Northern Lights Contribution to Benefit Realisation

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Table of contents

Contents

1 Northern Lights Contribution to Benefit Realisation

This report presents how the Northern Lights project realises benefits from the project, and how it plans to continue to do so. It has five chapters. The first chapter presents the plan for benefit realisation that has been developed for the Norwegian full-scale CCS demonstration project. It further describes how the Northern Lights has interpreted further guidance from the Norwegian government, to place particular focus on business and market development in realising the plan. The second chapter outlines how European climate policy can enable the Northern Lights and CCS in general, and how the Northern Lights can contribute to the realisation of national and EU climate policy goals. Contextualising the project in the climate and energy policy framework is important as the Northern Lights, like other CCS projects, are carried out as public-private partnerships, for which public policies are crucial. The third chapter describes how the project works to build business and markets, and outlines the results achieved so far. A key point is that markets are built by project and business development. Building on the concrete results, the fourth chapter provides an outlook for how the Northern Lights project can be a powerful driver of CCS development in Europe and globally. The final chapter links back to the benefit realisation plan and shows how the Northern Lights delivers and plan to continue to deliver on each of the 11 specific benefit realisation elements.

1.1 Benefit realisation, business and market development

The overall objective of the Norwegian Full-Scale CCS demonstration project has been defined as to contribute to the development of CCS, so that the long-term climate goals in Norway and EU can be achieved in a cost-effective manner. A plan for benefit realisation ("gevinstrealiseringsplan") from the project has been developed by the key stakeholders[1].

In the plan, four project goals have been formulated from the overall objective, stating that the project shall:

1. Demonstrate that CCS is feasible and safe.
2. Reduce cost for coming CCS projects through learning curve effects and economy of scale.
3. Give learnings related to regulating and incentivising CCS activities.
4. Contribute to new industrial opportunities.

Each of these goals has been further broken down into specific benefits, 11 in total, as shown in Figure 1 below.

[1] Gassnovas gevinstrealiseringsplan – Fullskalaprosjektet, approved in the Project Steering Committee 07.12.18

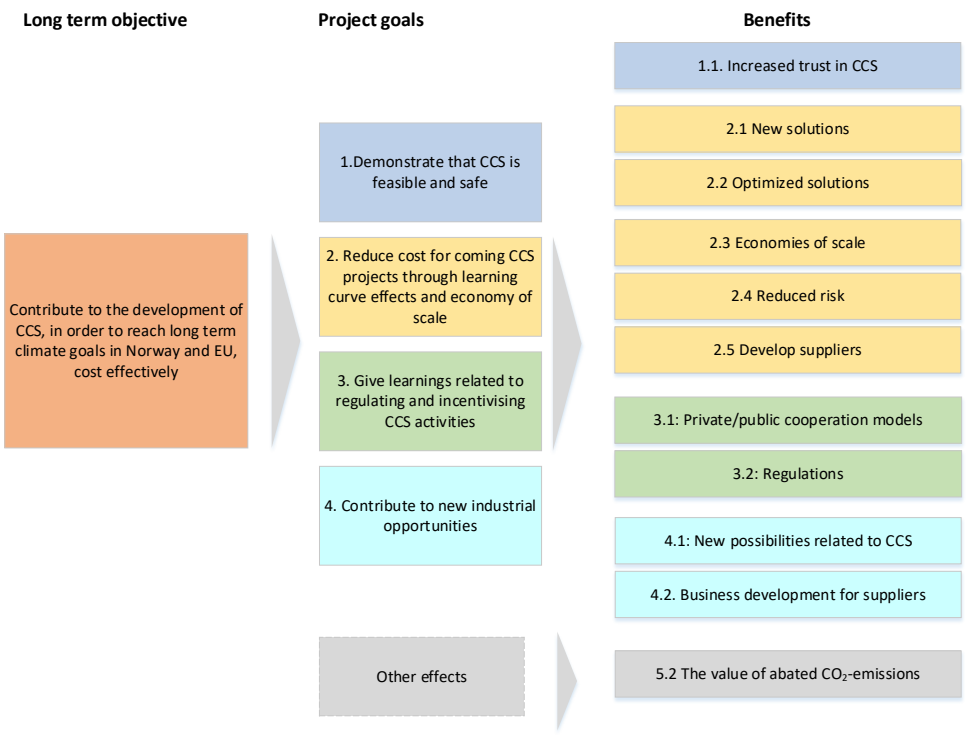


Figure 1. Illustration of long-term objective, project goals, and break down into specific benefits. Translation by Aslak Viumdal, Gassnova

This plan provides the basis for the Northern Lights' approach to benefit realisation. The approach has been further streamlined by two important communications from the Norwegian Government. The first came with the Norwegian Government's Revised National Budget 2018 (RNB 2018), which underlined and increased the importance and urgency of benefit realisation in general, and sourcing of 3rd party CO_2 volumes[2] and external funding specifically. Explained simply, 3rd party volumes and external funding were then re-defined from being something which the Northern Lights project was to provide plans for how to execute after the partner and state investment decisions (FIDs) were taken, to being something which the project must substantiate in the process leading up to the FIDs.

Further guidance from the Norwegian Government came with the political platform ('Granavolden-plattformen') 17/01/2019 for the new four-party government[3]. In their communication, the Government states that they have an ambition to realize a cost-effective solution for full-scale CO_2 management facility in Norway, given that this gives technology development in an international perspective. The Northern Lights project understands the statement to be fully in line with the original overall objective.

This guidance from the Norwegian Government has implications for how Northern Lights is to address the benefit realisation. The project interprets the overall guidance to be as follows:

[2] 3rd party sources are defined as any CO2 emission source outside the initial scope of the Norwegian Full-Scale CCS project that are interested in procuring transport and/or storage services from the Northern Lights.

[3] 'Granavolden-plattformen. Politisk plattform', *Rejeringen.no* website, last accessed 27/08/2019, accessible here

- Efforts to attract and source 3rd party CO_2 volumes and external funding are understood as being part of the scope of the project.

- The scope for 'demonstration effects' hence focuses more strongly on effects that are achieved in the efforts to attract and source 3rd party CO_2 volumes and external funding. Increasingly, it is hence effects achieved in those activities that determine how well Northern Lights succeeds with demonstration.

- References to future 'projects' also change. The most relevant 'projects' are now understood as all those 3rd party capture projects that are candidates for transport and storage services from Northern Lights. These projects, more so than other future full value chain CCS projects, are the key demonstration targets for Northern Lights

- In addition to showing how the project contributes to development of CCS so that long-term climate goals can be achieved in a cost-effective manner, it is also crucial to show how it contributes to technology development in an international perspective.

The Northern Lights project has responded to the Government's guidance by modifying its holistic approach to benefit realisation by increased urgency and efforts in its work to attract 3rd party CO_2 volumes and external funding. The holistic approach addresses all goals and benefits described earlier, though, e.g. by also including knowledge sharing and links to technology development. The increased focus on business and market development brings advantages also for the realisation of other project goals and benefits defined in the benefit realisation plan. One key example is the diffusion of learning which becomes more targeted and effective through this focus. The underlying mechanism for this effectiveness was precisely articulated by the quality assurance report KS2[4]. It points to the fact that for learning to give positive societal benefits, two pre-conditions need to be in place: there must be someone that wishes to learn, and the knowledge must be communicated at the right level, through the right channels and in the right context. As will be shown in this report, the project's efforts in business and market development aspire to meet these pre-conditions. The approach is to first identify those that are interested ('wishing to learn'), and then establish effective learning processes with private and public actors. The learning becomes targeted, as interested private and public parties actively seek to learn and collaborate with the Northern Lights and other public and private bodies in Norway with CCS expertise. Another positive effect is that one aligns the dual pathways of business and policy development that are both needed to realise all CCS projects and value chains. A third positive effect is integrated approaches for technology development, where project development, innovation and R&D go hand in hand.

[4] Kvalitetssikring (KS2) av demonstrasjon av fullskala fangst, transport og lagring av CO_2. Rapport fase 1 og 2. Utarbeidet for Olje- og energidepartementet og Finansdepartementet. 28 februar 2018, Atkins og Oslo Economics

1.2 European climate policy as a catalyst for CCS and Northern Lights

1.2.1 The climate change policy in the EU and Norway

In 2009, the EU committed to reduce its GHG emissions by 20% by 2020 compared to 1990, marking the start of an ambitious decarbonisation agenda. A signatory to the Paris Agreement, the EU and its individual member states have also committed to reduce its GHG emissions by at least 40% by 2030 compared to 1990. This commitment is crucial also to Norway as it has pledged to work towards '*joint fulfilment with the EU in order to achieve Norway's climate goals for 2030*'[5]. In line with the EU's climate policy, Norway takes part in the EU Emissions Trading System (EU ETS), which covers the industrial and energy sectors representing over 45% of the total GHG emissions. In addition, Norway has also committed to reduce emissions under the EU's Effort Sharing Regulation (ESR), which covers road transport, buildings and agriculture. Hence, the Norwegian climate policy is closely linked to the EU's in the framework of the Paris Agreement.

1.2.2 EU's decarbonisation policies in a 2030 and 2050 perspective

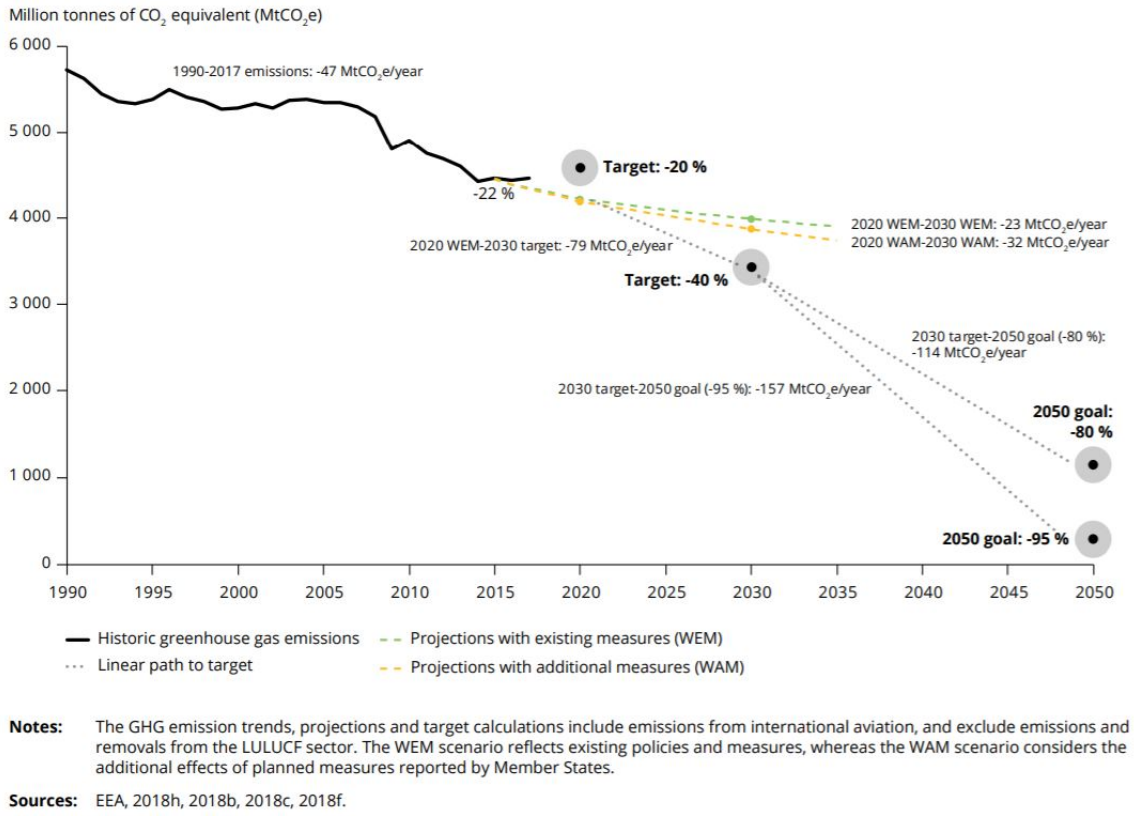
The EU's climate and energy policies are intrinsically linked: energy-related emissions are the largest source of GHG emissions. Therefore, decarbonising the energy sector is central to the EU's climate goals. The EU's clean energy strategy builds on three key components: 1) increasing the share of renewable energy in the overall energy supply; 2) improving energy efficiency; 3) increasing the share of electricity in the final energy consumption. These are indirect ways to reduce demand for fossil fuels and incentivise decarbonisation of the energy sector.

The EU's 2030 climate & energy framework foresees targets to increase the share of renewable energy to 32% as well as a 32.5% improvement in energy efficiency. According to the European Commission's projections, this is deemed sufficient to achieve the EU's GHG emission reduction target of 40% by 2030. However, renewables, electrification and energy efficiency do not abate emissions directly, which leaves most emissions-intensive sectors and sources outside of the scope of EU's decarbonisation policies.

In her political guidelines released ahead of the European Parliament hearings, the President-elect of the European Commission Ursula von der Leyen promised a number of policy initiatives to reinforce the EU's climate and energy framework for GHG emissions reduction. First, she promised to propose a European Green Deal in the first 100 days in office with the purpose of enshrining the 2050 climate-neutrality target. Similarly, von der Leyen also intends to increase the EU's 2030 GHG emission reduction target to 50-55%. She also aims to propose an extension to the EU Emissions Trading System to cover the maritime sector and gradually reduce the free allowances allocated to airlines over time. In a bid to protect the EU's industry exposed to a carbon price von der Leyen intends to introduce a carbon border tax. Furthermore, she will put forward a European industrial strategy with a vision for a low-carbon future. Circular economy is also under her agenda as a concept that will be employed to decarbonise the energy-intensive industries. To mitigate the socio-economic impacts of the energy transition, von der Leyen proposed to establish a Just Transition Fund to help regions dependent on carbon-intensive industries. She has also promised to put forward a strategy for green financing and a Sustainable Europe Investment Plan as well as to dedicate at least half of the European Investment Bank's financing to climate causes by 2025. This shows that the 2019-2024 European Commission is set to be considerably more environmentally oriented than the previous Commissions, which potentially implies a higher degree of climate ambition and commitment.

[5] 'Norway has ratified the Paris Agreement', *Government.no* website, 21/06/2016, accessible here

In order to achieve the EU's climate-neutrality ambition by 2050, a comprehensive carbon management framework is needed to prioritise the most cost-efficient and optimal low carbon solutions and to guarantee the affordability of energy system decarbonisation. Figure 2 illustrates the GHG emission reduction targets and future projections of actual emission reduction taking into account the existing emission reduction measures. It supports the idea that current policy measures fall short of achieving the decarbonisation targets by 2030, raising the need for more effective emission reduction policies and solutions. The graph also illustrates the need to increase the pace of decarbonisation post-2030 in order to meet an 80-95% decarbonisation target by 2050. The task would become even more challenging if a climate-neutrality target was endorsed. It shows that long-term GHG emissions reduction ambitions are unachievable without a much more comprehensive approach to decarbonising the emissions-intensive sectors.



Notes: The GHG emission trends, projections and target calculations include emissions from international aviation, and exclude emissions and removals from the LULUCF sector. The WEM scenario reflects existing policies and measures, whereas the WAM scenario considers the additional effects of planned measures reported by Member States.

Sources: EEA, 2018h, 2018b, 2018c, 2018f.

Figure 2. EU GHG emission trends, projections and targets. Source: European Environmental Agency (2018)

1.2.3 Underutilised decarbonisation tools: the use of CCS in the energy-intensive sectors

EU policy makers are now looking into the long-term vision of reducing GHG emissions beyond 2030, in compliance with the 'well below 2 degrees Celsius above pre-industrial levels' global warming scenario. In November 2018, the European Commission presented a Long-Term Strategy (LTS) for GHG emission reduction by 2050. The LTS comprises eight scenarios, which aim to demonstrate the feasibility of deep decarbonisation ranging from 80% reduction in emissions to achieving net carbon-neutrality by mid-century. While the LTS is not legally-binding, the Commission regards it as basis for ambitious mid-century decarbonisation commitments member states should make by early 2020, when the EU's GHG emission reduction targets are to be submitted to the UNFCCC as requested under the Paris Agreement.

To achieve unanimity among member states on an ambitious strategy, it is likely that the EU will have to offer trade-offs and possibly financial assistance to Central and Eastern European member states who are concerned with the affordability of financing climate change mitigation measures. A carbon-neutrality target would be legally-binding on the EU level making it likely that emission reduction targets will be shared disproportionally among member states based on the level of economic development as well as the emission reduction potential. That in turn increases the pressure on the more ambitious countries to project steeper national GHG emission reductions. Several governments in the EU member states have announced plans to adopt mid-century decarbonisation targets. In June 2019, both the UK[6] and France passed laws entailing carbon-neutrality by 2050[7], also paving the way for other ambitious member states to follow. These targets will need to be substantiated by robust decarbonisation policies that also protect economic activities.

Decarbonisation targets will be particularly relevant for the industrial sector in Norway and in the EU. Industrial sector activities make up roughly 15% of the EU's total CO_2 emissions[8] and are the largest contributor after energy supply and transport emissions. While industrial emissions in the EU have been declining in the past few decades, that relates to Europe's decreasing industrial capacities rather than more efficient production processes. The EU does not yet have a policy for industrial decarbonisation. In fact, the European Commission's assessment of the national energy and climate plans in the 2030 framework stressed the need for member states to create conditions for carbon-neutral transformation of the energy-intensive industries and encouraged them to use the EU ETS revenues to fund industrial decarbonisation[9]. The EU's growing preoccupation with industrial emissions as well as the future of the European industry in a low carbon environment accentuate the urgency to expand the pool of technological solutions that would directly address industrial emissions in time to reach the EU's decarbonisation commitments.

CCS plays an important role in industrial decarbonisation scenarios released by some of the most prominent international bodies. According to projections in the IEA's 2018 Sustainable Development Scenario, CCS accounts for 7% of the cumulative emissions reductions needed globally to 2040[10]. CCS and CCU in the scenario are expected to reduce global emissions by 1340 MTPA by 2040, of which 1160 MTPA in industrial sector applications[11]. Figure 3 below shows the existing gap between the CCS deployment scenarios and actual deployment rate to this date. It is illustrative of the need to significantly step up policies and investment support for CCS globally in order to meet ambitious climate targets. Similarly, CCS is recognised as one of the key decarbonisation technologies in the 2018 IPCC report, where its cumulative contribution to GHG reduction goes up to 300 $GtCO_2$ in one of the scenarios projecting a 1.5°C pathway[12]. In the EU's LTS, CCS is also listed as one of the strategic building blocks to achieve zero carbon emission economy[13]. The inclusion of CCS in global decarbonisation scenarios proves it to be an important but underexploited tool to significantly reduce carbon emissions in the energy-intensive sectors. The fact that relatively few investments have thus far been channelled to kick-

[6] 'UK commits to 2050 zero-carbon target as new legislation passes into law', by Jack Loughran, *Engineering and technology* website, 27/06/2019, accessible here
[7] 'French senate approves carbon neutrality law by 2050', *RFI* website, 19/07/2019, accessible here
[8] Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'United in delivering the Energy Union and Climate Action - Setting the foundations for a successful clean energy transition', European Commission website, 18/06/2019, accessible here
[9] Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'United in delivering the Energy Union and Climate Action - Setting the foundations for a successful clean energy transition', European Commission website, 18/06/2019, accessible here
[10] 'Carbon capture, utilisation and storage. A critical tool in the climate energy toolbox', IEA website, last accessed 19/08/2019, accessible here
[11] 'Carbon capture, utilisation and storage. A critical tool in the climate energy toolbox. Industry', IEA website, last accessed 27/08/2019, accessible here
[12] Chapter 2 'Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development', IPCC Special Report 'Global Warming of 1.5 ºC', p. 135, accessible here
[13] Communication from the Commission 'A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy', 28/11/2018, accessible here

start CCS further accentuates the urgency of government policies aimed at its rapid upscale in the energy-intensive sectors in particular.

