
Climate and the Norwegian Continental Shelf

- Introduction, Recommendations and Roadmap for the NCS

KonKraft report no. 2016 - 2



KonKraft in brief

KonKraft is a collaboration arena for the Norwegian Oil and Gas Association, the Federation of Norwegian Industries, the Norwegian Shipowners Association and the Norwegian Confederation of Trade Unions (LO), with LO members Fellesforbundet og Industri Energi. It serves as an agenda-setter for national strategies in the petroleum sector, and works to maintain the competitiveness of the Norwegian continental shelf (NCS), so that Norway remains an attractive area for investment by the Norwegian and international oil and gas industry – including suppliers and the maritime sector. The council is KonKraft's supreme body. In addition comes an executive committee and a secretariat responsible for ongoing activities and day-to-day operations.

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1. Introduction

The climate problem is one of the very greatest challenges of our times. At the 2015 UN climate summit in Paris, all member states concurred that measures need to be taken to prevent global warming from exceeding 2°C. They also agreed to strive to bring the rise in temperature down towards 1.5°C. Realising the goals of this agreement calls for big changes in the world energy systems. Global emissions must be sharply reduced towards 2050, and the ambition is to make the world carbon-neutral well before the end of this century. At the same time, a growing human population is demanding ever more energy and energy-related products. Access to energy at affordable prices is an important precondition for value creation, growth and prosperity. Sound economic progress will also be needed if the world is to achieve the transformation required by the twofold climate and energy problem.

An important purpose of this report is to describe how the Norwegian petroleum sector is working to reduce greenhouse gas emissions. It also seeks to describe which future opportunities for growth and development are offered by implementing good climate solutions on the basis of the substantial expertise in Norway's large petroleum cluster.

Petroleum is a capital intensive industry with a long time frame. It can only remain viable in the long term by developing technology and solutions tailored to the parameters established by the future low-emission society.

This report is intended to be a fact-based contributor in discussions on the petroleum sector's role in the short and long terms. The goal is to promote technological opportunities and important relationships, and to describe the industry's views on which priorities should be adopted when shaping future energy and climate policies.

Tomorrow's low-emission society will be shaped through a dynamic interaction between technology development, political operating parameters and market solutions.

Technological progress, for example, is affected by the parameters and incentive mechanisms established by government policies, while information on, and expectations for new technological solutions help to influence political priorities. Energy markets are heavily influenced by energy and climate policy regulations, which can have unintended consequences, if these are framed in an unfortunate manner. Another goal of this report is to shed light on this interaction and thereby serve as a constructive contribution to the public debate on priorities for the Norwegian energy and climate policies.

1.1.

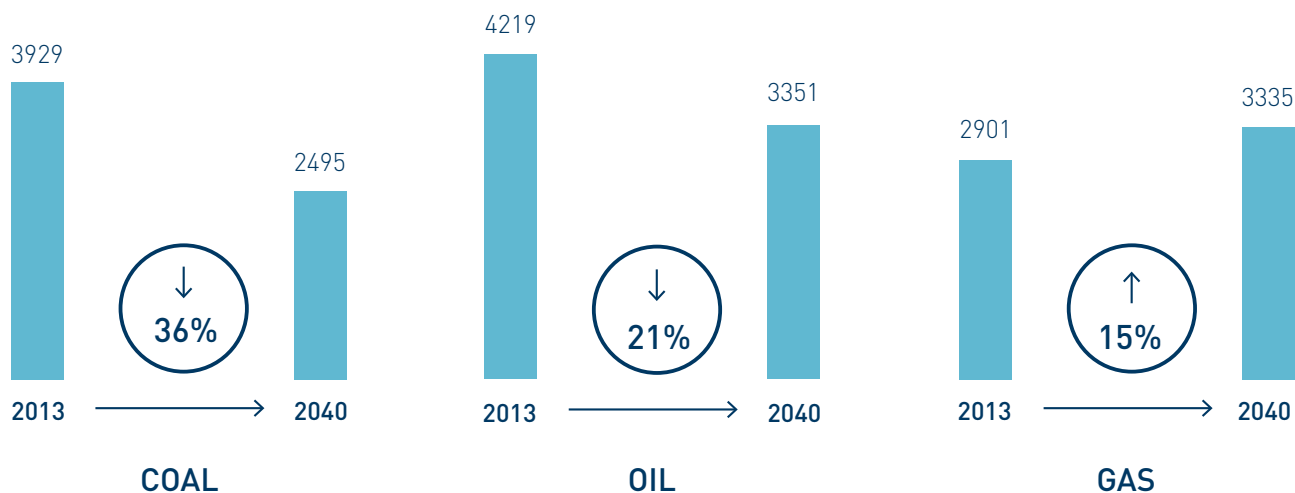
GREENHOUSE GAS EMISSIONS MUST BE CUT

A very high proportion of global greenhouse gas emissions is attributable to the use of fossil energy sources, which currently account for more than 80 per cent of world energy consumption. According to the 450 scenario¹ from the International Energy Agency (IEA), these sources will account for an estimated 60 per cent of global energy consumption in 2040. Demand is expected to rise by 15 per cent for natural gas and to decline by 20 and 40 per cent respectively for oil and coal. The Paris agreement also builds on an appreciation that the global economy will need fossil energy sources for a long time to come. It is therefore essential that production, transport and use of these sources yield the lowest possible greenhouse gas emissions – by converting, for instance, to those with the lowest carbon footprint: In other words, from coal to gas. In addition, a continuous and purposeful effort to develop new technology which reduces emissions from exploration, production, transport and use must be ensured.

¹ The IEA's 450 ppm scenario anticipates that the world avoids a temperature increase above 2°C in relation to pre-industrial times.

Figure 1.1.

Coal, oil and gas consumption in the IEA's 450 scenario². (Source: WEO 2015. IEA.)



A substantial part of the shift towards a low-emission society must take the form of new energy sources replacing fossil fuels and products. This transition will take time, and good alternatives are not available at present in a number of areas. Regional and geopolitical factors also determine how quickly it is possible to transform the energy system and products, and fossil energy sources and not all products can be equated. A substantial climate gain is offered by replacing coal with natural gas for electricity generation. Efforts to develop new technology which can make more efficient use of energy sources must be intensified. The same applies to technology and methodologies for minimising emissions from fossil energy sources. That will yield solutions which also provide scope for a substantial element of petroleum in a carbon-neutral global energy system in the long term.

The Norwegian petroleum industry has adopted new technology in most of its field developments, and has chosen efficient area and transport solutions, and lies well in the forefront of developing technology and implementing new solutions for reduced energy consumption and lower emissions. Norway's oil and gas companies and suppliers have expertise, technology and modes of operation which yield both lower emissions at home and contribute to emission reductions abroad through the adoption of their low-emission and energy-efficient solutions internationally.

² For a description of the assumptions underpinning the 450 scenario, see annex B on policies and measurement by scenario in World Energy Outlook 2015.

