overhead power lines traverse the area, above established industry.

The landscape near Naturgassparken which is part of the assessment area, is characteristic of Øygarden and similar areas in the region that extend out to the coast towards the open sea. In the overall guidelines, the landscape which forms part of Naturgassparken and Ljøsøyna is considered to be of high value. The planning area itself is classified as a common representative landscape of reduced value due to the existing industrial area. In terms of natural scenery, the assessment area is classified as **medium value.**

Assessment of impact and consequence
Upon completion (including Development Phase 2) the onshore facility will occupy an area of around 50 decares; around 35 decares for Development Phase 1 and an additional 15 decares for Phase 2. In addition, the plan calls for approximately 60 decares of surplus rock from blasting and levelling of the construction site to be deposited in Ljøsøysundet. Major levelling work will take place in connection with the project, which will involve major deposits and rock cuts. The rock cutting on the south side of Ljøsøyna may be highly visible from the south and east.

A tank facility with 12 tanks where the top of the tanks will reach approximately contour line + 45, will constitute a major intervention in the open and vulnerable landscape, with exposure towards the fjord and the islands in the east, but will also be visible from the northwest. The facility will dominate the scale of the landscape to a large extent, and significantly alter the appearance of the landscape. The tank facility is located close to the shore facing the fjord, which means it would be highly visible from the south-east in Phase 2. If only Phase 1 were developed, the facility would take up only 35 decares, and the visual impact would be somewhat reduced. There are plans to preserve parts of the landscape towards the north, east and a small section towards the south to create a shield towards the fjord, (cf. Figure 3-8, Figure 5-10 and Figure 5-11).

Figure 5-10 Illustration of the onshore facility, seen from the south. The illustration is based on the concept phase, and changes may occur. Photomontage: Rambøll.

The onshore facility area is currently characterised by existing industry and development activity. It will to a large extent be possible to integrate the proposed administration building and the quay facility with the existing buildings. With its high-quality materials and design, the new building displays an architectural unity that will improve the visual impression among the existing industrial buildings.

Figure 5-11 Illustration of a new quay and tank facility, seen from Hjeltefjorden. Illustration: Multiconsult

Photomontages have been prepared to show how the new facility will look in the landscape. The facility has been pasted into the landscape photo, which was taken from different angles and distances. The photos used for the photomontages were taken at locations where people often stay or walk, as shown in Figure 5-12.

Figure 5-12 photo location for the photomontage of Øygarden. From Rambøll /7/.

Figure 5-13 Photomontage 1, showing the tanks to the left, the administration building in the centre and the offloading arms to the right. Seen from the access road (Ljøsøyvegen) towards the industrial area by Hjeltefjorden. Illustration: Rambøll.

The onshore facility will not be visible from photo location no. 2, the bus stop on county road fv561, cf. Figure 5-14, due to the long distance from Ljøsøyna (approximately 1.4 km) and the elevation of the terrain in between. This will be the same even if some of the forest is taken down, as displayed by the visibility map, cf. Figure 5-17.

Figure 5-14 The current view towards Naturgassparken in the east. Seen from the bus stop on county road fv561. Municipal quay in Dalsneset, in the centre of the photo. Photo: Rambøll.

The upper part of the tank facility is barely visible from the Coastal Museum parking lot near county road fv561, cf. Figure 5-15.

Figure 5-15 Photomontage 3a shows that the tank facility is barely visible behind the ridge, seen from the Coastal Museum parking lot near county road fv561. Illustration: Rambøll.

Herdla is situated on the east side of Hjeltefjorden, in Askøy municipality. There are frequently visited national protected recreational areas in Herdla, including a golf course in South Herdla, approximately 3.5 km from Ljøsøyna. The onshore facility's impact on the landscape seen from Herdla is illustrated in Figure 5-16. The tank facility will be more prominent in the fjord landscape but will not break the horizon line to any significant extent.

In summary, the onshore facility will be highly visible, cf. Figure 5-17. The high visibility of the tank facility is due to the fact that it protrudes about 1 m above Ljøsøyna. However, as the upper part of the tanks will consist of transparent railings and other equipment, it will not appear dominant in the fjord landscape seen from the north side, even though it will show up on the visibility map.

Figure 5-16 Photomontage 4b shows that the tank facility seen from the Herdla golf course does not break the horizon line to any significant extent. The distance from Ljøsøyna is around 3.5 km. Illustration: Rambøll.

Total impact assessment

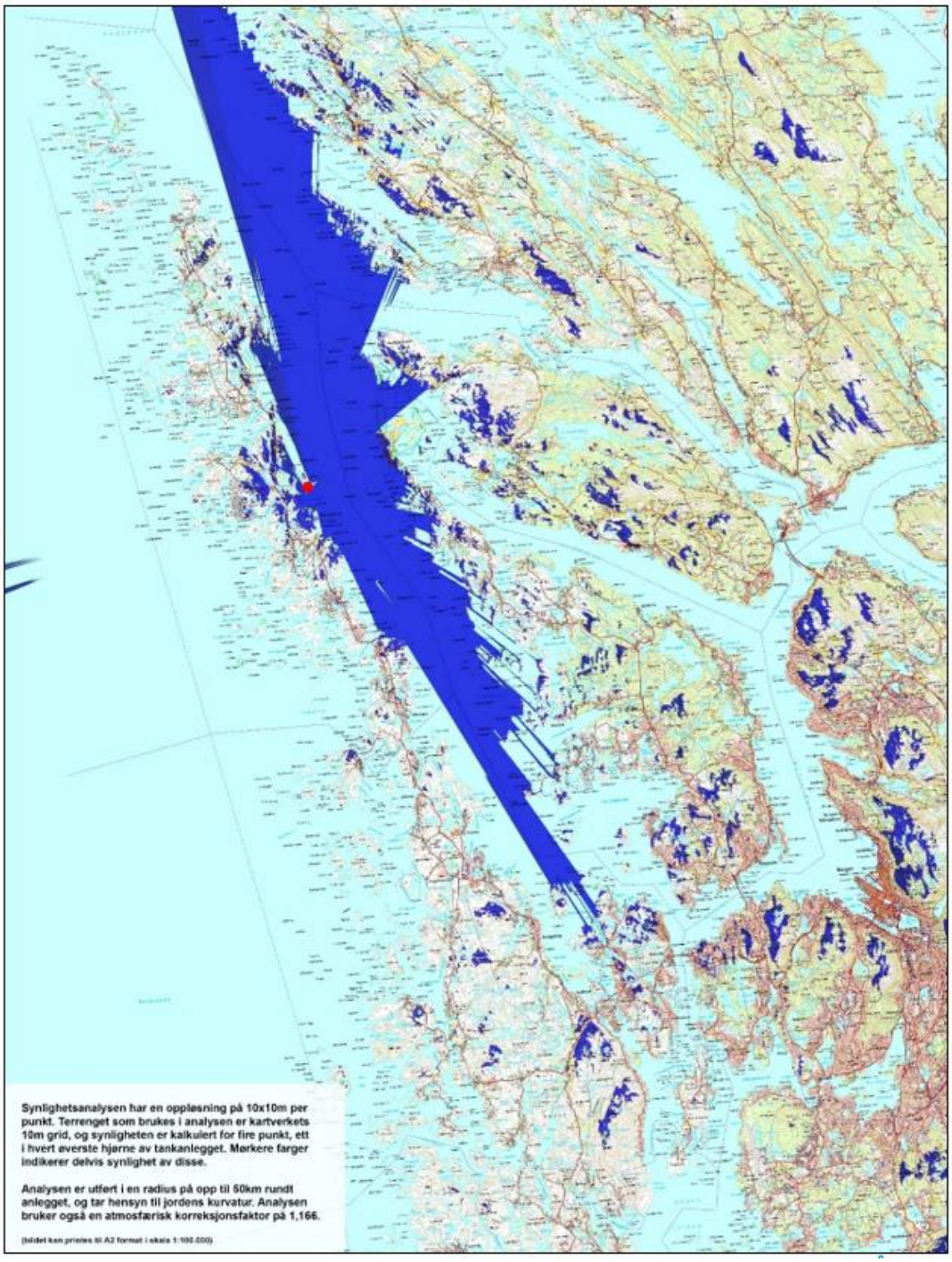
From Hjeltefjorden, the tank facility and comprehensive, large rock cuts will have a major visual proximity effect but preserving parts of the landscape towards the north and east will mitigate the visual impact, both close up and from a distance. A development in the undulating landscape is considered to have an adverse effect on the skyline, seen from the nearby fjord areas.

The total impact of a full development of the onshore facility is classified as **deterioration – severe deterioration.**

Total consequence assessment

The project will cause disruptions to an open and vulnerable coastal landscape with characteristic landscape features. There are plans to leave parts of the coastal contours to help shield and mitigate the development's impact on the landscape as seen from the sea. As the assessment area is estimated to be of medium value, and the project will cause deterioration **–** severe deterioration of the area, the consequences are considered to be significant. The project is considered to cause significant environmental degradation to the landscape in the assessment area.

Figure 5-17 The visibility map shows that the tank facility will be highly visible from many parts of Hjeltefjorden. - The high/wide visibility of the tank facility is due to the fact that it protrudes 1 m above Ljøsøyna. However, as the upper part of the tanks will consist of transparent railings and other equipment, it will not appear dominant in the fjord landscape seen from the north side, even though it will show on up the visibility map. Illustration: Rambøll.



Text in the figure: The visibility analysis has a resolution of 10 x 10m per point. The terrain used for the analysis is the Norwegian Mapping Authority's 10m grid, and visibility has been calculated for four points, one in each upper corner of the tank facility. The darker colour indicates partial visibility of these. The analysis was conducted within a radius of up to 50 km from the facility and takes into account the curvature of the earth. An atmospheric correction factor of 1.166 has also been applied to the analysis. (the picture can be printed in A2 format at a scale of 1:100.000).

Pipeline route in the sea

Current condition and value

The pipeline from the onshore facility will run in a drilled tunnel directly to the seabed in deep waters. The project in the island and fjord landscape will thus not be visible in the natural scenery after completion. The project area in the sea area has good visual qualities seen from the south, with a distinctive island and fjord landscape. The new pipeline route in Hjeltefjorden from Ljøsøyna to west of Fedje will not be installed in sea areas of identified landscape value. In terms of natural scenery, the planning area is classified as **very high value**.

Assessment of impact and consequence

The new pipeline route in Hjeltefjorden from Ljøsøyna to west of Fedje will not be visible in the area. The total impact on the natural scenery is classified as **no change**. The project is considered to cause **no environmental degradation**.

5.6.2 Fedje

Current condition and value

The landscape in Fedje is undulating, characterised by islands, islets and skerries. There are few pronounced hills in the area. Fedjebjørnen measures 42 metres above sea level and is the highest point in Fedje. The strandflat is a low and divided landscape, with a low relief. Few patches of soil give the landscape a stark and barren character, and the central part of the island is dominated by moors, damp heath vegetation and bogs. A divided land area gives many areas in the landscape a small-scale feel. Here, there are pronounced straits and bays, where most of the settlement and buildings are located, cf. Figure 5-18.

Figure 5-18 Fedje consists of flat and open heathland. Photo: Rambøll.

The outer part of Fedje is located within the Outer Skerries and the Open Sea. It has **great landscape value**, whereas the coastal heathland in the southern parts of the island, is classified as very high value. Overall, the natural scenery in the project area is considered to be of very high value.

Assessment of impact and consequence

The previous plans to install umbilical and cable landing points and an onshore control station in Rongsvågen were abandoned in the autumn of 2018 and are thus no longer relevant. The pipelaying operation in Fedje will be completed in two or three days and will consequently cause **no environmental degradation** to the natural scenery in Fedje.

5.7 Cultural artefacts and cultural environment

The following description and assessment are largely based on the publicly available assessment prepared especially for this project (/7/).

Øygarden is rich in stone age artefacts, and its topography and elevation above sea level indicate that there may be automatically protected cultural artefacts or sites in the planning area, in particular stone age settlement sites. As for marine cultural heritage sites, several discoveries have been made already (automatically protected cultural artefacts/sites) in the planning area, and the potential for additional findings is high.

5.7.1 Within the scope of the PBA

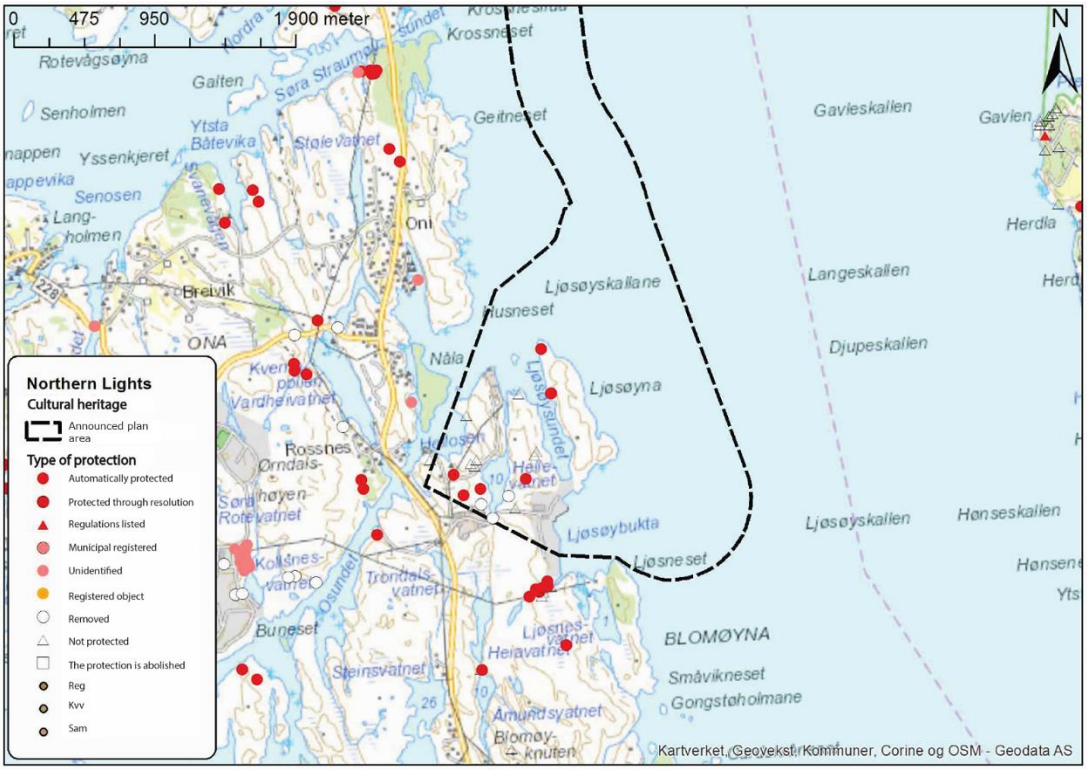
5.7.1.1 Øygarden

Current condition and value

In connection with the revised zoning plan for Naturgassparken, new archaeological registrations/pre-surveys were conducted in the summer of 2017. There have been no recent cultural artefact discoveries in the area. Three historic monuments/sites have been discovered in the announced planning area in Blomøyna: Askeladden ID 94874-1, 108943-1 and 94832-1. These will not be affected by the onshore facility for receiving and intermediate storage of CO_2. In Ljøsøyna, there are only two identified historic monuments/sites: Askeladden ID 94829 and 94830. These are located north and northwest on the island and will not be physically affected by the onshore facility, cf. Figure 5-19.

There are several known marine cultural heritage sites in the sea areas where the pipeline is located, but the pipeline route does not conflict with any such sites. Other potential marine cultural heritage sites will also be identified as part of the further seabed mapping of the relevant pipeline route, in consultation with Bergen Maritime Museum. The need for marine archaeological surveys will be clarified in discussions with the Maritime Museum.

Figure 5-19 Cultural heritage sites for the assessment area around Ljøsøyna. Source: Askeladden database. Illustration: Rambøll, last updated on 15 November 2018.



All findings are protected under the Act relating to cultural artefacts and are per definition of a **very high** value.

All discoveries of marine cultural monuments/heritage sites are protected under the Act relating to cultural artefacts and are per definition of **very high** value.

Assessment of impact and consequence
Impact of the project is considered to cause **no** change, as the findings are located far from the onshore facility and will not be affected by the project. The project is considered to cause **negligible** environmental degradation. A new pipeline route in Hjeltefjorden from Ljøsøyna to west of Fedje will not conflict with any known maritime cultural heritage sites, as the route is not in the vicinity of any such sites. The impact on cultural heritage sites is classified as **no change**. The project is considered to cause **no environmental degradation** to cultural monuments/heritage sites.

5.7.1.2 Fedje

The previous solution involving umbilical and cable landing points and an onshore control station was abandoned in the autumn of 2018 and is thus no longer relevant. No known marine cultural monuments/heritage sites within the scope of the PBA will be affected by the pipeline route. The planned pipeline will be located no closer than approximately 1,100 m from the U-864 wreck.

5.7.2 Outside the scope of the PBA

In the spring of 2019, fine-resolution seabed mapping was conducted of the pipeline route outside the Baseline and the umbilical route from Oseberg Field Centre to the well. No shipwreck discoveries that would conflict with the routes have been registered.

5.8 Planned emissions to air

5.8.1 Emissions to air from development and operation of Northern Lights

There will be various sources of planned emissions to air during the construction and operations phases. The various sources are described in brief below, together with a rough estimate of emission volumes. Please note that there is significant uncertainty relating to estimated diesel consumption, particularly for the marine operations, but also with regard to parts of the onshore work in Naturgassparken.

The construction and development phase

- During drilling and well operations, the West Hercules drilling rig will use diesel for power generation and to run engines. Average diesel consumption on the rig is estimated at 44 tonnes per 24 hours. The planned winter 2019/2020 operation is estimated to last 75 days (including 29 days of well testing). In addition, diesel will be used in connection with the subsequent drilling of side-track and completion of the verification well for the injection well. The estimated duration of this operation is 30 days. Which rig will be used for this operation has not yet been specified, but it is assumed that it will have a similar diesel consumption and NOx emission factor as the West Hercules. The total diesel consumption is thus 4,620 tonnes. Total emissions are estimated at 14,645 tonnes CO_2, 239.4 tonnes NOx, 23.8 tonnes nmVOC

and 4.6 tonnes SOx (based on applied NOROG factors, for NOx a rig-specific factor has been applied). In addition, fugitive emissions of 0.5 tonnes nmVOC and 0.5 tonnes of methane (CH_4) have been estimated in connection with drilling operations.

- In connection with the installation activities, several installation and support vessels will be used for marine operations. The installation work will commence in October 2019 with installation of parts of the seabed structure prior to drilling of the well. Other marine operations will take place in the summer seasons of 2021, 2022 and 2023. The vessels will use diesel for propulsion, positioning and power generation. The actual number of vessels will, amongst other factors, depend on the weather conditions offshore and the duration of any periods spent waiting for weather conditions to improve. Preliminary estimates are approximately 420 vessel days for the marine operations. Based on this, the total diesel consumption is estimated to be in the region of 7,100 tonnes, which would entail estimated emissions of 22,720 tonnes CO_2, 497 tonnes NOx, 7.1 tonnes SO_2 and 35.5 tonnes nmVOC.

- Various construction and installation work at Naturgassparken
  For the 2020-2023 construction work period, traditional diesel driven construction machinery will be used for blasting, levelling, handling of uncompacted material and depositing of surplus rock for the quay. The current plan is to transport tanks and other elements for the processing facility by ship to Naturgassparken. The equipment must be transported from the quay to the construction site for construction and installation of the onshore facility. Diesel-operated mobile cranes and other construction equipment will be used for this work. The amount of required equipment and the duration of the lifting operations have not yet been established. A conservative and preliminary estimate is that the need for transport and lifting operations would entail a diesel consumption of about 30% of the consumption related to blasting, levelling and preparation of the construction site. Some diesel will also be used in connection with construction of the administration building and warehouse that will be part of the onshore facility in Naturgassparken. Total diesel consumption in connection with the work in Naturgassparken is estimated at 534 tonnes, which would equate to emissions of approximately 1,806 tonnes CO_2, 5.5 tonnes NOx, and 0.1 tonnes SO_2.

The estimated diesel consumption and emissions to air from the construction and development phase are summarised in Table 5-4.

Table 5-4 Estimated diesel consumption and emissions to air from the construction and development phase

Description	Diesel (tonnes)	CO_2 (tonnes)	NOx (tonnes)	SOx (tonnes)	nmVOC (tonnes)
Drilling and well operations	4,620	14,645	239.4	4.6	23.8
Marine operations	7,100	22,720	497	7.1	35.5
Various construction and installation work at Naturgassparken	534	1,806	5.5	0.1	
Total	**12,254**	**39,171**	**741.9**	**11.8**	**59.3**

In addition, nitrous fumes (NOx and NH_3) will be produced from the blasting work in Naturgassparken. It has been estimated that approximately 260 tonnes of explosives will be used. Preliminary estimates indicate that the blasting work will generate emissions of about 74 tonnes NH_3.

The operations phase
During the Northern Lights operations phase, emissions will be released from the following sources:

- Consumption of electric power for the onshore facility. The onshore facility will be connected to the grid and will supply onshore power to the transport vessels when they are alongside the quay. Preliminary estimates indicate a total annual demand for power at 50,746 MWh. Consumption optimisation is

considered possible (see Chapter 5.11). Based on the preliminary estimated consumption, indirect emissions to the air are estimated at 666 tonnes CO_2 per year related to power consumption. The estimate is based on a CO_2 emission factor of 16.4 g/kWh, which was the emission factor for Norwegian power generation in 2017.

- Increased emissions on Oseberg A due to operation of chemical injection
  Operation of MEG and hydraulic fluid injection systems for the Northern Lights subsea facility and well will take place on Oseberg A as a host installation. Operation of these systems will result in a small increase in gas turbine load related to power generation on the facility. It has been estimated that this could increase CO_2 emissions from Oseberg A by around 40-45 tonnes per year. For 2018, total emissions of 760,371 tonnes CO_2 were reported to the Norwegian Environment Agency from the gas turbines on Oseberg Field Centre. Reported CO_2 emissions from all sources on Oseberg Field Centre totalled 789,994 tonnes in 2018. An increase of 40-45 tonnes from Northern Lights is considered marginal in this context.

- Fugitive emissions from the facility
  Preliminary estimates indicate that fugitive emissions of CO_2 from compression couplings, valves, flanges, etc. will make up less than 8 tonnes CO_2 per year.

Preliminary estimates indicate that operation of the Northern Lights onshore facility and permanent CO_2 storage on the Norwegian shelf will generate emissions of about 720 tonnes CO_2 per year. This corresponds to about 0.05% of the receiving capacity of 1.5 Mt CO_2 per year for Development Phase 1 of the facilities.

5.8.2 Northern Lights - impact on Norwegian greenhouse gas emissions

As part of the full-scale Norwegian CCS project, Northern Lights contributes solutions for transport and permanent geological storage of CO_2. The project aims to prevent that CO_2 from industrial activities is released to the atmosphere, thus contributing to the greenhouse effect and global warming. The capture players in Eastern Norway will capture CO_2 from their processing emissions, not from combustion of oil or gas as energy carriers. When Norcem cement factory converts limestone into cement during production, CO_2 is released which is chemically bound in the limestone from the conversion process. When Fortum Oslo Varme incinerates residue waste from the city of Oslo at Klemetsrud waste-to-energy plant, CO_2 is emitted from the incineration, and released as part of the fumes.

The CO_2 onshore facility at Naturgassparken in Øygarden will be developed in two phases.

- According to the zoning plan, Phase 1 will have a capacity for receiving, intermediate storage and export of 1.5 million tonnes CO_2 for permanent geological storage per year.
- Phase 2 will have a capacity for receiving, intermediate storage and export of up to 5 million tonnes of CO_2 for permanent geological storage per year.

The pipeline that will transport CO_2 from the onshore facility to the storage site has a planned transport capacity of up to 5 million tonnes of CO_2 per year. Norcem and Fortum Oslo Varme will only use 0.8 of the 1.5 million tonne capacity (about 53%) at the onshore facility in Naturgassparken in Development Phase 1. There will be a spare capacity of up to 700,000 tonnes of CO_2 per year, which can be used to receive CO_2 from other capture players.

According to Statistics Norway (SSB), reported Norwegian CO_2 equivalents (total greenhouse gases) totalled 52.9 million tonnes in 2018, of which 43.9 million tonnes were CO_2 (preliminary figures), or 83%. Oil and gas production, with its 13.7 million tonnes of CO_2 emissions (31.2% of total emissions), is followed by industry and mining, which was the second largest contributor to CO_2 emissions (26% of total emissions) in Norway in 2018, cf. Table 5-5, from Statistics Norway. Table 5-6 illustrates how Development Phase 1 and 2 may

affect total CO_2 emissions in a Norwegian context, based on the 2018 preliminary Emissions Inventory from Statistics Norway.

There was an increase in total Norwegian emissions of CO_2 equivalents of 0.4% from 2017 to 2018. Emissions from oil and gas production were reduced by 1.4 %, whereas industry and mining saw an increase of 0.2 % in 2018, compared with 2017.

Table 5-5 Norwegian greenhouse gas emissions, according to emission source. Last year (2018), preliminary figures. Source: Statistics Norway.

	2018						
	Million tonnes CO_2 eq.	Million tonnes	1,000 tonnes		Tonnes		
	Total greenhouse gasses	Carbon dioxide (CO_2)	Methane (CH_4)	N_2O	Hydrofluorocarbons (HFK)	Perfluorocarbons (PFC)	Sulphur hexafluoride (SF6)
All Sources	**52.9**	**43.9**	**202.4**	**8**	**669.1**	**17.4**	**2.5**
Oil and gas production	14.5	13.7	30.4	0	0	0	0
Industry and mining	12.1	11.4	8.1	1	0	17.4	0
Energy supply	1.8	1.7	1.1	0.1	0	0	0
Heating in other industries and households	0.8	0.6	6.3	0	0	0	0
Road traffic	9	8.9	1.2	0.3	0	0	0
Aviation, shipping, fisheries, motor equipment, etc.	7.5	7.2	6.4	0.2	0	0	0
Agriculture	4.5	0.1	104.5	5.9	0	0	0
Other sources	2.9	0.2	44.5	0.4	669.1	0	2.5

International shipping and aviation not included.

Table 5-6 Northern Lights - development phases 1 and 2, percentage of Norwegian CO_2 emissions in 2018 that can be removed from the atmosphere through injection and permanent geological storage.

	Total emissions 2018, mill. tonnes CO_2	Development Phase 1, annual quantity		Development Phase 2, annual quantity
		0.8 mill. tonnes CO_2	1.5 mill. tonnes CO_2	5 mill. tonnes CO_2
Industry and mining	11,4	7%	13%	44%
Total emissions in Norway	43.9	2%	3%	11%

Development Phase 2 with an annual receiving capacity of 5 million tonnes of CO_2, will be able to handle a volume corresponding to approximately 11% of national CO_2 emissions in 2018. The scheduled operation period for the onshore facility and other technical installations is 25 years.

Total CO_2 that will be permanently stored over the 25-year operational period for Development Phase 1 is as follows: 1.5 million tonnes CO_2 per year x 25 years = **37.5 million** tonnes CO_2

The onshore facility will have lower CO_2 emissions from operations over the year, including minor offloading volumes of liquid CO_2 from the vessel to the quay (such as during connection and disconnection of unloading equipment) and small volumes of fugitive emissions from the facility. Preliminary estimates indicate that the

volume of emissions from operations is below 8 tonnes of CO_2 per year, but this estimate will be revised in the detailed engineering phase.

Preliminary estimates indicate that operation of the Northern Lights onshore facility and permanent CO_2 storage on the Norwegian shelf will generate annual emissions of about 720 tonnes of CO_2 in Development Phase 1 (18,000 tonnes over a 25-year operating period).

The impact on the climate during the construction phase is classified as **some deterioration** due to construction activities such as blasting and transport of soil, rocks and other materials. Impact in the operations phase is considered as significantly improved based on the total volumes of permanently stored CO_2, as these volumes no longer exist in the atmosphere.

5.8.3 The Norwegian full-scale CCS project – Carbon footprint

As the overall project leader and coordinator of the Norwegian full-scale CCS project, Gassnova has developed a tool in cooperation with DNV GL to calculate the total carbon footprint for the entire full-scale project in a life cycle perspective ("from cradle to grave") (https://ccsnorway.com/experiences/carbon-footprint).

As the aim of CCS is to reduce CO_2 emissions through capture and permanent storage in geological reservoirs, it seems a reasonable prerequisite that the CCS process must not generate more emissions than are stored.

In the concept phase, Gassnova conducted early and preliminary estimates of the carbon footprint based on a case involving 25 years of operation and injection, and with full utilisation of the storage capacity in the Northern Lights Development Phase 1 (1.5 Mt CO_2 per year). For this case, Gassnova calculated the emissions of CO_2 equivalents from capture, transport and storage at approximately 0.03 tonnes (=30 kg) per tonne CO_2 stored (approximately 3%). In a case based on only one of the Norwegian capture facilities (0.4 Mt CO_2 per year) and operation with injection for only 5 years, the total emissions would make up approximately 10% of the stored volume.

During the autumn of 2019, all front-end engineering studies for the entire CCS value chain will be completed and made available to Gassnova. Based on these studies, Gassnova will prepare final carbon footprint calculations for the entire Norwegian full-scale CCS project.

5.9 Planned discharges to sea

To provide an overview, a short list of planned discharges to sea is included below. The emissions and discharges and their classified impact and consequences have been described in more detail in other sections of this IA.

- Construction period
  - Particle run-off during handling of uncompacted material and preparation of the construction site
  - Nitrogen leaks from blasted rock deposits
  - Particle dispersion during dredging and depositing work
  - Particle dispersion from directional drilling of the landfall tunnel
  - Particle dispersion from rock installation along the pipeline and from crossing of infrastructure
  - Grey water from the drilling rig and vessels during marine operations. Food waste will be ground and released to the sea.

  - Cuttings with adhering water-based drilling fluid from well drilling operations
  - Formation water from well testing
  - Chemically treated water from preparation of the pipeline for operation

- Operational period
  - Area run-off from the terminal area – non-contaminated water
  - Drainage to the existing municipal drain system
  - Discharges of hydraulic fluid from testing and valve operations at the subsea facility.

5.10 Assessment of best available techniques (BAT)

To ensure compliance with requirements stipulated in laws and regulations, as well as in governing Equinor documentation, the best available techniques (BAT) must be taken into account when selecting various solutions that may have different environmental impact.

The main focus of a BAT assessment is to consider technologies that meet the project requirements, while minimising the environmental impact. At the same time, it is necessary to find an appropriate balance between the environmental benefits gained by the technology on the one hand, and costs and practical implementation on the other. The economic aspect is also a criterion for determining what constitutes the best available techniques (BAT). In the following, we provide a brief overview of the BAT assessments and choices that were made during the project development.

Construction site and construction work in Naturgassparken

- Vertical tanks for intermediate CO_2 storage

Tanks for intermediate CO_2 storage can be horizontal or vertical. Horizontal tanks have less impact on the visual landscape but require a larger area than vertical tanks to store the same volume. The tank farm and processing facility are of a compact design, requiring a relatively small area. A larger area would require more blasting work which in turn would entail more handling of uncompacted material, higher emissions, a larger area for disposal of surplus rock material and higher development costs. The overall carbon footprint will be smallest using vertical tanks. This is generally regarded as the best solution and is considered to represent BAT.

- Handling contaminated dredged material

Contaminated sediments have been identified that need to be dredged in connection with construction of the quay facility. Furthermore, larger contaminated sediments than previously assumed have been discovered in the southern part of Ljøsøysundet, in the area where surplus rock material will be deposited. Several alternative deposit solutions were assessed. The selected solution involves depositing and isolation of the dredged material under the blasted rock fill. The selected solution is considered to be the most environmentally friendly and to represent BAT.

Naturgassparken onshore facility

- Optimal carbon storage conditions have been chosen to minimise energy consumption during receiving and storage, and also to reduce energy for heating, export and injection as much as possible.
- Well insulated tanks have been chosen to prevent heating of the surroundings which would require energy-intensive cooling during storage. This solution was selected instead of using energy-intensive cooling or gas recondensation systems for all tanks. It is essential to keep temperatures low, to prevent phase transition from liquid to gas, as the gas will expand and must be ventilated to the atmosphere. Cooling or recondensation facilities will increase investment costs. Furthermore, they will only have utility value in abnormal operating conditions, which are rare. Efficient insulation is considered to represent BAT.