In a bid to conceive a workable Industrial Strategy for significant GHG emission reductions from the industry, the European Commission has established a High-Level expert Group on energy-intensive industries. In October 2019, the Group will publish the Industrial Transformation Roadmap that will put forward a cross-sectoral vision of significantly reducing emissions in the EU's energy-intensive sectors. CCS is expected to play a role in the European industrial decarbonisation plan.

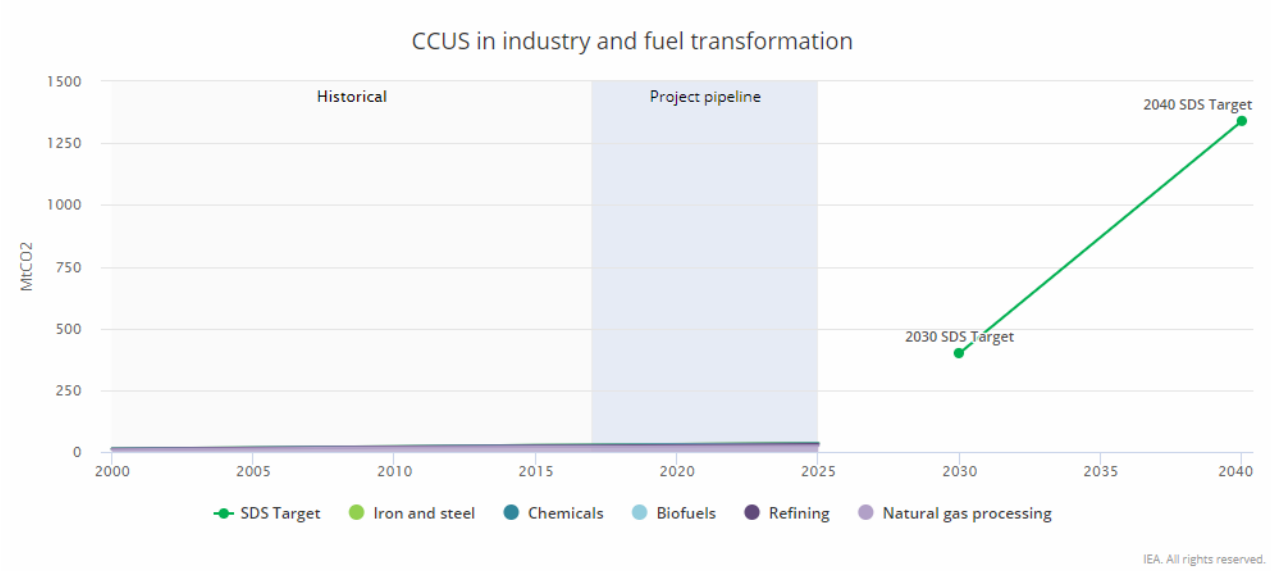


Figure 3. CCUS in industry and fuel transformation. Source: IEA (2018)

1.2.4 The EU's energy and climate framework to enable CCS

Growing pressure to cut emissions more deeply and rapidly has regenerated the European interest in CCS and CCU technologies. The EU budget is managed in seven-year periods and regulated under the multiannual financial framework (MFF) programme. As the EU's current MFF period is approaching the end in 2020, the EU institutions are in the process of negotiating funding priorities for the next budget cycle covering the period 2021-2027. Climate change mitigation will be one of the EU's key priorities in the next cycle and the institutions have agreed that some 25% of the EU's funds should go towards climate-friendly investments[14]. This includes low carbon energy technologies, including CCS which will be able to benefit from several EU funding programmes. They include the Innovation Fund to support demonstration and pre-commercialisation projects, as well as the Connecting Europe Facility that could be used to fund CO_2 transport. The funding potential for the Northern Lights project is discussed in detail in a later section.

At the same time, the EU institutions and member states are increasingly focusing on policies to tighten carbon price in line with the 'polluter pays' principle, either in the form of the EU ETS mechanism or in addition to it. Carbon pricing will be an increasingly relevant topic during the next Commission's mandate: in case the EU leaders fail to agree on more ambitious carbon pricing mechanisms, individual member states might adopt higher sectorial carbon prices to stimulate investments

[14] 'Supporting climate action through the EU budget', *European Commission* website, last accessed 19/08/2019, accessible here

in low carbon technologies. Either of the scenarios would be beneficial for the Northern Lights project as they could encourage the instigation of more CO_2 capture projects across Europe.

1.2.5 Northern Lights as gateway to decarbonising industrial activities in Europe

The Northern Lights project comes at a crucial point for the EU's climate and energy policy. On the one hand, the EU institutions are under pressure to commit to ever-more ambitious long-term GHG emission reduction targets. On the other hand, they are missing effective and realistic tools to decarbonise the energy-intensive sectors. The Northern Lights can prove the viability of CCS in decarbonising these sectors and help kick-start CCS projects leading to the development of a CCS network across Europe.

The Northern Lights aims to provide an open transport and storage solution for a number of CO_2 sources across Europe, thus lowering the development cost and the risks involved for carbon capture projects. This approach comes as a contrast to the one applied to the CCS projects that failed to realise under the EU's NER300 program a decade ago. An evaluation report by the European Court of Auditors pointed to several reasons for that failure, including adverse investment conditions; uncertainty in the regulatory framework; low carbon market price; poor programme design; and withdrawal of government support. These shortcomings are taken into account as the new generation of CCS projects is being realised.

1.3 Building a customer base and commercial markets for CCS

Adding substantial 3rd party CO_2 volumes is a key factor for the success of the Northern Lights. A positive FID on the Norwegian Full-Scale CCS project on behalf of the Norwegian government is to a large extent related to the potential for international development of CCS. It is also likely that income from 3rd party volumes will be paramount for building a business case for the Northern Lights Joint Venture.

3rd party sources are defined as any CO_2 emission source outside the initial scope of the Norwegian Full-Scale CCS project that are interested in procuring transport and/or storage services from the Northern Lights. 3rd party volumes are hence all CO_2 volumes other than the envisaged ones from Norcem and Oslo Fortum Varme.

To source 3rd party volumes, the Northern Lights project uses a multi-dimensional approach for building business and markets. There is currently no existing commercial market for CCS, which creates the need to engage in the broad market development to make it possible to realise 3rd party volumes and scale up CCS. This implies a broader scope of activities than the business development activities used where a functioning market already exists. The project team engages with potential customers and others (such as industry associations, government bodies, NGOs and research institutions) to try to secure funding, create enabling policy frameworks, improve CCS technologies and build public knowledge on CCS. The overall approach of Northern Lights for business and market development consists of the following elements:

- Business development
    - Identify, establish contact and indicate interest from 3rd parties
    - Formalize interest
    - Mature technical and commercial concepts
    - Commercial negotiation
    - Final investment decision
    - Execution and operation
- Market development to help realise business opportunities and scale up CCS:
    - Funding
    - Enabling policy frameworks
    - Research and technology development
    - Knowledge sharing

This chapter first explains the business development approach, activities carried out, and results achieved. It then outlines how the Northern Lights project works to develop markets for CCS, centred around the business opportunities that are identified and articulated together with prospective 3rd party customers. This approach ensures that the market building efforts on funding, policy, R&D and outreach are targeted and efficient.

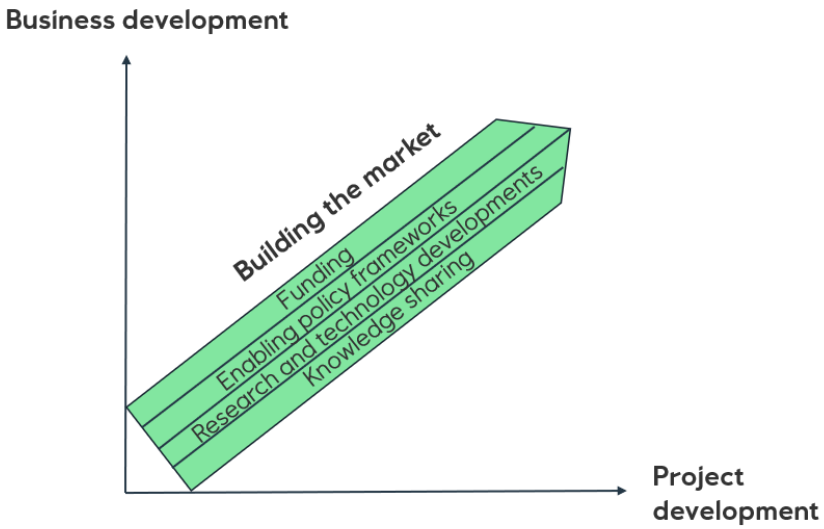


Figure 4: Conceptual illustration of how markets are by built by project and business development and co-ordinated specific market building activities

1.3.1 Business development

1.3.1.1 Business development is structured around a funnel with phases and milestones

The business development is structured around a stage-gate process with phases and milestones (decision-gates). This is illustrated as a funnel.This implies that many opportunities with 3rd party customers are identified and explored at early stages. The most promising ones are matured towards investment decisions through several phases and milestones, gradually making them more concrete and detailed. The relationships with 3rd party customers are at the same time gradually deepened and formalized. An illustration of the funnel is shown below. In the following sub-chapters, each of the phases and milestones are described, together with results achieved so far.

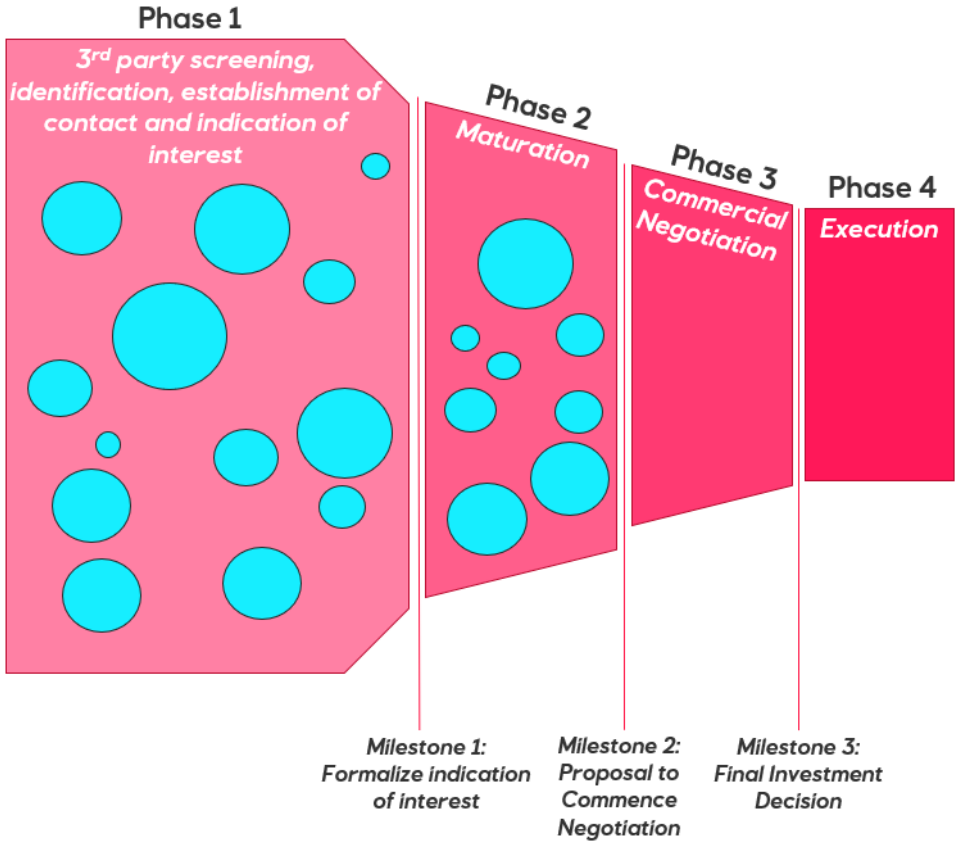


Figure 5. Funnel illustration of the business development process. The number, size (CO2 volume) and placing of business opportunities ("bubbles") are indicative only. The purpose of this graph is to picture a typical maturation of 3rd party opportunities. A typical business development strategy aims to have opportunities in each of the phases at all times.

1.3.1.2 First phase: 3rd party screening, identification, establishment of contact and indication of interest

The initial step in the business development strategy is to gain an overview of possible and attractive candidates. The main approach for doing so is desktop identification by use of a software developed by consultants Endrava and Carbon Limits for the Norwegian Oil & Gas Association (NOROG). The tool helps the project identify candidates by desktop screening of CO_2 volumes, qualities, port availability, distance to Naturgassparken, potential for cluster development as the main important factors determining the suitability of potential future CO_2 capture partners.

The analytical tool is based on a large amount of publicly available data, mainly from the European Pollutant and Transfer Register (E-PRTR). It includes all European emission points emitting more than 100 kT of CO_2 per annum. Figure indicates the market potential by screening all industrial sites with emissions larger than 100 kT per annum, less than 1200 km distance in direct line from Naturgassparken and located less than 25 km from a port. This approach estimates the total amounts to 613 sources and 600 million tonnes of CO_2 per annum. The different sources represent a range of industry segments, also illustrated in Figure . Based on the CO_2 concentration, the purity of the CO_2, and applicable capture technology, the relevance for applying CCS within each industry segment can also be estimated.

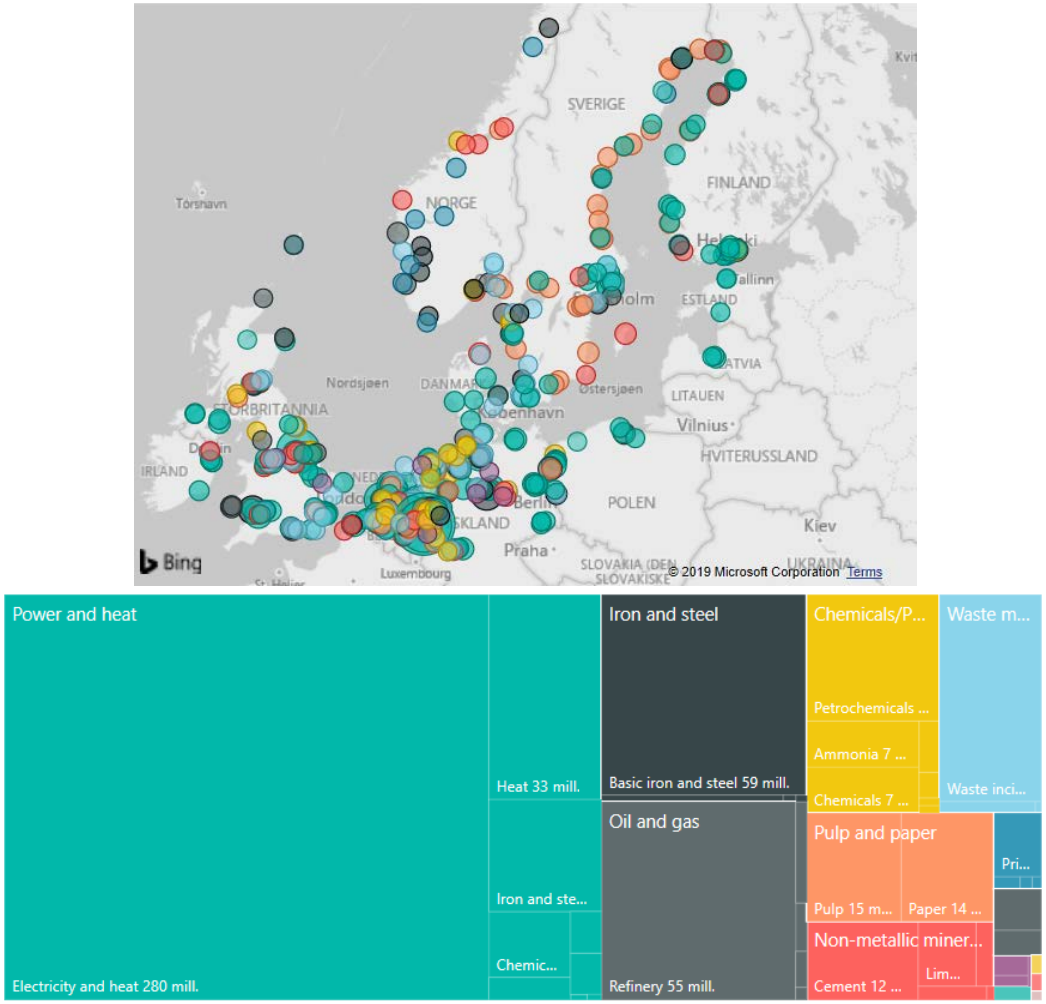


Figure 6. Mapping of industrial sources of CO2 emitting more than 100 kT per annum of CO2, located less than 1200 km direct distance from Kollsnes and less than 25 km from the closest port. The mapping tool was developed by Endrava and Carbon Limits in cooperation with NOROG and the Northern Lights project.

The analytical screening enables a structured approach of identifying relevant 3rd party CO_2 sources based on general geographic and industrial data. The strategic fit of CCS, and further technological feasibility is then tested through dialogue with specific companies. This enables a positive feedback loop, where the insight gained in these dialogues allows for a better understanding of which sectors that have the best potential for CCS in the short term. The current perspective is that these sectors (in non-ranked order) are:

- Hydrogen and electricity production from natural gas
- Waste incineration
- Cement
- Biomass and biofuel
- Steel
- Refineries

Of the 613 sources in the original screening shown in Figure , these most attractive sectors include approximately 350 facilities and 300 million tonnes of CO_2 emitted per annum. A crucial aspect of these sectors is that they, with the CCS solution in place, can be long lasting sectors that thrive through the energy transition.

The next step is to identify and initiate contact with specific 3rd party candidates. The Northern Lights business development team uses several ways to approach potential candidates, namely through: 1) targeted reach out resulting from desktop identification; 2) Northern Lights partner network suggestions; 3) participation and presenting at conferences and meetings; 4) other networking; 5) participation in research projects; 6) proposals from governmental bodies, NGOs and other parties.

In addition, the Northern Lights team cooperates with a number of Norwegian Embassies in Europe. Based on their network and national insights, the embassies are able to connect Northern Lights with representatives in companies and governments who could have an interest in CCS. The Northern Lights partners also use their industrial networks and trade associations they are part of to reach out to 3rd party candidates.

The project keeps an open dialogue with Gassnova and the Ministry of Petroleum and Energy (MPE) about business development already in the early phase. This is valuable, as successful company-to-company business development requires a complementing nation-to-nation process. Early involvement and dialogue from Gassnova and MPE makes it possible for them to early initiate contacts with the relevant other countries. One specific example is the highly valuable CCS safaris, in which Gassnova hosts delegations from authorities in other countries that come to Norway to learn more about CCS.