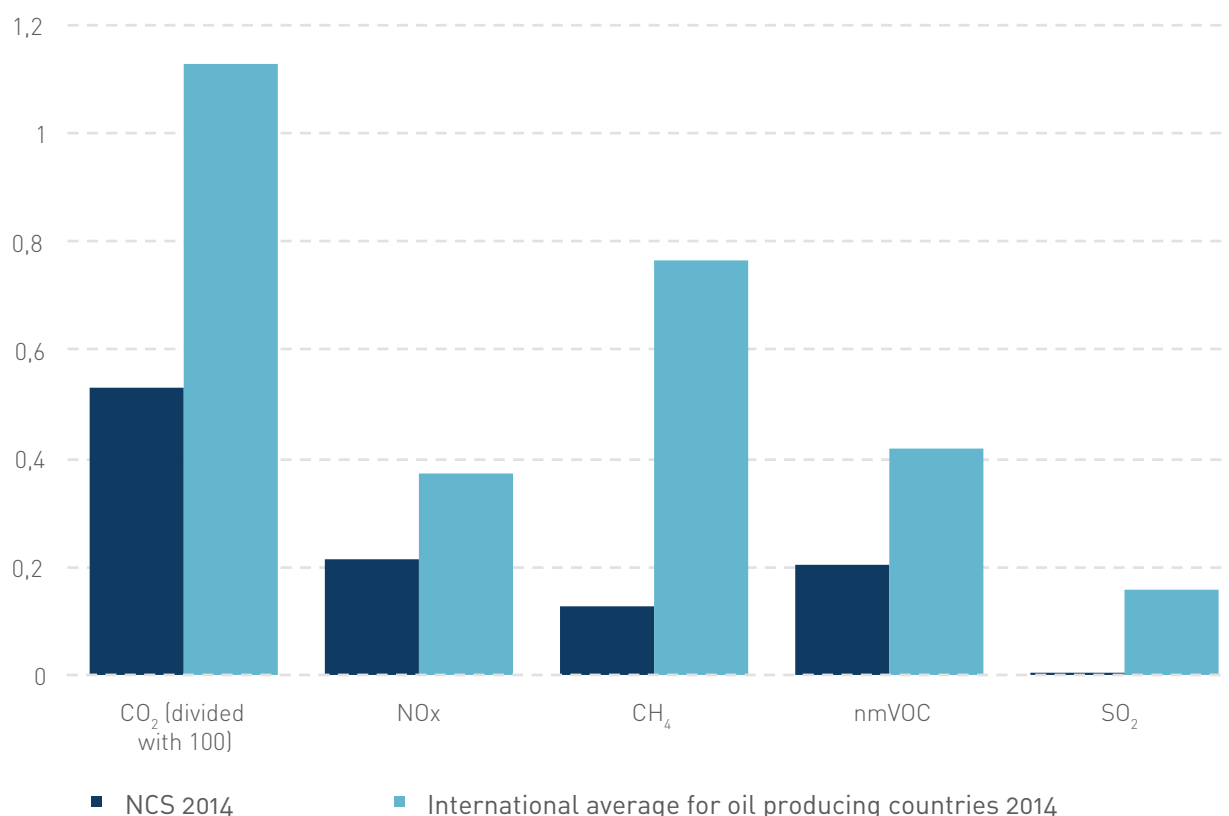
1.2.

NORWAY'S PETROLEUM SECTOR CONTRIBUTES THROUGH A LOW CARBON FOOTPRINT AND TECHNOLOGY DEVELOPMENT

As a major producer and exporter of energy, Norway plays an important role in the work of restructuring the energy system. With electricity generated almost exclusively from hydropower and access to such renewable energy resources as offshore wind power, the country has a very good starting point for reducing its greenhouse gas emissions by utilising electricity in new areas.

Figure 1.2.

Emissions to the air from the Norwegian and international petroleum industry per unit produced in 2014, kg/scm oe. (Source. Norwegian Oil and Gas, Environmental report 2016.)



Norway has, for example, committed substantial resources over the past 10-15 years to research into, and development of carbon capture and storage (CCS). The Snøhvit and the Sleipner fields are well-known examples of offshore CCS. As part of this commitment, oil and gas companies with operations in Norway have worked with technology suppliers and research institutes to qualify CCS solutions. The view that CCS must be adopted on a large scale in order to reach the goal of carbon neutrality in this century is widely held in such bodies as the UN intergovernmental panel on climate change (IPCC) and the IEA.

Europe is the largest market for Norwegian petroleum, and more than 90 per cent of its production is transported to and sold there. Norway is a strategic EU partner in the energy field, and the European Commission wants to integrate the Norwegian energy and petroleum sectors even more closely into the EU's single energy market. Norwegian petroleum deliveries are important for the security of European energy supplies, and have a low carbon footprint compared with petroleum from other

suppliers. A short distance to the European markets, compared with alternative suppliers, is also a factor which contributes to lower emissions throughout the chain because of lower energy requirements for oil and gas transport.

Norway's petroleum sector is an integrated part of the EU emission trading system (ETS), so that greenhouse gas emissions from the Norwegian oil and gas industry fall within the EU's emission allowance ceiling. This is reduced by a specified percentage every year. The EU's Roadmap 2050 has also set ambitious goals for reducing all emissions both within and outside the ETS by 2050. In other words, emissions from both oil and gas production on the Norwegian continental shelf (NCS) and from end users of petroleum products sold to Europe must be substantially reduced in the long term. This applies to emissions from the use of oil and gas in land-based industry, power generation, households and the transport sector.

1.3.

INDUSTRY WILL BE A KEY PART OF TOMORROW'S LOW-EMISSION SOCIETY

Industry plays a key role in developing and adopting solutions for a low-emission society. Norway has a unique starting point in the “green shift” currently under way. This relates to a great extent to natural advantages, but further development of these opportunities will require knowledge and expertise.

Suppliers to the oil and gas companies represent Norway's largest mainland industry and it is the second-largest export sector after petroleum sales.

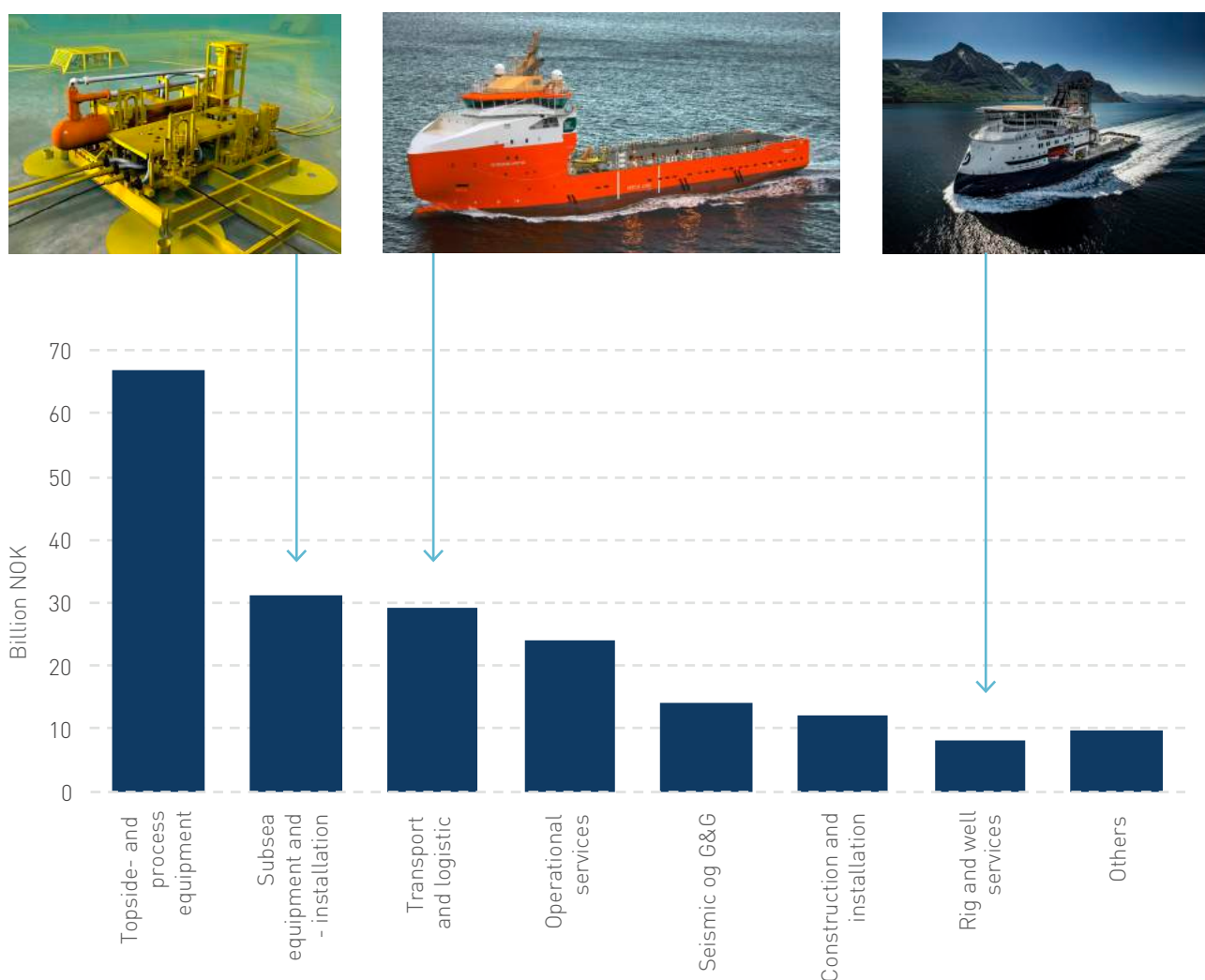
This industry has developed over 50 years of petroleum operations in Norway, and ranks today as a highly competent and internationally competitive sector distributed nationwide. Roughly 140 000 people were directly employed in the supplies industry in 2014³. Its turnover for that year was NOK 527 billion⁴, with about 40 per cent deriving from the international market. Deliveries are made to many countries worldwide, with South Korea, Brazil, the UK, the USA, Angola, Australia and Singapore as the largest markets.