- Light-coloured tanks have been decided, as light surfaces reflect more sunlight than dark surfaces, thus contributing to reduced heating of tanks and CO_2. Light-coloured tanks are more visible in the landscape, but reduced heating is considered to represent BAT.
- To reduce fugitive emissions, equipment and gaskets have been chosen that will reduce emissions. Leak detection equipment and systems will ensure that small fugitive leaks will be detected and repaired quickly.
- Export pumps with variable speed control have been chosen, as they are considered to be more energy-efficient at low injection rates than high-speed pumps (on/off), and are considered to represent BAT.
- For Development Phase 1, electrical heating elements for CO_2 have been chosen for export, which results in higher energy consumption. However, the elements are simple and inexpensive to procure and provide a safe and robust solution. Alternative heating solutions, such as the use of air or seawater exchangers were considered. However, such solutions would not exclude the use of electric heating for some months of the year. The use of hybrid water/seawater heat pumps would substantially reduce energy consumption for heating. However, there is little experience with this technology in the petroleum industry, and the solution is considered less robust. Studies are currently ongoing which may facilitate the use of a more energy efficient technology in Development Phase 2.
- For the administration building and the combined storage and service building, a seawater heat exchanger solution has been chosen as the energy source. This will significantly reduce the demand for electricity for heating, and the solution is considered to represent BAT.

CO_2 pipeline to the injection well

- Circulation of seawater in the landfall tunnel will help prevent freezing inside the tunnel at low export temperatures. In the upper part of the tunnel, pumps will be installed to facilitate exchange of seawater. This will reduce the demand for electric heating and thus the consumption of energy. The solution is considered to represent BAT.
- Leak detection. A leak detection system will be installed from the onshore facility up to and including the wellhead. Existing instrumentation for other purposes will be set up and used to make it possible to detect leaks within a reasonable time and according to defined acceptance criteria, including e.g. mass balance modelling. This will prevent small leaks from developing into major leaks over time. The solution is considered to represent BAT.

Hydraulic system for valve operations at the subsea facility

- An open water-based hydraulic system with return to sea has been selected for valve operations at the subsea facility. Oseberg A has been chosen as the offshore host installation for cable and umbilical and hydraulic systems and MEG systems. There is spare capacity in the existing open hydraulic system on the facility, with use of the water-based hydraulic fluid Oceanic HW 443 ND (colour classified as yellow – because of its low biodegradability due to the use of an additive, but it is not acutely toxic). The fluid mainly contains green components, but also some components that are classified as yellow (Y2). It is moderately biodegradable. The hydraulic fluid is on the Oseberg A substitution list and will be phased out and substituted by 2027. So far, no other alternatives have been identified with similar technical qualities. At the moment, the chosen solution is considered to represent BAT.

5.11 Optimisation of energy consumption

Energy optimisation will take place in various ways and at various times during the onshore facility's operations phase. Below follows a brief general description of the potential for such optimisation.

- CO_2 savings and optimisation of the injection rate. The injection strategy is based on continuous CO_2 injection due to several factors such as flow conditions in the pipeline, wellhead and well. This entails

that some liquid CO_2 must always be left in the onshore facility tank. The use of a variable speed drive (VSD) for export pumps makes it possible to optimise the injection rate and pump effect, and thus the energy consumption, with regard to the remaining intermediately stored CO_2 volumes and the arrival of the next CO2 load in the tanks.

- The most energy-intensive consumers of electric power will be the electric heating elements used to warm the cool CO_2 to approximately 1°C to prevent seawater from freezing in the landfall tunnel and on the seabed outside and north of Ljøsøyna. In order to reduce energy consumption for heating, heat pumps or air/seawater heat exchangers have been considered. However, the decision is to not implement such solutions in Development Phase 1. The decision was based on technical assessments during the pre-engineering phase, partly due to the need to limit the extent of new processing elements in a new CCS demonstration facility such as the Northern Lights project, and thus increase the robustness of the chosen solutions. This may be reconsidered for implementation in a potential Development Phase 2 with extended handling capacity.

- Seawater bilge pump in the landfall tunnel. Sacrificial anodes will be installed on the pipeline in the landfall tunnel, which will release anode material to the seawater in the tunnel. In order to maintain a stable water quality and conductivity over time, and to maintain the cathodic protection of the pipeline, it will be necessary to replace the seawater in the tunnel. This is most easily accomplished by pumping seawater out of the upper part of the tunnel and releasing the water to the sea. Fresh seawater will seep in from the tunnel floor, and seawater in the landfall tunnel will thus be circulated and replaced. This will help reduce the problem of freezing due to the cold CO_2 export stream, which will substantially reduce the demand for electricity. The solution will not replace the installation of electric heating elements, but installation and operation of relatively small seawater pumps will greatly reduce the need for heating and help reduce and optimise energy consumption at the facility.

6 Impact assessment for industries

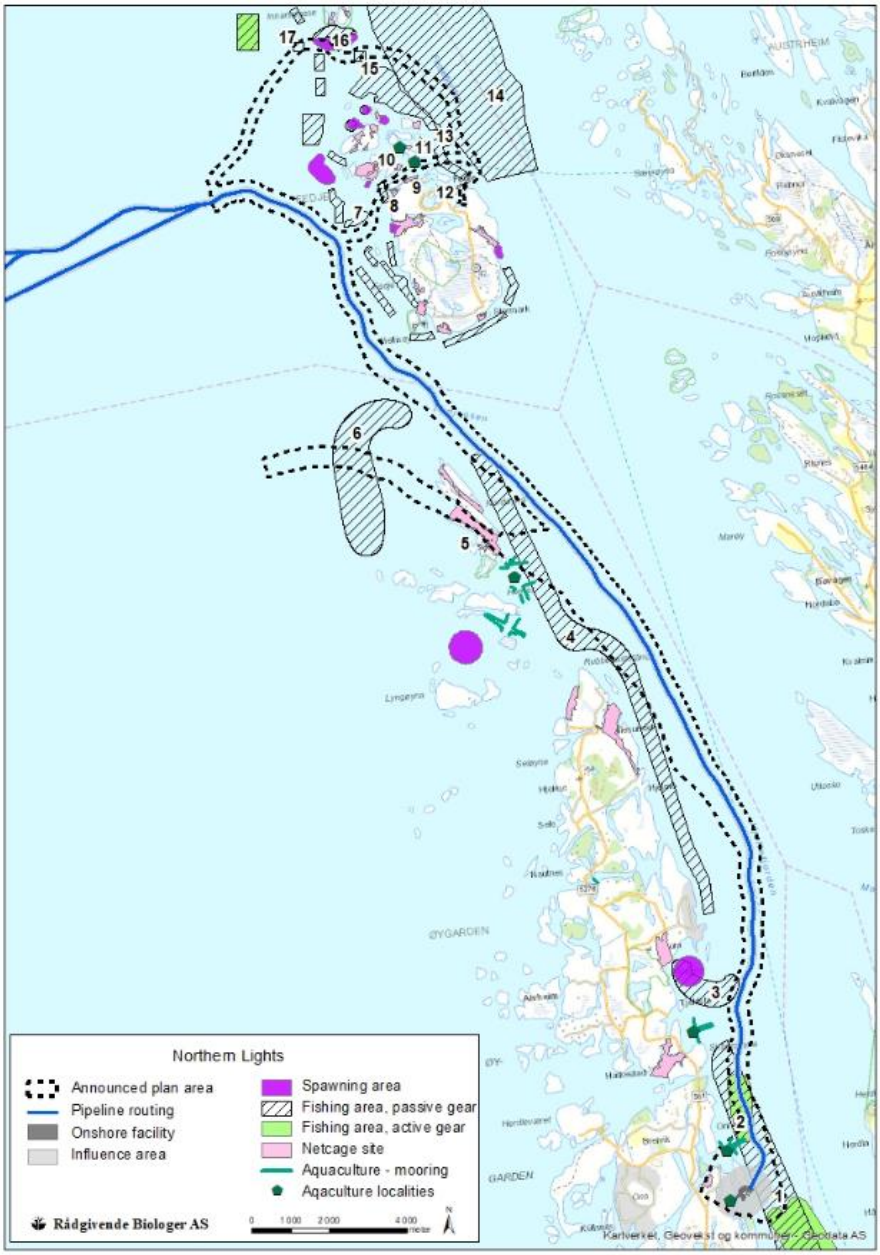
6.1 Fishery

6.1.1 Within the scope of the PBA

Current condition and value assessment

There are local fishery activities in Hjeltefjorden and near Fedje. Passive fishing gear is used to catch species such as cod, pollack, cusk, ling and anglerfish, whereas active gear is used for prawns, cf. Figure 6-1. Fishing grounds in the influence area are briefly described in Table 6-1.

Figure 6-1 Fishing grounds near the Northern Lights project and influence areas. Four localities inside the influence area have been numbered (cf. Table 6-1). The cable to Fedje and the pipeline south of Sulo are no longer relevant options. From Rambøll /6/.



The prawn fishing area Krossneset – Ljøsøyskallane is slightly affected by the existing pipeline that runs through the area (Mongstad gas pipe to Mongstad) and by two anchor lines that cross into the southern part of the area from the fish farm locality Ljøsøy Nord. There are two netcage sites near the shore in the fjord system, but none of them are located near the planning area.

The use of passive fishing and netcage sites is somewhat uncertain. However, an overview of passive fishing gear in the sea (https://www.barentswatch.no/fiskinfo) indicates that activities are highest on the western side of Øygarden, but that there is also some activity in Hjeltefjorden. Along the western part of Øygarden, fishing mainly takes place using hook-and-line as well as fishing nets. Other fishing gear is used to a limited extent.

Prawn fishing areas and netpen sites must be roughly assessed based on the information available in the Norwegian Directorate of Fisheries' databases. Fishing grounds that are used sometimes to frequently are estimated to be of medium value (cf. Table 6-1). The information about the use of fishing grounds is somewhat outdated, and dates back to around 2000-2005 (www.fiskeridir.kart.no). The fishing grounds are used by local fishermen.

Table 6-1 Registered fishing grounds (passive and active fishing gear) in the influence area. Locations are registered from the south towards the north part of Hjeltefjorden. The pipeline route south of Sulo and the umbilical and cable route to Fedje are no longer relevant options. These fishing grounds are consequently not included, cf. Figure 6-1. From Rambøll /6/.

No.	Area	Description	Value	Total value
1	Tofteøy-One in Hjeltefjorden	Passive gear. Local fishermen, recreational/tourist fishing. 3-4 vessels.	Medium	Medium
2	Krossneset-Ljøsøyskallane	Active fishing gear, prawn fishing area. Trawling at a depth of 180-200 m. Considered of medium importance.	Medium	
3	Tjeldstø	Passive gear. Local fishermen, recreational/tourist fishing. 3-4 vessels.	Medium	
4	Alvøy-Nordøyna in Hjeltefjorden	Passive gear. Local fishermen, recreational/tourist fishing. 3-4 vessels.	Medium	

There are several fishing grounds in the influence area where passive gear is used, as well as one prawn fishing area which is used locally (Figure 6-1). The fishing grounds are considered important locally and are of medium value. Overall, the fishery activities inside the Baseline are considered to be of **medium value**.

Assessment of impact and consequence

During the construction phase, it will not be possible to use the fishing grounds in the influence area for a short period of time whilst the pipeline is being installed. However, the pipelaying operation will soon progress and gradually move out of the area. The work will be of short duration and is not considered to have any significant adverse effect. Installation of a new pipeline will further diminish the value of the prawn fishing area Krossneset-Ljøsøyskallane compared with the current situation that has one pipeline. The local prawn seabed habitat along the pipeline will be changed compared to its original state, and during the operations phase the pipeline will cause some operational challenges as prawn trawling takes place using small vessels and light fishing gear. During the operations phase, the pipeline and installed rock will cause insignificant changes to passive fishing sites, as the installation is not considered to present any problems for fishing with passive fishing gear (fish pots, lines, nets).

Consequence

The total consequence for fjord and coastal fishing is considered to be negligible. In summary, there will be few or no conflicts with severe consequences for fishery activities in the construction phase or the operations phase.

6.1.2 Outside the scope of the PBA

Current condition and value assessment

Norwegian territorial waters are divided into catch areas, as stipulated by the International Council for the Exploration of the Sea (ICES). ICES area IVa extends from Lista to Stad and includes the Northern Lights assessment area, which forms a small part of the larger area. Both Norwegian and foreign fishing vessels

participate in fishery activities in the area. Scottish and Danish vessels dominate among the foreign fishing vessels that take part.

The western slope of the Norwegian Trench from the Viking Bank and northwards, as well as westwards towards the British sector, is a very important fishing ground for catching saithe, mackerel and blue whiting. As catch activities and fishing methods depend on the fish migration pattern, availability, economic operating conditions, regulations, etc., fishery conditions will change from year to year and over time. Most of the vessels that take part in the fishery activities in ICES area IVa are Norwegian. Over the last three years, annual catch in catch area IVa totalled 4-500,000 tonnes of fish. The value of catch from the total area is NOK 3-4 billion. However, it should be noted that ICES area IVa extends from Lista to Stad and comprises a much larger area than the area affected by the Northern Lights project.

All vessels of more than 15 metres have installed the Automatic Identification System (AIS), which transmits and exchanges information about the vessels' identity, position, speed, course, etc. Fishery activities primarily take place in a north-southerly direction. Data collected by the Norwegian Directorate of Fisheries show substantial fishery activity along the existing pipelines and subsea cables in the assessment area, cf. Figure 6-2. Fishery activities in the assessment area are mainly concentrated in the bank areas west of the injection well, whereas there is generally very little fishery activity between the Baseline and the Troll Field. The injection well is located at the outer edges of the most fishery-intensive area. In the well areas and west towards Oseberg, there is also heavy bottom trawling activity, as well as some floating trawl activity. There is also some fishery activity with Danish seines in the shallower areas east of Oseberg.

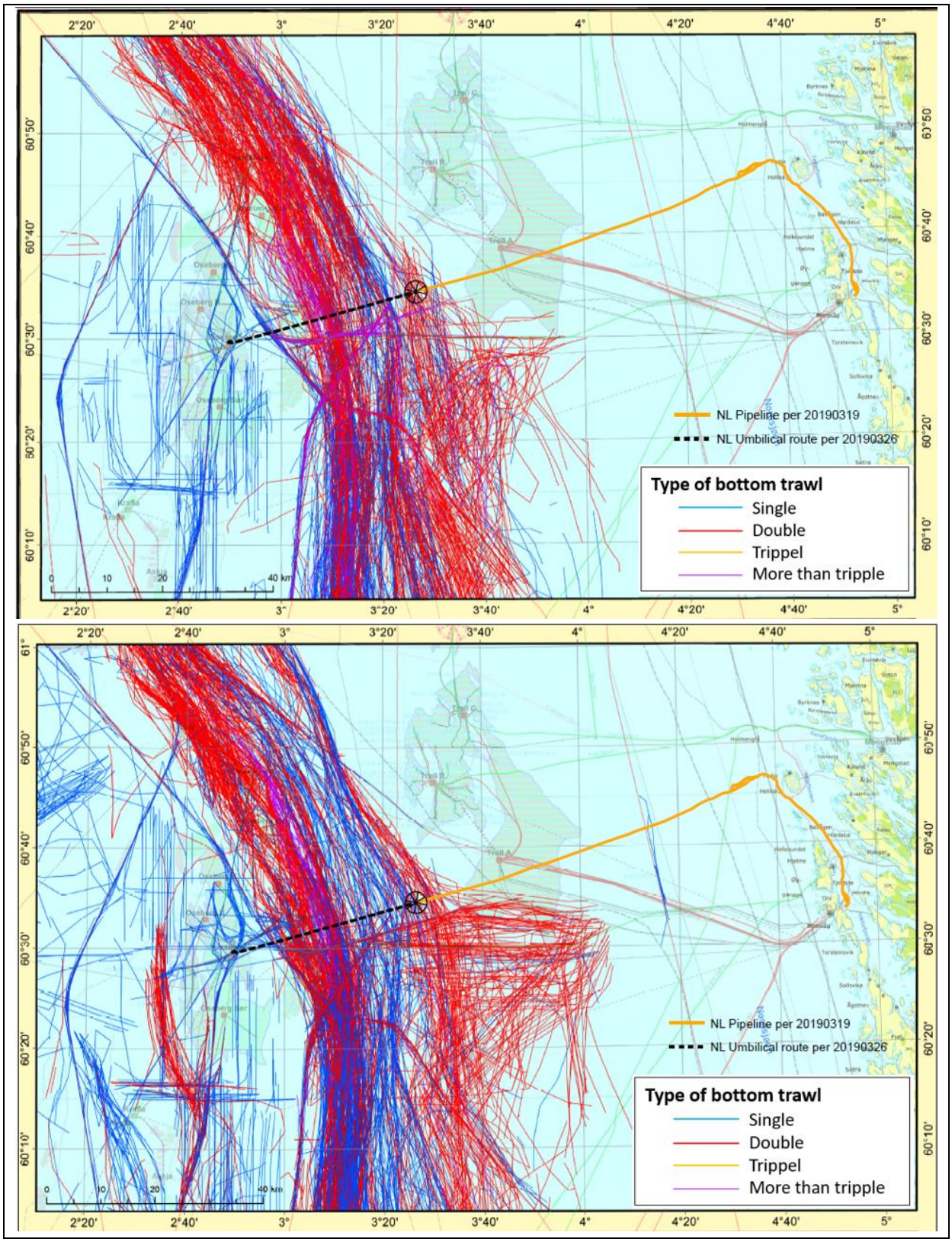
Fishing in the Northern Lights assessment area is mainly for saithe, cod and haddock, primarily using bottom trawling methods. There is also some floating trawl activity, but to a more limited extent. Prawn trawling takes place to a very limited extent in the area. In winter, there is substantial fishery activity in the deep areas, mainly by Norwegian vessels. Scottish fishermen often have smaller vessels and consequently avoid fishing in the coldest winter months. There are also many Danish vessels in the area, fishing primarily for crayfish and anglerfish. In spring and summer, Norwegian vessels often fish for saithe. Most of the sandeel fishing takes place further south in the North Sea, as the Viking Bank sandeel area east of Oseberg is closed for fishing.

As installations on the seabed may conflict with bottom trawling, and such trawling is the dominant fishery activity in the area, particular attention is given to bottom trawling in the following. Bottom trawling activities in 2017 and 2018 are presented in Figure 6-2. There is extensive bottom trawling activity in the area between the injection well southwest of Troll A and the Oseberg Field Centre.

Value assessment

The deep area of the Norwegian Trench has some fishery activity and is estimated to be of **some** value. On the western slope of the Norwegian Trench, there is substantial fishery activity in the area between the injection well and the Oseberg Field Centre, consisting primarily of trawling. The area is estimated to be of **medium** value. There is extensive fishery activity in the bank area west of the Norwegian Trench, using trawl, hook-and-line, Danish seines and nets. The area is estimated to be of **medium** value.

Figure 6-2 Bottom trawling activity (Norwegian and EU vessels) in the Northern Lights area during the period 2017 (top) - 2018 (bottom), based on AIS data from the Norwegian Directorate of Fisheries. The pipeline route is shown as an orange line, the injection well as a black circle with a star in the centre and the umbilical route as a black, dotted line.



Assessment of impact and consequence

During the development and installation period, a restriction/safety zone will be established around the area where the well will be drilled and the pipeline, umbilical and cabel will be installed. The restriction/safety zone will remain in place for the duration of the work. During this period, the relevant areas will be closed for fishery activities. For fisheries, this will entail a short-term ban on fishing in the area.

The lower section of the structure, through which drilling will take place, will be installed at the drilling location in October 2019. During drilling, the well will be anchored by 8 anchors, and a safety zone of 12-13 km^2 will be established around the rig. Fishing in the zone will be prohibited for 2-3 months during the winter of 2019/2020, for as long as the rig remains in place. This will be announced in Notifications to Seafarers and in the fishery press. After the drilling rig has plugged the well and left the area, a satellite structure will remain on the seabed, including a protective and trawl rejecting structure, to ensure that normal trawling can resume. If the well and reservoir are found to be suitable for CO_2 injection, a drilling rig will return in the summer of 2023 for well completion and commissioning, and a temporary safety zone will be established for the duration of the work. The area to be restricted will depend on which rig is chosen and will be determined later. Restrictions on fishery activities will also apply in a smaller area by the well itself for a period of time in the summer of 2023, in connection with commissioning and hook-up of the system to the well. The impact on fisheries is classified as causing **some** deterioration.

The umbilical and cable will be installed near each other in the same cable routing. Along the whole route, the umbilical and cable s will be installed in the seabed by trenching, or alternatively by jetting if trenching is not possible. The route corridor may be closed for fishery activities for a couple of months in the summer of 2022, as several installation activities will have to be completed before the umbilical and cable are protected from bottom trawling. The ban on fishery activities is expected to be in place for a limited period of time, and impact on fisheries is consequently considered to cause **some** deterioration. The pipeline is relatively small (12¾"). It will mainly be installed in an area with generally low fishery activity. Impact is therefore considered to be low. The pipeline section located in fishery-intensive areas in the western part will be jetted into the seabed.

According to the development plan, rocks of about 10-12.5 cm will be installed where the new infrastructure crosses existing pipelines and cables. The rock installations will have a slight angle of inclination, to make it easier for bottom trawling vessels to cross. This will reduce any operational disadvantages for fisheries during the operations phase. During regular operations, the entire subsea system will be designed and installed in accordance with regulatory requirements with respect to allowing fishery activities, and no fishery restrictions are planned during regular operation of the system.

The geological CO_2 storage site will be monitored through seismic surveys. Prior to injection, seismic shooting is scheduled to be conducted (duration approximately two months) in order to establish a baseline which will serve as a reference for subsequent surveys. Seismic shooting will also take place during operation, at some years' intervals over a period of about one month per campaign. In addition to area occupation during the operation, seismic shooting is known to change the behavioural pattern of fish and potentially scare fish away from the area during shooting.

Consequence

For fisheries in the construction phase, the total consequence is classified as **some** deterioration, as the well drilling, umbilical and cable installation and western section of the pipeline will require area occupation, thus making fishery-intensive areas temporarily unavailable for periods of time. The main pipeline section will be installed in an area with little fishery activities, and impact is thus considered to be negligible. For the operations phase, the total consequence is classified as **some** environmental degradation, as seismic shooting in fishery-intensive areas will result in closure of some fishing areas for a period of up to one month every few years. The new subsea infrastructure is not expected to have any significant impact on fishery activities.

6.2 Aquaculture

Aquaculture and mariculture

There are two fish farming locations outside the pipeline route from Ljøsøyna in Hjeltefjorden to Fedje (The Norwegian Directorate of Fisheries, www.kart.fiskeridir.no), cf. Figure 6-1. Location 35517 Vadholmen is located inside the zoning plan area (mooring lines) but outside the project's influence area. Location 14435 Ljøsøy N north of Ljøsøyna has two mooring lines inside the project's influence area. Location 11671 Ljøsnes is located on shore in Naturgassparken and is an onshore aquaculture facility for wrasse. An overview of registered fish farming locations is presented in Table 6-2.

Table 6-2 Aquaculture facilities in or close to the project and influence areas. MTB: Maximum allowed biomass in tonnes (production) Facilities that are not affected are shown in grey. From Rambøll /6/.

Location	Type	Owner	MTB
11671 Ljøsnes	Wrasse	MOWI AS (previously Marine Harvest Norway AS)	169
14435 Ljøsøy N	Edible fish	Blom Fiskeoppdrett AS	2 340
35517 Vadholmen	Edible fish	Erko Seafood AS	5 460

Assessment of impact and consequence

In Naturgassparken, there is an onshore wrasse fish farm, located approximately 300 metres west-southwest of the area where the onshore facility is situated. During the construction phase, work will be carried out in Ljøsøyna that may cause noise and vibrations for nearby buildings. A previously installed rock fill between the fish farm and Ljøsøyna will probably help dampen vibrations from the heavier work at Ljøsøyna. Fish in the water are vulnerable to water-born noise and vibrations, but the construction work is not expected to cause adverse effects on fish in water tanks on land surrounded by buildings. There is, however, some uncertainty relating to this, as there is little knowledge of how construction work affects fish in onshore aquaculture facilities.

Several alternative routes have been considered for pipelaying past fish farm location 14435 Ljøsøy N north of Ljøsøyna. Due to the topographical conditions on the seabed, it is not considered practical to install the pipeline so far east that it would be situated east of the two easternmost fish farm anchor points, cf. Figure 3-14, right. Just north of Ljøsøyna, the pipeline is likely to cross the anchor lines of the two easternmost anchors in the fish farm mooring arrangement.

Close dialogue and cooperation will be established with the owner of the fish farm in question. During the pipelaying operation itself, these two anchors will have to be raised for a few hours while the pipeline is being installed and the pipe-laying vessel will pass the location, before the anchors are re-established. This is not considered to have any operational consequences for the fish farm. The construction phase is considered to cause negligible changes to aquaculture and mariculture. The operations phase at the onshore facility is not considered to affect offshore or onshore fish farms. The project will cause negligible changes to aquaculture and mariculture during the operations phase.

Consequence

The project will cause negligible change and consequences for aquaculture during the construction and operations phases. The total consequence for aquaculture and mariculture is considered to be negligible.

6.3 Extraction of shell sand

Current condition
Shell sand is classified as an important marine nature type consisting of partially disintegrated calcified shells from shellfish and other marine organisms. Shell sand is also a natural product used as liming material in agriculture and has economic value. Shell sand deposits are described in more detail in Chapter 5.4.3.2.

Shell sand and underwater sand and gravel deposits are resources governed by the Continental Shelf Act. Licences for extraction are granted by the county authorities. There are no active licences for extraction of shell sand in the areas affected by the Northern Lights pipeline.

Assessment of impact and consequence
There are no registered shell sand deposits in the selected pipeline route. Project implementation will therefore have **no** impact on or consequences for shell sand or shell sand extraction as an industry.

6.4 Kelp harvesting

Current condition
Kelp deposits and kelp forest as nature types are described in more detail in Chapter 5.4.3.1. There are several kelp forests of national importance north west of Fedje. Commercial kelp harvesting (mainly the large kelp species Laminaria hyperborea) takes place along the coast and at depths down to approximately 20 metres. Harvesting is regulated by the Norwegian fisheries authorities and is subject to licensing. Small vessels drag a large rake along kelp forests just above the seabed, cutting the fronds. The coast is divided into zones and the zones are harvested every five years. The areas proposed for pipeline installation are located at significantly greater depths than the kelp forests.

Assessment of impact and consequence
Project implementation would have no impact on kelp harvesting.

6.5 Shipping

Shipping is a large and essential key industry along the coast providing important transport and logistics services for society and other industries. The industry also generates ripple effects in the form of employment and value creation. Shipping is also a key industry for petroleum activities on the continental shelf. For more details about shipping in the Northern Lights influence area, see Chapter **Error! Reference source not found.**, which contains a description of maritime traffic in the area. Potential consequences for shipping traffic are considered to have minor impact on shipping as an industry.

6.5.1 Within the scope of the PBA

The construction phase
Consequences for parallel shipping activities in Hjeltefjorden are considered to be minor, due to the narrow passage and the pipe-laying vessel's limited manoeuvring capability. Crossing vessels, particularly calls at Naturgassparken, may, however, be somewhat more affected and potential lane adjustments may be necessary during this period. The overall impact and consequences for other shipping in Hjeltefjorden are considered to be negligible – cause some deterioration. The consequence for other shipping traffic through Fedjeosen, south of Fedje, will be very limited for a short period of time. The impact is consequently considered to be **negligible** or cause **some deterioration**.

The operations phase

In the area near the seaward approach to Fedjeosen, sea transport of CO_2 will increase the number of voyages to approximately 146 per year, corresponding to an increase of approximately 4% or about 1 ship every other day /32/). The increase in the number of voyages will change the area's risk profile from a theoretical probability of 0.46 accidents per year to 0.48 accidents per year as a consequence of the operations phase. As in Fedjeosen, transport of CO_2 from the southern part of Hjeltefjorden passes through a high-risk zone by Hjelteskjæret in Byforden. It has been estimated that the increase in shipping traffic by Hjelteskjæret as a result of CO_2 transport will correspond to 49 annual voyages, an increase of well below 3% (/32/). Consequently, no noticeable consequences are expected for shipping traffic in the area during the operations phase. Consequences for shipping are thus considered to be **negligible**.

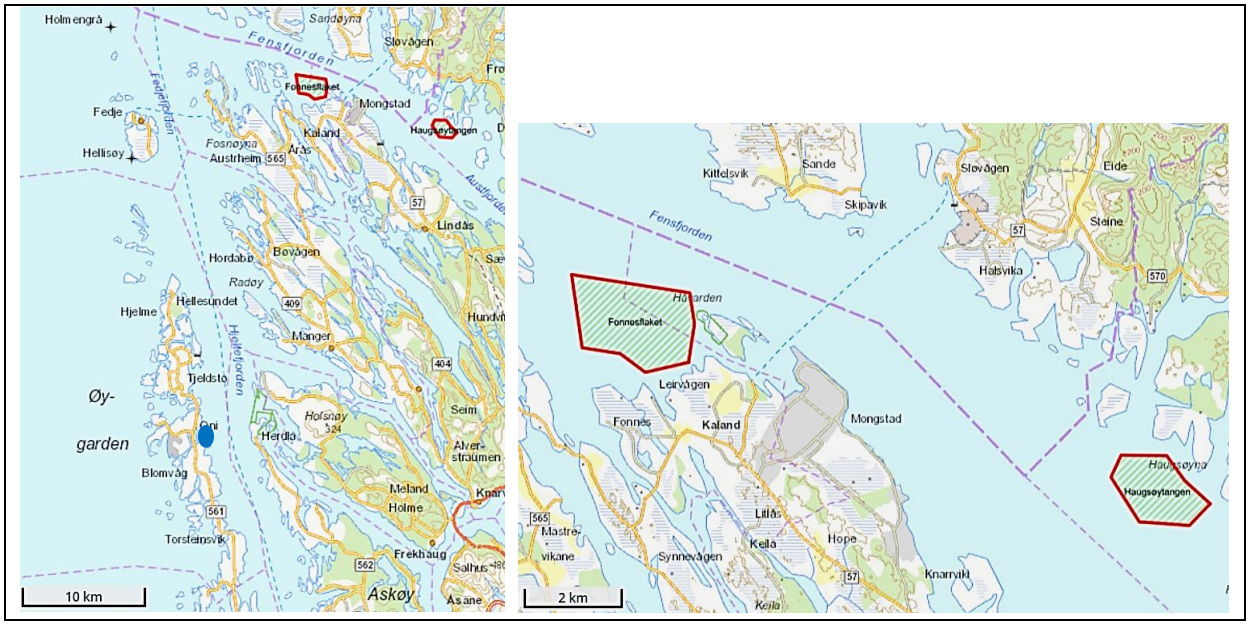
As consequences for shipping and maritime safety are classified as negligible or causing some deterioration in the construction phase and negligible/very limited in the operations phase, consequences for shipping as an industry are considered to be **negligible**.

Anchoring sites

The Norwegian Coastal Administration has defined dedicated anchoring sites for larger vessels. The following anchoring sites have been defined for the areas Hjeltefjorden and Fensfjorden, cf. Figure 6-3:

- Fonnesflaket (Anchoring ID 12001), 3.54 km^2, west of Mongstad - Austrheim municipality
- Haugsøytangen (Anchoring ID 12029), 1.89 km^2, east of Mongstad - Masfjorden municipality

Figure 6-3 Registered anchoring sites in the Hjeltefjorden and Fensfjorden area. Naturgassparken is marked in blue. Screenshot from www.kystinfo.no



Assessment of impact and consequence

Development and operation of Northern Lights is not considered to cause any conflict or consequences for use of the defined anchoring sites Fonnesflaket and Haugsøytangen. Should the CO_2 vessels need to anchor due to adverse weather conditions or while waiting to call at Naturgassparken for unloading, they will be able to communicate with Fedje sea traffic central which will assign an anchoring site in one of the established anchoring areas.