As of September 2019, Northern Lights is in dialogue with some 25 potential customers from several European countries. The individual dialogue with potential 3rd parties aims to verify the customer's interest and evaluate his ability to capture CO_2. To uncover the 3rd party's viability for the early phases of the Northern Lights, the initial focus is put on the timeline, volumes and specific needs of the 3rd party to transport the first CO_2 for storage. In case of positive evaluation, cooperation with promising customers is matured and formalised as quickly as possible. The following section describes how partnerships with potential 3rd parties are formalized for Milestone 1.

1.3.1.3 Milestone 1: Formalise indication of interest

Milestone 1 is achieved when engagement with potential 3rd parties has confirmed that there is a real interest from the 3rd party customer to connect with the Northern Lights. Several means are used to formalise this interest, with joint applications, joint projects, NDAs and MOUs being the most important ones. This is described below.

Northern Lights has applied for expanding its European Project of Common Interest (PCI)

Projects of Common Interest are European infrastructure projects that are recognised by the EU as projects of strategic importance. Applying for, and being added to, the PCI list allows infrastructure projects to be prioritised in terms of facilitating the regulatory framework. In addition, having the PCI status is a prerequisite to apply for funding under the Connecting Europe Facility funding programme. In the energy sector, infrastructure projects in the power, gas networks as well as CCS can apply to be recognised as PCIs.

The Northern Lights project first applied to be recognised as a PCI in 2016 and was subsequently added to the third PCI list in 2017 (under the title PCI 12.4). The first Northern Lights PCI is based on the project scope as of the first half of 2018 and includes the Norwegian full-scale project, the H2M hydrogen project in Eemshaven, the Netherlands as well as the Teesside Cluster CCUS Project in UK. In March 2019, the Northern Lights project reapplied for the PCI status to be expanded under the title 'Northern Lights – Enabling a ship-based European CO_2 Transport and Storage Network'. This re-application reflects the interest in the Northern Lights storage potential on behalf of European industrial companies, which

has grown tremendously since the first PCI application was submitted. The new PCI application expands the Northern Lights PCI project scope in three directions:

i. The inclusion of the full Northern Lights partnership with Shell and Total, in addition to Equinor.
ii. The inclusion of several more European capture sites. In total the application includes 15 capture sites from 6 countries (France, Belgium, Netherlands, Germany, Sweden and Norway).
iii. The inclusion of three European CCS full value chain projects as reciprocal storage alternatives; Acorn and Teesside Cluster CCUS project in UK, and Ervia in Ireland. These storage alternatives all plan to include shipping as a part of their scope for CO_2 transport.

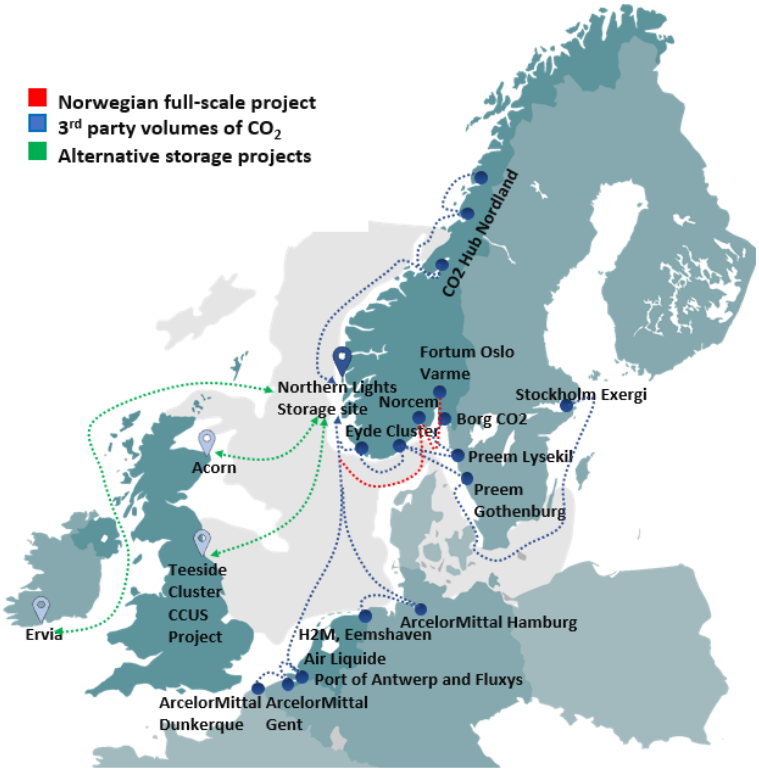


Figure 7. Map illustrating the partners in the 'Northern Lights – Enabling a ship-based European CO2 Transport and Storage Network' PCI application from March 2019, and potential logistics routes

The PCI application represents a portfolio of leading industrial companies in Europe who are technically and strategically well-positioned for developing capture of CO_2 at their sites and connect to the Northern Lights infrastructure in the short term (5-10 years). In the application each applicant describes their strategic rationale for developing CCS, the volume of CO_2 they would capture, where the capture infrastructure would be built, as well as the logistics related to the Northern Lights. The majority of the applicants have experience with CCS, and several are conducting concept and/or feasibility studies, including pilot testing. Given successful results from these studies and tests, the capture sites are still dependent on a confirmed storage site in order to develop their capture to a commercial scale. A positive FID for the Northern Lights is therefore key to enable further development of these capture initiatives. Below is an overview of initial CO_2 volumes, processes, expansion possibilities beyond the initial volumes and start-up dates indicated by the 3rd parties.

Company	Country	Capturable initial volumes indicated in PCI [tonnes per annum]	Operational start up and/or future expansions (information from PCI application)

Figure 8. Overview of the capture sites included in the PCI application, indicated CO2 volumes that would be relevant for capture and transport by Northern Lights, and quoted details on start-up and/or future expansions from the individual partner

The total volumes of CO2 from these sites add up to considerably more than 5 MTPA, which is the current targeted capacity of Phase 2 of Northern Lights. Expansion from Phase 1 to Phase 2 and any further expansions thereafter would be considered by the Northern Lights project partners subject to market conditions as well as a final investment decision.

The ship transport solution provides flexibility that facilitates the scale-up of a CO_2 transport and storage network. As a result, Northern Lights could also act as a reciprocal storage alternative to other CCS project in Europe, making a European CCS network more robust and flexible. This would allow for the individual storage locations to act as complementary solutions, offering optionality in development and operational phases. Acorn, Teesside Cluster CCUS Project and Ervia agreed to join the PCI application as reciprocal storage sites.

As a result of having matured their project further, and with Northern Lights having a potential start up already in 2023, Ervia has since submitting the PCI application informed that they would have an interest in shipping their volumes to Northern Lights for a period of 10-15 years. This is the time which Ervia now estimates it will take to develop their own storage solution and for Ireland to be ready to approve it. Therefore, the Ervia project is now considered a potential 3rd party customer, rather than reciprocal storage alternative. This confirms how valuable an early investment decision and start-up of the Northern Lights can be for kick-starting European capture and storage.

The status of the PCI application as of September 2019 is that it has passed the technical assessment from the European Commission's Joint Research Centre (JRC), where it was concluded that the project is compliant with the TEN-E regulation and recommended to be included to the PCI list. It has also received no objections after the public consultation on the CCS projects initiated by the European Commission. The European Commission has recommended the Northern Lights project to be added to the fourth PCI list. The remaining step in the approval process is to confirm the support from the EU member states included in the application. The final outcome with regard to being added on the fourth PCI list is expected in Q4 2019.

Joint projects

Another way of formalising 3rd party interest is through joint projects. One such example is when Preem in 2018 invited Equinor, on behalf of Northern Lights, to take part in an R&D project. The project is about testing CO2 capture technology (Aker Solution mobile test unit) at the Preem refinery in Lysekil and placing the demonstration into a pathway towards full-scale implementation of CCS. The partners for the R&D project are Preem AB, Aker Solutions, Sintef, Chalmers University and Equinor R&D. Funding has been received from Norway (Climit) and Sweden (Energimyndigheten). It started up Q1 2019 and will conclude about the feasibility of full-scale CCS implementation in Q4 2021. Equinor will contribute with interface information to ensure that CO2 capture design is compatible with Northern Lights and share generic learnings from the Northern Lights work.

Non-Disclosure Agreements (NDAs)

Relevant elements to be assessed and addressed with potential 3rd parties include the CO2 volumes and specifications; logistics; timeline; need for external funding; credit risk; scale-up opportunities and risks; key challenges; as well as indicative tariffs and possible tariff structures.

The NDAs put in place allow the parties to share commercially sensitive material. Commercial negotiations can however only start once the Northern Lights has reached an agreement with the Norwegian Government with the subsequent incorporation of a Joint Venture.

Northern Lights has taken a precautionary approach to competition law issues by early establishing a small designated 'Clean Team' which is governed by a specific set of rules. Within the boundaries of this framing, the members of the Clean Team can receive, provide and discuss commercially sensitive information.

Memorandum of Understanding

A Memorandum of Understanding (MoU) between Northern Lights and a 3rd party confirms that the parties have matured their understanding and agree to develop technical and commercial scope to greater detail. The objective of a MoU is therefore for the involved parties to formally agree to enter into further good faith discussions to explore the possibility of cooperating in CCS development, which includes CO2 capture and liquefaction at the site of the relevant 3rd party, with subsequent transportation and storage with the Northern Lights. It further aims to establish the general terms and scope of this cooperation, which includes, but is not limited to, the following activities:

- Cooperate in developing logistics that address the optimal ship size for current and future volumes, ship loading frequency, storage and potential cluster developments.
- Define CO_2 specifications that are optimized across each segment of the value chain (capture, transport, storage), and the viability of CO_2 specification for different volumes and rates.
- Further explore timeline for the potential start of operation, including key activities and milestones to enable a positive FID for each of the parties.

- Joint advocacy towards national and EU authorities about CCS, its importance for the successful decarbonization of European industry, and suggesting how can policies can be upgraded, and funding made available.
- Facilitate bilateral dialogue between Norway and the authorities at relevant regional, national and international level.

Equinor, on behalf of Norther Lights, signed MOUs with seven companies in connection with the European High-Level Conference on CCS in Oslo, 5 September 2019. They are:

- Air Liquide, Belgium
- ArcelorMittal, Luxembourg
- Ervia, Ireland
- Fortum Group, Finland
- Heidelberg Group, Germany
- Preem, Sweden
- Stockholm Exergi, Sweden

1.3.1.4 Second phase: Maturation

After having passed the first milestone of formalizing interest together with the 3rd party companies, the Northern Lights team will work closely with them to further mature and deepen the joint understanding and technical and commercial concepts. For several of the potential 3rd parties such further maturation has already commenced. Discussion points include technical and commercial topics, including but not limited to:

- rates/volumes (e.g. whether supply rates of CO_2 change over time)
- timelines (e.g. commencement date and duration of supplies)
- CO_2 specification (e.g. whether the CO_2 supplied meet existing specifications, or will there be a need to perform technical updates to existing facilities in order to accommodate so-called off-spec CO_2)
- logistics (e.g. who performs transportation; in some rare cases the emitter might want to do this)
- scope for synergies and economies and scale (e.g. between several 3rd parties with adjacent emissions and hence scope for joint liquefaction and offloading facilities)
- the potential risk of failure to supply agreed volumes and pay agreed tariffs, in particular in the long term, e.g. due to discontinuation of the industrial activities that results in CO_2 emissions (so-called Credit Risk; e.g. due to relocation of the activities to countries outside the ETS, bankruptcy, or other fundamental changes).

Following a natural commercial maturation process, Northern Lights and the 3rd party will enter a so-called Heads of Terms (HoT), which is a contract that confirms the main technical assumptions and the key commercial elements the parties agree to. It is expected that some HoTs will be entered into during the first half of 2020, in time for the 3rd parties to strengthen their applications for support from the Innovation Fund. Entering into HoTs during 1st half of 2020 will also help the Northern Lights JV partners to take their FID, as well as help the Norwegian state take its State FID during Parliament's autumn session in 2020. Subsequent to, and building on the HoT, the parties will in the third phase work towards so-called fully termed agreements, where all aspects of the relationship between the parties will be regulated. Such a fully termed agreement is hence a detailed version of the HoT. A fully termed agreement is needed to take a final investment decision on the contractual scope between the 3rd party and Northern Lights.

1.3.1.5 Further milestones and phases

Moving forward through the funnel, there will be additional milestones and phases, leading up to investment decisions, execution and operations. They are:

- Milestone 2: Proposal to commence negotiation
- Third phase: Commercial negotiation
- Milestone 3: Final investment decision
- Fourth phase: Execution

1.3.2 Market development

The Northern Lights project aims to realise markets to enable business opportunities and scale up the Northern Lights and large-scale CCS application in Europe. Below is a description of how this can be achieved by engaging with a multitude of stakeholders to try to secure funding, create enabling policy frameworks, improve CCS technologies as well as communication methods.

1.3.2.1 Enabling funding for Northern Lights scale up and 3rd party customers

While identifying and maturing business opportunities with third-party customers it becomes clear that all of them will need public funding support to be able to realise their capture solutions and to pay the necessary tariffs for transport and storage. A possible scenario for how this could play out, irrespective of which transport and storage operator they choose, can be as follows for Northern Lights:

> *The investments in the Norwegian CCS value chain, including the initial Northern Lights infrastructure, are made by the Norwegian government and the companies involved. Other governments in Europe and EU programs then support and co-fund European capture projects, including their use of the Northern Lights transport and storage solution. Extension of Northern Lights infrastructure to accommodate larger CO2 volumes is likewise co-funded by governments and EU schemes. Through such partnerships will third-party companies and Northern Lights be able to pull together "funding packages" that realise their projects. The packages would combine EU support, national support, carbon prices (ETS), loans, increased income from higher value (CO_2 free) products, company investments and possibly other sources.*

Northern Lights is engaging with national and the EU administrations to examine the relevance of various public funding programmes for covering the development costs of different parts of CCS value chains. This is often done in collaboration with customers and other parties such as the Zero Emission Platform (ZEP) and industry associations. Below is an outline of the most relevant funding programs the Northern Lights project will consider as well as the project team's engagement with the authorities managing them.

1) **EU support schemes:**

- The EU **Innovation Fund (IF)**, which will be tailored to support pre-commercial CCS projects, can help finance the whole CCS value chains, including CO_2 capture installations across Europe linked to the Northern Lights. The Fund, to be set up in coordination with the fourth trading period of the EU ETS (2021-2030), will be composed of the value of 400 million allowances as well as the value of an additional 50 million unallocated allowances from the market stability reserve together with the unspent funds form the NER300 programme. While the exact budget

of the Fund is yet unclear and will depend on the EU ETS price, it is estimated that it could amass around €10bn during the 7-year operating period[15]. The main criteria for projects seeking support includes the GHG emission reduction potential as well as potential for scale up and wide-spread use. The IF can finance up to 60% of the relevant costs of individual projects. CCS projects will be eligible, but there will not be earmarked funding for CCS which will have to compete with other solutions.

- The EU **Modernisation Fund (MF)** is another potential funding mechanism that could be used to cover capital costs for CO_2 capture installations in specific member states eligible for it. The MF will be financed by auctioning 2% of the total European Emission Allowances (EUA) to foster energy efficiency and the modernisation of the energy sector in member states with a GDP per capita below 60% of the EU average. These member states will be able to derogate from the principle of full auctioning for electricity generation by using the option of free allocation in order to support investments in the generation and use of electricity from renewable sources, the improvement of energy efficiency, energy storage and modernisation of energy networks, in addition to support a just transition in carbon-dependent regions. It remains to be seen whether CCS could be included in the scope of the MF.

- The **Connecting Europe Facility (CEF)** – the EU's fund for cross-border energy infrastructure – could support the transport part of the Northern Lights project. Only the projects that are added to the list of common interest (PCIs) of the EU can qualify for funding. These projects must have the potential to contribute to energy security and completion of the EU internal energy market; provide benefits in terms of system integration, innovation, cost savings as well as prove that they would not materialise without a grant. In the period 2021-2027, some €8.65bn will be made available to energy projects, including CCS projects. A more detailed explanation of the CEF fund and its regulatory framework is provided in further sections.

The aforementioned EU funds can help to scale up CCS in Europe and can benefit the Northern Lights project and the project's partners during the period 2021-2027. The Northern Lights team is closely following the developments with regard to these funds, including close engagement with the European Commission's services responsible. In early September, the Northern Lights team took part in an Innovation Fund-related workshop organised by the ZEP in cooperation with the European Commission. The workshop was held in combination with the EU-Norway High Level Conference on CCS. The conference as well as the workshop were excellent opportunities to showcase the Northern Lights as one of the most promising CCS projects in Europe and discuss funding and outreach opportunities on the EU's side. The project team is also considering different scenarios for using the EU funds across the CCS value chain and will issue recommendations to CO_2 capture partners once the exact application procedures for these funds are set.

2) **CCS policies and funding in member states.** State aid will be necessary, in addition to EU funding and price on carbon, to cover the CO_2 capture and transport and storage tariff costs for 3rd party customers. Some governments in the EU, like the Netherlands, Sweden or the UK, are planning to earmark funds to support CCS development, which could fund industrial capture installations. CO_2 capture projects to benefit from such funds are among likely candidates for the first two phases of the Northern Lights project. Such first movers will help standardise the equipment and logistics related to CO_2 capture and reduce costs for the next generation capture projects, thus lowering the need for public funding and contributing to the scale-up potential of CCS. The Northern Lights team and 3rd party supplier companies will engage with national administrations to explore the opportunities for state support for the first-mover CO_2 capture projects in Europe. It will follow partnership maturation with 3rd parties and the planning of concrete capture projects.

[15] 'Innovation Fund', *European Commission* website, last accessed 19/08/2019, accessible here

In line with the EU Governance regulation[16], member states must submit national energy and climate plans (NECPs) indicating national policy measures to achieve climate and energy targets in the 2030 framework. The first drafts, submitted in December 2018, were illustrative of the member states' plans to support the deployment of CCS to achieve their national decarbonisation commitments. 11 member states included CCS in their national strategies, which indicates their willingness to explore CCS technologies to support GHG emission reduction targets. Another 6 member states are involved in various European research initiatives aimed at accelerating CCS technologies on the EU level but have not mentioned CCS in their national climate strategies. Governments in the UK as well as the Netherlands are already considering ambitious CCS support policies, focusing on industrial decarbonisation. Others, including Sweden, Denmark and Finland, already have or are planning to allocate substantial funding to research and demonstration activities linked to CCS. Most member states do not have specific CCS deployment plans but have expressed the intention to develop CCS to mitigate emissions. It is therefore crucial that the first-mover governments are able to realise Europe's first CO_2 capture projects, thereby encouraging other member states to consider taking concrete steps towards a full-fledged CCS strategy.

3) **Carbon price mechanisms in Europe.** The EU ETS is the main carbon pricing mechanism for the energy intensive industries in the EU and Norway. The first three trading phases of the EU ETS mechanism have been marked with relatively low prices for obtaining emission allowances, with prices crashing in the immediate aftermath of the economic recession. This has had negative consequences for advancing CCS projects in Europe in the past.