³ Industribyggerne 2015 (Industry Builders). Report Iris – 2015/031.

⁴ Rystad Energy: International turnover for Norwegian service companies. Report to the Ministry of Petroleum and Energy. 15 December 2015.

Figure 1.3.

International turnover for the supplier industry in 2014 by segment, with examples of export of climate-related technologies. (Source: Rystad Energy, Intsok and KonKraft. Photos: FMC Kongsberg/Statoil, Solstad Offshore, and Ulstein Group/Marius Beck Dahle).



The ability to establish operating parameters, develop new technology and commercialise innovations in the form of cost-effective and competitive solutions forms the basis for future value creation and lower greenhouse gas emissions. Historically, nitrogen oxide (NO_x) reductions, reinjection of produced CO₂, long-distance multiphase transport, banning flaring, subsea installations, integrated environmental monitoring and the use of liquefied natural gas (LNG) to fuel ships are good examples of developments on the NCS which have reduced emissions.

1.4.

ROADMAP FOR THE NCS

A Roadmap has been drawn up for Norway's oil and gas sector (see appendix 1). This has a twofold purpose. It specifies ambitions for greenhouse gas reductions on the NCS to 2030 and 2050, and ambitions for the industry's long-term production and value creation in these waters. It also provides an action plan for the sector's specific follow-up of the climate goals, and recommendations on how collaboration between industry, government and academia can be further developed in order to speed up necessary technology development. The KonKraft partners are also following up the ambitions specified for production and value creation by initiating specific work in the industry to ensure long-term and genuine improvements in the competitiveness of Norway's oil and gas sector.

The petroleum industry in Norway has set the following overall climate and commercial goals for 2030.

Maintain safe and profitable production at the present level, and implement CO₂ reduction measures from 2020 which correspond cumulatively to 2.5 million tonnes of CO₂ equivalents per annum by 2030.

- This means that output from the NCS, measured in oil equivalent (oe), will be at about the same level as in 2015. Gas is expected to account for roughly half of 2030 production. While the bulk of volume will still come from mature areas of the North Sea and the Norwegian Sea, the far north will be more important in 2030 than it is today.
- The ambition for greenhouse gases includes emission cuts related to electricity and heat supply on oil installations, to short-lived climate forcers such as methane, and to drilling operations from mobile rigs, as well as enhanced energy efficiency at field and area level.

In addition, oil companies, suppliers and ship/rig owners will help to reduce emissions from the maritime part of

the sector. By 2030, maritime operations on the NCS will be conducted with low- or zero-emission technology in the offshore fleet. Reductions from this part of the sector come in addition to the ambition of 2.5 million tonnes of CO₂ equivalents.

Where 2050 is concerned, the industry has the following ambition:

Maintain its position as Norway's most important value creator and increase its average recovery factor to at least 60 per cent. The NCS will remain the world leader for low CO₂ emissions, and the sector will develop and adopt technology and solutions which substantially reduce average CO₂ emissions per unit produced compared with the 2030 level.

- Through its follow-up of the action plan, the petroleum industry will identify the potential for emission reductions from various technological solutions in order to put a figure on ambitions for reduced releases of greenhouse gas from the sector in 2050.
- Systematic efforts will be made by the industry to help develop and implement technology and technological solutions which reduce emissions related to the end use of oil and gas.
- The ambition means that the industry will be characterised by a high level of value creation, increased productivity and substantial employment in 2050. Vigorous offshore clusters will deliver substantial volume to markets both in Norway and globally. Export deliveries will include low-emission technologies and other solutions which contribute to greater safety and more sustainable development in the industry.
- The value creation goal means both that time-critical resources close to infrastructure are realised before the facilities are shut down, and additional resources must be proven and infrastructure developed in new areas of the NCS.

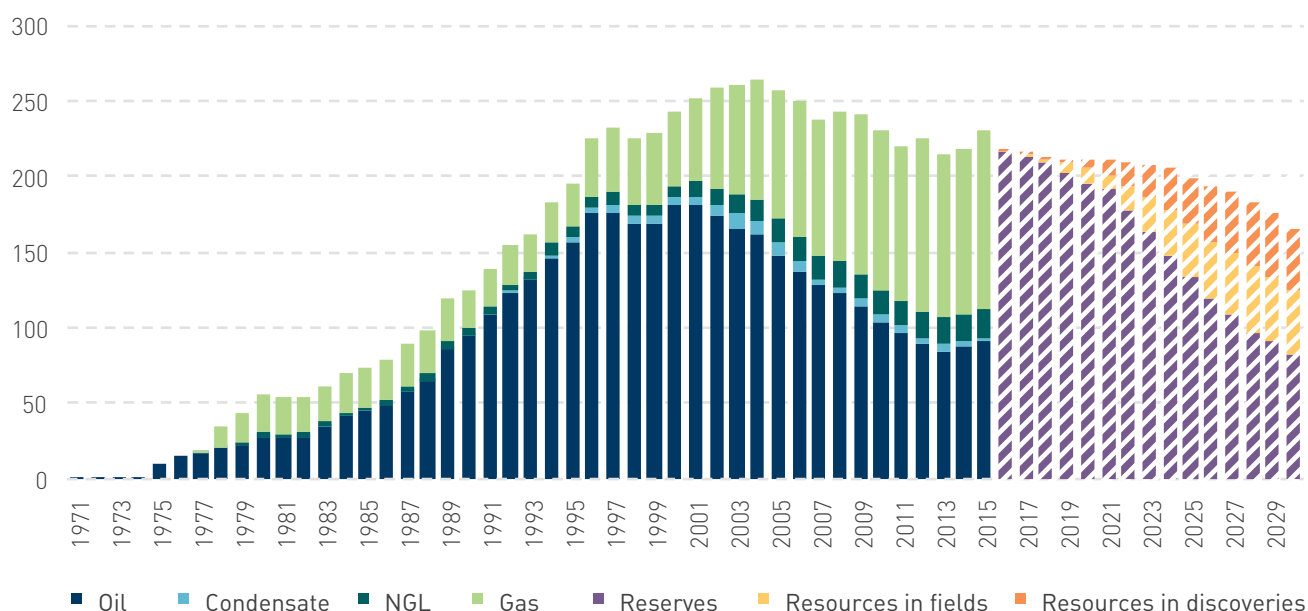
The industry will continue to maintain a high safety standard and to work for continuous improvements in safety.

The action plan in the Roadmap contains the industry's specific proposals for the way further development and implementation of low-emission technology and operating methods can be strengthened in order to fulfil the ambitions in the Roadmap, as well as proposals for a more focused collaboration between academia, the industry and government policy instruments in order to develop low-emission technology.

The industry will prepare a status report on technology development and reassess goals and milestones every

Figure 1.4:

Historical production of oil, gas, natural gas liquids and condensate in Norway, 1971-2015, and a forecast for future production by resource class, 2016-30 (in million scm oe). (Source: NPD)



fifth year. Assessing the targets set in the Roadmap will follow the same model as the Paris agreement, with goals either maintained or strengthened. At the same time, the sector undertakes to submit annual status reports of measures implemented to the relevant authorities.

An overall description of the above as well as further recommendations will form a key part of the five-yearly updates to the KonKraft climate report.

A substantial potential exists for the export of low-emission technology from the petroleum sector which has been developed in Norway. The industry will maintain and further develop existing initiatives, and create methods for estimating the global climate benefit and value of such exports.

1.5.

A CHANGING NCS

Overall oil and gas production on the NCS peaked in 2004, and oil output has more than halved since 2001. Total Norwegian petroleum production has stabilised because of a substantial rise in gas output in recent years. The NCS has substantial remaining gas volumes in existing fields, and a big potential exists for improved recovery from and exploration close to existing fields. But new commercial discoveries are required if Norway

is to remain a long-term gas supplier at today's level and exploit its existing gas infrastructure.

Looking further ahead, production on the NCS can be maintained at a high and relatively stable level up to 2025-30. This requires that existing discoveries, such as Johan Castberg in the Barents Sea, are actually developed and brought on stream. In addition, new volumes have to be tied back to existing fields and work on lasting cost reductions in the industry must succeed. Production will decline from the end of the 2020s, and several of the large fields on the NCS – particularly in the North Sea – are likely to be shut down after 2030.