6.5.2 Outside the scope of the PBA

After having passed the Baseline, the vessel is in the open North Sea, where traffic is less and more dispersed. On their way to the injection well, vessels will cross the north-south traffic separation scheme (TSS). Due to generally lower traffic volumes and sufficient space to give way to other vessels, other traffic west of the Baseline is considered to be **negligibly** affected by the pipelaying and other marine operations associated with the installation activities.

During the operations phase, transport vessels will travel along the coast between Oslo, Brevik and Øygarden, and will become part of the ordinary maritime traffic along the coast. Vessels will follow the established fairway system and relate to other maritime infrastructure as normal. **No** impact or consequences are expected for other maritime traffic along the coast.

Assessment of impact and consequence
As there is not expected to be any significant impact on shipping traffic, consequences for shipping as an industry are considered to be negligible. Overall consequences for the shipping industry are thus considered to be **negligible**.

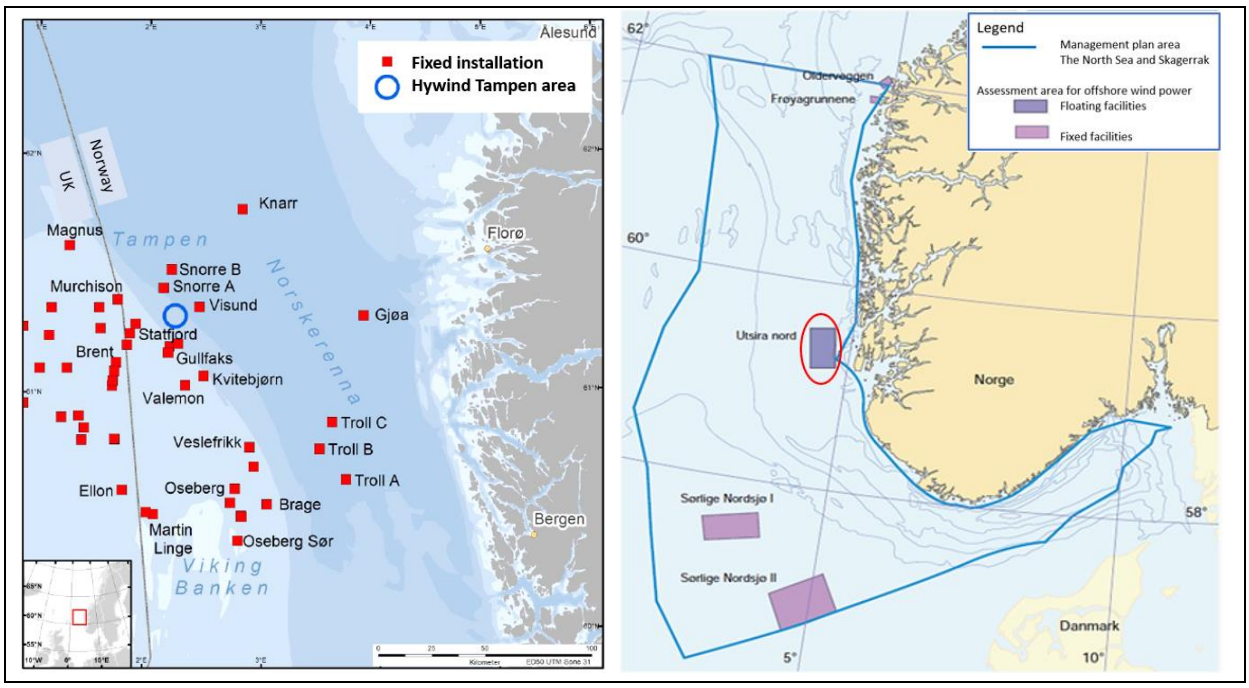
6.6 Offshore wind power

Current condition
Equinor and its partners in the Snorre and Gullfaks licences (PL050, PL057 and PL089) are planning to develop and operate the Hywind Tampen project in the Tampen area, located in the north-western part of the North Sea. The project will consist of 11 floating 8 MW wind turbines, with a total capacity of 88 MW, cf. Figure 6-4, left. Six of the turbines will supply electric power for the Snorre A facility, whereas the other five turbines will supply power for the Gullfaks A facility. The impact assessment for the project will be submitted for public consultation in March 2019 (link). Hywind Tampen is scheduled to come online in the autumn of 2022.

The Norwegian Marine Energy Act paves the way for energy production at sea through development and establishment of offshore wind facilities. The Norwegian Water Resources and Energy Directorate (NVE) has identified analysis areas for offshore wind energy and has also prepared a strategic impact assessment. The correlation between future offshore wind developments and other use of the sea areas was addressed as part of the work on the Integrated Management Plan for the North Sea and Skagerrak, including potential conflicting interests and the need for coordination.

In the Management Plan, an area of 1,010 km^2 west of Karmøy and Utsira in Rogaland county has been identified for analysis of future offshore wind power – "Utsira North", as presented in Figure 6-4, right. There are currently no wind power facilities in the area. In the summer of 2019, the Ministry of Petroleum and Energy proposed to open up the Utsira North area to applications for offshore wind power development. The proposal has been circulated for consultative comments (MPE press release).

Figure 6-4 Location of Hywind Tampen (left) and the assessment area for floating and fixed facilities for production of offshore wind power (right). Figure 4.11 in Report No. 37 (2012 – 2013) to the Storting (legend translated).



Assessment of impact and consequences

The entire Northern Lights project and influence area will be located far south of Hywind Tampen (indicated in blue in Figure 6-4) and far north of the Utsira North area (indicated in red in Figure 6-4). Development and operation of the Northern Lights project will have no consequences for Hywind Tampen or for the development of offshore floating wind power in the Utsira North area.

6.7 The petroleum industry

Movement of stored CO_2 inside the storage complex is not considered a leak to the surrounding areas, but defined as migration in the regulations. Assessment of leakage risks and potential impact on nearby petroleum facilities has been described in Chapter 3.14.4, and reference is made to this chapter for further evaluation.

Current condition and value

Below follows a summary of the evaluations in Chapter 3.14.4. It describes how injection and storage of CO_2 may affect the existing petroleum industry in the vicinity of the storage facility in Aurora. As shown in Figure 3-21 the mapped structure indicates that injected CO_2 will move northwards. The producing reservoirs in the Troll Vest area are located 15-20 km north of the injection point, and at a vertically level several hundred metres shallower than the Johansen and Cook formations, cf. Figure 3-22. The possibility of injected CO_2 reaching this hydrocarbon zone before the Troll Field is shut down, has been evaluated. Simulations of how CO_2 migrates over time show that this is highly unlikely.

East of the injection well, the structure drops off into deeper area (indicated in blue in Figure 3-21), which prevents CO_2 migration towards Troll Øst (East). The same applies to migration towards the west and the Brage and Oseberg Øst (East) fields. The Johansen formation thins out completely towards the west and is not present on the two fields. The Cook formation is spread out over a larger area and present, but due to its

structural configuration, injected CO_2 will not migrate westwards towards these fields. The upper Cook Formation has the same structural configuration as the upper Johansen formation and CO_2 in the Cook formation will migrate northwards towards shallower levels.

The hydrocarbon resources in nearby geological reservoirs are of a very high value and generate value creation and employment through petroleum industry in the area.

Assessment of impact and consequence
Due to the structural configuration, injected CO_2 can only migrate towards the north. Simulations of how CO_2 migrates over time show that it is **highly unlikely** that CO_2 will reach the hydrocarbon-bearing zone in the Troll Vest area before the Troll field is shut down. The PDO for Troll Phase 3 was approved in December 2018 by the authorities, with a scheduled production period from Troll Vest from 2021 till beyond 2050.

6.8 Agriculture

One previous option was to install the export pipeline by burying it in a trench that would run westwards over land towards the Kollsnes gas terminal, with landfall towards the sea, north or south of the gas terminal, cf. Figure 2-5. Such a solution would have had consequences for use of the pipeline route as a grazing area, both during and for a while after the construction activities. The onshore pipeline solution towards the west was abandoned in May 2018.

Current condition and value assessment
The Naturgassparken landowner CCB Kollsnes AS has purchased all property parcels at Ljøsøyna and is now the only landowner on the island. The aim of the land purchase was to develop industry by including it in Naturgassparken. Thus, the area holds no value as an agricultural area.

Assessment of scope and consequence
Development and operation of the Northern Lights project will have no impact or consequences for the agricultural industry.

6.9 Other onshore industries

There are several established companies with business activities in Naturgassparken. Below follows a brief overview of the businesses and how they may be affected by development and operation of the onshore facility.

<u>Existing activity in Naturgassparken includes:</u>

- Gasnor AS, LNG plant (liquid gas). Gasnor imports gas by pipeline from Kollsnes gas plant, focusing on the production, sale and distribution of LNG.
- BKK produksjon AS, cogeneration plant (generation of electric power from waste gas from the LNG facility). Transmission of generated power in cables to Gasnor LNG. Operated by Gasnor. Cooling water heat transferred to Mowi).
- Mowi AS, covered onshore wrasse aquaculture facility established to combat salmon lice in the aquaculture industry, for more details see Chapter 6.2.
- GE Energy (Norway) AS, testing of gas turbines
- CCB Kollsnes AS / Coast Center Base
- West team AS
- Torsvik elektriske AS

Mowi AS neighbours Naturgassparken and is the facility closest to the construction site, located at a distance of 250 meters southwest of the southern part of Ljøsøyna. The facility is located north of and close to Ljøsøyvegen, the access road to Naturgassparken and Ljøsøyna. West team AS and Torsvik elektriske AS are located by the entrance to Naturgassparken, at a distance of approximately 850 meters from Ljøsøyna. Other industry is located south of Ljøsøyvegen, near the quay facilities by the sea.

Assessment of impact and consequence
The construction work will involve blasting, levelling and landscaping of the construction site, depositing of surplus rock and piling. The traditional construction work will generate noise, vibrations and dust in the same way as any other construction work where rock blasting and handling of surplus materials is required. A mobile crushing facility will be used to crush rock material used to prepare the site. This will reduce the need to transport material to the construction site. All transport and depositing of soil and rock material will take place inside Naturgassparken.

The established deep-water quay operated by CCB Kollsnes will serve as a construction quay during the construction period. This will reduce the need for heavy transport on public roads. The use of the quay will be coordinated in close dialogue with CCB Kollsnes to avoid conflict with other users of the quay. Chapter **Error! Reference source not found.** discusses the increase in road traffic on Ljøsøyvegen. The increase in traffic due to construction activities in Naturgassparken has been estimated to cause insignificant changes to traffic load during the period. In dry periods, some fugitive dust emission will occur from the work and roads in the area. The prevailing wind direction in the area is south-southwest (cf. the wind rose in Figure 5-1), which will help minimise dispersion of fugitive dust to neighbouring businesses. Emissions of fugitive dust from the construction activities in Ljøsøyna are likely to be highest when the wind comes from the north and northeast, blowing towards the neighbouring companies located further south in the area. Wind from the northeast occurs only 10% of the time on an annual basis, and this is not considered to be a major problem.

Like the other neighbours, the covered onshore wrasse aquaculture facility (Mowi) will experience noise and vibrations from heavy construction work in Ljøsøyna. The rock-fill established between the southern part of Ljøsøyna and the mainland where the aquaculture facility is situated, is likely to dampen the vibrations somewhat. Chapter 6.2 concludes that the construction work is unlikely to cause any significant consequences for the wrasse farming.

Preliminary estimates indicate that, during the construction phase, the construction work will generate noise levels of between 55 and 90 dB during the day, within a relatively restricted area. The industrial area in the southern part of Naturgassparken will experience noise levels of between 55 and 65 dB, which is within the permitted level (cf. Figure 7-6).

During the engineering phase, Equinor has held meetings with neighbouring businesses in Naturgassparken. The company will continue to do so throughout the further engineering work, and after start-up of the construction work. Equinor will, in dialogue with the neighbouring companies, discuss potential measures to reduce any inconvenience that may arise in relation to implementation of the construction work, such as fugitive dust. The company aims to establish solutions for engaging in an open dialogue with affected neighbours, before, during and after the construction work. The selected civil contractor for the site preparation will be made responsible for implementing specific measures to reduce fugitive dust emissions, such as cleaning of roads, and watering of roads and stored uncompacted material in dry weather, etc.

The revised zoning plan for Naturgassparken was approved in December 2018. It promotes expansion of the industrial areas and establishment of new industrial activity in the areas both north and west of the existing businesses. This entails that realisation of the zoning plan will result in extensive long-term construction work and handling of uncompacted material in the area, regardless of implementation of the Northern Lights project.

Overall, the Northern Lights construction and installation work is considered to cause only limited inconvenience and challenges for neighbouring businesses in Naturgassparken.

Industry outside Naturgassparken

Development and operation of the onshore facility may have potential positive consequences for industries and companies that are able to supply goods and services during the construction and operation period, respectively, such as local and regional value creation and employment. This is described in more detail in Chapter 7.17.

Chapter 7.16 discusses increased opportunities for tourism and the travel industry as a result of the development and operation of the Northern Lights onshore facility. The site may become a potential travel destination as a result of increased interest in CCS as a climate policy. The discussions are based on experience from TCM at Mongstad. See Chapter 7.15 for a discussion of the potential for industrial and commercial development linked to CCS in a broader business perspective.

7 Societal impact assessment

7.1 Method

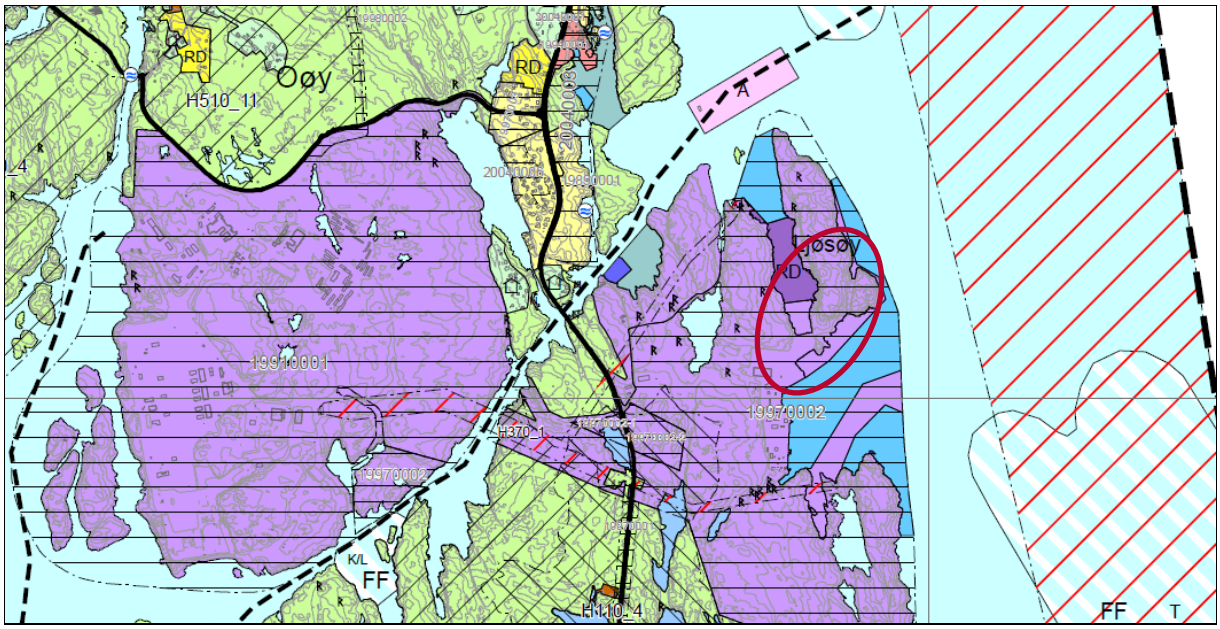
As a basis for descriptions and impact assessments of the construction and operation of Northern Lights in relation to a number of societal issues, Rambøll has prepared a base report (/8/). The numeric basis for Rambøll's impact assessments of traffic conditions, traffic safety and childhood environment (Chapter 7.4) stems from a traffic analysis made by the zoning plan consultancy ABO Plan & Arkitektur (ABO) (/32/). As part of the zoning work, a risk and vulnerability analysis (RVA) has also been made, which forms the basis for Chapter 7.5 (/22/).

The assessment method in the Norwegian Public Road Administration's handbook V712 of 2018 (/30/) is the basis for the assessments summarised in this impact assessment. The unpriced subjects focus on the effect that the initiative has on society, and the impact is assessed based on how the development project affects the reference situation, including location, dimension/scale as well as design. The assessment of the impact focuses on the operating phase, and any measures in the construction phase that will lead to changes. Moreover, the total impression of the scope will be assessed according to a five-part scale, ranging from greatly impaired to improved impact.

7.2 Plan status, land use and zoning work

Øygarden municipality and the land use part of the municipal master plan (2014-2022)
The development area has mainly been reserved for commercial activities in the current municipal master plan, see Figure 7-1. A future rock deposit in Ljøsøysundet is included in the land use part of the municipal master plan. This will be made up of material from the levelling of Ljøsøyna. In Hjeltefjorden there is a zone requiring special consideration for military training and two fishing grounds (north and south of Ljøsøyna). North of Ljøsøyna there is an area for aquaculture.

Figure 7-1 Status of land use part in the current municipal master plan for Øygarden municipality (2014-2022). Land regulated for commercial purposes is shown in purple, while LNF areas (agriculture, nature and recreation areas) are shown in green. Registered automatically preserved cultural heritage sites are indicated with a runic R.



Fedje municipality and the land use part of the municipal master plan (2012 – 2024)

The marine areas in the municipal master plan are mainly regulated for fairways and the use and protection of sea and waterways with associated beach zone. Some areas are regulated for aquaculture and casting and netcage sites, see Figure 7-2.

Figure 7-2 Status of development area in current land use part of the municipal master plan for Fedje municipality 2012-2024.

Zoning work for Northern Lights
The Northern Lights zoning plan covers the onshore and offshore areas that are necessary to implement the planned initiative. The zoning process has been carried out in accordance with the provisions of Chapter 12 of the Norwegian Planning and Building Act, cf. Chapter 1.8. The zoning plan was approved by both municipalities in late September 2019.

7.3 Landowner processes

To acquire the necessary areas for the onshore facility for receiving and temporary storage of CO_2, commercial negotiations were held in 2017 with the owners of the alternative land areas (Mongstad, Sture and Naturgassparken in Øygarden). An agreement in principle, has been entered into with CCB Kollsnes AS for the acquisition of southern parts of Ljøsøyna, subject to the Storting's positive investment decision and approval of the development plans.

The alternatives featuring umbilical, cable and pipeline routes across land to the west towards Kollsnes, and the alternative landing of a cable to Fedje were abandoned in 2018. Thus, there is no need to acquire land or rights to use third parties' land for these purposes.

The subsea pipeline from the receiving facility will be installed just east of the 14435 Ljøsøy Nord aquaculture site, where Blom Fiskeoppdrett AS' fish farm is located, see Chapter 6.2. The facility has anchor lines that stretch relatively far eastwards, towards greater depths in Hjeltefjorden. Due to seabed topography, it would not be recommended to place the pipeline further east. A dialogue will be started with the owner of Blom Fiskeoppdrett AS to find constructive solutions to avoid conflict with the anchor lines underneath the pipeline installation, and to address the concerns of the aquaculture site during operation of the transport system.

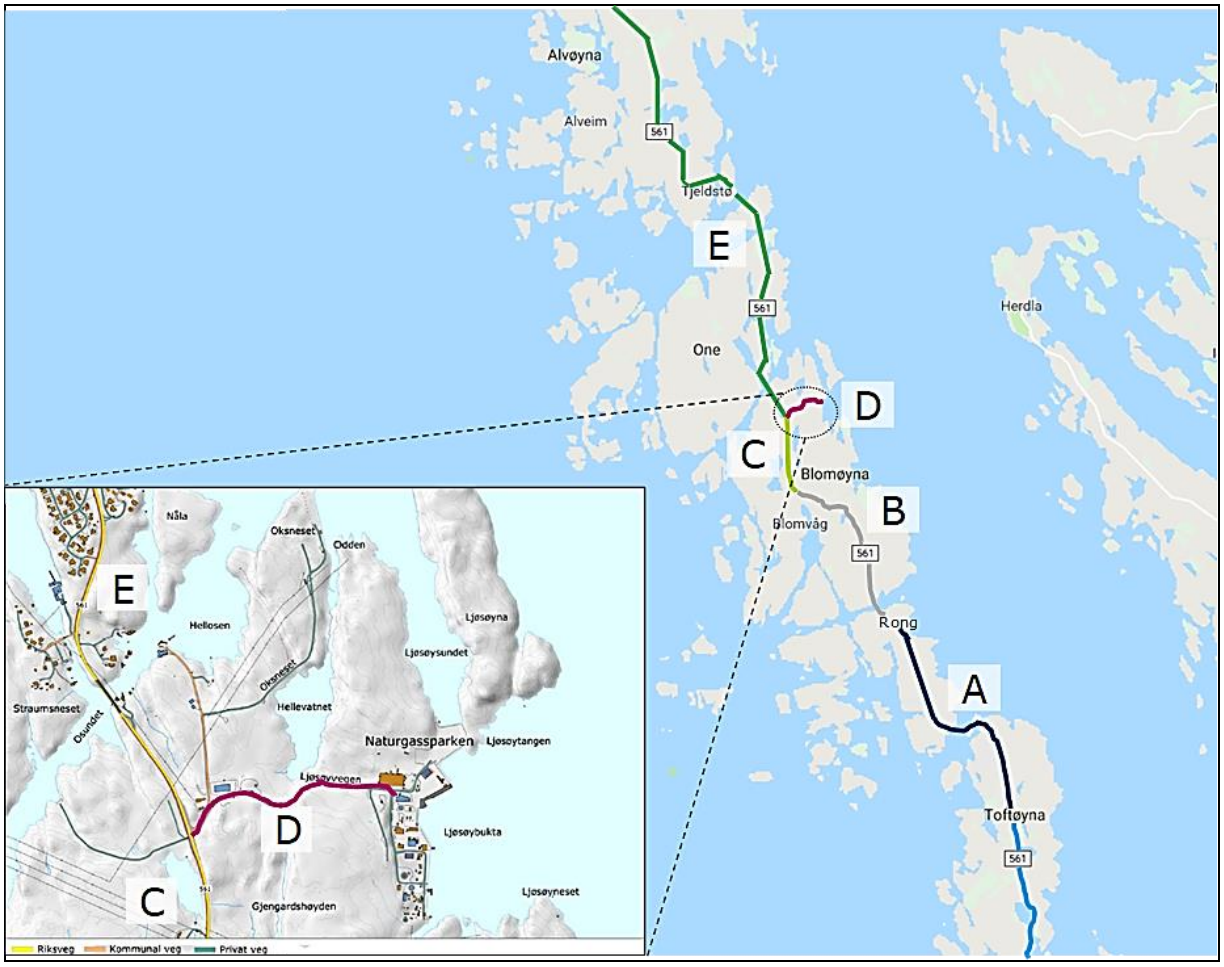
7.4 Traffic conditions, traffic safety and childhood environment

As part of the detailed zoning plan for the development project, the zoning plan consultancy ABO Plan & Arkitektur AS (ABO) has developed a traffic analysis (/32/), describing the current traffic patterns on land and at sea, and made projections up to 2040. ABO's traffic analysis provides the numeric basis for Rambøll's impact assessment of traffic conditions, traffic safety and childhood environment (/8/).

7.4.1 Road traffic

Current conditions and status
The land facility is localised in the Naturgassparken industrial area on the east side of Blomøyna at Ljøsøybukta. Today, traffic to and from Naturgassparken takes place on the Blomøyvegen county road (Fv561), which stretches around 36 km north through Øygarden municipality and the Ljøsøyvegen road of approximately 850 m, of which around 120 m is a municipal road. (see Figure 7-3). Ljøsøyvegen road forks north of the Dalsnesvegen road, which is a municipal gravel road leading to the Helleosen small craft harbour. Maintenance and development of the county road is the responsibility of the Norwegian Public Roads Administration, while the municipality is responsible for the municipal roads.

Figure 7-3 Fv561 and Ljøsøyvegen in Øygarden municipality divided into sections according to traffic load (AADT) indicated by letter and colour. From Rambøll /8/.



ABO's traffic analysis (/32/) estimates that the annual traffic load, or "annual average daily traffic" (AADT), on Fv561 is distributed among 5,200 AADT on Toftøyna in the south and 1,300 AADT on Alvøyna in the north. A more detailed distribution of the AADT for the Fv561 section is stated in Table 7-1.

Table 7-1 AADT for sections along Fv561 within Øygarden municipality. AADT for Ljøsøyvegen has been estimated by ABO.

Sections along Fv561	AADT (2019)
A. Toftøyna to Rong centre	5,200
B. Downtown Rong to Dale	3,800
C. Dale to Ljøsøyvegen exit road	2,900
D. Ljøsøyvegen	220
E. North of the intersection with Kollsnesvegen to Alvøyna	1,300

Of the annual traffic, approximately 7% belongs in the “heavy” traffic category, of which a considerable part is heavy traffic to and from the gas terminal at Kollsnes and the oil terminal at Sture to the north (section E), in addition to gas from the Gasnor plant in the Naturgassparken industrial area.

According to ABO’s estimates, the traffic at the intersection between Ljøsøyvegen and Fv561 (see map section in Figure 7-3) is distributed such that around 65% of the traffic turns south from Ljøsøyvegen to Fv561, while the remaining 35% heads north on Fv561. A bus lay-by has been made on the left side of Fv561, south of the intersection. The traffic load for Ljøsøyvegen has been estimated by ABO based on land use and functions related to the operation of Naturgassparken. The estimated annual traffic load will be around 220 AADT, consisting of road tankers, other major vehicles and common passenger cars.

County road Fv561 consists of two asphalted lanes with a separate broad bicycle and pedestrian path along the west side of the road, and it is around 7.4 metres broad. The road has been classified as a category 3 road with a speed limit of 80 km/h, and is the only road leading from the south to the north part of the municipality. Fv561 also functions as a school road on the southern stretches around Dale and Rong. The intersection between Fv561 and Ljøsøyvegen has a left turn deceleration lane in the southward direction. Ljøsøyvegen (see Figure 7-4) has two asphalted lanes with a pedestrian lane along the municipal part of the road, and it is around 7.4 metres broad. Ljøsøyvegen is dimensioned for heavy traffic to and from the Naturgassparken industrial area.

Øygarden municipality har registered a total of 163 traffic accidents in the period from 1977 – 2018 (41-year span, with an average of 3.9 accidents per year), of which around 80 % have been registered on Fv561 (/32/). Of these, 51 accidents have been registered on the section from Rong centre to the exit to Ljøsøyvegen, while 62 have been registered on the section from Rong and south towards Toftøyna. Most of the registered accidents are car accidents (71.2%), while accidents related to bicycles (6.1%) and pedestrians (10.4%) made up the lower share.

Figure 7-4 Ljøsøyvegen (top) and photos of exit from Fv561 to Ljøsøyvegen (bottom left) northbound and Ljøsøyvegen at the exit to Dalsnesvegen (bottom right eastbound). From Rambøll /32/.

Assessment of impact and consequences

Most of the equipment and components for the actual onshore facility are expected to be delivered by ship directly to the existing or a new quay at Naturgassparken. All transport and use of soil and rock materials will take place inside Naturgassparken, without any use of public roads. There will be some transport by road of building materials for the administration building and other buildings, such as reinforcement bars, sand and concrete, in addition to other minor building and equipment components. The use of a mobile crushing mill to crush rock material for levelling the site and landscaping will reduce the need to transport mass to the construction site. Certain special long-haul transports cannot be ruled out. However, based on a preliminary assessment, total road transport is still expected to be limited.

The traffic increase following from the construction activity in Naturgassparken is considered to yield just a slight change in traffic load throughout the construction period. This applies to all the sections that have been assessed, cf. Figure 7-3 and Table 7-1.

The establishment and operation of the receiving facility is expected to contribute to a certain increase in traffic along Fv561 and Ljøsøyvegen. The underlying assumptions for this future development are shown in Table 7-2 (/32/). The assumptions have been made by ABO, and contain a general increase in traffic, for example due to development and growth in the municipality, in addition to the additional traffic that the operation of Northern Lights will cause.

Table 7-2 Assumptions for increased traffic load along Fv561 and Ljøsøyvegen due to operation of the receiving facility. See Figure 7-3 for different road sections.

Traffic contribution / year	2019 - 2020	2020 - 2030	2030 - 2040
General increase in annual traffic	1.2 %	1.4 %	0.9 %
(A.–C.) & E. Fv561 (Toftøyna – Alvøyna)	2,900	2,935 – 3,373	3,373 – 3,656
D. Ljøsøyvegen	220	223 - 256	256 - 277
Additional traffic caused by CO_2 receiving facility	**0**	**0 - 41**	**41 – 44**

Consequences
In the operating phase, increased traffic related to the Northern Lights project will mainly consist of commuting personnel and visitors to and from the facility. The increased traffic in the operating phase has been estimated by ABO (/32/) and is listed in the bottom row in Table 7-2. In the operating phase, the increased traffic that the Northern Lights project contributes to corresponds to (an increase of 44 ADT in 2040) an average increase of around 13% in the traffic load along Ljøsøyvegen and 0.14% along Fv561. The traffic load on **Ljøsøyvegen** will thus be **somewhat** affected in the operating phase, while the increase for **Fv561** is so limited that the impact is considered **negligible**.

7.4.2 Childhood environment

Naturgassparken is zoned as an industrial area without any through-traffic. Neither are there any residential areas in close proximity to the area. The closest residential area is Rossnes. The assessment is that there are no interests related to childhood environment in the industry area.

Traffic safety in connection with the construction and operating phase has been assessed (/8/). All handling of dredging and surplus materials from the construction activities will according to plan take place inside the Naturgassparken industrial area, without any need for transport on public roads used by children and youth. A mobile rock crushing mill has been planned on the construction site for crushing of rock material for landscaping, which also makes a small **contribution** to the need for road transport along Fv 561.

The assessment is that the increase in traffic load will be negligible along Fv 561 due to construction and operation of the onshore facility. This, combined with several implemented and publicly planned increased traffic safety measures along the road, means that the impact and consequences for traffic patterns and childhood environment are considered **negligible**.

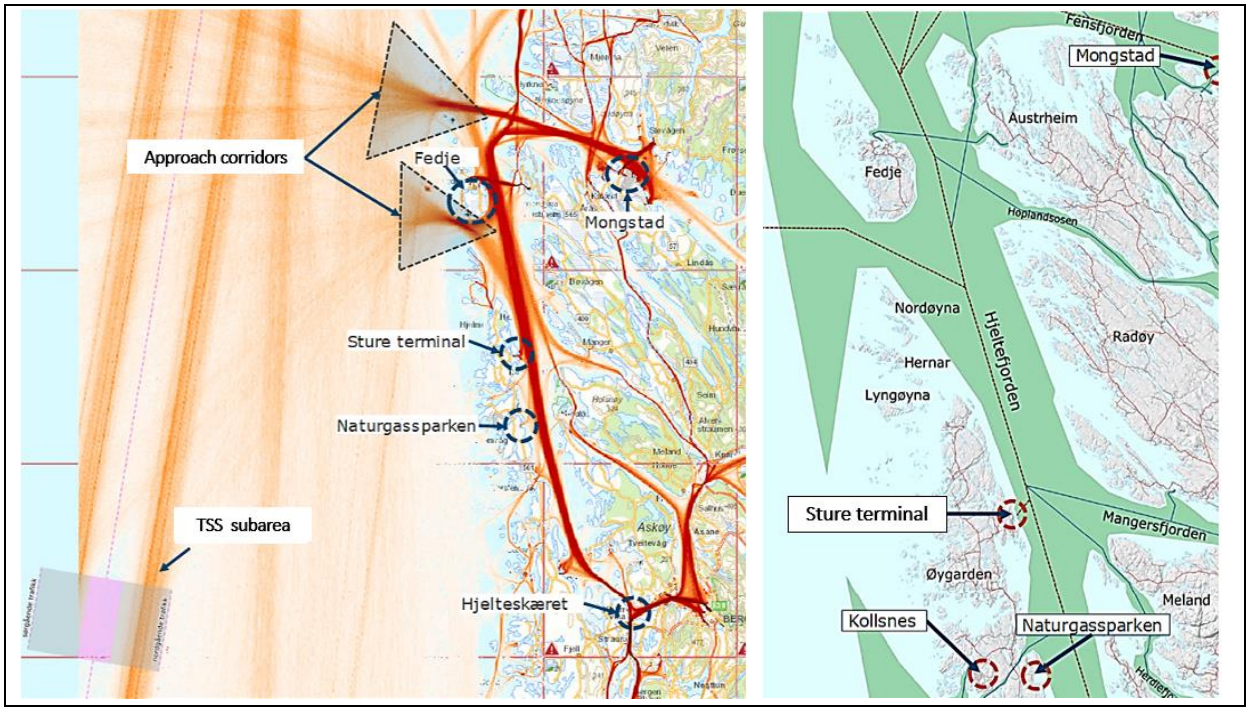
7.4.3 Sea traffic

Current situation and value

There is currently extensive ship traffic in the northern part of the North Sea, Fensfjorden and Hjeltefjorden. The traffic situation is characterised both by heavy coastal traffic and extensive transversal traffic to ports and supply bases, and by high traffic density (see Figure 7-5, left part). The ship traffic in the influence area is centred around three areas: The approach corridors to Fensfjorden (north of Fedje) and Fedjeosen (south of Fedje), and the approach south of Hjeltefjorden by Hjelteskjæret and Byfjorden to e.g. Bergen.