To reinforce the EU ETS mechanism in the forthcoming trading phase (2021-2030) and guarantee a stable carbon price, the EU has revised the EU ETS Directive to add a Market Stability Reserve (MSR) in 2018. Under the revised model, the number of total emission allowances available will contract by 2.2% annually starting from 2021. Furthermore, the amount of allowances put in the MSR will double to 24% of the allowances in circulation during 2019-2023. In addition, the revision established a gradual reduction of free allocation for less exposed sectors: it foresees a phase out of free allocation after 2026, gradually reducing from a maximum 30% to 0 by 2030. These measures aim to improve the functioning of the EU ETS and guarantee a more stable and predictable framework to encourage long-term investment in decarbonisation. Following the revision, the EU ETS price has been gradually increasing to reach approx. €25 t/CO_2 (September 2019). While this has indeed been a positive development for the Northern Lights project concept, it is clear that the ETS price level is still below what is needed to fund CCS value chains and achieve ambitious climate goals.

Carbon pricing will be a determining factor for investments needed to speed up the transition to a low-carbon economy in Europe. As a result, the EU and individual member states are under growing pressure to establish effective carbon pricing mechanisms that would encourage decarbonisation projects. It is likely that some of the most ambitious EU member states will on an individual basis introduce additional carbon pricing or carbon price floors to supplement the EU ETS and encourage European industries to invest in measures to reduce their GHG emissions. In her political guidelines as future president of the European Commission, Ursula von der Leyen promised to introduce a carbon border tax to avoid carbon leakage, applicable to a number of selected sectors and gradually extended over time[17]. If realised, such a tax could strengthen the case for a strong carbon price in the EU and as a result incentivise investments in low carbon technologies. Nevertheless, the realisation of a carbon border tax remains a controversial issue, not least because of the WTO rules and potential trade disputes.

Ms von der Leyen made a legally-binding climate-neutrality by 2050 target one of her political priorities for the next European Commission[18]. In case the European institutions succeed to agree on such a target, carbon pricing mechanisms

[16] Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action
[17] Political guidelines for the next Commission (2019-2024) – 'A Union that strives for more: My agenda for Europe', *European Commission* website, 16/07/2019, accessible here
[18] Political guidelines for the next Commission (2019-2024) – 'A Union that strives for more: My agenda for Europe', *European Commission* website, 16/07/2019, accessible here

will need to become more stringent. While the outlook for it is uncertain yet, it is highly unlikely that the EU's tendency to set ever-more ambitious GHG emission reduction targets will be reversed. Northern Lights and 3rd party customers will continue to closely monitor CO_2 price developments in the EU and individual member states.

1.3.2.2 Upgrading the regulatory framework: engagement with the EU and member states

The national and European regulatory framework is not fully in place to enable a functioning and efficient network for CO_2 transport and storage. Along with the Norwegian Ministry of Petroleum and Energy, the Northern Lights project is actively working to adapt the regulatory regime for CCS to take off in Europe. This is done by identifying specific regulatory and policy issues that need to be revised or complemented to help to realise Northern Lights opportunities. We have identified several cases where CCS regulations need to be altered. On the international level, the London Protocol creates a legal barrier for cross-border transport of CO_2. On the EU level, the EU's regulatory framework for CCS is outdated and should be reviewed and revised to incorporate the latest market developments and new solutions. This pertains in particular to CO_2 transport by ships: the CCS and the EU ETS Directives as well as the TEN-E Regulation incorporate elements that could hinder the development of a European network for CO_2 management. This section explains the nature of these issues as well as our actions to address them.

1) **London Protocol**. The purpose of the London Protocol[19] is to prevent pollution of the marine environment caused by dumping or incineration at sea. According to Article 6 of the Protocol 'contracting parties shall not allow the export of wastes or other matter to other countries for dumping or incineration at sea.' CO_2 sequestration was considered waste dumping under the Protocol until its inclusion to the exemption list, which is why CO_2 storage under the seabed is now accepted. However, cross-border transport of CO_2 for the purpose of storage under the seabed remains illegal. While an amendment text that would change this has been agreed among contracting parties, it has not yet entered into force as too few signatories have ratified it. The Governance of the London Protocol requires a ratification of the amendment by two-thirds of the signatories in order to enter into force. Effectively, cross-border CO_2 shipping is today hence considered a breach of the treaty in signatory countries of the London Protocol.

The Norwegian government is in the lead of addressing the London Protocol issue. While the ultimate solution is to gather enough signatories that ratify the amendment, Norway is also advancing an interim option in case the process of ratification is too slow. Together with the Netherlands, Norway has submitted a resolution for that purpose for the next IMO/LP meeting in October 2019. The resolution is based on Article 25 of the Vienna Convention on the Law of Treaties which states that if Parties to a treaty agree on something, they can act upon this agreement immediately pending administrative implementation in the treaty. In order to assist the Norwegian government, the Northern Lights project intends to make a detailed description on its fulfilment of the London Protocol guidelines for CO_2 export and sequestration under the seabed. This description would hopefully help Norway and the Netherlands to get support for their resolution.

2) **CCS Directive**. Article 3 item 22 of the CCS Directive[20] defines the CO_2 transport network as 'the network of pipelines, including associated booster stations, for the transport of CO_2 to the storage site.' The definition does not refer to ships, effectively excluding it from what can be considered a CO_2 transport network. The definition of a CO_2 transport network, as defined in the CCS Directive, is used in multiple EU legal acts, including the EU ETS Directive as well as the TEN-E Regulation.

The Northern Lights has engaged with the European Commission on the issue of the CCS Directive. The Directive was last open for review in 2014 – no changes were made due to lack of experience with CCS. While it is unclear whether the

[19] 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 1972
[20] Directive 2009/31/EC on the geological storage of carbon dioxide

European Commission would consider reviewing the CCS Directive sometime soon, opening it might entail some risks due to some political opposition to CCS in Europe. Therefore, it should be explored whether both the EU ETS Directive as well as the CCS Directive could be 'adjusted' to include shipping without opening either for review. The Northern Lights will continue the dialogue with the relevant units in the European Commission.

3) **EU ETS Directive**. The EU ETS Directive[21] limits the CO_2 transport to pipeline only in the definition of a CO_2 transport network. As shipping is not considered part of the CO_2 transport network, it is not clear whether the CO_2 captured and transferred to ships can be considered captured and verified emissions once they are offloaded and injected for permanent storage. In case they cannot, the emitter who chooses to transport CO_2 by ship would lose the right to retain emission allowances and therefore the financial incentive to capture CO_2 for permanent storage.

The Norwegian government has been engaging with the European Commission to clarify the shipping issue under the EU ETS. In spring 2019, the Ministry of Petroleum and Energy has sent a letter to the European Commission asking for clarification on their interpretation of the EU ETS Directive. In the letter, the Ministry referred to the Implementing Regulation (EU) 2018/2066, which sets more detailed rules on the operationalisation of the EU ETS Regulation. The Ministry argued that because shipping is not included in the transport network, it is equally not covered by an obligation by the ship to surrender allowances under the ETS. Furthermore, they argue that the transfer of captured CO_2 to a ship does not prevent the right to subtract the CO_2 when it later on is transferred from the ship to a pipeline transport network or directly to a storage site. Should the European Commission conclude that the Ministry's interpretation of the EU ETS Directive and its Implementing Regulation is correct, the issue of ETS allowances retained through the use of CCS would no longer be an obstacle for the Northern Lights.

4) **TEN-E Regulation**. The TEN-E Regulation[22] defines the scope of the Connecting Europe Facility (CEF) funding for cross-border energy projects. Annex II item 4 sets out the scope of cross-border CCS infrastructure that can be funded under the CEF Regulation:

'(4) concerning carbon dioxide:
(a) dedicated pipelines, other than upstream pipeline network, used to transport anthropogenic carbon dioxide from more than one source, i.e. industrial installations (including power plants) that produce carbon dioxide gas from combustion or other chemical reactions involving fossil or non-fossil carbon-containing compounds, for the purpose of permanent geological storage of carbon dioxide pursuant to Directive 2009/31/EC of the European Parliament and of the Council;
(b) facilities for liquefaction and buffer storage of carbon dioxide in view of its further transportation. This does not include infrastructure within a geological formation used for the permanent geological storage of carbon dioxide pursuant to Directive 2009/31/EC and associated surface and injection facilities;
(c) any equipment or installation essential for the system in question to operate properly, securely and efficiently, including protection, monitoring and control systems.'

The provisions do not include ship infrastructure in the definition, which means that shipping costs cannot be funded through the CEF. Such a legislative setup risks creating unfair treatment of ship-based CO_2 transport projects vis-à-vis pipeline projects.

The Northern Lights project has engaged with the European Commission on the interpretation of the CEF rules with regard to CO_2 transport by ship. According to the Commission's initial interpretation, ships per se cannot be funded under the CEF

[21] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Union
[22] Regulation 347/2013 on guidelines for trans-European energy infrastructure

rules, however, other parts of the CO_2 transport network are eligible for infrastructure funding, including CO_2 liquefaction and buffer storage.

The European Commission asserts that the reason for excluding ships is that the CEF grant system cannot guarantee that shipping infrastructure is not used for another purpose, which could potentially breach the competition rules. The CEF funding is given in the form of grants to project developers and the European Commission does not have a mandate to recuperate the funds unspent or misused, as defined in the Financial Regulation 2018/1046.

However, funding mobile assets in not unprecedented under the CEF, in particular for LNG projects. For instance, mobile infrastructure is explicitly mentioned as eligible to receive funding under the 2019 CEF call, which the European Commission noted as the only exception tailored for several LNG FSRU projects of common interest, for which developers must legally commit to special-purpose use of the mobile infrastructure funded.

The Northern Lights project hopes that if developing CO_2 transport across the EU will be high enough on the EU's agenda, rules defining the CEF distribution could be interpreted in a different way, to allow for full eligibility of the CO_2 shipping projects. The issue would nevertheless have to be raised with high-ranking EU officials, who realise the strategic importance of decarbonising the energy systems in Europe.

5) **Engaging governments.** The Northern Lights project is in constant dialogue with the European institutions as well as the Norwegian government, whose lead and contribution are indispensable for making effective changes to the legislative acts described. In addition, Northern Lights is aiming to step up engagement with EU member states through the Northern Lights PCI partners. These partners have been advised by Northern Lights to contact their national administrations informing them about the Northern Lights project and its relevance for the development of CCS in Europe. The PCI list will have to be voted by representatives of member states in the Council of the EU in late 2019, which implies national administrations should be made aware of the project and be ready to support it on a European level. In addition, the PCI partners will advise these member states to list the Northern Lights PCI in their national energy and climate plans that need to be submitted by December 2019. It is important that the project is regarded as one of the effective ways to reduce GHG emissions in the energy-intensive industries. Such engagement can further reinforce the Northern Lights' links to governments across Europe and enhance their understanding of the CCS technology as well as encourage further CO_2 capture projects.

Specific example – Sweden

Sweden represents an example where both the bilateral dialogue, both state-to-state and project-to-project, has helped to drive and mature the relevance of CCS as a tool for mitigation of climate change and increased competitiveness for future industry. Based on the bullet points presented below it is reasonable to assume that CCS is now on the Swedish agenda, partly thanks to the dialogue with Northern Lights and Norwegian authorities.

- 2018, June: Norwegian Government emphasize the need for Northern Lights to have relevance and interest for European industry outside Norway.
- 2018, August: Establish contact with Swedish Environmental Protection Agency (EPA). Continuous dialogue follows.
- 2018, October: Presentation to EPA and Ministeries with Gassnova.
- 2018, Q3-Q4: Continuous business development activity towards Swedish industry. Preem and Stockholm Exergi were two of the relevant companies.
- 2019, January: Visit by EPA and Swedish authorities to Norway on "CCS Safari".
- 2019, January: The "Swedish Public Commision on policies for negative emissions" visiting Norway on a "CCS Safari".

- 2019, February: Three Swedish industrial sites (Stockholm Exergi, Preem Lysekil, Preem Gothenburg) join the Northern Lights' "Project of Common Interest" application to the EU. Two additional sites state strong interest, but are not able to join before the deadline of submitting the application.
- 2019, March: Interpellation debate on CCS in the Swedish Parliament. The importance of the Parliament to support the developing CCS network between Swedish capture sites and storage in Northern Lights was addressed, as well as the need for an overall CCS strategy in Sweden.
- 2019, March: EPA Present their action plan on how Sweden will reach their climate goals to Swedish Parliament. CCS is highlighted as one of three key enablers, together with electrification and financing.
- 2019, April: Swedish Government set up investment fund for bio-CCS, total value of 100 million SEK.
- 2019, September: Preem and Stockholm sign Memorandums of Understanding (MoU) with Equinor, on behalf of Northern Lights.

1.3.2.3 Shaping and sharpening research and technology development to enable CCS scale up by more cost-efficient solutions

Northern Lights works closely with the R&D organizations of the partner companies to identify and prioritize the most relevant and urgent industrial research needs that enable more cost-efficient solutions for scaling up CCS in Europe through the next generation of CCS projects. This has caused a change in focus for the ongoing R&D projects and initiated several dedicated new projects. Below we first describe how the Northern Lights shapes the R&D activities of Equinor, and how these are expected to help improve the next generation of CCS. We then describe similarly for Shell and Total, but with less detail and with a larger CCS portfolio perspective.

Northern Lights shapes Equinor's R&D

The effects of the Northern Lights project on Equinor R&D activities can be summarized as follows:

- **Prioritisation of the most relevant and urgent industrial research needs**. This real, commercial project sharpens the focus of Equinor and its consortium partners and has led to identification of specific technology gaps to be filled by internal and external R&D activities.
- **Attracting R&D providers, industry and suppliers**. Connection with a real project attracts and stimulates R&D providers, industry and suppliers to come up with high quality proposals and to offer their best resources, as this real case increases chances for award of public funding. Also, during the project execution, these projects get higher priority in terms of resources and lab access.
- **Enhancing engagement, collaboration and knowledge dissemination**. Our own near-and mid-term need for results from the R&D projects stimulates stronger, active engagement of the Northern Lights partners in external R&D projects. Also, R&D providers and suppliers seek close collaboration with the Northern Lights partners to ensure the relevance of their contribution. This results in overall much tighter cooperation between all project partners and in mutual learnings, which in turn benefits future projects.

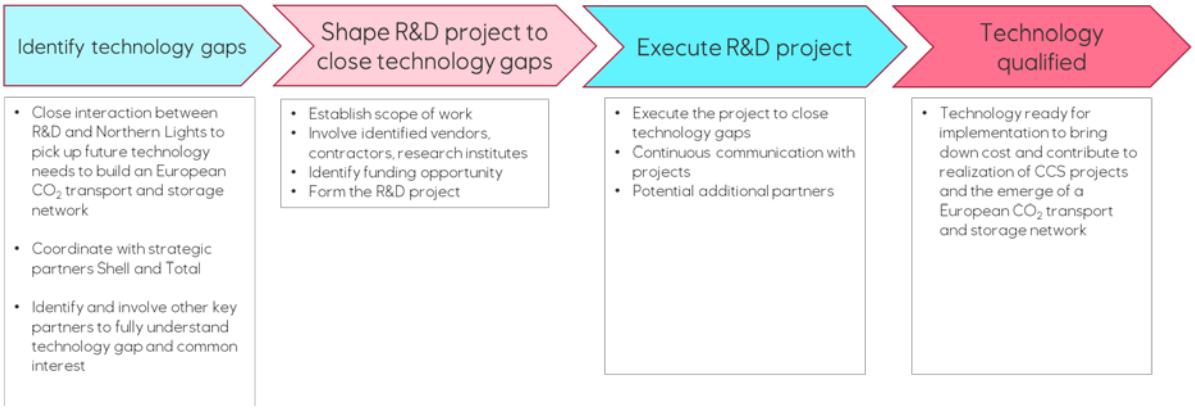


Figure 9. Shaping of Equinor R&D projects based on learnings from the Northern Lights project

Equinor R&D has a strategic technology project to accelerate CCS deployment

Strategic R&D projects in Equinor get prioritization in terms of resources and budgets. A strategic R&D project with three relevant workstreams has been established to support Northern Lights and the development of a European CO_2 transport and storage network:

- WS1: Reducing cost for expanding Northern Lights beyond first CO_2 volumes
- WS2: Radical cost cut through simpler and more flexible value chains
- WS3: Enabling large scale CO_2 underground storage

WS1: Reducing cost for expanding Northern Lights

As developer of the Northern Lights project, Equinor and its partners are in a unique position to get hands-on knowledge on where conventical technologies meet limitations. This gives a strong guide on technology development needs for future CCS projects to enable more cost-efficient solutions. Key challenges and technology gaps have been identified in close collaboration with the Northern Lights project team, the main ones being listed below and addressed by the strategic R&D project through internal work and through collaboration with the broader CCS community:

- Improved simulation tools for facility design to increase confidence and hence reduce costly safety margins
- Improved understanding of consequences in case of CO_2 leakage/release subsea.
- Develop guidelines for establishing CO_2 specification of allowable impurities in the CO_2 stream for future cost-effective CCS value chains.
- Qualification of CO_2 ship transport at lower pressures (~7 barg) enabling cost-effective CO_2 carriers with larger volumes and optimised logistic chains.
- Establish procedures for safe and cost-effective design of CO_2 pipelines with respect to running ductile factures.
- Develop fiscal metering technologies for larger CO_2 mass flows.

WS2: Radical cost reduction through simpler and more flexible value chains

This workstream is looking into how to considerably reduce costs in the transport and storage part of the CCS value chain. Looking at Northern Lights cost break down (see Figure below) with a radical mindset inspires the question 'What if we could remove or reduce the onshore facilities and pipeline scope?' The project is further developing such concepts to properly understand (i) the most promising concepts; ii) the cost reduction potential; and (iii) how to reduce the associated technology gaps to make the concepts feasible in the years following the implementation of Northern Lights.

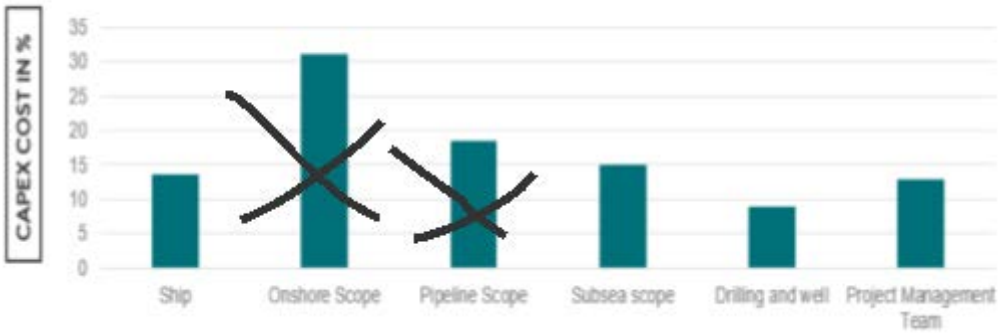


Figure 10. Northern Lights cost break down (preliminary figures) with radical question: 'What if we for future CCS value chains could remove onshore and pipeline scope?'

Total and Equinor have together announced a request for a high-level concept study with the objective to assess the cost reduction potential for the most promising CO_2 offshore receiving and injection concepts, as well as identifying associated technology gaps when using such solutions. The study will give direction for further research and development needs to bring down the cost of future larger scale CO_2 transport and injection. The inquiry announcement has stimulated considerable interest in the market and the quality of the bids are high. The study is expected to finish in early 2020 and will give basis for further detailed studies. An important aspect of such inquiries is to prepare suppliers for future CCS projects by indicating potential developments. Such collaboration is expected to motivate suppliers to have CCS on their agenda, inspire further technology development, and secure suppliers' early adaption of new technology.