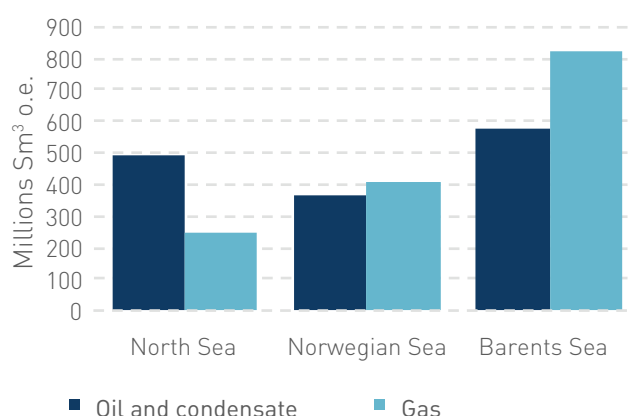
A failure by Norway to maintain its level of production would mean contractions in revenues, value creation, expertise and jobs for the industry which would in turn affect opportunities for maintaining prosperity. In addition, oil and gas would be delivered from other parts of the world with higher greenhouse gas emissions than the NCS.

The North Sea is the most mature part of the NCS, with no less than 61 fields on stream, including such large producers as Gullfaks, Ekofisk, Oseberg and Troll. Parts of the Norwegian Sea, with 16 fields on stream, are also by and large mature. The exception is its northernmost areas.

The largest remaining undiscovered resources are expected to lie in the far north. According to the Norwegian Petroleum Directorate (NPD), estimated undiscovered resources on the NCS amount to 2 920 million standard cubic metres of oil equivalents (scm oe). After almost 50 years of oil and gas production on the NCS, just under 50 per cent of its resources have been sold and delivered. Figure 1.5 shows that the Barents Sea is the region of the NCS where the largest total future resources are expected to lie, particularly with regard to gas. Only a third of the gas resources on the NCS have been produced, and more than half the remaining undiscovered gas resources are likely to be in the Barents Sea.

Figure 1.5.

Total undiscovered resources by oil, gas and condensate for the North, Norwegian and Barents Seas. (Source: NPD.)



1.6.

CONTENT OF THE REPORT

Chapter 2 summarises the main points of the report and KonKraft's recommendations to the government and the industry. Chapter 3 describes the twofold energy and climate challenge, where the world must overcome the climate challenge through a sharp reduction in emissions at the same time as its growing human population requires increased supplies of energy.

International climate conventions, the Paris agreement, the EU's energy and climate policies and Norwegian climate commitments determine the climate policy parameters for petroleum operations in Norway. This is described in chapter 4. The petroleum sector's greenhouse gas emissions in Norway are covered by chapter 5, while chapter 6 provides a more detailed description of the role of oil and gas in the transition to a low-emission society.

On the way to a future low-emission society, the NCS competitiveness will be strengthened through success with CCS. This is a key technology for achieving the Norwegian process industry's vision of zero emissions by 2050. CCS is also important if oil and gas are to be part of the future energy system together with renewable and other low-carbon energy sources. Chapter 7 describes where CCS stands today, Norwegian experience and expertise, and its future development in Norway.

Chapter 8 provides a description of the role played by greater energy efficiency in reducing emissions from petroleum operation. More efficient use of energy is an important priority for the petroleum industry. The opportunity space is widest for new installations, while a good deal can still be achieved with facilities in operation through operational optimisation and modifications.

New technology and improved energy solutions for offshore installations will reduce greenhouse gas emissions related to Norwegian production and transport of petroleum. Power from shore has been the alternative so far, but the petroleum sector is also working on other options for supplying energy. Chapter 9 deals with alternative energy solutions for the NCS, while chapter 10 looks at other areas for future emissions reductions, such as in the maritime sector.

2. Conclusions and Recommendations

The Norwegian climate policy is based on the Framework Convention on Climate Change, the Kyoto protocol, the scientific understanding expressed in reports from the Intergovernmental Panel on Climate Change (IPCC), and a number of decisions by the Storting (parliament) – most recently in 2016. At the UN climate summit in Paris during 2015, all member states concurred that measures need to be taken to prevent global warming from exceeding 2°C. They also agreed to strive to bring the rise in temperature down towards 1.5°C. Realising the goals of this agreement calls for big changes in world energy systems.

Norway's collaboration with the EU in the energy and climate area means that its greenhouse gas emissions occur within the framework of the carbon budget set by the EU at any given time. The Norwegian petroleum industry is one of the sectors subject to the ETS, and has paid carbon tax as well as buying emission allowances since the 1990s. It therefore pays a high emission cost compared with other sectors of the economy. The Norwegian government also sets stringent requirements through its other sectoral policies to ensure that the petroleum industry is operated in the most climate- and environment friendly manner.

Greenhouse gas emissions from the petroleum sector

The petroleum sector accounts for just over a quarter of the Norwegian greenhouse gas emissions. However, stringent emission standards and the great attention paid to the environment have helped to place the Norwegian Continental Shelf (NCS) among the petroleum provinces with the lowest greenhouse gas emissions in the world. These are less than half the global average per unit produced.

Future emissions from the NCS depend on production developments and the implementation of emission-reducing measures. Technological developments and cost reductions for low-emission technology will have great significance.

The role of oil and gas in the transition to a low-emission society

Norway ranks as a substantial exporter of oil and gas. Most of these foreign sales go to customers in Europe. Norway is a strategic EU partner in the energy area. The EU regards Norway as a very important gas producer, both because Norwegian gas has a low carbon footprint and because Norway's gas deliveries help to maintain sufficient security of supply as domestic output declines in important EU member states.

Natural gas has a market share of 20-25 per cent in Europe. European gas consumption has declined somewhat in recent years because of lower economic activity following the financial crisis, falling coal prices and the development of renewable energy sources. Until emission-free alternatives are developed, gas-fired generation will be a secure source of the necessary flexibility and back-up capacity for the electricity system in both the short and long terms. Moreover gas for heating and cooking will continue to be a very flexible and energy efficient source of energy for European households.

Carbon capture and storage

CCS is very important in long-term efforts to reduce global greenhouse gas emissions from both land-based industry and the electricity sector. The IPCC emphasises the importance of developing CCS if the world is to meet its climate goals, and the necessity of achieving negative CO₂ emissions in the second half of this century through carbon capture from processes using biofuel as well as active forest management.

At the same time, CCS is very important for reaching Norway's national climate goals. It represents a key technology for achieving the Norwegian process industry's vision of zero emissions by 2050. This also offers a major industrial opportunity for Norway's supplies sector, which can export technological solutions for all stages in a CCS chain.

Enhancing energy efficiency

More efficient use of energy is an important priority for the petroleum industry. The opportunity space is widest for new installations, while a good deal can still be achieved with facilities in operation through operational optimisations and modifications. Since much has already been done, opportunities for further improvements in energy efficiency will vary between installations. Adoption of new technology is nevertheless a key factor, and the industry is pursuing a number of R&D projects which will help to enhance energy efficiency and thereby reduce the carbon footprint.

Alternative energy solutions

New technology and improved power solutions for offshore installations will reduce greenhouse gas emissions related to Norwegian production and transport of petroleum. Power from shore has been the alternative so far, but the petroleum sector is also working on other options for supplying energy. Hybrid solutions, wind, fuel cells and offshore CCS are among the concepts which could make important contributions.

2.1.

CONCLUSIONS

KonKraft supports the goals and ambitions of the Paris agreement for preventing damaging climate changes. The Paris agreement also builds on an appreciation that the world faces a twofold challenge, in that affordable energy supplies must be secured for a growing human population while greenhouse gas emissions need to be reduced. Even with an expected massive development of renewable energy, the global economy will depend on fossil energy supplies for a long time to come. The production, transport and utilisation of such sources must therefore yield the lowest possible greenhouse gas emissions. Within the 2°C scenario, the best estimates from the International Energy Agency (IEA) indicate that the world will need 65 per cent of present oil production and 88 per cent of today's gas output in 2050¹. Norway's petroleum sector has a very low carbon footprint, and develops climate-relevant technology which can be utilised globally.

KonKraft believes that the single most important competitive advantage for the NCS is the overall expertise and innovative drive of the Norwegian offshore cluster. The industry has been willing to assume the risk of qualifying and adopting new technologies. New solutions have been developed through collaboration and competition, and labour relations based on open dialogue between employers, employees and government. Combined with strict government standards and enforcement, this has been crucial to the NCS becoming the world leader for

both high recovery factors and low greenhouse gas emissions. NCS achievements have also been crucial for the attractiveness and competitiveness of Norway's offshore supplier industry, and for its substantial export.