Due to the significant traffic load and complexity, a traffic separation scheme (TSS) has been implemented along the coast (TSS subarea). Ship traffic associated with particularly high accident and environmental risk should follow the marked routes. In the fjord system and along the coast there is a system of fairways, a main fairway and secondary fairways, see Figure 7-5. It is evident from the figure that the pattern and intensity of traffic varies considerably between the North Sea area, the approach corridors and the fjords.

Figure 7-5 Left: Ship traffic in the influence area (2016/2017 AIS data), parts of the North Sea and the approach corridors around Fedje, Hjeltefjorden and Byfjorden. The lines on the picture illustrate shipping routes in the period, where darker areas indicate heavy and frequent traffic. Right: Established main (red lines) and secondary (blue lines) fairways for ship traffic in the fjord system. From Rambøll /8/.



The approach area around Fensfjorden, Fedjeosen and Hjelteskjæret is characterised by heavy transverse shipping traffic, a narrowing of the sailing area and a great variation in types of vessel. This entails a very complex traffic situation in the area around Fedje and Hjelteskjæret by Byfjorden. In particular, the traffic to and from the Mongstad terminal in Fensfjorden accounts for a large share of the traffic load at the approach corridors (particularly at Fedjeosen) and along Hjeltefjorden to Bergen. Mongstad has 1,500 calls per year, which corresponds to around 43% of the total number of sailings in the area of influence.

There is a ferry connection on Fv 568 between Fedje and Sævrøy in Austrheim municipality. Fedje is located south and north of two of the most important approach corridors in the area. This means that there is heavy sea traffic, particularly north, east and south of the island municipality, Hjeltefjorden and the affected fjord areas around Fedje are considered to be of **substantial** value to ship traffic.

7.4.3.1 Within the scope of the Planning and Building Act (PBA)

Hjeltefjorden is a traffic artery from the northern part of the North Sea to and from Bergen, including the ship traffic to Naturgassparken and Sture oil terminal. In addition to Hjeltefjorden, Fensfjorden, Fedjefjorden and Fedjeosen are main fairways for shipping transport, while Osundet and Ulvsundet function as secondary fairways. (see Figure 7-5, right part). The ship traffic in Hjeltefjorden is characterised by high traffic density and variation in type and size of vessel. The sailing direction in the fjord is mainly parallel with the coast, with some transverse calls at ports and through secondary fairways to and from the North Sea. Some of the transverse traffic in Hjeltefjorden consists of calls to the Sture terminal and Naturgassparken, respectively. The Sture terminal receives some 120 oil and LPG tankers each year, while Naturgassparken receives between 100-150 calls each year, of which around 100 are gas tankers collecting liquid natural gas (LNG) from Gasnor. The remaining around 50 calls, consisting of general cargo ships, supply vessels etc., go to CCB Kollsnes (/32/).

Ship accidents and risk zones
Complex traffic conditions increase the risk for ship accidents. The accident risk is centred around the approach corridors north of Hjeltefjorden, and in the area around Hjelteskjæret and Byfjorden outside Bergen. While Hjeltefjorden carries a certain accident risk due to the relatively high traffic density, the risk in most of the North Sea is almost negligible. The Norwegian Coastal Administration's Vessel Traffic Service Centre on Fedje monitors and regulates the ship traffic to and from Bergen through Fensfjorden and Hjeltefjorden, and consequently also the ship traffic to and from Mongstad, Sture and Naturgassparken.

Assessment of impact and consequences
The existing quay at Naturgassparken will be used as construction quay during the construction phase. The construction work can be expected to have a certain effect on other calls to Naturgassparken. There is still room to approach the port in Ljøsøybukta, and proper coordination of activity will reduce the effect on existing traffic. Consequences for shipping traffic to and from Naturgassparken in the construction phase are thus considered to be limited.

The pipeline installation will take place by use of a laying vessel with dynamic positioning (DP). From Ljøsøyna, the lay vessel will move north in Hjeltefjorden at an average speed of around 4 km per day. During the pipeline laying process, the vessel will not have much opportunity to yield for oncoming traffic. In Hjeltefjorden, the pipeline will be laid parallel to the main fairway. The need for space and the limited ability to yield for oncoming traffic will entail a minor narrowing of the fairway around the pipeline laying operation as it moves forward. The assessment is that the pipeline laying could affect transverse traffic to and from the Sture terminal for approximately ½ day. The laying vessel and other vessels will have pilots onboard and keep active radio communication with the Fedje VTS Centre as well as other nearby vessels. In total, the impact and consequences for other shipping traffic in Hjeltefjorden is considered **negligible – somewhat impaired.**

South and southwest of Fedje, the pipeline will be laid across the southern approach corridor in Fedjeosen and to the west of Fedje, which means that the installation vessel for a stretch of 5 km will cross some of the busiest passages in the area. The extremely demanding seabed topography in Fedjeosen leads to reduced laying speed, and the assumption is that Fedjeosen will be affected for around 1.6 days. Based on analyses of AIS data regarding ship traffic in the area, it is assumed that some 8-10 ships will pass through Fedjeosen during this period. The consequences for other shipping traffic in Fedjeosen are considered **somewhat impaired**.

It has been estimated that the ship transport of CO_2 (1.5 million tons per year) to the receiving facility will entail around 195 extra calls to Naturgassparken each year, which amounts to an increase of 134 % in annual calls in Ljøsøybukta compared to the current traffic load. Of these calls, some 75% are expected to come from the northern part of Hjeltefjorden, while the remaining 25% will come from the southern part (/32/). The

ship transport of CO_2 will go directly to the facility's import quay, and any calls at this quay will not prevent calls at other quays in Naturgassparken. The increase in annual calls are therefore not assumed to affect current traffic in Ljøsøybukta. As for the traffic in Hjeltefjorden, transport to the onshore facility makes up less than 3% of the annual ship traffic. (/8/ and /32/). Based on the low accident risk in Hjeltefjorden near the receiving facility, it is not assumed that the traffic increase will have any consequences for other shipping traffic in the operating phase.

In the area around the approach corridor to Fedjeosen, the shipping of CO_2 will represent an increase of around 146 sailings per year, corresponding to a growth of around 4% or about 1 ship every other day. /8/ and /32/). The increased number of sailings is estimated to change the risk profile of the area from a theoretical probability of 0.46 accidents per year to 0.48 accidents per year as a result of the operating phase. The CO_2 transport coming from the southern part of Hjeltefjorden passes through a high-risk zone at Hjelteskjæret in Byfjorden. The small increase (less than 3%) in an the already very heavy traffic load at Hjelteskjæret is not considered a noticeable consequence for the ship traffic in the area during the operating phase. In total, the consequences for other shipping traffic in the operating phase are considered **negligible**.

7.4.3.2 Outside the scope of the Planning and Building Act (PBA)

The shipping pattern in the North Sea is characterised by heavy traffic load along the coast (parallel) and transverse traffic (e.g. to ports and approach corridors into the fjord system). In the area of influence, the transverse traffic concentrates around the approach corridors at Fensfjorden northeast of Fedje and Fedjeosen south of Fedje, respectively, cf. Figure 7-5. Beyond the TSS routes, the North Sea shipping traffic is relatively scattered and the vessel density far lower than in the fjords. This is illustrated by a lower colour intensity in the North Sea area in Figure 7-5. The annual traffic in the North Sea mainly consists of oil and product tankers, offshore and general cargo shipping and fisheries.

Assessment of impact and consequences

After crossing the baseline, the pipelaying vessel will be out in the open North Sea, with less and more scattered traffic, cf. Figure 7-5. North and southbound TSS routes will be crossed on its way to the injection well. In the North Sea, the low vessel density, and consequently the low probability of collision, in addition to the introduction of TSS areas, mean that the annual number of accidents is relatively low. Due to a lower ship traffic load in general and plenty of space for giving way, the impact of the pipeline laying on other traffic west of the baseline is considered **negligible**. In the operating phase, transport ships will sail along the coast between Oslo, Brevik and Øygarden, and will be part of the ordinary shipping traffic along the coast. The ships will sail in accordance with the established fairway system, and relate to other maritime infrastructure in a usual way. **No** impact or consequences are expected for other ship traffic along the coast.

7.4.4 The ferry connection with Fedje

Current situation and value

Fedje is an island community without any road connection to the mainland. There is a ferry connection between Fedje and Sævrøy in Austrheim municipality (county road fv568). This connection is the only public transport connection to and from Fedje, beyond organised tourist trips during summer, and is of very high value to the local community.

Assessment of impact and consequences

The ferry connection to Fedje will not be affected, and the project will thus cause **no** impact on or consequences for the ferry connection.

7.4.5 Assessment of need to upgrade local infrastructure

Current situation
The road system for transport to and from Naturgassparken consists of Fv561 and Ljøsøyvegen, which are described in more detail in Chapter **Error! Reference source not found.**. *Fv561* runs from Beinastaden to Blomvåg primary school, and from Dale to Skjold, and is classified in use class 10 and road group A. Between Blomvåg primary school and Dale, the classification is reduced to road group B, which means that the road is narrower. Fv561 has the capacity to handle special transports up to a length of 19.5 m, and with a maximum total weight of 50 tonnes. Fv561 is thus approved for special transports.

Assessment of impact and consequences
Provided that the constraint of 50 tonnes is maintained during the construction phase, it has been assessed that the road infrastructure will not be affected during this phase. As part of the zoning plan process, there are sequence requirements demanding the construction of a right turn deceleration lane from the south on Fv561 at the intersection with Ljøsøyvegen. The plan is to perform most of the heavy transport by sea, directly to the existing quay at Naturgassparken. No need for further upgrading of local roads has been identified beyond what is planned to carry out the project, and there is no need to upgrade any of the marine infrastructure.

In the operating phase, the increased traffic load is marginal, and both Fv561 and Ljøsøyvegen are considered to be dimensioned to handle the increased traffic required by the receiving facility in this phase. It has been assessed that there is no need to upgrade existing marine infrastructure.

Overall assessment of consequences
Following an overall assessment, there is no need for further measures to upgrade local roads beyond what has been planned to carry out the project. As a sequence requirement, a right turn deceleration lane will be constructed towards the north in the intersection between Fv561 and Ljøsøyvegen. Ljøsøyvegen will be extended from the public quay at Naturgassparken onto the construction site. Pavement will also be established to ensure the safety of pedestrians along this section of roan.

7.5 Risk and vulnerability analysis (RVA analysis)

The following description is based on an RVA analysis prepared by ABO Plan & Arkitektur (/22/) in February, last updated 19 September 2019, as part of the zoning plan pursuant to the provisions of the Planning and Building Act (Section 4-3) for the development project. ABO's traffic analysis provides the numeric basis for assessment of traffic conditions and traffic accidents, both onshore and at sea.

7.5.1 Method

The RVA analysis is based on the guide on civil protection in municipal land use planning *(Samfunnssikkerhet i kommunens arealplanlegging)*, prepared by the Norwegian Directorate for Civil Protection (DSB), 2017, and complies with the requirements of TEK17 (Regulations on technical requirements for construction works). The RVA analysis also complies with Øygarden municipality's acceptance criteria, adopted on 20 June 2012, in addition to the comprehensive risk and vulnerability analysis for Fedje municipality *(Heilskapleg risiko og sårbarheitsanalyse for Fedje kommune)* from November 2016.

Risk = Probability x Consequences	➡	Combination of probability and impact of an incident

A risk and vulnerability analysis is a systematic assessment of:

- Possible undesirable incidents that could occur in the future
- Probability that the undesirable incident will occur
- Vulnerability in systems, which could affect probabilities and consequences
- Consequences of the incident
- Uncertainty in assessments

Societal assets and types of consequences form the basis of the impact assessments in the RVA analysis. Safety includes the safety of the population. Society's ability to function technically, financially and institutionally is related to the "Stability" consequence type.

In the RVA analysis, probability is used as a measure of the likelihood of a specific undesirable incident occurring within the area for which the RVA analysis has been performed, based on our knowledge base.

Unambiguous criteria have been defined for probabilities and consequences. The results of the RVA analysis are inserted in risk matrices. This gives an overview of the assessment of probabilities and consequences related to the various undesirable incidents. The colour code is an expression of whether the risk is acceptable or not.

Risk acceptance criteria	
Red field / category	Unacceptable risk. Risk mitigation measures must be implemented, or more detailed RVA analyses must be made to invalidate the risk level.
Yellow field / category	ALARP zone, i.e. measures must be implemented to reduce risks to an ALARP level (= As Low As Reasonably Practicable). It would be natural to use a cost-benefit analysis as a basis for considering further risk mitigation measures.
Green field / category	Generally acceptable risk, however, further risk mitigating measures should be implemented when possible based on financial and practical considerations.

7.5.2 Risks assessed in the RVA analysis

Just west of the development area, there are several minor lakes, where Steinsvatnet, Eidevatnet, Heievatnet and Trondalsvatnet and the surrounding area have been registered as a special consideration zone in the land use part of the municipal master plan, i.e. H110 – Protected zone – catchment area for drinking water. An alternative onshore pipeline route crossing this zone, and conflicting with restriction provisions was previously considered. However, this alternative was abandoned in May 2018, and is thus no longer relevant. The planned development project will therefore not conflict with the H110 zone (cf. Chapter 7.11).

The following subjects have been considered in detail in the RVA analysis to visualise risks with study requirements in the zoning plan:

- Sea level rise and extreme weather
- Traffic safety
- CO_2 leaks and dispersion
- Chemical leaks
- Risk of fire and explosion
- Noise loads for third parties
- General safety

Of these undesirable incidents, the following were considered potential hazards:

- Traffic safety onshore (likely x some risk = **yellow category** for life and health)
- Traffic safety at sea (less likely x some risk = **yellow category** for life and health, less likely x some risk = **yellow category** for material assets)

- Handling of hazardous materials (unlikely x some risk = **green category** for life and health, unlikely x harmless = **green category** for environment, unlikely x some risk = **green category** for material assets)

For description and assessment of general safety and port security (ISPS), please see Chapter 3.15.4.

7.5.3 Conclusions from the RVA analysis

The probability of traffic accidents has been considered based on projections of traffic on the road network connected to the planned development project. The project has been estimated to generate a traffic load of 37 AADT. At the intersection of Ljøsøyvegen and Fv561, the current AADT has been estimated at 220, while the projection in 2039 is 320 AADT. An increased traffic load increases the probability of traffic accidents. The speed limit on Fv561 Blomøyvegen along the exit to the planned site is currently 80 km/h. One mitigating measure would be to reduce the speed limit on the county road in this area, and to establish a right turn deceleration lane at the intersection.

The probability of accidents at sea has been considered based on projections of expected shipping traffic generated in connection with the planned development project. Main fairway 1508 Hjeltefjorden is just east of the planned site and gives access to the quay at Naturgassparken. The ship traffic to and from Naturgassparken will amount to some 340 vessels annually, of which traffic to the CO_2 receiving facility on Ljøsøyna will constitute about 195. This represents an increase in ship traffic to Naturgassparken of about 130% (/32/). The planned development project will lead to a marginal increase in ship traffic in the main fairway of Hjeltefjorden, but the ship traffic to Naturgassparken will increase considerably. Assessments have been made in relation to quay planning. New quays will be placed in such a way that they facilitate safe manoeuvring of ships going to the CO_2 receiving facility and allow sufficient distance to the existing quay in Naturgassparken.

In accordance with regulations from DSB, the zoning plan shows land use restrictions with associated planning regulations for the neighbourhood and third-party activities (special consideration zones) around the planned onshore facility regarding undesirable incidents such as discharges of hazardous materials. Modelling of CO_2 dispersion shows that there will be no hazards for the nearby residential area (Rossnes). These factors have been described in more detail in Chapter 3.15.3 and Chapter 8.3.

The overall environmental risk in the water column and on the seabed for minor leaks from the pipeline (most conservative estimate/largest area of influence) is considered low. The total environmental risk on the surface for major leaks from the pipeline (most conservative estimate) is considered low to moderate. The result of the analysis is generally considered conservative as regards the method for calculating influence zones and consequences for overlapping resources. A detection system will be established, which will also be able to detect minor leaks.

On the basis of the performed risk and vulnerability assessments, the total assessment is that the impact on risk and vulnerability is **somewhat impaired**.

7.5.4 Relevant mitigating measures in the RVA analysis regarding risks and vulnerability

Traffic accidents
Mitigating measures could be to reduce the speed limit on the county road in this area.

Accidents at sea

New quay(s) will be placed in such a way that they facilitate safe manoeuvring of ships going to the CO_2 receiving facility and allow sufficient distance to the existing quay at Naturgassparken. In the event of an accident at sea, there is a risk of oil/fuel discharge, and this will be handled by the existing preparedness organisation.

Fire and explosion
The volume of combustible materials is very limited. Area restrictions (special considerations zones) in the zoning plan, with associated planning restrictions, should ensure the safety of neighbourhood around the planned development project from undesirable incidents. An emergency preparedness plan will be prepared for the facility, which will secure the limited volume of combustible materials within the area.

Handling of hazardous materials
There will be no industrial processing of liquid CO_2 at the receiving facility. Nothing should be added to or removed from the CO_2 arriving at the facility. Area restrictions in the zoning plan, with associated planning restrictions, should ensure the safety of the area surrounding the planned development project from undesirable incidents such as dispersion of CO_2.

The likelihood of damage to the pipeline, leading to a discharge of CO_2, for a period of 100 years has been estimated as low. Sensors measuring changes in pressure can detect major leaks. An emergency preparedness plan will be prepared for the facility for handling of undesirable incidents.

7.6 Possible accidental incidents with major emissions of CO_2

In the event of a major emission of CO_2, the medium will expand from liquid into gas and dry ice particles. The particles will gradually evaporate (sublimate) due to warming from the surroundings. The resulting gas cloud will be heavy and follow the terrain. The concentration will be greatest closest to the ground and will decline with the height above ground.

The direction of the emission will be of great importance to the dispersion of the gas. If the emission is directed upwards and is not slowed down by obstructions, it will turn into a gas jet which will be quickly and efficiently diluted, limiting the endangered area. If the emission is directed down towards the ground, the gas will quickly lose its impulse, and the dilution with air will be much less efficient and take longer. The gas will spread along the ground at low speed and follow the terrain towards low spots, and drain downwards to the sea surface if the terrain allows this, see Chapter 3.15.3.2.

The duration of an emission depends on where it happens, how quickly it is detected, and the system for sectioning and shutdown. Major emissions will be detected quickly, due to CO_2 gas detectors as well as the process monitoring system. Confirmed gas detection will close the automatic shutdown valves, and the discharge may be further restrained by means of the process control system or by operators opening or closing motor-operated valves. Automatic shutdown valves and other options for shutdown and isolation are described in Chapter 3.7.4.

Third-party risk, including nearby enterprises, residential area, shops etc., is acceptable according to DSB's acceptance criteria on which the special consideration zones in the zoning plan are based cf. Chapter 8.3.2. This has been described in more detail in Chapter 3.15.3.2.

7.7 Residential areas

Current situation
According to Statistics Norway, there were 4,897 inhabitants in Øygarden municipality at the end of Q2 2018 (/8/). In January 2020, the existing Øygarden municipality will be merged with the Fjell and Sund municipalities

into a new municipality ("Nye Øygarden"). The population in the new municipality has been estimated at 38,673 inhabitants. In Fedje, there were 565 inhabitants by the end of the second quarter of 2018, and the projections from Statistics Norway indicate that there may be 492 inhabitants there in 2030. If this projection turns out to be correct, there will be a reduced housing need in Fedje in 2030. The closest residential area around Naturgassparken is Rossnes, which is located around 1.2 km away. As for noise assessments regarding existing residents, see Chapter **Error! Reference source not found.**. The land use part of the municipal master plan (cf. Chapter 7.2) contains no plans for new residential areas in the immediate vicinity of Naturgassparken.

Assessment of impact and consequences

The project is still in the engineering phase, and contracts for the construction phase have not yet been awarded. Preliminary assessments indicate that there will be around 100-120 people involved in the construction activities in Naturgassparken. In the construction phase there will be available accommodation for personnel in Ågotnes and at Kollsnes gas terminal. In Ågotnes, there are 352 rooms located 21 km away from Naturgassparken. The accommodation at Kollsnes is 5 km away from the construction site, and comprises 139 flats and 211 single rooms, i.e. 350 rooms and apartments in total. Based on the ample accommodation capacity in the area, there is considered to be sufficient available capacity for accommodation in the construction period. The development project will not involve any activity in Fedje.

The number of permanent employees at the facility is not expected to be significant, and those working there will probably also be working in other positions at nearby oil and gas facilities (cf. Chapter 3.17). Most of the people who will work at the onshore facility in the operating phase are therefore expected to already be established with local residences in the area. There is thus considered to be no need to build any new dwellings for those who will be working at the facility in the operating phase. The future residential development in Øygarden municipality is expected to remain unaffected by the development project in the operating phase. A comprehensive assessment indicates that the development and operation of Northern Lights will have **no** impact on or consequences for the residential development in the area.

7.8 Noise

The mapping of noise levels and assessment of the consequences the noise will have for the community in the construction and building phases will be assessed based on noise analyses prepared by Multiconsult and Granherne, in addition to the traffic analysis prepared by ABO Plan & Arkitektur. These have been summarised in reference (/8/) from Rambøll.

According to the regulations, the defined limits for noise affecting third parties are as shown in Table 7-3. Noise levels below these limits are not assumed to lead to impaired societal conditions.

Table 7-3 Noise limits

Affected party	Maximum noise level allowed dB(A)	
	Day (07:00 – 22:00)	Night (22:00 – 07:00)
Residences, institutions and education	55	45
Business and industry	70	70

Current situation

The primary existing source of noise is Naturgassparken. Due to the distance between Naturgassparken and the closest residential area, the current activities at Naturgassparken are not considered to result in any

significant noise load. Gasnor has performed noise measurements for the operation of the LNG plant, showing that the company does not exceed the noise limits in the discharge permit (/33/).

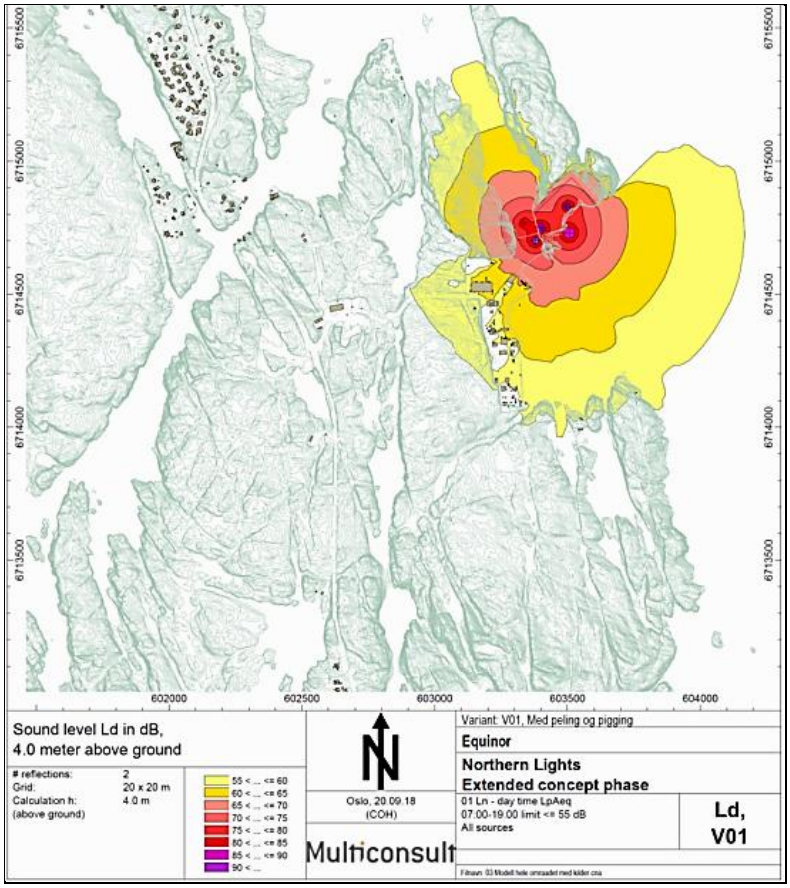
Another source of noise is the traffic along county road Fv561, as the residential area is located alongside this road. The average annual daily traffic (AADT) on Fv561 from the southern part of Toftøyna has been estimated at 5,200, where a considerable share (56%) of the traffic along Fv561 continues north towards and beyond the exit to Naturgassparken, up to the intersection with Kollsnesvegen to the north. The current noise load from traffic along Fv561 is thus not considered significant.

Assessment of impact and consequences

The blasting and landscaping prior to the establishment of the receiving facility will entail an increased level of noise during the construction phase. The primary sources of noise in the construction phase are drilling and blasting of rock, handling, transport and depositing of rock materials, crushing of rock materials, piling and dredging.

Based on these activities, a noise analysis has been prepared for the construction phase, where the noise contribution from all construction machinery has been modelled and mapped geographically. The noise model is based on the concept phase and is considered conservative, meaning that the noise levels could be overestimated. These early noise calculations are used as a basis for the assessments of noise and noise loads in the base reports to this impact assessment, cf. Figure 7-6.

Figure 7-6 Noise map modelled in concept phase of the construction period, noise during the day with all noise sources included. Estimate is considered conservative.



As shown in Figure 7-6, the construction work will produce noise in the range of 55 to 90 dB during the day in the construction phase, within a relatively limited area. The industrial area south of Naturgassparken will experience a noise level in the range of 55 to 65 dB, which is within the allowed limits.

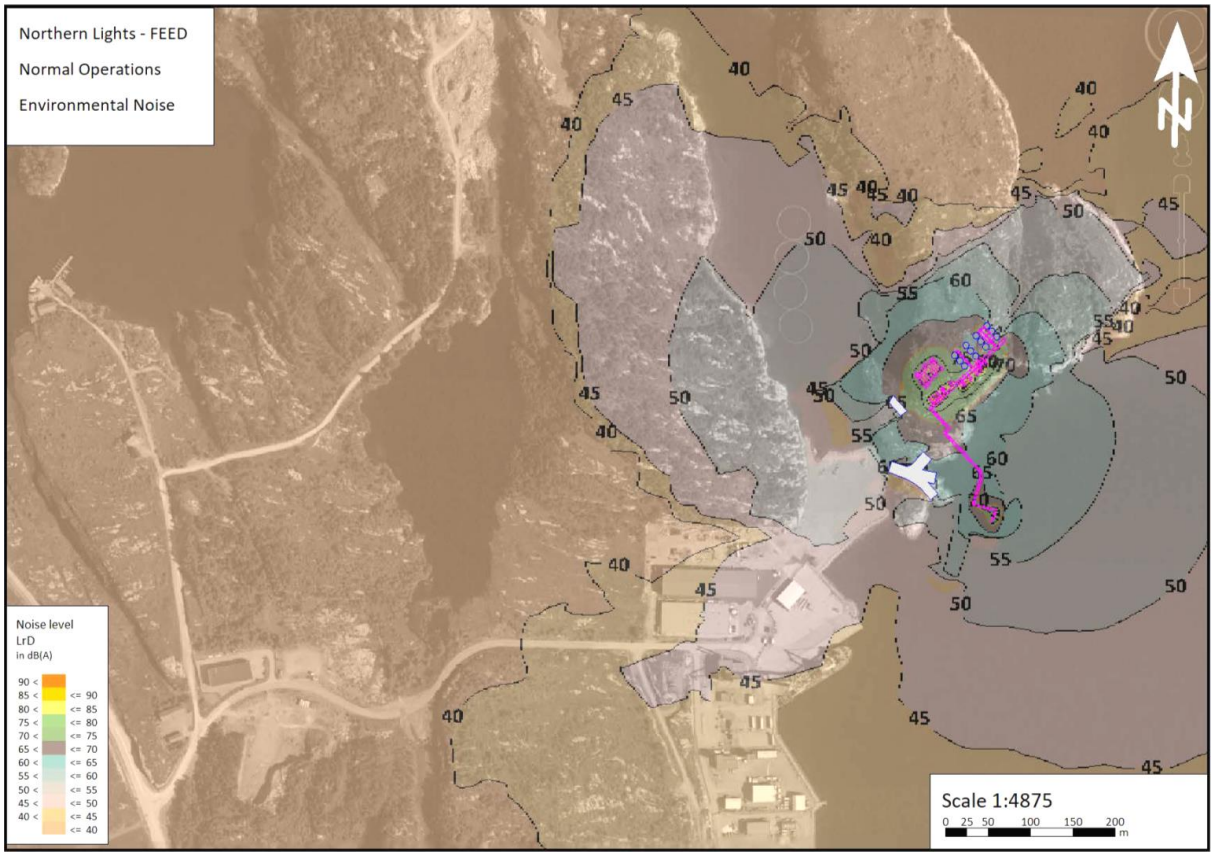
The model also shows that the residents of the closest residential area of Rossnes are unaffected by noise levels above the allowed limit of 55 dB. Surplus rock materials from the construction work will be deposited in Ljøsøysundet, and soil mass will be deposited in an approved landfill inside Naturgassparken. This means that there will be no transport of surplus materials from the facility on Fv561. Residential areas along Fv561 will thus not experience any noise from heavy vehicle traffic transporting surplus materials for deposit. Thus, no significant noise increase is expected for third parties along the road.

Operating phase

During the concept studies, a preliminary noise map was developed for the operating phase of the facility, based on previous noise models. This map was considered conservative and was used as a basis for the noise and noise assessments in the base reports to this impact assessment. These noise calculations were updated during the front-end engineering of the onshore facility. The updated map is shown in Figure 7-7, where the noise contours are superimposed on an aerial photo of Naturgassparken. The updated map generally shows a somewhat reduced noise load in the operating phase compared to the previous concept phase model.

During the noise modelling, a data acoustic model called SoundPLAN (version 8.1) has been used, including the CONCAWE prediction methods and international standards. The model considers noise generation from the receiving facility under ordinary operating conditions and 24-hour operation year-round. The noise model also takes the surrounding terrain into account, including the steep hillside north of the facility.

Figure 7-7 Calculated noise contours under normal operating conditions at the receiving facility in Naturgassparken.



The process plant is relatively small, with a limited amount of noise generating equipment. The noise limit for working environments is 85 dB(A) for a working period of eight hours. The noise model shows that the noise level will vary between 55 - 85 dB(A) inside the fence of the plant, which means that the requirement related to maximum noise limit in working environment will be achieved without any need for ear protection inside the industrial area.

The noise model shows that the required noise levels for third parties will be satisfied outside the plant during normal operation of the receiving facility. The maximum noise level for neighbours is 45 dB(A) at night. The closest neighbours to the receiving facility are the industrial enterprises at Naturgassparken, and the approved zoning plan calls for expanded industrial activity at Naturgassparken. The nearest residential area is located about 1.2 km northwest of the facility, and according to calculations, noise levels here will be lower than 30 dB(A). As shown in Figure 7-7, noise will already be reduced to less than 40 DB(A) just east of Hellevatnet.