WS3: Enabling large scale CO_2 underground storage

Injection of large CO_2 volumes (> 5 MTPA per site or per hydraulic unit) is anticipated from around the late 2020s and represents a significant scale-up from current experience[23]. The Northern Lights project has influenced subsurface work to enable large scale CO_2 underground storage in two dimensions: 1) it has provided improved understanding of risk description/quantification necessary for industrial decisions and 2) it has inspired CCS research communities and partners to work and mature underground cases perceived to be realistic locations for future CO_2 storage scale-up options (i.e. Horda platform, see below).

The Northern Lights' 'CO_2 storage exploitation lease' is located in the southern part of the Horda Platform, a strategically interesting area in terms of future large-scale CO_2 storage. This area has been extensively studied after the discovery of the Troll field and it is known for several thick sand layers with a very large theoretical CO_2 storage potential[24] .

Large-scale storage case studies at the Horda Platform are being conducted by the strategic R&D project. These will validate new technology ideas and concepts and at the same time mature back-up and scale-up options for mega-scale CO_2 storage near the planned Northern Lights storage site (Aurora). Similarly, the Northern Lights project has also inspired

[23] Current operating CO_2 projects are at the 1 MTPA scale (e.g. Sleipner, Snøhvit)
[24] The so-called Viking aquifer with a theoretical potential of storing 18 Gigatonne (Gt) of CO_2 (including the Troll aquifer) and the Cook-Johannsen aquifer with a theoretical potential of storing 2 Gt of CO_2 could be highlighted; figures according to NPD CO_2 Storage Atlas

large research programs such as NCCS[25] and Pre-ACT[26] to conduct case studies on the Horda platform area to test and verify new technologies, quantify subsurface risk and mature the area for future large-scale CO_2 storage.

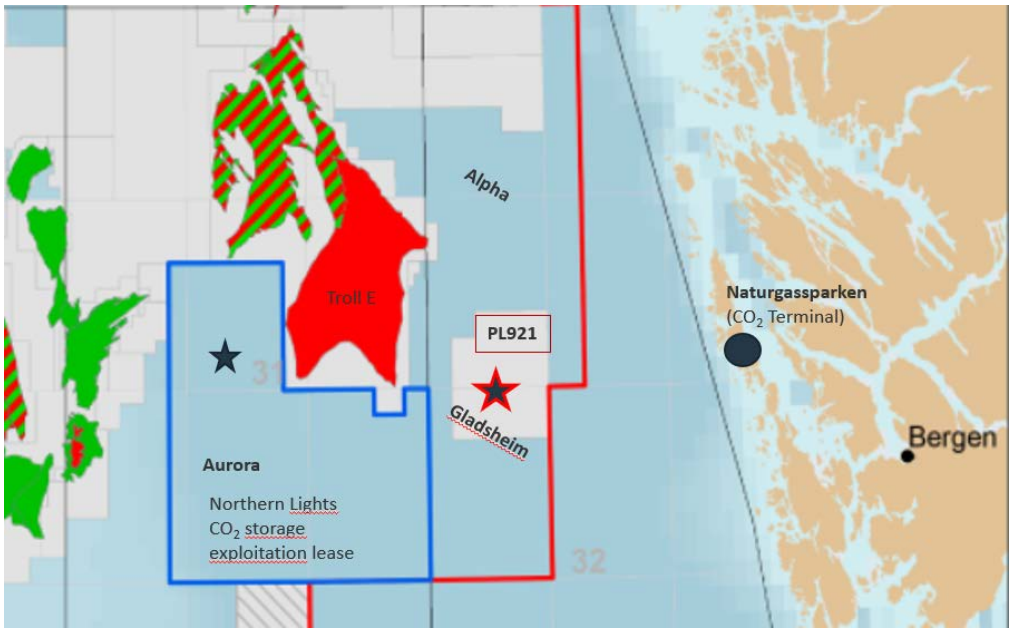


Figure 11. Map with the Gladsheim exploration well at the Horda platform, in the context of the Northern Lights Aurora well and the planned CO2 land terminal near Kollsnes.

National and European funded research projects grow the broader CCS community

National and EU funding instruments complement each other and are important to accelerate CCS project in Europe. The national funding instruments have proved to be efficient for closing specific CCS technology gaps. They are typically flexible on research topics and allow R&D projects to progress specific technology developments efficiently; particularly CLIMIT-Demo is highlighted as an efficient tool for maturing technology towards commercialisation (high TRL level). Most of the projects listed in Table A are nationally funded by CLIMIT.

A major strength of EU-funded projects is the opportunity to grow and mature a broader community with interest in CCS, including the general public, specialists, policy groups, bureaucrats and politicians in the EU and its member states. The EU research & innovation agenda is closely linked to the EU policies and the regulatory framework for the deployment of low carbon energy technologies. Hence, being part of these research programmes is strategically important to advance the CCS technology. It is one of key technologies identified in the SET-Plan, also included in the scope of the Horizon 2020 programme. Equinor takes part in the following CCS projects within the scope of Horizon 2020:

- Pre-ACT - Pressure control and conformance management for safe and efficient CO_2 storage - Accelerating CCS Technologies (ACT[27])
- ELEGANCY - Enabling a Low-Carbon Economy via Hydrogen and CCS (ACT)
- ALIGN - Accelerating Low carbon Industrial Growth through CCUS (ACT, attendance via Technology Centre Mongstad)

[25] At present, the main active FME (Forskningssentre for miljøvennlig energi – funded by Norwegian Research Council) within CCS and hydrogen, in which Equinor is involved, is the Norwegian CCS Centre (NCCS)
[26] ACT: Accelerate CCS Technologies, an ERA NET Cofund established under the Horizon 2020 programme. Pre-ACT: Pressure control and conformance management for safe and efficient CO_2 storage - Accelerating CCS Technologies
[27] ACT is an ERA NET Cofund, which is a tool established by the European Commission under the Horizon 2020 programme for research and innovation. ACT means Accelerating CCS Technologies

In addition, these new projects with Equinor participation have recently been awarded funding through the ACT (Phase 2) programme:

- DIGIMON - Digital Monitoring of CO_2 storage projects; coordinated by NORCE
- SENSE - Assuring integrity of CO_2 storage sites through ground surface monitoring, coordinated by NGI
- REX-CO_2 - Reusing existing wells for CO_2 storage operations; coordinated by TNO

Equinor, on behalf of Northern Lights, also submitted Letters of Intent to support two project proposals for the Horizon 2020-LC-SC3 Call (deadline 27/08/19); ACCSESS and REALISE. ACCSESS was initiated as a direct consequence of Northern Lights work on business development, while REALISE is linked to the maturation of the scope for Ervia, who decided to use Northern Lights as their currently preferred storage (described in section 1.3.1.3). Both specific examples are described in this section.

Specific example – ACCSESS: LC-SC3-NZE-5-2019-2020: Low carbon industrial production using CCUS

ACCSESS is a project proposal coordinated by SINTEF Energy AS, which came as a direct consequence of the scope in the PCI application. After seeing the PCI map at an industry conference in Q2 2019, representatives from SINTEF Energy initiated a project proposal linked to the H2020 Call that aims to develop new value chain for CCS with Northern Lights as the primary storage location. The relevance of these value chains could then be replicated in other similar projects.

ACCSESS will innovate and align technologies and business models with stakeholder and public interests along European CCUS chains. The ambition is to realize integrated-chain CCUS for early movers in European industry. Four Pioneering chains will be developed and optimized for CO_2 from inland Cement and Waste-to-Energy (WtE) plants in Germany and Switzerland. The aim is that minimum one of the Pioneering chains will be in operation by end of 2024. This is enabled through the close link to the Norwegian Full-Scale CCS project and the Northern Lights PCI with offshore storage operation and a flexible transport infrastructure largely relying on ships. Industrial willingness to be early movers in CO_2 capture has been decisive in choice of CO_2 sources. Financial plans and business models will be developed for Pioneering Chains to enable funding application to e.g. the ETS Innovation Fund. Technology Improvements, to be duly integrated in chain analyses for future CCUS chains, will be made for:

- CO_2 capture and integration in WtE plants (-30% CO_2 avoided cost for post-combustion and oxyfuel)
- CO_2 capture and integration from cement plants (-15% CO_2 avoided cost for post-combustion, detailed CPU design for the oxyfuel technology, already proven to be cost efficient in the preceding H2020 CEMCAP project)
- Low-pressure (6-8 bar) ship transport of liquid CO_2, with an estimated cost reduction potential of 55% compared to mature ship transport at 15 bar.

Future CCUS chains will in a second stage be developed for Italy and Eastern Europe, using the methodology established for the Pioneering Chains. The societal feasibility of CCUS will be investigated through investigations of concerns, needs and perceptions of citizens, CO_2 emitting industries and stakeholders. The results will provide guidance for understandable communication about CCUS. European and international dissemination and cooperation will ensure broad uptake of results and high impact.

Specific example 2– REALISE: LC-SC3-NZE-5-2019-2020: Low carbon idustrial production using CCUS

The REALISE project proposal is driven by a strong industrial consortium, including 10 industrial partners and Sintef Industry as project leader, among which major refineries in EU, China and Brazil, along with the complete technology value-chain. An external Advisory Board will further contribute to replicate the concept thanks to Concawe (association of refineries with 40 industry members), SARAS, and Petroineos.

Refining industry is a highly energy-intensive sector with direct CO_2 emissions typically ranging from 100 to 200 kg CO_2/tonne crude oil. The challenges related to CCUS lies in taking into account a large number of relatively small sources with various levels of CO_2 **c**oncentration. Today, CO_2 capture from the sources with highest CO_2 volume are mainly considered for capturing, leaving out small sources, thus limiting the overall capture rates to 50-60%.

REALISE novel concept will capture up to 90% CO_2 from operating refineries by integrating a multi-absorber concept for capturing CO_2 from different stacks at 30% lower CO_2 capture cost compared to the state-of-the-art technology based on 30 wt% monoethanolamine solution.

The cost reduction potential will be demonstrated in REALISE onsite operating refinery-centered cluster at Cork, Ireland, by using a novel low energy solvent (30% lower energy demand, 70 times lower corrosion, 3 times lower thermal degradation), innovative concepts for reducing oxidative degradation (80% lower active component loss), cheaper construction materials (10% lower CAPEX), intelligent Nonlinear Model Predictive Control (10% lower OPEX compared to operation without NMPC), and optimal integration with the available heat sources.

Assessment of the full CCUS chain from Emitter to Storage will be performed taking advantage of having consortium partner in common with transport and storage projects Northern lights and Cork CCS. Socio-political aspects will be addressed in REALISE and societal readiness index calculated for at least 3 business cases relevant to Ireland, China and Brazil.

CCS R&D projects conducted in partnerships

Equinor has an open and collaborative approach to R&D within CCS. The advantage of conducting R&D projects in partnership is ‘gearing and sharing’ of both funding, experience and knowledge.

Equinor is currently engaged in more than 40 R&D projects within CCS and through these projects we collaborate with more than 70 partners from industry, research institutes, universities, vendors and governments. The effort within CCS is already significant and the ambition is to increase even more. One of Equinor’s goals to create a low carbon advantage is to reach an allocation of 25 % share of the company’s research funds to new energy and low carbon solutions by 2020. In this context, CCS is acknowledged as a strategic technology.

The table below (Figure) lists an extensive number of R&D projects that are influenced by the Norwegian CCS project / Northern Lights, and in which Equinor is engaged together with other partners. Projects in which two or all of the three partners in Northern Lights are cooperating is highlighted in orange. The list does not provide a compressive overview of all R&D projects influenced by the Norwegian CCS project. Neither does it show internal Equinor projects. The table indicates which of the three identified R&D workstreams each project is contributing to:

- **WS1**: Reducing cost for expanding Northern Lights beyond first CO_2 volumes
- **WS2**: Radical cost cut through simpler and more flexible value chains
- **WS3**: Enabling large scale CO_2 underground storage

Project name	Description	Partners	WS1	WS2	WS3
NCCS	Norwegian national research center, covering the whole CCS chain	Sintef Energy coordinates; ca. 25 industry and R&D partners			
Technology Centre Mongstad (TCM)	Maturing supplier-driven post-combustion CO_2 capture technologies, creating competition and variety	Gassnova, Shell, Total			
IMPRECCS	Investigate physical properties (density, viscosity, thermal conductivity) for CO_2 and impurities, and establish correlations.	NCCS partners			
JIP CARDICE	Validate a simulation tool for predicting temperature behaviour of tanks during CO_2 pressure release operations. Increases operational flexibility by decreasing necessary safety margins.	Total, Petrell, INERIS			
JIP CO2FACT	Validate CO_2 flow assurance tools for CO_2 operations. Increase operational flexibility by decreasing necessary safety margins.	Total, Gassco, Schlumberger, LedaFlow, IFE			
JIP CO2WELLMAT	Map suitable materials for CO_2 injection wells with respect to oxygen as impurity and reservoir conditions.	Total, Shell, Gassco, Vallourec, NSSMC, IFE			
JIP DeFACTO	Construct and operate a new vertical flow loop for CO_2 to be able to validate flow assurance tools. Increase operational flexibility by decreasing necessary safety margins.	Total, SINTEF Energy			
JIP KDC-III	Validate a tool for simulating potential chemical reactions of impurities in CO_2 streams when mixed together. Increases amount of tolerated impurities and hence decreases costs for necessary purification of CO_2 streams.	Total, Shell, Gassco, Vallourec, Arcelor Mittal, IFE, OLI			
Preem CCS	Testing of capture technology at Preem refinery in Lysekil and feasibility study on full scale CCS implementation based on CO_2 delivery to Northern Lights	Preem AB, Aker Solutions, Sintef, Chalmers University			
Study: Lit. Review on the effect of CO_2 on soft materials	Review of public available state-of-the-art information on the impact of CO_2 on non-metallic materials for CO_2 applications	SINTEF Industry, Total			
Study: HAZID study of low pressure CO_2 transportation	Identify risks related to low pressure CO_2 ship transport compared to solution of medium pressure	DNV-GL, Total			
Study: Assessment of software tool "Hydraflash" for CO_2	Assessment of software tool "Hydraflash" for CO_2 rich mixtures for hydrate prediction, water solubility, etc.	Heriot Watt, Total			
Study: CO2Spec - CO_2 specifications along the value chain	Understand the economical impact of removing impurities from CO_2 streams and their impact along the chain	Carbon Limits, Total			
ZEROC - Zero carbon industry in Norway and Sweden	Evaluate how to reduce CO_2 emissions in Norwegian and Swedish industry, including necessary infrastructure.	Fortum Oslo Varme, Herøya Industripark, Sintef, Chalmers University, Cementa, Svensk avfall, Vestra Gøtaland Region, Preem, Gøteborg Energi, Stockholm Exergi AB, Svensk skogsforsk, Energimyndigheten			
3C	Maturing rotating absorption/desorption post-combustion CO_2 capture to TRL2 and 3	Fjell Technology Group, SINTEF, CMR			
CO2LOS	CO_2 ship logistics study to develop toolbox for cost-effective logistic chains	Total, Air Liquide, Sogestran, Gassco, Sintef, Brevik Engineering			
Study: offshore CO_2 receiving and injection concepts	Identify most promising offshore CO_2 receiving and injecting concepts with associated cost and technology gaps	Total			

ACQurate CO_2 monitoring	Improved detection using multiple monitoring sources	Sintef, Quad, GFZ, U. Calgary			
Act4Storage	Marine environmental monitoring - Accoustic and Chemical technology (new ROV/AUV survey and detection methods)	NGI, Total, Shell; U. Bergen			
CO_2_Data Store	Reference strorage datasets for improved understanding of storage	Sintef, U. Illinois			
Demodas	Pilot testing of fibre-optic (DAS) sensing for CO_2 injection wells and projects	Norce(CMR), NORSAR, NTNU, Octio			
ELEGANCY	Enabling a Low-Carbon Economy via Hydrogen and CCS	Sintef (coord.), BGS, PSI, ECN TNO, Swerea Mefos, Imperial College, ETH, RU Bochum, Utrecht Univ., UiO, Aker Solutions, Climeworks, First Climate, Gassco, GERG, INEOS, Open Grid Europe, Scottish Enterprise, Sustainable Decisions, Total, Uniper			
FRISK	"Quantification of fault-related leakage risk" for CO_2-storage sites	Norwegian Geotechnical Institute (coord.), UiO, NORCE, UiB, Total,			
ICO2P	Developing noble gas signatures as a monitoring schemes for offshore CO_2 storage	U. Oslo, Shell, Eawag, NTNU			
IGCCS	Induced-seismicity geomechanics for CO_2 storage	NGI, NORSAR, Total			
OASIS	"Overburden analysis and seal integrity study for CO_2 sequestration in the North Sea". Improve integrity evaluation by development of a workflow for geomechanical models for seal and overburden constrained by seismic and well data.	UiO (coord.), Norwegian Geotechnical Institute, Norwegian Computing Center, National Oceanography Centre (UK), Colorado School of Mines (US), Curtin Univ. (AU), Total			
Pre-ACT	Pressure control and conformance management for safe and efficient CO_2 storage - Accelerating CCS Technologies	Sintef, (coord.), Norsar, BGS, Plymouth Marine Lab., TNO, GFZ, Shell, TAQA, Total			
Pressure toolkit	Pressure Analysis Toolkit and Active Pressure Management - Cypress toolkit	LLNL, USDoE			
SNS-Net	Smeaheia Natural Seismicity Network. Designing an optimal system for monitoring background microseismicity at Horda Platform in a cost-efficient way	Gassnova, Norsar, Shell, Total			
SWAP	Strategic Well Acquisition Project - Gladsheim	The PL921 license partners are Equinor (50%), DNO (15%), Lundin (15%) and Petoro (20%)			
JIP HIPREC	Identify need and feasibility of a high-pressure test center for testing CO_2 technologies in near industrial scale (e.g. fiscal metering, membrans, etc.)	Aker Solutions, BP, Krohne, SINTEF Energy			
COMPMEM	Test novel membran technologies to understand performance within relevant operational windows for subsea gas processing	CCP-Alliance, TOTAL, Pertamina, Aker Solutions			

Figure 12. List of Equinor's R&D projects related to CCUS, conducted in partnership and/ or influenced by the Norwegian CCS project and the Northern Lights. Project where two or three of the Northern Lights partners participate are marked in orange.

Shell - Focus on R&D and innovation linked to CCS/CCUS

To thrive in the Energy Transition, Shell is developing new lower carbon business models, CCS is part of this overall strategy. Deployment of CCS at scale is widely recognised as critical to deliver on the Paris objectives, and CCS is one of the levers for decarbonisation of Shell's assets as well as providing routes for the production of lower carbon intensity products and creating new business opportunities linked to CO2 utilisation and storage.

The Northern Lights project offers a number of opportunities to establish different ways in which commercialisation of CCS can be progressed. Specific examples include validating the economic attractiveness of a CCS tariff; testing a CCS split value chain business model to connect emitters (countries and industries) to a remote storage location and establishing the viability of cross-border CO2 transportation (London Protocol). Northern Lights provides a concrete test case for the London Protocol which could have far reaching implications for exporting CO2 between countries, also

outside of the EU. The export of CO2 through this route relies heavily on the success of CO2 liquefaction and shipping and the technical work carried out as part of the Northern Lights project is one step on a roadmap to development of larger scale CO2 shipping.