Norway's strong technical community has helped to turn sales of Norwegian-based technology and concepts from the supplier industry into the country's second largest export sector after oil and gas. Examples include long-distance multiphase transport, horizontal drilling, subsea processing, water treatment, continuous environmental monitoring, lower emissions of such gases as NO_x and volatile organic compounds (VOCs), and reduced discharges of oil in produced water. The petroleum sector has also been an innovation engine with positive ripple effects for other Norwegian industries over many decades.

Norway's petroleum industry has a unique starting point. Ninety fields will soon be in operation with associated infrastructure such as pipelines and land-based plants for processing, refining, storage and export. This means that a substantial potential exists for realising profitable volumes by improving recovery or by tie in discoveries back to existing fields and pipelines in the mature parts of the NCS. Time-critical resources close to infrastructure must be realised before the latter are shut down, while new resources need to be discovered and new infrastructure developed in frontier areas of the NCS.

KonKraft would point out that the far north will be very important for the long-term progress of the NCS. Since existing infrastructure in these areas is limited, attention over the next few years will be concentrated primarily on exploring for and maturing new resources which provide the basis for future developments. Close collaboration between companies and government to ensure good commercial solutions will continue to be needed here. Access to new exploration acreage is important as a basis both for new profitable projects and for establishing infrastructure which can be utilised by discoveries in areas which are already opened.

A substantial commitment to both research and development will continue to be needed for exploration operations, production methods, low-emission technologies and field development solutions. The largest technological leaps have earlier been achieved through big projects with robust economics and through collaboration in the industry. The growing maturity of the NCS and smaller average discovery size, higher costs and low oil prices call for more attention to cost-effective solutions.

¹ IEA – Energy Technology Perspective, June 2016

Given the ambitious climate goals set by the EU and internationally, the price of CO₂ emissions is likely to be substantially above today's level in 2050. To meet the ambitions for emission reduction and reduce carbon costs, technological solutions must be developed to improve energy efficiency and to generate electricity from emission-free or low-emission sources.

Both public and industrial research efforts to advance technology for reducing greenhouse gas emissions must be strengthened. In the short term, the most important steps will be increased adoption of existing low-emission technology on existing installations as well as incremental improvements to established technologies in order to boost their efficiency and/or reduce their cost. Looking further ahead, completely new technology areas, solutions and value chains than those available today must be developed and adopted.

Low greenhouse gas emissions must be a key requirement in planning new development projects, and the oil and gas companies have to assess the climate effects of various development solutions. The sector is subject to Norway's carbon tax and part of the EU ETS. To ensure their implementation, measures not triggered by the overall cost of CO₂ need to be supported by government incentives.

Norway's petroleum industry is primarily about the production of oil and gas. Since by far the largest proportion of emissions relate to the use of these products, however, the industry has a clear ambition of strengthening its role in the development of CCS. This will be a significant and crucial technological field if the world is to reach its climate goals, but calls for good operating parameters, clarification of roles and piloting of full-scale projects. Further work must build on the substantial expertise available in Norway's offshore cluster and land-based industry. Good forms of collaboration have been established between government, industry and academia, which must be extended to achieve the realisation of full-scale chains from capture to storage in Norway. Experience with fully established value chains is the only way to speed up learning to achieve the goal of cost-efficient CCS-solutions. CCS is an important priority area internationally, and collaboration and experience transfer across frontiers and industries are crucial. CCS could also be relevant offshore to reduce production emissions.

Feasibility studies for full-scale carbon capture have been carried out for three industrial plants in Norway, along with studies of how to transport and store CO₂ on the NCS. This work offers a unique opportunity for the country to demonstrate a complete CCS chain from capture at an industrial source to transport and storage offshore. In addition, this commitment is crucial for maintaining and continuing to develop the substantial expertise with CCS

which exists in Norway's offshore cluster and land-based industry. Such industrial experience is the only way to improve costs and efficiency at every stage. Norway could then contribute to a stronger commitment and experience transfer across national frontiers, so that CCS can also be realised in other parts of the world.

Hydrogen can be used to fuel offshore gas turbines. That could be an interesting way of reducing CO₂ emissions, particularly for existing NCS installations where limited modifications would be required. Maturing and qualifying this technological solution calls in part for improved understanding of the cost picture along the whole value chain, including costs and CO₂ emissions related to hydrogen production, as well as for good assessments of the safety aspects of utilising this gas as a fuel offshore.

A government contribution through predictable and competitive operating parameters is crucial. Given the long time frame in the industry from the opening of new areas until petroleum production begins, the authorities must clearly communicate long-term operating parameters which facilitate continued profitable development and operation of Norwegian petroleum resources. The tax regime must be structured in such a way that the companies want to invest in activities which are socio-economically profitable. Where long-term value creation on the NCS is concerned, access to new acreage will be crucial. The opening of new areas must be clarified through open processes, such as impact assessments and management plans. Furthermore, the regulations must involve a minimum of bureaucracy and contribute to competition and diversity.

Speeding up further development of the most promising technological solutions which could yield significant long-term emission reductions will be important. The government should reduce company risk where triggering good socio-economic measures on the basis of purely commercial considerations would be demanding. The industry will continue to work on initiatives for achieving lasting changes and improvements in order to improve its competitiveness.

KonKraft takes the view that substantial future opportunities for growth and development are offered by implementing good climate solutions on the basis of the expertise possessed by Norway's petroleum sector. It also believes that exports of low-emission technology represent a major industrial opportunity for the Norwegian offshore cluster in a world set to experience stricter regulation of greenhouse gas emissions.

In addition, the petroleum sector will follow up opportunities to utilise expertise from oil and gas operations in contributing to further development of other commercial activities in the ocean space through collaboration with relevant players and government agencies.

The petroleum industry in Norway has set the following overall climate and commercial goals for 2030.

Maintain safe and profitable production at the present level, and implement CO₂ reduction measures from 2020 which correspond cumulatively to 2.5 million tonnes of CO₂ equivalents per annum by 2030.

In addition, oil companies, suppliers and ship/rig owners will help to reduce emissions from the maritime part of the sector. By 2030, maritime operations on the NCS will be conducted with low- or zero-emission technology in the offshore fleet. Reductions from this part of sector come in addition to the ambition of 2.5 million tonnes of CO₂ equivalents.

Where 2050 is concerned, the industry has the following ambition.

Maintain its position as Norway's most important value creator and increase its average recovery factor to at least 60 per cent. The NCS will remain the world leader for low CO₂ emissions, and the sector will develop and adopt technology and solutions which substantially reduce average CO₂ emissions per unit produced compared with the 2030 level.

2.2.

RECOMMENDATIONS

KonKraft makes the following recommendations.

- A national centre for low-emission technology in the petroleum industry is created. This should be established on the basis of competition between universities/research institutes and with partners from the oil and supplies industries. It is proposed that the centre would be supported by government funding, while industry too contributes financing. The centre will make recommendations on the development of low-emission technology, and coordinate the commitment to and direction of this work with such national strategies as OG21 and Maritim21 as well as the other relevant policy instruments.
- Appropriations must be strengthened for research, development and demonstration of low-emission solutions for the petroleum industry. The government should provide NOK 100 million in fresh funds in the first year, and increase this by increments of NOK 100 million annually for 10 years. The industry would put up the same amount when making applications through the research programmes.
- Established arrangements and strategies, such as the research and technology (FoT) scheme, OG21, Maritim21, Demo 2000, Petromaks and the Skattefunn tax incentive scheme for R&D, have functioned well, and the industry will continue to make active use of these programmes in order to achieve further progress for the Norwegian oil and gas cluster. The role INTSOK has played in promoting technology and company expertise internationally must be reinforced.
- In collaboration with the industry, the government must maintain and strengthen key research programmes such as Climit and the Technology Centre at Mongstad (TCM).
- The oil companies, vessel owners and suppliers must work purposefully to industrialise and implement new and existing technological solutions which reduce greenhouse gas emissions and costs.
- When developing new installations or implementing major developments, the companies must study both the use of gas turbines and power from shore in connection with the plan for development and operation/plan for installation and operation (PDO/PIO). In addition, other energy options such as wind power, hybrid solutions and fuel cells should be assessed when technology and abatement cost make them viable.
- The government must continue the next phase of establishing a full-scale CCS chain in Norway following the feasibility studies submitted in the summer of 2016. Developing such a chain calls for an efficient organisation. During a phase when CCS remains non-commercial, this means the government must accept a strong role in financing and risk-sharing for the various parts of the chain during both development and operational phases. At the same time, industrial players must accept the necessary responsibility and contribute expertise and resources to every stage. The development and operational model must deal with key issues such as incentives, risk-sharing, storage risk, opportunities for further development and how unexpected incidents in such a pioneering project are handled.
- Furthermore, in cooperation with the government, the industry should identify barriers to using CO₂ for improved recovery and identify necessary policy instruments for realising a possible demonstration project. Where new gas fields with a high CO₂ content are concerned, carbon storage in geological formations should be considered.
- Norway should participate actively in international work in this area, and make a particularly active contribution to good collaboration with European players over the possibility of using the NCS as a storage location for big emission sources in Europe through shipborne CO₂ transport. That will make it possible to reduce costs for individual projects and thereby lower the threshold for realising CCS projects outside Norway. Establishing specific CCS value chains in Norway will help to disseminate this

solution in the EU and the rest of the world.