Northern Lights will cause a marginal increase in traffic on Fv561 during the operating period, (0.14% per year in 2020-2030 and 0.13% per year in 2030-2040, respectively). Residential areas are sheltered by vegetation, and the traffic increase is very limited. The traffic increase is not considered to produce any further noise.

Consequences
Noise limits will not be exceeded, either in the construction or the operating phase.

7.9 Power requirements and connection to the power grid

7.9.1 Current situation concerning power grid and power supply

There are several power lines close to and passing through the area. A 420-kV power line between Mongstad and Kollsnes crosses north-western parts of the zone, with a subsea section northwest of Ljøsøysundet. There is also a 22-kV power line between the Kollsnes gas terminal and Naturgassparken, which has been laid underground through the area from Fv 561 to the industrial site. The southern part of the area has a power line route with several overhead sections. It features a 22-kV line in addition to a 132-kV line which is part of the section from Merkesvik to Kollsnes, with a subsea section southeast in Ljøsøybukta.

The Ljøsøybukta area is currently supplied with power based on gas from the Kollsnes gas terminal via a separate pipeline, combined with ordinary electricity supplied from the outside. Gasnor receives natural gas in a separate 6" pipeline from the Kollsnes gas terminal for LNG production. Waste gas from the LNG production is delivered to BKK Produksjon AS's co-generating plant, generating power which is supplied back to the Gasnor LNG plant in a separate cable. Heat in cooling water is transferred to Mowi (previously Marine Harvest Norway). A couple of companies in the area use sea water for cooling and heating, and this is a system which is possible to develop further. It is also possible to use surplus heat (waste heat) e.g. from a possible future biogas plant for heating.

BKK Nett AS is the grid owner and area licensee. The external power supply to Naturgassparken currently comes via Blomøy transformer station at Fv561. BKK has laid an underground cable along Ljøsøyvegen to a local grid station located centrally in Naturgassparken, which is owned and operated by BKK Nett. This local grid station is currently able to deliver 1 MW of power beyond existing consumption.

7.9.2 Power needs and grid connection

Current situation
A meeting was held with grid owner BKK Nett in 2018 to clarify the current grid situation and the need for future grid solutions to ensure the supply of electricity to the receiving facility. In the construction period, there is an estimated need of 1 MW of construction power. BKK Nett has confirmed availability of this, which can be supplied from the existing BKK grid station inside Naturgassparken without any reinforcements required.

During operation of the receiving facility, the estimated power need will be about 10 MW for Development Phase 1, and somewhat more for a possible subsequent Development Phase 2, depending on needs and the scope of any new energy-intensive equipment such as export pumps etc. During autumn 2019, new information has arrived, indicating that there is insufficient capacity in the region's transmission grid to support the operating phase, and Statnett is working to study and suggest what needs to be done in order to offer connections. Statnett will present the results from this study in summer 2020.

New grid stations for connections
As grid owner, BKK Nett will expand the Blomøy transformer and lay new underground cables to the existing grid station at Naturgassparken to provide increased levels of power in the operating phase. The construction period for these reinforcement measures will be around 2-2.5 years, from preparation of a license application until the installation of plants and cables is completed. BKK will not start this work until Equinor orders power supply for the operation of the facility.

From the existing BKK grid station at Naturgassparken, the following measures are planned for connection.

- BKK will establish a new grid station near the new administration building on Ljøsøyna. The grid station will be owned and operated by BKK Nett and will provide new and permanent power supply to the administration building.
- From the new grid station, a high voltage ring power grid will be established around the site. This ring grid will be located inside the permanent fence of the plant and will be owned and operated by the operator of the onshore facility. Local grid stations will be established along the ring power grid for internal plant distribution inside the fence. This includes the supply of shore power to CO_2 transport ships at the import quay during offloading of CO_2.
- As for energy supply to the actual process plant, a new grid station will be established inside the plant, which will be supplied via separate cables from an expanded Blomøy transformer station. The new grid station will be owned and operated by the operator of the onshore facility.
- No connection is planned between the grid station for the process plant and the high voltage ring power grid, as these will be supplied and operated as two separate and independent systems. This means, if there is a need to shut down power supply to the process plant for maintenance or a future expansion, power will still be supplied to the administration building and to other parts of the area inside the fence of the plant via the ring power grid.

There are no plans for new overhead power lines in the area. New connections will be laid underground or in culverts at the onshore facility. The operator of the onshore facility will have to apply for and be awarded a plant licence pursuant to the Energy Act (NVE is the licensing authority) in order to build and operate the high voltage grid.

Assessment of impact and consequences
There is sufficient construction power available from the existing BKK grid station at Naturgassparken. As of autumn 2019, there is insufficient capacity in the region's transmission grid to support the operating phase, and Statnett is working to study and suggest what needs to be done in order to offer connections. Statnett will present the conclusions from this study in summer 2020. Furthermore, it will be necessary to apply for a licence to expand the Blomøy transformer station (BKK Nett), and to establish new local grid reinforcement from Blomøy transformer station to Naturgassparken. A new grid station and a local grid for power supply to the receiving facility must also be established. There are no further plans for new overhead power lines in the area. Engineering and construction of any new grid systems will be performed in close dialogue with BKK Nett as the area licensee.

Based on an updated dialogue with BKK Nett in autumn 2019, there is new information indicating that the connection of additional consumption will be challenging until Statnett has concluded its ongoing studies. This includes the connection of Northern Lights with about 10MW to BKK Nett's regional grid.

7.10 Crossing third-party infrastructure

In order to cross third party infrastructure, crossing agreements must be entered into with the owners of the relevant infrastructure. These agreements govern how the crossing should be carried out, any measures for physical separation and protection, responsibilities and other factors. Model agreements have been prepared for use among companies on the Norwegian continental shelf under the auspices of the Norwegian Oil and Gas Association (NOROG), which should be used in such cases. These model agreements can also be adapted to industries other than the petroleum industry, as needed.

7.10.1 Within the scope of the Planning and Building Act (PBA)

The following third-party infrastructure needs to be crossed locally at Naturgassparken:

- Mowi – onshore sea water intake line
- Mowi – onshore discharge line

Other infrastructure that needs to be crossed will be mapped through the detailed engineering, and crossing agreements will be entered into with the relevant owners. Agreements must also be entered into for connections to existing infrastructure at Naturgassparken, such as the municipal water and sewage system. Several agreements must be entered into with BKK Nett AS, which will regulate the expansion, connection and operation of necessary infrastructure for supplying power to the receiving facility.

At sea, the following identified third-party infrastructure will be crossed by the CO_2 pipeline from the receiving facility out to 1 nautical mile outside the baseline, see Table 7-4.

Table 7-4 Identified third party infrastructure at sea within the scope of the Planning and Building Act that will be crossed by the CO_2 pipeline. Kp indicates distance alongside the pipeline from an onshore reference point.

Description	Owner	Kp (m)	External diameter (m)	Operating status
BKK power cable Ljøsøysundet – Kuvågen 2	Statnett	1426	-	In operation
BKK power cable Ljøsøysundet – Kuvågen 1	Statnett	1437	-	In operation
BKK power cable Ljøsøysundet – Kuvågen 3	Statnett	1450	-	In operation
BKK power cable Ljøsøysundet – Sætrevika	BKK Nett	1475	-	In operation
12" Mongstad gas pipeline (P182) - EVM	MGR co-ownership	1805	0.32385	In operation
BKK power cable Sture-Skansen (Merkesvik)	BKK Nett	6266	0.187	In operation
Unknown cable 01		8549		In operation
BKK power cable Sture - Storneset	BKK Nett	9535	0.05	In operation
BKK power cable Ådneset - Storneset	BKK Nett	9801	0.11	In operation
TELENOR communication cable Ådneset - Ellingsviki	Telenor	9876	0.11	In operation
BKK power cable Ådneset - Klubben (Toska)	BKK Nett	10966	0.11	In operation
12" Vestprosess pipeline P86D (VPS)	Vestprosess DA (Operator Gassco)	16741	0.32385	In operation
TELENOR communication cable Fedje-Hellesøy	Telenor	24866	-	In operation

7.10.2 Outside the scope of the Planning and Building Act (PBA)

The following identified third-party infrastructure will be crossed by the CO_2 pipeline west of 1 nautical mile outside the baseline, see Table 7-5.

Table 7-5 Identified third party infrastructure at sea outside the scope of the Planning and Building Act that will be crossed by the CO_2 pipeline. Kp indicates distance alongside the pipeline from an onshore reference point.

Description	Owner	Kp (m)	External diameter (m)	Operating status
36" Oil, Johan Sverdrup oil pipeline (P352)	Johan Sverdrup licence	39010	0.9144	In operation
42" Gas, Åsgard transport pipeline (P121)	Gassled	55917	1.0668	In operation
Kollsnes - Troll B power cable	Troll licence	65863	-	Planned
30" Gas, Kvitebjørn gas pipeline (P192)	Gassled	73280	0.762	In operation
Power cable Troll P60A	Troll licence	73558	-	In operation
36" Troll gas pipeline (P12)	Gassled	74208	0.9144	In operation
36" Troll gas pipeline (P11)	Gassled	74531	0.9144	In operation
36" Troll gas pipeline (P10)	Gassled	74793	0.9144	In operation
4" Troll glycol pipeline (P20)	Troll licence	74959	0.1016	In operation
Cable Troll P60	Troll licence	80110	0.054	In operation

Description	Owner	Kp (m)	External diameter (m)	Operating status
Cable Troll P61	Troll licence	80422	0.0752	In operation
Cable Troll P62	Troll licence	81043	0.0752	In operation
Power cable Troll P61A	Troll licence	83861	-	In operation
Power cable Troll P62A	Troll licence	84465	-	In operation

The following identified third-party infrastructure will be crossed by DC/FO cable and umbilical from Oseberg field centre to the injection well, see Tabell 7-6.

Tabell 7-6 Identified third party infrastructure that will be crossed by NL DC/FO cable and umbilical from Oseberg field centre to the injection well. KP indicates distance alongside the cables from J-tube at Oseberg A.

Description	Owner	KP (m)	External diameter (m)	Operating status
Oseberg umbilical Delta P	Oseberg licence	253	0.128	In operation
Oseberg umbilical/cable Vestflanken	Oseberg licence	371	-	In operation
Krafla MEG TEG pipeline	Krafla licence	386	0.0603	Planned
Oseberg umbilical B-51H ISU	Oseberg licence	399	-	Shut down, not in operation
Oseberg 12" oil pipeline OSØ - OSA	Oseberg licence	403	0.324	In operation
Oseberg 9" oil pipeline, PL1	Oseberg licence	461	0.219	In operation
Oseberg umbilical RCU 710	Oseberg licence	468	-	Shut down, not in operation
Oseberg Vestflanken 2, 9" oil pipeline PL2	Oseberg licence	484	0.219	Planned
Krafla OSA 16" oil pipeline	Krafla licence	493	0.324	Planned
Oseberg 2" methanol line 612	Oseberg licence	572	0.060	Shut down, not in operation
Oseberg 8" flowline 501	Oseberg licence	602	0.219	Shut down, not in operation
Oseberg 14" flowline MTS	Oseberg licence	703	0.356	In operation
20" Gas pipeline Troll – Oseberg B (TOGI – UK301)	Oseberg licence	728	0.508	Shut down, not in operation
Oseberg Vestflanken 2 umbilical UM-OSA-H	Oseberg licence	780	-	Shut down, not in operation
Oseberg Vestflanken RCU 706	Oseberg licence	844	-	Shut down, not in operation
Brage 12" oil export pipeline	Brage licence	915	0.324	In operation
20" gas pipeline Troll – Oseberg B (TOGI-UK301)	Oseberg licence	7 696	0.508	Shut down, not in operation
Statpipe 30" gas pipeline (P31)	Gassled	8 323	0.762	In operation
Communication cable 3 F3c	Shefa	24 713	0.043	In operation
Langeled Nord 44" (P231) gas pipeline	Gassled	30 826	1.118	In operation
Communication cable Danice segment 1	Farice Ltd	33 499	-	In operation

7.10.3 Relationship with interconnectors for power exchange

In its consultation statement regarding the proposed study programme, the Norwegian Water Resources and Energy Directorate (NVE) stated that in their view, the planned injection location and pipeline will not conflict with any known plans for interconnectors.

Current situation

An interconnector from Suldal in Rogaland County to Blyth near Newcastle in England is under construction (North Sea Link, Statnett), and the plan is to commission it in 2021. In January, a licence application was submitted for an interconnector from Eidfjord in Hordaland County to Peterhead in Scotland (NorthConnect). The plan is to commission this cable in 2023.

Assessment of impact and consequences
Both the planned interconnectors North Sea Link and NorthConnect have cable routes south of the areas affected by Northern Lights. The development and operation of Northern Lights will not affect or have any consequences for existing or known planned interconnectors for power exchange.

7.11 Drinking water supply

Current situation
Øygarden municipality is responsible for supplying water to the municipality, and supplies inhabitants and local business and industry from two main water plants (Alvheim and Blomvåg). Naturgassparken and the surrounding area get their drinking water from Blomvåg water plant, with the Steinsvatnet lake as its main source and Stølevatnet as a back-up source. (Øygarden municipality – water supply). The water plant has a capacity of 3,500 m³ with dedicated pumps and pipe systems supplying CCB Kollsnes and Naturgassparken. At any given time, the water plant can supply up to around 220 m³ per hour to the area (/8/). According to the plan, the receiving facility will need a fire water supply of 50 l/s and a drinking water supply of 4 l/s.

Assessment of impact and consequences
The development project's need for water supply will not exceed the existing supply capacity of Naturgassparken and is not expected to require any increase in capacity. The project is thus not expected to affect or cause any consequences for the drinking water supply in Øygarden municipality.

7.12 Municipal emergency preparedness, fire protection

Current situation
Øygarden municipality has an emergency preparedness plan that includes routines and instructions in the event of crises or disasters. A municipal crisis team will ensure necessary follow-up and help to the inhabitants of the municipality in an emergency situation. In the event of major accidents, disasters or crises, the municipality will establish an emergency response team to ensure proper overall management and correct prioritisation of resources.

The fire brigade must be able to respond on short notice in the event of fire, traffic accidents, sea rescue, oil spills or other urgent societal tasks. The Øygarden fire brigade is organised through the inter-municipal company Øygarden brann og redning IKS (ØBR), owned by the Øygarden, Fjell and Sund municipalities, and has a fire station in each of the municipalities. Øygarden fire station is located close to Naturgassparken, at the intersection between Fv561 and Ljøsøyvegen, see Figure 7-8.

Figure 7-8 Location of Øygarden fire station close to Naturgassparken. Kollsnes gas terminal to the left. From Rambøll /8/.

The fire station has a crew of 20 part-time employees on a fixed shift rotation, and is equipped with a crew car, a tanker, a "first response" car, a boat, surface rescue equipment. etc. ØBR also has administrative responsibility for the Norwegian Coastal Administration's oil spill protection depot at CCB Ågotnes. In addition to Øygarden fire station, crew and equipment from Sotra fire protection and Bergen fire department will be available on demand. Furthermore, the Norwegian Home Guard, Bergen civil defence district and non-governmental organisations can supply personnel if required.

Assessment of impact and consequences

During the construction phase, incidents could happen onshore at Naturgassparken or at sea in connection with the marine operations related to the installation work, which could cause oil or fuel spills to the environment. In the event of incidents onshore with associated oil and/or diesel spills, the building contractor will have oil absorbents on the construction site to remove the spill. The contract with the building contractor will include measures and procedures for maintenance, oil change, diesel refuelling etc. to avoid leaks, in addition to handling of incidents, if any.

In the event of a discharge from a vessel, there will be oil/diesel slicks on the surface. Waves, currents and microbial and photolytic processes will help evaporate, disperse or decompose the slicks. Since the pipeline route is planned to follow a fjord and to a certain degree close to the shore, it is very likely that a possible slick from an accidental discharge during the pipelaying process will reach the shore. However, long-term soiling effects are unlikely, as long as the released oil consists of diesel or other light oils, since it will evaporate quickly and be resolved with wind and waves. The marine operations will take place during summer.

Consequences

The planned construction work onshore and the marine installation activities will normally not entail any increased needs for emergency preparedness. In the event of undesirable incidents in the construction or operating phases, there will be internal and external alerts in line with the prepared notification plan for the project, including the fire brigade and the municipal oil spill response committee. The impact on and change in municipal preparedness is considered **negligible,** both in the construction and operating phases.

7.13 Municipal health services

Current situation
All the GPs in the existing Øygarden municipality are located at the same medical centre in Rong, about 6 km away from Naturgassparken. The medical centre treats inhabitants in need of emergency assistance during normal opening hours. The emergency ward has been transferred to Sotra emergency ward, or to Straume health centre. Sotra emergency ward is open 24 hours a day, however patients must call before they arrive.

Other facilities in Øygarden
In addition to the planned receiving facility, there are other industrial facilities in Øygarden municipality, i.e. the gas terminal at Kollsnes and Sture oil terminal. The Sture terminal is located just over 10 km away from the receiving facility, while Kollsnes is around 5 km from the facility. The facilities have continuous operations, and internal 24-hour preparedness. The preparedness function of the two facilities aims to implement measures to save lives, the environment and material assets if accidents should occur. There are other companies with preparedness plans at Naturgassparken, such as Gasnor. It would be natural to consider a preparedness cooperation with Gasnor, Naturgassparken and CCB Kollsnes, which operates the industrial park. In the event of a potential major incident at the receiving facility, it would probably also be possible to mobilise extra personnel and equipment from Sture and Kollsnes, in addition to health personnel and crew from Øygarden fire and rescue.

Assessment of impact and consequences
In January 2020, the Øygarden, Fjell and Sund municipalities will be merged into one municipality, with a total population of just over 38,000. The municipal health services will be dimensioned with a considerably higher capacity than for the current population of Øygarden, which is just below 5,000 people.

The construction and commissioning phases at Naturgassparken is at present planned to take just above 2.5 years from January 2021. During the construction period, there will be more people in the municipality than usual, although this will represent a marginal increase in the merged municipality. This could lead to a marginally increased need for health services.

Due to the nature of the construction work, a somewhat higher accident risk has been assumed compared to an average workplace. In the event of a sudden incident on board a pipeline or cable laying vessel, the injured person will probably be taken directly to the hospital in Bergen. The generally higher activity level could still entail a somewhat higher risk for increased use of health services, although we must expect this increase to be minor, since contractors will be assessed based on their HSE and accident track records. The number of people involved in the construction work will at all times be limited compared to the population in the municipality.

In the operating phase, there will be only a handful of people working at the receiving facility. Some of the time, the facility will be unmanned, monitored and controlled from a central control room located outside Naturgassparken. Work tasks will mainly consist of monitoring/office work, maintenance and non-hazardous work. Normal operation and maintenance of the facility has not been considered to lead to an increased need for health services.

Consequences
The construction and operation of the receiving facility in Naturgassparken is considered to have **no** or **negligible** impact on and consequences for municipal health services.

7.14 Water, sewage, waste and waste management

Current situation
Ljøsøyna is currently without any technical infrastructure, but there are connection points for municipal drinking water and sewage centrally located in Naturgassparken. The distance from the receiving facility to the connection points is short, about 350 metres. There is ample available capacity for water supply and discharge of waste water in the municipal sewage system. The supply of drinking water has been described in more detail in Chapter 7.11.

Øygarden's municipal services related to public waste disposal for dwellings are supplied through the FjellVAR company (water, sewage and waste disposal).The company is responsible for collection and recycling of waste, in addition to planning, development and operation of 18 waste stations and a recycling station in Straume, including seven waste stations in Øygarden. For waste from industrial parties, there is competition between public and private waste management companies. CCB Kollsnes, owner and operator of the Naturgassparken industrial area, has entered into agreements with waste management companies for skip hire and collection of waste from the industrial activities.

Assessment of impact and consequences
The receiving facility will have the following capacity needs within the currently developed capacity in Naturgassparken:

- Fire water supply: 50 l/s
- Drinking water supply: 4 l/s
- Waste water: 4 l/s delivered to existing sludge separator and sewage system

A water and sewage system will be established as part of the construction activity, connected to the existing public system at Naturgassparken. The temporary construction rig on the existing landfill will also be connected to the existing water and sewage system. A pumping station will be built to pump the waste water from the receiving facility to the connection point in Naturgassparken, for further transport to a treatment plant before it is discharged to sea.

Industrial and hazardous waste will be generated both in the construction and operating periods. In addition, transport vessels will deliver their waste at the import quay for further waste management onshore. A booth with waste containers will be built in the arrival zone near the administration building for easy access for waste collection trucks in the operating phase. During the construction period, waste stations will be established around the construction site, with containers for different waste fractions. The waste must be source separated in line with established systems in the region. Some hazardous waste will be generated in connection with maintenance of construction machines, such as oil rags, waste oil etc.

In the operating phase, the facility will be partly unmanned and partly have a small crew during normal operations. It is currently estimated that an annual amount of around 10-12 tonnes of ordinary waste will be generated from the operation of the facility. The transport vessels will also generate some waste. There will also be some waste generation in connection with visitors to the facility. Only limited generation of hazardous waste is expected during normal operation. More waste will be generated in periods with major maintenance work than during normal operations, both industrial and hazardous. Necessary agreements will be established with Naturgassparken or directly with the waste management company for skip rental and waste collection, both for the construction and the operating phase. Systems will be established for source separation and handling of hazardous waste in line with applicable regulations, for the construction as well as for the operating phase.

Consequences
The existing water and sewage systems at Naturgassparken are considered to have sufficient capacity to handle the needs of the receiving facility, and the facility is considered to have **no** or **negligible** impact and

consequences regarding water and sewage. No special waste issues are expected due to development and operation of the receiving facility, as there are good waste management systems for all types of waste in the region. The receiving facility is considered to have **no** or **negligible** impact and consequences regarding waste and waste management.

7.15 Potential for industrial and commercial development

Introduction
The possibilities for industrial and commercial development in general and CCS technology development in particular as a result of the Northern Lights project will be assessed in further detail in the following. The assessments are derived from a publicly available base report for this impact assessment, prepared by Rambøll (/8/), which for this subject is based on data collected from the government, the Ministry of Petroleum and Energy, the European Commission and concept descriptions received from the project.

The potential for tourism related to the receiving facility has been considered in Chapter 7.16, while the socio-economic consequences and spin-off effects of the specific cost estimates in the construction and operating phases are discussed in Chapter 7.17.

Like most municipalities in Norway, Øygarden too has experienced a transition of employment from the primary industries to an increasing share in secondary and tertiary industries since the 1970s. Kollsnes natural gas terminal and the oil terminal at Sture are currently the largest private employers in the municipality. The municipality aims to work on the establishment of industrial employment opportunities in industries related to gas, renewable energy and alternative forms of energy. This is reflected in the municipality's land-use policy, which emphasises that it must help reduce CO_2 emissions. The updated zoning plan for Naturgassparken (approved in December 2018) is set up for expanded industrial areas and development of commercial activities related to e.g. natural gas and CCS.

Carbon capture and storage technology (CCS) has developed considerably the last decade, and there is currently a broad, national and international company structure built around the development and use of CCS technology and its by-products. In the period from 2010 to the end of 2017, the number of international operating facilities increased from less than 10 to 18. Two of these are located to the southwest (Sleipner) and north (Snøhvit) on the Norwegian continental shelf, and both are operated by Equinor. Norway and Equinor with its associated licence partners are thus the only players in Europe with experience from storing CO_2 in offshore geological formations.

Norwegian experience with CCS technology
CCS has been designated as an essential measure to achieve the CO_2 emission reduction targets established in the Paris Agreement. The Norwegian market for developing CSS-related technology is dominated by the large oil and gas majors: Equinor, Sasol and Shell. These companies, along with Gassnova and Total, are co-owners of Technology Centre Mongstad (TCM, http://www.tcmda.com/no/). Total has experience with CCS facilities, too. Companies such as Aker Solutions, DNV GL, Norcem and Fortum Oslo Varme are important as regards services and consulting, as well as testing of CCS. Aker Solutions, DNV GL and Equinor all have offices in Bergen.

National knowledge and experience in the field of CO_2 capture was operationalised in 2012 through TCM at Mongstad, which is the world's largest centre for testing and improvement of CO_2 capture technologies. The centre has a capture facility for up to 100,000 tons of CO_2 per year, which makes it possible to test and escalate CO_2 capture technologies. The TCM facilities are at the disposal of companies and industrial enterprises for testing and demonstration of their solutions, and to reduce the risks and costs related to this.

Work performed at TCM provides a basis for the Norwegian authorities' regulation of emissions from CO_2 capture plants.

Over the last 10 years, Norwegian research communities and industry and technology suppliers have cooperated with international partners to carry out more than 300 CCS development projects, totalling about NOK 3.4 billion. This has stimulated international recognition of Norwegian research and industry within CO_2 management.

Since the establishment of the Sleipner CO_2 storage facilities in 1996, Norway and Equinor have gained experience with injection and geological storage of CO_2. Beyond this, considerable experience has been gained on a national level as regards transporting gas through pipelines. Gassco is the operator of an extensive gas transport system, consisting of several platforms and more than 8,800 km of pipelines.

In connection with the Norwegian full-scale CCS project, which includes Northern Lights, a number of feasibility studies have been carried out at three different industrial plants in Norway with a high level of CO_2 emissions. A number of leading Norwegian companies within CCS technology took part in implementing the studies.

Impact on and consequences for local and regional commercial development

All major procurement contracts related to the implementation of Northern Lights will be announced in international tender processes where Norwegian companies can also take part. When goods and services are procured locally and regionally, this creates direct as well as indirect value for the local and regional community. The demand for local and regional goods and services will thus help strengthen business and industry, which is directly and indirectly related to the delivery of goods and services for construction and operation of the project. Consequences of this related to both the construction and the operating phase have been considered and described in more detail in Chapter 7.17.

The location of the receiving facility in Øygarden, close to existing process plants, could – as experience from TCM has shown – provide synergy effects regarding e.g. infrastructure conditions. This could create incentives for CCS technology companies to establish or locate their operations locally or regionally.

If more companies move to the area, this could create a cluster effect in that the CCS expertise would increase in the area, which in turn supports the establishment of further CCS companies. Provided that the technical and political infrastructure facilitates such a future cluster development, this region and local area could become a Norwegian CCS cluster in the long run. The overall assessment of consequences for local and regional industry and commercial development is shown in Table 7-7.

Table 7-7 Impact on local and regional commercial development as a result of Northern Lights

Development phase	Impact on future local and regional commercial development	Impact
Construction phase	• Demand (short-term) for goods and services • Indirect effect (short-term) on existing goods and services	Improved
Operating phase	• Demand (long-term) for goods and services • Indirect effects (long-term) on existing goods and services • (Possible) attraction of CCS-related companies • Increased experience and stronger expertise within CCS technology • "Branding" of local and regional area within CSS technology and innovation	Improved

Both the construction and the operating phases of Northern Lights are expected to lead to **improved** opportunities for local and regional trade and industry, both to secure existing activity and to open up new development opportunities.

Consequences for commercial development within CCS technology on a national level
The engineering and construction phases will help develop expertise and knowledge in design and construction of the components and processes needed to establish and operate a full-scale receiving facility, transport, injection and geological storage of CO_2. This is expertise and knowledge that can be strengthened in this area in order to escalate the CCS value chain on a national and global level.

Specific experience with design and execution of technological full-scale solutions, in addition to the management of vast volumes of liquid CO_2, will create expertise and thus competitive advantages for the Norwegian CCS companies and industry. In the long run, this could create a market for exporting Norwegian construction and transport solutions and expertise. The sale of solutions and designs could also help strengthen Norwegian CCS skills and communities, which would reinforce the Norwegian competitive advantages.

The consequences of the operating phase for national commercial development are results of A) the direct experience gained from the actual transport and storage of CO_2, in addition to operation of the receiving facility and B) the facility's contribution to the CCS value chain. The direct experience developed through transport and storage could, just like the experience developed in the construction phase, increase national expertise within CCS solutions and help create a market for export. Beyond this, Northern Lights enables access to large-scale transport and geological storage of CO_2, and also creates a national and international market for the sale of geological storage space. Beyond the operating experience, Northern Lights would thus help support existing and other CCS-related industry in Norway. This is because full-scale transport and storage create a number of unique advantages, such as reducing market barriers and increasing demand for CO_2 capture for Norwegian companies and research communities (cf. Table 7-8).

In its summarised feasibility study for full-scale CO_2 management from 2016 (/3/), the Ministry of Petroleum and Energy identified a number of advantages which the transport and storage part of the CCS value chain could result in, see Table 7-8.

Table 7-8 Advantages for trade and industry and society in general due to a full-scale solution for transport and storage of CO_2. Excerpts of table 8.2.1 from OED (/3/).

Learning and dissemination	Economies of scale – storage	Safe and effective climate measure	Market situation
- Realisation and operation could provide learning from the capture source and the industry it represents. - Regulatory learning associated with full-chain CCS, e.g. carbon credit system, storage permits, HSE and the environment. - Establishing commercial model for CCS for involved commercial players in the chain. - Updated costs for full-chain CCS.	- Establishing storage with surplus capacity and storage operator will reduce a considerable barrier and costs for future projects. - Establishing standard terms for transport and storage of CO_2 will facilitate further utilisation of the storage site. - Quay facilities can be built flexibly to receive CO_2 from ships of different sizes. - Quay facilities will be more robust for various	- Realisation and operation of a single-source chain provides an opportunity to bolster the trust in and reputation of CCS. - A chain based on a single source results in considerable dependency on the availability and performance of the one industrial plant and capture project. - The solutions are based on technology ready for realisation on an industrial scale. - The storage solution will be based on familiar technology, as well as an opportunity to	- Establishing a full CCS chain will increase commercial interest in CCS and further developing CCS technology. This is expected to stimulate supplier markets and bolster research and development efforts in the field. - Building/rebuilding ships for CO_2 transport will increase market expertise for this type of ship. - Establishing CO_2 infrastructure will

Learning and dissemination	Economies of scale – storage	Safe and effective climate measure	Market situation
- Full-scale demonstration of capture provides opportunities to further develop technology. - Establishing infrastructure that can handle more CO_2 in the future, represents an option value.	weather conditions than direct injection. - Storage and storage solution could be developed as a hub for additional volumes of CO_2.	use standardised transport solutions. - The measure costs for the alternative will be 2,000 NOK/tonne CO_2, but will vary depending on the volume captured in the chain. - In this instance, the transport ship can be scaled back to actual needs and contribute to reduced operating and investment costs.	facilitate a CO_2 storage market for other emission owners.

These four main categories of advantages will together help break down e.g. the price and maturity barrier for future development of CCS technology and solutions. The Northern Lights project could thus support national innovation and technological maturity on the CCS market (see "market situation") and the development of unique Norwegian CCS-related expertise through "learning and sharing". Overall, this will support the future position and "branding" of Norway as a leading country within innovative CCS solutions and expertise.

Such a position will attract international attention from business and industry, research communities as well as from the tourism industry (typically the political kind or from special interest groups). This attention could help create cluster effects, since it will help attract international researchers and expertise, which in turn will support local and national innovation and development within CCS and other climate-related solutions. The total assessment of consequences for national commercial development is shown in Table 7-9.

Table 7-9 Impact on national industry and commercial development and branding as a result of Northern Lights.

Development phase	Impact on future national commercial development	Impact
Construction phase	• Export of knowledge and expertise, including cluster effects due to strengthened experience and knowledge.	Improved
Operating phase	• Increased export opportunities for CCS technology, solutions and expertise • Reduction of market barriers to development and innovation of CCS technology and solutions • Strengthened national brand as a leading country within CCS technology • Cluster effects strengthening the Norwegian competitive position	Improved

Both the construction and operating phases of Northern Lights are expected to lead to **improved** opportunities for national trade and industry, both to secure existing activity and to open for new development opportunities.

The administration building in the receiving facility in Naturgassparken will include an area for visitors to the facility (see Chapter 3.7.4). The visitor area will be established to receive and attend to visitors who for various reasons are interested CCS, and to inform about and demonstrate CCS and the Norwegian full-scale project in general, and the transport and storage of CO_2 through Northern Lights in particular.

7.16 Potential for tourism associated with the receiving facility

In its societal impact assessments, (/8/) based on the municipal master plan and experiences from TCM at Mongstad (Technology Centre Mongstad), Rambøll discussed the potential for tourism associated with the Northern Lights receiving facility and in Øygarden municipality in general as a result of the project. Rambøll gathered experience from TCM based on annual reports and a conversation with the head of communications at TCM.