As part of Shell's work in advancing CCS, the CO2 Abatement Technology Platform works to develop and deploy technology solutions. For CCS the focus areas are Post-combustion CO2 capture, Decarbonization and CO2 Utilization for assets and CO2 Storage. Shell works in collaboration with industry peers (through the Oil and Gas Climate Initiative), 3rd party technology providers and knowledge institutes. The Northern Lights project, and the associated Norway CCS project, provide essential proof points in CCS technology deployment. Examples include post combustion CO2 capture from industrial processes and development of cost-effective, fit for purpose, monitoring technologies for standalone storage in a subsea environment. These, along with associated clarification of European regulation on long term storage liabilities, assurance and insurance options, have the potential to provide a replication template for global CCS deployment.

Total - Focus on R&D and innovation linked to CCS/CCUS
Convinced by the potential of the technology to combat climate change, Total is strongly engaged into the promotion and development of CCUS worldwide. Actively involved in R&D and industrialization, Total has an open and collaborative approach and is working with many different actors in order to give CCUS the attention and development it deserves.

R&D efforts are put not only on the development of internal competencies but significant means are also dedicated to boost innovative technologies, start-ups and knowledge developed by others. Total is indeed convinced that a strong collaborative effort is needed to kick off the CCUS industry. To build on its strengths and maximize the benefit of an open approach by working in partnership with other leaders in the area, Total wishes to position itself as an integrator of the full CCUS value chain. In order to boost the development of a CCUS industry Total has developed its CCUS R&D program around four main objectives:

1. To reduce CCS Cost
2. To evaluate and address mass market opportunities in CO_2 Utilization
3. To be present all along the value chain of CCUS
4. To scale-up CCUS impact on Climate

To reach those challenging objectives, significant means have been allocated to build up a strong R&D CCUS programs. Total is engaged together with 150 partners into 80 different partnerships all over the world. Continuously increasing its efforts, Total has the ambition to devote up to 10% of its overall R&D budget to research into CCUS technology.

Northern Lights is one of the key projects driving the strategy of Total R&D on CCS, especially on the transport and facilities side. The project contributes to identify or confirm some of the technological gaps that exists in the CCS value chain. Indeed, this work of gap identification is often done based on literature review and gives a rather theoretical and academic point of view of technological development status. This point of view might then be sometime non exhaustive or misaligned with industrial reality. Hence, Northern Lights as first of a kind – especially on the ship transport part, is key to identify and prioritize R&D actions to be performed, in order to obtain fully developed and qualified the technology that is needed to enable industrial scale development of CCS.

Total has an open R&D approach for most of the building bricks of the CCS value chain. Hence, Northern Lights contribute to strengthen collaborations in-between the partners outside of the projects for the purpose of R&D. Many ideas or R&D topics initiated in Northern Lights are further developed in collaboration amongst the partners. Strategies

and way forwards on those topics are naturally aligned to best serve the objectives of the project. As highlighted in Figure 11 above, a lot of the on-going R&D projects includes two or three Northern Lights partners.

In addition to the partners, Northern Lights promotes also R&D collaborations between Total and vendors / technology providers contributing to Northern Lights. Thanks to the project, Total is then more and more solicited by those new players who wish to be active in the CCS industry but that need to be assisted in their technological development for the benefit of Northern Lights and further potential projects.

1.3.2.4 Knowledge sharing

The external dimension of Northern Lights stretches across several domains. To share learnings, attract potential 3rd parties, and to advocate for the importance of CCS as an effective tool for mitigation of climate change, Northern Lights presents at a range of conferences and for dedicated organisations, collaborates with relevant organisations and networks, and has developed a project website to inform relevant stakeholders about the project.

External presentations

The Northern Lights project regularly meets with a diverse set of external stakeholders and presents at many conferences and events. Over the last year, such interactions have averaged around 15 per month. To illustrate, a list of external interactions in May 2019 is shown below.

29.05 Norske Skog, Norway
28.05 GRTgaz, France
27.05 Rolincap, Sweden
27.05 ArcelorMittal, Belgium
27.05 Hydrogen Platform, Netherlands
24.05 ACT Partnership, Norway
24.05 Blue Growth Forum, France
23.05 France - Norway CCS, France
22.05 Fortum Oslo Varme, Norway
21.05 Øygarden municipality, Norway
20.05 H2M, Netherlands
16.05 Gas industry days, Sweden
15.05 North Sea Basin Task Force
15.05 Norway Offshore Day, Norway
15.05 Air Liquide, France
13.05 EEW - Energy to Waste, Germany
09.05 Lloyd's Register, Norway
09.05 GCCSI Webinar
09.05 CO2Geonet, Italy
08.05 Buzzi and Leap, Italy
08.05 Norwegian Innovation Day, Poland
07.05 Scandinavian-Polish Energy Debate, Poland
07.05 Port of Bergen, Norway
06.05 MPE Financing workshop, Norway
06.05 PGE, Poland
06.05 Enea, Poland

OGCI has selected Northern Lights as one of five initial Kickstarters

The Oil and Gas Climate Initiative (OGCI) is a voluntary CEO-led and industry driven initiative taking practical actions on climate change. The members consist of 13 of the major global oil and gas companies, who combined are producing 30

% of the global oil and gas production, operate in 130 countries, and spent a total of 6.3 billion dollars on R&D for low carbon technologies in 2017.

The OGCI aspires to play a major role in the development of a commercially viable, safe and environmentally responsible CCUS industry. One focus is on helping to identify, connect to, and develop regional hubs for accelerated CCUS development. OGCI announced concrete plans for this in New York, 23 September 2019, with the Kickstarter initiative in which Northern Lights is one of five initial regional hubs.

OGCI's CCUS KickStarter initiative is designed to facilitate large-scale investment in a commercially viable, safe and environmentally responsible CCUS industry. To achieve this, OGCI will start by building on the work of many others to jointly put five emerging hubs into operation – in the US, UK, Norway, the Netherlands, and China. Its aspiration is to double the amount of carbon dioxide that is currently stored globally, while building a pipeline of potential future hubs to bring this new industry to scale.

In parallel, OGCI has launched a joint CCUS Acceleration Framework with the 11 countries supporting the Clean Energy Ministerial (CEM) CCUS Initiative, which brings governments and industries together to create a global, commercial CCUS industry at the scale needed to meet the Paris Agreement.

Northern Lights will continue to work with the OGCI Kickstarter organization to make sure that knowledge and learnings from the project are shared, and that OGCI can support the success of the project. Some initial ideas about the latter include knowledge sharing, introductions and linkages to potential capture customers in Europe, contributions and collaboration with Clean Energy Ministerial (CEM CCUS), and spreading the relevance of ship-based systems to other regions.

CCUS Project Network

The CCUS Project Network builds on the European CCS Demonstration Project Network (2009-2018) and is initiated and financed by the European Commission. It was started in 2019 and aims to represent and support major industrial projects under way across Europe in the field of carbon capture and storage. It aims to share knowledge and learning across the network, and Northern Lights was invited as a member alongside the other major European CCS projects. The current member portfolio includes Acorn, Ervia, Ecra, Leilac, Tata Steel, Technology Centre Monstad, CarbFix, Drax and KVA Linth, with more CCS projects expected to join in the coming months. The network is currently structured into three thematic groups:

- Policy, regulation and public perception: a platform to address the majority of non-technical challenges facing large-scale CCUS projects. Policy and regulations are interrelated, and social acceptance can influence policy developments.
- CO2 capture and utilization: CO2 utilization processes are expected to be developed in the close vicinity to capture sources. There are a number of overlaps in the chemical engineering domain between CO2 capture and conversion processes, such as process design and catalysis.
- CO2 transport, storage and networks: CO2 transport and storage development are to a large extent dependent on one another – the storage site characteristics will determine the transport conditions of the CO2. Some EU Member States have no access to geological storage sites and therefore cross-border networks (including PCIs) are highly relevant here.

Northern Lights will be represented in two of the three thematic groups, respectively "Policy, regulation and public perception" and "CO2 transport, storage and networks". The CCUS Project Network is still developing its focus areas as a

result of the interests and need of the members, but it is already driving alignment on key elements like the Innovation Fund, combined national and EU funding, the London Protocol, realizing CO2 storage pilots and managing CO2 composition standard in multiuser transport networks.

Bilateral knowledge sharing with CCS projects

In addition to relevant knowledge sharing platforms like OGCI and CCUS Project Network, the Northern Lights project is active in bilateral knowledge sharing directly with other relevant CCS project in Europe. One example is a two-day knowledge sharing workshop with the Porthos project in Bergen in 2018, addressing both commercial and technical aspects. Another example is the frequent dialogue and cooperation with Pale Blu Dot and the Acorn project

Webpage

In order to make information about Northern Lights easily available for governmental stakeholders in the EU and Norway, potential 3rd parties, and the public in general, the Northern Lights project has developed its own website. The website covers relevant information about the project, and how it could represent business opportunities for 3rd parties and a tool for decarbonisation in the EU. In addition, the website has several illustrations and videos that aim to explain the complexity of Northern Lights and CCS. The webpage is hosted with .no, .com, .eu, and .uk domains. The primary language is currently English, with a plan to include a Norwegian version. The address for the website is www.northernlightsccs.com, but it is also functional with .eu and .uk. A .no version will be added when the website is a available in Norwegian.

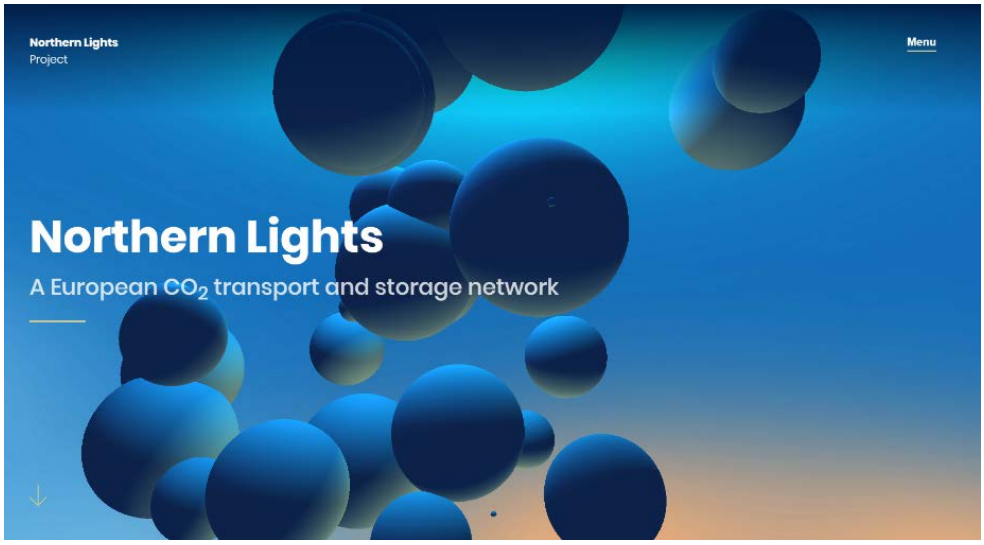


Figure 13. Frontpage of the website for Northern Lights

1.4 Outlook: Northern Lights is a strategic project for CCS development in Europe and globally

Realisation of the Northern Lights project will drive technological development and innovation in relation to CCS, help standardise transport and storage-related equipment and logistic solutions, effectively contributing to cost reduction. In addition, it will incentivise the first industrial capture projects across Norway and Europe, further cutting the costs of deployment across the value chain. Furthermore, the project will incentivise regulatory adjustments to allow full-scale deployment of CCS across Europe – a process that both the project partners and the Norwegian government are already engaged in. An enabling regulatory framework is a necessary precondition for subsequent CCS projects to be realised. Below we describe some of the key benefits which Northern Lights contribute to realizing.

1.4.1 Kick-starting CO_2 capture in Europe

The first attempt to commercialise CCS in Europe a decade ago resulted in a number of unrelated CCS projects, which aimed to integrate CO_2 carbon, transport and storage on an individual basis. All six CCS projects under the European Energy Recovery Programme (EERP) were modelled to store CO_2 individually in nearby onshore or offshore fields and saline aquifers[28]. This in turn increased both the project development costs as well as the risks involved. Inevitably, all projects failed and the difficulty of handling the entire value chain in each project was to some degree responsible for it. A key learning was the need for doing things differently.

The Northern Lights offers an innovative and different approach to CCS deployment: the project aims to build an integrated CO_2 transport and storage solution, open to multiple capture sites across Norway and Europe. CO_2 transport by ship offers a flexible option to reach large carbon emission points, enabling the development of an open source transport and storage for multiple capture plants across Europe.

The shipping solution allows the potential capture projects across Europe to no longer rely on specific national or local circumstances regarding storage. This in turn enables a number of potential CO_2 capture projects that would otherwise not materialise, thus paving the way for cost reduction and a gradual scale up of CCS. Assuming a positive FID by the Northern Lights partners and the Norwegian state in 2020, potential 3rd parties in Norway and Europe could already start developing capture projects for proven storage capacity from Q4 2023.

The Northern Lights pools critical resources needed to realise CO_2 capture across Europe. These critical resources are transport and storage, but also business development, regulatory advocacy, and decision-making insights. Hubs are often understood from the perspective of volume and geography. The Northern Lights brings a new concept of CO_2 hub development: it can gather CO_2 sources from those capture sites that due to volume, cost-efficiency and geographical reasons cannot become full value chain hubs independently. This would for instance concern waste incinerators in cities. Given that many cities across Europe have and will have ambitious climate targets, CCS for waste incineration is likely to be the only cost-efficient solution to address emissions. On the other hand, it should not be expected that waste incinerators could always form part of established CO_2 clusters. The Northern Lights aims to provide a flexible solution to reach these CO_2 sources. Northern Lights can also help to kickstart the development of large capture hubs by providing a cost-effective and flexible solution for the early industrial development when companies and governments are building experience and volumes, which in later steps can be scaled up into large volumes and solutions.

It is likely that many of the early CO_2 capture projects will be done by leading companies that target quite modest volumes as their first investments. They will do this to get real industrial experience with CCS, while at the same time keeping costs

[28] 'EEPR CO_2 capture and storage projects', *European Commission* website, accessible here

and risks low. Such a mindset of 'get started early but keep the initial size small' makes a lot of sense. As CO_2 prices (e.g. ETS) and CO_2 reduction requirements are expected to become higher and CCS costs lower over time, these companies see strategic value in both getting started early and delaying their very large CCS investments until later.

It makes sense to understand Northern Lights and its network of 3rd parties as an "industrial start up lab". Northern Lights' transport and storage service makes it as easy as possible for those interested and willing to get started with CO_2 capture to do so, irrespective of whether they are part of an emission hub or not. And being interested and willing is a crucial condition for being an early starter within CCS. This willingness can outweigh disadvantages of having higher cost per tonne.

Identifying and realizing the first capture projects is often more complicated than to just find the biggest volume and lowest cost per ton of CO_2. It may rather be about identifying the best "capture projects-to-be-realized" of the size that companies and governments actually are willing to realize in the short term. These will probably be of the sizes that we see the Northern Lights third-party party customers coming forward with, e.g. 500.000 tonnes per annum. Northern Lights provides a cost-effective and attractive solution for many such companies with their initial modest volume projects.

1.4.2 Realisation of the vast CO_2 storage potential on the NCS

Norway has some of the best conditions in Europe to develop CO_2 transport and storage capacities. First of all, the Norwegian Continental Shelf (NCS) has vast CO_2 storage potential due to excellent geological conditions. According to the 2019 CO_2 Storage Atlas prepared by the Norwegian Petroleum Directorate, the total storage capacity of the NCS is estimated to be more than 80 billion tonnes[29]. In comparison, the EU's total GHG emissions were around 4.4 billion tonnes of CO_2 in 2017[30]. The sheer size of available, safe and most importantly, viable geological storage sites make the NCS the most promising option for kick-starting CCS in Europe. Vast storage potential can accommodate cost reduction in terms of developing the first optimal storage locations, standardising transport routes and facilitating storage access to Europe's pioneering CO_2 capture projects.

1.4.3 Addressing CCS safety concerns in Europe

The Northern Lights partners Equinor, Total and Shell have extensive experience in offshore operations, which is an important aspect regarding the overall value chain risk and cost reduction. In addition to their experience in offshore and shipping operations, the partners have also built decades of relevant experience in safe CCS operations in Sleipner, Snøhvit and Quest projects. The relevant competences of the partners make them the best equipped parties to commence the world's first decoupled CO_2 transport and storage project. The Northern Lights can contribute to decreasing the overall risk of the value chain, in particular for the 3rd party capture projects that have less experience in transport and storage of CO_2.

This is particularly valuable as insufficient geological conditions, unfavourable regulatory schemes or public opposition could in several European countries prevent the near time development of CCS projects. Saty is often quoted as one of the primary reasons of concern regarding the CCS technology. As mentioned, the three partner companies have been working on CCS projects for nearly three decades, which is proof of the technology's reliability and future potential. These projects also support the argument that Norway is one of the best locations in Europe to guarantee high safety standards when developing large-scale CO_2 storage. The Norwegian CO_2 storage potential allows other countries, who have difficulty

[29] 'Carbon capture and storage', *Norwegian Petroleum Directorate* website, last accessed 19/08/2019, accessible here
[30] 'Total greenhouse gas emission trends and projections', *European Environment Agency* website, 19/12/2018, accessible here

in developing CO_2 storage capacities locally or are concerned about the safety aspects, to dissociate from the storage part of the value chain. Therefore, the Northern Lights project could help the CCS technology avoid the NIMBY ("Not In My Back Yard") effect, which is a growing concern for some other low carbon energy technologies in Europe, notably wind power. Developing scalable CO_2 storage capacities on the NCS can therefore help European companies, governments and the public to learn to trust the CCS technology and encourage its widespread use in the energy-intensive sectors.

1.4.4 Encouraging ambitious industrial decarbonisation policies and contributing to industrial competitiveness in Europe

Industrial decarbonisation policies and solutions are currently lacking in both the Norwegian as well as the EU contexts with few tools available for the energy-intensive sectors. Enabling large-scale and affordable CO_2 storage for Europe's high-emitting sectors that are exposed to high carbon emission pricing can encourage their commitment to ambitious decarbonisation strategies. The past CCS projects in Europe focused almost exclusively on decarbonising fossil fuel-based power production. In contrast, Northern Lights potential 3rd party volumes include a much wider range of emission-intensive activities, including hydrogen, steel and cement production, as well as waste, refineries, biomass and gas combustion. Demonstrating the viability of CCS in a variety of industrial applications can reinforce the Norwegian and EU decarbonisation policies and hopefully contribute to building a European industrial decarbonisation strategy.

As the EU is committing to ever-more stringent climate ambitions, the European industries are under increasing pressure to significantly reduce their carbon footprint. If CCS is mainstreamed across industries in Europe as a result of significantly reduced costs, growing availability and carbon price pressure, it could contribute to preserving industrial activity in Europe and prevent carbon leakage. Proving that CCS can be a viable alternative to moving industrial activities outside of Europe will reinforce Europe's industrial competitiveness in a low carbon environment and most importantly, preserve jobs and create new employment opportunities. According to a 2018 study by SINTEF, the Norwegian full-scale project could contribute to creating a substantial market for CO_2 management in Europe. Their estimates show that a European CCS industry could generate 30,000 to 40,000 jobs in 2030 and 80,000 to 90,000 jobs[31] in the high CCS deployment scenario[32]. According to the same study, high CCS deployment could improve the competitiveness of some 80,000-90,000 of existing jobs in the Norwegian process industry, natural gas operations and shipping[33]. The study demonstrates the potential of CCS to boost the European industrial competitiveness by preserving the existing industries and creating new opportunities in associated low carbon value chains, such as the hydrogen market.