- In cooperation with the industry, the government must facilitate the further development of fuel cell technology, which is currently in a phase for market introduction.
- Together with the government, the industry should assess the potential for developing a further value chain for hydrogen on the NCS.
- A method should be established for conducting annual analyses which show the export value of low-carbon technology/energy-efficient solutions, and a method developed for calculating the climate benefit of implementing low-emission technology developed for the NCS outside Norway.
- International initiatives launched by or involving oil companies must be continued and their follow-up made more specific. Examples include the Oil and Gas Climate Initiative (OGCI), Global Gas Flaring Reduction (GGFR), the Climate and Clean Air Coalition (CCAC), the Low Carbon Technology Partnerships Initiative (LO²) and a large number of initiatives to support the introduction of CO₂ emission pricing.
- Together with the Norway's maritime sector, the Norwegian government must work to influence an ambitious international regulatory regime so that the regulations help to raise standards, enhance energy efficiency and boost the environment-friendliness of international shipping, including offshore-related maritime activities.

To ensure that the ambitions and goals in the Roadmap are followed up, and that follow-up and prioritisation of technology development are optimal, the petroleum industry will do the following.

Prepare a status report every fifth year on the development and adoption of low-emission technology and technological solutions by establishing a coordinated collaboration between OG21, Maritim21 and the proposed centre for low-emission technology in the petroleum sector.

The industry will also:

- Prepare further plans and recommendations for its own companies and the policy instruments
- Study the potential of emission-reducing technology and solutions with the aim of quantifying a goal for greenhouse gas emissions from the NCS in 2050
- Update KonKraft's climate report every fifth year
- Report annually to the environmental authorities on measures implemented.

Appendix 1

Roadmap for the Norwegian Continental Shelf (NCS)

VALUE CREATION ON AND REDUCED GREENHOUSE GAS EMISSIONS FROM THE NCS UP TO 2030 AND 2050

Introduction

Global warming is one of the greatest challenges of our time, and sharp cuts in anthropogenic greenhouse gas emissions are essential. Emissions from the petroleum industry must therefore be reduced, and oil and gas must be utilised in the most energy-efficient way possible. The Norwegian petroleum sector will contribute to global climate targets, while the long-term value creation potential on the NCS is realised through intelligent management of Norway's natural resources and industrial expertise.

Purpose of the Roadmap

The NCS road map has been developed by the Norwegian Oil and Gas Association and the Federation of Norwegian Industries through KonKraft. The other participants in this collaboration body are the Norwegian Confederation of Trade Unions (LO), including the Fellesforbundet and Industri Energi, and the Norwegian Shipowners Association. It has two main goals:

- Establish ambitions for the industry's long-term production and value creation on the NCS up to 2030 and 2050
- Establish ambitions for reducing greenhouse gas emissions in the petroleum sector up to 2030 and 2050.

The Roadmap deals first and foremost with the ambitions for reducing greenhouse gas emissions from the petroleum sector, and contains an action plan which describes the specific steps the industry will take to follow up the established goals. At the same time, the KonKraft partners are following up the ambitions set for production and value creation by initiating a dedicated process in the industry which will ensure long-term and genuine improvements in the Norwegian oil and gas sector's competitiveness.

Attention in the Roadmap is concentrated primarily on the value chain from drilling to field cessation, since these are the areas which the companies operating on the NCS have the greatest influence over. The petroleum industry in Norway will nevertheless look at how it can contribute to technology developments which reduce emissions from end users of oil and gas. Technology and solutions which cut emissions from production, transport and end use of oil and gas can also be exported and contribute to reducing emissions outside Norway.

KonKraft has drawn up a climate report which provides a more detailed description of petroleum operations on the NCS in light of the climate and energy challenge, as well as various technologies which can contribute to emission reductions both in Norway and globally.

Background

Global population growth and rising prosperity mean increased energy demand. The world's population is expected to expand from seven to nine billion people by 2050. Access to sustainable energy which everyone can afford and halting anthropogenic climate change are two of the UN sustainability goals agreed by world leaders in 2015. A large proportion of today's energy consumption is met from fossil sources and releases greenhouse gases, which contribute to global warming.

The UN's COP21 climate summit in Paris adopted ambitious climate targets. While the goal of preventing the average global temperature from rising beyond 2°C still stands, the nations also agreed to seek to bring the increase down towards 1.5°C. The Paris agreement also specifies that the climate goals will be reached in a way which does not undermine employment and prosperity. Between 2050 and 2100, anthropogenic greenhouse gas emissions must not exceed the level which can be absorbed naturally and through carbon capture and storage (CCS). This provides the framework for tomorrow's low-emission society.

Big commitments are being made globally to renewable energy and enhanced energy efficiency. At the same time, energy systems will also require a large proportion of oil and gas in a long-term perspective. Within the 2°C scenario defined by the International Energy Agency (IEA), oil consumption in 2040 will be somewhat lower than the present level while gas output is expected to be higher. Fossil energy bearers will decline significantly in total, but coal will account for the bulk of this reduction. Even in scenarios which meet the climate targets, a significant proportion of fossil fuels will be required to meet world energy requirements in 2050. Gas will be important in the future low-emission society, since it emits half as much CO₂ as coal per unit of energy produced. Gas-fired electricity is far more flexible than coal-fired power generation, and thereby represents a very suitable system partner in the power supply sector for renewable solar and wind energy, which cannot be regulated. Gas utilised directly for heating is very energy efficient, too, and thereby has very low CO₂ emissions per calorific unit.

Oil and gas are also important feedstocks for chemicals, plastic raw materials and other finished products. Demand for these will also rise with the expected growth in population and prosperity.

Global oil demand shows a steadily rising trend. However, several factors – such as the shale oil revolution in the USA and the Organization of the Petroleum Exporting Countries's (OPEC) change of strategy to protect market share – have caused supply to increase faster than demand in recent years. The result has been a sharp drop in oil prices, which has substantially reduced the level of investment in the industry worldwide. In the longer term, expectations are that the balance between supply and demand will be restored and that oil prices will rebound to higher levels. That will in turn trigger investment in new and existing facilities to balance supply and demand, and to ensure the availability of new resources.

Norway's petroleum sector has been a massive success, which has benefited the Norwegian society in the form of jobs, robust centres of expertise and value creation. The Norwegian supplier industry operates globally in a number of areas, and ranks today as the second most important export sector for the country, after export of petroleum. Value creation by the petroleum activity has given the Norwegian government the opportunity to build up and maintain good welfare systems and to accumulate revenues in the government pension fund – global.

Forecasts from the Norwegian Petroleum Directorate indicate that less than half the resources on the NCS have been recovered so far. Gas is expected to represent more than half the remaining resource potential.

Norway is a leader for recovery factors from oil and gas fields on the NCS. That reflects a purposeful commitment to technology development and implementation, as well as close collaboration between different technical disciplines. Important areas include improvements to methods for data acquisition and modelling in order to identify new drilling targets, big advances in drilling technology, extensive use of gas or water injection for pressure support, and low-pressure production in the late life of the fields.

The Norwegian offshore fleet is part of a complete national maritime cluster where great attention is devoted to the environment and the interaction between the players have been crucial in securing the development of new environment-friendly technologies and forward-looking concepts. The innovative drive in this cluster has resulted in battery-powered vessels and ferries, energy-efficient and low-emission gas-fuelled engines, new hull and propeller designs and various solutions combining gas, batteries and fuel cells.

Sustainable solutions and more environment-friendly vessels are expected to be in even bigger demand by the oil companies in the future.