Current status
The Øygarden municipal master plan for 2014-2022 emphasises the importance of stakeholders within tourism, hospitality and experiences for employment and value creation in the municipality. The municipality has a number of different tourist attractions, where the majority are based on activities in the area's wonderful and diverse nature. Tourists come from around the world to enjoy this nature and many outdoor recreation activities. Despite the good resource base for tourism, the municipality has little to offer as far as hotel accommodations and food service. The importance of the tourism industry and the industry's improvement potential, means that the municipality has chosen to focus on and improve the industry, and is also part of the destination portal "Kysteventyret" *(coastal adventure)*. Cooperation with Kystmuseet in Ovågen will make the municipality a more attractive destination, both for ordinary tourists and those with more academic interest. The municipalities of Øygarden, Fjell and Sund will be merged into a single municipality in January 2020.

Technology Centre Mongstad (TCM)
The technology centre for CO_2 capture at Mongstad (TCM, http://www.tcmda.com/no/) aims to contribute to technology development and qualification for increased dissemination of CO_2 capture on a global scale, thus reducing the cost and risk of full-scale CO_2 capture. The Northern Lights receiving facility will have an operative terminal function associated with transport and permanent geological storage of CO_2.

Experience from TCM
TCM experienced significant interest during the construction phase, and more than 1,000 people from a broad range of backgrounds visited the facility; both politicians, bureaucrats, NGOs/non-profit organisations and people from the energy industry. The project attracted substantial international interest, with delegations from authorities and/or industry from several continents.

Interest has also been significant after the facility was opened. In January 2014, it was said that they had more than 5,000 visitors at Mongstad. TCM has an average of 300-400 visitors each year. There are also visits from schools and educational institutions, but recent figures for this are not available. Numbers from e.g. schools and educational institutions could be substantial with increased marketing. Most visitors are technology developers and suppliers, oil companies and other companies interested in using or learning about the facility (estimated at approximately 40%). There is a significant number of visitors from the parent companies in TCM, e.g. project managers and people who want to learn more about operations at TCM (estimated at approximately 30%). The private sector and representatives from the "CCS community", politicians and authorities as well as media account for the remainder, estimated at approximately 30% (approximately 15%, 10% and 5%, respectively).

TCM attracted increased attention again in recent years. Increased awareness around climate change and the Paris Agreement are likely contributors to this, as CO_2 capture and storage is considered to be a very important technology in order to achieve adequate emission reductions to reach the objective in the Paris Agreement. TCM recently signed a number of agreements that are expected to lead to increased visitor activity at TCM.

Assessment of impact and consequences of Northern Lights
Northern Lights will be the world's first CCS project to handle captured CO_2 from multiple independent sources without physical connection. The project and the receiving facility will therefore most likely also be interesting to the "CCS community" in Europe, even in the construction phase. It is also reasonable to presume that

companies and authorities from other countries will also express interest, as indicated by experiences from TCM. General increased focus on climate change and CCS means that an increasing interest in visiting the facility during the construction period is likely. The municipality's focus on tourism and facilitating hospitality etc., contributes to this likelihood.

During the operations phase, Northern Lights will be Europe's first real full-scale project, and therefore a "game changer" for CCS in Europe. There will be natural synergies between TCM and Northern Lights; for example, it would be natural to combine visits at TCM with the Northern Lights facility.

Similar to TCM, Northern Lights will be interesting to the CCS community both in Europe and globally. It is presumed that the composition of visitors will be relatively similar to the experiences at TCM. It is therefore considered likely that the visiting area at the receiving facility will increase the volume of tourists and travellers to Øygarden municipality. The potential for tourism and travel activity in connection with the receiving facility is expected to be at approximately the same size as for TCM.

Consequence
A considerable potential for tourism to the facility and area is considered likely both during the construction and operation periods. The scope could be in the same range as that experienced at TCM. This entails a positive impact on the potential and an **improved** situation for CCS-related tourism is particular and thus also Øygarden municipality in general.

7.17 Socio-economic impacts

7.17.1 Scope

For more detailed descriptions of what is included in the cost estimates as a basis for the socio-economic impact assessments, please refer to Chapter 3.19. The cost estimates do not include costs for construction and operation of ships to transport CO_2 from capture players to the receiving facility, cf. Chapter 3.19 and Section 1-6 (i) of the CO_2 Storage Regulations. Construction and operation of the transport ships will nevertheless result in employment and procurement of Norwegian goods and services, which will provide positive ripple effects in the Norwegian society. However, these effects are not described in the IA in the following.

Due to the lack of established, functioning CCS market mechanisms with purchase and sale of CO_2 for permanent storage, the implementation of Northern Lights will depend on partial state funding of the development and operations. The financial framework conditions for the project have not been clarified at the time of consultation for the present IA. There is therefore no basis for calculating the societal profitability of the project in the present IA.

The cost estimates that form the basis for the analyses are preliminary and associated with relatively significant uncertainty (+/- 30%), which also leads to relatively significant uncertainty in the socio-economic impact assessment. In the following, the socio-economic impact assessments are based on a report prepared by Rambøll (/28/). All cost figures are stated in MNOK-2018 values.

7.17.2 Investment and operating expenses

Investment costs
The investment costs for the project are based on preliminary concept studies from autumn 2018 with +/- 30 uncertainty, taking into account Oseberg A as offshore host installation for umbilicals to the subsea facility. The total investment costs associated with implementing the project amount to approximately NOK 6,354

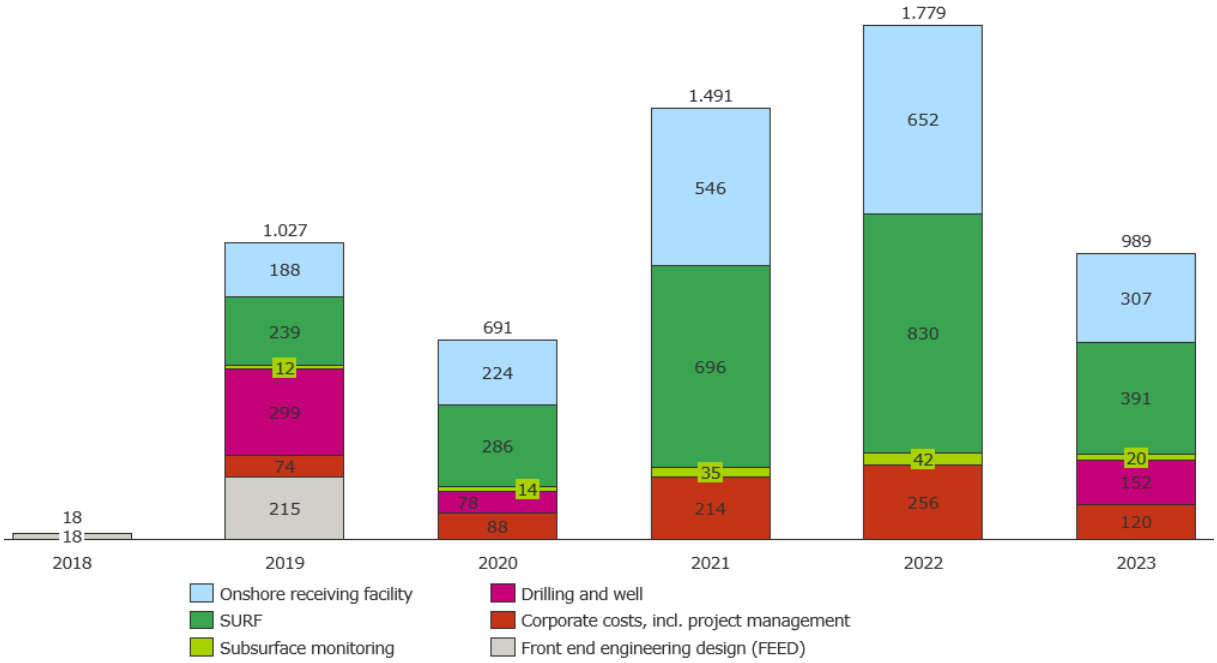
million in 2018 prices. This includes NOK 359 million for removal and cleaning of the subsea facility and onshore facility once the operating period is complete (25 years).

Project maturation and updates of cost estimates could lead to changes in the estimates. Unbiased investment and operating costs (+/- 20%) will be made available to the authorities through the submission of the PDO and PIO in spring 2020.

Figure 7-9 shows the investment distributed across the different main categories in the project. Please note that the costs of NOK 359 million in removal expenses once the operating period is complete are not included in the figure.

The largest investment component is SURF (collective term for costs associated with procurement and installation of the pipeline, subsea facility and umbilical- and power/signal cabel systems), which accounts for approximately NOK 2,400 million, corresponding to about 40% of the overall investment. Beyond this, establishment of the receiving facility at Naturgassparken accounts for approximately 30% of the overall investment. This comprises design and establishment of the actual receiving facility, including landscaping. The third largest investment component is partnership costs, including land acquisition and project management. This component covers internal costs in Equinor and its partners in the form of project management and other related project costs.

Figure 7-9 Investments distributed across components and years (MNOK 2018).



**) The costs of 359 MNOK-2018 for removal and clean-up of the subsea facility and onshore facility are not included.*
(SURF = procurement and installation of pipeline, subsea facility and umbilicals.).

The majority of the investment will take place in 2021-2022, with approximately NOK 3,300 million, which corresponds to more than one-half of the overall investment.

Even though the Northern Lights project is not a petroleum project, it is relevant to compare the investment with the total overall investment in petroleum projects on the Norwegian shelf. This is because implementation

of the project is based on much of the same equipment and same suppliers in the market as in traditional oil and gas projects. Overall investments on the Norwegian shelf are based on historical data from the Norwegian Petroleum Directorate on actual investments for the 2007-2017 period, as well as forecasts for future investments in the 2018-2023 period.

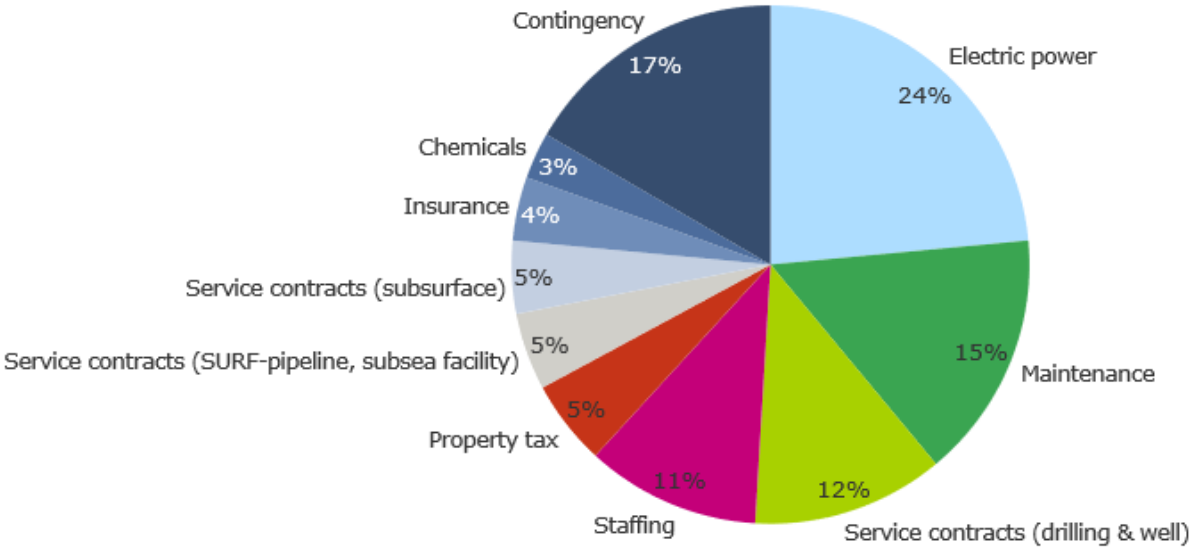
The project implementation coincides with a period with a lower expected investment level on the Norwegian shelf compared with the 2012-2015 period. The 2012-2015 period was characterised by a long period with a high oil price, with a dramatic drop in oil price over a short time in autumn 2014. The large Johan Sverdrup field will start production in autumn 2019, and this is a contributing cause to declining investments after 2019.

In the 2019-2023 period, investment costs for the Northern Lights project are estimated to account for between 0.5% and 1.7% of the overall investments on the Norwegian shelf.

Operating costs

The planned 25-year operating period for the Northern Lights project entails numerous annual costs. In the concept phase in autumn 2018, annual operating costs (+/- 30% uncertainty) were estimated at NOK 178.6 million (2018), distributed across main components as shown in Figure 7-10.

Figure 7-10 Percentage distribution of operating costs in the Northern Lights project.



About 40% of the annual operating expenses will be spent on electric power and maintenance. Beyond this, service contracts associated with drilling, wells and staffing account for an additional 20% of overall operating costs.

As a point of departure, no new people will be employed to operate the facility, but operations personnel from the existing facilities at Kollsnes and Sture (shared operating organisation) will operate the Northern Lights facilities as needed (24/7 basis). This will largely take place through a combination of different full-time equivalent percentages within existing flexibility in the operating organisation. At start-up, the plan is to use 9-12 full-time equivalents, which will be reduced to 7-10 full-time equivalents during ordinary operations. In the same way, maintenance will primarily be based on using existing personnel at Sture/Kollsnes and through the use and exploitation of existing maintenance contracts. For a more detailed description of the operating philosophy and staffing, please see Chapter 3.17.1.

7.17.3 Value creation in goods and service deliveries for development and operation

Both development and operating costs are expected to entail increased demand for Norwegian goods and services, and thus value creation and a number of employment effects, both nationally, regionally and locally. This chapter will highlight the expected value creation in goods and service markets, while the employment effects will be highlighted in Chapter 7.17.4.

In order to calculate value creation for Norway as a whole and for the region and local communities, we have mapped the share of overall costs for the Northern Lights project with an effect on Norway as a whole, the region and local communities, respectively. This applies for both the construction and operations phases. The point of departure for this is the breakdown of overall calculated investment and operating costs. Based on this and a presumed distribution of national, regional and local deliveries, we will calculate Norwegian, regional and local value creation for the individual main groups in the budget. All amounts are stated in 2018 kroner.

The Norwegian State's final investment decision to implement the project will not be made until December 2020, so contracts will not be awarded for quite some time. This means that commercial uncertainties could also affect the actual distribution of Norwegian and foreign deliveries. This is in addition to the cost estimates, which were prepared in the concept stage with an expected uncertainty of +/- 30%. There is therefore some uncertainty associated with the calculated value creation, which must be taken into consideration in the interpretation of results.

7.17.3.1 Value creation in the construction phase

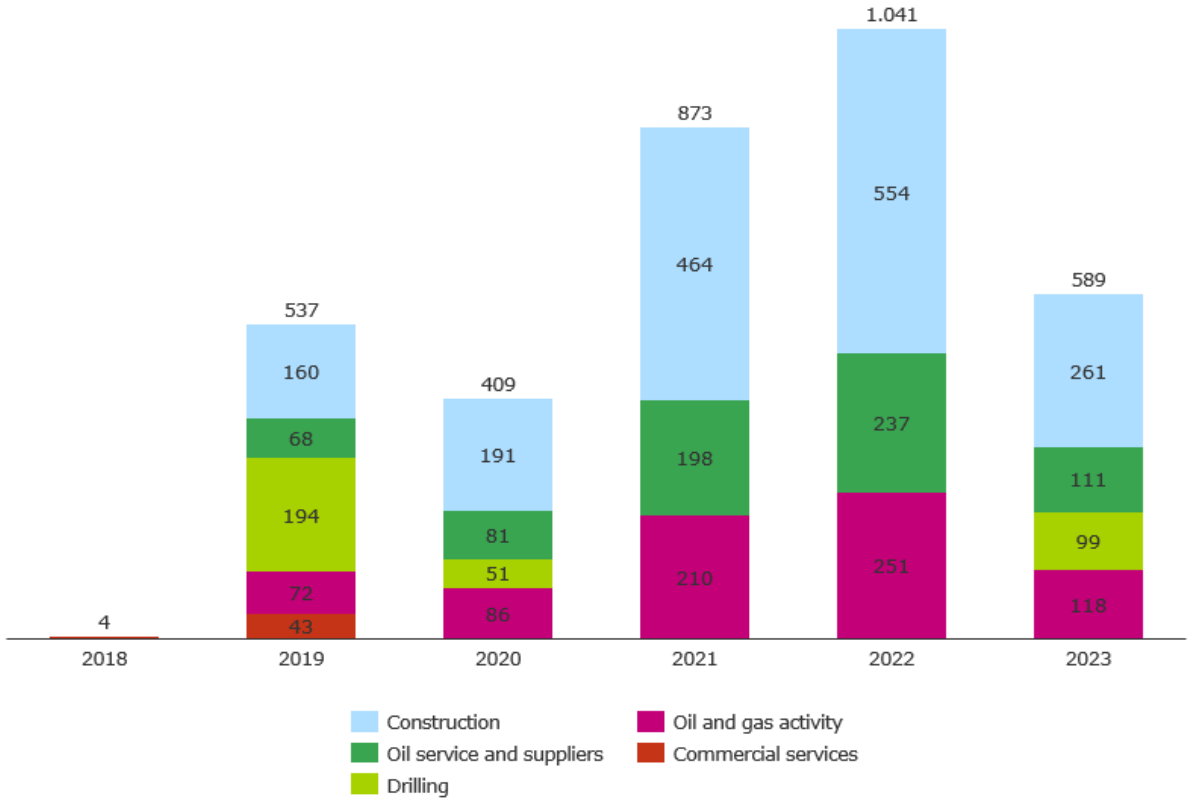
The overall investment costs are calculated at NOK 6,354 million. The presumed distribution of Norwegian, regional and foreign delivery shares is based on experience from previous projects as supplied by Equinor, and constitutes the basis for assessments of Norwegian and regional value creation. The analysis limits the regional area to Nordhordland, while the Norwegian area covers all companies operating in Norway. Some uncertainty is expected in the calculated value creation, both with regard to the Norwegian and foreign share, but also in the form of distribution between regional and the rest of Norway.

The Norwegian share of the value creation has been calculated at approximately 57%, which corresponds to approximately NOK 3,600 million. This is a higher projection than those found in the conclusions of studies of recent petroleum projects. For example, the Norwegian share of value creation for the Johan Castberg development is calculated at 48%, while the Norwegian share of export pipelines for oil and gas from Johan Sverdrup was 46% (low projection) and 52% (high projection).

The regional value creation is relatively limited, and is calculated at approximately 6%, which corresponds to approximately NOK 380 million. This corresponds to the level for regional value creation for the Johan Castberg development, where the share was calculated at 6.5% for Northern Norway.

A breakdown of value creation in the calculated Norwegian goods and service deliveries by primary industry and year is shown in Figure 7-11. More small industries could be involved in the delivery of a main component than what is reflected in the primary categories in the figure. Please note that removal of the subsea facility and onshore facility is not included in the figure.

Figure 7-11 Calculated Norwegian value creation distributed by industry and year in the construction phase (MNOK 2018).



The costs of 359 MNOK (2018) for removal and clean-up of the subsea facility and onshore facility are not included.

The Norwegian value creation from the Northern Lights project is NOK 3,453 million in the 2018-2023 period, and peaks in 2021 and 2022, with totals of NOK 837 million and NOK 1,041 million, respectively. Value creation is greatest within construction (NOK 1,629 million). Beyond this, there is significant value creation within oil and gas enterprises (NOK 737 million), oil service and suppliers (NOK 696 million) and drilling (NOK 344 million).

In the same way as for Norwegian value creation, calculations have been carried out for the regional value creation distributed by industry and year. As expected, the greatest regional value creation takes place in 2021 and 2022. The largest value creation item is within construction, which accounts for nearly 80% of the calculated regional value creation. This corresponds to NOK 287 million in the 2019-2023 period. There will also be lower value creation items in oil and gas activities (10%), drilling (7%), as well as oil service and suppliers (3%).

7.17.3.2 Value creation in the operations phase

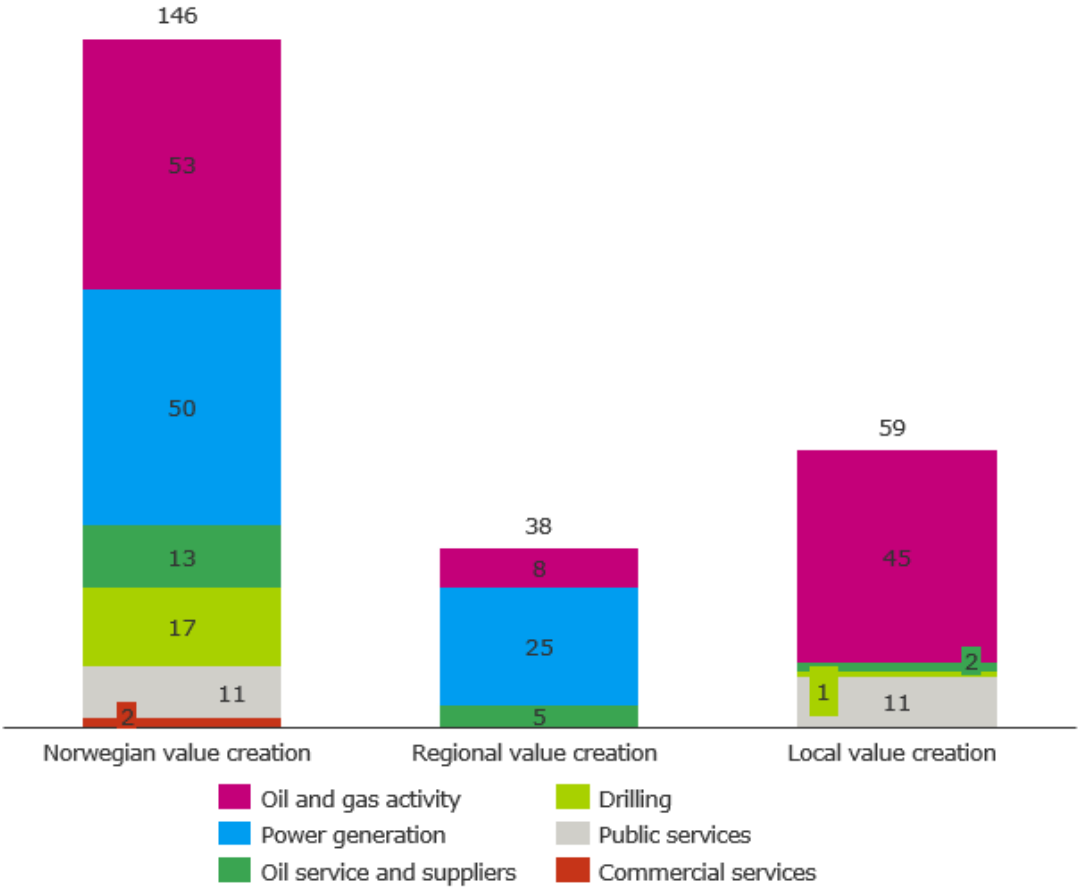
The largest share by far of the value creation in the operations phase is Norwegian, as the operations personnel are exclusively Norwegian, and a significant share of the other deliveries of goods and services associated with operations are expected to be produced in Norway. The analysis defines Norway as all enterprises operating in Norway, the region as Nordhordland and the local area is defined as Øygarden municipality after the merger with Fjell and Sund. The presumed distribution of Norwegian, regional and local value creation is based on information from Equinor, based on experience from other projects.

The calculated Norwegian share of value creation in the operations phase is 82%, which corresponds to approximately NOK 150 million. Furthermore, 21% of the overall value creation is regional (NOK 38 million) and 33% is local (NOK 59 million). The largest single item in the operations phase is procurement of electric power, which is also expected to be 100% Norwegian value creation. 50% of this is expected to be regional value creation (NOK 25 million). Maintenance is the second-largest item, and here as much as 80% is expected to be local value creation (NOK 26 million). The Norwegian, regional and local value creation in the operations phase is shown in Figure 7-12.

The annual Norwegian value creation from the project is calculated at NOK 146 million, where approximately 36% can be attributed to oil and gas enterprises. Power generation also accounts for about the same share as oil and gas activities of approximately 35% of the Norwegian value creation. Oil service and suppliers, drilling and public services account for 9%, 11% and 8%, respectively. Limited value creation is expected in commercial services.

The annual regional value creation is calculated at NOK 38 million. This is distributed between oil and gas enterprises (21%), power generation (66%) and oil service and suppliers (13%). Local value creation is expected to be NOK 59 million, more than 75% of which can be attributed to value creation in oil and gas enterprises (NOK 45 million). Public services, including property tax, will amount to approximately NOK 11 million in Øygarden municipality, but also a limited local value creation within drilling and oil service and suppliers.

Figure 7-12 Calculated value creation in Norway, regionally and locally in the operations phase (MNOK 2018).



7.17.4 Employment effects in the construction and operations phase

A simplified cross-discipline calculation model has been used to calculate the effects of the Northern Lights project on employment at the national level. The model takes a point of departure in calculated value creation in goods and service deliveries from Norwegian, regional and local businesses distributed by industry and year. On this basis, the overall production value created in Norwegian and regional businesses as a result of these deliveries is calculated, both at supplier companies and their sub-suppliers. The production value is then converted into employment measured in full-time equivalents with the aid of statistics from Statistics Norway (SSB) which concern value creation (gross product) per full-time equivalent in different sectors. The model calculations show direct employment effects at supplier companies and indirect employment effects at their sub-suppliers. In sum, this shows the project's production impacts. In addition to the production impacts, the model also calculates the project's consumption effects in Norwegian society as a whole, regionally and locally. The consumption effects occur because the people employed will pay taxes and purchase consumer goods and services.

The project's overall employment effects are the sum of the project's production impacts and consumption effects. It is emphasised that there is considerable uncertainty associated with these figures. The uncertainty is caused by both the calculation method and uncertainty associated with the size of construction investments and operating costs, which both form a basis for employment effects.

Please note that not all of this labour is new employment. Implementation of the project provides increased value creation in the Norwegian private sector, which entails an increase in activity. Some of these full-time equivalents will most likely fill available capacity with people already employed. Other full-time equivalents will be covered through the intake of existing labour, while the rest will be covered by new employees. As a point of departure, no new people will be hired to operate the facility, as operations will be handled by personnel at Kollsnes and Sture. Operations management at Kollsnes and Sture will independently assess the need to increase staffing based on the overall activity level at the facilities in the normal manner.

7.17.4.1 Construction and development phase

Norwegian employment effects

Norwegian employment effects in the development phase are calculated at more than 2,100 full-time equivalents, distributed over six years in the 2018 – 2023 period. The peak years for employment effects are 2021 and 2022, where the Northern Lights project is expected to result in 549 - 655 full-time equivalents. The calculated Norwegian employment effects are distributed among 986 full-time equivalents (47%) in direct employment effects in the project's supplier companies, and 522 full-time equivalents (25%) in indirect effects in their sub-suppliers. Overall production effects are calculated at a total of 1,507 full-time equivalents (72%). The remaining 593 full-time equivalents are consumption effects as a result of the employed people's consumption, payment of taxes, etc.

Construction will experience the project's largest calculated employment effects, with almost 1,350 full-time equivalents in the development period, and the majority in 2021 and 2022 with 838 full-time equivalents. Oil service and oil suppliers (130 full-time equivalents), drilling (63 full-time equivalents) and oil and gas activities (137) will have relatively limited employment effects.

Regional employment effects

The development phase will yield a calculated regional employment effect of more than 250 full-time equivalents, distributed over five years in the 2019 - 2023 period. The peak years in the development phase are 2021 and 2022, with 70 and 84 full-time equivalents, respectively. The employment effects (direct effects) are distributed across almost 140 full-time equivalents (55%) in direct production impacts in supplier companies, more than 70 full-time equivalents (29%) in indirect production impacts in their sub-suppliers and the remaining 40 full-time equivalents (16%) in consumption effects.

Construction is the industry with the vast majority of regional employment effects in the development phase, with just under 200 full-time equivalents or 78% of the total. The remaining industries constitute a very small share of the full-time equivalents, and the 'other industries' group constitutes 36 full-time equivalents or 14%.

7.17.4.2 Operations phase

Norwegian, regional and local employment effects

In contrast to the construction phase, a permanent effect is expected in the operations phase. The employment effect consists, in part, of the number of employees at the receiving facility and, in part, of the number of employees as a result of demand for goods and services in the economy. Employment effects of the value creation for the private sector in the operation of the Northern Lights facilities has been calculated for the operations phase in a manner equivalent to that of the construction phase.

National employment effects from operation of the Northern Lights facilities is calculated at 46 full-time equivalents in an average operating year. The employment effects are distributed among around 21 full-time equivalents (approximately 45%) in direct production impacts and in supplier companies during operations, around 12 full-time equivalents (26%) in indirect production impacts in their sub-suppliers and the remaining 28% in consumption effects from the employees' own consumption and payment of taxes.

Oil and gas activities are expected to have a national employment effect of 13 full-time equivalents per year from operation of Northern Lights, while power generation is expected to experience a Norwegian employment effect of 9 full-time equivalents. The remaining 24 full-time equivalents are distributed among other sectors, including commercial services, public services and other industries.

The regional employment effect in the operations phase is calculated at almost 9 full-time equivalents. Four full-time equivalents are expected in direct production impacts, 3 full-time equivalents in indirect production impacts and the remaining 1 full-time equivalent in consumption effects (due to rounding in the calculations, this is aggregated as 9 full-time equivalents). Power generation with 4 full-time equivalents is expected to be the industry with the largest regional employment effects.

The local employment effects of operation of Northern Lights are calculated at 18 full-time equivalents in an average year. Seven of these full-time equivalents are expected within oil and gas activities, and 6 in public services, primarily due to the calculated municipal property tax of NOK 9.5 million. The rest of the local employment effect is distributed among other sectors.

Municipal revenues

Equinor's preliminary estimates from autumn 2018 presume an annual property tax of approximately NOK 9.5 million (2018), and this constitutes the basis for the implemented calculations. Potential property tax from 2024 for the Northern Lights facility will be decided by the Øygarden municipal council at a later date. Calculations of expected tax revenue are based on preliminary concept studies. Future actual tax revenues could thus deviate from the calculations, and could potentially be eliminated entirely depending on the future tax regime.

8 Preparedness for CO_2 leaks and acute pollution

The Regulations relating to exploitation of subsea reservoirs on the continental shelf for storage of CO_2 and relating to transportation of CO_2 on the continental shelf (the CO_2 Storage Regulations) contain the following definitions in Section 1-6:

- j) *Facility*, installations, plants and other equipment for exploitation of subsea reservoirs for storage of CO_2, but excluding supply and utility vessels or vessels that transport CO_2 in bulk. Facility also includes pipelines and cables unless otherwise determined,
- k) *Storage complex*, storage location and the geological surroundings that may be of significance for the security of the storage,
- l) *Storage location*, a certain area within a geological formation that is used for geological storage of CO_2, and associated surface and injection facilities,
- m) ***Leakage***; release of CO_2 from the storage complex,
- q) *Migration*, movement of CO_2 in the storage complex,

Leakage of CO_2 thus entails that CO_2 moves out of the storage complex to other surrounding parts of the subsurface. Over time, CO_2 could potentially move further from the subsurface outside the storage complex to the seabed and be released to the sea and air. Movement of stored CO_2 within the storage complex is not to be considered leakage to the surroundings but is defined as *migration* in the regulations. In addition to potential release of CO_2 to the external environment as a consequence of initial leakage from the storage complex, CO_2 may also be released to the sea and air through direct emissions from the receiving facility, pipeline and other facilities.

In the following, CO_2 leaks and other undesirable emissions and discharges to the environment (seabed and air) are addressed in Chapters 8.1 - 8.6. Migration of CO_2 within the storage complex and how this is assessed as potentially impacting nearby petroleum reservoirs and petroleum activity is addressed in Chapter 6.7.