1.4.5 Enabling future low carbon value chains

Establishing a CO_2 transport and storage solution will also enable the development of new low carbon energy carriers. Key options are low-carbon hydrogen produced from natural gas with CCS, and emission-free power produced by combustion of gas, biomass, waste, etc. with CCS.

The Partner companies are advancing new low carbon energy carriers through a combination of political advocacy and business development. The actual business development is mainly done by the individual Partner companies. One example is the hydrogen business development agenda which Equinor is developing. These are large-scale projects that integrate CCS solutions and aim to address GHG emissions related to power production, industrial activities, heating and

[31] *Industrial opportunities and employment prospects in large-scale* CO_2 *management in Norway*, Sintef study, p. 19-20, 01/06/2018, accessible here
[32] The High CCS scenario foresees storage of over 1000 MTPA of CO_2 by 2050
[33] *Industrial opportunities and employment prospects in large-scale* CO_2 *management in Norway*, Sintef study, p. 11, 01/06/2018, accessible here

maritime transport. It can create momentum for broad roll-out of CCS solutions EU-wide. A major driver for these projects is the fact that renewables alone, and for zero-emission 2050 perspectives, will not be able to guarantee security of supply and system reliability due to intermittency and seasonality constraints. The power system will have to be designed in a way to reward flexibility of dispatchable clean power units at times when renewable power supply is insufficient to meet the demand.

The possible business opportunities from hydrogen could be substantial. For example, the aforementioned SINTEF study estimate that investment in Norway in hydrogen production from natural gas may result in sales of 220 billion NOK in 2050, and between 25,000 and 35,000 new jobs. A precondition for this is, among other things, that adequate storage capacity is developed for CO_2 in the North Sea.

CCS is also the crucial enabler for process industries to be able to transition to emission-free products, in sectors such as cement, fertilizer, metal or other production. CCS is also needed for achieving negative emissions through so-called bio-CCS or BECCS applications.

Given the high share of industrial emissions, reaching net zero emissions by 2050 is impossible if they are left unaddressed. Industrial decarbonisation must be as cost-efficient as possible. Electrifying steel, cement or other heavy industry will prove expensive. To remain competitive, the European industry needs options that can deliver large-scale and cost-efficient decarbonisation. These options must be replicable and scalable EU-wide. CCS can be a viable option for industrial and power production decarbonisation, especially when combined with clean hydrogen.

1.4.6 Northern Lights expansion scenarios

The energy intensive industry is the second largest source of CO_2 emissions in the EU, representing approximately 15% of the total GHG emissions or 700 MTPA of CO_2 (2015)[34]. The Northern Lights project targets emission reduction in many of EU's industries and can directly mitigate the emissions from some of the largest sources of CO_2 across Europe. The sections below explore four different expansion scenarios of the Northern Lights project: ranging from 1.5 MTPA, 5 MTPA, 20 MTPA and 100 MTPA. The first two scenarios correlate with phases 1 and 2 of Northern Lights, while the 20 and 100 MTPA scenarios describe possible further build-up into what would start to look like a European network for CO_2 management. The solutions in these phases may extend beyond the infrastructure and solutions developed for Northern Lights phases 1 and 2.

A combination of factors discussed in the previous sections renders the Northern Lights project well-placed to trigger rapid scale-up potential and contribute to realising large-scale CCS application in Europe. The Northern Lights concept is based on decoupling the CO_2 source from the sink, which effectively distributes the financial burden and responsibility to different parts of the value chain and can help to reduce risk along the capture, transport and storage parts of the initial phase of CCS deployment. The first emission volumes from 3rd parties will constitute a fraction of these companies' total emissions, implying a high potential to scale up CO_2 supply in later project stages. Similarly, the storage potential on the NCS can be further exploited after the first two phases of the Northern Lights are successfully realised. CO_2 transportation will also benefit from expansion and standardisation of equipment and logistics as more capture sites and higher volumes are added. Experience gained in developing the CCS value chains will increase trust in both the technology as well as in the operators' ability to deliver the transport and storage service to Europe's industries. Experience will help to optimise operations. As the project engages with potential CO_2 suppliers, it is also in contact with a number of national administrations across Europe. Cooperating with governments can be helpful in creating a favourable policy environment for the future scale-up.

[34] p. 24, https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

1.5 MTPA Scenario

Phase 1 of the Northern Lights has an annual capacity of storing 1.5 MTPA of CO_2, which will likely be used up by a combination of emission sources from the Norwegian Full-Scale CCS demonstration project and the most mature 3rd party candidates included in the PCI. Assuming positive FIDs for both Fortum Oslo Varme and Norcem, as well as sufficient state support, they will each capture approx. 400,000 tonnes of CO_2, resulting in 800,000 tonnes of CO_2 annually to be transported and stored by the Northern Lights. This leaves 700,000 tonnes of spare capacity in Phase 1 for other 3rd party volumes, which will likely enable one or two non-Norwegian 3rd parties to connect to the Northern Lights. Based on the information in the PCI application (see Figure) do Air Liquide, Preem, and H2M Eemshaven describe their start of CCS operation to be in 2025, with a resulting necessity to store their CO_2 emission in the same timeframe. This is also confirmed by the level of maturity of the dialogue between Northern Lights and these 3rd parties. There are also additional 3rd parties who could be ready to store their CO_2 in Northern Lights in the same timeframe without having indicated this in the PCI application. These 3rd parties have trough requests for information (RFIs) for the development of a full-chain CCS solution, and/or through piloting capture technology, indicated to Northern Lights that their start of operation would fit with Northern Lights Phase 1.

The accumulated volumes of captured CO_2 communicated by the 3rd parties with an indicated start-up in 2025 hence amount to far more than 1.5 MTPA. Given sustained interest from the 3rd parties, this could result in a 'first to store' situation where several 3rd parties wish to utilise the spare capacity of Phase 1. This could also generate momentum for the expansion to Northern Lights Phase 2.

A final investment decision (FID) for Northern Lights in 2020 enables the relevant 3rd parties to apply for the first call of the Innovation Fund, as this is expected to match this timing. Given a final approval of the PCI application, each of the PCI partners will also be eligible to apply for funding from the Connecting Europe Facility Fund.

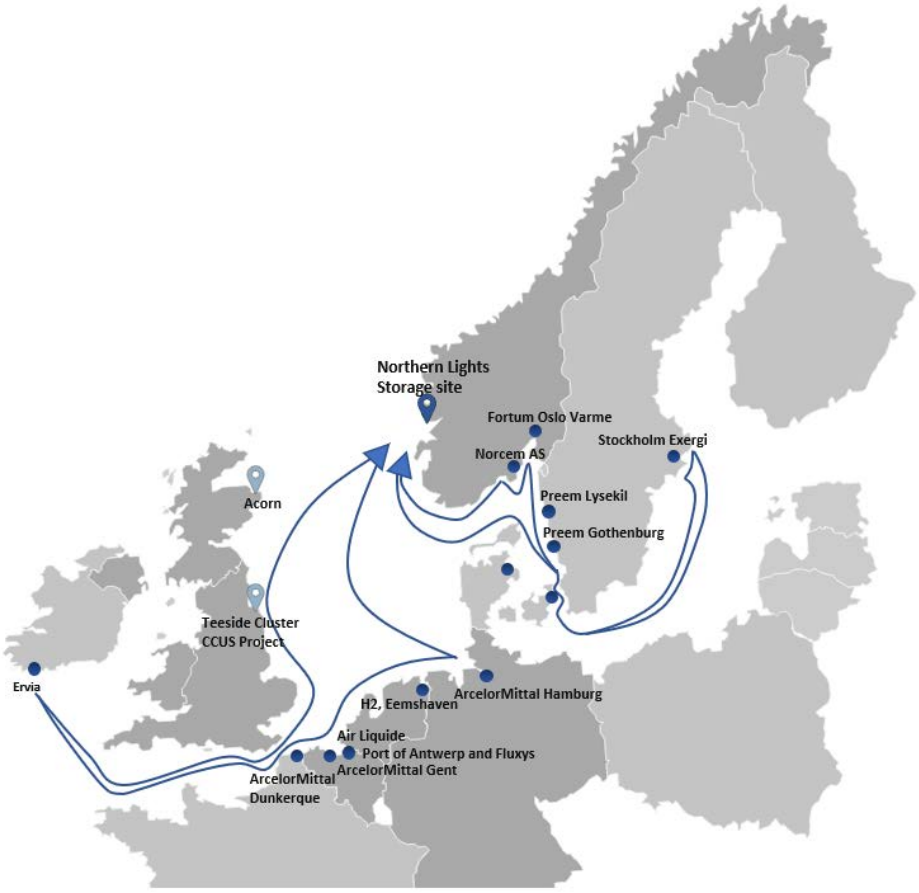


Figure 14. Mapping of potential CO2 suppliers in a 1.5MTPA scenario of the Northern Lights

5 MTPA Scenario

The expansion to 5 MTPA storage capacity would necessitate additional investment from the Northern Lights partnership. The expansion could be triggered by an anchor supplier that will increase the total volumes of CO_2 significantly above 1.5 MTPA, alternatively several relatively smaller suppliers in parallel. The relevant first moving 3rd parties highlighted in the 1.5 MTPA scenario constitute a total volume of CO_2 that exceeds the capacity of Phase 1 and could therefore create the necessary momentum and market pull to enable an investment for Phase 2. The expansion will therefore likely be started by adding 3rd party CO_2 volumes from some of the industrial sites in Sweden, Germany, Belgium, France, Netherlands, Ireland or Denmark. Additional CO_2 volumes could be sourced from Norway as well – from emission sites which are not part of the Norwegian full-scale CCS project. Potential candidates include the CO_2 Hub Nordland, Eyde Cluster, and Borg CO_2. It is important to note that the ongoing R&D efforts as described in the previous sections will enable to lower the infrastructure extension costs as a result of reduced design margins, optimised logistic chains, and CO_2 specifications.

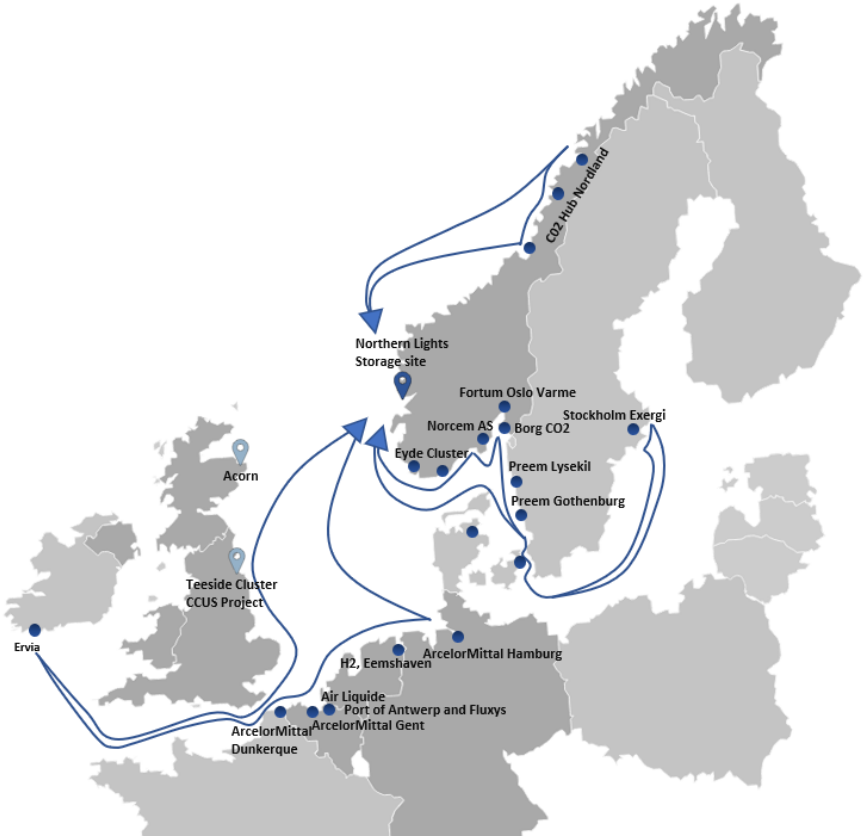


Figure 14. Mapping of potential CO2 suppliers in a 5MTPA scenario of the Northern Lights

20 MTPA Scenario

R&D research efforts are instrumental to realise cost reductions along the different parts of the value chain beyond the first two phases of the project. Larger CO_2 transport ships could enable larger volumes while the development of barge transport could allow CCS to reach emission sites located in proximity to rivers. In turn, CO_2 transport by ship could become available to a wide range of emission sites in Europe that have the relevant characteristics for capturing significant volumes of CO_2 for permanent storage. Project development could also facilitate the upscale of CO_2 injection capacities and allow Northern Lights to identify and prepare a large CO_2 storage location for the volumes beyond 5 MTPA. Improved logistic chains and transport modes could trigger new demand for CO_2 storage across the European industries.

At this stage, 3rd parties in the Baltic region and Poland could come on stream, as the combination of the decreasing CCS costs and the EU funds available to less developed EU member states to develop tools for decarbonisation will make it an attractive market for CCS activities. During this phase, additional volumes could come from CO_2 capture sites in Sweden, France, Denmark, Germany, and Belgium. This would mainly be a scale-up of existing value chains which already have been in operation with volumes in the range of 200 to 500 ktpa. As indicated by for example ArcelorMittal in the PCI description, their captured volume of CO_2 could increase significantly with a factor of 3-10 times (depending on the facility), as the operational experience of successfully capturing smaller volumes enables this increase. This logic has been confirmed in dialogue with other relevant 3rd parties as well, as each company will need to test the technology at smaller, but yet industrial, volumes before scaling up.

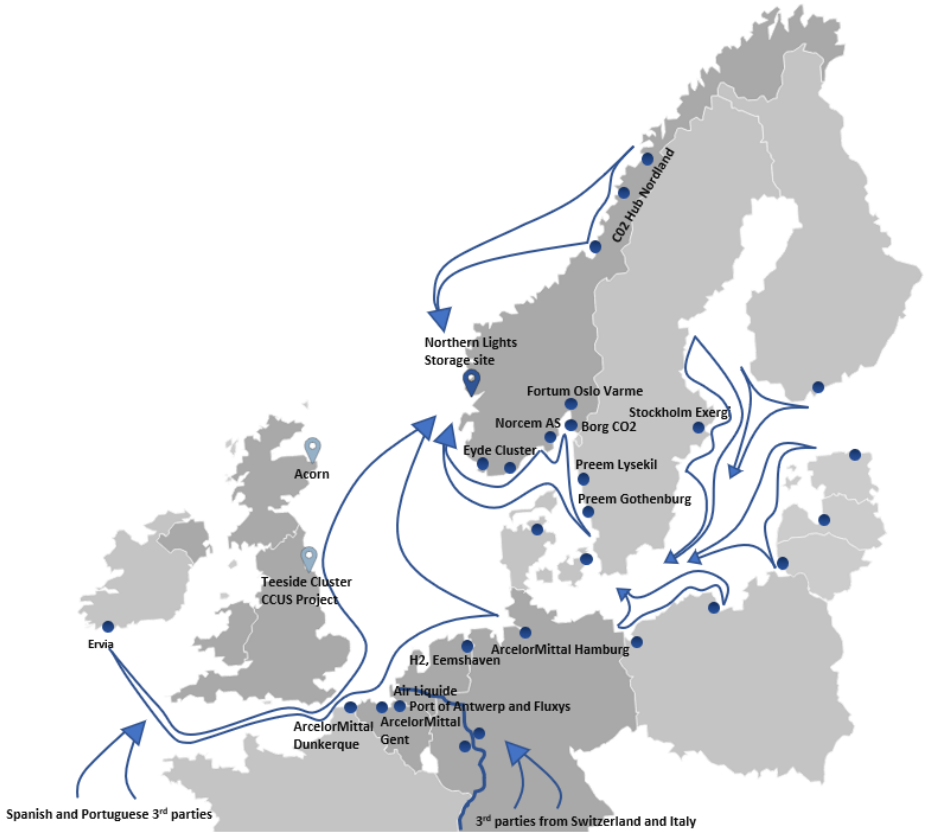


Figure 16. Mapping of potential CO2 suppliers in a 20MTPA scenario of the Northern Lights

100 MTPA Scenario

The combination of operational experience from the Northern Lights and its scaling up, other CCS projects, and R&D projects could enable the emergence of a European network of CO_2 capture, transport and storage coming in place, with ship-based and pipeline transport complementing each other.

At this stage, with CO_2 capture having scaled up to large volumes, it could also be possible to develop offshore pipelines from the European mainland to Naturgassparken or directly to new storage sites at NCS. Project expansion could also allow the development of clusters along rivers with extensive industrial activities, such as the Ruhr area along the Rhine. These clusters could be connected to pipeline infrastructure that enable more inland 3rd parties to be connected to storage on the NCS. Inland volumes in central Europe could hence be connected to storage through ships on rivers and sea, trains, and pipelines. This stage will also allow for a considerable scale up of the total volumes of CO_2 collected from each site.

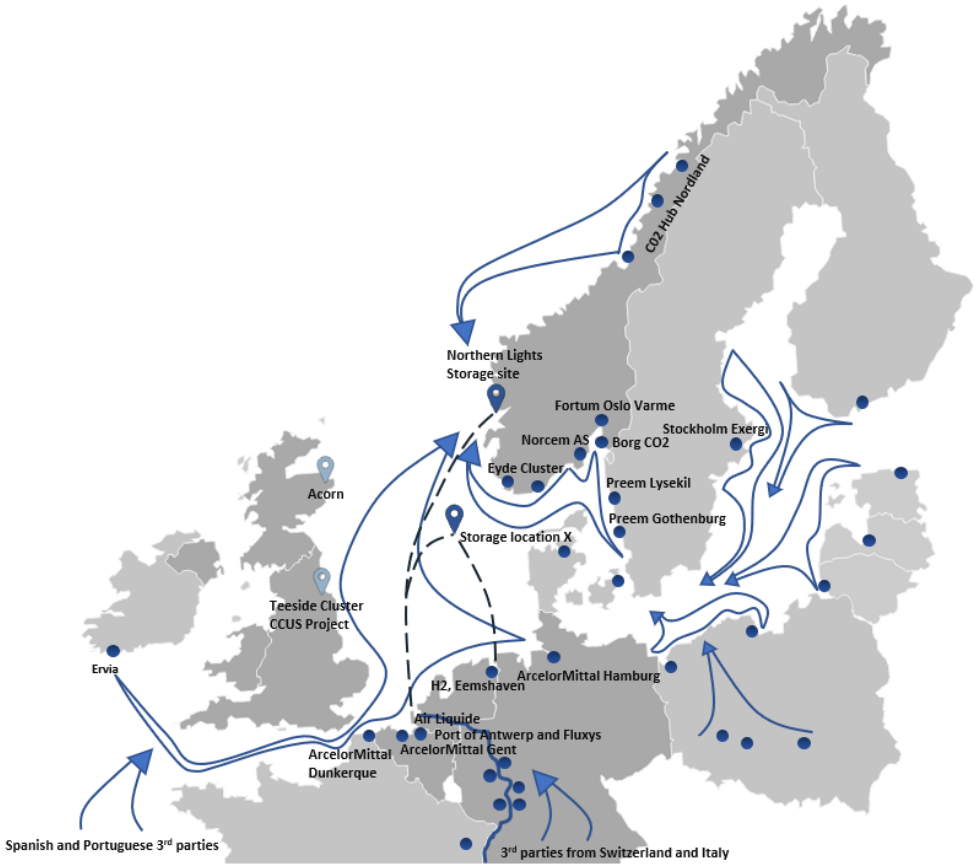


Figure 17. Mapping of potential CO2 suppliers in a 100MTPA scenario of the Northern Lights

1.5 Summing up and future plans for benefit realisation

This report has provided a detailed explanation of the Northern Lights' business and market development. It has also outlined how the Northern Lights project helps to kick-start and drive the scale-up of CCS in Europe, thereby also realising the NCS storage potential as well as provide concrete tools to mitigate Europe's industrial emissions.