Norwegian petroleum production already leads the world for low greenhouse gas emissions. The average amount released per unit produced is less than half the global figure. This sector is subject to a number of policy instruments, such as the EU emission trading system (ETS), carbon tax, strict flaring provisions, emission/discharge permits with requirements for energy management, and requirements to use the best available technology and to assess power from shore for new developments. These instruments have had a substantial effect, and the industry is documented to have implemented measures which have cut its emissions by more than five million tonnes of CO₂ in total since 1996. Since measures to improve recovery would normally increase energy consumption per barrel produced, maintaining low emissions per unit produced on the NCS while substantially boosting recovery factors represents a considerable achievement.

Given that starting point, further emission reductions from the petroleum sector will be demanding and probably involve a high marginal cost if existing technological solutions are used. In a 2050 perspective, emissions along the whole value chain from drilling and production to field cessation and end use of oil and gas must be substantially reduced from their current levels.

Climate policy parameters

All parties to the Paris agreement have been asked to sign by April 2017. Once the agreement comes into force, each country's Intended Nationally Determined Contributions (INDCs) will no longer be regarded as indicative but as its official and binding climate plans. A status report must be produced every fifth year to assess the goals, with the alternatives being to either maintain or increase national ambitions.

The EU ETS has been adopted and functions as the EU's main instrument for reducing greenhouse gas emissions from industry up to 2030. The goal for the sectors subject to the system is a 43 per cent reduction in emissions in 2005-30. Norway's petroleum sector is part of the EU ETS. In addition, a national carbon tax is paid on emissions from petroleum operations on the NCS.

The ambition for the EU's Roadmap 2050 is to achieve an overall emission reduction of more than 80 per cent by that year compared with 2005. Continued step-by-step lowering of the emission allowance ceiling, also post-2030, is expected to be one of the instruments for meeting that target. The ambition will also be significant in developing and implementing low-emission solutions for the use of oil and gas exported from the NCS to the EU.

A system proposed in 2013 for Monitoring, Reporting and Verification (MRV) of CO₂ emissions from shipping was adopted by the EU in May 2015, and requires that the shipping sector reports its release of CO₂. This will form the basis for an estimate of actual CO₂ emissions by the industry. The International Maritime Organisation (IMO) decided in April 2016 to establish a binding global reporting system for CO₂ emission from the shipping sector. This requirement could come into force on 1 January 2018, with actual reporting starting in August 2019. It is important for the maritime industry that the European and global systems develop in parallel to avoid having to deal with several regional systems.

The petroleum industry in Norway has set the following overall climate and commercial goals for 2030:

Maintain safe and profitable production at the present level, and implement CO₂ reduction measures from 2020 which correspond cumulatively to 2.5 million tonnes of CO₂ equivalent per annum by 2030.

This means that output from the NCS, measured in oil equivalents (oe), will be at about the same level as in 2015. Gas is expected to account for roughly half of 2030 production. While the bulk of output will still come from mature areas of the North and Norwegian Seas, the far north will be more important in 2030 than it is today.

The ambition for greenhouse gases includes emission cuts related to electricity and heat supply on oil installations, to short-lived climate forcers such as methane, and to drilling operations from mobile rigs, as well as enhanced energy efficiency at field and area level.

In addition, oil companies, suppliers and ship/rig owners will help to reduce emissions from the maritime part of the sector. By 2030, maritime operations on the NCS will be conducted with low- or zero-emission technology in the offshore fleet. Reductions from this part of sector come in addition to the ambition of 2.5 million tonnes of CO₂ equivalent reduction.

Where 2050 is concerned, the industry has the following ambition:

Maintain its position as Norway's most important value creator and increase the average recovery factor to at least 60 per cent. The NCS will remain the world leader for low CO₂ emissions, and the sector will develop and adopt technology and solutions which substantially reduce average CO₂-emissions per unit produced compared with the 2030 level.

Through its follow-up of the action plan, the petroleum industry will identify the potential for emission reductions from various technological solutions in order to substantiate ambitions for reduced releases of greenhouse gas from the sector in 2050.

Systematic efforts will be made by the industry to help develop and implement technology and technological solutions which reduce emissions related to the end use of oil and gas.

The ambition means that the industry will be characterised by a high value creation, increased productivity and substantial employment in 2050. Vigorous offshore clusters will deliver substantial volumes of products and services to markets both in Norway and globally. Export deliveries will include low-emission technologies and other solutions which contribute to greater safety and more sustainable development.

The value creation goal means both that time-critical resources close to infrastructure are realised before the facilities are shut down, and that additional resources must be proven and infrastructure developed in new areas of the NCS.

The industry will continue to maintain a high safety standard and to work for continuous improvements in safety.

What is required to realise the ambitions?

The most important competitive advantage for the NCS is the overall expertise and innovative drive of the Norwegian offshore cluster. The industry has been willing to assume the risk of qualifying and adopting new technologies. New solutions have been developed through collaboration and competition, and labour relations based on open dialogue between employers, employees and government. Combined with strict government standards and enforcement, this has been crucial to the NCS becoming the world leader for both high recovery factors and low greenhouse gas emissions. NCS achievements have also been crucial for the attractiveness of Norway's supplier industry and its substantial exports.

Together with the Norway's maritime sector, the Norwegian government must work to influence an ambitious international regulatory regime. These regulations must help to raise standards, enhance energy efficiency and boost the environment-friendliness of international shipping, including offshore vessels.

Norway's strong technical community has helped to turn sales of Norwegian-based technology and concepts from the supplies industry into the country's second largest export sector after oil and gas. Examples include long-distance multiphase transport, horizontal drilling, subsea processing, water treatment, continuous environmental monitoring, lower emissions of such gases as NO_x and volatile organic compounds (VOCs), and reduced discharges of oil in produced water. The petroleum sector has also been an innovation engine with ripple effects for other Norwegian industries over many decades.

Maximising value creation from and the competitiveness of the Norwegian offshore cluster while meeting ambitious climate goals calls for a new and strengthened commitment from the companies throughout the value chain. A far-sighted government must help to maintain the level of activity by providing stable and competitive operating parameters relating both to predictable access to acreage and to fiscal terms.

Norway's petroleum industry has a unique starting point. Ninety fields will soon be in operation with associated infrastructure such as pipelines and land-based plants for processing, refining, storage and export. This provides a substantial potential for realising profitable volumes by improving recovery or by tying discoveries back to existing fields and pipelines in the mature parts of the NCS.

The far north will be very important for the long-term progress of the NCS. Since existing infrastructure in these areas is limited, attention over the next few years will be concentrated primarily on exploring for and maturing new resources which provide the basis for future developments. Close collaboration between companies

and government to ensure good commercial solutions will continue to be needed here. Access to new exploration acreage is important as a basis both for new profitable projects and for establishing infrastructure which can be utilised by discoveries in areas which are already opened.

A substantial commitment to both research and development will continue to be needed for exploration operations, production methods, low-emission technologies and field development solutions. The largest technological leaps have earlier been achieved through big projects with robust economics and through collaboration in the industry. The growing maturity of the NCS and smaller average discovery size, higher costs and low oil prices call for more attention on cost-effective solutions. That includes a greater degree of coordination and standardisation/simplification of company-specific requirements, components, systems, and methodology, as well as operational optimisation based on better use of large volumes of information (Big Data) and an increased level of automation/robotisation.

Given the ambitious climate goals set by the EU and internationally, the price of CO₂ emissions is likely to be substantially above today's level in 2050. To meet the ambitions, technological solutions must be developed to improve energy efficiency and to generate electricity from emission-free or low-emission sources in an economically sustainable way.

Both public and industrial research efforts to advance technology for reducing greenhouse gas emissions must be strengthened.

Where shipping is concerned, the aim must be to establish "green operations" in order to reduce fuel consumption as well as systems for measuring and registering the effect of measures. Publishing and sharing information between the various shipping companies will be crucial. Experience so far demonstrates that measures initiated to reduce emissions have proved to be cost-effective, hence resulting in lower total costs than operating without such measures, even when CO₂ prices or support schemes are ignored. In addition to measures at the project level, the companies should work actively with suppliers and partners to reduce emissions from rigs and support vessels and to improve logistics through better vessel utilisation, coordination across licences, and incorporating energy efficiency requirements in tendering processes.

Low greenhouse gas emissions must be a key requirement in planning new development projects, and the oil and gas companies have to assess the climate effects of various development solutions. The sector is subject to Norway's carbon tax and part of the EU ETS. To ensure

their implementation, measures not triggered by the overall cost of CO₂ need to be supported by government incentives.