8.1 Detection of CO_2 leaks

Early detection of leaks is important for several reasons:

- Technical extent of damage and repair of pipeline
  - Water penetration in the CO_2 pipeline could create acidic and corrosive conditions, and the pipeline will be exposed to high corrosion rates which, over time, could increase the scope of damage and the repair costs.
  - Early detection of small leaks will make it possible to repair the pipeline rather than having to replace longer sections of the entire pipeline, in the event of late detection of major leaks.
- Environmental factors
  - Reduce emissions of CO_2 to the surroundings in the event of a leak. This is CO_2 that has already been removed from the atmosphere with a view to geological storage. Without a mass balance system, a leak could lead to emission of CO_2 over several months, with emission of large volumes of CO_2 to the sea, where some of this volume will reach the sea surface and become available in the atmosphere.
  - Purchase of CO_2 emission credits with a financial consequence.
  - Larger influence area, with risk of negative media coverage and loss of reputation for Northern Lights and CCS as a solution for dealing with CO_2 emissions.
- Health-related factors (cf. Chapter 3.15.3)

A system will be implemented for leak detection in the transport system from the onshore facility to the wellhead. Existing instrumentation for other purposes will be set up and used in a way that will enable detection of leaks within a reasonable time period in accordance with defined acceptance criteria. Therefore,

there will be no need to install special instrumentation or systems for this purpose. Like other monitoring, control and management systems, leak detection will also be monitored from local and central control rooms.

During normal injection in the pipeline system, it will be difficult to detect leaks by looking at the pressure in the system. A leak will cause a very minor change in pressure but will result in a higher rate inside the pipe. This is because automatic pressure control will be used to guide the speed of the export pump. Therefore, during normal operation of the system, rate measurement of CO_2 inside the pipe will be used, in relation to rate measurement on the wellhead to perform mass balance. Potential changes inside the pipe will be estimated using pressure metering, which is included in the mass balance model. In the event of discrepancies between metering and expected condition (mass balance), an algorithm will trigger an alarm in the control room.

If a leak alarm is triggered, the control room operator will shut down well valves on the wellhead and export pumps on land. Pressure monitoring of the shut-in pipe volume will then be used to verify whether there is a leak. Pressure loss can be used to identify the size of the leak. If a leak is confirmed, the next step will be to identify the location of the leakage and prepare to repair the leak.

Pressure conditions in the pipeline will also be monitored during planned situations involving shutdown/stopping injection. In a system without leakage, the pressure conditions will not change over time. Minor leaks will be detected using pressure monitoring on shut-in volumes compared with the mass balance model for normal system operation.

Inside the receiving facility onshore, there will be various sensors and systems for monitoring the CO_2 streams and the processes in the facility. These systems will also detect, identify and locate potential leaks from the process equipment and valves, etc. For example, low-mounted CO_2 detectors will be placed to detect leaks in the area. If defined acceptance criteria are exceeded, this will trigger an alarm in the control room.

8.2 Risk analyses and CO_2 dispersion estimates

A quantitative risk analysis has been performed for the receiving facility and CO_2 dispersion estimates given a leak incident as a basis for calculating risk contours around the plant. This is described in more detail in Chapter 3.15.3. The analysis is based on a selected combination of possible leak events with associated probabilities.

The calculated risk contours show the geographical distribution of individual risk by showing the expected frequency of incidents capable of causing CO_2-related hazards in a given location. The risk contours form the basis for establishing zones that require special consideration around the receiving facility in the zoning plan pursuant to the Planning and Building Act, see Chapter 8.3.

8.3 Hazard and safety zones (zones requiring special consideration)

Currently, the safety of the surroundings around the facility with flammable, reactive, pressurised, explosive and other hazardous materials is primarily governed by the Act relating to the prevention of fire, explosion and accidents involving hazardous substances and the Planning and Building Act with associated regulations.

With authority in the Regulations relating to handling of hazardous substances and the Planning and Building Act, area restrictions can be established around a facility through zones requiring special consideration, with associated zoning restrictions. Based on risk analyses, three risk contours are normally established, defining three zones: **inner** zone, **middle** zone and **outer** zone, see Table 8-1.

Table 8-1 Extent of and restrictions for zones requiring special consideration. Ref. DSB 2012 (/34/).

Special consideration zone	Delimitation of zone	Restrictions for the special consideration zones
Inner zone	Risk contours 10^{-5}	As a point of departure, this is the enterprise's own area. Only brief passers-by for third party individuals (e.g. walking trails.)
Middle zone	Risk contours 10^{-6}	Public roads, railways, quays and the like. Regular workplaces, within industrial and office activity can also be located here. No overnight accommodations or residences are permitted here. Sparse residential settlements may be accepted in certain cases.
Outer zone	Risk contours 10^{-7}	Area zone for residential purposes and other use by the general population can take place in the outer zone, including shops and smaller overnight accommodations.
Outside outer zone	No special consideration zone outside outer zone	Schools, kindergartens, nursing homes, hospitals and similar institutions, shopping centres, hotels or major public arenas must be placed outside the outer zone.

8.3.1 Fire and explosion

A BLEVE (Boiling Liquid Expanding Vapour Explosion) is an explosion caused by breach in a vessel containing a liquid at a temperature above boiling point temperature (/16/). Since the boiling point of a liquid rises with increasing pressure, the content of the vessel can remain in liquid form as long as the vessel is intact. If the vessel's integrity is impaired, loss of pressure and a falling boiling point can cause an extremely rapid transition from liquid to gas. For CO_2, such a volume expansion/pressure explosion could lead to pressure waves, fragments that could be thrown great distances with high impetus, and dispersion of heavy, suffocating gas. Some such pressure explosions have occurred throughout history in connection with CO_2 storage tanks, with serious consequences. (/17/). The causes of the incidents have been loss of control over the process conditions and/or failure of materials. Overheating and overpressure have occurred due to overfilling, loss of control over the heat source, freeze-up of safety and depressurisation systems, etc. This underlines the extreme importance of maintaining an overview of and control over the thermodynamic conditions in process equipment, pipelines and storage tanks under all imaginable conditions, both during normal operations and in nonconforming situations.

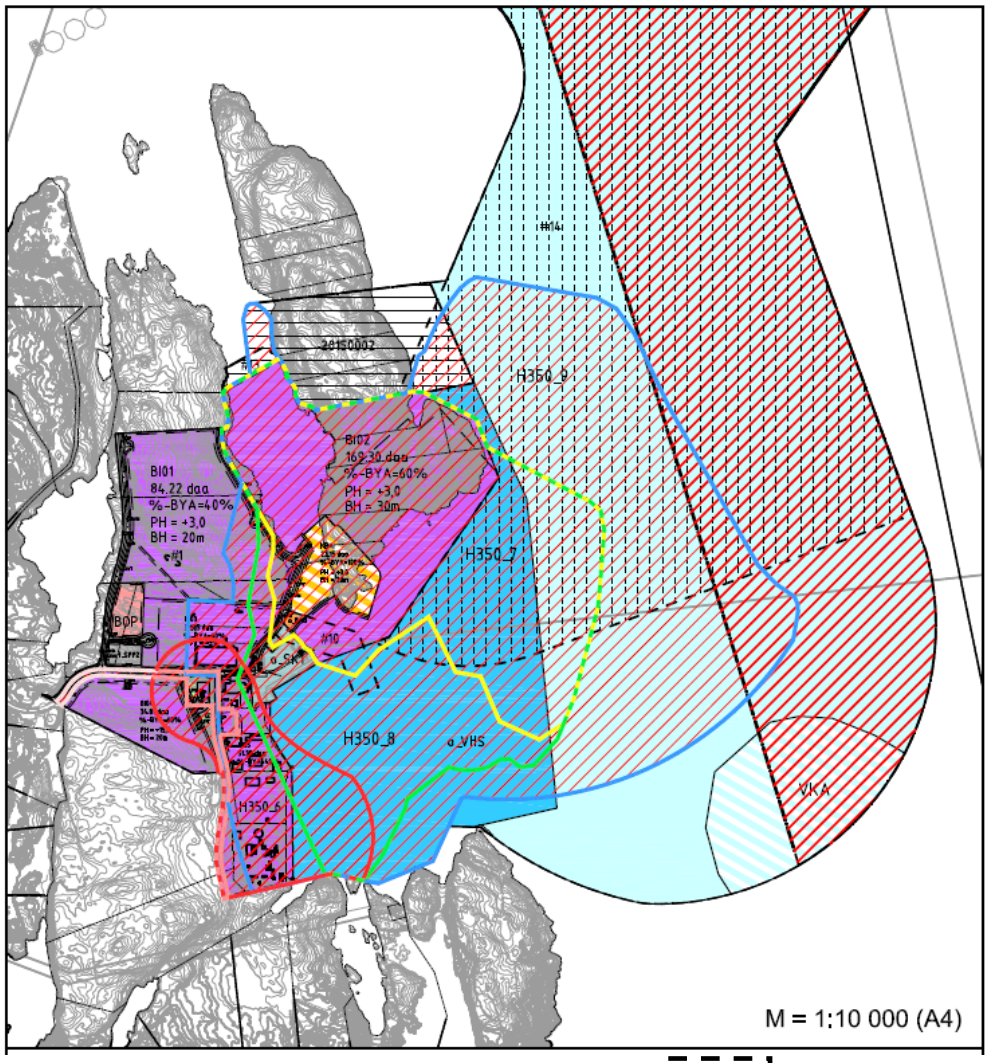
It is emphasised that the likelihood of a BLEVE is very low ($1.2x10^{-6}$), which is so low that it is not included in the basis for "design loads" in the facility. Fire and explosion hazard in connection with receiving and intermediate storage of CO_2 is considered unlikely with the planned measures. CO_2 is not an ignitable gas and is not an explosive substance; in fact, CO_2 is used as an extinguishing agent for fires. No special consideration zones have been established in the zoning plan that directly deal with the hazard of pressure explosion; but the consequence of a pressure explosion with dispersion of CO_2 is dealt with in the CO_2 dispersion analysis.

8.3.2 CO_2 dispersion

Risk contours have been prepared for the receiving facility based on CO_2 dispersion analyses (cf. Section 3.15.3). These risk contours are used as an information basis when setting up special consideration zones in the zoning plan for the project. In line with the DSB guidelines, the criteria and restrictions shown in Table 8-1 are used as a basis for defining the special consideration zones: inner, middle and outer, respectively, see Figure 8-1. The restriction provisions are incorporated in the restrictions in Section 9, Special consideration zones.

In addition to the special consideration zones around the Northern lights receiving plant, Figure 8-1 also shows special consideration zones related to fire and explosion hazard (marked red) around Gasnor's existing LNG plant in Naturgassparken.

Figure 8-1 Special consideration zones incorporated in the zoning plan for the project. Illustration: ABO Plan & Arkitektur.



Fire and explosion hazard

H350_4

H350_5

H350_6

Plan limits

Special consideration zone, hazardous substance CO_2

H350_7 – Correspond to DSB Inner zone (10^{-5})

H350_8 – Correspond to DSB Middle zone (10^{-6})

H350_9 – Correspond to DSB Outer zone (10^{-7})

8.4 Chemical pollution

No measures are planned that would lead to a particular risk of discharge of chemicals at the receiving facility. No chemicals are used in the handling of CO_2 in the process plant prior to export for injection. The laboratory and technical rooms will only contain minor amounts of chemicals. Installations at the plant which may contain chemicals are transformers and hydraulic systems at the quay facility. The assessment is that a chemical leak will not entail risk at the receiving facility.
The chemicals that will be used at the underwater facility for well control will be handled on Oseberg A, and will be transported directly from the relevant supply base to the installation. As explained in Chapter 3.11, overpressure safety systems for the control system and wells will ensure that overpressure does not occur in the system. Chemicals handling for Northern Lights will be covered under the operating and reporting procedures on Oseberg A, and will be included in the installation's preparedness schemes for undesirable incidents.

8.5 Preparedness analysis and preparedness plan

A workshop was conducted in connection with the Total Risk Analysis (TRA) with focus on preparedness for the receiving facility, and a list of relevant defined hazard and accident situations (DFUs) was established. The DFUs include CO_2 emissions, acute medical accidents, fire and explosion, acute environmental pollution on sea or on land, persons in the sea and security-related incidents.

The emergency preparedness organisation for Northern Lights has not yet been finally defined. Based on requirements set by the Norwegian Industrial Safety and Security Organisation (NSO), a dedicated emergency preparedness organisation stationed at the facility is not a requirement as the facility will, for the most part, be unmanned and the operations organisation will be located elsewhere. The receiving facility will be permanently manned the first year due to running-in, as well as facilitating a number of visitors. It must therefore be ensured that preparedness is designed to handle accident incidents that will involve operations personnel and visitors. Later on in the project work, a preparedness plan will be drawn up for the start-up and operations phase at the facility.

8.6 Organisation of preparedness work

Equinor, together with its partners, has extensive experience from operating process facilities for gas, including quay facilities for loading and unloading ships, pipeline systems, subsea facilities and wells. This expertise and experience will be available to the operations and preparedness organisation at the facility. As shown in Figure 3-26, there is a short distance to the facilities at Kollsnes and Sture. Northern Lights can also seek cooperative solutions with the local *Øygarden Fire and Rescue Service*. Cooperation with neighbours in Naturgassparken may also be appropriate in areas where this can be beneficial and optimise organisation of the preparedness work. Resources can be allocated from a combination of the above when designing 1st, 2nd and 3rd line preparedness.

Assessments indicate that traditional oil spill preparedness linked to petroleum activity in connection with drilling and well activity as well as operation and maintenance of the injection well is not relevant, as there is no risk of a hydrocarbon blowout. Reference is made to Chapter 3.13.5 for assessments and measures related to potential presence of shallow gas during drilling in November 2019. The Eos well is included in the offshore area covered under the area preparedness contingency for Troll-Oseberg. Plans will include necessary instruction and training of personnel to take into account the special challenges associated with a CO_2 facility. If new potential CO_2-related hazard or accident scenarios are introduced in connection with routine use of service and intervention vessels in the operations phase or in connection with specific incidents, necessary adjustments must be made to reflect this.

9 Summary of impacts and mitigating measures

9.1 Summary of impacts

The impact assessments in relation to the various study topics are summarised in Table 9-1.

Table 9-1 Summary of impact assessments

	Impact assessments	
Study topic	**Construction phase**	**Operations phase**
Natural environment and biological diversity on land	Somewhat impaired	Somewhat impaired
Landscape	Significant environmental degradation	Significant environmental degradation
Outdoor recreation	Insignificant change	Insignificant change
Cultural artefacts and cultural environment on land	No change	No change
Plankton and benthic fauna (within PBA)	No change	No change
Important marine topography (within PBA)	Somewhat impaired	Somewhat impaired
Fish populations, incl. anadromous salmon fishing (within PBA)	Insignificant change	Insignificant change
Fisheries (within PBA)	Insignificant change	Insignificant change
Fish farming	Insignificant change	Insignificant change
Seabirds (within PBA)	Somewhat impaired	Somewhat impaired
Shell-sand	No change	No change
Kelp harvesting	No change	No change
Marine mammals (within PBA)	Insignificant change	Insignificant change
Marine archaeological assessments	Insignificant change	Insignificant change
Marine topography – corals (offshore)	No change	No change
Seabed habitat and benthic fauna (offshore)	Insignificant change	Insignificant change
Plankton (offshore)	Insignificant change	Insignificant change
Marine mammals (offshore)	Insignificant change	Somewhat impaired
Fish populations (offshore)	Insignificant	Somewhat impaired
Seabirds (offshore)	Insignificant	Insignificant
Particularly valuable areas (SVO)	Insignificant	Insignificant
Fisheries (offshore)	Somewhat impaired	Somewhat impaired
Social consequences	Insignificant change	Insignificant change
Socio-economic consequences	Somewhat improved	Somewhat improved
Tourism and business development opportunities	Somewhat improved	Somewhat improved
Risk and vulnerability analyses	Somewhat impaired	Somewhat impaired
Climate	Somewhat impaired	Significantly improved
Seismic activity – pipeline	No change	No change
Shipping, incl. anchoring areas	Insignificant change	Insignificant change
Offshore wind	No change	No change
Petroleum activity	No change	No change
Agriculture	No change	No change
Other industries on land	Somewhat impaired	Insignificant change

9.2 Mitigating measures

Based on the assessments linked to environmental impacts (cf. Chapter 5), the following relevant mitigating measures have been identified in the project.

Landscape, local environment and outdoor recreation

- Let parts of the external part of the terrain/coastline remain partly untouched, so that a barrier is formed toward the fjord. This is already planned as a mitigating measure in the project.

Important marine nature types – corals

- A “pre-lay survey” will be carried out in connection with the pipelaying operation, and minor route adjustments will be considered to avoid conflicts with confirmed nearby coral reefs.

Actions to prevent spread of sediment particles and plastic

- The plan is to use electronic detonators in connection with the blasting work, which will significantly reduce the volume of plastic bits in the blasted rock material.
- Silt curtain will be established in the northern end of the work area in the Ljøsøysundet strait. The silt curtain will also reduce the spread of sediment particles and potential contamination of the work area. The silt curtain will also reduce the spread of potential plastic particles that accompany the rock material for depositing which makes it easier to collect bits of plastic.
- Consideration will also be given to establishing silt curtain outside the deposit area in connection with depositing rock to establish a quay in Ljøsøybukta bay. The area is more exposed to weather than Ljøsøysundet strait, and the effect of the silt curtain can consequently be reduced as a consequence of the effect of waves.

Plankton and benthic fauna near the injection well

- The hydraulic fluid planned to be used is the same as is used on Oseberg A. The hydraulic fluid is on the substitution list for Oseberg A, with planned phase-out and substitution by 2027. So far, no alternatives have been identified with comparable technical properties.

Fish populations and marine mammals

- Seismic can result in direct harm to fish and marine mammals, but mitigating measures such as “soft-start” and use of fishery experts on board can reduce the risk of harm to fish and individual marine mammals.

Based on the assessments linked to impacts for industries (cf. Chapter 6), the following relevant mitigating measures have been identified in the project:

Fishery industry

- The marine installation work in areas with significant fishery activity will be planned and implemented with maximum efficiency over the shortest possible time period. This will reduce the period when fishery activity is restricted.
- Dialogue will be established with the fishery organisations and the fishery authorities for information about activity and time periods for activities.
- Notices will be given as regards the marine installation work and will also be announced to the fishery industry through the Notice to Mariners and the fishery press.
- When planning seismic surveys during the summer months, attempts should be made, insofar as possible, to take the fishery activity in the affected areas into consideration.
- When shooting seismic, the plan is to do this using “soft start” procedures and use of fishery experts on board.

Fish farming

- In connection with construction work in the sea in the Ljøsøysundet strait, silt curtain will be established outside the work area to reduce the spread of particles outside the area, and thus reduce the volume of particle spread that can entail disadvantages and complications for nearby aquaculture facilities at location 14435 Ljøsøy N.
- Installation of pipeline north of Ljøsøyna may present a conflict with two anchor lines for Blom Fiskeoppdrett AS at aquaculture location 14435 Ljøsøy N. If necessary, dialogue will be established with the owner of the aquaculture facility to plan concrete measures for temporary lifting of affected anchors and anchor lines during the pipelaying past the aquaculture location.

Other industries on land

- The established practice of dialogue meetings with neighbours at Naturgassparken will continue. Several information and dialogue meetings will be held with neighbours at Naturgassparken before and during the construction work on land.
- In dialogue with neighbouring firms at Naturgassparken, noise abatement and other measures will be considered to reduce the disadvantages caused by the construction activities. Relevant measures will be discussed in cooperation with the construction contractor selected to carry out the work. The selected construction contractor will be made responsible for implementing agreed measures.

9.3 Assessments in relation to the Nature Diversity Act

Public decisions affecting natural diversity must, insofar as reasonable, be based on scientific knowledge about the situation for various species, the type and extent of topographies and their ecological conditions, as well as the effect of influences. The knowledge base requirement must be reasonable in relation to the nature of the issue and the risk of harming natural diversity (Section 8).

The knowledge base must be assessed as being good for the topics addressed in this value and impact assessment linked to the considered onshore areas. Botanical surveys were conducted by Rådgivende Biologer in the area in 2017. No specific bird surveys were carried out and only existing information has been used as a basis. The comparison of existing and new information is considered to be an adequate basis of knowledge in relation to the nature of the matter and the risk of harm to nature diversity. Rådgivende Biologer point out an uncertainty linked to the incidences of Eurasian eagle-owls near Naturgassparken. To reduce this uncertainty and to expand the knowledge base, listening studies have been performed for calling Eurasian eagle-owls in February/March 2019. No territorial calls were registered, and biologists from Ecofact Sørvest with Eurasian eagle-owl expertise conclude that there is no basis for tracking searches to confirm nesting in the area. The precautionary principle (Section 9) does not apply, according to the assessment of the Rådgivende Biologer.

The knowledge basis is assessed as good enough for the addressed topics for the sea areas within the baseline in the existing IA. Several impact assessments have been previously conducted in the area, and new surveys were performed in January 2019 of sediment and contamination factors at Ljøsøyna. Sediment and pollution data are also available from areas outside the Sture terminal in Hjeltefjorden. Good data is available in official databases and map tools. New seabed surveys have been performed along the relevant pipeline route, including mapping of corals. Local and existing impact on the ecosystems within the influence area have been accounted for and the overall impact has been included in the assessments.

The sea areas outside the baseline are covered by the technical baseline material for the Integrated management plan for the North Sea and Skagerrak, and they are also covered by the Regional environmental monitoring programme (Region III), most recently examined in the summer of 2019. The area around these

fields can therefore be assessed as well-known as regards physical, chemical and biological composition of the sediments. No valuable environmental resources have been identified in the area. New seabed surveys have been performed along the relevant routes for pipeline, umbilical and DC/FO cable, which include mapping of corals and marine cultural artefacts. The assessment is that there is a sufficiently good basis of knowledge regarding the topics in the affected sea areas in relation to the nature of the matter and the risk of harming nature diversity.

Ecosystem approach and overall footprint (Section 10)
An impact on an ecosystem shall be assessed based on the overall footprint that the ecosystem is or will be exposed to. The current footprint on the ecosystem on land is small to medium. The relevant impact area is affected by existing interventions and an expansion of the industry area will entail an increased load on the ecosystem, mainly in the form of area occupation.

Local and existing impacts on the marine ecosystems within the influence area have been accounted for and the overall footprint has been included in the assessments. The ecological condition in Northern Hjeltefjord is moderate, while the chemical condition is poor (Vann-nett, 2018). Northern Hjeltefjord is affected by fish farming and point source discharges from industry, but only to a minor degree (Vann-nett, 2018). There are five smaller water treatment plants with mechanical treatment that have discharges to the fjord.

In the Fedje West water body, the ecological condition is reported as poor, while the chemical condition is unknown (Vann-nett, 2018). Due to lack of data, the degree of reliability for the condition classification is low. The water body is affected by mercury from a submarine wreck at Fedje (Vann-nett, 2018), while mapping of the pollution in the sediment near the submarine indicates that the mercury pollution extends a maximum of 150 metres from the wreck, but the pipeline will be installed at a minimum distance of approximately 1,100 metres from the wrecked submarine. The ecological condition is set as poor because parts of the water body are affected by mercury. The regional environmental monitoring shows that the sediments on the shelf are somewhat affected by the petroleum activity at the stations that are closest to producing fields, while the regional reference stations reveal an unaffected condition.

9.4 Assessment in relation to the EU Water Framework Directive

In its report on marine biological diversity, Rambøll assesses the development and operation of Northern Lights in relation to the EU Water Framework Directive (/6/). The assessments are made on the basis of the solutions and implementation plans that existed in the autumn of 2018.

Rambøll sums up the assessments of development and operation of the project in relation to the relevant water bodies as follows: "*No change is expected in ecological or chemical condition in Hjeltefjorden, Northern Hjeltefjorden (0261030201-1-C) and Fedje West (0261000035-2-C). No added environmental toxins are expected in connection with the construction work or operation of the facility, nor is any spread of environmental toxins to unaffected areas expected. No significant impact is expected on any of the relevant biological quality elements phytoplankton, benthic fauna or micro-algae.*"

Based on new sediment surveys in January 2019, a larger volume of soft contaminated sediments was revealed in the Ljøsøysundet strait than previously assumed. Therefore, in the spring of 2019, new solutions were assessed and developed for handling dredging material and disposal of surplus amounts of rocks in the Ljøsøysundet strait (cf. Chapters 2.1.5 and 3.7.3).

The solution for handling and disposal of dredging material and surplus material in Ljøsøysundet strait that has now been selected is considered to be a better technical and environmental solution than the earlier plans. The solution will isolate and secure the contaminated sediments, and it is deemed to represent a smaller risk of spread of polluted sediments outside the construction area in the sea. Consideration for the

aquaculture facility north of Ljøsøyna as a third party will be better safeguarded than was the case for the earlier solution that was used as a basis for Rambøll's assessment.

The solution that has now been selected is considered to represent BAT for handling and disposal of the relevant material from landscaping and levelling of the construction site. Based on this, Rambøll's conclusion in relation to the Water Directive is considered to still be valid for development and operation of Northern Lights.

10 Follow-up surveys and monitoring

10.1 Monitoring the permanent CO_2 storage complex

A description is provided in the following of the preliminary strategy for monitoring the CO_2 storage facility that is being contemplated, insofar as this has been prepared as of the date of the current impact assessment.

The framework for the planned monitoring plan is based on statutory requirements for a good understanding of how CO_2 is dispersed in the storage complex, detection of potential leakage to sea and corrective measures. A leakage risk analysis has been performed to identify and rank the risks of leaks to the seabed through wells (injection well(s)) and existing petroleum activity wells), as well as potential geological weak zones. This analysis shows generally little risk of leakage to sea, but that wells constitute a greater risk than geological weakness zones.

The main strategy for the monitoring plan is two-fold:

- Injection well (primary monitoring)
    - Monitoring of injected volume of CO_2 and CO_2 rate at the wellhead to verify the volume of injected CO_2.
    - Monitoring temperature and pressure in the well to detect changes in reservoir conditions and potential leaks in or near the well.

- Subsurface (secondary monitoring)
    - Seismic shooting campaigns to monitor changes in the subsurface ("4D seismic", 3D seismic repeated over time, where the time aspect constitutes the 4th dimension). The results from such measurements will be used to confirm and update reservoir understanding and indicate when and if CO_2 should move out of the storage complex. Existing wells are situated more than 15 km from the injection location, and seismic monitoring will indicate whether stored CO_2 moves in the direction of these wells. The frequency of these seismic acquisitions will be determined based on modelling the CO_2's speed of dispersion in the subsurface, and may be updated during the course of the monitoring programme.
    - Passive monitoring beyond the existing network in the area (NNSN) is under consideration and will, if adopted, focus directly on the injection operations. Solutions being studied are downhole monitoring in the well using fibre optics (Digital Acoustic Sensing - DAS) or a small permanent or semi-permanent system of seismic nodes on the seabed (PRM).

Strategy and plans for monitoring the CO_2 storage complex will be developed and further matured in the project. A more detailed description of the planned strategy and monitoring plans will be described in the PDO for Northern Lights, and will also be included in the application for permission for injection and storage of CO_2, as well as in the application for a storage permit pursuant to the provisions of the Pollution Control Regulations.

10.2 Environmental monitoring with consideration for potential leakage from the CO_2 storage complex

10.2.1 Environmental risk analysis

The strategy and plan for environmental monitoring is based on results from CO_2-related environmental risk assessments conducted for the storage site in exploitation licence EL001 (/29/). The environmental risk analysis takes its point of departure in assessments of the risk of leaks from the storage complex and

environmental resource mapping within the exploitation licence (EL001) and the adjacent Troll area (Risktec, 2019) (/35/), as well as internal memos.

In assessments of the risk of leakage (cf. Chapter 3.14.4) and in the environmental risk analysis, it is assumed and used as a basis that the injection volume will be increased beyond the initial volume of 37.5 million tonnes over 25 years (Development Phase 1). A total injected volume of 100 million tonnes CO_2 over a period of 25 years is assumed, through a total of four injection wells. However, in the Plan for Development and Operation (PDO) for Northern Lights, a volume of less than 40 million tonnes of CO_2 is assumed (1.5 Mt per year for 25 years = 37.5 Mt).

Environmental risk assessments were conducted for the period where the operator of exploitation licence EL001 will be responsible for monitoring the environment. This is the period from start-up of CO_2 injection (planned for autumn 2023) up until the responsibility is transferred to the Norwegian State pursuant to the provisions of the CO_2 Storage Regulations. The presumption is injection for 25 years, followed by 20 years of risk management, including potential environmental monitoring. This means that only leakage scenarios that can lead to an observable negative environmental impact before 2070 were assessed in the environmental risk analysis.

Furthermore, a threshold value was used for significant leakage rate of 50 kg CO_2/m^2/day, where leakage under the specified rate will not entail significant (observable) negative environmental impact. This threshold value is set based on results from the CO_2 environmental risk analysis for Sleipner, which was performed as part of the ECO_2 project (DNV GL, 2015) (/36/). The environmental risk analysis revealed that this leakage rate gave rise to a negligible/low negative environmental impact. At a general level, it is believed that the Sleipner environmental risk analysis is also representative in the Aurora and Troll area. Therefore, as a consequence of this, it is assumed that a leakage rate of 50 kg CO_2/m^2 per day within a similarly limited area will have comparable environmental impact, and this is therefore also assumed for the storage reservoir.

Three categories of potential leakage routes from the storage reservoir have been identified: leaks from injection wells, leaks from other existing wells and leaks along faults and geological leakage paths, cf. Chapter 3.14 and Figure 3-24. All leakage scenarios assessed as relevant for environmental risk assessments (over the threshold value and to seabed) are linked to potential leakage through wells or along a well path. The likelihood of these leakage scenarios occurring is assessed as low (<1%). There is no expectation of finding vulnerable species or habitats on the seabed or in the water column within licence EL001, nor in the area over the Troll reservoir. Since the maximum leakage rate from the injection well is very low, all CO_2 from a potential leak will be mixed into the water column within a few metres over the seabed. It is therefore assessed that environmental risk associated with a leak from the storage complex is negligible/low (/29/).

Environmental risk linked to the receiving facility at Naturgassparken (including CO_2 ship at jetty) has been assessed. DNV GL (/29/) concludes as follows:

- The environmental risk is regarded as *Low/negligible* for CO_2 emissions to air from the onshore receiving facility
- The environmental risk is regarded as *Low/negligible* for emissions of LNG from CO_2 ships when moored at the quay at the onshore facility
- The environmental risk of marine diesel discharge from ships is regarded as *low*
- It is not considered necessary to prepare a dedicated monitoring plan for CO_2 emissions for the environment
- It is recommended to prepare an oil spill preparedness plan (marine diesel) for nearby areas where red-listed species occur at Ljøsneset and Kobbervåg

Environmental risk has also been assessed in relation to the pipeline from the receiving facility to the injection well. DNV GL (/29/) concludes as follows:

- The environmental risk to the seabed and water column as regards a minor leak from the pipeline (most conservative estimate), is considered *Low*.

- The environmental risk above the sea surface for a major leak from the pipeline (most conservative estimate), is assessed as *Low to moderate*.

A potential dilution of CO_2 gas in the marine environment is considered to yield *Negligible* impact. This is due to the type of incident, i.e. acute emission with limited dispersion area. Such mixed gas is expected to be rapidly diluted in the water masses.

10.2.2 Strategy for environmental monitoring

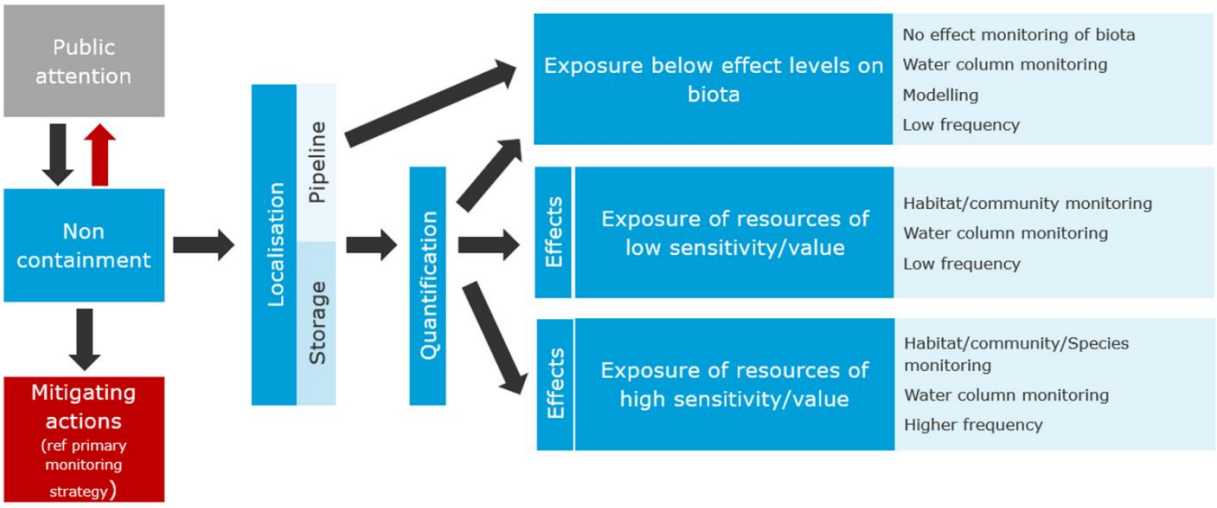
Potential emission scenarios identified in risk assessment studies and environmental risk analyses will be used as a basis for shaping the strategy and plan for environmental monitoring. The fact that the environmental impact is considered low will provide some guidelines in the environmental monitoring plan with regard to frequency and mobilisation time for execution.

Environmental monitoring has been developed as a part of Northern Lights' secondary monitoring strategy (/29a/) which will not be initiated until there is proven or presumed leakage on the seabed through the primary monitoring (cf. Chapter 10.1). The main objective of the primary monitoring is to ensure that CO_2 is permanently stored, and to detect potential leakage incidents or the risk of incidents that could entail a potential for leaks.

Secondary environmental monitoring will have four objectives, depending on the scenarios, cf. Figure 10-1:

1. Locating the leak
2. Verifying the leak
3. Quantifying the leak
4. Measuring effects on the environment

Figure 10-1 Framework for secondary environmental monitoring strategy. From /29a/.



An assessment has been made of relevant technologies regarding applicability and maturity in order to "deliver" on the objective of the strategy, as well as the associated costs. The method of assessment is based on the same methodology used in connection with assessment of future monitoring technology for sediment monitoring in deep water for Norwegian Deepwater program (/37/).

Two different monitoring designs have been proposed for secondary monitoring (/43/); an ROV-based design (remote-operated underwater vehicle) and an AUV-based design (autonomous underwater vehicle/drone). These designs can be supported or partially replaced by a third alternative design – which combines several methodologies.

- ROV-based design: It is expected that using an ROV will solve all tasks satisfactorily in an overall monitoring operation. Work class ROVs are normally readily available as standard equipment on anchor handling vessels or other survey vessels, and can be mobilised rapidly. These ROVs normally come with standard equipment for positioning and side scan sonar. There will also be a need for sensors for pH, pCO_2 (partial pressure CO_2), pO_2 (partial pressure oxygen), rate chamber (flux chamber), as well as support parameters such as temperature and salinity.

- AUV-based design: It is expected that using AUVs will solve all tasks in a moderately satisfactory manner in an overall monitoring operation. A dilution/dispersion model must be established in order to quantify the leak based on the measurement parameters. Such a model will entail an investment cost, but at the same time, could be re-used. The AUV based design is beneficial if there are large areas to be mapped.

In order to locate, verify, quantify and evaluate the effect of CO_2 emissions on the seabed and in the water column, the correct measurement parameters must be selected, and sensors must be used that have adequate precision. Leakages of CO_2 via geological leak routes over larger geographical areas could be difficult to detect since they are quickly camouflaged by natural variations in both biological and physical parameters. Therefore, it is important to measure several parameters in order to interpret the results based on a comprehensive perspective. The national monitoring programme for ocean acidification has established good measurement parameters that are considered good supporting parameters into the secondary monitoring (Chierici et al. 2014 (/38/), 2015 (/39/), 2016 (/40/) and 2017 (/41/).

There are synergies between the monitoring of benthic fauna (regional environmental monitoring) and potential monitoring of effects on biota after a potential CO_2 leak from the storage facility. This means that benthic fauna monitoring is considered a relevant measurement parameter. There is little need to establish basic data for this type of monitoring, as sufficient information is already available from nearby (<10km) regional monitoring stations linked to fields such as Oseberg, Brage, Veslefrikk and Tune, as well as other similar fields such as Troll. Measurements of relevant hydrological parameters are carried out in part through the regional water column monitoring, and to a more extensive degree in the ocean acidification programme (Chierici et al., 2014, 2015, 2016 & 2017) (/38/ - /41/). The closest stations are Svinøy NV, 270 km northeast of the Aurora area. Temporary vertical variations in the water column are assessed as being larger than the natural local variations between different areas. Therefore, it is considered more appropriate in terms of following up a leakage incident to measure reference values downstream of the emission point when a leak occurs. This will form a better basis for identifying abnormal water chemistry conditions in the water column.

On this basis, it can be concluded that existing basic data in the area can be considered sufficient for the purpose, but local reference values must be obtained and established in connection with a potential leak. This can be done by establishing a reference station downstream of an identified leakage point in the event of a leakage incident.

Synergy effects can be extracted between planned ROV-based inspection campaigns of seabed facilities and pipelines in the Troll-Oseberg-Grane area and the need for secondary monitoring of potential CO_2 leaks. Coordination of such survey campaigns can contribute to reduce costs and streamline monitoring execution.

10.2.3 Sleipner and Snøhvit risk assessment and monitoring plan

Risk associated with CO_2 storage in the subsurface at the Sleipner and Snøhvit fields is considered low based on the likelihood of an incident and potential harm to the environment (/36/). 4D seismic and well information

is used as the primary monitoring method on both Sleipner and Snøhvit. 4D seismic makes it possible to monitor CO_2 movements in the reservoir, while well data such as pressure and temperature provide information about changes in reservoir conditions. This also provides good opportunities for discovering a leak.

Monitoring biological and chemical parameters in sediment is governed by the Activities Regulations. Monitoring of the sediments at Sleipner and Snøhvit has been conducted every three years, pursuant to regulatory requirements. The primary purpose of this monitoring is not to monitor possible environmental effects related to potential CO_2 leaks. However, with the aid of reference stations, this monitoring can make it possible to collect background data in the area about local benthic fauna as well as for chemical parameters.

10.3 Other follow-up surveys

It is presumed that the ordinary and ongoing programme for Regional environmental surveys of sediments on the shelf will continue for a long time to come. The Aurora and Troll area is covered under Region III of this programme. Chapter 10.2 discusses how the Regional monitoring can be exploited and used in connection with environmental monitoring linked to the CO_2 storage complex in Aurora.

The planned emissions to air and discharges to sea during normal operation of the Northern Lights facilities for the geological CO_2 storage facility in Aurora are extremely small. On this basis, there is not considered to be a basis or need for further follow-up surveys than those already described and discussed. Therefore, there are no plans to implement other follow-up surveys than those described in Chapters 10.1 to 10.2.2.

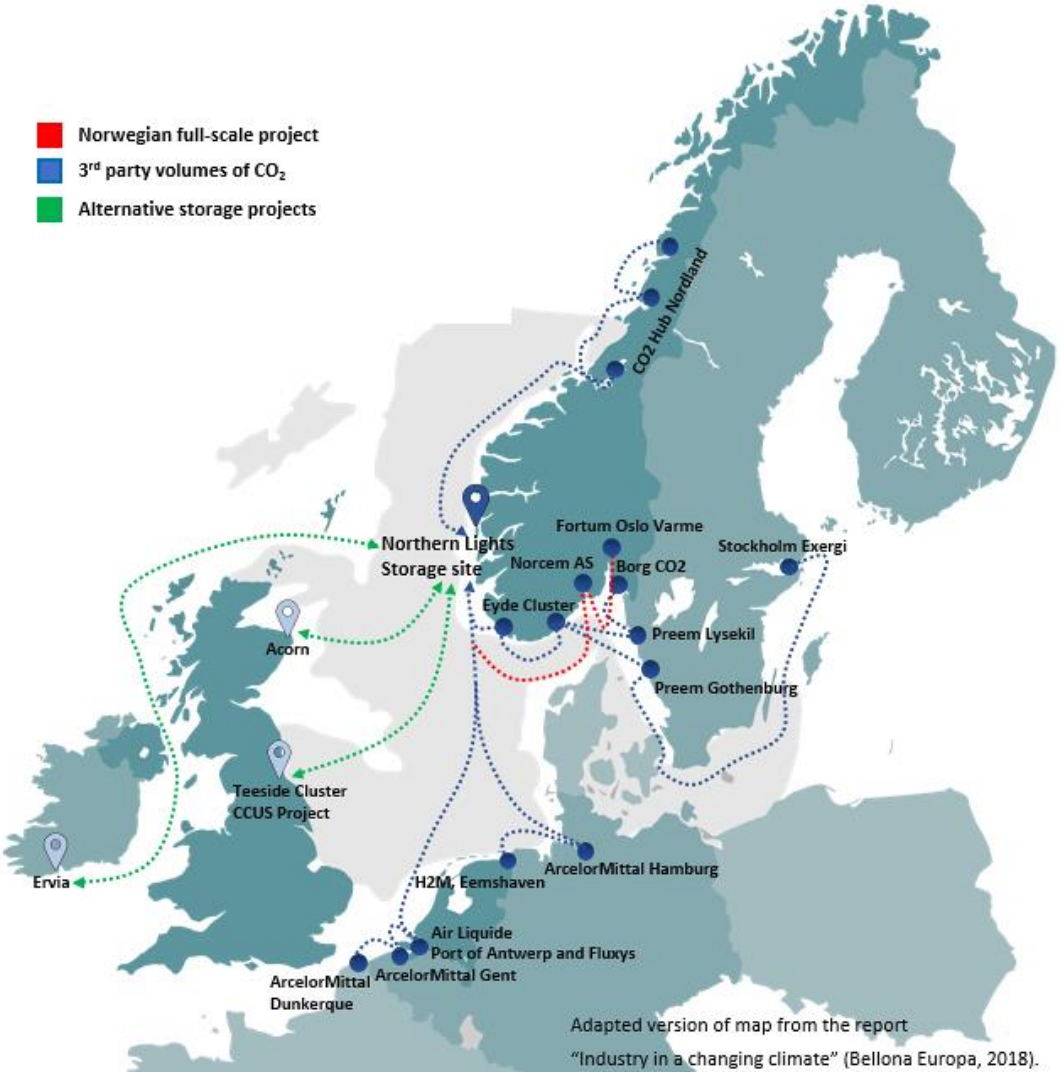
11 Northern Lights – European CO_2 transport and storage network

There are multiple initiatives and projects associated with capture and storage of CO_2 (CCS) around the North Sea. Of these, the Norwegian full-scale CCS project and Northern Lights are furthest along as regards realisation. The EU has a system for "Projects of Common Interest" - PCIs, where stakeholders in multiple countries band together in binding collaboration in larger networks.

Northern Lights, along with 14 partners, submitted an application for approval as a PCI project to the EU on 1 March 2019. The application is expected to be approved by November 2019. Once the network is approved as a PCI project, it can later receive funding from the EU system through separate applications, cf. Figure 11-1.

As regards permanent CO_2 storage, there are three other storage projects in addition to Northern Lights; Acorn and Teeside Cluster CCUS Project in the UK and Ervia in Ireland. The thought is that these storage locations could complement and complete each other. If injection at one storage site is temporarily shut down, it will be possible to send CO_2 cargoes to one of the other storage locations for injection and storage. This will strengthen and increase the robustness of CO_2 storage as a solution.

Figure 11-1 Northern Lights as part by a European CO_2 capture, transport and storage network.



In early September 2019, Equinor signed letters of intent on behalf of Northern Lights with the following seven companies as regards receiving and geological storage of CO_2:

- Air Liquide (Belgium, chemicals, and with a strong hydrogen strategy https://www.airliquide.com/
- ArcelorMittal (Luxembourg, iron and steel) https://corporate.arcelormittal.com/
- Ervia (Ireland, natural gas supply/distribution) https://www.ervia.ie/
- Fortum group (Finland, energy supplier – Fortum Oslo Varme is 50% owned by Fortum) https://www.fortum.com/
- HeidelbergCement (Germany, cement – Norcem is owned by Heidelberg) https://www.heidelbergcement.com/a
- Preem (Sweden, refinery and fuel) https://www.preem.com/in-english/about/
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Appendices

Appendix A: Early considered concepts, before awarding the Gassnova study agreement and establishment of Northern Lights

Appendix B: Letter from the Ministry of Petroleum and Energy of 14 January 2019, concerning transmission of exploitation licence 001

Appendix C: Map of sampling stations at Ljøsøyna, December 2018

Appendix D: Letter from the Ministry of Petroleum and Energy of 13 August 2019, concerning stipulation of study programme for impact assessment for Northern Lights

Appendix A

Early considered concepts, before awarding the Gassnova study agreement and establishment of Northern Lights

Background - feasibility study (2016) from the Ministry of Petroleum and Energy

In May 2015, Gassnova SF completed a pre-feasibility study of potential full-scale CCS projects in Norway, which identified a number of emission sources and storage locations that could be technically suitable for CCS and industrial stakeholders that could be interested in participating in further studies. In autumn 2015, the Government decided to continue the project in a feasibility study phase (/3/). The Ministry of Petroleum and Energy (MPE) had overarching responsibility for the work on feasibility studies. Gassnova SF acted as coordinator and was responsible for the capture and storage parts of the project, while Gassco AS was responsible for the transport part.

Three industrial players have carried out CO_2 capture studies; Norcem AS has assessed the feasibility of capturing CO_2 from the flue gas at its cement factory in Brevik, Yara Norge AS has assessed capturing CO_2 from three different sources at the ammonia factory on Herøya in Porsgrunn and the City of Oslo's Waste-to-Energy Agency (EGE) has assessed capturing CO_2 from the energy recovery plant at Klemetsrud (Klemetsrudanlegget AS). Gassco has carried out a ship transport study with assistance from Larvik Shipping AS and Knutsen OAS Shipping AS. Statoil ASA carried out a feasibility study for CO_2 storage at three different locations on the Norwegian continental shelf.

The feasibility study from the MPE (2016) (/3/) generally summarises which alternative CCS chains with solutions for development and operation of permanent storage were assessed in the effort. The feasibility study also recommends that a potential continuation of the project should be based on the following main concept:

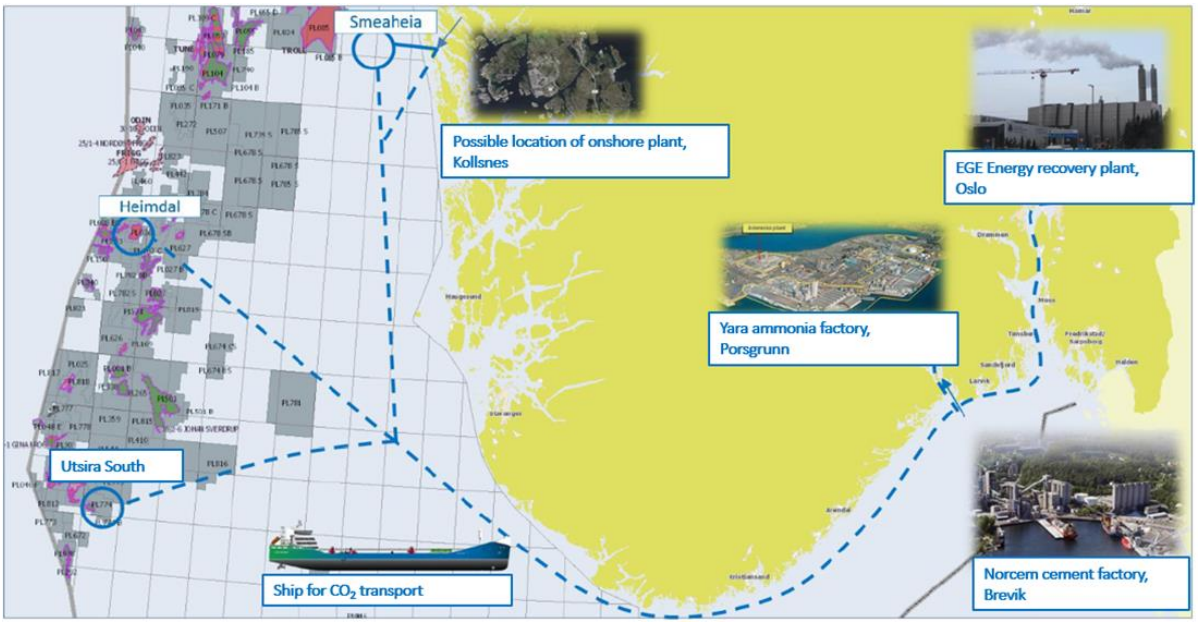
The transport ships transport cooled, pressurised and liquid CO_2 from capture players to a receiving and intermediate storage facility on land in Western Norway. Cooled and liquid CO_2 will be in intermediate storage at the onshore facility, before it is pumped through an export pipeline for injection for permanent storage in one or more new injection wells in a suitable geological reservoir in the Smeaheia area east of the Troll field.

Brief account of alternative considered storage locations on the continental shelf

The feasibility study from the Ministry of Petroleum and Energy from 2016 (/3/) points out three alternative subsea reservoirs on the shelf which have been considered as potential permanent storage locations, cf. Figure A-1. The considered reservoirs are:

- Smeaheia (east of the Troll field)
- Heimdal
- Utsira South

Figure A-1 Illustration of CO_2 chains considered in the feasibility study (MPE 2016) (/3/), translated from Norwegian. Yara ammonia factory on Herøya in Porsgrunn withdrew from the further work in spring 2018.



The MPE's feasibility study assesses the choice of storage and development solution as follows (p 41): *"Based on Statoil's and Gassnova's recommendations, it will be natural to continue a single storage location and single development solution in the next phase. Smeaheia is considered to be the most suitable location. In addition to the fact that the relevant storage formations in Smeaheia have the capacity to store CO_2 volumes beyond the volumes in the feasibility studies, the reservoir's seal is considered to be secure. The onshore facility at Smeaheia and the pipeline to the storage location will be based on familiar technology and could be realised with considerable surplus capacity. This is the development solution that best facilitates the exploitation of economies of scale in the transport and storage part of the project."*

In 2017, the project was based on permanent storage of CO_2 in a geological reservoir in the Smeaheia area East of the Troll field.

Early considered concepts – before establishing Northern Lights cooperation

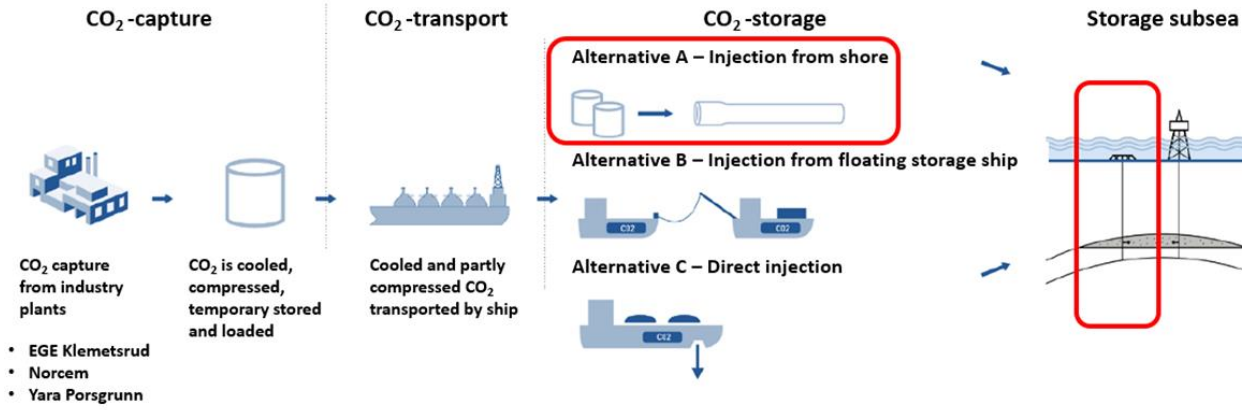
The feasibility study from the MPE (2016) (/3/) generally summarises which alternative CCS chains with solutions for development and operation of permanent storage were assessed. Industrial capture players will capture CO_2 from their own activity, the CO_2 will be cooled, compressed and placed in intermediate storage in liquid form for further transport in custom-built ships.

Chosen main concept for storage solution

The ships will transport cooled, pressurised and liquid CO_2 from capture players to Equinor's receiving and intermediate storage facility on land. At the onshore facility, cooled and liquid CO_2 will be in intermediate storage, before it is pumped through an export pipeline for injection (see alternative A) in one or more new injection wells in a suitable reservoir for permanent storage, preliminarily estimated at 1,000-2,000 metres below the seabed. Moving the permanent storage to a new storage location means that the storage depth is increased to about 3,000 metres below the seabed (see Chapter 2.1.1.2).

Consideration was previously also given to injecting CO_2 from a storage ship as intermediate storage for CO_2 received from transport ships (alternative B), and injection directly from the transport ship (alternative C). These alternative concepts have already been abandoned, but the concepts are briefly described in the following, cf. Figure A-2.

Figure A-2 Schematic representation of a CCS chain with interfaces (Figure 3.1.1. in (/3/)), translated from Norwegian. Chosen solution for storage is indicated red. Yara Porsgrunn withdrew from the CCS chain in 2018.



Alternative B – Injection from floating storage ship

- A sister ship of the transport ships will presumably be used, which will be modified and an injection plant will be installed.
- Using an offloading buoy (STL buoy), which will be connected to the subsea facility (or to the platform as regards Heimdal as storage location) with a flexible riser to transfer CO_2 from the ship. Such a buoy can be disconnected in critical situations. The ship must then also be equipped with a swivel and other connection equipment for the offloading buoy.
- One option under consideration is to connect the transport ships to the storage ship with flexible hoses. The ships will be dynamically positioned. One challenge will be small ships and considerable movements in poor weather compared with the shuttle tankers for oil, which is the industry's experience base today.
- Alternative solutions for transferring CO_2 between the different parts of the concept can be considered in subsequent phases. This solution requires the development of new technology, which

will take time and involve increased project risk. Among other things, experience is lacking with the use of flexible hoses to transfer CO_2 under water.

Alternative C – Direct injection

- In the alternative based on Smeaheia, CO_2 is injected from the ship through a seabed facility to the storage location. The concept involving direct injection takes a point of departure in the transport ship. The transport ship is equipped with an injection plant and connection equipment for the offloading buoy. The ship will connect and disconnect from the offloading buoy at each call.
- The number of connections and disconnections will be significantly higher than what has been experienced, and the pressure will also be higher. This could result in considerable wear and tear on the buoy and reduced regularity. One particular challenge is the constant shutdowns of the well with a risk of water flowing in from the reservoir at the bottom of the well, which requires corrosion-resistant materials in well completion.
- This solution will also allow for handling additional volumes, in that the number of transport ships is increased. Both Smeaheia and Heimdal have sufficient well capacity, but the costs increase with the number of ships and injection plants.
- On Heimdal, the wellhead is located on the field's main platform. The ship will be connected to the well through a flexible riser, a pipeline on the seabed and a riser on the platform. The transport ship will be connected to the well/platform through an offloading buoy here as well.
- Alternative offloading systems will potentially be considered in the next phase for both storage alternatives.

The ship-based alternatives for injection have been abandoned due to e.g. technical risk factors. The most significant risk elements in the technical solutions can be summarised as follows:

- Ship-based offloading systems between ships for the alternative with a floating storage and injection ship will require technology development
- Reduced regularity in offloading systems offshore for all ship solutions
- Impaired integrity in the riser (between offloading buoy and seabed facilities) in the event of low CO_2 temperature into the riser for all ship solutions
- A high connection frequency for the offloading buoy in connection with direct injection could result in increased wear and tear and reduced regularity

This means that implementation risk is considered to be higher for ship-based solutions than for a solution based on an onshore facility.

Appendix B

Letter from the Ministry of Petroleum and Energy of 14 January 2019, concerning transmission of exploitation licence 001

DET KONGELIGE
OLJE- OG ENERGIDEPARTEMENT

Equinor ASA

4035 STAVANGER

Deres ref	Vår ref	Dato
	18/305-	14. januar 2019

Oversendelse av utnyttelsestillatelse nr 001

Det vises til brev 4. januar 2019 fra Equinor ASA, der selskapet aksepterer Olje- og energidepartementets tilbud 20. desember 2018 om utnyttelsestillatelse.

Den 11. januar 2019 besluttet Kongen i Statsråd tildeling til Equinor ASA av tillatelse nr 001 til utnyttelse av et undersjøisk reservoar på norsk kontinentalsokkel til injeksjon og lagring av CO_2 i tråd med det aksepterte tilbudet.

Olje- og energidepartementet har med dette gleden av å oversende en undertegnet versjon av den første tillatelse til injeksjon og lagring av CO_2 på norsk sokkel.

Med hilsen

Gunnar Hognestad (e.f.)
avdelingsdirektør

Lars Jakob Alveberg
underdirektør

Kopi: Oljedirektoratet

Vedlegg: Utnyttelsestillatelse nr 001

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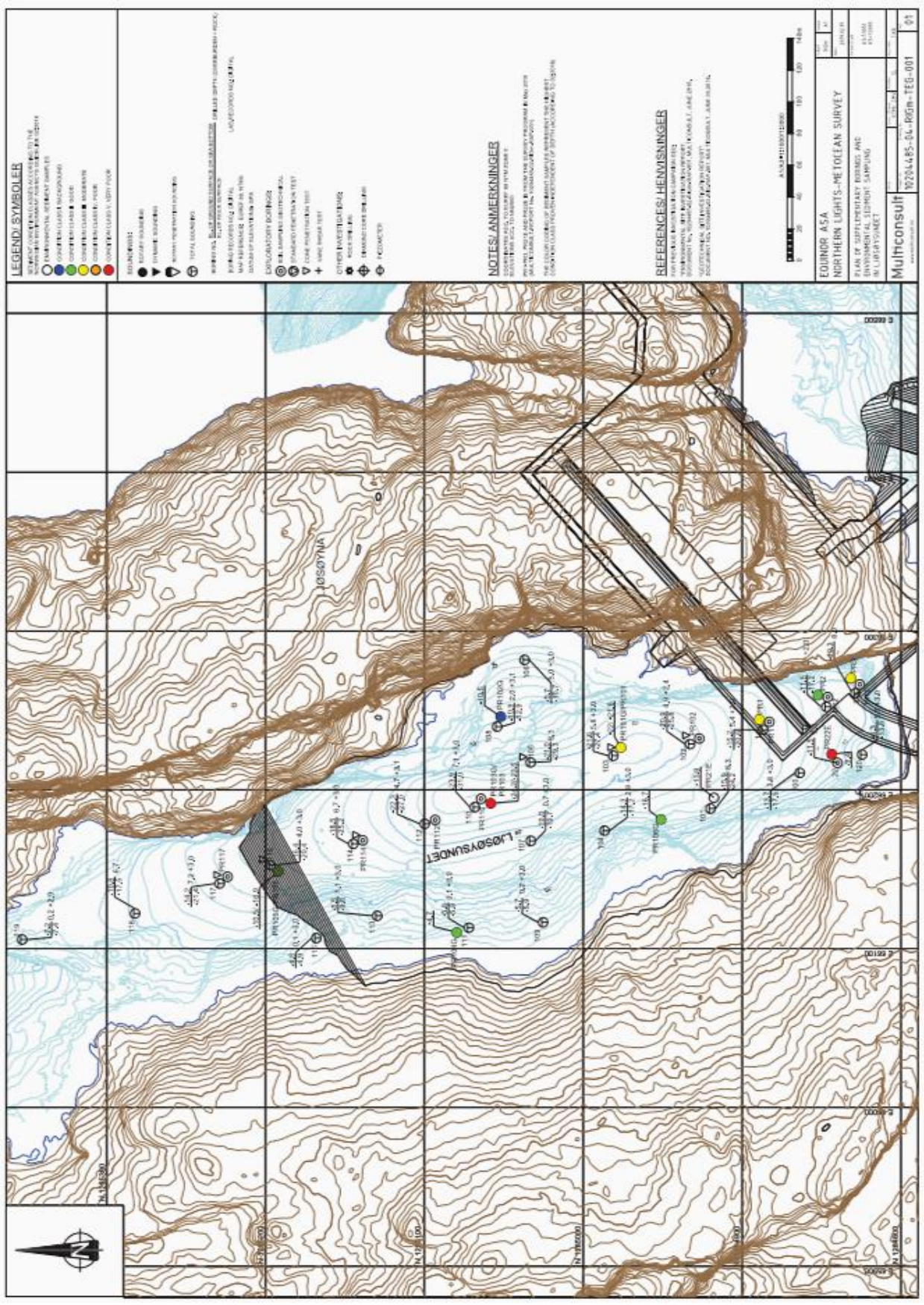
Appendix C

Map of sediment sampling stations at Ljøsøyna, December 2018


LEGEND/ SYMBOLER
NOTES/ ANMERKNINGER
REFERENCES/ HENVISNINGER
EQUINOR ASA
NORTHERN LIGHTS-METOCEAN SURVEY
Multiconsult
LØSØYNA
LØSØYSUNDET

Enclosure A
Coordinates and seabed elevation of environmental sample stations

Table 1: Coordinates, water depth and seabed elevation of the environmental sediment sample stations. Coordinate system EUREF 89 NTM ZONE 5.

Sample	Date	Time	X - East	Y - North	Water Depth (m)	Water Level NN2000 (m)[1]	Seabed elevation NN2000 (m)
PR101G	17.12.2018	08:39	66218.37	1284982.78	21,9	-0,09	-22,0
PR102G	17.12.2018	09:07	66246.83	1285051.96	10,4	-0,13	-10,5
PR103G	17.12.2018	09:27	66188.39	1285072.82	24,1	-0,16	-24,3
PR104G	17.12.2018	09:49	66112.16	1285076.57	4,5	-0,18	-4,7
PR105G	17.12.2018	10:19	66150.53	1285190.36	10,3	-0,2	-10,5
PR106G	17.12.2018	10:11	66183.38	1284949.88	16,5	-0,19	-16,7
PR101	14.12.2018	16:03	66220.91	1284985.44	21,8	0,28	-21,5
PR103	13.12.2018	13:30	66186.14	1285067.66	23,7	0,2	-23,5
PR105	05.01.2018	14:47	66153.27	1285194.96	16,6	-0,39	-16,9

[1] *The water level is from https://www.kartverket.no/sehavniva/*

Appendix D

Letter from the Ministry of Petroleum and Energy of 13 August 2019, concerning stipulation of study programme for impact assessment for Northern Lights

DET KONGELIGE
OLJE- OG ENERGIDEPARTEMENT

Equinor ASA

4035 STAVANGER

Deres ref	Vår ref	Dato
	18/248-31	13. august 2019

Northern Lights - fastsettelse av program for konsekvensutredning

Det vises til forslag til program for konsekvensutredning for Northern Lights-prosjektet, som ble sendt av Equinor ASA (Equinor) på offentlig høring 5. februar 2018 med høringsfrist 9. april 2018, samt til tillegg til forslag til program for konsekvensutredning som ble sendt av Equinor på offentlig høring 17. juli 2018 med høringsfrist 11. september 2018. Det vises videre til brev fra Equinor av 4. januar 2019, oppdatert gjennom brev av 3. juli 2019, med en oppsummering av innkomne høringsuttalelser og Equinors kommentarer til disse, og der det bes om departementets fastsettelse av konsekvensutredningsprogrammet.

Olje- og energidepartementet fastsetter med dette utredningsprogrammet for Northern Lights-prosjektet i tråd med det fremlagte forslaget til utredningsprogram, innkomne høringsuttalelser og operatørens kommentarer til disse, jf. forskrift 5. desember 2014 nr. 1517 om utnyttelse av undersjøiske reservoarer på kontinentalsokkelen til lagring av CO_2 og om transport av CO_2 på kontinentalsokkelen § 4-7 tredje ledd. Det forutsettes at Equinor i det videre konsekvensutredningsarbeidet tar hensyn til de innkomne høringsuttalelsene slik det fremgår av vedlegget. Kopi av fastsatt program skal sendes til dem som har avgitt uttalelse i saken.

Med hilsen

Kristoffer Stabrun (e.f.)
underdirektør

Henrik Mohr Nordviste
rådgiver

Dokumentet er elektronisk signert og har derfor ikke håndskrevne signaturer

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Kopi

Oljedirektoratet

Vedlegg

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COS - 190366. 2019.