This final chapter links back to the benefit realisation plan presented earlier, to summarize how the Northern Lights has contributed to the specific project goals and benefits to this point. It also presents the updated plan for benefits realisation activities in the next phases project of the project. The summary and plans are structured around the four main project goals. In general, the plan for future phases is to continue with more of the same activities as described in this report. This is described in more detail below.

Project goal 1. Demonstrate that CCS is feasible and safe

Summary of outcomes to date

Public acceptance is often quoted as a major concern for developing large-scale CCS in Europe. Lack of public awareness of the CCS technology and its CO_2 emission mitigation potential contribute largely to this. Therefore, working towards improving the public knowledge of the CCS technology and potential is a crucial objective for Northern Lights. As explained in section 1.3.2.4, the project is in constant dialogue with industry, academia, NGOs and policy makers in Norway, the EU as well as in a number of EU member states to inform about the project progress, discuss the regulatory and policy framework, as well as to answer concerns with regard to operations and safety. In addition, the Northern Lights team presents the project at numerous conferences and meetings, thereby engaging with the public as well as the relevant stakeholders in public administration in the EU member states. The Northern Lights represents a crucial step in terms of

realising the storage potential on the NCS, and linking it to the large need for storage in Europe. Therefore, successful operation of the Northern Lights storage site will be an important milestone for proving the viability of the CCS technology in Europe. In this context, it is particularly relevant to have many European partners involved in the CO_2 capture part to maximise the outreach potential in the EU. With Northern Lights' growing number of capture candidates outside of Norway, the network for spreading information, addressing issues and building trust about transport and storage of CO_2 expands accordingly. The flexible open source model of Northern Light makes CCS relevant for many. Northern Lights' European outreach potential is therefore fundamental to building confidence in the CCS technology across Europe (Benefit 1.1). The model, with storage in Norway, also fends of many arguments about safety concerns as a primary reason for not investing in CCS projects.

Plan for the next phases

The further progress on project goal 1 will be driven by two main activities, worked in parallel; Continued business development, and knowledge sharing:

Continued business development to drive the development of safe and robust 3rd party projects: A clear learning from the current business development activity is that the development of 3rd party CO2 capture sites helps to demonstrate the feasibility and relevance of CCS. An example is the positive publicity and increased momentum resulting from the official signing of seven Memorandums of Understanding on September 5th 2019. In order to capitalise on this increased momentum, the project will continue to work with 3rd party projects to support them towards positive FIDs on their plans for commercial scale CCS. This helps to demonstrate that both the technical and financial aspects of such a project can be executed and later operated in a safe and robust manner. Business development towards relevant 3rd parties, including further commercial maturation towards FID, will therefore continue to be a key activity in the next phases of Northern Lights.

Knowledge sharing: As the network for spreading information, addressing issues and building trust on CCS is expanded through Northern Lights' growing number of capture candidates outside Norway, this helps to share knowledge and aligning the messaging on CCS across Europe. The credibility of information is supported by the proof of actual project development, and with an increased number of CCS projects in different European member states this drives the dialogue on both national and EU level. As a consequence of the expanded network, the Northern Lights is receiving an increasing number of requests to present the project externally. In addition to these requests, the project is actively seeking opportunities to present the project at conferences and meetings in the EU member states who still experience are lacking support for CCS. The knowledge sharing activities will be coordinated around these main points going forward:

a. External presentations: The project will continue to hold many external presentations.
b. Bi-lateral dialogue and CCS Safaris: The development of the European CCS network requires both a company-to-company and a country-to-country cooperation. As a result, the bilateral dialogue between the Norwegian Government and national governments in countries of relevant 3rd parties are key in developing the required political support for CCS. Gassnova has been, and will continue to be, a key enabler for this dialogue, and the relevance of "CCS Safaris" will continue to be an important tool quality dialogue. The Norwegian embassies in relevant EU member states will also continue to be an important help in establishing and maintaining this bilateral dialogue.
c. CCUS Project Network and OGCI: The project will be an active member in several knowledge sharing platform, initiated both by industry and the EU. The two main platforms are currently the CCUS Project network and the OGCI, but as the project is also supporting two H2020 applications. These will hopefully also represent opportunities for knowledge sharing.
d. Website: The Northern Lights website will continue to be updated to be an accessible source of information for key stakeholders.

Project goal 2. Reduce cost for coming CCS projects through learning curve effects and economy of scale

Summary of outcome to date

Rolling out an open source CO_2 transport and storage service that is available and relevant to many CO_2 emission sources across Europe will reduce costs and project development risk for CO_2 capture projects, thereby encouraging more of them to take off. Successful realisation of a centralised transport and storage solution would hence decrease the risks related to the development of full-scale CCS value chains in Europe (Benefit 2.4). The project's flexibility in using shipping to transport CO_2 can be used to rapidly scale up the transport and storage potential, effectively developing economies of scale for the CCS applications (Benefit 2.3). Assuming both a growing interest in industrial CCS use and availability of large-scale CO_2 storage solutions will further drive the R&D agenda in attempts to find new and optimised solutions to diminish costs across CCS value chains as exemplified in section 1.3.2.3 (Benefits 2.1 and 2.2). The Northern Lights project aims to facilitate the market development for CCS by making it the preferred carbon emission mitigation solution for many emission-intensive industries. Such expansion of demand for CCS would further develop the transport and storage services by demonstrating its commercial potential and as such contribute to realising Benefit 2.5.

Plan for the next phases

In order to reduce costs for coming CCS projects two main effects need to take place; 1) a sufficient number of full-scale projects must be developed, with DNV GL estimating approximately 60 full-scale new CCS plants needed in order to see cost reductions of 30 % from today's level, and 2) the cumulative global capacity of CCS needs to increase. These are logically interlinked, however with respect to potential for cost reduction there is a difference between initiating a small number of projects with large capacity compared to having the same volume of accumulated capacity spread over a larger number of individual projects. For the latter, the potential for knowledge sharing and standardization increases with the number of projects, in which Northern Lights can provide key infrastructure to enable this development to happen. As a result, the main focus in business development has been to connect a broad portfolio of 3rd party volumes, both in terms of geographical location and industry segment, to the project. The 3rd parties targeted have mainly constituted CO2 volumes in the range of 400 ktpa to 1 mtpa, which therefore allows for an increased number of 3rd parties to connect to Northern Lights within the current capacity of Phase 1 and 2. Several of these 3rd parties do however have a large potential for scaling-up their volumes five to ten times, given successful operation at these smaller, but yet commercial volumes. The continued business development to drive the development of safe and robust 3rd party projects, as highlighted in Project goal 1, is in effect a key enabler for cost reductions through market development.

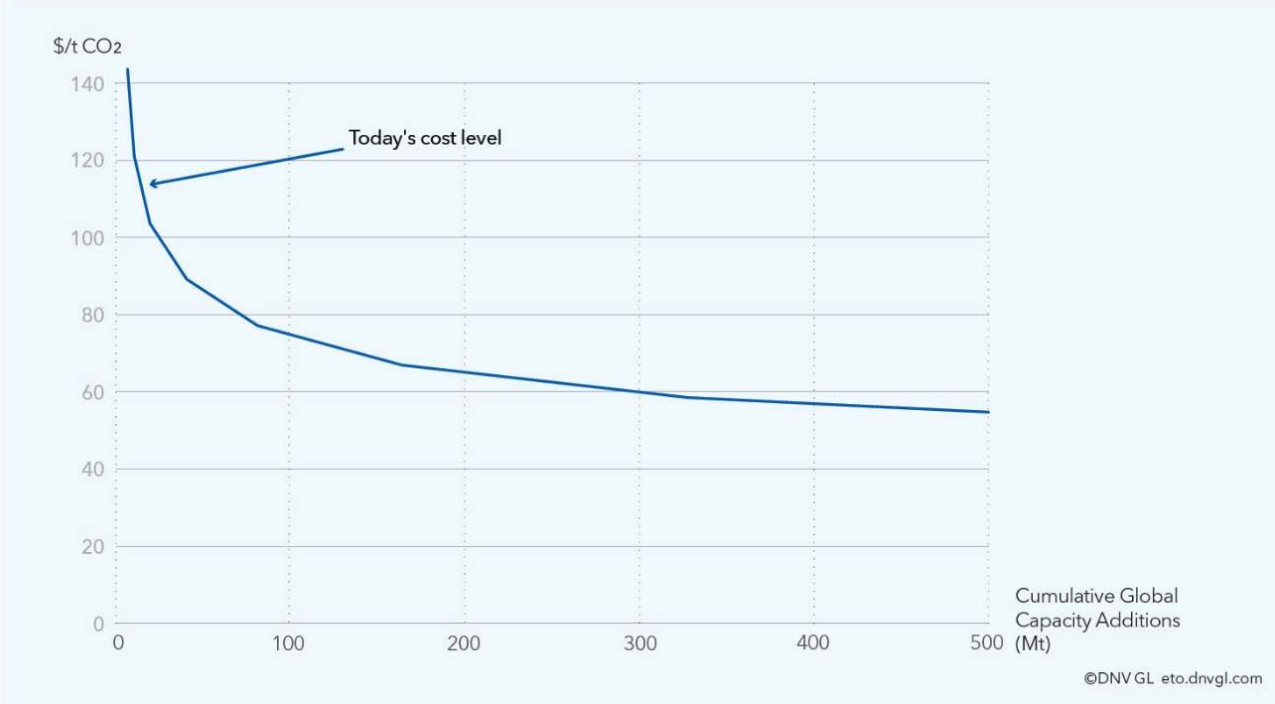


Figure 18: DNV GL has indicated the potential for cost reduction in CCS given a sufficient number of projects are initiated, linking the potential for cost reduction to cumulative global capacity additions.[35]

As 3rd parties will offload their captured CO2 to ships provided from Northern Lights, this includes replicable scope for process equipment that can be standardized across each 3 party.
The required scope of equipment for each 3rd party to connect to Northern Lights' transport and storage infrastructure is:

- CO2 capture system – Dependent on industrial segment and capture process
- Metering and liquefaction – Similarities across all industry segments, large potential for standardization
- Intermediate storage for CO2 – Similarities across all industry segments, large potential for standardization
- Transfer pumps and offloading systems - Similarities across all industry segments, large potential for standardization

There are several elements of the required equipment for 3rd parties that will be similar for each site, and also have similarities with the scope of Phase 1 for the intermediate storage site in Northern Lights, in particular tanks, metering systems, and loading arms. The project is currently working to identify the scope for standardization of such equipment in dialogue with the Norwegian full-scale project, relevant suppliers, and potential 3rd party customers. The project also recognize that this scope is not a part of the core activities for some of the 3rd party candidates who have an interest in connecting to the Northern Lights infrastructure, and the plan for the future phases includes to identify how this risk can be mitigated to allow for each 3rd party to connect to Northern Lights most efficiently and cost effectively.

[35] https://www.dnvgl.com/feature/carbon-capture-storage-ccs.html

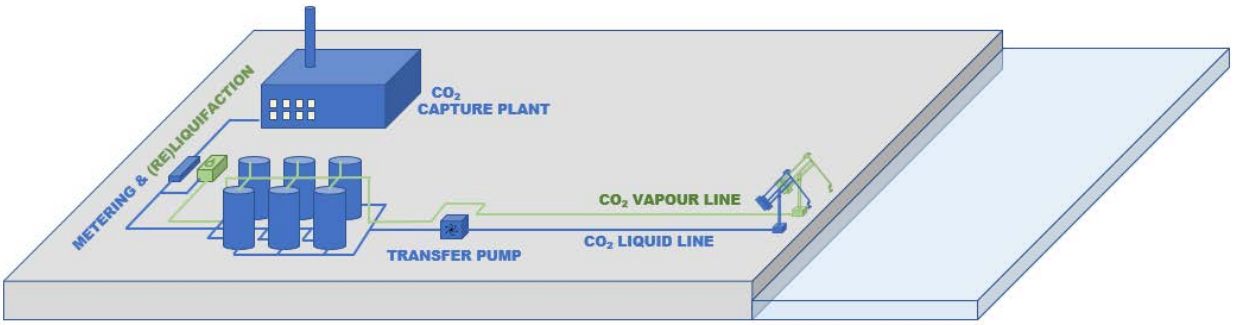


Figure 19: Simplified illustration of capture and process equipment scope required at each 3rd party location to offload their CO2 to Northern Lights' ships.

Project goal 3. Give learnings related to regulating and incentivising CCS activities

Summary of outcomes to date

For the Northern Lights project to advance and provide its valuable services to capture companies, finding suitable funding models and implementing favourable regulatory frameworks remain the most important challenges. Section 1.3.2.1 outlines how the project has worked to enable funding which would enable the first two phases as well as a potential future expansion. Northern Lights is a first-of-a-kind project as it aims to both deliver a scale-up of the CCS solution for industries as well as to decouple the carbon sink from the source. The first phase is expected to be financed by public-private funding. Additional funding for capture projects and transport and storage expansion will be needed from companies, governments and the EU. All this is giving, and will continue to give, lots of relevant experience-based learning about how private / public cooperation models can be made to work (Benefit 3.1).

Plan for the next phases

Section 1.3.2.2 describes the regulatory concerns for Northern Lights as well as the team's engagement with the authorities to address them. This engagement will continue in the next phases of the project. On the EU dimension, the framework for CCS is considered outdated as it fails to recognise the shipping solution as a viable alternative to transport CO_2, thus impeding access to some public funding opportunities. In addition to addressing the existing gaps in the current legislation on CCS, the Northern Lights project aims to pave the way for setting up an enabling regulatory framework for large-scale CCS operations across Europe in the mid- to long-term. As with funding, the project's activities provide specific and targeted insights about regulatory concerns and how these could be fixed (Benefit 3.2). A specific example is related to the London Protocol, where The Norwegian Ministry of Petroleum and Energy have developed a proposal for resolution to allow for cross-boundary shipping of CO2. This proposal would need bilateral support between Norway and the governments of the relevant 3rd party country, and Northern Lights will emphasise the importance of supporting this proposal in their company to company dialogue, for the relevant 3rd party to raise this relevance to their respective government.

With respect to funding, both the Innovation Fund and the Connecting Europe Facility are expected to announce a call in 2020. Both funds are relevant for both Northern Lights and its related 3rd party sources, and the next phases of the project will therefore include coordination between Northern Lights and the interested 3rd parties to submit an application to one or both of the calls for funding of the applicable scope

Project goal 4. Contribution to new industrial opportunities

Summary of outcomes to date

The deployment of CCS in Europe is important not only for direct emissions mitigation in industrial applications but also to enable the development of low carbon industries around it, e.g. for hydrogen as described in section 1.4.5. It is important to note that the European industry's ability to establish low carbon value chains and operate under increasing carbon price pressure will determine both the EU's ability to reduce GHG emission in line with ambitious climate commitments as well as to retain industry jobs. As demonstrated in the SINTEF study, mentioned in section 1.4.4, large-scale deployment of CCS in Europe can have substantial benefits for employment opportunities in low carbon industries (Benefit 4.1). High carbon price and enabling policies can encourage the use of low carbon hydrogen for products and services, potentially expanding the application of CCS to other energy-intensive sectors such as transport, heating or energy storage (Benefit 4.2).

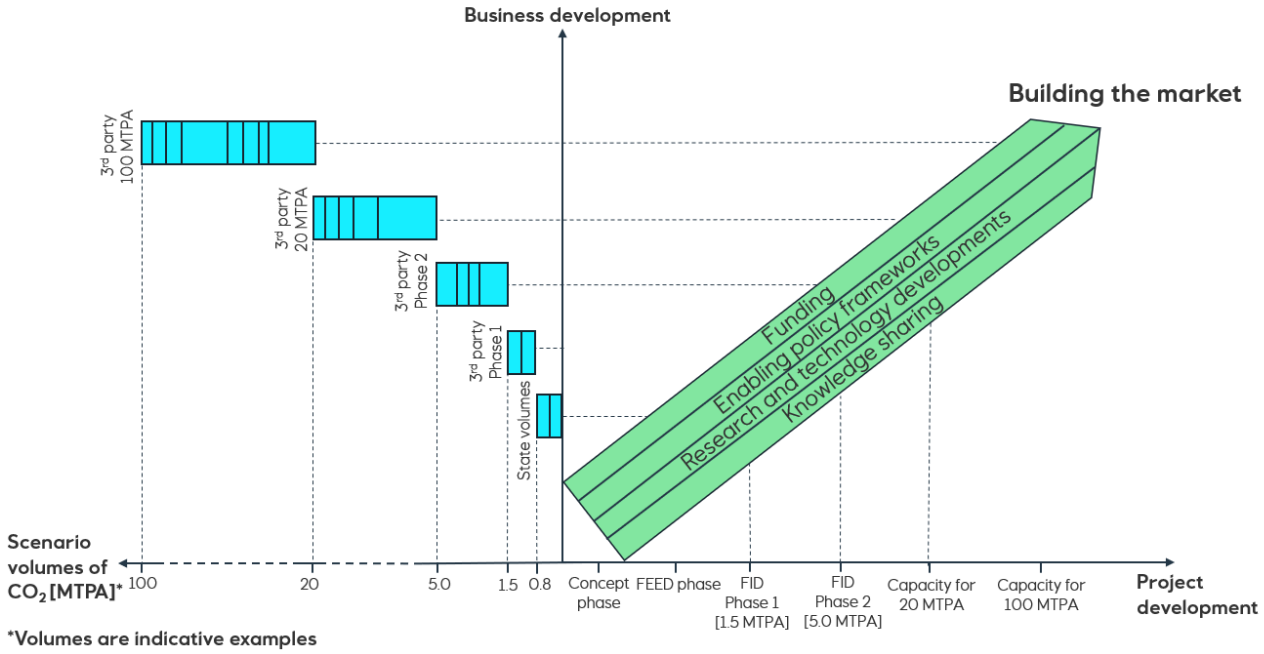


Figure 20: Further conceptual illustration of how markets are by built by project and business development and co-ordinated specific market building activities, linking to the Northern Lights development scenarios.

Plan for the next phases

Each of the partners in Northern Lights are in parallel to cooperating to make Northern Lights and CCS a technical and commercial success also developing their individual low carbon project portfolio. This will continue to be worked individually by each partner, with some exceptions in R&D where showstoppers for new low carbon value chains are addressed in cooperation. In compliance with competition law, the commercial details of 3rd party activity in Northern Lights will be limited to the "clean team", ensuring confidentiality and "Chinese walls" towards the individual business development for each individual partner company. This allows for both Equinor, Shell and Total to develop their low carbon products and services independently of Northern Lights.