Norway's petroleum industry is primarily about the production of oil and gas. Since by far the largest proportion of emissions relate to the use of these products, however, the industry has a clear ambition of strengthening its role in the development of Carbon Capture and Storage (CCS). This will be a significant and crucial technological field if the world is to reach its climate goals, but calls for good operating parameters, clarification of roles and specific full-scale projects. Work must build further on the substantial expertise available in Norway's offshore cluster and land-based industry. Good forms of collaboration have been established between government, industry and academia, which must be extended to achieve the realisation of full-scale chains from capture to storage in Norway. Experience with fully established value chains is the only way to speed up learning to achieve the goal of cost-efficient CCS-solutions. CCS is an important priority area internationally, and collaboration and experience transfer across frontiers and industries are crucial. CCS could also be relevant offshore to reduce production emissions.

In the short term, the most important steps will be increased adoption of existing low-emission technology on existing installations as well as incremental improvements to established technologies in order to boost their efficiency and/or reduce their cost. Looking further ahead, completely new technology areas, solutions and value chains than those available today must be developed and adopted.

Action plan – follow-up of the Roadmap's climate goals

The action plan concentrates primarily on climate measures, but a government contribution through predictable and competitive operating parameters is crucial. Given the long time frame in the industry from the opening of new areas until petroleum production begins, the authorities must clearly communicate long-term operating parameters which facilitate continued profitable development and operation of Norwegian petroleum resources. The tax regime must be structured in such a way that the companies want to invest in activities which are socio-economically profitable. Where long-term value creation on the NCS is concerned, access to new acreage will be crucial. The opening of new areas must be clarified through open processes, such as impact assessments and management plans. Furthermore, the regulations must involve a minimum of bureaucracy and contribute to competition and diversity.

The action plan describes what the industry can and should do itself, and what contribution the government

can make to accelerate action. Speeding up further development of the most promising technological solutions which could yield significant long-term emission reductions is important. The government should reduce company risk where triggering good socio-economic measures on the basis of purely commercial considerations would be demanding.

The industry will continue to work on initiatives for achieving lasting changes and improvements in order to improve its competitiveness.

Proposals to strengthen the commitment to developing the necessary low-emission technology

1) A national centre for low-emission technology in the petroleum industry should be created.

This should be established on the basis of competition between universities/research institutes and with partners from the oil companies and the supplier industry. It should be supported by government funding, but the industry is also prepared to contribute financing. The centre will make recommendations on the development of low-emission technology, and coordinate the commitment to and direction of this work with such national strategies as OG21 and Maritim21 as well as the other relevant policy instruments.

2) Increased appropriations are also proposed for research on and development and demonstration of low-emission solutions for the petroleum industry:

- The government should provide NOK 100 million in fresh funds in the first year, and increase this by increments of NOK 100 million annually for 10 years. The industry would put up the same amount when making applications through the research programmes.

The assumptions are that the government contributes new appropriations and that the companies, including suppliers, participate with funds through applications for projects.

3) Established arrangements and strategies, such as the research and technology (FoT) scheme, OG21, Maritim21, Demo 2000, Petromaks and the Skattefunn tax incentive scheme for R&D, have functioned well, and the industry will continue to make active use of these programmes in order to achieve further progress for the Norwegian oil and gas cluster. The role INTSOK (Norwegian Energy Partners) has played in promoting technology and company expertise internationally must be reinforced.

Various time frames and technological solutions

Up to 2030, a potential still exists for further energy efficiency measures on existing installations. Where costs are higher than the price of CO₂, instruments such as Enova and the NOx fund could serve as triggers.

The oil companies and vessel owners will work purposefully to industrialise and implement new and existing solutions and technology in collaboration with suppliers.

Examples of such areas include the following:

Power generation

- Measures and R&D which yield more efficient gas turbines (including existing machines).
- Further development of combined cycle power stations (heat recovery units with steam turbines).
- Hybrid solutions such as offshore wind power, batteries, fuel cells and wave energy.
- Cost cuts and technology development for power from shore to facilities (including rigs).
- Hydrogen for blending with natural gas.

Drilling and production operations

- More efficient and automated drilling technology.
- Reduction of and zero-emission solutions for flaring.
- Tailored solutions and operation for lower emissions in the late life phase (turbines, separation, compressor operation, energy optimisation).
- Subsea solutions which reduce energy requirements.
- Improved recovery with low emissions.
- Automated operations and robot technology.
- Increased degree of joint operation and remote operation.

Logistics, base operation and support vessels

- Optimise the use of support vessels, coordinate operation, maintenance and logistics – including bases – across licences.
- Monitoring, reporting and verification of greenhouse gas emissions from ships.
- Battery technology and provision of electricity on ships.

The following areas are central for new developments which will produce up to 2050:

- A value chain where technology development and concept choice in all phases of the field's producing life, from development to cessation, help to reduce energy consumption per unit produced.
- Study and implement power supply solutions with low emissions.
- Optimised production strategies in relation to greenhouse gas emissions.
- Possible new value chains, such as hydrogen production from natural gas offshore and on land.

The industry will contribute to the development of CCS and make an aggressive commitment to:

- Further development of the Technology Centre at Mongstad (TCM)
- Developing new methods and technologies for CCS
- Storage of CO₂ on the NCS
- Using CO₂ to improve oil recovery
- Transporting and storing CO₂ sources from land-based industry
- International involvement to secure the adoption of CCS at gas-fired power stations.

The government must help to reduce risk for the companies in establishing full-scale value chains for CCS, and clarify the division of roles, incentives and commercial conditions in collaboration with the industry.

In addition, the petroleum sector will follow up opportunities to utilise expertise from oil and gas operations in contributing to further development of other commercial activities in the ocean space through collaboration with relevant players and government agencies.

Follow-up of commitments, milestones and reporting

To ensure that the ambitions and goals in the Roadmap are followed up, and that follow-up and prioritisation of technology development are optimal, the petroleum industry will do the following.

- Prepare a status report every fifth year on the development and adoption of low-emission technology and technological solutions by establishing a coordinated collaboration between OG21, Maritim21 and the proposed centre for low-emission technology in the petroleum sector.

The industry will also:

- Prepare further plans and recommendations for its own companies and for the policy instruments,
- study the potential of emission-reducing technology and solutions with the aim of quantifying a goal for greenhouse gas emissions from the NCS in 2050
- update KonKraft's climate report every fifth year.
- Report annually to the Norwegian Environment Agency (NEA) on measures implemented to enhance energy efficiency and reduce emissions.

The industry will also:

- Maintain the Norwegian Oil and Gas network for energy efficiency and measures to reduce emissions in order to ensure and encourage the exchange of experience between companies.
- Report annually to the Norwegian Environment Agency (NEA) on potential and planned future measures (not made public because of commercially sensitive information).
- Organise annual meetings with the ministries of climate and environment and petroleum and energy on the following subjects:
 - The industry's status, progress and future plans.
 - Review applications to the various R&D programmes for low-emission technology in the petroleum sector.

International collaboration

INTSOK was established to market Norwegian technology and expertise internationally, and utilising its network of contacts and knowledge will be important for disseminating information and developing a market for emission-reducing technology globally. This will contribute to implementing technology and technological solutions developed on the NCS which reduce production emissions in other petroleum provinces and some solutions may also help cut emission from land-based industries.

A great many initiatives have been launched by or involve oil companies internationally. Examples include the Oil and Gas Climate Initiative (OGCI), Global Gas Flaring Reduction (GGFR), the Climate and Clean Air Coalition (CCAC), the Low Carbon Technology Partnerships Initiative (LO²) and a large number of initiatives to support the introduction of CO₂ emission pricing. These initiatives must be continued and their follow-up has to become more specific.

Export of low-carbon technology – industrial opportunities and global climate benefits

Further development of energy-efficient/technological solutions which yield reduced emissions will have a potential for export to other petroleum provinces, which could help to reduce greenhouse gas emissions outside Norway.

Natural conditions in Norway qualify the country for developing tomorrow's environment-friendly and sustainable transport solutions. It has a maritime industry with long experience of solving demanding transport and logistical assignments internationally. The long Norwegian coastline should be able to function as an incubator for technical solutions which can subsequently be exported and provide global spin-offs.

This represents an industrial opportunity for the supplier sector, while such technology can reduce emissions beyond the NCS. The following should therefore be done:

- establish a method for conducting annual analyses which show the export value of low-carbon technology/energy-efficient solutions
- develop a method for calculating the climate benefit of implementing low-emission technology developed for the NCS outside Norway.

The development of methods should be coordinated with such government agencies as the ministries of climate and environment and petroleum and energy to ensure agreement over the choice of methods and results.

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KonKraft is a collaboration arena for:

